Oxygen Therapy Management for Patients at Risk of Respiratory Dysfunction

by

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Submitted in fulfillment of the requirements for the degree of

Doctor of Philosophy

Deakin University

December, 2012
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DEAKIN UNIVERSITY

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Publications and presentations arising from this thesis

Publications arising from this thesis


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**Presentations arising from this thesis**


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Abstract

Oxygen therapy is one of the major interventions used to manage respiratory dysfunction. The failure to recognise and respond to respiratory dysfunction may result in patients suffering respiratory related adverse events such as cardiac arrest, unplanned intensive care unit admissions or unexpected death. It is recognised that management of oxygen therapy for patients at risk of respiratory dysfunction is primarily undertaken by nurses, is multi-factorial and often carried out in complex clinical settings. There is a paucity of literature that takes account of the multiple factors that influence the management of oxygen therapy in clinical practice. Therefore, to understand practice and improve patient safety there is a need for a more comprehensive study that investigates the management of oxygen therapy for patients at risk of respiratory dysfunction.

This research examined, in detail, the oxygen therapy management for patients at risk of respiratory dysfunction. Specifically, the research sought to (a) measure and compare the oxygen flow rate required to maintain oxygen saturation equal to or greater than 95% in adult patients using nasal prongs, face mask and nasopharyngeal oxygen catheter devices, (b) explore intensive care patients’ and intensive care nurses’ perceptions of oxygen therapy, and (c) describe how intensive care nurses’ manage and document oxygen therapy in clinical practice.

To appropriately examine the complexity of oxygen therapy management, this thesis comprised three sequentially linked studies situated within a modified World
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Health Organisation patient safety conceptual framework. A mixed methods research design was used. Data were collected by a randomised crossover trial involving 37 adults patients (Study One – part A) and participant interviews with 37 patients and 25 nurses (Study One – part B). In addition, a retrospective medical record audit (Study Two) of 210 cardiac surgical patients first 24 hours of admission to the intensive care unit was conducted. Finally, a prospective clinical practice observational study (Study Three) involving 16 patients and 16 intensive care nurses was performed. These three studies were conducted within a single healthcare organisation located in the Eastern suburbs of Melbourne, Australia.

The findings demonstrated that nasal prongs, face mask and nasopharyngeal oxygen catheter devices were effective at maintaining a pulse oximetry derived oxygen saturation (\(\text{SpO}_2\)) greater than 95% with no evidence of patients altering their respiratory rate to compensate for a change in oxygen supply between devices. Face masks, which use a higher oxygen flow compared to nasal devices, were deemed by patients to be the least comfortable device. Importantly, patients wanted to receive oxygen via nasal prongs or nasopharyngeal oxygen catheter as these devices were the most comfortable, permitted ease of eating, drinking and talking. Conversely, nurses reported using measures of a patient’s \(\text{SpO}_2\) and respiratory rate as drivers for their oxygen therapy decisions. Nurses preferred to use the face mask as their first choice for oxygen supplementation because of the ability to provide high oxygen flow rates. However, differences in patients’ and nurses’ perspectives of oxygen therapy may compromise the effectiveness of oxygen therapy with patients resistive to using a face mask.

Additionally, results showed that episodes of respiratory dysfunction were common
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among post-operative patients in the intensive care environment. However, despite the occurrence of respiratory dysfunction the management of oxygen therapy did not change in response to such events. The study also revealed that what nurses documented in the intensive care environment including oxygen saturation and respiratory rate measures did not reflect patient status and some nursing actions such as a failure to escalate oxygen delivery in response to respiratory dysfunction and removal of oxygen therapy to perform mouth care, hindered effective oxygen therapy. Collectively, the findings revealed a need for health care professionals to review oxygen device selection in specific clinical settings, the importance of involving patients in decisions about their care and the need to appropriately document care that is provided.

These research findings fill gaps in the literature by providing overarching information about perceptions and practice. Improvements are necessary in the selection of oxygen delivery devices and the tailoring of the device choice to match the clinical condition and activity of the patient. Similarly, documentation systems need to undergo review in order to appropriately match the acuity, complexity and pace of contemporary intensive care unit practice.

This research significantly contributes to understanding the interplay of the multiple factors that impact on the effective management of oxygen therapy for patients at risk of respiratory dysfunction. These findings can now inform future interventions aimed at improving oxygen therapy management so that patient safety and outcomes can be optimised.
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**Terms and abbreviations**

<table>
<thead>
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<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>ABG</td>
<td>Arterial blood gas</td>
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<tr>
<td>APACHE III score</td>
<td>Acute physiology and chronic health evaluation III score</td>
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<tr>
<td>Bradypnoea</td>
<td>Respiratory rate less than eight breaths per minute</td>
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<tr>
<td>CO$_2$</td>
<td>Carbon dioxide</td>
</tr>
<tr>
<td>ED</td>
<td>Emergency department</td>
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<tr>
<td>FiO$_2$</td>
<td>Fraction of inspired oxygen</td>
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<tr>
<td>FM</td>
<td>Face mask</td>
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<tr>
<td>Flow rate</td>
<td>The rate at which oxygen enters an oxygen delivery device in litres per minute</td>
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<tr>
<td>HCO$_3$</td>
<td>Bicarbonate</td>
</tr>
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<td>HREC</td>
<td>Human research ethics committee</td>
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<tr>
<td>HVAS</td>
<td>Horizontal visual analogue scale</td>
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<td>Hypoxia</td>
<td>A state of oxygen deficiency at the tissue or cellular level</td>
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<tr>
<td>Hypoxaemia</td>
<td>A state of oxygen deficiency in arterial blood</td>
</tr>
<tr>
<td>Hyperoxia</td>
<td>A state of oxygen excess is a state of higher than normal partial pressure of oxygen</td>
</tr>
<tr>
<td>Hyperoxaemia</td>
<td>A state of above normal oxygen levels in the arterial blood</td>
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<tr>
<td>ICPS</td>
<td>International Classification for Patient Safety</td>
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ICU
Intensive Care Unit, a dedicated hospital ward specialising in the care and management of patients experiencing or likely to experience serious illness

Intensive care nurse
A registered nurse employed in an intensive care unit who is accountable and responsible for the care of an intensive care patient

Intensive care patient
A patient admitted to an intensive care unit

LPM
Litres per minute

mmHg
Millimetres of Mercury

MET
Medical emergency team

Minute volume
Volume in millilitres of gas inhaled over a one minute period

NP
Nasal prongs

NPO
Nasopharyngeal oxygen catheter

O₂
Oxygen

OFR
Oxygen flow rate: The rate at which oxygen enters an oxygen delivery device in litres per minute

PACU
Post-anaesthetic care unit

PaO₂
Partial pressure of oxygen in arterial blood

PaCO₂
Partial pressure of carbon dioxide in arterial blood

PO₂
Partial pressure of oxygen

RR
Respiratory rate per minute

Respiratory dysfunction
For the purposes of this thesis respiratory
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dysfunction is defined as bradypnoea (less than
eight breaths per minute), tachypnoea (greater than
24 breaths per minute) and / or hypoxaemia
(oxygen saturation of less than 95% measured by
pulse oximetry)

\[ \text{SaO}_2 \]  
Oxygen saturation of arterial blood measured by
arterial blood gas sampling

\[ \text{SpO}_2 \]  
Oxygen saturation measured by pulse oximetry

**Tachypnoea**  
Respiratory rate greater than 24 breaths per minute

**Tidal volume**  
Volume in milliliters of gas inhaled during one
breath
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Chapter 1: Introduction

Introduction

Oxygen therapy is one of the major interventions used to manage respiratory dysfunction. Nurses play a vital role in the management of oxygen therapy in patients at risk of respiratory dysfunction. The failure of nurses to recognise and respond to respiratory dysfunction may result in patients suffering respiratory related adverse events such as unexpected death, cardiac arrest, or unplanned intensive care unit admissions. Although oxygen management is an important aspect of patient care, there is a paucity of literature that takes account of the multiple factors that influence the management of oxygen therapy. Therefore, to understand practice and improve patient safety there is a need for a comprehensive study that investigate the management of oxygen therapy for patients at risk of respiratory dysfunction.

Respiratory dysfunction is life threatening and well-recognised as a precursor to in-hospital adverse events such as cardiac arrest, unplanned admission to the intensive care unit and death (Cretikos et al., 2008; Harrison, Jacques, Kilborn, & McLaws, 2005). In order to decrease mortality from adverse events, nurses must actively assess and treat patients with respiratory dysfunction, rather than respond to respiratory related adverse events (Considine, 2005a; Quach et al., 2008). The evidence base regarding the recognition and response systems for respiratory dysfunction is developing. To provide a safety buffer for patients whose respiratory function is deteriorating, there is a strong need to explore the features and factors that are associated with the clinical management of respiratory dysfunction.
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For the purposes of this thesis, respiratory dysfunction is defined as bradypnoea (less than eight breaths per minute), tachypnoea (greater than 24 breaths per minute) and / or hypoxaemia (oxygen saturation of less than 95% measured by pulse oximetry). Respiratory rate is the most important and sensitive indicator of serious illness in adults but also the most poorly measured and documented clinical indicator (Cretikos et al., 2008). Respiratory rate abnormalities, in particular tachypnoea, are indicative of deteriorating respiratory function, or the manifestation of an abnormal physiological state in another body system (Cretikos et al., 2008). Evidence from hospital based studies of general ward patients suggests that an adult at rest with a respiratory rate greater than 20 breaths per minute is likely to be unwell (Davey, McCance, & Budd, 1994; Kennedy, 2007) and that those with a respiratory rate greater than 24 breaths per minute are likely to be critically ill (Cretikos et al., 2008; Grap, Glass, & Constantino, 1994; Harrison et al., 2005).

Hypoxaemia, a state of oxygen deficiency, is a clinical indicator of respiratory dysfunction. Prolonged untreated hypoxaemia is life threatening because of the imbalance between oxygen supply and oxygen consumption (Levy, 2008). The presence of hypoxaemia prior to an adverse event increases the need for advanced respiratory interventions (such as non-invasive ventilation), or transfer to the intensive care unit, to avoid a fatal adverse event (Goldhill & McNarry, 2004; Skrifvars, Nurmi, Ikola, Saarinen, & Castrén, 2006). In hospital settings nurses are responsible for the assessment of patients’ overall physiological status and the detection of physiological abnormalities, including hypoxaemia, bradypnoea and tachypnoea.
Patients who are at high risk of respiratory dysfunction are admitted to the intensive care unit for increased monitoring and specialised care. Australian intensive care units are staffed on 1:1 or 1:2 nurse-patient ratios to ensure a high level of patient monitoring, in particular monitoring of respiratory function and oxygen therapy management (Australian College of Critical Care Nurses [ACCCN], 2003). This level of staffing is required so that nurses can provide timely and appropriate interventions amidst a number of competing physiological factors and patient care requirements. Intensive care nurses are well placed to recognise and respond to the clinical signs of respiratory dysfunction. Additionally, many intensive care nurses have post-graduate specialist qualifications, with advanced skills in the assessment and management of patients. Despite the importance of effective oxygen therapy management, there remains minimal research on the oxygen delivery device, patient and nurse factors that impact on the oxygen management practices used by intensive care nurses.

Oxygen therapy is commonly administered to intensive care patients to prevent or relieve hypoxaemia. In order to manage oxygen therapy, intensive care nurses are required to select an oxygen delivery device (such as nasal prongs and face mask) and an oxygen flow rate to deliver oxygen to the patients. The majority of oxygen delivery devices are suitable for use in patients with minimal respiratory distress and adequate ventilatory patterns but who still require supplemental oxygen for therapeutic (Eastwood, Gardner, & O’Connell, 2007). Few of the basic, commonly used, oxygen delivery devices have been subjected to rigorous clinical review to establish their levels of clinical comfort and effectiveness (Eastwood, Reeves, & Cowie, 2004). In order to
better understand the processes involved in administering oxygen therapy it is essential to further explore all stages of the oxygen therapy management process.

The choice nurses make about the oxygen delivery devices used and the management of oxygen therapy is complex and influenced by a number of factors. These factors are: nurses’ knowledge of oxygen therapy, patient preferences, and patient care activities (Eastwood et al., 2007). According to Murphy et al. (2001) decisions about oxygen therapy are often ad hoc, and other researchers highlight a lack of empirical evidence to inform nursing practice (Considine, Botti, & Thomas, 2006; O’Driscoll, Howard, & Davison, 2008). Studies in non-critical care settings have shown that patients are at risk of respiratory dysfunction due to suboptimal monitoring, management and documentation of oxygen therapy (Albin, Criner, Thomas, & Abou-Jaoude, 1992; Attia, Nair, Mears, & Hitchcock, 2004; Boyle & Wong, 2006; Brokalaki et al., 2004; Howell, 2001; Kor & Lim, 2000; Nolan, Winyard, & Goldhill, 1993; Small et al., 1992; Stausholm, Rosenberg-Adamsen, Skriver, Kehlet, & Rosenberg, 1995). These findings are alarming as suboptimal oxygen management can result in adverse patient outcomes (Considine, Botti, & Thomas, 2005; Kernick & Magarey, 2010; Murphy et al., 2001). Further work is necessary to provide information on how intensive care nurses manage and document oxygen therapy for patients at risk of respiratory dysfunction.

An important factor that requires attention and further exploration is the patients’ perspective including their experiences of oxygen therapy and their assessment of how oxygen therapy impacts on their comfort and wellbeing. Patient perspectives are an
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important aspect of care as oxygen delivery device comfort has a direct impact on patients’ acceptance and compliance with oxygen therapy (Nolan, Winyard, & Goldhill, 1993; Sasaki et al., 2003; Stausholm et al., 1995). Patient anxiety and discomfort wearing oxygen devices may lead to non-compliance and increased interruptions to oxygen therapy (Eastwood et al., 2007). Interruptions to oxygen therapy place the patient at risk of hypoxaemia that may result in death or cardiac arrest (Considine, 2005b; Eastwood et al., 2007). Therefore, identifying patients’ perceptions of oxygen therapy is an important step in highlighting ‘real world’ factors that nurses could address to optimise patient comfort and compliance with oxygen therapy.

The research agenda to date has largely ignored the interplay between these multi-factorial clinical situations and the implications for patients at risk of respiratory dysfunction. Gaps in the literature exist because most previous studies have tended to investigate factors that impact on oxygen therapy in isolation, such as device effectiveness, device comfort, or appropriateness of nursing practice without an overarching in-practice approach. Consequently, the previous studies are unable to provide strong evidence to inform intensive care nurses’ daily practice of oxygen therapy.

There are two imperatives influencing the need for systematic research into how oxygen therapy is managed for patients at risk of respiratory dysfunction: (a) the clinical risk of respiratory dysfunction leading to increased morbidity and mortality, and (b) the lack of evidence specifically supporting intensive care nurses’ management and documentation of oxygen therapy. Due to the interplay of a number of factors that
influence how nurses manage oxygen therapy, a multi-stage approach using linked studies is necessary to increase understanding of the relationships between the numerous factors that influence oxygen therapy.

**Aim and objectives**

The overall aim of this research was to provide a detailed analysis of oxygen therapy management for patients at risk of respiratory dysfunction. The research comprises a pilot study and three sequentially linked studies. The aims of the three linked studies were to investigate:

- The clinical efficacy and user-friendliness of oxygen delivery devices
- Patients’ and nurses’ perception of oxygen therapy
- How intensive care nurses’ manage and document oxygen therapy for patients at risk of respiratory dysfunction

The specific aims and objectives of the three studies are detailed below.

**Study One**

The aim of Study One was to evaluate the clinical efficacy and user-friendliness of oxygen therapy devices from both the patient and nurse perspective. Study One was divided into two parts – part A and part B. The objective of part A was to measure and compare the oxygen flow rate required to maintain oxygen saturation equal to or greater than 95% in adult patients using different oxygen delivery devices. A crossover trial design was used to assess efficacy of nasal prongs, face mask, and nasopharyngeal oxygen catheter. The objective of part B was to assess and compare patients’ and
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nurses’ perspectives of oxygen therapy. Patients and nurses participated in semi-structured face-to-face interviews, within a descriptive exploratory design.

Study Two

The aim of Study Two was to describe how intensive care nurses administered and managed oxygen therapy for adult cardiac surgical patients during the first 24 hours of intensive care admission. Of particular interest to this study were the types of oxygen delivery devices used, the frequency of documented hypoxaemia, the frequency of documented respiratory rate abnormalities (tachypnoea and bradypnoea) and changes in oxygen flow rate or oxygen delivery device in response to respiratory dysfunction (hypoxaemia and / or tachypnoea).

Study Three

The aim of the third and final study was to prospectively observe how intensive care nurses manage oxygen therapy. Of particular interest to this study was oxygen delivery device fit, placement and flow rate, assessment of key indicators of oxygenation (oxygen saturation and respiratory rate) and alterations to oxygen therapy in response to hypoxaemia and / or tachypnoea. In Study Three a descriptive exploratory study was used and data were collected using a structured observation tool, field notes and nursing observation chart review.
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Significance

Intensive care nurses frequently manage oxygen therapy in patients with respiratory dysfunction. Despite the common use of oxygen therapy by intensive care nurses, the literature indicates that oxygen management practices vary and the body of evidence on which to guide practice is lacking. Appropriate and timely management of oxygen therapy is a key component to the prevention or treatment of respiratory dysfunction. Oxygen therapy is a complex clinical activity and the results of the three linked studies will contribute to the further knowledge of the factors that impact intensive care nurses’ management of oxygen therapy. A greater understanding of oxygen therapy management for patients at risk of respiratory dysfunction will aid patient safety initiatives and identify other opportunities for practice improvement. In addition, the findings from the research reported in this thesis will inform future exploratory, observational and interventional studies to support the further development of evidence based guidance for oxygen therapy management by intensive care nurses.

Thesis structure

This thesis is divided into seven chapters. In Chapter Two the literature related to how intensive care nurses manage oxygen therapy is reviewed. This review of the literature is set out in four sections. First, foundational concepts of oxygen physiology and respiratory dysfunction and hypoxaemia as clinical risk and a threat to patient safety are presented. Second, respiratory dysfunction and the role of oxygen therapy for the treatment of respiratory dysfunction are described. Third, a review of the device, patient and nurse related factors that influence the clinical management of oxygen therapy is provided. Finally, a conceptual framework for this study of nursing management of
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oxygen therapy for patients at risk of respiratory dysfunction is detailed.

Fundamentally, the literature review identifies the gaps in the literature and demonstrates an urgent clinical need for a better understanding of how oxygen therapy is managed for patients at risk of respiratory dysfunction.

Chapter Three is the Methods Chapter. In Chapter Three the methods undertaken to conduct the three linked studies are described and the aim, method, results, and recommendations arising from the pilot study are detailed. The conduct of the pilot study was a valuable and important methodological choice that enabled the process and outcome measures of Study One to be validated.

The discussion in Chapter Four, Chapter Five and Chapter Six describe the background, aim, method and a summary of key findings of the three linked studies, respectively. In Chapter Seven, the research findings in relation to the overall research aim are discussed. To conclude, the clinical implications of the findings are discussed and recommendations for nursing practice, nursing research, and nursing education are presented.
Introduction

Intensive care nurses play a major role in patient safety and risk management. In the intensive care unit, it is nurses who monitor the patient 24-hours a day and who are uniquely placed to recognise and respond to the early signs of respiratory dysfunction. The purpose of Chapter Two is to define terms, provide background to the topic and to review the literature related to interventions used to manage oxygen therapy for patients experiencing, or at risk of, respiratory dysfunction. The five sections in Chapter Two specifically explore or provide:

- The foundational concepts of respiratory physiology and oxygen delivery
- Respiratory dysfunction and hypoxaemia as clinical risk and the use of oxygen therapy in the management of respiratory dysfunction
- Patient related factors that influence effective oxygen therapy
- Nurse related factors that influence the management and documentation of oxygen therapy
- A description of, and rationale for, the conceptual framework supporting the research presented in this thesis

Medical and nursing literature was accessed to inform the literature review of oxygen therapy for patients at risk of respiratory dysfunction. In particular, the review included referred healthcare journals, review articles, physiology textbooks as well as specialist medical and nursing textbooks. Importantly, the literature review and discussion presented in Chapter Two identifies gaps in the literature and demonstrates
the clinical need for a better understanding of oxygen therapy management for patients at risk of respiratory dysfunction.

Foundational concepts of respiratory physiology and oxygen delivery

Normal respiratory physiology

The human body needs to use oxygen from the atmosphere effectively to maintain normal cell function. Aerobic metabolism is the normal process to produce energy in the human body (Marieb, 2004). Under normal circumstances, every molecule of oxygen generates 38 molecules of adenosine tri-phosphate as energy (West, 2008). If a person cannot breathe in sufficient quantities of oxygen, or is in an atmosphere with reduced oxygen, anaerobic metabolism occurs when glucose is used to generate the energy required for the function of cells (Marieb, 2004). Anaerobic metabolism is very inefficient, generating only two adenosine tri-phosphate molecules of energy and produces a toxic by-product, lactic acid (West, 2008). Excessive anaerobic metabolism causes a build-up of lactic acid that can damage intracellular function (Marieb, 2004) and if untreated can cause lactic acidosis and hypoxia because of insufficient quantities of glucose, fatty acids and oxygen which are needed for metabolic energy production (Edwards, 2003). Left untreated, both excessive lactic acid build-up and prolonged hypoxia can result in cell death leading to organ failure and the person dying (Considine, 2005a).

To understand how cells in our body use oxygen, it is necessary to understand how oxygen moves from the atmosphere to the cells. The major stages in oxygen supply
to the cells are: (a) ventilation, (b) external respiration (c), oxygen transport, and (d) internal respiration (cellular metabolism).

**Ventilation**

Ventilation, or breathing, consists of inspiration and expiration. Ventilation is a cyclic process that enables the exchange of oxygen and carbon dioxide between the atmosphere and the lung (Marieb, 2004). During inspiration several muscle groups work together to increase the volume of the thoracic cavity (Marieb, 2004; West, 2008). An increase in the volume of the thoracic cavity results in a decrease in intra-thoracic pressure causing air, containing oxygen, to move from the atmosphere (an area of higher pressure) and into the lung (an area of lower pressure) (Marieb, 2004). Expiration is a passive process and occurs as inspiratory muscles relax. When the inspiratory muscles relax pressure in the thoracic cavity increases and the volume of the thoracic cavity decreases. The change in pressure (from an area of lower pressure to higher pressure) within the lung enables carbon dioxide to leave the lung (Marieb, 2004; West, 2008).

**External respiration**

External respiration is the process of gas exchange between the pulmonary blood and alveoli (Marieb, 2004). As air enters the lung alveoli, oxygen moves across the alveolar membrane and into the pulmonary blood via diffusion and pressure gradients (West, 2008). The major factors that influence the movement of oxygen and carbon dioxide across the alveolar membrane are the partial pressure gradients of the gases, structural characteristics of the alveolar membrane, and the matching of pulmonary blood flow and alveolar ventilation (West, 2008).
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Oxygen transport

When oxygen has crossed from the alveoli into pulmonary capillary blood it is transported in the bloodstream in two forms. Most of the oxygen (98.5%) is transported bound to haemoglobin as oxyhaemoglobin (O$_2$Hb) and a lesser amount of the oxygen (1.5%) is transported dissolved in the blood plasma (Marieb, 2004). Haemoglobin is a large protein molecule containing four subunits, each subunit contains a ferrous ion within a haem group. A maximum of four oxygen molecules can bind reversibly to each normal haemoglobin molecule (Berne & Levy, 1998). Two important physiological properties of oxygen and haemoglobin are (a) that oxygen combines reversibly with haemoglobin and (b) that molecular oxygen quickly and easily dissociates from haemoglobin to enable a fast release at the site of tissues (Berne & Levy, 1998).

Haemoglobin is loaded with oxygen in the lungs where the partial pressure of oxygen is highest (Marieb, 2004). Therefore, haemoglobin level is a major determinant of the effectiveness of oxygen transport to the tissue (Levy, 2005). After transfer across the alveolar-capillary membrane and becoming bound to haemoglobin, oxygen is efficiently carried to the tissues for use in internal respiration by the cardiovascular system (Marieb, 2004). Cardiac output determined by heart rate and stroke volume is another major determinant of the effectiveness of oxygen transport around the body (Marieb, 2004). Clinically, the most common proxy measure for cardiac output is blood pressure, making the assessment of a patient’s blood pressure an important surrogate indicator of impaired cardiac output and therefore decreased oxygen delivery (Considine, 2005a).
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Internal respiration

Internal respiration occurs as oxygen and carbon dioxide are exchanged between capillary blood and body cells via diffusion (West, 2008). Once inside the cell, mitochondrial enzymes use oxygen to synthesise adenosine di-phosphate to the high-energy adenosine tri-phosphate for the support of normal cellular function (West, 2008).

Normal and abnormal oxygen states

Normal oxygen states

The amount of oxygen contained in blood can be described and measured in two ways, reflecting the ways oxygen is transported. One method is to describe the presence of oxygen measured as millimetres of mercury (mmHg) to denote the measurement of PaO₂ measured in the arterial blood gas (ABG) sample. A second method is to measure oxygen saturation, the percentage (%) of haemoglobin in the arterial circulation (SaO₂) or peripheral circulation (SpO₂) saturated with oxygen (O’Driscoll et al., 2008). Oxygen saturation can be obtained either by arterial blood gas sampling or using pulse oximetry (O’Driscoll et al., 2008). There is a consensus in the literature that a normal oxygen saturation reading for adults is SaO₂ or SpO₂ equal to or greater than 95% (Considine, 2005a; Crapo, Jensen, Hegewald, & Tashkin, 1999). These measurements are explained later in the chapter, in the discussion on ways oxygen levels are monitored in the clinical setting.

The relationship between SpO₂ and PaO₂ has important implications for clinicians. When assessing the effectiveness of oxygen therapy both via pulse oximetry and arterial blood gas analysis, clinicians must pay particular attention to correcting a
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low SpO2 due to the potential for a large decrease in PaO2. For example, a SpO2 drop from 98% to 96% would shift the PaO2 from 104 mmHg to 82 mmHg, while a SaO2 drop from 95% to 87% would result in a PaO2 fall from 75 mmHg to 52 mmHg (O’Driscoll et al., 2008). The ability of oxygen to bind to haemoglobin changes when there are changes in the body, for example, changes in temperature, acidity (pH), carbon dioxide and 2,3-diphosphoglycerate (2,3 DPG) (O’Driscoll et al., 2008). Physiological instances that give rise to a release of oxygen from haemoglobin include exercise or elevated temperature due to infection or inflammation. The release of oxygen from haemoglobin results in more oxygen being available for cells to use (Coggan, 2008a; O’Driscoll et al., 2008).

In the lungs, oxygen more readily binds to haemoglobin as pH increases, PCO2 decreases, or as temperature falls, and the haemoglobin then become saturated with oxygen. During times of rest, or normal body temperature, oxygen remains bound to haemoglobin and ready for use by body tissues rather than being consumed by them. Knowing the physiological factors associated with oxygen consumption in the body aid’s clinician’s clinical decision regarding when and how to administer oxygen (Coggan, 2008). Oxygen therapy management practices that ensure the patient is provided with supplemental oxygen during times of physiological stress can optimise the amount of oxygen available for use by the tissues (Coggan, 2008a, 2008b).

States of oxygen deficiency

Hypoxia and hypoxaemia are the terms used to describe the two states of oxygen deficiency. Both may be the cause or the consequence of respiratory dysfunction and
Hypoxia

Hypoxia is a state of oxygen deficiency at the tissue or cellular level (O’Driscoll et al., 2008) and if prolonged it disrupts cellular function due to a lethal accumulation of lactic metabolites, the by-product of anaerobic metabolism (West, 2008). There are four causes of hypoxia: hypoxic hypoxia, anaemic hypoxia, stagnant hypoxia and histotoxic hypoxia. Treatment and prevention of hypoxia, as assessed on pulse oximetry (SpO₂), arterial blood gas analysis (PaO₂ and SaO₂) or cardiac function (heart rate), is the underlying rationale that supports the administration of supplemental oxygen (Considine, 2005; Considine, 2005a). However, in the case of anaemic hypoxia, stagnant hypoxia and histotoxic hypoxia a patient may present have a normal SpO₂ or PaO₂ despite the use of supplemental oxygen being warranted. Consequently, clinician’s knowledge of physiology, pathophysiology of oxygen states and other clinical indicators, to assess the oxygenation status of patients together with oxygen saturation should inform oxygen therapy management decisions (Considine, 2005a).

Hypoxaemia

Hypoxaemia is a state of oxygen deficiency in arterial blood and is defined as a PaO₂ value lower than 80 mmHg, or an SaO₂ or as an SpO₂ value less than 95% when measured by pulse oximetry (O’Driscoll et al., 2008). Since the publication of studies in the 1990s, it has been widely accepted that states of hypoxaemia are categorised into mild, an SpO₂ of 90%-94%, moderate hypoxaemic, an SpO₂ less than 90% (Eastwood &
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Dennis, 2006; Leaver, Conway, & Hogate, 1994), and severe hypoxaemia, an SpO2 less than 85% (Leaver, et al., 1994). Although it is widely acknowledged that a PaO2 less than 60 mmHg clearly indicates hypoxaemia, a PaO2 between 60 and 80 mmHg with a corresponding SaO2 or SpO2 between 90% and 95% remain clinically undefined (Considine 2005). Published ranges for hypoxaemia, normoxaemia, and hyperoxaemia are shown in Table 2.1.

Table 2.1 Published ranges for hypoxaemia, normoxaemia and hyperoxaemia

<table>
<thead>
<tr>
<th></th>
<th>SpO2 (%)</th>
<th>SaO2 (%)</th>
<th>PaO2 (mmHg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypoxaemia</td>
<td>&lt; 95</td>
<td>&lt; 95</td>
<td>&lt; 60</td>
</tr>
<tr>
<td>Normoxaemia</td>
<td>95-100</td>
<td>95-100</td>
<td>80-100</td>
</tr>
<tr>
<td>Hyperoxaemia</td>
<td>n/a</td>
<td>n/a</td>
<td>&gt; 120</td>
</tr>
</tbody>
</table>

*Note. n/a = not applicable; PaO2 = partial pressure of oxygen; SaO2 = arterial oxygen saturation; SpO2 = oxygen saturation measured by pulse oximetry. Adapted from Considine (2005a) and O’Driscoll et al. (2008).*

There are four causes of hypoxaemia: (a) alveolar hypoventilation, (b) diffusion defects, (c) ventilation / perfusion mismatch, and (d) cardiac shunting. Each of these four causes of hypoxaemia will now be described.

*Alveolar hypoventilation*

Alveolar hypoventilation is the insufficient inflation of alveoli due to a decreased tidal volume or a low respiratory rate and considered the most usual form of hypoxaemia.
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(Considine, 2005a). If the alveoli do not inflate sufficiently then the amount of oxygen reduces, carbon dioxide accumulates and tissue oxygenation decreases due to ineffective external respiration (Treacher & Leach, 1998). Oxygen therapy is used to manage alveolar hypoventilation and is effective in increasing the amount of oxygen available during inspiration (Strachan & Noble, 2001). Definitive management of alveolar hypoventilation however, requires identification and correction of the underlying cause (O’Driscoll et al., 2008).

Diffusion defects

Diffusion defects occur when there is poor oxygen exchange across the alveolar-capillary membrane during external respiration (Leach & Treacher, 2002). Poor gas exchange will result in insufficient oxygen availability at the cellular level (Leach & Treacher, 1998; Treacher & Leach, 1998). Oxygen therapy in the management of hypoxaemia associated with diffusion defects will increases PaO₂, SaO₂ and SpO₂ by making more oxygen available to bind with haemoglobin for use by the cells, however definitive treatment of the underlying cause is necessary (Leach & Treacher, 2002).

Ventilation / perfusion mismatch

Ventilation / perfusion (V/Q) mismatch occurs when blood passes inadequately ventilated alveoli, or the alveoli are adequately ventilated but blood flow is impaired or there is a failure of haemoglobin to become saturated with oxygen in the lung (O’Driscoll et al., 2008). Prolonged severe V/Q mismatch is a known clinical risk, which can lead to death (Levy, 2005). Oxygen therapy will be of no value if the cause is
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due to a lack of blood perfusing the lungs, but will be of some benefit if the cause is reduced ventilation (Considine, 2005a).

Cardiac shunting

Cardiac shunting, as the cause of hypoxaemia, arises from an anatomical abnormality in which blood fails to reach the lungs due to venous blood passing from the right to the left side of the heart (Considine, 2005a). Blood that bypasses the pulmonary circulation cannot become saturated with oxygen, resulting in increasing amounts of deoxygenated blood entering the systemic circulation (Considine, 2005a). Hypoxaemia due to cardiac shunting is typically severe and the response to oxygen therapy is poor, the main treatment option is surgical repair of this anatomical defect (Considine, 2005a). The four causes of hypoxaemia and the responsiveness of each cause to oxygen therapy are shown in Table 2.2.
## Table 2.2 Causes of hypoxaemia and responsiveness to oxygen therapy

<table>
<thead>
<tr>
<th>Cause</th>
<th>Response to oxygen therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alveolar hypoventilation</td>
<td>Occurs due to a decrease in respiratory rate or tidal volume. Good</td>
</tr>
<tr>
<td>Diffusion defects</td>
<td>Decreased movement of oxygen or carbon dioxide between lung alveoli and pulmonary capillaries. May occur as a result of thickening of the alveolar-capillary membrane in the lung. Good</td>
</tr>
<tr>
<td>Ventilation/Perfusion Mismatch</td>
<td>Occurs when there is impaired pulmonary blood flow passed inflated lung alveoli or when the blood passes inadequately inflated lung alveoli. Generally useful if poor ventilation, limited effects if poor perfusion</td>
</tr>
<tr>
<td>Cardiac shunting</td>
<td>Occurs when venous blood passes from the right to the left side of the heart thereby blood is not exposed to lung alveoli. Poor</td>
</tr>
</tbody>
</table>

*Note.* Adapted from Considine (2005a) and McCance & Heuther (2002).
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States of oxygen excess

States of oxygen deficiency carry significant risk and are typically avoided (O’Driscoll et al., 2008). Similarly, states of oxygen excess, while providing a buffer of safety in some patients, may also be injurious (de Jonge et al., 2008; Kilgannon et al., 2010). For example, hyperoxia in the lungs causes histopathological injury, atelelectasis, tracheobronchitis and alveolar protein leakage resulting in impaired oxygen exchange (Altemeir & Sinclair, 2007; O’Driscoll et al., 2008). Systemically, oxygen excess can generate free radicals in various organs and decrease cardiac output (Altemeir & Sinclair, 2007; O’Driscoll et al., 2008).

Hyperoxia and hyperoxaemia are states of oxygen excess. Hyperoxia is a state of higher than normal partial pressure of oxygen (PO2) and hyperoxaemia as a state of elevated PaO2 (O’Driscoll et al., 2008). While it is widely acknowledged that hyperoxaemia is reached at PaO2 values higher than >300 mmHg, a PaO2 of greater than 120 mmHg is also considered to be excessive (Kilgannon et al., 2010). Lack of a clear definition of hyperoxaemia may cause confusion and lead to inconsistent practice regimens among clinicians when deciding to reduce or cease oxygen therapy. While hypoxaemia, with its physical signs and symptoms is relatively easily identified using oxygen saturation and or PaO2, diagnosis of hyperoxaemia is only possible by measuring PaO2 because SpO2 and SaO2 are only measured as a percentage and normal is 100% (O’Driscoll et al, 2008).

Notwithstanding the risks associated with states of oxygen excess, there are certain clinical situations in which raising PaO2 to values higher than normal is
indicated. Carbon monoxide poisoning is one specific clinical condition in which high concentrations of inspired oxygen are desirable (Harper & Croft-Baker, 2004). Carbon monoxide has a 200 times greater affinity for haemoglobin than oxygen and remains bound to haemoglobin for longer than oxygen (Weaver, 2009), causing anaemic hypoxia and preventing oxygen from reaching the tissues (Harper & Croft-Baker, 2004; Weaver, 2009). Emergency management of the patient with carbon monoxide poisoning is to remove the person from the carbon monoxide source and administer high concentrations of inspired oxygen (Harper & Croft-Baker, 2004; Turner, Hamilton-Farrell, & Clark, 1999; Weaver, 2009) in an attempt to optimise oxygen uptake and delivery to displace the carbon dioxide molecules from haemoglobin (Harper & Croft-Baker, 2004).

Oxygen monitoring methods

Oxygen therapy management is complex and clinicians must balance the appropriate use of oxygen therapy to treat oxygen deficiency and avoid oxygen excess. Although it is noted in the current literature that there are limitations to the assessment methods used to measure oxygenation, the combination of monitoring and physical assessment provides clinicians the tools to detect respiratory related abnormalities.

Monitoring PaO₂, SaO₂ and SpO₂ using oxygen monitoring methods arterial blood gases (ABGs) and pulse oximetry is an essential adjunct to patient assessment. It is important to understand the advantages and disadvantages of these two methods of monitoring oxygen because the majority of decisions made by clinicians to commence, change or stop oxygen therapy are based on the findings of pulse oximetry or arterial blood gas sampling. A full discussion of the clinical assessment of oxygenation,
including respiratory rate, heart rate and blood pressure, skin pallor and conscious state and how they relate to clinical assessment undertaken by nurses is presented later in the chapter.

**Arterial blood gases**

The variables of interest when assessing the amount of oxygen in arterial blood gases are PaO₂ and SaO₂ (Higginson & Jones, 2009). To obtain an arterial blood gas sample a small amount of arterial blood is drawn from an indwelling intra-arterial catheter, if available, or arterial puncture (Andrews & Waterman, 2008; Chenuel, Poussel, Nguyen, Villemot, & Haouzi, 2008). Arterial blood gases provide information about the adequacy of ventilation and can be used to measure the partial pressure of arterial carbon dioxide (PaCO₂) (Higginson & Jones, 2009). Arterial carbon dioxide tension is a major modulator of respiratory rate in humans (Curley, Laffey, & Kavanagh, 2010). Under normal conditions, increased levels of arterial carbon dioxide will increase ventilation as the body attempts to clear excess carbon dioxide via the lung (O’Driscoll et al., 2008).

Arterial blood gas samples also provide information about acid-base balance, as pH levels can be measured via this method (Higginson & Jones, 2009). Knowledge of acid-base balance provides insight into the forces behind many respiratory related processes. Acidity in any solution is determined by the concentration of hydrogen ions (H⁺) and is often expressed in terms of pH with the notation pH = -log₁₀(H⁺) (Marieb, 2004). The importance of pH and its effect on oxygen to be released from haemoglobin were discussed previously in this chapter. Acidosis may be caused by respiratory or
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metabolic disorders (acid-base imbalances). Knowing the underlying cause of the acidosis or alkalosis provides information with which nurses can use to make oxygen therapy management decisions.

**Pulse oximetry**

Oxygen saturation monitoring using pulse oximetry (SpO₂) refers to the estimation of the oxygen saturation of arterial blood (SaO₂) by using an oximeter device. Pulse oximeters measure pulsatile changes in red and infrared light transmission across a tissue bed (O’Driscoll et al., 2008). Pulse oximeters work on the principle that oxygenated haemoglobin and deoxygenated haemoglobin absorb light of different wavelengths (Jubran, 2004).

Seminal studies conducted in the late 1980s and 1990s identified a significant positive correlation between arterial oxygen saturation measured by arterial blood gas analysis (SaO₂) to the oxygen saturation measured by pulse oximetry (SpO₂) (p<0.0001, r = 0.920) (Tittle & Flynn, 1997). In healthy volunteers, the accuracy of pulse oximeters was established with a mean difference (bias) of less than 2%, and a standard deviation of less than 3% when SaO₂ is greater than or equal to 90% (Morris, Nairn, & Torda, 1989; Nickerson, Sarkisian, & Tremper, 1988). For critically ill patients with good arterial perfusion results are comparable. Yet, in both hypoxaemic healthy volunteers or critically ill patients in the emergency department (Wilson, Cowan, Lord, Zuege, & Zygun, 2010), or critically ill mechanically ventilated patients, the accuracy of pulse oximetry diminishes (Jubran & Tobin, 1990). Thus, pulse oximetry measurements
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together with assessment of other clinical indicators of oxygenation are important when assessing a patient’s respiratory state.

Pulse oximetry has some important limitations that need to be considered when identifying the type of respiratory dysfunction experienced by the patient and to determine if oxygen therapy is appropriate management. An important limitation of pulse oximetry is that it does not provide information on ventilation (PaCO₂ and pH) (Clark, Giuliano, & Chen, 2006; Howell, 2002). Therefore, SpO₂ readings should form a part of a comprehensive clinical assessment of indicators of oxygenation and respiratory function (Wong & Elliott, 2009) and play a key role in determining the need for arterial blood gas sampling and when to seek further information about a patient’s oxygen status (Miller, 1992; Van de Louw et al., 2001).

Potential sources of error in pulse oximetry measurements include intravenous dyes (e.g. methylene blue), low-perfusion states (e.g. shock, sepsis and hypotension) (Grace, 1994; Saito, Fukura, Shimada, & Fujita, 1995), dark skin pigmentation (Feiner, Severinghaus, & Bickler, 2007) or the use presence of nail polish (Hinkelbein, Genzwuerker, Sogl, & Fiedler, 2007) causing resulting in poor signal quality or strength. Pulse oximeter probe placement is also known to affect the accuracy of readings (Kisiel & Perkins, 2006) and poor placement may lead to errors related to oxygen management (Wong & Elliott, 2008). Oximetry readings obtained from finger and earlobe probes have been demonstrated to be more accurate than those obtained by placing the probe on a toe (Jubran, 2004). However, the patient’s tolerance to having a probe placed on a finger, earlobe or toe will also impact on the ability to obtain an accurate SpO₂ reading.
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(Jubran, 2004). Thus, site selection for the pulse oximetry probe is another important consideration during the respiratory assessment of the patient.

So far, the physiological need for oxygen, normal and abnormal oxygen states, and oxygen monitoring methods have been discussed. In the following section the clinical risk of respiratory dysfunction and the evidence supporting the use of oxygen therapy for the management of respiratory dysfunction is presented. The following discussion includes information about nasal prongs, face mask and nasopharyngeal oxygen catheter devices which are examined in the research studies discussed in subsequent Chapters of this thesis.

Respiratory dysfunction and the role of oxygen therapy

Respiratory dysfunction and adverse events

Respiratory dysfunction is a clear clinical risk and indicator of serious illness and precursor to adverse events such as cardiac arrest, unplanned intensive care unit admission and death (Cretikos et al., 2008; Harrison et al., 2005; Quach et al., 2008). When Considine (2004) reviewed the relationship between hypoxaemia and adverse events, hypoxaemia was the most common reason for the activation of a Medical Emergency Team. Respiratory dysfunction places patients at high risk of adverse events and warrants timely and appropriate response from intensive care nurses.

Two of the strongest early warning signs of respiratory dysfunction are hypoxaemia and abnormal respiratory rates. Unfortunately, many investigators have identified that many patients in hospital have unrecognised or inappropriately treated
Hypoxaemia is a significant risk factor for adverse events and a significant risk factor for death following an adverse event (Goldhill & McNarry, 2004; Hillman et al., 2001; Santiano et al., 2009; Schein, Hazday, Pena, Ruben, & Sprung, 1990; Skrifvars, Nurmi, Ikola, Saarinen, & Castren, 2006; Suljaga-Pechtel, Goldberg, Strickon, Berger, & Skovron, 1984). Buist et al. (2004) conducted a retrospective study to determine whether abnormal clinical observations in a patient population could predict subsequent in-hospital mortality. Over the study period, 6303 patients were admitted to five general hospital wards at a suburban tertiary teaching hospital. A chart review of these patients revealed that 564 (8.9%) experienced 1598 pre-determined clinical abnormal events and 146 (0.9%) patients died. The two most common clinical events were arterial oxygen desaturation and hypotension. Buist et al., (2004) used a logistic regression model to identify six abnormal clinical observations that could increase by almost seven-fold the risk of onset of a medical emergency including cardiac arrest or mortality, with two of those clinical observations related to respiratory dysfunction: respiratory rate less than
six breaths per minute and an oxygenation saturation of less than 90%. Suljaga-Pechtel et al. (1984) examined arterial blood gas samples of patients who experienced a cardiac arrest and found that more than half of the patients had significant hypoxaemia (PaO$_2$ less than 50 mmHg), but less than half of those patients were successfully resuscitated. The findings of these two studies, although separated by 20 years are important, as the presence of hypoxaemia remains a significant clinical indicator of a serious adverse event.

Respiratory rate is a routine component of the physiological assessment of a patient (Higginson & Jones, 2009; Simpson, 2006); however, greater awareness of the importance of abnormal respiratory rates, as an indicator of serious illness, is advocated (Cretikos et al., 2008). Crekitos et al. (2008) report that clinical studies conducted over the past 20 years have shown that abnormal respiratory rates, in particular tachypnoea, is an important predictor of serious adverse events such as cardiac arrest, or admission to the intensive care unit. While respiratory rate, may be a non-specific indicator of hypoxaemia, assessing and documenting respiratory rate is important because as noted above tachypnoea is an early warning sign of a clinical adverse event. To help identify and manage patients at risk of a respiratory related adverse event Crekitos et al. (2008) concluded that improvements needed to be made to the frequency and recording of respiratory rate in hospital observation charts. Table 2.3 provides a summary of key studies that have specifically examined the association between derangements in the clinical indicators of respiratory dysfunction (bradypnoea, tachypnoea and hypoxaemia) and the occurrence of outcomes such as death, cardiac arrest, or admission to an intensive care unit.
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Table 2.3 Summary of key research relating to bradypnoea, tachypnoea and the presence of hypoxaemia as a precursor to an adverse event

<table>
<thead>
<tr>
<th>Study</th>
<th>Sample</th>
<th>Results</th>
<th>Critique</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camarata et al., 1971</td>
<td>193 cardiac arrests in 132 patients</td>
<td>40% (13/33) of patients experienced a cardiac arrest deemed to be ‘unexpected’.</td>
<td>Unexpected sudden deterioration in hospitalized patients may result in cardiac arrest.</td>
</tr>
<tr>
<td>Suljaga Pechtel et al., 1984</td>
<td>207 cardiac arrests.</td>
<td>59% of patients had significant hypoxaemia (PaO₂ less than 50 mmHg).</td>
<td>Significant respiratory dysfunction at the onset of resuscitation is a strong indicative of a poor patient outcome.</td>
</tr>
<tr>
<td>Goldhill et al., 1999</td>
<td>79 admission to intensive care for 76 patients.</td>
<td>34% of patients experienced cardiac arrest prior to ICU admission. 75% of patients received oxygen, 37% had an ABG and 61% had SpO₂ measurements (of which</td>
<td>Significant hypoxaemia was commonly in the hours preceding a cardiac arrest and prior to ICU admission.</td>
</tr>
</tbody>
</table>
## OXYGEN THERAPY MANAGEMENT

<table>
<thead>
<tr>
<th>Study</th>
<th>Sample</th>
<th>Results</th>
<th>Critique</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>63% were less than 90% in the preceding 6-hours prior to ICU admission.</td>
<td></td>
</tr>
<tr>
<td>McGloin et al., 1999</td>
<td>89 unexpected admission to intensive care.</td>
<td>60% of patients had recognisable abnormal physiological signs prior to their unexpected admission to intensive care. 32% (6/19) patients had inappropriate treatment of their physiological abnormality prior to intensive care admission.</td>
<td>Recognisable abnormal vital signs commonly precede unaccepted admission to ICU and failure to recognize abnormal vital signs delays treatment.</td>
</tr>
<tr>
<td>Buist et al., 2004</td>
<td>43 cardiac arrests and 79 unplanned ICU admissions from five general hospital wards of a single hospital.</td>
<td>122 adverse events in total: 76% of adverse events were preceded by abnormal physiology for greater than 1 hr, 33% of adverse events had abnormal physiology for greater than 24 hrs. 34.9% (n = 20) of the adverse observations that reach</td>
<td>Although this was a single-centre study with a MET team and a study population that included patients with not for resuscitation order and potential for underestimate of</td>
</tr>
</tbody>
</table>
### Study Sample Results Critique

**Quach et al., 2008**  
Retrospective medical record audit of 200 patients who had a MET call from a single acute care hospital. Patients with respiratory distress more likely to be postoperative (40% vs 28%, \(p = 0.07\)). Hospital mortality for MET calls due to respiratory distress was 38%. The median duration of delay for MET activation for patients with respiratory distress was 12 hrs. A delay in activation a MET was associated with an increase in mortality (OR, 2.10; 95% CI: 1.01-4.34; \(p = 0.045\)).

### Study Sample Results Weaknesses/limitations

**Considine et al., 2009**  
Retrospective case-control study of predictors of respiratory rate abnormalities at triage (low RR less than 12 or high RR greater than 22) was associated with an increase in mortality (OR, 2.10; 95% CI: 1.01-4.34; \(p = 0.045\)).
## OXYGEN THERAPY MANAGEMENT

<table>
<thead>
<tr>
<th>Study</th>
<th>Sample Description</th>
<th>Results</th>
<th>Weaknesses/limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICU admission of 386 ED patients.</td>
<td>had increased risk of admission to intensive care (OR 1.66, 95% CI: 1.05-2.06).</td>
<td>delivered but undocumented care.</td>
<td>Between-group differences that failed to reach statistical significance may be related to sample size.</td>
</tr>
<tr>
<td>Santino et al., 2009 Descriptive study of MET calls in six hospitals over a 12-month period.</td>
<td>35.2% (n = 324) of ‘breathing’ related problems results in the calling of a MET with a low SpO₂ resulting in 29.2% (n = 249) of MET activations. Breathing abnormalities resulting in low SpO₂ readings contributed to over a quarter of MET calls. Se of subjective MET call criteria can be a useful adjunct to standard MET call criteria. Breathing problems accounted for most (46%) of the unexpected admissions to ICU for ‘worried’ MET calls.</td>
<td>Breathing abnormalities resulting in low SpO₂ readings contributed to over a quarter of MET calls. Se of subjective MET call criteria can be a useful adjunct to standard MET call criteria. Breathing problems accounted for most (46%) of the unexpected admissions to ICU for ‘worried’ MET calls.</td>
<td></td>
</tr>
</tbody>
</table>

*Note.* ABG = arterial blood gas; ED = emergency department; ICU = intensive care unit; MET = medical emergency team; PaO₂ = partial pressure of arterial oxygen; RR = respiratory rate; SpO₂ = Oxygen saturation measured by pulse oximetry.
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Oxygen therapy

For the purpose of this thesis, oxygen therapy is defined as the therapeutic administration of supplemental oxygen to patients using nasal prongs, face mask and nasopharyngeal oxygen catheter. As the central tenant of this thesis is intensive care nurses’ management of oxygen therapy, it is necessary to describe how oxygen therapy is administered and the various factors that may make oxygen therapy difficult to manage or ineffective.

In the following section three issues will be discussed. These are:

• Oxygen therapy, oxygen flow rate and mode of breathing
• Oxygen device size and fit
• Efficacy of the nasal prongs, face mask and nasopharyngeal oxygen catheter to achieve and maintain adequate SpO₂

Oxygen therapy and flow rates

All oxygen delivery devices assist patients to breathe air which has greater concentrations of oxygen than room air (Stich & Cassella, 2009). The basic requirements for the therapeutic use of oxygen delivery devices include: the ability to control the percentage of oxygen in inspired gas, minimal accumulation of carbon dioxide, minimal resistance to breathing (inspiration and expiration), efficiency and economy in oxygen use and, adaptability to different respiratory rates (O’Driscoll et al., 2008). Knowledge of the general characteristics of oxygen therapy is required to ensure appropriate oxygen delivery device selection and use (O’Driscoll et al., 2008).
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Knowledge regarding oxygen management is vital for patient safety interventions. Ensuring appropriate oxygen delivery device selection is a fundamental step in response to and prevention of respiratory dysfunction. Commonly used oxygen delivery devices include nasal prongs, face mask and nasopharyngeal oxygen catheter. Each of these devices provide the patient with more than 21% FiO₂ but less than 100% due to the interrelationship of oxygen flow, device factors, such as functional apparatus dead space, and patient factors such as peak inspiratory flow rate and expiratory pause (Wagstaff & Soni, 2007; West, 2008). Differences in the oxygen flow, peak inspiratory flow rate and the length of the expiratory pause will result in variations of the effectiveness of oxygen delivery between patients and at times with an individual patient on a breath-by-breath basis (Barnes, 2000; Calianno, Clifford, & Titano, 1995; O'Connor & Vender, 1995).

The concentration of supplemental oxygen administered can be described either as a concentration of oxygen expressed as a percentage (%), or as a fraction of inspired oxygen expressed as a decimal (Stich & Cassella, 2009). For example, the concentration of oxygen in room air is 21% oxygen or oxygen at a fraction of inspired oxygen of 0.21 (Pruitt & Jacobs, 2003; Stewart & Howard, 1990). Thus, an increase in the concentration of supplemental oxygen can range from 22% to 100% or from 0.22 to 1.0 (Sim, Dean, Kinsella, Black, Carter, & Hughes, 2008; Stich & Cassella, 2009). For the purpose of this thesis, the concentration of oxygen will be described as a percentage.

The performance of oxygen delivery devices is commonly described in terms of ‘delivered oxygen concentration’ and ‘inspired oxygen concentration’. ‘Delivered
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‘inspired oxygen concentration’ refers to the concentration of oxygen at the site of the oxygen delivery device (Goldstein, Young, & Rebuck, 1982; Stich & Cassella, 2009). Delivered oxygen concentration is closely linked to the flow of oxygen into an oxygen delivery device and has a direct impact on the concentration of oxygen that will be inspired by the patient (Mulryan, 2009). For the purposes of this thesis the term ‘inspired oxygen concentration’ refers to the concentration of oxygen actually inspired by the patient.

Normal inspiratory flow, in a healthy adult, ranges between 25 litres per minute and 53 litres per minute. Patients with respiratory dysfunction can increase their inspiratory flow by 50 to 300 litres per minute (Rose & Hanlon, 2012). Because oxygen delivery devices deliver oxygen at set flow rates, generally less than 30 litres per minute, the additional volume of gas is obtained from the surrounding atmosphere (Rose & Hanlon, 2012). Thus, when room air is entrained the inspired oxygen concentration is decreased as the room air dilute the amount of oxygen delivered to the patient when oxygen delivery devices are used (Corley & Ringdal, 2012).

When respiratory rate or minute ventilation (the amount of oxygen drawn into the lungs over a minute) increases, due to pain, anxiety or serious illness, the peak inspiratory flow rate increases proportionately (Higginson & Jones, 2009). Conversely, a decrease in respiratory rate or minute ventilation will decrease the volume of room air entering the lungs and result in an increase in the inspired oxygen concentration (O’Driscoll et al., 2008).

As discussed in the paragraphs above, oxygen flow rate is a key decision point in the selection and use of oxygen delivery devices. Oxygen flow rate is the speed at...
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which oxygen enters the oxygen delivery device and it is described as litres per minute
and equates to the value displayed by the oxygen flow meter (Barnes, 2000). Oxygen
flow meters, in use in Australian intensive care units, generally have a maximum flow
capacity of 15 litres per minute.

During normal breathing the respiratory pattern of air movement into and out of
the lung is essentially sinusoidal, with the peak inspiratory flow rate occurring during
the middle of inspiration (West, 2008). The term ‘inspiratory flow rate’ is the speed at
which air is drawn into the lungs and has a direct impact on the percentage of inspired
oxygen concentration (West, 2008).

Mode of breathing, via the nose or mouth, impacts on efficacy of oxygen
delivery devices to achieve satisfactory oxygen concentration (O’Driscoll et al., 2008).
Clinical studies have identified that mouth breathers receive higher concentration of
oxygen in the nasopharynx than nasal breathers when nasal devices are in use (Fairfield,
Goroszeniuk, Tully, & Adams, 1991; Waligora, 1970). To assess the impact of device
fit on a known FiO₂, Boumphrey et al. (2003) tested 20 healthy adults to demonstrate
that tight fitting masks, opposed to loose fitting masks, resulted in higher expired oxygen
concentrations. They conclude that by using tight-fitting face masks it was possible to
achieve an expired concentration of oxygen of 85%, which equates with inspired oxygen
concentration of 97%. Thus, the potential implication of face mask fit should recognised
as delivered and inspired oxygen concentrations will vary depending on the fit of the
device (Boumphrey et al., 2003; Higginson & Jones, 2009).
The difference between delivered and inspired oxygen concentration is a physiological concept that nurses must understand when administering supplemental oxygen. Respiratory rate and peak inspiratory flow rate directly influence the effectiveness of oxygen delivery devices and the ability of the patient to maintain adequate \( \text{SpO}_2 \) or \( \text{PaO}_2 \) levels (Eastwood et al., 2007). For example, when nasal prongs or a simple face mask are used to deliver oxygen therapy, the inspired oxygen concentration is less than the delivered oxygen concentration because during inspiration room air is entrained (drawn in) to the lungs as well as the delivered oxygen (Sim et al., 2008).

Whether oxygen therapy is effective or not depends on several patient-related factors including: mode of breathing (e.g. nose breathing or mouth breathing); the shape and fit of the oxygen delivery device and if it is comfortable for the patient to wear.

**Oxygen device size, shape and fit**

The oxygen delivery device influences effective oxygen therapy, especially the device related factors of size, shape and fit. A device that is not the correct size or fits poorly, either too small or too large may lead to variable amounts of oxygen being delivered to the patient or device displacement resulting in periods that the patient does not receive any supplemental oxygen. To demonstrate the importance of correct fit and device placement, Nolan et al. (1992) investigated nocturnal activities and the impact of oxygen delivery device removal by measuring the \( \text{SpO}_2 \) on pulse oximetry of 30 postoperative patients, randomly allocated to face mask at four litres per minute or nasal prongs at two litres per minute, and identified that in the face mask group the device
remained in correct position in five patients but in ten patients the device was removed a total of 28 times for up to 78 mins, 17 of those were for nursing duties. For the nasal prongs group, one patient removed the device 18 times for a total period of 16 min 28 secs with an average SpO\textsubscript{2} of 97% (range 90.8 – 99.3%), meaning that nasal prongs were better tolerated. Consequently, nurses need to be aware of any activity that may interrupt oxygen delivery and actively engage in strategies to prevent device removal.

To summarise, any change in oxygen flow rate and a patient’s peak inspiratory flow rate on has an effect on the concentration of inspired oxygen. Mouth breathing when wearing nasal prongs can decrease the concentration of inspired oxygen. However, mouth breathers received higher oxygen concentration in the nasopharynx than nasal breathers when nasal oxygen delivery devices were used (Dunlevy & Tyl, 1992; Nolan, Baxter, Winyard, Roulson, & Goldhill, 1992; Nolan et al., 1993; Ooi, Joshi, & Soni, 1992). Factors influencing effective oxygen therapy included mode of breathing and device size, shape and fit. As with oxygen flow rate and peak inspiratory flow rate, mode of breathing, either by mouth or nose, has also been shown to impact on FiO\textsubscript{2} (Dunlevy & Tyl, 1992). Thus, it is important for nurses to assess the mode of breathing in order to tailor the appropriate oxygen delivery device to optimise the therapeutic effect of oxygen administration.

**Oxygen delivery devices**

Nasal prongs, face mask and nasopharyngeal oxygen catheter are often the first choice selected by nurses for the management of respiratory dysfunction (Eastwood et al., 2007). The discussion in the section to follow focuses on the general characteristics
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and care requirements for nasal prongs, face mask, and nasopharyngeal oxygen catheters.

Nasal prongs

Nasal prongs consist of two short tapered prongs (about 1 cm in length) (Eastwood et al., 2007), which when applied correctly to the patient’s face, each prong lies approximately 1 cm within each nostril (Eastwood et al., 2007; Pruitt & Jacobs, 2003). To facilitate optimal positioning and functioning the tubing of the nasal prongs is looped over the ears and secured under the patient’s chin (Barnes, 2000; Eastwood et al., 2007). Oxygen flows for nasal prongs range from half a litre per minute to six litres per minute and flow are adjusted to achieve a target oxygen saturation (Eastwood et al., 2007).

The delivery of oxygen therapy via nasal prongs may be considered unsuitable in any patient at risk of nasal damage, deformity or blockage, as adequate supplemental cannot be assured (Eastwood & Dennis, 2006). Nasal prongs should be used with caution in patients immediately following upper airway or nasal surgery, those with impaired airway protection, or severe forms of hypoxaemia (Eastwood & Dennis, 2006).

Patients receiving supplemental oxygen via nasal prongs are monitored for signs of ventilator adequacy including oxygen saturation, respiratory rate and respiratory depth. The need to escalate therapy should be considered when oxygen saturation levels are not being maintained. Patients receiving oxygen via nasal prongs need to be
monitored for pressure sores at the base of the nose, ears or face, and that the nasal prongs are positioned correctly (Kacmarek, Dimas, & Mack, 2005).

**Face mask**

The simple face mask is a plastic, ‘pear shaped’ device that covers the nose and mouth. For optimal effect the face mask should fit firmly to the face and be secured in place with a band around the back of the head (Barnes, 2000). Recommended oxygen flow rates when using a face mask range from six litres per minute to 15 litres per minute (Eastwood & Dennis, 2006). Typically, flow rates of five to 10 litres per minute are used in the clinical setting to treat symptoms of moderate hypoxaemia (SpO₂ 90-95%) (Eastwood & Denis, 2006). Oxygen flow rates of less than six litres per minute when using a face mask are discouraged (O’Driscoll et al., 2008). Low oxygen flow rates during face mask therapy may be insufficient to eliminate exhaled carbon dioxide which may then be re-breathed by the patient (Jensen, Johnson, & Sandstedt, 1991; O’Driscoll et al., 2008).

Some patients may experience claustrophobic sensations, drying of the mucous membrane in the mouth and nose, or be at higher risk of aspiration if they vomit and it collects in the mask. The patient receiving oxygen via a face mask requires ongoing assessment of ventilation, pulmonary function and oxygenation and must be monitored for compliance with therapy and assessed for the need to progress to more advanced or simplified supports (Eastwood & Dennis, 2006). Additional monitoring should be directed at detection of respiratory fatigue, non-compliance with therapy, device removal or displacement, and device related complications such as undue mask pressure.
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on the bridge of the nose, or soreness related to the mask’s strapping (Eastwood & Dennis, 2006; Kacmarek et al., 2005; O’Driscol et al., 2008; Sasaki et al, 2003).

Nasopharyngeal oxygen catheter

Nasopharyngeal oxygen catheters deliver of supplemental oxygen directly into the nasopharynx (Eastwood et al., 2004; Frey, McQuillan, Shann, & Freezer, 2001). Nasopharyngeal oxygen catheters are placed through the nose to the depth of the nasopharynx and secured in position by using tape (Eastwood, et al., 2004). Recommended oxygen flow rates for nasopharyngeal oxygen catheters is 1 litre per minute to 6 litres per minute, to achieve approximate inspired oxygen concentration of 25-35%, with the oxygen flow rate adjusted to meet SpO₂ targets (Eastwood & Dennis, 2006).

The nasopharyngeal oxygen catheter may be suitable when there are physical limitations to the use of a face mask to deliver oxygen therapy, or if discomfort with face masks or nasal prongs exist (Eastwood & Dennis, 2006). Contraindications to the use of the nasopharyngeal oxygen catheter include epistaxis, nasal trauma or in patients receiving anti-coagulant therapy (Eastwood & Dennis, 2006). Monitoring patients receiving oxygen via the nasopharyngeal oxygen catheter include continuing evaluation of pulmonary function, respiratory effort, and therapy-related complications such as undue catheter pressure on the base of the nose or excessive nasopharyngeal drying.
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A comparison of general characteristics and relative advantages and disadvantages of nasal prongs, face mask and nasopharyngeal oxygen catheter is shown in Table 2.4.
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Table 2.4 Comparison of nasal prongs, face mask and nasopharyngeal oxygen catheter oxygen delivery devices

<table>
<thead>
<tr>
<th>Device</th>
<th>Oxygen flow rates</th>
<th>Approximate FiO₂</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPO</td>
<td>1 to 6 LPM</td>
<td>25-35%</td>
<td>Low cost per unit, eating and drinking not hindered, constant oxygen delivery into upper airway, difficult to dislodge</td>
<td>Catheter blockage, excessive mucus accumulation in nasopharynx, invasiveness of insertion procedure, risk of nasal trauma and potential for bleeding</td>
</tr>
<tr>
<td>NP</td>
<td>0.5 to 6 LPM</td>
<td>22-40%</td>
<td>Simple to apply and eating and drinking not hindered</td>
<td>OFR greater than 4 LPM may cause discomfort, device can be easily dislodged, device can irritate skin around the ears and nares</td>
</tr>
<tr>
<td>FM</td>
<td>6 to 15 LPM</td>
<td>30-90%</td>
<td>Useful for short periods, able to deliver higher FiO₂ than nasal prongs, or oxygen catheters</td>
<td>Recommended OFR greater than 6 LPM. Device removal to eat, cough or allow the passage of vomitus, may induce feelings of claustrophobia, CO₂ re-breathing can occur</td>
</tr>
</tbody>
</table>

*Note. CO₂ = carbon dioxide; FiO₂ = fraction of inspired oxygen; LPM = litres per minute; OFR = oxygen flow rate. Oxygen flow rate reported in litres per minute. Adapted from Barnes (2000), Calianno et al. (1995), Eastwood and Dennis (2006) and O’Connor and Vender (1995).*
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Research comparing oxygen delivery devices

Oxygen therapy is a frequent intervention commonly applied to hospitalised adult patients (Bateman & Leach, 1998; Shelly & Nightingale, 1999). Despite the importance of oxygen therapy for prevention and treatment of respiratory dysfunction, few of the commonly used oxygen delivery devices have been subject to critical examination (Kernick & Magarey, 2010), and neither have the oxygen therapy management decisions by intensive care nurses been explored (Eastwood et al., 2012).

The purpose of this section of the literature review is to describe and critique the published research comparing nasal prongs, face mask and nasopharyngeal oxygen catheters in adult hospitalised patients. Studies were included if they compared the three aforementioned devices assessing effectiveness to achieve and maintain adequate oxygen saturations and patient-related measures of comfort and compliance with therapy. Studies were excluded if they:

- did not refer to oxygen saturation (SaO₂ or SpO₂) as an outcome measure (Heller, Watson, & Imredy, 1965)
- did not report comfort outcome measures from bench studies (Bazuaye, Stone, Corris, & Gibson, 1992; Fairfield et al., 1991; Goldstein et al., 1982; Leigh, 1970; Ooi et al., 1992; Redding, McAfee, & Gross, 1978)
- were studies undertaken in healthy individuals (Boumphrey et al., 2003; Hess, D’Agostino, Magrosky, Myers, & Shuman, 1984; Sasaki et al., 2003; Waldau, Larsen, & Bonde, 1998)
- did not pertain to the population of interest: adult hospitalised patients (Cogliano, Graham, & Clark, 2002; Frey et al., 2001; Muhe et al., 1998;
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- did not report primary research (Eastwood & Dennis, 2006; Kernick & Magarey, 2010; Stewart & Howard, 1990), were not reported in English (Lund, Holm-Knudsen, Nielsen, & Foge Jensen, 1996)
- did not include a comparison between two of the three oxygen delivery devices under examination (Bambridge, 1993; Costello, Liston, & McNicholas, 1995; English & Brown, 1994; Hudes, Marans, Hirano, Scott, & Ho, 1989; Jacobsen, Neilsen, Brinklov, Stokke, & Hartmann-Andersen, 1980; Williams, Jones, & Mapleson, 1988)

The literature review identified six key studies that had compared oxygen therapy delivered via nasal prongs with face mask or oxygen therapy delivered via face mask with nasopharyngeal oxygen catheter. The six identified studies were published from 1993-2009 and had sample populations of drawn from the general ward, post-anaesthetic care unit (PACU) or the ICU. Therapeutic innovations are frequently introduced into clinical practice in an attempt to optimise patient outcomes. However, oxygen delivery devices have not developed significantly for decades resulting in therapy being administered with oxygen delivery devices, as such comparison of oxygen delivery devices and their use over time is possible (Kernick & Magarey, 2010). Five of the six studies were a comparison between nasal prongs and face mask (Ayhan, Iyigun, Tastan, Emin, & Ozturk, 2009; Bolton & Russell, 2001; McBrien & Sellers, 1995; Nolan, et al., 1993; Stausholm et al., 1995) and the sixth study compared the face mask device with the nasopharyngeal oxygen catheter device (Eastwood et al., 2004). None
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of the studies identified had included a simultaneous comparative study of nasal prongs, face mask and nasopharyngeal oxygen catheter devices. Oxygenation saturation (SaO₂ or SpO₂) was the primary outcome identified for the six studies selected.

In all studies SpO₂ values were greater than or equal to 95% when the oxygen delivery device remained in position. Eastwood, Revees & Cowie (2004) in a prospective crossover study, identified a higher PaO₂ for face mask therapy compared with nasopharyngeal oxygen catheter use for 50 intensive care patients. The higher PaO₂ in this study could be attributed to the higher oxygen flow rate used with the face mask device. Similarly, McBrien & Sellers (1995) in their crossover trial of nasal prongs and face mask for 11 post-operative patients also showed that oxygen therapy via face mask provided higher PaO₂ values than that of the nasal prongs. In addition, using a quasi-experimental design conducted in the post-anaesthetic care unit, Nolan et al. (1993) identified patients randomly allocated to receive nasal prong oxygen therapy had a higher incidence of hypoxaemia than that of patients who received face mask oxygen therapy. The conclusion being drawn was that oxygen therapy via face mask would reduced the incidence of hypoxaemia in patients requiring simple oxygen therapy during periods of post-operative recovery.

The findings of the reviewed studies have important implications for the selection of oxygen delivery devices by clinicians for the management of respiratory dysfunction. However, the strength and level of evidence that can be derived from these studies is not strong. As such, it is necessary to conduct further investigations into the clinical effectiveness of nasal prongs, face mask and nasopharyngeal oxygen catheter
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devices, so that any future recommendations can be compared to a known quantity and specific to the intensive care patient.

Patient comfort and compliance with therapy was the second outcome for the review and a description of patient comfort or compliance with therapy was reported in the identified studies (Ayhan et. al, 2009; Bolton & Russell, 2001; Eastwood et al., 2004; McBrien & Sellers, 1995; Nolan et al., 2009; Stausholm et al., 1995). Patient comfort is an influential factor on the clinical effectiveness of oxygen therapy because an uncomfortable device is likely to be removed by the patient and expose the patient to episodes of hypoxaemia. Findings from each of the reviewed studies showed that patients preferred nasal devices compared with face mask. Importantly, findings reported by Nolan et al., (1993) and Ayhan et al., (2009) identified that face mask devices were more frequently removed than nasal prongs. A detailed description of the various factors known to influence patient comfort and compliance with therapy is presented later in this chapter. Table 2.5 presents a summary of six studies that have compared the clinical effectiveness and comfort of nasal prongs, face mask and nasopharyngeal oxygen catheter devices in adult hospitalised patients.

More information pertaining to the efficacy of oxygen therapy devices, the potential complications of each device, how patients experience the use of the devices and the experience of nurses in applying the devices to deliver oxygen therapy, would provide knowledge on which nurses could base their practice. Gaps in the literature exist because previous studies have failed to explore the multiplicity of factors that
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influence effective oxygen therapy practice. Consequently, the previous studies are unable to provide strong evidence to inform clinicians’ oxygen management practices.

In summary, oxygen therapy enables clinicians to manage the risks associated with respiratory dysfunction and the management of oxygen deficient states. The section above has described oxygen therapy and focused on three specific oxygen delivery devices. However, in clinical practice there is an interplay between oxygen delivery device, patient, and nurse related factors. These factors each exert an influence on the effectiveness of oxygen therapy. In the following sections of the literature review the patient and nurse related factors known to influence oxygen therapy management are discussed.
Table 2.5 Summary of studies that have compared the clinical effectiveness and comfort of nasal prongs, face masks and nasopharyngeal oxygen catheters in adult hospitalised patients

<table>
<thead>
<tr>
<th>Author</th>
<th>Design</th>
<th>Sample/Setting</th>
<th>Oxygen delivery device</th>
<th>Outcome/Result</th>
<th>Weaknesses/Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nolan et al., 1993</td>
<td>Quasi-experimental</td>
<td>30 patients, general surgical ward: 1st postoperative night.</td>
<td>NP FM NPO</td>
<td>X X The mask for patients in the FM group positioned correctly in five of the 10 patients. FM removed a total of 28 times: (17 for nursing tasks) for a median time of 2 min 39 sec (range 30 sec to 7 hr 40 min 40 sec). One patient in the NP group removed the NP for 16 min 38 sec and eight times in another patient for a total of 1 hr 18 min 7 sec. The mean SpO2 with FM on was 98% (range 96.1–99.9%), and for the NP group 97% (range 90.8–99.3%); with FM removed 95% (range 89.8–98.8%).</td>
<td>Randomisation method not explicit. Patients in the face mask group commenced with a oxygen flow rate of 4 litres per minute. Primary outcome measures based on compliance with therapy and not satisfactory oxygenation. Failure to intervene when patients became hypoxaemic. Statistical analysis not clearly presented and results predominantly descriptive. No measure of patient comfort or oxygen delivery device preference.</td>
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</table>
## OXYGEN THERAPY MANAGEMENT

<table>
<thead>
<tr>
<th>Author</th>
<th>Design</th>
<th>Sample/Setting</th>
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<th>Outcome/Result</th>
<th>Weaknesses/Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stausholm et al, 1995</td>
<td>Prospective crossover</td>
<td>25 surgical ward patients.</td>
<td>Patients rated oxygen delivery device comfort using a visual analogue score (0 mm most uncomfortable to 100 mm most comfortable).</td>
<td>At inclusion, median SpO₂ was 91% (76-94%). During oxygen therapy SpO₂ increased to 97% (93-100%) using the NP (p &lt; 0.0001) and 97% using the FM (p &lt; 0.001). In terms of comfort, NP scored 72 (19-100) mm and FM 42 (0-94) mm. (Friedman’s analysis, p &lt; 0.0001). The main problem identified with the FM by the patients was difficulty eating/drinking.</td>
<td>Small sample size. Randomisation method not explicit. Potential time and order effects associated with crossover trials.</td>
</tr>
<tr>
<td>McBrien &amp; Sellers, 1995</td>
<td>Prospective crossover</td>
<td>11 adult patients in the general ICU</td>
<td></td>
<td>SpO₂ readings remained between 96 and 98% for each device. Greater PaO₂ with FM than NP (p &lt; 0.05). Ten patients ranked the devices with FM being more comfortable than NP.</td>
<td>Small sample size. Randomisation procedure poorly described. Presence of the naso-gastric tube is a potential confounder influencing the effectiveness of nasal oxygen delivery devices.</td>
</tr>
<tr>
<td>Bolton &amp; Russell, 2001</td>
<td>Quasi-experimental</td>
<td>255 patients, PACU: randomly allocated to receive FM or NP oxygen therapy on arrival. SpO₂ was monitored for 15 minutes immediately following surgery.</td>
<td></td>
<td>Desaturation episodes were 7% (10/135 patients) for FM group and 14% (17/120 patients) of the NP group (p = 0.10). Desaturation occurred more frequently in male patients with NP undergoing abdominal surgery. There was a non-</td>
<td>Randomisation procedure not free of bias as each patient was allocated a device based on their medical record number. Anaesthetic agent a potential confounder for patient comfort ratings. Statistical methods not clearly describe and multiple subgroup analysis not</td>
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</table>
## OXYGEN THERAPY MANAGEMENT

<table>
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<tr>
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</thead>
<tbody>
<tr>
<td>Eastwood et al., 2004</td>
<td>Prospective crossover</td>
<td>50 adult patients, medical-surgical ICU.</td>
<td>NP FM NPO</td>
<td>Desaturation episodes were defined as two consecutive SpO2 readings less than 94% or one SpO2 reading less than 90%. SpO2 readings every 5 minutes for 15 minutes.</td>
<td>significant difference between groups in terms of comfort for either NP or FM device ($p = 0.44$, Fisher’s exact test).</td>
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<td></td>
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<td></td>
<td></td>
<td>X X</td>
<td>well justified.</td>
</tr>
<tr>
<td>Ayhan et al., 2009</td>
<td>Randomised trial</td>
<td>106 patients, PACU</td>
<td></td>
<td>NPO consumed significantly less oxygen than FM therapy (3.0 LPM, SD: 0.9 vs 6.7, SD: 2.1 LPM, $p &lt; 0.001$) and was associated with significantly higher comfort than FM (75 mm, SD: 16 mm vs 52 mm, SD: 18 mm, $p &lt; 0.001$).</td>
<td>Order of device allocation was fixed (face mask was the first device) and not randomised as would be desirable. Possible carry-over effects associated with oxygen content in the blood. SpO2 range may have exposed patients to episodes of hypoxaemia.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X X</td>
<td>No difference between nasal prong group and face mask group in terms of oxygenation. SpO2 for time when devices removed not reported. The oxygen flow rate was 5 litres per minute for both devices, below recommended flow rate for face mask. Authors comment that patients transported to recovery without supplemental oxygen. Baseline imbalances</td>
</tr>
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</table>

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<table>
<thead>
<tr>
<th>Author</th>
<th>Design</th>
<th>Sample/Setting</th>
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<td></td>
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<td></td>
<td>NP</td>
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<td>FM</td>
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<td></td>
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<td></td>
<td>NPO</td>
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</table>

Desaturation defined as two consecutive
SpO2 readings between 90 and 94% or one
SpO2 reading less than 90% for the FM
group was 16 times and no episode of
desaturation by the NP group.

Note. ICU = intensive care unit; LPM = litres per minute; NP = nasal prongs; FM = face mask; NPO = nasopharyngeal oxygen catheter; PACU = post-anesthetic care unit; PaO2 = partial pressure of arterial oxygen; SpO2 = Oxygen saturation measured by pulse oximetry; HVAS: Horizontal visual analogue scale, measured in millimeters (0 mm = most uncomfortable to 100 mm = most comfortable).
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Patient related factors and their influence on oxygen therapy

It is hypothesised that patient compliance with oxygen therapy is a major factor in the type of device use and level of patient comfort experienced (Eastwood & Dennis, 2006; Sasaki, et al., 2003). Indeed, for optimal health care and safe outcomes, clinicians, including nurses, must be responsive to the needs, preferences and involvement of patients (Australian Commission on Safety and Quality in Healthcare [ACSQHC], 2011). While, nurses draw on multiple sources of knowledge in the course of their clinical practice and interactions with patients, the nurse-patient interaction and involvement is rarely acknowledge or explored (Rycroft-Malone, 2004). Studies have demonstrated significant clinical quality and safety outcomes from involving patients in decisions about their care (ACSQHC, 2011) and associated benefits that include dramatically improved adherence to treatment regimens (Arbuthnott & Sharpe, 2009), decreased rates of iatrogenic adverse events (Edgcumbe, 2009), decreased mortality (Meterko, Wright, Lin, Lowy, & Cleary, 2010) and healthcare cost savings (Charmel & Frampton, 2008).

There are three major determinants associated with oxygen therapy effective that involve the patient. These three determinants of oxygen therapy effectiveness are:

- Device comfort
- Patient activity
- Patient compliance with therapy

Each of these factors will be described and discussed. It is important to recognise the impact of patient related factors on the effectiveness of oxygen therapy.
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because an ineffective device or the patient not accepting the application of the device will directly impact on the nurse’s ability to manage oxygen therapy and prevent or treat respiratory dysfunction.

The key patient related determinants that have a direct impact on the effectiveness and efficacy of oxygen delivery devices include: device comfort and compliance with therapy, and size, shape and fit of the oxygen delivery device. Each of these factors will be described and discussed in the following sections. It is important to recognise the impact on patient related factors and oxygen therapy effectiveness because an ineffective device will directly impact on the ability to prevent or treat respiratory dysfunction.

Patient comfort and compliance

Device comfort has a well-recognised impact on patient compliance with oxygen therapy and may be a major factor in oxygen therapy effectiveness (Nolan et al., 1993; Sasaki et al., 2003; Stausholm et al., 1995). Uncomfortable devices decrease efficacy because the patient will remove an uncomfortable device. Australian investigators Bolton & Russell (2001) compared comfort and performance of nasal prongs and face mask in 255 patients in the post-anaesthetic care unit. Patients were randomly allocated to receive either nasal prong oxygen therapy at 4 litres per minute or face mask oxygen therapy at 6 to 8 litres per minute. Comfort data was recorded after the first 15 minutes of oxygen therapy for each device. Although not reaching statistical significance, findings identified a trend towards patients in the nasal prong group experiencing a higher rate of desaturation (a SpO₂ less than 94%)(14%) compared to the face mask
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group (7%;\(p = 0.10\)) for face mask oxygen therapy. Comfort data was recorded after the first 15 minute period of recovery and showed that 94% of the nasal prongs group found nasal prongs comfortable compared to the face mask group where 91% of these patients found the face mask comfortable (Bolton & Russell, 2001).

Seminal studies conducted in the early 1990s have highlighted the importance of optimising patient compliance with oxygen therapy as a means of ensuring satisfactory \(\text{SpO}_2\) and avoiding potential complications associated with hypoxaemia. Goldhill et al. (1994) used a simplified education approach to investigate the effect of nurse and patient education on oxygen mask placement after surgery, instructing nurses on the importance of correct mask placement and teaching 15 patients the importance of keeping the mask in place. Using video-surveillance during the night (22:00 – 06:00) the investigators recorded the number of times the mask was removed, replaced and the associated events the duration of time that the mask was on or off and any changes in \(\text{SpO}_2\) values associated with mask position. Goldhill et al. (1994) compared the findings of this study with the previous study reported by Nolan et al. (1992) in which the same surveillance method – minus the education – was used. Findings of Goldhill et al. (1994) identified that masks were removed 37 times and the median time the mask was off per patient was 4 mins and 3 secs and on four occasions masks were removed for greater than 10 mins, but no masks were removed due to nursing interventions. Compared to the study by Nolan et al. (1992) the duration of mask removal was decreased and nursing interventions did not play a factor in mask removal.
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The frequency and duration of hypoxaemia can be associated with disruption to oxygen therapy due to patient-related and nurse-related activities (Nolan et al., 1992). It could be expected that disruption with oxygen therapy would be more consistent during day-light hours as opposed to at night. Comparing the use of nasal prongs to Venturi face mask, which is similar to the simple face mask, Costello et al. (1995) conducted a crossover study involving 20 hypoxaemic patients. The investigators collected data a half-hourly intervals between midnight and 08:00 noting whether the device was positioned correctly and the device preference of the patient. Results showed that Venturi face mask was more frequently dislodged (mean 2.0, SD 2.4 times per shift) than nasal prongs (mean 0.7, SD 1.4 times per shift), and that nasal prongs were preferred by patients. These results prompted the investigators to comment that, although the benefit of controlling the inspired concentration of oxygen associated with the Venturi face mask exists, this benefit is lost if the device is not being worn by the patient. In addition, Costello et al. (1995) remarked that care must be taken to ensure compliance with therapy so that hypoxaemic episodes are avoided. However, nasal devices may be easily dislodged, which may result in hypoxaemia (Eastwood & Dennis, 2006; Hess et al., 1984; Stewart & Howard, 1990). Due to the paucity of information specific related to the ‘patient and oxygen therapy in the hospital setting’, it is important that studies address the issues patients’ consider important in the management of respiratory dysfunction and the use of oxygen therapy. Therefore, it is important that nurses monitor device comfort as an uncomfortable device may lead to increased interruptions to the therapy and increased episodes of hypoxaemia (Eastwood et al., 2007).
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Throughout the literature review there has been intermittent reference to the role of the nurse in relation to oxygen therapy. The nurse is the key clinical decision maker and has a large role to play in ensuring the effectiveness of oxygen therapy. In the following section, nurse related factors impacting on the effectiveness of oxygen therapy are discussed.

Nurse related factors and their influence on oxygen therapy

Irrespective of context, nurses as well as other key health personnel involved in the management of oxygen therapy are responsible for the safe administration of oxygen therapy and appropriate monitoring of patients receiving oxygen therapy. Almost all intensive care patients receive some form of oxygen therapy during their admission to the intensive care unit (Eastwood & Dennis, 2006). If intensive care nurses do not manage oxygen therapy appropriately and safely the patient will be at risk of hypoxaemia and worsening respiratory dysfunction (Considine et al., 2006; Eastwood & Dennis 2006). To optimise the delivery of care and patient outcomes the factors that impact on nurses’ management of oxygen therapy need to be explored. In this section of the literature review, three key themes are discussed namely, monitoring respiratory function and oxygen therapy effectiveness, exploring nurses’ management of oxygen therapy in the clinical setting, and documentation of respiratory function and oxygen therapy management interventions. Importantly, the discussion presented in this section of the literature review identifies the gaps in the literature and demonstrates the urgent clinical need for a better understanding of the how the intensive care nurse monitors, manages and documents oxygen therapy.
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Monitoring respiratory function and oxygen therapy effectiveness

The discussion thus far has highlighted the importance of oxygen therapy for patient safety and the strong deleterious relationship between respiratory dysfunction and life-threatening adverse events. Accurate assessment and monitoring of respiratory function is essential to the safety of intensive care patients, particularly in the prevention of respiratory related adverse events. Despite the use of modern monitoring methods, such as pulse oximetry, respiratory dysfunction remains a common precursor to suffering an adverse event (Buist et al., 2002; Considine, Thomas, & Potter, 2009; Harrison et al., 2006; Hodgetts et al., 2008, Kenward, Vlachonikolis, Payne, & Castle, 2002; Quach et al., 2008). To intervene in a timely fashion, it is important for clinicians to continuously assess for, recognise, and respond to signs of respiratory dysfunction, and if necessary, initiate oxygen therapy (Crekitos et al., 2008).

Nurses are the key personnel responsible for recognising the clinical signs of respiratory dysfunction. Intensive care nurses assess respiratory function by observation of respiratory rate and quality of respiration and use of clinical assessment tools, such as pulse oximetry and arterial blood gas sample analysis. The latter two, pulse oximetry and arterial blood gas sample analysis, have been discussed previously in this chapter. In this section of the literature review the discussion centres on what intensive care nurses actually do when performing and documenting a patient respiratory assessment (ACSQHC, 2011). The following section examines the relationship between elements of clinical assessment including observation of respiratory rate, heart rate, blood
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pressure, skin colour and conscious state as clinical indicators of respiratory dysfunction, known precursors to adverse events.

Respiratory rate

Respiratory rate abnormalities, in particular tachypnoea, are a concern and a clear indicator of worsening respiratory function, or the manifestation of the abnormal physiological functioning in another body system (Cretikos et al., 2008). The way in which nurses assess, document and interpret respiratory rate is influential in identifying patients at risk of respiratory dysfunction. Abnormal respiratory rates have been identified as having strong associations to the occurrence of respiratory related adverse events (Crispin & Daffurn, 1998; Hourihan, Bishop, Hillman, Daffurn, & Lee, 1995; Rubins & Moskowitz, 1988). In the majority of conditions an increase in respiratory rate may indicate the presence of hypoxaemia and physiological derangements of other body systems (Cretikos et al., 2008). As a consequence it is important for nurse to be cognisant of the significance of an abnormal respiratory rate and relate this abnormality to the overall clinical state of the patient.

Normal breathing is itself a rhythmic and largely effortless process (Kisiel & Perkins, 2006). Breathing, as previously described, is a process of ventilation for the exchange of oxygen between the atmosphere and the lungs. Alveolar ventilation, a product of respiratory rate and tidal volume, is carefully controlled by the actions of central and peripheral chemoreceptors and lung receptors (Cretikos et al., 2008). The body attempts to correct hypoxaemia by increasing respiratory rate and tidal volume (O’Driscoll et al, 2008) to increase the amount of oxygen available in the lung. Thus,
changes in respiratory rate or tidal volume can be detected by counting, assessment and documenting respiratory rate. For a healthy adult at rest, a respiratory rate of 12 to 18 breaths per minute is considered normal (Kisiel & Perkins, 2006).

Hospital based studies of general ward patients suggests that an adult at rest with a respiratory rate greater than 20 is likely to be unwell (Davey, McCance, & Budd, 1994; Kennedy, 2007) and that a person whose respiratory rate is greater than 24 breaths/minute is likely to be critically ill (Cretikos et al., 2008; Grap et al., 1994; Harrison et al., 2005). Bradypnoea is a late and insensitive sign of extreme hypoxaemia (Considine & Botti, 2004) and may indicate severe respiratory system deterioration or other underlying body system physiological derangement (Kennedy, 2007), or it may be induced therapeutically via the use of an anaesthetic agent to intentionally depress the respiratory drive, or be a consequence of narcotic analgesics (Strachan & Noble, 2001).

**Heart rate and blood pressure**

An abnormal heart rate or blood pressure may identify a patient at risk of respiratory dysfunction and each must be viewed as a warning sign that requires further investigation. Heart rate abnormalities, either bradycardia or tachycardia, have been associated with respiratory related adverse events (Buist et al., 2002; Crispin & Daffurn, 1998; Jacques, Harrison, McLaws, & Kilborn, 2006). However, heart rate abnormalities are not specific indicators of hypoxaemia or respiratory dysfunction (Considine et al., 2005).
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Tachycardia may be a sign of early hypoxia and may be the way the body is attempting to increase oxygen delivery to body cells during times of increased demand (O’Driscoll et al., 2008). While respiratory dysfunction may be one of the causes of tachycardia, there are a variety of additional physiological and pharmacological reasons for an increased heart rate. Medications such as inotropes (e.g., noradrenaline) or an intravenous fluid bolus, are commonly used in the management of intensive care patients and increase the heart rate (Strachan & Noble, 2001). Thus, it is necessary to be cognisant of the effect of medicines and other interventions on heart rate when assessing the oxygenation status of their patients.

Blood pressure is a key component of tissue oxygenation as an adequate blood pressure is necessary to ensure the circulation of blood through the body and oxygen delivery. Fluctuations in blood pressure, first hypertension and then hypotension, is physiologically plausible in the presence of respiratory dysfunction as such a trend would indicate a physiological response to increase blood flow and hence blood supply to effected areas prior to fatigue or overwhelming tissue hypoxia (Kallstrom, 2002; Nerlich, 1997; O’Driscoll, et al., 2008; Thelan, Urden, Lough, & Stacy, 1998). Like heart rate abnormalities, changes in blood pressure may not be specific indicators of respiratory dysfunction (Considine, 2005). Therefore, the reliability of using blood pressure alone as a clinical indicator to define the need for oxygen therapy is weak and requires continued re-evaluation of the patient’s oxygen requirements (Considine, 2005).
SKIN COLOUR

Although a patient’s skin colour is not routinely documented or recorded in the same way as respiratory rate, heart rate or blood pressure (McGain et al., 2008), alterations in skin colour may still influence a nurse’s decision about the need for supplemental oxygen (Considine, 2005). Changes to skin colour is a late sign and may not accurately indicate the presence of hypoxaemia. Cyanosis and pallor of the skin of the face or limbs is a clinical observation indicating oxygen deficient states, identified during a patient assessment.

Cyanosis itself is distinguished as a bluish appearance of the skin and occurs as a late sign of significant hypoxaemia (Clark et al., 2006) however, some authors state there are specific assessment parameters to confirm cyanosis on blood analysis: reduced haemoglobin concentration or when the PaO2 is less than 45 mmHg (Considine 2005). Pallor, the pale appearance, of the skin associated with a reduction in the amount of oxyhaemoglobin circulating through the peripheral circulation as the body attempts to concentrate oxygenated blood to vital organs (Berne & Levy, 1998). Pallor is most typically identified on the face or palms of the hands and is evident by a pale appearance of the lips, tongue and mouth and mucous membranes (Berne & Levy, 1998). Unfortunately, pallor is a poor indicator of oxygen deficient states as there are many causes of pallor, such as states associated with low haemoglobin, or vasoconstriction of the extremities association with cold (Berne & Levy, 1998). Consequently, nursing assessment should include other clinical indicators of respiratory dysfunction and nurses should be alert to the possible presence of cyanosis.
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The areas of the body usually observed to detect cyanotic skin changes are the mucus membranes, for example the lips, gums and inner eyelid, or nail bed and ear lobes (Considine, 2005a; McCance & Heuther, 1994) however, detecting cyanotic states through observation of skin is more difficult in patients with dark skin pigmentation (Considine, 2005a) and for these patients it may be easier to detect cyanosis in the mucus membranes and nail bed, rather than the ear lobes or on the broader surfaces of the skin (Feiner, et al., 2007). Both ventilatory and circulatory problems can lead to cyanosis; however, the patient who does not have signs of cyanosis may still be hypoxaemic. It is therefore necessary for nurses for re-evaluation other indicators of oxygen deficiency for their patients (O’Driscoll et al., 2008).

Conscious state

The brain is particularly susceptible to changes in oxygen supply and an alteration in neurological status is an early sign of hypoxia because of inadequate oxygen delivery to the tissue of the brain (Diringer, 2008), therefore, an altered conscious state is a very reliable indicator of oxygen deficiency (Considine, 2005). This ‘sensitivity’ of brain function to hypoxemia or hypoxia can be explained by the brain’s extremely high metabolic rate and reliance on oxygen as the primary source of cellular energy (Diringer, 2008). Neurological signs associated with hypoxaemic states include restlessness, agitation and anxiety (Nerlich, 1997; Pruitt & Jacobs, 2003), followed by confusion and loss of consciousness (Bateman & Leach, 1998; Nerlich, 1997; Pruitt & Jacobs, 2003). Prolonged cerebral hypoxia will result in neural death, brain failure and body system failure (Considine, 2005a; Diringer, 2008). While neurological symptoms, including altered conscious state, will manifest in the presence of hypercapnia and
cerebral vasodilation (O’Driscol et al., 2008) it is important for nurses to be vigilant in their assessments oxygen deficiency.

In summary, nurses play a vital role in the assessment, recognition and management of the signs of respiratory dysfunction and should be aware that respiratory rate and conscious state are the most reliable clinical indicators of oxygenation but are poorly assessed and documented (Considine, 2005a; Cretikos et al., 2008).

In the section to follow, the literature supporting nurses’ management of oxygen therapy is reviewed. The discussion in the sections to follow focus on the role of the nurse in making oxygen therapy management decisions and the importance of applying knowledge in relation to oxygen therapy management.

**Managing oxygen therapy in the clinical setting**

Clinical decisions related to oxygen therapy management are vital to the effective treatment or prevention of respiratory dysfunction. Intensive care nurses are often the first members of the health care team to recognise and respond to the signs of respiratory dysfunction (Eastwood & Dennis, 2006). Effective clinical decisions and competent clinical care related to the management of oxygen therapy can result in safe patient outcomes. Nurses frequently and independently make decisions about oxygen therapy while planning and delivering care to patients (Eastwood & Dennis, 2006). Therefore, an understanding of how nurses recognise and respond to the signs of respiratory dysfunction is important in terms of the educational preparation of nurses, to increase their knowledge and improve practice.
Despite the importance of the nurse being able to recognise the signs and symptoms of respiratory dysfunction, little is known about how intensive care nurses respond to these signs and symptoms. A review of the current literature reveals a lack of information to inform oxygen management practices and a poor understanding among nurses of the legislative requirements governing the administration of oxygen in Australia. However, there is a plethora of literature pertaining to the monitoring of oxygen states and use oxygen delivery devices that is difficult to interpret, contradictory, or based on opinion or physiological principles. The result is an inadequate knowledge base and a lack of sound information that can guide nurses in making informed clinical decisions about oxygen therapy (Considine, Botti & Thomas, 2007).

Legislative requirements regarding oxygen therapy in Australia

Nurses need to be aware of the legislative requirements that govern their responsibilities when administering oxygen. In many non-Australian based texts, oxygen is described as a medicine (or drug) with specific physiological and pharmacological, dose related effects (Bateman & Leach, 1998; Bell, 1995; Dodd et al., 2000; Oh & Duncan, 1988; Pruitt & Jacobs, 2003; Small et al., 1992). Such recommendations may lead to incorrect assumptions being made by nurses in different locations or jurisdictions about their legal responsibilities regarding supplemental oxygen administration (Considine, 2009). For example, in two publications, one from the United Kingdom (Dodd, et al., 2000) and one for the United States of America (Small et al., 1992), recommendations are made for oxygen to be formally prescribed by a doctor with specific requirements for oxygen flow rate, oxygen delivery device, and
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for oxygen delivery to be documented. Such recommendations may lead to nurses in different jurisdictions making incorrect assumptions about their legal responsibilities regarding supplemental oxygen administration.

In Australia, oxygen is not regarded as a medicine and there is no legal requirement for oxygen to be prescribed in the hospital setting (Considine, 2009). According to the material safety data sheet for compressed (medical) oxygen, under the Standard Uniform Scheduling of Drugs and Poisons (SUSDP) criteria, oxygen has not been allocated a poison schedule number and is classified as an unscheduled substance (BOC gases, 2005 – MSDA #115). In the State of Victoria, Australia, oxygen is listed as a unscheduled substance, it is not regulated by the Therapeutic Goods Act (Victoria)(1994) or the Drugs, Poisons and Controlled Substances Act (Victoria) (1981), and a prescription by a medical officer for oxygen is not required. However, in the clinical setting doctors may make specific recommendations or provide assessment parameter for when supplemental oxygen should be commenced or altered for specific patients (Considine, 2009). As with the application all therapeutic interventions in the intensive care setting, care is needed and a team approach to decisions that include nurses, medical staff and allied health personnel responsible for the patient; and includes decisions made in relation to supplemental oxygen administration (Considine, 2009).

Acute care hospitals now have an increasing proportion of patients with complex clinical problems who are at risk of suffering an adverse event (Bellomo, Goldsmith, Russell, & Uchino, 2002). An investigation of 21 hospitals in The Netherlands revealed that 5.7% of 1.3 million hospital admissions in 2004 resulted in the unintentional harm
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of the patient (Sheldon, 2007). A similar a report published in 2002 into the 13 general hospitals in New Zealand showed the proportion of hospital admissions associated with an adverse event was 12.9% (Davis et al., 2002), compared with 16.6% in Australia (Wilson et al., 1995) and 10.8% in the United Kingdom (Vincent, Neale, & Woloshynowycz, 2001). Ensuring that patients who are at risk of deterioration receive appropriate and timely care has become, with increasing vigour, a key safety and quality challenge for hospital managers.

Patient safety is an essential component of clinical practice and exceedingly so for patients admitted to the intensive care unit (College of Intensive Care Medicine [CICM], 2011). Intensive care units are dynamic environments characterised by complex interactions among several healthcare specialties for patients who are vulnerable to iatrogenic injury due to the acuity of their illness and the frequent application of high-risk interventions (Dodek & Raboud, 2003; Rothschild et al., 2005). Considering the tight coupling between the complexity of the intensive care setting and the high risk of patient harm, the need to strengthen patient safety initiatives is striking. However, several reports (Beckmann et al., 2003; Dodek & Raboud, 2003; Gillman et al., 2006) have demonstrated an urgent need for those working within intensive care units to improve the safety of common care processes, such as medication administration and equipment use. Because oxygen therapy forms such an integral component of the care of the intensive care patient, a greater focus on how nurses manage oxygen therapy and critique of oxygen therapy management is desired.
Knowledge and oxygen management decisions

A first step in the prevention of adverse events is acknowledgement that adverse events can occur and importantly, to recognise that making improvements to prevent such events, is possible (Valentin et al., 2006). Patient safety research uses information gained by studying actual harmful incidents and investigating risky situations or processes (Valentin et al., 2006). Indeed, it is fortunate that not every mistake leads to patient harm or an adverse event. Although intensive care nurses are frequently confronted with unforeseeable situations, it is obvious that many care activities are routine and based on protocols. While routine activities may largely be innocuous with respect to serious adverse events, variation to routine practice protocols between nurses is undesirable and may precipitate an adverse event (Valentin et al., 2006). Given that essentially all patients admitted to the intensive care unit receive oxygen therapy, the practice of oxygen therapy management should be investigated as an attempt to improve patient safety.

Once the decision to administered supplemental oxygen has been made, it is usually the responsibility of the nurses to select the appropriate oxygen delivery device and oxygen flow rate (Eastwood et al., 2007). Selection of oxygen delivery devices enables efficient use of resources and appropriate tailoring of therapy to meet individual patient needs. Selecting the right device can be difficult as there are a variety of devices from which to choose from, and a lack of practical information on selecting the right device (Eastwood et al., 2004). Variation in practice may reflect a lack of clinical knowledge or evidence to support nurses’ practice of oxygen therapy.
Providing education regarding the use of oxygen delivery devices to nurses is important; because improved knowledge will improve decision-making and inform oxygen therapy practice. Education about the therapeudic use of supplemental oxygen could facilitate changes to practice to reduce inconsistencies in oxygen administration practices (Considine et al., 2007). Investigators have reported on educational interventions or the introduction of clinical practice guidelines and protocols to change the oxygen administration practices of nurses and other healthcare professionals (Considine et al., 2006; Cook, Reeve, Griffith, Mookadam, & Gibson, 1996; Goldhill et al., 1994; Kor & Lim, 2000; Wong et al., 2000).

Considine et al., (2006) conclude that improving factual knowledge alone did not appear to improve oxygen administration practices, and therefore a greater understanding of the relationship between factual knowledge and clinical decision-making is required. For example, using a pre-test/post-test, quasi-experimental design Considine et al., (2007) aimed to examine the effect of educational preparation on 88 nurses in an emergency unit, a clinical specialty area that requires advance practice interventions, and analysed the decisions they made regarding supplemental oxygen administration. Fifty-one participated in the education program used in that study, a written self-directed learning package and knowledge acquisition was evaluated using a validated parallel multiple-choice questionnaire and 20 nurses were observed in scenarios and ten were observed in clinical practice to evaluate clinical decision-making. Findings demonstrated no change in the number or types of parameters used by nurses to assess oxygenation, there was a significant decrease in device selection for specific clinical scenarios, and an increase in the identification of respiratory distress as an
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outcome of the hypothetical respiratory distress scenario. The evaluation of education, on evidence based information, and other ways that nurses attain knowledge and make decisions is useful and further studies in the intensive care setting are recommended. Only when nursing clinical practice, related to the management of oxygen therapy, is observed and critiqued will it be possible for nursing practice to improve.

Previous studies have identified unwarranted variation in the oxygen therapy practices of emergency department nurses (Considine et al., 2007). For example, in a review of oxygen administration in general ward beds in a University-affiliated hospital over twenty years ago, Albin et al. (1992) identified concerns over the use, prescription and monitoring of oxygen therapy. A total of 274 ward patients had 507 SaO₂ assessments performed via pulse oximetry. Using a oxygen saturation as greater than or equal to 92%, Albin et al. (1992) identified that in 16% of assessments, all performed while patients were receiving oxygen therapy, the prescribed oxygen flow rate was insufficient to maintain a SaO₂ greater than or equal to 92%. While in 46% of assessments patients were classified as receiving more oxygen flow than required to maintain a SaO₂ greater than or equal to 92%. This finding demonstrates that there is inconsistency in the administration of oxygen therapy to ward patients.

Recently, Australian investigators Eastwood et al. (2012) evaluated oxygen administration and monitoring for adult ward patients in a teaching hospital of 400 beds. These investigators, on a single day audited all patients to document the proportion of patients receiving oxygen therapy and the method of its delivery. In addition, these investigators sought to assess oxygen saturation and respiratory rate monitoring. Of all
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323 eligible patients included in the audited, seventy-seven patients (24%) were receiving oxygen therapy, and of these 57 patients (75%) received oxygen by nasal prongs. Oxygen saturation was documented in the medical record in 310 (93%) and respiratory rate documented in 283 patients (88%) in the previous 12 hours. Importantly, patients receiving oxygen had a lower median SpO₂ (94% vs. 96%, \( p < 0.0001 \)) and had a higher median respiratory rate (20 breaths per minute vs. 18 breaths per minute, \( p = 0.0005 \)). Crucially, the in-hospital mortality of patients receiving oxygen therapy was 15.8% compared with 5.3% for those not on oxygen therapy. The clinical implications of these findings as identified by the investigators were that oxygen saturation and respiratory rate measures were not documented in approximately 10% of patients. Furthermore, these investigators identified that oxygen therapy in ward patients identifies individuals with increased mortality. Consequently, nurses must recognise that patients receiving oxygen therapy are high-risk and strategies to detect patients at risk of hypoxaemia are advised.

Unwarranted variation in how intensive care nurses implement, manage and document oxygen therapy is problematic, given that any decisions made by a nurse in delivering or changing care interventions directly influences patient outcomes. To establish if variability occurred in the reported oxygen therapy practices of intensive care nurses, Eastwood et al. (2012) conducted an on-line questionnaire of intensive care nurses working in Australia and New Zealand. A total of 542 nurses responded to the survey and self-reported on their oxygen therapy practices. It was found that in response to a falling SpO₂, 8.9% of nurses would never escalate oxygen therapy without a request from a medical doctor, and 51% of nurses would not routinely escalate oxygen therapy
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in the absence of a medical order, and more than 60% of nurses reported a tolerance for a stable SpO₂ of 90%. As described previously in this chapter a SpO₂ of less than 95% is considered indicative of hypoxaemia therefore, it is worrying that such a high proportion of respondents reported a tolerance for an SpO₂ of 90%. In the absence of evidence to support maintaining a lower SpO₂, the literature recommends it would prudent to target higher SpO₂ values (e.g. SpO₂ 95% or higher) as a buffer of safety from hypoxaemia (O’Driscoll et al, 2008). A greater understanding of the clinical assessment of indicators of oxygenation that influence intensive care nurses management of oxygen therapy would be beneficial in helping to establish the nature of current practice and aspects of practice amenable to change.

Several researchers have acknowledged that the challenge posed in the variability of oxygen therapy management may be confounded by past published protocols and reviews, that have often failed to provide practical information to assist nurses with the selection and use of oxygen devices (Cunningham, 1997; Kallstrom, 2002; O’Connor & Vender, 1995; Treacher & Leach, 1998). As part of the clinical decision making process, nurses may rely on information from their peers, or their own previous clinical experience and limited knowledge gained elsewhere, to support their practice. In 2008, the British Thoracic Society published, ‘Guideline for emergency oxygen use in adults’ (O’Driscoll et al., 2008) a guideline for the emergency use of oxygen for adult patients, which provides all clinicians with a detailed, comprehensive and evidence-based supported information on a range of aspects of oxygen therapy to aid clinical care of hospitalised patients. While the evidence amassed to inform this guideline is comprehensive, the authors recognised gaps in the literature and still
Clinical practice guidelines for oxygen therapy offer limited support to inform and guide the clinical decisions of nurses (O’Driscoll et al., 2008) and other investigators have evaluated the impact of such guidelines on the general administration of oxygen in hospital. Kabar & Campbell (2006) used a pre-test/post-test method to evaluate a guideline on the use of nasal prongs to deliver oxygen therapy, including a pre-intervention hospital-wide audit of local oxygen management and the development of the protocol, the intervention phase implementing the guideline and providing didactic education to all nurses, and post-intervention phase a repeat audit. Findings implied that increased knowledge gained via personal (verbal) education the oxygen management of nurses can change. However, as some researchers note, the sustainability of improvements to clinical practice produced because of educational interventions remains under explored (Considine et al., 2007).

**Documenting respiratory function and oxygen therapy**

One of the main responsibilities of intensive care nurses is the comprehensive and detailed documenting of physiological monitoring and assessments and the assessment of interventions applied including the effectiveness of oxygen therapy. What nurses document and how they use clinical indicators, for example of respiratory dysfunction, is influential in identifying patients at risk of adverse event and preventing adverse events related to respiratory dysfunction (Considine, 2005; Kisiel & Perkins, 2006). Current evidence to support intensive care nurses’ documentation practices is not
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strong and, little is known about how oxygen therapy is delivered on a daily basis (Eastwood et al., 2012). A better understanding of how intensive care nurses document respiratory function and oxygen therapy interventions is required. Information obtained would inform the development of clinical practice recommendations to improve what intensive care nurses document and how that information is used to support the implementing or changes to interventions, for example to correct respiratory dysfunction. This section of the literature reviews how, why and the importance of intensive care nurses documenting respiratory function and oxygen therapy management interventions.

Documentation of physiological monitoring assessment, measurements and therapeutic interventions is of vital importance to patient safety. The Australian intensive care setting offers a high level of patient monitoring and safety via: recommended 1:1 nurse-patient ratios (ACCCN, 2003), continuous physiological monitoring devices and, ease of rapid access to medical staff (CICM, 2011). Patient admitted to an intensive care unit are at high risk of developing respiratory dysfunction because of acute illness, chronic pathology, or requiring peri-operative care (Rodriguez-Roisin & Roca, 2005). In an Australian intensive care setting it is customary to document and perform on-the-hour physiological surveillance. Clinical information systems may also be used in the intensive care unit to capture patient physiology, yet their use in triggering interventions to mitigate potential adverse events has yet to be fully explored (Adamson & Elliott, 2007; Buist et al., 2002). Importantly, the documentation of physiology assessments and therapeutic interventions enable the nurse
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and other care staff to review a patient’s status, it forms part of the patient’s medical
record and is a legal requirement.

Three of the most important respiratory related variables that are documented by
intensive care nurses on an hourly basis are SpO₂, respiratory rate and oxygen flow rate
for intensive care patients receiving oxygen therapy (Higgins & Jones, 2009; Simpson
2006). Accurate recording of SpO₂, respiratory rate and oxygen flow rate values is of
particular importance because clinical decisions of other intensive care professional are
made in response to documented values. As an example, the importance of documenting
an accurate SpO₂ can be emphasised by the non-linear relationship of PaO₂ and SpO₂ as
described by the oxyhaemoglobin dissociation curve (Marieb, 2004; O’Driscoll et al.,
2008). As previously described in this chapter, a small decrease in SpO₂ can result in a
large decrease in PaO₂ (O’Driscoll et al., 2008; Marieb, 2004).

Variability in clinical practice in relation to oxygen administration has been
identified previously (Considine et al., 2006; Gravil, O’Neill & Stevenson, 1997) and
relates to choice of oxygen device, oxygen flow rate and supportive care interventions to
match the acuity of the intensive care patient. In hospital settings, excluding intensive
care, previous studies have demonstrated suboptimal documentation of oxygen
management (Albin et al., 1992; Attia et al., 2004; Boyle & Wong, 2006; Brokalaki et
al., 2004; Gravil, et al., 1997; Hogan, 2006; Howell, 2001; Kor & Lim, 2000; Small et
al., 1992). There remain few published studies on how intensive care nurses document
the accuracy of SpO₂, respiratory or oxygen flow rates for their patients. In response,
exploration of how intensive care nurses document respiratory function and oxygen therapy interventions is warranted (Hogan, 2006).

The documentation of respiratory function and oxygen therapy interventions has important clinical implications for patient safety and clinical decision-making in the intensive care unit. Accurate documentation is an important form of communication between shifts and as a benchmark from which to compare the patient’s current physiological state. Inaccurate recording of SpO2, respiratory rate or oxygen flow rate may result in diagnostic errors, either under-diagnosing a potential or existing clinical problem, or diagnosing a clinical problem that does not exist (Croskerry, 2002; Croskerry 2003; Szafarski, 1997). Educating intensive care nurses of the importance of accurate documentation of respiratory function and oxygen therapy interventions may be one step toward improving intensive care nurses’ documentation of oxygen therapy. As Considine, et al. (2007) found in their study of emergency nurses, the acquirement of specific knowledge related to oxygen therapy does not necessarily translate to clinical competence or practice change. The clinical implication being that other additional strategies to aid and improve oxygen management decisions made by nurses working in advance practice environments may be required.

Overall, there have been few studies that have explored the routine documentation practices of intensive care nurses in relation to respiratory function and oxygen therapy interventions (Considine, 2005), nor have there been studies that evaluate or provide a critical examination of how intensive care nurses document and use clinical indicators of respiratory dysfunction to guide oxygen management. Only
when further in-depth studies, exploring how intensive care nurses document and respond to respiratory dysfunction, are undertaken will it be possible to identified areas of clinical care that are sub-optimal. If such deficiencies in practice are identified and respiratory related adverse events are to be prevented, then intensive care nurses must take responsibility for documenting and appropriately responding to signs of respiratory dysfunction.

**Conceptual framework for nurses management of oxygen therapy**

As demonstrated throughout the discussion in this chapter, the interplay of factors on effective oxygen therapy included: the appropriate oxygen delivery device, patient experience, nursing knowledge and practice and contextual characteristics, of which the impact of each on the other remains poorly understood. The literature review has highlighted the multi-factorial influences on the management of oxygen therapy and the risk to patients exposed to long periods of untreated respiratory dysfunction. Previous studies’ involving nurses and how nurses manage oxygen therapy, from both the critical care and non-critical care settings, has shown that the interplay between factors is complex. To guide the study reported in this thesis, it was necessary to develop a conceptual framework that included the key components impacting on the management of oxygen therapy for patients at risk of respiratory dysfunction.

The aim of the research reported in this thesis is to examine, in detail, the oxygen therapy management for patients at risk of respiratory dysfunction. Given the strong relationship between respiratory dysfunction, the intensive care context and adverse events, the conceptual framework used in this research is patient safety and clinical risk
management. The specific framework selected to underpin the research reported in this thesis was the World Health Organisation International Classification for Patient Safety (ICPS) (Runciman, Hibert, Thomson, Van Der Schaaf, Sherman & LeWalle, 2009).

The World Health Organisation World Alliance for Patient Safety developed the ICPS conceptual framework to provide a common formal and uniform approach to patient safety concepts (Runciman et al., 2009; Runciman et al., 2010). This conceptual framework has 10 high level classes:

- Incident type
- Patient outcome
- Patient characteristics
- Incident characteristics
- Contributing factors/ hazards
- Organisation outcomes
- Detection
- Mitigating factors
- Ameliorating actions
- Actions taken to reduce risk

The ICPS conceptual framework provides foundational structure and can act as a tool to guide investigations into aspects of clinical practice, such as respiratory dysfunction and the management of oxygen therapy.
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The ICPS conceptual framework was specifically chosen because it incorporates system, clinical, and descriptive information in relation to an actual or potential threat to patient safety (Runciman et al., 2009; Runciman et al., 2010). The key elements of the conceptual framework were:

- **Incident type**, a descriptive term for a category of incidents with common features such as a clinical process or procedure
- **Patient characteristics**, which categorises patient demographics, original reasons for seeking care and incorporates primary diagnosis
- **Contributing factors / hazards**, which encompasses the circumstances thought to have played a part or contributed to the development of an incidence or to increase the risk of an incident
- **Detection**, which is defined as the action or mechanism that leads to the discovery of an incident, and
- **Mitigating factors**, which are the actions or circumstances that prevent or moderate the progression of an incident toward harming the patient (Sherman et al, 2009).

Figure 2.1 is the World Health Organisation conceptual framework for the International Classification for Patient Safety (ICPS).
Figure 2.1 World Health Organisation conceptual framework for the International Classification for Patient Safety (ICPS).
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The use of the ICPS conceptual framework for the research conducted in this thesis was informed by the findings of the literature review. The goals of the literature review were to understand the impact of device related factors on compliance and effectiveness of oxygen therapy, identifying patient and nurse perspectives on oxygen therapy, and critically appraising the environmental characteristics associated with monitoring and documentation of oxygen therapy. The outcome of the literature review was the identification of key patient characteristics, nurse characteristics and monitoring/documentation factors associated with how nurses manage oxygen therapy.

The conceptual framework developed for the research consisted of the central component (the incident type) and four interconnecting key components. The central component of the framework was the focus of this thesis: how nurses in the intensive care unit manage oxygen therapy for patients at risk of respiratory dysfunction. Hence, with the goal to critically review how nurses manage oxygen therapy for patients at risk of respiratory dysfunction, the findings of the literature review and the ICPS conceptual framework appropriately support the research reported in this thesis.

The four key components that bespoke this central component were:

- Contributing factors
- Patient characteristics
- Nurse characteristics
- Monitoring and management

The conceptual framework used in this thesis is shown in Figure 2.2.
Figure 2.2 Conceptual framework of the key factors that influence oxygen therapy management for patients at risk of respiratory dysfunction
The management of oxygen therapy for patients at risk of respiratory dysfunction often involves complex tasks which are performed in complex clinical settings. It is essential for clinicians to promptly recognise and respond to the signs of respiratory dysfunction to minimise the impact of respiratory related adverse events. Knowledge of how intensive care nurses manage oxygen therapy and select the appropriate oxygen delivery devices is largely absent from the current literature. The current evidence base of intensive care nurses’ oxygen management practices has been limited by a paucity of clinical studies and little detailed knowledge of the multi-factorial influences effective oxygen therapy. Additionally, few studies have explored the patient experience of oxygen therapy and the factors that either assist or hinder patient compliance with oxygen therapy. Moreover, clinical studies have not explicitly addressed the interplay between the management of oxygen therapy, patient factors, and nurse factors including assessment, monitoring, documentation practices and decisions made to implement therapy. Consequently, the management of oxygen therapy between nurses and the impact of this variability of practice on safe patient outcomes remains unknown (Cunningham 1997; Kallstrom 2002; O’Connor & Vender 1995; Treacher & Leach 1998).

In order to examine understand how oxygen therapy is managed oxygen therapy for patients at risk of respiratory dysfunction, the World Health Organisation ICPS conceptual framework was modified. The conceptual framework developed from an analysis of the literature related to clinical risk and includes the goals of:
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- Understanding the impact of device related factors on compliance and effective oxygen therapy
- Identifying patient and nurse perspectives on oxygen therapy
- Critically appraising the monitoring and management characteristics associated with oxygen therapy

The developed framework was based on the clinical determinants of effective oxygen therapy management as practiced by intensive care nurses and supported by the literature.

The literature review has detailed the physiological need for oxygen. Evidence has been presented that suggests the choice of oxygen delivery device, patient, nurse and contextual characteristics impact individually and in combination on how effectively nurses manage oxygen therapy. The first point is that oxygen delivery devices must effectively maintain adequate SpO₂ levels but are also required to be efficient in terms of resource use and comfort. Yet, despite the universal use of oxygen delivery devices in all areas of the hospital, including the intensive care unit, the current evidence to support the selection and use of any particular delivery devices remains lacking.

The second point of the discussion centred on the complexity of the decisions made by nurses when managing oxygen therapy and what informs those decision: knowledge of physiology and pathophysiology, oxygen delivery device performance, and, evaluating the appropriateness of oxygen management interventions. However, decisions about oxygen therapy management made by health care professionals,
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including nurses, remain unsupported, due to a lack of sound evidence (Considine et al., 2007). There is evidence that when patients have aspects of their care clearly explained and are involved in their care, the risk of adverse events is reduced because the patient feels engaged with and therefore complies with treatment decisions and interventions (ACSQHC, 2011).

The third point of the discussion centres on the patient perspective of care and current philosophies and practice in patient care that directly involved patients in decisions about their care, and it is noted there are few recent studies that have explored oxygen therapy from a patient’s perspective. To minimise patient-related interruptions to oxygen therapy it is important to identify the factors the patient may consider has an impact on the experience of the therapy. A fourth point focuses on the intensive care environment, where critically ill patients who are at high risk of respiratory dysfunction are admitted for continuous monitoring and rapid access to specialist medical staff and care. Nonetheless, the impact of the intensive care setting on the ability of nurses to appropriately monitor and document oxygen therapy in response to respiratory dysfunction has not been adequately explored. Variability among individual nurses and how they manage oxygen therapy is problematic, as the decisions made by nurses about oxygen therapy may result in poor patient outcomes.

Chapter Two was devoted to reviewing the literature related to the complexity of effective oxygen therapy management for patients at risk of respiratory dysfunction, and the characteristics the impact on effective oxygen therapy management. The discussion highlighted the deleterious impact of respiratory function and the key role nurses play in
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preventing or early recognition of respiratory related adverse events. Oxygen therapy is an important aspect of patient care, however, there is a paucity of literature accounting for the multiple factors that influence oxygen therapy management. To gain an understanding of the interplay between the factors that impact the decisions made by nurses when managing oxygen therapy, an innovative methodological approach was required.

Chapter Three will expand on the methodological approach used to provide a detailed analysis of oxygen therapy management for patients at risk of respiratory dysfunction. The discussion is separated into two key sections: the research method of the three sequentially linked studies; and the pilot study, that was conducted as the prelude for Study One.
Chapter 3: Method

Introduction

This thesis comprises a pilot study and three sequentially linked studies (see Figure 3.1). The purpose of Chapter Three is to provide a detailed description of the aims, methods, results and recommendations of the pilot study and an overview of the other three linked studies. The pilot study was conducted prior to the commencement of Study One of the three linked studies. A detailed description of the methods used in each of the three linked studies will be presented in Chapter Four, Chapter Five and Chapter Six respectively.

Oxygen therapy management for patients at risk of respiratory dysfunction is complex and multifactorial. The literature on oxygen therapy management identifies a number of key factors such as oxygen delivery devices used, patient factors, and nurse factors that impact on the process. In addition, there are few studies that have addressed patients’ experiences as recipients of oxygen therapy and the factors that enhance and hinder their compliance with this therapy. Also, few studies have reviewed the nurses’ management of oxygen therapy or nurses’ perspective of the factors that assist or hinder effective oxygen therapy. In the absence of sound research evidence on the management of oxygen therapy there is a need for further research in order to address this gap. Specifically, further research is necessary to determine the impact of the type of device used, patient factors and nurse factors on oxygen therapy for patients at risk of respiratory dysfunction.
The purpose of this research was to provide a detailed analysis of oxygen therapy management for patients at risk of respiratory dysfunction.

*Overview of research aims*

To address the research aims a pilot study and a series of three linked studies were conducted. The pilot study was conducted to test the process and clinical outcome measures of Study One.

The aim of Study One was to evaluate the effectiveness and user-friendliness of oxygen delivery devices from both the patient and nurse perspective. Study One was divided into two parts – part A and part B. The objective of part A was to measure and compare the oxygen flow rate required to maintain oxygen saturation equal to or greater than 95% in adult patients using different oxygen delivery devices (nasal prongs, face mask and nasopharyngeal oxygen catheter). A crossover trial design was used to assess efficacy of nasal prongs, face mask, and nasopharyngeal oxygen catheter. The objective of part B was to assess and compare patients’ and nurses’ perspectives of oxygen therapy. A complete description of the method of Study One is provided in Chapter Four.

Study Two was undertaken to describe how intensive care nurses administered and managed oxygen therapy for adult cardiac surgical patients during the first 24 hours of intensive care admission. Of particular interest to this study were the types of oxygen delivery devices used, the frequency of documented hypoxaemia, the frequency of documented respiratory rate abnormalities (tachypnoea and bradypnoea) and changes in
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oxygen flow rate or oxygen delivery device in response to respiratory dysfunction (hypoxaemia and / or tachypnoea). A complete description of the method of Study Two is provided in Chapter Five.

The aim of Study Three was to prospectively observe how intensive care nurses manage oxygen therapy. Of particular interest to this study was oxygen delivery device fit, placement and flow rate, assessment of key indicators of oxygenation (oxygen saturation and respiratory rate) and alterations to oxygen therapy in response to hypoxaemia and / or tachypnoea. A complete description of the method of Study Three is provided in Chapter Six.

A summary diagram of three linked studies used to provide a detailed analysis of oxygen therapy management for patients at risk of respiratory dysfunction is shown in Figure 3.1.
Figure 3.1 Summary diagram of the three linked studies reported in this thesis.
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Design

Mixed methods research design was used to address the study objectives. Mixed methods research combines quantitative and qualitative approaches to collecting, analysing, interpreting and reporting data (Creswell, Shope, Plano-Clark, & Green, 2006; Whitehead & Elliott, 2007). Mixed methods design was deemed suitable as it allows the participants to detail their own experience, and it allows the selection of methods to answer complex research questions (Sandelowski, 2000).

Ethical considerations

The study commenced after Human Research and Ethics Committee approval was granted by Deakin University (Burwood, Victoria, Australia) (Appendix A) and Epworth Healthcare (Richmond, Victoria, Australia) (Appendix B). This research was conducted in accordance with the National Statement on Ethical Conduct in Research Involving Humans (National Health and Medical Research Council [NHMRC], 1999; National Health and Medical Research Council [NHMRC], 2003), and the Australian Code for the Responsible Conduct of Research (Australian Government, 2007). During the conduct of the research, amendments were made to the study protocol and the two Human Research and Ethics committees approved these changes prior to the commencement of data collection.

As the consent procedures for the pilot study and each of the three linked studies were different, specific issues related to consent are presented for each specific study in Chapters Three, Four, Five and Six.
Confidentiality, privacy and data storage

The main ethical issues raised by this research related to maintaining nurses’ and patients’ anonymity, privacy and confidentiality, informed consent, and the secure storage of data. Anonymity was maintained using a numerical coding system in which each participant was allocated an identification number. All participant data were only identifiable via their identification number. The identification numbers were kept separate from identifying details including completed participant information sheets and consent forms and were stored in locked filing cabinets separate to the data. The data used in analyses was de-identified and did not contain any unique identifiers.

Privacy and confidentiality were maintained by ensuring that identifiable information obtained was not disclosed to people not directly involved in the research. Patients and nurses who participated in the study were informed that they could receive a summary of the findings at the completion of the study if they wished, but none took this option. All data pertaining to the study was stored in a password protected computer database or on paper record that was only accessible to the researcher. Reports and publications arising from the data presented only de-identified or aggregated data.

During the study period, data were stored at the Austin Health Department of Intensive Care Unit in a locked office. On completion of the study, the data were archived at Deakin University in accordance with the Deakin University Human research ethics guidelines for privacy and data storage. All data will be retained from a period of 7 years from the date of publication in accordance with the Australian Code for
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the Responsible Conduct of Research (Australian Government, 2007). At the completion of this requirement, the raw data sheets will be destroyed in accordance with procedures for the destruction of confidential information. Electronic data will be disposed of by erasure from portable USB drives and hard disks. Lists of names and medical record numbers were destroyed at the completion of data collection and analysis.

In general, informed consent was obtained by providing all participants with a plain language statement that described the aims of the study, the requirements of the participants and provisions for anonymity, privacy and confidentiality. For patient participants, it also stated that participation in the study was voluntary and whether or not they participated would not influence their care. Likewise for nurse participants, it stated that participation in the study was voluntary and whether or not they participated would not influence their employment. Both patient and nurse participants were offered the opportunity to ask questions about the study.

Pilot study

A pilot study was conducted prior to the commencement of Study One to test the research processes and clinical outcomes to be used. Conducting this pilot study enabled reflection and refinement to the research design and clinical outcome measures with the objective of improving the subsequent formal conduct of Study One (Gardner, Gardner, MacLellan, & Osborne, 2003).
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Objectives

The four objectives of the pilot study were to:

- Evaluate recruitment and consent procedures
- Evaluate the patient randomisation procedure
- Validate data collection tools and data analysis methods
- Estimate the sample size for Study One (part A)

Method

Design

The objectives of the pilot study were addressed using a prospective randomized crossover trial and a descriptive exploratory design. Randomised crossover trials are experiments in which participants are randomly allocated to study arms where each arm consists of two or more treatments administered consecutively (Mills et al., 2009; Sibbald & Roberts, 1998). Descriptive exploratory studies enable researchers to form a close relationship with participants in order to understand personal experience, interpretations and constructs of chosen phenomena (Pope & Mays, 1995; Sim & Wright, 2000).

Setting

The research setting for the pilot study was the Epworth Eastern ICU. Epworth Eastern is a 220-bed, tertiary level, acute care hospital in the suburb of Box Hill, Victoria, Australia. The Epworth Eastern ICU is an 8-bed general unit specialising in cardio-thoracic and respiratory care.
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Sample

A convenience sample of 10 intensive care patients and five intensive care nurses was used. Convenience sampling was chosen to efficiently and expeditiously obtain the sample for this pilot study (Endacott & Botti, 2005). Patients were eligible to participate in the study if they were aged 18 years or over, were receiving supplemental oxygen, and were able to provide written informed consent. All intensive care nurses employed on a full-time, part-time or casual basis in the Epworth Eastern ICU of the study setting were eligible to participate. Intensive care nurses employed on a temporary basis from a nursing agency were ineligible.

Procedure

The pilot study commenced after Human Research and Ethics Committee approval from Deakin University (Burwood, Victoria, Australia) (Appendix A) and Epworth Healthcare (Richmond, Victoria, Australia) (Appendix B).

There were two groups of participants in this study, these were: the patient group and the nurse group. Initially, the researcher liaised closely with the Nurse Unit Manager and scheduled times to come to the ICU for the purpose of patient and nurse recruitment.

Patient group

Patients were recruited across all three shifts (morning, afternoon, evening) and days of the week (weekdays and weekends). During these times, the researcher liaised closely with ICU nursing staff to identify eligible patients. With the approval of the
primary nurse, the researcher approached eligible patients and invited them to participate in the study and provided them with the plain language statement and consent form (Appendix C).

Consenting patients were randomised into one of two ‘treatment’ arms of the prospective crossover trial (see Figure 3.2).

- Treatment arm A: nasal prongs, nasopharyngeal oxygen therapy, face mask
- Treatment arm B: nasal prongs, face mask, nasopharyngeal oxygen therapy

Figure 3.2 Pilot study patient randomisation and treatment allocation sequence for the randomised crossover trial. NP = nasal prongs; NPO = nasopharyngeal oxygen catheter; FM = face mask; R = randomisation.

Randomisation was stratified using a random permuted block method to ensure balance of intervention allocations between the two treatment arms (Altman et al., 2001;
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Beller, Gebski, & Keech, 2002). An independent person not involved in the pilot study performed the randomisation procedure and placed the treatment arm identification slip within a sealed opaque envelope. After the patient provided written informed consent the envelope was opened, the treatment arm identified, and the study procedures commenced.

Patients in both treatment arms received oxygen by nasal prongs as their first treatment to ensure that each patient could be adequately oxygenated. Oxygen was administered via nasal prongs at half a litre to six litres per minute to ensure that each patient had an adequate oxygen saturation (SpO₂ greater than or equal to 95%) prior to the change in device. Using the plethysmographic waveform on the pulse oximeter the researcher determined accuracy of the oxygen saturation measurement. After a washout period of 10 minutes, the patient’s oxygen saturation, respiratory rate and device oxygen flow rate were recorded on a specifically-designed data collection tool (Appendix D). The purpose of the washout period was used to reduce the likelihood of ‘carry-over’ effects between consecutive treatment periods (Sibbald & Roberts, 1998).

For patients in treatment arm A, the nasal prongs were removed and replaced with nasopharyngeal oxygen catheter and for patients in treatment arm B nasal prongs were changed to a face mask. For nasopharyngeal oxygen catheter, oxygen was administered at one to six litres per minute and when face mask were used, the oxygen flow rate ranged from six to 15 litres per minute in order to maintain SpO₂ greater than or equal to 95%. Again, after another washout period of 10 minutes the patient’s oxygen saturation, respiratory rate and device oxygen flow rate were recorded. The final oxygen
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delivery device used for patients in treatment A was the face mask and the final device for patients in treatment B arm was nasopharyngeal oxygen catheter. Oxygen was administered using these devices as described above.

Following the third treatment period patients rated their level of comfort for each device using a horizontal visual analogue scale (HVAS) (0 mm = most uncomfortable to 100 mm = most comfortable). Patients were asked to rate each device after the third treatment period so that their comfort rating was informed by having experienced each device under examination. Visual analogue scales are measurement tools used by researchers to measure characteristics or attitudes that range across a continuum, such as pain or comfort (Crichton, 2001). From the participant’s perspective a visual analogue scale provides an opportunity to document, in simple form, their subjective level of device comfort.

Immediately following the trial of nasal prongs, face mask and nasopharyngeal oxygen catheter, patients were invited to participate in a face-to-face semi-structured interview with the researcher. Patients were asked a few questions specifically about their experiences of having oxygen therapy; which device made their breathing feel easier, if they had experienced any difficulties associated with oxygen therapy, were they able to eat, drink and perform basic personal activities while receiving oxygen therapy, and how comfortable they perceived each oxygen device to be. At the end of the interview patients were also asked if they could identify any additional factors that may assist or hinder oxygen therapy. Patient interviews were audio-taped using a portable voice recorder to facilitate transcription and data analysis.
Nurse group

Nurses were approached in the intensive care unit and invited to participate in the study during all three shifts (morning, afternoon, evening) and days of the week (weekdays and weekends). Nurses who expressed an interest in the study were given an explanation of the study by the researcher and provided with a plain language statement and consent form (Appendix E). Consenting nurses then participated in a face-to-face semi-structured interview lasting approximately 20 minutes, conducted at a mutually convenient time and in a quiet place. Nurses were asked questions relating to their management of oxygen therapy, how they helped patients to comply with oxygen therapy and what difficulties were encountered when delivering oxygen therapy to patients (Appendix D). At the end of the interview nurses were also asked if they could identify any additional factors that may assist or hinder oxygen therapy. Nurse interviews were audiotaped using a portable voice recorder. The nurse interview recordings were then transcribed verbatim to facilitate the analysis of the data.

Data analysis

Quantitative data from the crossover trial was analysed using the Statistical Package for the Social Sciences (SPSS) Version 11.5 for Windows (SPSS Inc, Chicago, Ill.) software package. Data were analysed using descriptive statistics and repeated-measures paired t-test. Qualitative data obtained from the interviews of patients and nurses were managed using QSR Nvivo 2.0 (2002) computer software package. Audiotaped interviews were transcribed verbatim. Interview data were analysed using content analysis procedure. Common themes for patients and nurses were identified.
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(Braun & Clarke, 2006). Initially data were analysed sentence by sentence in order to
capture major themes (Braun & Clarke, 2006). After this initial analysis, the researcher
and two research supervisors reviewed the information and coded the data into two
major categories for the patient group (issues associated with compliance with oxygen
therapy and ability to maintain activities of daily living) and three major categories for
the nurse group (factors that assist oxygen therapy compliance and effectiveness; factors
that hinder oxygen therapy compliance and effectiveness; and, strategies to optimise
oxygen therapy compliance and effectiveness). To achieve reliability in coding, coding
was undertaken by the researcher and two research supervisors until 100% agreement
was achieved.

Results

The findings of the pilot study are presented in three sections. The first section
details the findings of the randomised crossover trial involving the nasal prongs, face
mask and nasopharyngeal oxygen catheter. The second section describes the findings of
patients’ perspective of oxygen therapy. The third section describes the findings of
nurses’ perspective of oxygen therapy.

Details of oxygen delivery device effectiveness and comfort

Twenty-three patients were screened for eligibility over a 6-week period, of these
13 patients declined to participate in the study because they did not feel well enough to
participate or did not like the thought of the catheter being inserted into their nose. A
total of ten patients were recruited in the pilot study, four were male and six were
female, with a mean age of 68 years \((SD = 10.9 \text{ years})\). Enrolled patients were admitted to the intensive care unit with cardio-vascular and respiratory related diagnoses.

Eight of the ten patient participants received oxygen by all three devices during the study. Two of the ten patients received oxygen by nasal prongs and face mask only because of failure of the nasopharyngeal oxygen catheter to be positioned correctly in the nasopharynx and one patient declining to receive oxygen via the nasopharyngeal oxygen catheter. The primary outcome measures associated with this randomised crossover trial were \(\text{SpO}_2\), respiratory rate, oxygen flow rate and comfort with each oxygen delivery device.

The normal pulse oximetry derived oxygen saturation is 95 to 100\% (Considine 2005a). All patients \((n = 8)\) that received oxygen by all three devices achieved \(\text{SpO}_2\) greater than or equal to 96\%; the mean \(\text{SpO}_2\) for nasal prongs was 96.88\%, the mean \(\text{SpO}_2\) of the face mask was 97.88\% and the mean \(\text{SpO}_2\) for nasopharyngeal oxygen catheter was 96.88\%. The respiratory rate amongst patients was also within normal range (12-20 breaths per minute) demonstrating that no patient was in respiratory distress or needed to alter their respiratory rate to compensate for a change in oxygen supply. The mean respiratory rate for nasal prongs was 20.12 breaths per minute, for face mask the mean respiratory rate was 20.50 breaths per minute and for nasopharyngeal oxygen catheter the mean respiratory rate was 20.63 breaths per minute. Oxygen flow rate describes the flow of oxygen delivered by each device. The nasopharyngeal oxygen catheter required a lower oxygen flow rate than that of nasal prongs and face mask to achieve equivalent \(\text{SpO}_2\). Therefore the rate of oxygen delivery
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was greater for the nasal prongs and face mask oxygen devices. In terms of comfort, where 0 mm = *most uncomfortable* to 100 mm = *most comfortable*, the nasopharyngeal oxygen catheter device rated higher in comfort (mean, 73.88 mm), than nasal prongs (mean, 67.5 mm) and that of the face mask (mean, 47.38 mm). The results for patients ($n = 8$) that received oxygen by all three devices are shown in Table 3.1.

Table 3.1 Comparison of nasal prongs, face mask and nasopharyngeal oxygen catheter oxygen delivery devices ($n = 8$)

<table>
<thead>
<tr>
<th>Variable</th>
<th>$M (SD)$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NP</td>
</tr>
<tr>
<td>Oxygen saturation (%)a</td>
<td>96.88 (1.55)</td>
</tr>
<tr>
<td>Respiratory rate (rate/min)</td>
<td>20.12 (2.64)</td>
</tr>
<tr>
<td>Oxygen flow (l/min)</td>
<td>3.63 (2.64)</td>
</tr>
<tr>
<td>Device comfortb</td>
<td>67.50 (16.44)</td>
</tr>
</tbody>
</table>

*Note.* NP = Nasal prongs; NPO = nasopharyngeal oxygen catheter; FM = face mask.

*a*SpO$_2$: oxygen saturation measured by pulse oximetry. *b*HVAS: Horizontal visual analogue scale, measured in millimeters (0 mm = most uncomfortable to 100 mm = most comfortable).

**Patients’ perspectives of oxygen therapy**

A total of nine of the ten pilot study patients who were recruited, participated in the interview process. The one patient who did not participate in the interview declined as he was feeling too tired. Analysis of patient interview data on patients’ perceptions of oxygen therapy revealed two themes, these were:
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- Issues associated with compliance with oxygen therapy
- Ability to maintain activities of daily living

A description of the two patient themes is presented below.

_Theme 1: Issues associated with compliance with oxygen therapy_

Patient compliance with keeping on an oxygen delivery device is a key determinant of oxygen therapy effectiveness. Patients stated that how comfortable a device was, having a well-fitted device, and feeling that they were breathing easily, were important factors that assisted them to comply with oxygen therapy. One patient described nasal prongs as the most user-friendly and comfortable oxygen device.

“Well I reckon it [nasal prongs] is easier to apply and manipulate and doesn’t cause so much trouble when you’re moving around in the bed. It’s [oxygen flow] more consistent, you don’t get much interruption to the flow.” (Patient 7: Pilot study)

Patients identified that having a well-fitted device was a contributing factor to improving their compliance with oxygen therapy. Patients reported poor face mask fit as contributing to feelings of discomfort because of poor fit over the nose and mouth. One particular patient stated that the face mask was too large for her face and that receiving face mask oxygen therapy was cumbersome.

“The face mask, on a hot day you can’t scratch your nose, it’s too big and cumbersome.” (Patient 9: Pilot study)
Patients highlighted that device comfort was a key factor that contributed to their compliance with oxygen therapy. The patients described experiences with the oxygen device both at the commencement of oxygen therapy, as in the case of nasopharyngeal oxygen catheter or during therapy. One patient said that tubing of the nasal prongs that looped over his ears was painful when he rested his head on the pillow.

“I’ve been wearing the nasal prongs for a long time and the only discomfort I have is if I lie on my side and my ear squashes against the tube behind my ear but then I’ve learnt to pull that out.” (Patient 1: Pilot study)

The insertion of the nasopharyngeal oxygen catheter was considered the most uncomfortable aspect of oxygen therapy. One patient likened the insertion of the nasopharyngeal oxygen catheter to that of a sharp instrument being inserted into their nose.

“When it [nasopharyngeal oxygen catheter] was going in, yes it was sort of like a sharp instrument cutting up the higher end of my cheek that’s what it felt like.”

(Patient 5: Pilot study)

However, the initial discomfort associated with the oxygen catheter insertion did not persist during nasopharyngeal oxygen catheter use. Patients became accustomed to receiving oxygen therapy via the nasopharyngeal oxygen catheter and did not report
further discomfort during the treatment periods. On reflection one patient commented that he found the nasopharyngeal oxygen catheter very comfortable.

“Yes I do think it’s [nasopharyngeal oxygen catheter] much more comfortable I haven’t been moving about very much but it’s, you don’t really realise it’s there after a while which is very good.” (Patient 2: Pilot study)

Patients perceived that the therapeutic benefit of receiving oxygen as contributing positively to their compliance with oxygen therapy. None of the patients reported experiencing breathing difficulties during the randomised crossover trial. Patients did however differ in their device preference. Because the nasal prongs were less invasive than the nasopharyngeal oxygen catheter and not as obstructive as the face mask, one patient indicated her preference for nasal prongs.

“Probably the nasal prong, I suppose it probably felt less invasive, it seemed less invasive perhaps and the access to the oxygen was all there when you needed it, things like that.” (Patient 1: Pilot study)

In contrast, a different patient indicated that she preferred the nasopharyngeal oxygen catheter because the position of the catheter in one nostril only was beneficial.

“Well I think the one I’ve got in now. The one prong [nasopharyngeal oxygen catheter], I think it feels easier because it’s not rubbing on both sides of the
Theme 2: Ability to maintain activities of daily living

Patients’ ability to maintain activities of daily living impacted on their level of compliance with oxygen therapy. Specifically, talking, eating, drinking, and changing body position are common activities performed by patients during oxygen therapy. Patients reported that nasal prongs and the nasopharyngeal oxygen catheter did not hinder their ability to eat and drink, change body positions or perform basic physiotherapy exercises. One patient described being able to perform basic activities such as eating and drinking without a problem during oxygen therapy via the nasopharyngeal oxygen catheter.

“…while it [nasopharyngeal oxygen catheter] has been there I’ve had my breakfast and ate and had my drinks and things like that and got out of bed,… and I really wouldn’t even know it [nasopharyngeal oxygen catheter] is there.” (Patient 8: Pilot study)

For a different patient however, the ability to eat and drink was difficult during face mask therapy and he went on to indicate a preference for the nasopharyngeal oxygen catheter.
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“I reckon they’re [face mask] uncomfortable and they never ever fit properly and now that I’m inclined to eating I flick them off the top of my head and then forget about it.” (Patient 8: Pilot study)

Nurses’ perspectives of oxygen therapy

A total of five nurses who were recruited participated in the interview process. Of these five nurses, one was male and four female. Three of the nurses were employed as clinical nurse specialists in intensive care. The mean length of intensive care nursing experience for the five nurses was 8.9 years ($SD = 4.58$ years). Two nurses were employed on a full-time basis, two nurses were employed on a part-time basis and one nurse was employed on a casual basis.

Analysis of nurse interview data on nurses’ perceptions of oxygen therapy revealed three themes, these were:

- Factors that assisted oxygen therapy compliance and effectiveness
- Factors that hindered oxygen therapy compliance and effectiveness
- Strategies to optimise oxygen therapy compliance and effectiveness

A description of the three themes will now be presented.

Theme 1: Factors that assisted oxygen therapy compliance and effectiveness

Nurses’ ability to help patients comply with oxygen therapy is central to achieving oxygen therapy effectiveness. Nurses reported that device comfort and a patient’s previous experience with oxygen therapy as helping patients comply with
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Oxygen therapy. In a succinct summary one nurse describes aspects of both device comfort and causes of discomfort that will contribute to oxygen therapy compliance.

“I think nasal prongs seem to be more favoured by patients from degree of flexibility and comfort, they can just put it in the nostrils and it doesn’t bother them a lot, except for pressure point around the ear some times, then some people who don’t tolerate them. But the mask [face mask] is generally well tolerated too except for a few people who might have some fear of being enclosed.” (Nurse 1: Pilot study)

One other nurse remarked that patients who had previously experienced and were familiar with what is required were more likely to comply with oxygen therapy treatment.

“I’d say previous experience. If the patient has had them before, they’re familiar with them and they know what it feels like because for the first time a patient putting it on they can find it uncomfortable.” (Nurse 3: Pilot study)

Theme 2: Factors that hindered oxygen therapy compliance and effectiveness

Nurses identified that an ill-fitting oxygen delivery device causes discomfort and can lead to ineffective oxygen therapy if the patient removes the device. One particular nurse stated that nasal prongs are often found displaced and oxygenating the forehead rather than remaining in correct position.
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“To tell you the truth I think the most problematic ones are nasal prongs, I don’t think the prongs are long enough, that’s just me I find quite often they’re up people’s eyes, forehead and [on top of] nose, and more likely than not there’s one prong in and the other one hanging out and quite often they shift around people’s ears, they’re [nasal prongs] quite uncomfortable…” (Nurse 3: Pilot study)

Similarly, a nurse highlighted a problem using the face mask as it is prone to stick to the patient’s face because of the heat and moisture associated with breathing into the face mask. A sticky mask is likely to be irritating and then be removed by the patient.

“Not necessarily. I prefer to stay away from masks because they’re too drying, they’re irritating, they get stuck on the patient’s face, they often don’t stay on the face, they slide down or slide up, they oxygenate the eyes, ears or head where something that’s, like I always tend towards the nasal prongs or even less compliant patients the INT [nasopharyngeal oxygen catheter] because they’re smaller, they don’t seem to get in the way, they’re not as irritating” (Nurse 2: Pilot study)

The impact of a patient being confused and agitated during oxygen therapy was another factor nurses identified as hindering oxygen therapy compliance. This is because confused and agitated patients are likely to remove, though unintentionally, the oxygen device they are wearing. One nurse stated that it was this ‘unintentional’
removal of the mask that negatively impacted on oxygen delivery and the need to change oxygen devices to improve compliance.

“Mainly I think that about whether the patient is confused or not. If they’re confused they’re more likely to keep pulling the mask off or even sometimes the nasal prongs, with the inner-cannula you can actually hide it a bit better, so they will keep it on a bit better.” (Nurse 4: Pilot study)

Theme 3: Strategies to optimise oxygen therapy compliance and effectiveness

All nurses described a number of different strategies they used to help patients comply with oxygen therapy. Analysis of the nurses’ interviews revealed educating the patient and involving the patient in the management of oxygen therapy as key strategies that optimise oxygen therapy compliance and effectiveness.

“I think it’s really important not to just plonk it [the oxygen delivery device] on their face. You have to tell people or explain to people it’s really important you do this because of these reasons and we’re doing this intervention for this outcome and even though they might be people who are compliant I still think still you have a responsibility to educate people and let them know why you’re doing something.” (Nurse 3: Pilot study)

Nurses stated that patients tended to comply with oxygen therapy when they were involved in the decision making process. One nurse described showing the patient different devices and detailing the benefits and limitations of each device to the patient.
“To gain patient compliance I try and put the decision into their hands so they feel they’re in control of what type of oxygen flow they’ve got and they’ve got the decision to make. By obviously giving them a choice, educating them about their choices, giving them to option that they can trial if they don’t like they can remove.” (Nurse 2: Pilot study)

Changing from one oxygen delivery device to another was an alternative strategy that nurses used in an attempt to optimise patient compliance with oxygen therapy and therefore oxygen therapy effectiveness. The main triggers for changing oxygen delivery devices were a decrease in the patient’s oxygen saturation, increase in the patient’s respiratory rate or effort, and the need for the patient to perform activities such as eating, drinking or physiotherapy.

“Generally saturation, also respiratory rate, you know effort of breathing. If I find that they seem fine and their saturations are great and you know like everything is going fine. I always give them a trial on nasal [prongs], oh I’ll just try you on some nasal prongs see how they go and if they’re dropping their saturations or not maintaining them well generally you’ll do a, you know I’ll have them on it for while … I generally fine that patients are more comfortable on the intra nasal or the nasal prongs than the face mask.” (Nurse 5: Pilot study)
Findings and recommendations of the pilot study objectives

The pilot study examined the feasibility of conducting Study One. The findings and recommendations for each of the pilot study’s objectives are listed in Table 3.2. Aspects of the pilot study that did not require change were the consent process for patients and nurses, the content of the data collection tools and the method of data analysis.

Pilot study data were used to estimate the sample size required for Study One (part A). The most important clinical variable assessed during the pilot study was SpO2. Using the standard deviation of means (0.47) and standard deviation (1.30) of SpO2 the effect size was calculated to be 0.36. Based on this effect size a biostatistician calculated that a sample size of 78 patients would be required to detect a mean difference of 0.5 (medium effect size) (Cohen, 1988) in SpO2 with a power of 0.8 at a 0.05 significance level. The formula used to calculate the effect size was:

\[
\text{Standard Deviation of means} / \text{Standard Deviation} = \text{Effect size}
\]

The most significant finding of the pilot study and changes made in Study One were related to the recruitment procedure for patients and the randomisation procedure. Recruitment of sufficient numbers of patients in a timely fashion is a fundamental component to the successful completion of clinical trials (Grap & Munro, 2003). The patient recruitment procedure for the pilot study was unsatisfactory because it took 6-weeks to recruit 10 patients. At that patient recruitment rate a total of 24 weeks would be required to reach the sample of 39 patients. Screening for patients on non-
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consecutive days was identified as a potential cause of the protracted patient recruitment period. To reduce the time to recruit patients, a change to the recruitment procedure was required. For Study One, patients would be screened for eligibility of consecutive days. Visiting the intensive care unit on consecutive days would enable the early identification of eligible patients by the researcher. The changed patient recruitment procedure was used in Study One.

Pilot study patients were randomised to one of two trial arms. The procedure for randomisation involved the creation of sequentially numbered sealed opaque envelopes that contained the treatment arm identification slip. Randomisation was stratified using a random permuted block method and a balance of patients allocated to each treatment arm achieved. Permutated block randomisation was repeated for Study One using three treatment arms and not two treatment arms. The decision to use three treatment arms was to reduce the likelihood of order effects by ensuring a balance in the number of devices and the sequence in which they were trialled.
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Table 3.2 Findings and recommendations for each of the pilot study’s objectives

<table>
<thead>
<tr>
<th>Pilot study objective</th>
<th>Findings of the pilot study and recommendations for Study One</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluate consent and</td>
<td>The existing inclusion and exclusion criteria used were suitable for identifying and recruiting patients and nurses into the Pilot study. No change was made to the patient or nurse consent form for Study One.</td>
</tr>
<tr>
<td>recruitment procedures</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The patient recruitment procedure for the pilot study was unsatisfactory because it took 6-weeks to recruit 10 patients. Screening for patients on non-consecutive days was identified as a potential cause of the protracted patient recruitment period. For Study One, patients would be screened for eligibility of consecutive days. Visiting the intensive care unit on consecutive days enabled the early identification of eligible patients by the researcher for Study One.</td>
</tr>
<tr>
<td>Evaluate the patient</td>
<td>All 10 patients enrolled in the pilot study participated in the randomised crossover trial. Pilot study patients were randomised to one of two trial arms. The procedure for randomisation involved the creation of sequentially numbered sealed opaque envelopes that contained the treatment arm identification slip. Randomisation was</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>Pilot study objective</th>
<th>Findings of the pilot study and recommendations for Study One</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>stratified using a random permuted block method and a balance of patients allocated to each treatment arm achieved. Permuted block randomisation was repeated for Study One using three treatment arms to reduce the likelihood of order effects by ensuring a balance in the number of devices and the sequence in which they were trialled.</td>
</tr>
<tr>
<td>Validate data collection tools and data analysis methods</td>
<td>Pilot data focused on measures of device effectiveness (SpO2, respiratory rate, oxygen flow rate), device comfort, and patients’ and nurses’ perspectives of oxygen therapy. Specifically designed data collection tools were used to record data. Reliability and validity of the data collection tool was assured by subjecting the data collection tools to expert review by two PhD prepared researchers and pilot testing in the real clinical environment. The pilot testing included 10 patients and 5 nurses. The interview questions of the pilot study for the nurse group and the patient group were repeated in Study One. No changes were made to the data collection tools or the method of data analysis for Study One.</td>
</tr>
</tbody>
</table>
Pilot study objective | Findings of the pilot study and recommendations for Study One
---|---
**Estimate the sample size for Study One (part A)** | A key function of the pilot study was to determine the sample size required for Study One (part A). The most important clinical variable assessed during the pilot study was SpO2. Using the standard deviation of means (0.47) and standard deviation (1.30) of SpO2 the effect size was calculated to be 0.36. Based on this effect size a biostatistician recommended that a sample size of 78 patients would be required to detect a mean difference in 0.5 in SpO2 with a power of 0.8 at a 0.05 significance level.
Summary

Chapter Three has presented the pilot study and an overview of the three sequentially linked studies of this thesis. Research processes and ethical considerations of all studies were also provided. The objectives, methods and findings of the pilot study were described. Importantly the recommendations of the pilot study that were incorporated into Study One were identified. Chapter Four, Chapter Five and Chapter Six present the aim, methods, results and a summary of key findings for each of the three sequentially linked studies.
Chapter 4: Randomised crossover trial & descriptive exploratory interviews

Introduction

The purpose of Chapter Four is to report the aim, method, result and a summary of key findings from Study One. The aim of Study One was to evaluate the effectiveness and user-friendliness of oxygen delivery devices from both the patient and nurse perspectives. Study one was divided into two parts – part A and part B. The objectives, method and results for part A and part B will be presented separately followed by a summary of the key findings for Study One.

Study One (part A): randomised crossover trial

Introduction

Intensive care nurses frequently use nasal prongs, face mask and nasopharyngeal oxygen catheter to administer oxygen therapy. Despite evidence of the efficacy of nasal prongs, face mask and nasopharyngeal oxygen catheter, there are no published studies comparing the efficacy and comfort of these three devices in the same patients (Eastwood et al., 2004; O’Driscoll et al., 2007).

Objectives

The objective of part A was to measure and compare the oxygen flow rate required to maintain oxygen saturation equal to or greater than 95% in adult patients using different oxygen delivery devices (nasal prongs, face mask and nasopharyngeal oxygen catheter). The primary outcome measures were:

- Patient oxygen saturation (SpO₂)
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- Oxygen flow rate (litres per minute)
- Patient respiratory rate (per minute)
- Patient perceptions of comfort for each device using a horizontal visual analogue scale (HVAS)

Method

Design

The objectives of Study One (part A) were addressed using a prospective randomised crossover trial (Sibbald & Roberts, 1998; Mills et al., 2009). The use of the crossover trial design was an important methodological choice for this study. A particular strength of the crossover design is that treatments under investigation are evaluated within the same patients, thereby eliminating between-subject variability (Mills et al, 2009). Additionally, this design permits the opportunity for patients to receive multiple consecutive treatments and express preferences for or against particular treatments (Mills et al, 2009), such as oxygen delivery devices.

Setting

The research was conducted in the Epworth Eastern and Epworth Hospital Intensive Care Units (ICUs). These two hospitals are part of the Epworth Healthcare organisation. Epworth Eastern is a 220-bed, tertiary level, acute care hospital in Box Hill, Victoria, Australia. The Epworth Eastern ICU is an 8-bed general unit specialising in cardio-thoracic and respiratory care. Epworth Hospital is a 520-bed, tertiary level, acute care hospital in Richmond, Victoria, Australia. The Epworth Hospital ICU is a 15-bed adult general ICU that admits approximately 1,100 patients per year.
Sample

A convenience sample of 37 intensive care patients were recruited into this randomised crossover trial. Although 78 patients were recommended based on power analysis, a convenience sample of 37 patients was deemed sufficient based on interim analysis.

Patients were eligible to participate in the study if they were aged 18 years or over, were receiving supplemental oxygen, and were able to provide written informed consent. Patients were ineligible for recruitment into the study if they required high-flow oxygen therapy, non-invasive oxygen therapy or mechanical ventilation, or had a contraindication to the insertion of a nasopharyngeal oxygen catheter (e.g. nasal deformity, facial trauma, epistaxis and nasal/sinus congestion).

Procedure

Study One (part A) commenced after approval from the Human Research and Ethics Committee of Deakin University (Burwood, Victoria, Australia)(Appendix A) and Epworth Healthcare (Richmond, Victoria, Australia)(Appendix B). The researcher liaised closely with the Nurse Unit Managers of both Epworth Eastern and Epworth Hospital ICUs to scheduled times to attend each ICU for the purpose of patient recruitment.

Patients were recruited across all three shifts (morning, afternoon, evening) and days of the week (weekdays and weekends). The researcher visited both ICUs on
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consecutive days to facilitate the early identification and recruitment of eligible patients.

With the approval of the primary nurse caring for the patient, the researcher approached
eligible patients, invited them to participate in the study, described the study procedures
and provided them with the plain language statement and consent form (*Appendix C*).
Patients were given time to read the plain language statement and consider their
participation in the study. Prior to obtaining written consent patients were offered the
opportunity to ask questions about the study.

Consenting patients were randomised into one of three ‘treatment’ arms of the
randomised crossover trial (see Figure 4.1).

- Treatment arm A: nasal prongs, nasopharyngeal oxygen catheter, face mask
- Treatment arm B: nasopharyngeal oxygen catheter, face mask, nasal prongs
- Treatment arm C: face mask, nasal prongs, nasopharyngeal oxygen catheter
Randomisation was stratified using a random permuted block method to ensure balance of the numbers of patients allocated to each of the three treatment arms (Beller, et al., 2002). The order of the devices used in each treatment arm varied in order to achieve a balance between the number and sequence of the type of device used. An independent person not involved in Study One (part A) performed the randomisation procedure and placed the treatment arm identification slip within an opaque enveloped that was then sealed. Sequentially numbered envelopes were opened after informed consent was obtained and the corresponding treatment arm followed.
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For patients in treatment arm A, nasal prongs were the first treatment. Oxygen was administered via nasal prongs at half a litre to six litres per minute. For patients in treatment arm B, the nasopharyngeal oxygen catheter was the first treatment. Oxygen was administered via nasopharyngeal oxygen catheter at one to six litres per minute. For patients in treatment arm C, the face mask was the first treatment. Oxygen was administered via face mask at six to 15 litres per minute. Oxygen flow rates for all three devices were administered to achieve a patient SpO₂ of greater than or equal to 95% at the lowest achievable oxygen flow rate. The researcher, using the plethysmographic waveform on the pulse oximeter, determined accuracy of the SpO₂ measurement (O’Driscoll, et al, 2008; Jubran, 2004). After a period of 10 minutes with a stable plethysmographic waveform, the patient’s SpO₂, respiratory rate and device oxygen flow rate were recorded on a specifically designed data collection tool (Appendix D).

The period of 10 minutes was used as a washout period. Washout periods are an important aspect of randomised crossover trials. A washout period is performed to reduce the potential for the effects of one treatment impacting on subsequent treatments, known as ‘carry-over’ effects (Sibbald & Roberts, 1998). The period of 10 minutes has been shown to be adequate for the saturation of oxygen in the blood to stabilise after a change in inspired oxygen concentration (Cakar et al., 2001).

For patients in treatment arm A, the nasal prongs were removed and replaced with nasopharyngeal oxygen catheter, for patients in treatment arm B the nasopharyngeal oxygen catheter was changed to face mask, and for patients in treatment arm C, face mask was changed to the nasopharyngeal oxygen catheter. The oxygen flow rate was administered to maintain SpO₂ greater than or equal to 95%. After a washout
period of 10 minutes the patient’s SpO2, respiratory rate and device oxygen flow rate were recorded.

The final oxygen delivery device used for patients in treatment arm A was the face mask, for patients in treatment arm B the final device was nasal prongs, and for patients in treatment arm C the final device was nasopharyngeal oxygen catheter. Oxygen was administered using these devices as described above. After a final washout period of 10 minutes the patient’s SpO2, respiratory rate and device oxygen flow rate were recorded.

Following the third treatment period patients were asked to rate their level of comfort for each oxygen delivery device using a horizontal visual analogue scale (HVAS) (0 mm = most uncomfortable to 100 mm = most comfortable). Patients were asked to rate each device after the third treatment period so that their comfort rating was informed by having experienced each device under examination. All data for Study One (part A) were collected between February and September 2007.

**Data analysis**

Quantitative data from the crossover trial were analysed using the Statistical Package for the Social Sciences (SPSS) Version 14 for Windows (2005)(SPSS Inc, Chicago, Ill.) software package. Descriptive statistical tests (frequency, mean and standard deviation) were used to examine patients’ demographic characteristics (age, gender, reason for admission to intensive care). One-way repeated analysis of variance (ANOVA) was used to compare the mean scores of each dependent variable (SpO2,
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respiratory rate, oxygen flow rate and device comfort) *between* and *within* patients (Pallant, 2005; Polit & Hungler, 1997). One-way ANOVA was appropriate for use in this study because ANOVA is a parametric procedure used to test the significance of mean group differences between two or more groups (Polit & Hungler, 1997). A series of multiple comparisons (*post hoc* tests) were performed to examine the statistical significance of the difference between group means for each dependent variable (Pallant, 2005; Polit & Hungler, 1997). The findings of multiple comparisons identify where the differences amongst groups exist and are reported at a significance level of *p* < 0.05 (Pallant, 2005; Polit & Hungler, 1997).

*Ethical considerations*

Participation in this study was voluntary and patients were informed that whether they participated or not would not influence their care. Patients were informed of the requirements of participation and the provisions made for anonymity, privacy and confidentiality verbally by the researcher and in writing by the participant information sheet and consent form. Patient anonymity was maintained by the use of a numerical coding system in which each patient was allocated a unique identification number. Patient identification numbers were kept separate from identifying details (including completed plain language statement and consent forms) and were stored in locked filing cabinets separate to the data.

All data pertaining to the study was stored in a password protected computer database or on paper record that was only accessible to the researcher. The data used in analyses was de-identified and did not contain any identification numbers. Publications
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and presentations arising from the study presented only de-identified or aggregated data. Patients who participated in the study were informed that they could receive a summary of the findings at the completion of the study if they wished, but none took this option.

On completion of the study, the data were archived at Deakin University in accordance with the Deakin University Human research ethics guidelines for privacy and data storage. All data will be retained from a period of seven years from the date of publication in accordance with the Australian Code for the Responsible Conduct of Research (Australian Government, 2007). A broader discussion of these ethical considerations was provided in Chapter Three.

Agreement was reached between the researcher and the Human Research and Ethics Committees that if the researcher were to witness patient circumstances that were life threatening or potentially life threatening, the researcher would notify the intensive care nurse caring for the patient or the intensive care nurse in charge of the intensive care unit at the time. If a time critical life-threatening event, such as a cardiac arrest, was to be un-witnessed by other staff, the researcher would activate the emergency response alarm. Aside from conducting study-related procedures the researcher did not actively participate in patient care.

Results

Of 70 eligible patients, 37 patients participated in the study (53%). Reasons for why eligible patients did not participate were: did not wish to participate without providing a reason ($n = 21$); did not wish to participate because they did not like the
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thought of the nasopharyngeal oxygen catheter being inserted through the nose \((n = 7)\); and, the patient stating that they did not feel well enough to participate \((n = 5)\). Of the 37 patients that consented to participate in the study, 24 were male and 13 were female. Their mean age was 68 years \((SD 10.18)\). Twenty patients \((54\%)\) were admitted to the ICU with a medical/surgical diagnosis while the remaining 17 patients \((46\%)\) were cardio-thoracic admissions.

The primary outcome measures for Study One (part A) were patient oxygen saturation (SpO2), patient respiratory rate, oxygen flow rate, and patient perception of comfort with each oxygen delivery device. The normal SpO2 for adults is 95 to 100\% (Considine, 2005a; Crapo, et al, 1999). All three devices were effective at maintaining SpO2 at or greater than 95\%: the mean SpO2 for nasal prongs was 97.0\%, for face mask the mean SpO2 was 98.8\%, and the mean SpO2 for nasopharyngeal oxygen catheter was 97.7\%, as shown in Table 4.1. Although there was a statistically significant difference between these SpO2 for the different devices \((p < 0.001)\), the difference was not clinically significant as all measurements were within normal limits (Considine, 2005a; Crapo, et al, 1999).

Oxygen flow rate indicates the amount of oxygen being delivered by an oxygen delivery device when providing oxygen therapy. Nasopharyngeal oxygen required a lower oxygen flow rate \((2.1 \text{ litres per minute})\) than nasal prongs \((2.2 \text{ litres per minute})\) and face mask \((6.1 \text{ litres per minute})\) \((p < 0.001)\) to achieve an equivalent SpO2 during the treatment period, as shown in Table 4.1. The mean respiratory rate for nasal prongs was 19.9 breaths per minute, for the face mask the mean respiratory rate was 19.8
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breaths per minute and for the nasopharyngeal oxygen catheter the mean respiratory rate was 19.9 breaths per minute ($p = 0.491$). There were no significant differences in patients’ respiratory rates between devices, as shown in Table 4.1.

In terms of oxygen delivery device comfort, where 0 mm = most uncomfortable to 100 mm = most comfortable, patients rated the nasal prongs (mean 65.5 mm) the most comfortable device followed by the nasopharyngeal oxygen catheter (mean 62.8 mm) and then the face mask (mean 49.4 mm) ($p < 0.001$), as shown in Table 4.1.

Table 4.1 Comparison of nasal prongs, face mask and nasopharyngeal oxygen catheter delivery devices ($N = 37$)

<table>
<thead>
<tr>
<th>Variable</th>
<th>(1) NP</th>
<th>(2) NPO</th>
<th>(3) FM</th>
<th>$p$</th>
<th>Multiple Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen saturationa (%)</td>
<td>97.0 (1.9)</td>
<td>97.7 (1.7)</td>
<td>98.8 (1.3)</td>
<td>&lt;0.001</td>
<td>(1) ≠ (2) ≠ (3)</td>
</tr>
<tr>
<td>Oxygen flow (l/min)</td>
<td>2.6 (1.0)</td>
<td>2.2 (0.9)</td>
<td>6.1 (0.4)</td>
<td>&lt;0.001</td>
<td>(1) ≠ (2) ≠ (3)</td>
</tr>
<tr>
<td>Respiratory (rate/min)</td>
<td>19.9 (3.2)</td>
<td>19.9 (3.0)</td>
<td>19.8 (3.1)</td>
<td>0.491</td>
<td></td>
</tr>
<tr>
<td>Device comfortb</td>
<td>65.5 (14.3)</td>
<td>62.8 (19.4)</td>
<td>49.4 (21.4)</td>
<td>&lt;0.001</td>
<td>[(1) = (2)] ≠ (3)</td>
</tr>
</tbody>
</table>

Note. NP = Nasal prongs; NPO = nasopharyngeal oxygen catheter; FM = face mask.

aOxygen saturation measured by pulse oximetry. bHVAS: Horizontal visual analogue scale, measured in millimeters (0 mm = most uncomfortable to 100 mm = most comfortable).

The findings of this study have shown that nasal prongs, face mask and the nasopharyngeal oxygen catheter were able to maintain an $\text{SpO}_2$ greater than 95%. In addition, oxygen delivery by nasal prongs and nasopharyngeal oxygen catheter allowed for less oxygen rate of oxygen delivery and greater device comfort compared to the face...
mask in adult patients. All three oxygen delivery devices achieved an SpO\textsubscript{2} greater than 95% but there were clear differences in patient comfort so it was important to gain a deeper understanding of patient’s perspectives of oxygen therapy and to explore nurse’s perspectives of how they optimise oxygen therapy effectiveness.

**Study one (part B): descriptive exploratory interviews**

*Introduction*

Patients and nurses play an equally important role in optimising compliance with, and effectiveness of, oxygen therapy. Despite the frequent use of oxygen therapy as an intervention in hospital settings, few studies have explicitly reviewed patients’ and nurses’ perspectives of oxygen therapy (Considine et al, 2006; Eastwood et al., 2007; Stausholm et al., 1995). Understanding patients’ and nurses’ perceptions of oxygen therapy is important in order to identify the factors that enhance or hinder effectiveness of, and compliance with, oxygen therapy. A better understanding of oxygen therapy from patients’ and nurses’ perspectives will make a significant contribution to the evidence-base related to oxygen therapy.

*Objectives*

The objectives of Study One (part B) were to assess and compare patients’ and nurses’ perspectives of oxygen therapy. Of particular interest were patients’ preferences and experiences of receiving oxygen therapy using nasal prongs, face mask and nasopharyngeal oxygen catheter and nurses’ perspectives of the factors that influence their management of oxygen therapy.
Method

Design

The objectives of Study One (part B) were addressed by using a descriptive exploratory design that included face-to-face interviews with participants. Descriptive exploratory studies enable researchers to form close relationships with participants in an attempt to understand personal experience, interpretations and perspectives of chosen phenomena, such as oxygen therapy (Pope & Mays, 1995; Sim & Wright, 2000).

Setting

Study One (part B) was conducted in the Epworth Eastern and Epworth Hospital ICUs. A detailed description of the study setting is presented earlier in this chapter (part A: Setting).

Sample

There were two groups of participants in this study: patients and nurses. A convenience sample of 37 intensive care patients (the same as those from Study One, part A) was recruited for this study and participated in the interview process. Eligible patients were those aged 18 years or over, were receiving supplemental oxygen, and were able to provide written informed consent. Patients ineligible to participate were those who required high-flow oxygen therapy, non-invasive oxygen therapy or mechanical ventilation, or had a contraindication to the insertion of a nasopharyngeal oxygen catheter (e.g. nasal deformity, facial trauma, epistaxis and nasal/sinus congestion). All intensive care nurses employed on a full-time, part-time or casual basis in the Epworth Eastern and Epworth Hospital ICUs were eligible to participate.
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Intensive care nurses employed on a temporary basis from a nursing agency were ineligible. A convenience sample of 25 intensive care nurses was recruited into this study and participated in the interview process.

Procedure

The study commenced after Human Research and Ethics Committee approval from Deakin University (Burwood, Victoria, Australia) (Appendix A) and Epworth Healthcare (Richmond, Victoria, Australia) (Appendix B).

For the purpose of patient and nurse recruitment the researcher liaised with the Nurse Unit Managers of both ICUs to arrange times to visit each ICU. Recruitment of participants and the conduct of all interviews occurred between February 2007 and September 2007.

Procedure: Patient group

Patients were recruited into the study during all three shifts (morning, afternoon, evening) and days of the week (weekdays and weekends). During these times, the researcher visited the Epworth Eastern and Epworth Hospital ICUs to identify eligible patients. The researcher approached eligible patients, invited them to participate in the study, described the study procedures and provided them with the plain language statement and consent form (Appendix C). Patients were given time to read the plain language statement and consider their participation in the study. In addition, prior to obtaining written consent patients were offered the opportunity to ask questions about the study.
Consenting patients then participated in a face-to-face semi-structured interview lasting approximately 15 minutes with the researcher. Interviews were conducted at the patient’s bedside located within the intensive care unit. Patients were asked a series of questions about their experiences of having oxygen therapy; which device made their breathing feel easier; if they had experienced any difficulties associated with oxygen therapy; if they were able to eat, drink and perform basic personal activities; and, how comfortable they perceived each device to be. At the conclusion of the interview patients were asked if they could identify any additional factors that may assist or hinder oxygen therapy. Patient interviews were audio-taped using a portable voice recorder. Patient interview recordings were then transcribed verbatim to facilitate data analysis.

**Procedure: Nurse group**

Nurses were approached in the ICU and invited to participate in the study during all three shifts (morning, afternoon, evening) and days of the week (weekdays and weekends). Nurses who expressed an interest in the study were provided with a verbal explanation of the study and provided with a plain language statement and consent form (*Appendix E*). Nurses were given time to read the plain language statement and consider their participation in the study. Prior to obtaining written consent nurses were offered the opportunity to ask questions about the study.

Consenting nurses then participated in a face-to-face semi-structured interview lasting approximately 20 minutes, conducted at a mutually convenient time and in a quiet place. Nurses were asked questions relating to their management of oxygen
therapy; how they helped patients to comply with oxygen therapy; and, what difficulties were encountered when delivering oxygen therapy to patients. At the end of the interview nurses were also asked if they could identify any additional factors that may assist or hinder oxygen therapy (Appendix D). Nurse interviews were audio-taped using a portable voice recorder. The nurse interview recordings were then transcribed verbatim to facilitate the analysis of the data.

Data analysis

Qualitative data obtained from patient and nurse interviews were managed using QSR Nvivo 2.0 (2002) computer software package. Interview transcripts were analysed using content analysis procedure (Braun & Clarke, 2006). Content analysis enabled the researchers to extract the keywords and themes recorded in the interview transcripts (Braun & Clarke, 2006). Initially, interview transcripts (raw data) were analysed sentence by sentence in order to capture major themes (Brauen & Clarke, 2006). The researcher and supervisors then reviewed the collated information and coded the data into three major categories for the patient group (level of comfort with oxygen delivery devices, ability to maintain activities of daily living and therapeutic effect) and five major categories for the nurse group (therapeutic effect, issues associated with oxygen therapy compliance, strategies to optimise oxygen therapy compliance, familiarity with oxygen delivery devices, and triggers for changing oxygen delivery devices). The process of theme development was emergent and all subthemes were compared and unified around a core theme central to the patient/nurse experience of oxygen therapy. To achieve reliability in coding of patient and nurse interview data, coding was
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undertaken by the researcher and two research supervisors until 100% agreement was achieved.

Ethical considerations

Participation in this study was voluntary and patients and nurses were informed they could withdraw at any time, yet none took this option. In particular, patients were informed that whether they participated or not would not influence their care. Nurses were informed that whether they participated or not would not influence their employment status. Patients and nurses were informed of provisions for anonymity, privacy and confidentiality both verbally by the researcher and in writing via the plain language statement and consent form. To maintain anonymity, patient data and nurse data were allocated a numerical code and only aggregated data or re-identified quotations were used in publications and conference presentations.

Results

The findings of Study One (part B) are presented in two sections. The first section describes patients’ perspectives of oxygen therapy. The second section describes nurses’ perspectives of oxygen therapy.

Patients’ perspectives of oxygen therapy

Seventy patients were approached to participate in the study, of whom 37 (53%) agreed to participate in the study. Reasons why eligible patients did not participate in the study were: did not wish to participate without providing a reason (n = 21); did not wish to participate because they did not like the thought of the nasopharyngeal oxygen
catheter being inserted through the nose (associated with participation in Study One, part A) \((n = 7)\); and, the patient was not feeling well enough to participate \((n = 5)\). Of the 37 consenting patients, 24 were male and 13 were female and their mean age was 68 years \((SD = 10.18)\). Twenty patients \((54\%)\) were admitted to the ICU with a medical/surgical diagnosis while the remaining 17 patients \((46\%)\) were cardio-thoracic admissions.

Analysis of patient interview data revealed three themes impacted on patients’ perceptions of oxygen therapy:

- Level of comfort with oxygen delivery devices
- Ability to maintain activities of daily living
- Therapeutic effect

A description of each theme on the patients’ perceptions of oxygen therapy will now be presented.

Theme 1: Level of comfort with oxygen delivery devices

Patients perceived that the level of device comfort contributed positively to their compliance with oxygen therapy. Patients described negative aspects of the oxygen devices as being the tubing of the nasal prongs causing discomfort around the ears or that an ill-fitting face mask made it difficult to eat and talk. One patient described the face mask as making him feel miserable because the face mask had become sticky, smelly and that the flow of oxygen through the device was noisy.
Patients who had experienced nasopharyngeal oxygen catheter described the insertion of the nasopharyngeal oxygen catheter as being unpleasant. Patients however reported that the nasopharyngeal oxygen catheter did not become displaced or mal-positioned as often as nasal prongs or face mask devices. One patient described the pros and cons of oxygen therapy associated with the face mask, nasal prongs and the nasopharyngeal oxygen catheter.

“Well, with the [face] mask you can’t see beyond the mask…I don’t think I would be able to read fine print. With the [nasal] prongs…I can see everything, vision is retained, and with the [nasopharyngeal oxygen] catheter it is the best of the three - you can read and it’s off your face, except for the intrusion. (Patient 16)

Theme 2: Ability to maintain activities of daily living

Patients’ ability to maintain activities of daily living impacted on their level of compliance with oxygen therapy. Patients had a desire to talk, drink and change body positions without interruption to oxygen therapy or having the device make such activities difficult. Of the devices trialled, patients reported that nasal prongs and the nasopharyngeal oxygen catheter did not hinder their ability to eat, drink and talk compared with the face mask.
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“The mask was good for delivery of the oxygen, but I found it inconvenient because you can’t eat and [it was] difficult to communicate. People don’t really understand what you’re saying, so you have to remove it to converse.” (Patient 18)

For one patient, the physical structure of his face resulted in poor face mask fit that in turn contributed negatively to his ability to talk effectively.

“My jaw was, even though the straps were quite tight talking to you, the bottom jaw kept knocking the mask down.” (Patient 19)

Theme 3: Therapeutic effect

Patients considered the nasal prongs, face mask and the nasopharyngeal oxygen catheter to be safe and effective oxygen delivery devices. Overall, analysis of patient interview data indicated that they preferred using nasal prongs and the nasopharyngeal oxygen catheter to using the face mask. Patients felt nasal prongs to be the least cumbersome of the three devices. However, the feeling of receiving oxygen associated with the rate of flow of oxygen through the mask gave a sense of comfort to one patient.

“Well, the mask made you realise you were getting air - you were conscious of the flow of air, you felt your face was getting air. Whereas with the catheter [nasopharyngeal] you are unaware you have air coming into your system.” (Patient 16)
Nurses’ perspectives of oxygen therapy

A total of 25 intensive care nurses participated in the interview process. Of these 3 were male and 22 were female. Three nurses were employed as Clinical Nurse Specialists in intensive care and three nurses held Associate Nurse Unit Manager positions. Nine nurses (36%) were employed on a full-time basis, twelve nurses (48%) were employed on a part-time basis and four nurses (16%) were employed on a casual basis. Eleven nurses (44%) reported having nine or greater years of critical care nursing experience.

Analysis of nurse interview data revealed six themes impacted on nurses’ perceptions of oxygen therapy:

- Therapeutic effect
- Issues associated with oxygen therapy compliance
- Strategies to optimise oxygen therapy compliance
- Familiarity with oxygen delivery devices
- Triggers for changing oxygen delivery devices

A description of each theme on the nurses’ perception on oxygen therapy will now be presented.

Theme 1: Therapeutic effect

Nurses play a key role in recognising the clinical signs of respiratory dysfunction. Accurate assessment and monitoring of respiratory dysfunction is an essential step in the process of minimising respiratory related adverse events. Nurses
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reported monitoring SpO₂ and PaO₂ as essential determinants of oxygen therapy effectiveness. In particular, nurses specified that maintaining oxygen saturation at greater than 95% was the typical SpO₂ target for patients receiving oxygen therapy.

“Normally we try and keep them above 95%, especially because most of our patients are cardiac patients, and, yeah, 99% is ideal but, yeah, 95%.” (Nurse 9)

Other indicators of respiratory function and oxygen therapy effectiveness that the nurses reported using included respiratory rate, heart rate and blood pressure.

“Well, clinically looking at the patient and taking into account the parameters, but [also] their oxygen saturation, their respiratory rate and the workload of respiration with breathing - are they getting adequate flow? And then the other parameters, of course, being the heart rate, blood pressure.” (Nurse 10)

One nurse mentioned the importance of being aware of a patient’s past medical history as a means to identify conditions that may impact on respiratory function.

“Obviously you’ll be looking at the patient as a whole - you’ll be looking at if they’ve got an arterial line and their oxygenation and their gases. It’s not just their oxygen saturation - you’ll be looking at their past history, so looking at their chest X-ray, underlying conditions, smoker or anything like that.” (Nurse 20)
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Theme 2: Issues associated with compliance with oxygen therapy

All nurses described various factors they perceived as impacting on a patient compliance with oxygen therapy. Nurses regarded a patient’s conscious state as being a key determinant of whether or not a patient would leave an oxygen delivery device in the correct position. An altered conscious state impacts on the ability of the patient to follow commands or retain information. Nurses identified that agitated confused patients were particularly difficult to achieve effective oxygen therapy because of the increased incidence of device displacement or removal. Nurses remarked that in the management of oxygen therapy for a confused agitated patient they were continually re-positioning the oxygen device and frequently encouraging the patient to comply with oxygen therapy.

“It’s repetitive and ongoing education, not once-off. But people who are oriented, probably once or twice would be enough for them to understand.” (Nurse 14)

Nurses identified that an ill-fitting oxygen delivery device causes discomfort, leading to irritation, which can lead to device removal by the patient. Nurses commented that if the patient experienced device discomfort then the patient was more likely to move the device partially or entirely.

“I think compliance is directly related to patient comfort, so I think if they’re not comfortable they probably won’t be compliant.” (Nurse 20)
Theme 3: Strategies to optimise oxygen therapy compliance

All nurses described, in varying detail, strategies that can be employed to optimise patient compliance with oxygen therapy. Analysis of the nurses’ interview data revealed that educating the patient and providing reassurance were key strategies they used to optimise oxygen therapy compliance and effectiveness.

“Letting them [to] know why they’ve got the oxygen on and that it is needed and [for] how long. If you can sort of give them an idea of how long they’re going to be having it on for, and if they are a confused patient you might have to restrain them or maybe stick it down to their face so they can’t take it off so easily.”

(Nurse 1)

Another strategy employed by nurses to optimise device comfort and increase compliance with oxygen therapy was comfort measures. For the nasal prongs the nurses stated that they would place gauze behind the ears to act as padding to limit the pressure of the tubing. For the face mask, nurses would loosen the strapping to avoid an overly tight fit and to minimise the amount of pressure the strapping would exert on the patient’s cheeks.

“Well, again I think just ensuring that they’re comfortable and making sure that the elastic is not digging into their ears and making sure the nasal prong isn’t going into their cheeks or anything like that - make sure it’s in the correct position and it’s not too tight around their necks or anything like that.”

(Nurse 20)
Manufacturers do not recommend modifying oxygen delivery devices, however nurses reported that at times cutting a face mask or tips of the nasal prongs in an attempt to improve patient comfort.

“Making them as comfortable as you can, like cutting off the tips of the nasal prongs or just putting tape on their nose.” (Nurse 5)

This willingness to modify the oxygen therapy device was echoed by another nurse:

“If they don’t like the face mask, then sometimes I’ll just cut the face mask into half so that it doesn’t really irritate their nose.” (Nurse 21)

**Theme 4: Familiarity with oxygen delivery devices**

The type of oxygen delivery device nurses preferred to use differed. At times nurses indicated a preference for face mask, while other nurses preferred to use nasal prongs where possible. A majority of nurses were aware of the nasopharyngeal oxygen catheter but few nurses described using this device in their routine practice of oxygen therapy.

“I find them all fairly user-friendly. The nasal prongs often fall off so [they are] not so user-friendly, and I’ve used the nasal catheter oxygen [nasopharyngeal oxygen catheter] therapy before and I’ve found that quite good. We just haven’t
Nurses identified that, where a patient had nasal prongs in situ, mouth care could be attended without disrupting therapy. However, nurses also mentioned that because nasal prongs may be easily dislodged or can cause nasal discomfort with higher oxygen flow rates there are disadvantages associated with nasal devices.
“...some people have a thing about the [face] mask and prefer nasal prongs and vice versa sometimes. The nasal pharyngeal [nasopharyngeal oxygen catheter] seems to be less discomfort I guess and you get more compliance with it [nasopharyngeal oxygen catheter].” (Nurse 25)

**Theme 5: Triggers for changing oxygen delivery devices**

Changing from one oxygen delivery device to another is an important strategy that nurses used in maintaining patient compliance with and effectiveness of oxygen therapy. Nurses would use different triggers to escalate oxygen therapy or as a means to reduce / remove oxygen therapy when the patient no longer required supplemental oxygen. Triggers associated with escalation of oxygen therapy were hypoxaemia or an increase in a patient’s respiratory rate or respiratory effort. While triggers to remove or cease oxygen therapy involved preparing the patient for transfer to the ward setting or assessing the patient’s respiratory function without oxygen therapy.

“Mainly I start with face mask and you can give a higher percentage of oxygen, and then it depends on changing it to nasal prongs with results of their arterial blood gases.” (Nurse 6)

**Summary of key findings**

The key findings of Study One identified that nasal prongs, face mask and nasopharyngeal oxygen catheter were able to maintain an oxygen saturation (SpO₂) greater than 95%. Importantly, oxygen therapy by nasal prongs and nasopharyngeal
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oxygen catheter provided greater device comfort for patients and required less oxygen use compared to face mask in adult patients. Analysis of interview data revealed patients and nurses had both similar and different perspectives of oxygen therapy. Patients wanted to receive oxygen via the most comfortable device that also permitted ease of eating, drinking and talking whereas nurses used physiological measures of effectiveness (SpO2 and respiratory rate) as drivers for oxygen therapy decisions. Differences in patients’ and nurses’ perspectives of oxygen therapy may compromise the effectiveness of oxygen therapy. Therefore, shared decision making, goal setting, and partnering with patients to integrate patient preferences into nurses’ oxygen therapy decisions may increase the effectiveness and comfort of oxygen therapy.

Having established the patient experience as a previously under-reported factor in oxygen therapy effectiveness, the contextual issues that have an impact on nurses’ oxygen management practices warrant further examination in order to describe how nurses managed oxygen therapy in response to documented evidence of respiratory dysfunction.

In Chapter Five, the aim, objective and results of Study Two is presented. Study Two is a retrospective descriptive exploratory study that undertaken to was to describe how intensive care nurses administered and managed oxygen therapy for adult cardiac surgical patients during the first 24 hours of intensive care admission.
The purpose of Chapter Five is to present the aim, method, findings and a summary of key findings of Study Two.

Study Two was designed to enable the researcher to retrospectively evaluate and describe how intensive care nurses administered and managed oxygen therapy for adult cardiac surgical patients during the first 24 hours of intensive care admission.

Introduction

Patients admitted to intensive care units following cardiac surgery receive oxygen therapy to minimise the risk of experiencing hypoxaemia and to assist respiratory function (Wynne & Botti, 2004). Failure to maintain adequate oxygen saturation and respiratory function can compromise a patient’s cardiac function, and if prolonged, can result in death (Considine, 2005a). Intensive care nurses are responsible for the monitoring, management and documentation of oxygen therapy for patients in the intensive care unit following cardiac surgery.

Variability in the oxygen management practices of nurses has been identified previously (Considine et al., 2006; Eastwood et al., 2009; Gravil et al., 1997) and relates to the selection of oxygen delivery devices, oxygen flow rate and response to clinical indicators of respiratory dysfunction. Current evidence to support intensive care nurses management of oxygen therapy is not strong, and little is known about how intensive care nurses manage oxygen therapy for patients during the first 24 hours after cardiac
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surgery. A greater understanding of how intensive care nurses manage oxygen therapy will aid patient safety initiatives and identify opportunities for practice improvement aimed at correcting or preventing respiratory dysfunction.

Objectives

The objectives of Study Two were to describe how intensive care nurses administered and managed oxygen therapy for adult cardiac surgical patients during the first 24 hours of intensive care admission. Key outcome measures were:

- Details of oxygen delivery devices (nasal prong, face mask and nasopharyngeal oxygen catheter) including frequency of device use and oxygen flow rate used for each device
- Frequency of documented hypoxaemia
- Frequency of documented respiratory rate abnormalities (tachypnoea and bradypnoea)
- Changes in oxygen flow rate or oxygen delivery device in response to respiratory dysfunction (hypoxaemia, tachypnoea or bradypnoea)

For the purposes of this study hypoxaemia was defined as an SpO2 less than 95%, tachypnoea was defined as a respiratory rate greater than 24 breaths per minute (Cretikos et al., 2008) and bradypnoea was defined as a respiratory rate less than eight breaths per minute (Davey et al., 1994). These physiological parameters were selected, as they are key indicators of respiratory dysfunction (Considine, 2005a; Fieselmann, Hendryx, Helms, & Wakefield, 1993; Goldhill & McNarry, 2004; Goldhill et al., 2005; Hodgetts et al., 2002).
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Method

Design

Retrospective studies focus on reviewing events that have occurred enable researchers to describe the phenomena under investigation and to quantify the relationship between factors associated with study variables (Hess, 2004; Sim & Wright, 2000). A retrospective descriptive design was used to address the objectives of Study Two. Descriptive studies are non-experimental studies that use existing data that have been recorded for non-research related reasons (Hess, 2004). A descriptive design was chosen because it assisted the researcher to examine management approaches and patterns for oxygen therapy in the complex clinical setting of intensive care (Elliott & Thompson, 2007).

Setting

This study was conducted in the Epworth Eastern hospital in Box Hill, Victoria, Australia. At the time of the audit Epworth Eastern had an 8-bed level-2 ICU that admitted approximately 100 adult cardiac surgical patients each year.

Sample

The medical records of adult patients who underwent a cardiac surgical procedure between 1 January 2005 and 31 May 2008 were examined. Patients were included if they met one of the following Australian refined diagnostic-related group (DRG) codes (Australian Government, 2006): cardiac valve procedure [F03Z, F04A, F04B]; coronary bypass [F05A, F05B, F06A, F06B]; or cardiothoracic/vascular
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procedures [F07Z]. Patients less than 18 years of age, who remained mechanically ventilated for greater than 24 hours or who had received non-invasive ventilation during the first 24 hours of intensive care admission were excluded from the audit.

Procedure

Data were collected using a retrospective medical record audit. Retrospective medical record audits are used to examine variables of interest (e.g. oxygen delivery device use, clinical indicators of respiratory dysfunction) and to explore relationships between those variables with outcomes or management processes (e.g. nursing management of oxygen therapy) (Elliott & Thompson, 2007; Gearing, Mian, Barber, & Ickowicz, 2006). This data collection method also enables the researcher to access a large number of records, evaluate practice over a long period of time and to collect data in a standardised fashion without disrupting clinical practice (Gearing et al., 2006; Worster & Haines, 2004).

The medical records of 247 patients were retrieved from the computerised document management system of Epworth Eastern. A single researcher extracted data from each record using a purposefully designed data extraction tool (Appendix F). The following variables were extracted from each medical record:

- Demographic data: age, gender, Acute Physiology And Chronic Health Evaluation (APACHE) II score (Knaus, Draper, Wagner, & Zimmerman, 1985)
- System data: ICU and hospital length of stay and hospital discharge destination
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- Physiological data: patient oxygen saturation (SpO₂) and patient respiratory rate
- ICU management data: oxygen delivery device used, oxygen flow rate and duration of mechanical ventilation

Physiological and ICU management data were extracted from the hourly entries from the nursing observation charts. Data was collected for the first 24 hours of the patient’s admission to the ICU to capture the first device used after extubation and any subsequent changes in oxygen therapy during the immediate post-operative period. All data extraction was completed between June 2008 and October 2008.

Data analysis

Quantitative data from the medical record audit were analysed using the IBM Statistical Package for the Social Sciences (SPSS) Statistics (Version 20) software package. Descriptive statistical tests were used to examine patients’ demographic characteristics, frequency of the oxygen delivery devices used, and frequency of documented hypoxaemia and respiratory dysfunction. When data were not normally distributed, median and inter-quartile range (IQR) are reported. No imputation was performed, as the proportion of missing values was so low: <3% of available data points had missing data.

Ethical consideration

Study Two was approved by the Human Research and Ethics Committees of Deakin University (Burwood, Victoria, Australia)(Appendix A) and Epworth Healthcare
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(Richmond, Victoria Australia)(Appendix B) as ‘Low & Negligible Risk Research’ (NHMRC, 2007). Patients were not informed of the research and no additional consent was required as the research involved secondary use of previously collected data. A waiver for the need for participant consent was granted in accordance with Section 2.3 of the National Statement on Ethical Conduct in Human Research 2007 (NHMRC, 2007). The research qualified for a waiver of consent because the benefit from the research justified any risks of harm associated with not seeking consent; it was impracticable to obtain consent, and there was adequate protection of patient confidentiality.

Patient anonymity was maintained by the use of a numerical coding system in which each medical record was allocated a unique identification number. Identification numbers were kept separate from identifying details (patient log) and were stored in locked filing cabinets separate to the data. The data used in analyses was de-identified. All data pertaining to the study was stored in a password protected computer database or on paper records that were only accessible to the researcher.

On completion of the study, the data were archived at Deakin University in accordance with the Deakin University Human research ethics guidelines for privacy and data storage. All data will be retained for a period of seven years from the date of publication in accordance with the Australian Code for the Responsible Conduct of Research (Australian Government, 2007). Publications and presentations arising from the study presented only de-identified aggregated data. A broader discussion of these ethical considerations was provided in Chapter Three.
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Results

The findings of Study Three are presented in two sections. The first section describes the patient characteristics and details of the oxygen delivery devices used. The second section describes the frequency of respiratory dysfunction (hypoxaemia, bradypnoea and tachypnoea) and the changes in oxygen flow rate or delivery device in response to hypoxaemia and respiratory dysfunction.

Patient characteristics

Of 247 eligible patients, a total of 210 patients met the inclusion criteria and were included in this audit. The medical records of 37 patients were excluded because 12 patients required mechanical ventilation for greater than 24 hours, 23 patients received non-invasive ventilation during the first 24 hours of intensive care admission, and the medical records of two patients were missing.

There were 164 males (78%) and the median age was 73 years (IQR 63-78 years). A total of 142 patients (68%) had a coronary bypass procedure, while 63 patients (30%) had a cardiac valve procedure, and the remaining five patients (2%) had a cardiothoracic/vascular procedure. The median APACHE II score was 17 (IQR 14-20) indicating an overall low severity of illness in this cohort of patients (Knaus et al., 1985). A full description of the demographic, surgical type and outcomes for the 210 cardiac surgical patients is shown in Table 5.1.
Table 5.1 Demographic, surgical type and outcomes for the cardiac surgical patients included in this medical record audit ($N = 210$)

<table>
<thead>
<tr>
<th>Patient characteristics</th>
<th>n (%)</th>
<th>Median (IQR)</th>
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<tbody>
<tr>
<td>Age (yr)</td>
<td>73 (63-78)</td>
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<tr>
<td>Male</td>
<td>64 (78.1)</td>
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<tr>
<td>Surgical procedure</td>
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<tr>
<td>Cardiac valve</td>
<td>63 (30.0)</td>
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<tr>
<td>Coronary bypass</td>
<td>142 (67.6)</td>
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<tr>
<td>Cardiothoracic/vascular</td>
<td>5 (2.4)</td>
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<tr>
<td>Severity of illness scores</td>
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<tr>
<td>APACHE II&lt;sup&gt;a&lt;/sup&gt;</td>
<td>17 (14-20)</td>
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<tr>
<td>Length of stay</td>
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<tr>
<td>Intensive care unit (days)</td>
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<tr>
<td>Hospital (days)</td>
<td>10 (8-13)</td>
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<td>Discharge destination</td>
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<tr>
<td>Home</td>
<td>163 (77.6)</td>
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<tr>
<td>Other healthcare institution</td>
<td>45 (21.4)</td>
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<tr>
<td>Deceased</td>
<td>2 (1)</td>
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<sup>Note.</sup> ICU = intensive care unit. <sup>a</sup>APACHE: Acute Physiological and Chronic Health Evaluation.
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Oxygen delivery devices

All 210 patients were mechanically ventilated when admitted to the intensive care unit following their cardiac surgical procedure. The median time from intensive care unit admission to extubation was eight hours (IQR 5-12 hours). All patients received oxygen via one or more of the oxygen delivery devices (nasal prongs, face mask and nasopharyngeal oxygen catheter) examined in this thesis. Following extubation until the end of the first 24 hours of intensive care unit admission, 172 patients (82%) received oxygen via nasal prongs, 197 patients (94%) received oxygen via face mask, and 56 patients (27%) received oxygen via the nasopharyngeal oxygen catheter. These results include patients who received more than one oxygen delivery device.

During the audit period, 22 patients (10%) received supplemental oxygen by one oxygen delivery device. Of these, four patients received oxygen via nasal prongs, 14 patients received oxygen via face mask and four patients received oxygen via nasopharyngeal oxygen catheter. Two oxygen delivery devices were used for 165 patients (79%). Of these, 146 patients received oxygen via nasal prongs and face mask, 14 patients received oxygen via face mask and nasopharyngeal oxygen catheter and five patients received oxygen via nasal prongs and nasopharyngeal oxygen catheter. All three oxygen delivery devices (nasal prongs, face mask or the nasopharyngeal oxygen catheters) were used in 23 patients (11%).

The median oxygen flow rates used during the audit period were three litres per minute for nasal prongs (IQR 3-4 litres per minute), six litres per minute for face mask
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(\textit{IQR} 6-7.25 litres per minute), and three litres per minute for the nasopharyngeal oxygen catheter (\textit{IQR} 3-4 litres per minute).

\textbf{Respiratory dysfunction}

During the audit one or more episodes of respiratory dysfunction were documented for 55(26\%) patients. This result includes six patients who experienced episodes of both hypoxaemia and tachypnoea. There are two sections to follow. The first section describes the patients who experienced one or more episodes of hypoxaemia. The second section describes the patients who experienced one or more episodes of tachypnoea or bradypnoea.

\textit{Hypoxaemia}

Sixty-six episodes of hypoxemia were documented in 42 patients (20\%) while receiving supplemental oxygen, as shown in Table 5.2. The median number of hypoxaemic episodes per patient was 2 (\textit{IQR} 1-3 episodes). The severity of hypoxaemic episodes varied (\textit{Md}n = SpO\textsubscript{2} 94\%, \textit{IQR} = SpO\textsubscript{2} 92-94\%) and the lowest level of hypoxaemia documented was 90\% for seven episodes in six patients; one patient had two episodes of SpO\textsubscript{2} of 90\% and five patients had one episode of SpO\textsubscript{2} of 90\%. Hourly entries from the nursing observation chart were examined to determine the duration of hypoxaemic episodes. Forty-nine episodes of hypoxaemia were documented for one hour, eight episodes for two hours, four episodes for three hours, three episodes for four hours and two episodes for five hours. These results show that hourly observations recorded hypoxaemia for 14 patients (21\%) for two or more consecutive hours.
### Table 5.2 Episodes of hypoxaemia (SpO₂ < 95%) while receiving oxygen therapy per patient

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<thead>
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<th>Patient number</th>
<th>Time</th>
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Respiratory rate abnormalities

Twenty-five episodes of tachypnoea were documented in 19 patients (9%) while receiving supplemental oxygen, as shown in Table 5.3. The median number of tachypnoeic episodes per patient was 1 ($IQR$ 1-2 episodes). The severity of tachypnoeic episodes varied ($Mdn$ = respiratory rate 28 breaths per minute, $IQR$ = respiratory rate 26-28 breaths per minute) and the highest respiratory rate documented was 32 breaths per minute documented once in two different patients. Hourly entries from the nursing observation chart were examined to determine the duration of tachypnoeic episodes. Twenty episodes of tachypnoea were documented for one hour, three episodes for two hours, one episode for three hours and one episode for four hours. These results show that hourly observations recorded tachypnoea for five patients (20%) for two or more consecutive hours. Two episodes of bradypnoea occurred in two patients, both with a respiratory rate of seven breaths per minute for a duration of one hour.
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Table 5.3 Episodes of tachypnoea (respiratory rate > 24 / minute) while receiving oxygen therapy per patient

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Note. RR = respiratory rate.
Changes in oxygen flow rate or oxygen delivery device in response to respiratory dysfunction

Hypoxaemia

Hourly entries from the nursing observation charts were examined to determine if, in the following hour, the oxygen flow rate or the oxygen delivery device had been altered in response to episodes of hypoxaemia. For 51 of the 66 episodes (77%) of hypoxaemia in 34 patients there was no change to the oxygen flow rate or oxygen delivery device. For 11 episodes (17%) of hypoxaemia in eight patients, the oxygen delivery device changed from nasal prongs to face mask hence there was an increase in oxygen flow rate as a result of the change in oxygen delivery device. In four episodes (6%) of hypoxaemia in three patients, the oxygen delivery device was changed from face mask to nasal prongs decreasing the oxygen flow rate as a consequence of the change in oxygen delivery device. These results include three patients where there was both no change and a change in the oxygen delivery device and flow rate in response to more than one episode of hypoxaemia.

Respiratory rate abnormalities

Hourly entries from the nursing observation charts were examined to determine if, in the following hour, the oxygen flow rate or the oxygen delivery device had been altered in response to episodes of respiratory rate abnormalities. There were 23 episodes (92%) of tachypnoea in 18 patients where the oxygen flow rate and the oxygen delivery device were not changed. For the remaining two episodes (8%) of tachypnoea in two patients, the oxygen delivery device changed from nasal prongs to face mask increasing the oxygen flow rate as a consequence of the change in oxygen delivery device. These
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results include one patient who had both no change and a change in the oxygen delivery device and flow rate in response to more than one episode of tachypnoea. There were two episodes of bradypnoea in two patients, where neither patient had the oxygen flow rate or oxygen delivery device changed.

Summary of key findings

The key findings of Study Two were that nasal prongs, face masks and nasopharyngeal oxygen catheters were used to administer oxygen to all cardiac surgical patients during the first 24 hours of intensive care admission. Respiratory dysfunction (hypoxaemia and / or respiratory rate abnormalities) affected a quarter of the patients in this study. Of major concern is that all episodes of hypoxaemia and respiratory rate abnormalities occurred when the patient was receiving supplemental oxygen. In addition, few changes to oxygen delivery devices and / or oxygen flow rates were documented following episodes of respiratory dysfunction. These findings suggest that despite being in the intensive care unit for close monitoring by nurses, there were many episodes of respiratory dysfunction that remained untreated according to the nursing observation charts. These findings also raise the question of whether or not documentation on the nursing observation charts accurately reflects clinical practice, as it is possible that hypoxaemic, tachypnoeic and bradypnoeic episodes were treated but not documented.

In the following chapter, the third and final of the three linked studies is described. Study Three was a clinical practice observation study that sought to prospectively observe how intensive care nurses’ managed oxygen therapy and compare
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observed practice with nurses’ documented measures of patients’ oxygen saturation and respiratory rate. Study Three was an important study for the researcher to undertake as it provided the ability to assess and critically examine intensive care nurses’ management and documentation of oxygen therapy in actual clinical practice thus overcoming the limitations of medical record audit.
The purpose of Chapter Six is to present the aim, method, findings and a summary of key findings for Study Three.

Study Three was the final of the three sequentially linked studies reported in this thesis exploring oxygen therapy management for patients at risk of respiratory dysfunction. The findings of Study One and Study Two have provided valuable information and insights into the management of oxygen therapy in intensive care including the clinical efficacy of three devices (nasal prongs, face mask and nasopharyngeal oxygen catheter) and insights into the patient and nurse experience of oxygen therapy. However, the findings of Study One and Study Two were unable to describe how nurses managed oxygen therapy in daily practice and whether or not the nurses treated hypoxaemia and tachypnoea despite not documenting the intervention. In response, Study Three was designed to enable the researcher to prospectively observe how intensive care nurses’ manage and document oxygen therapy in the actual clinical setting.

**Introduction**

Australian intensive care units are staffed on a 1:1 or 1:2 nurse-patient ratio to ensure a high level of patient monitoring with rapid access to specialist medical staff and care (ACCCN, 2003; CICM, 2012). Intensive care patients receive oxygen therapy for the treatment or prevention of hypoxaemia due to acute illness, chronic pathology, or peri-operative care (Eastwood et al., 2004, Rodriquez-Roisin & Roca, 2005). The
findings of Study Two demonstrated that all patients in Study Two received oxygen by nasal prongs, face mask and nasopharyngeal oxygen catheters in the first 24 hours of intensive care following cardiac surgery. However, the findings of Study Two also showed that despite being in the intensive care unit and receiving oxygen therapy, one in five patients (20%) had documented hypoxaemia and one in ten patients (9%) had documented tachypnoea. Prolonged exposure to hypoxaemia and tachypnoea place patients at risk of worsening respiratory dysfunction and potential death (Considine et al., 2006; Eastwood & Dennis, 2006). However, the congruence between documented practice and real clinical practice is yet to be determined and warrants further investigation.

Studies conducted in non-critical care settings have shown that patients are at risk of respiratory dysfunction due to suboptimal monitoring, management and documentation of oxygen therapy (Albin et al., 1992; Attia et al., 2004; Boyle & Wong, 2006; Brokalaki et al., 2004b; Howell, 2001; Kor & Lim, 2000; Nolan et al., 1993; Small et al., 1992; Stausholm et al., 1995). Gaps in the literature on how intensive care nurses manage oxygen therapy exist because previous studies have tended to investigate factors related to device effectiveness or influences on device comfort in isolation, without examining how intensive care nurses manage oxygen therapy. Given the clinical consequences of hypoxaemia, inconsistencies in the management of oxygen therapy by intensive care nurses may compromise patient safety. Thus, in light of the findings from Study One and Study Two, it is important to understand how intensive care nurses manage and document oxygen therapy in actual clinical practice in order to
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identify opportunities for practice improvement, specifically related to nurses’
management of oxygen therapy during episodes of respiratory dysfunction.

Objectives

The objectives of Study Three were to: (a) observe how intensive care nurses
manage and document oxygen therapy and, (b) compare observed and documented
oxygen therapy. Outcome measures were:

- Details of oxygen delivery devices (nasal prongs, face mask and nasopharyngeal
  oxygen catheter) including frequency of device use and oxygen flow rate used
  for each device
- Frequency of documented and observed hypoxaemia
- Frequency of documented and observed tachypnoea
- Frequency of observed episodes of respiratory dysfunction (hypoxaemia and
  tachypnoea) that were, and were not, documented
- Nursing activities that promote or hinder effective oxygen therapy

For the purposes of this study hypoxaemia was defined as a SpO₂ less than 95%
and tachypnoea was defined as a respiratory rate greater than twenty-four breaths per
minute (Cretikos et al., 2008; Davey et al., 1994). These physiological parameters were
selected because they are key clinical indicators of respiratory dysfunction (Considine,
2005a; Fieselmann et al., 1993; Goldhill et al, 2004; Goldhill et al., 2005; Hodgetts et
al., 2002).
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Method

Design

A prospective observational design was used to address the objectives of Study Three. Observational designs are non-experimental studies that aim to better understand phenomena that are insufficiently described in the literature or poorly understood (Elliott & Thompson, 2007). The prospective direction of the design was chosen because it enabled the researcher to examine the management approaches and factors impacting oxygen therapy management in the complex setting of intensive care as they occurred (Elliott & Thompson, 2007). The collection and analysis of observational data was an important methodological choice for this study as it allowed for a differentiation between what participants say they do and what participants actually do in clinical practice (Beanland, Schneider, LoBiondo-Wood, & Haber, 1999; Wolf, 2007).

Setting

This study was conducted in the Epworth Hospital in Richmond, Victoria, Australia. At the time of the study, Epworth Hospital had a 15-bed level-3 ICU that admitted approximately 1,100 adult patients per year.

Sample

A convenience sample of 16 intensive care patients and 16 intensive care nurses were observed in this study. Intensive care patients were eligible to participate in the study if they were aged 18 years or older, were receiving oxygen therapy by nasal prongs, face mask or nasopharyngeal oxygen delivery devices, and had continuous SpO₂
and respiratory rate monitoring. Intensive care nurses included in the study were those caring for the intensive care patients that met the patient eligibility criteria.

Procedure

Study Three commenced after Human Research and Ethics Committee approval from Deakin University (Burwood, Victoria, Australia) (Appendix A) and Epworth Healthcare (Richmond, Victoria, Australia) (Appendix B). To establish a schedule of days to visit the ICU to conduct the observation periods and extract data from the nursing observation charts, the researcher liaised with the Epworth Hospital ICU Nurse Unit Manager. During each observation period data was extracted from the nursing observation charts on three occasions and observation measurements were made on six occasions. A description of the time point measurements for the collection of documented data and observational data is shown in Table 6.1.

Table 6.1 Study time points for review of nursing observation charts and clinical observation measurements

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<td>Clinical observation</td>
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Study data were collected using a purposefully developed structured data collection tool that incorporated structured observation, field notes and nursing
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observation chart review (*Appendix G*). Structured observation is a quantitative approach that enables the researcher to quantify behaviour and events through the use of purposefully developed data collection tools (Whitehead & Annells, 2007; Mulhall, 2003; Robson, 2002). Structured observation was deemed an important methodological choice for this study as it allowed for the researcher to prospectively observe and capture the activities of intensive care nurses and patients related to oxygen therapy as they occurred (Mulhall, 2003; Polit & Hungler, 1997; Wolf, 2007). Field notes augmented the structured observation data. The structured data collection tool recorded events and effects of oxygen therapy monitoring and management while the field notes captured the contextual influences on oxygen therapy. Nursing observation charts were reviewed to examine documented variables of interest (SpO₂, respiratory rate, oxygen flow rate).

The structured data collection tool was based on prior research findings of the researchers (Eastwood et al., 2007), key clinical indicators of respiratory dysfunction (hypoxaemia and tachypnoea) as identified in the literature review (Buist et al., 2004; Considine et al., 2009; Cretikos et al., 2008; Quach et al., 2008) and known influences on oxygen therapy effectiveness (Eastwood et al., 2009; Goldhill et al., 1994; Nolan et al., 1992).

Reliability and validity of the data collection tool was assured by subjecting the tool to expert review by two PhD prepared researchers and pilot testing in the real clinical environment. The pilot testing period included six participants (three couples consisting of an intensive care nurse and an intensive care patient). Following analysis
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of the pilot study data no changes were made to the observation procedure or data collection tools. The data collected were objective in nature and included:

- Situational data: nurse to patient ratio, time period of observation; day of the week the observation was performed
- Device data: oxygen delivery device in use, device fit and correct placement, oxygen delivery device displacement, removal or change
- Patient specific data: demographic data, oxygen saturation (SpO₂) and respiratory rate, Riker sedation agitation score (Riker, Picard, & Fraser, 1999) activities of daily living (e.g. eating, transferring from bed to chair, visitors in attendance, medical or allied health professional review)
- Nurse specific data: demographic data, performance of a respiratory assessment, oxygen delivery device check, oxygen flow meter check, any changes to oxygen flow rate, oxygen delivery device placement or manipulation

Eight two-hour observation periods were conducted. The observation periods were: 08:00-10:00 (n = 2), 12:00-14:00 (n = 2), 14:00-16:00 (n = 2), and 16:00-18:00 (n = 2) hours. Observation period times were purposefully selected to coincide with key periods of patient/nurse activities, for example, nursing/medical handover, meal times, visitation times, and afternoon/evening rest periods. The study included 32 participants (sixteen intensive care nurses and sixteen intensive care patients).

During each observation period, documented data and observed data were collected concurrently. Documented data was extracted from the hourly entries made on
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the nursing observation chart and included the patient’s SpO₂ and respiratory rate, the oxygen flow rate and the oxygen delivery device in use.

During each two-hour observation period, data were collected every 20 minutes giving six points of measurement per patient and a total of 96 points of measurement for 16 patients. Observed data collected included oxygen delivery device in use, oxygen delivery device removal or change, SpO₂, respiratory rate, Riker sedation agitation score, and patient activities of daily living (eating, drinking, transferring from bed to chair). During each observation period, field notes were written by the researcher to describe the interplay of nurse and patient activities on oxygen therapy; for example respiratory assessment, repositioning of an oxygen delivery device and changes to the oxygen flow rate.

One researcher performed all observations to prevent observer bias and optimise consistency in the use of the data collection tools. For each observation period, the researcher adopted a ‘pure observer’ role to minimise any disruption to patient care (Mulhall, 2003; Polit & Hungler, 1997). During each observation period the researcher sat at a desk located in close proximity to the study participants and so was able to easily observe the interactions between intensive care patients and intensive care nurses, see the displayed physiological monitoring (for SpO₂ and respiratory rate), and hear bedside conversations between the intensive care patient and intensive care nurse. All observation periods were conducted between May and June 2009.
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Data analysis

Quantitative data from the data collection tool were analysed using the IBM Statistical Package for the Social Sciences (SPSS) Statistics (Version 20) software package. Descriptive statistical tests were used to examine patients’ documented and observed measures of SpO₂ and respiratory rate. When data were not normally distributed, median and inter-quartile range (IQR) are reported. Data were also analysed to identify changes in oxygen delivery device, changes in oxygen flow rate in response to hypoxaemia and tachypnoea and differences between documented and observed SpO₂, respiratory rate and oxygen flow rate.

Content analysis was used to analyse the qualitative data obtained from the field note transcripts. Content analysis enabled the researcher to objectively and systematically extract the keywords and themes recorded in the field notes (Bryman, 2008; Neuendorf, 2002). Each set of field notes were transcribed verbatim and reviewed. Transcripts (raw data) were then coded using keyword/phrase descriptions to describe key activities, for example ‘sitting out of bed’ or ‘deep breathing and coughing exercises’. Next, the keywords/phrases were grouped into behavioural concepts, for example behaviours that either assisted or hindered oxygen therapy effectiveness. Reliability in coding was achieved as the researcher and research supervisors undertook coding until 100% agreement was reached.

Ethical considerations

Study Three was approved by the Human Research and Ethics Committees of Deakin University (Burwood, Victoria, Australia)(Appendix A) and Epworth Healthcare
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(Richmond, Victoria Australia)(Appendix B) as Low & Negligible Risk Research involving limited disclosure (NHMRC, 2007). A waiver for the need for participant consent was granted in accordance with Section 2.3 of the National Statement on Ethical Conduct in Human Research 2007 (NHMRC, 2007). The research qualified for a waiver of consent because it did not involve active concealment or planned description; there was no suitable alternative involving fuller disclosure by which the objectives of the research could be achieved; the benefit from the research would justify any risks of harm and there was adequate protection of participant confidentiality. Limited disclosure for consent was an important methodological choice to facilitate the aims of the research without unduly influencing participant behaviour.

During the conduct of Study Three, patients and nurses were aware that they were being observed due to the presence of the researcher. Patients and nurses were informed of the broad aims of the study and were told that the researcher was seeking to explore how patient care was being delivered in the ICU. No patient or nurse declared that they did not wish to participate in the study.

Anonymity was maintained by providing each patient and nurse with a unique identifier and data for analysis was de-identified. Patient and nurse anonymity was maintained by the use of a numerical coding system in which each patient and nurse was allocated a unique identification number. Identification numbers were kept separate from participant identifying details and were stored in locked filing cabinets separate to the data. Only de-identified data was used in analyses. All data pertaining to the study was stored in a password protected computer database or on paper record that was only
On completion of the study, the data were archived at Deakin University in accordance with the Deakin University Human research ethics guidelines for privacy and data storage. All data will be retained for a period of seven years from the date of publication in accordance with the Australian Code for the Responsible Conduct of Research (Australian Government, 2007). A broader discussion of these ethical considerations was provided in Chapter Three.

The conduct of Study Three, like that of Study One, required that the researcher be present in the intensive care unit and be witness to patient care activities. As described previously (Study One, part A, ethical considerations), agreement was reached between the researcher and the Human Research and Ethics Committees that if the researcher were to witness patient circumstances that were life threatening or potentially life threatening, the researcher would notify the intensive care nurse caring for the patient or the intensive care nurse in charge of the intensive care unit at the time. If a time critical life-threatening event, such as a cardiac arrest, was to be un-witnessed by other staff, the researcher would activate the emergency response alarm. The researcher did not actively participate in patient care.

Results

The findings of Study Three are presented in three sections. The first section describes the patient and nurse characteristics and oxygen delivery device use. The
second section describes the frequency of episodes of hypoxaemia and tachypnoea that were, and were not, documented and changes in oxygen flow rate or delivery device in response to hypoxaemia or tachypnoea. The final section describes nurses’ activities that assisted or hindered oxygen therapy effectiveness.

**Patient and nurse characteristics and oxygen delivery device use**

*Patient and nurse characteristics*

Over the 32 hours of recorded observations, there were 96 points of observed data and 48 points of documented data involving 16 patients and 16 intensive care nurses. There were eight female and eight male patients observed during this study. Twelve patients (75%) were admitted to the intensive care unit with a cardio-respiratory diagnosis, two patients (6.25%) were orthopedic admissions, one patient was a neurological admission and the final patient was a general-surgical admission. The nurse-to-patient ratio during each observation period was 1:1. The demographic characteristics of the 16 intensive care patients are shown in Table 6.2.
Table 6.2 Demographic characteristics of the intensive care patients (\(N = 16\))

<table>
<thead>
<tr>
<th>Patient characteristic</th>
<th>N</th>
<th>%</th>
<th>Median (IQR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td></td>
<td></td>
<td>70.5 (62-73.75)</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>8</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>8</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Reason for ICU admission</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardiac-Respiratory</td>
<td>12</td>
<td>75.0</td>
<td></td>
</tr>
<tr>
<td>General-Surgical</td>
<td>1</td>
<td>6.25</td>
<td></td>
</tr>
<tr>
<td>Neurological</td>
<td>1</td>
<td>6.25</td>
<td></td>
</tr>
<tr>
<td>Orthopaedic</td>
<td>2</td>
<td>12.5</td>
<td></td>
</tr>
<tr>
<td>Sedation score(^a)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calm and Cooperative</td>
<td>14</td>
<td>87.5</td>
<td></td>
</tr>
<tr>
<td>Sedated</td>
<td>2</td>
<td>12.5</td>
<td></td>
</tr>
<tr>
<td>Day in ICU at observation</td>
<td></td>
<td></td>
<td>2 (2-2.75)</td>
</tr>
</tbody>
</table>

Note. ICU = intensive care unit. \(^a\)Riker Sedation-Agitation Scale (Riker et al., 1999).

All 16 intensive care nurses in this study held post-graduate qualifications in intensive care nursing. Fourteen nurses were female and two nurses were male. Nine of the sixteen nurses had five or more years of intensive care nursing experience and one nurse held the position of clinical nurse specialist in intensive care nursing. The demographic characteristics of the 16 intensive care nurses are shown in Table 6.3.
OXYGEN THERAPY MANAGEMENT

Table 6.3 Demographic characteristics of the intensive care nurses (\(N = 16\))

<table>
<thead>
<tr>
<th>Nurse characteristic</th>
<th>(n)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>2</td>
<td>12.5</td>
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<tr>
<td>Female</td>
<td>14</td>
<td>87.5</td>
</tr>
<tr>
<td>Current clinical position</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intensive care nurse(^a)</td>
<td>15</td>
<td>93.75</td>
</tr>
<tr>
<td>CNS (ICU)(^b)</td>
<td>1</td>
<td>6.25</td>
</tr>
<tr>
<td>Intensive care experience (in years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 – 4</td>
<td>7</td>
<td>43.75</td>
</tr>
<tr>
<td>5 – 8</td>
<td>6</td>
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<tr>
<td>9 – 12</td>
<td>1</td>
<td>6.25</td>
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<tr>
<td>13 – 16</td>
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<tr>
<td>17+</td>
<td>1</td>
<td>6.25</td>
</tr>
</tbody>
</table>

Note. \(^a\)Intensive care nurse, a registered nurse employed in an intensive care unit who is accountable and responsible for the care of an intensive care patient. \(^b\)CNS (ICU), an intensive care nurse who is employed as a clinical nurse specialist in the intensive care unit setting.

Oxygen delivery device use

All 16 patients received oxygen during the observation periods: 13 patients received oxygen solely via nasal prongs and two patients received oxygen solely via face mask. The remaining patient first received oxygen via a face mask and then nasal prongs. No patient received supplemental oxygen by a nasopharyngeal oxygen catheter.
The median oxygen flow rates used during the audit period were 4 litres per minute for nasal prongs (IQR 2.75 – 4 litres per minute) and 10 litres per minute for face mask (IQR 10 – 10 litres per minute). One patient had one documented oxygen flow rate of 10 litres per minute via the nasal prongs, which is higher than the recommended oxygen flow rate for this device.

Analysis of the 96 points of observed data revealed 11 episodes in eight patients when the patient did not wear the oxygen delivery device and was therefore not receiving supplemental oxygen. Entries from the field notes were examined to determine the reasons why the oxygen delivery devices were not being worn. Of the 11 episodes, four episodes occurred with one patient (Patient 9) during a trial of room air prior to ICU discharge and three single episodes occurred with three different patients (Patients 1, 6 and 10) to facilitate eating. Single episodes for two patients (Patients 5 and 7) coincided with the transfer of the patient from the bed to a chair. Another single episode for Patient 4 occurred during a respiratory function assessment performed by a physiotherapist. Finally, there was one episode where Patient 12 removed her face mask because the face mask was too large and uncomfortable.

**Documented and observed hypoxaemia and tachypnoea**

Documented and observed SpO₂ and respiratory rate were examined to identify episodes of hypoxaemia and tachypnoea. Separate comparisons of the documented and observed hypoxaemia and tachypnoea will now be presented.
OXYGEN THERAPY MANAGEMENT

Documented and observed hypoxaemia

Documented SpO₂ measurements from the hourly entries of the nursing observation chart were examined to identify episodes of hypoxaemia (defined as an SpO₂ less than 95%). All SpO₂ measurements were documented on the nursing observation charts hourly: all entries were made on the hour and there was no documentation of SpO₂ at any other time during the observation periods. There were a total of 46 documented SpO₂ measurements recorded; pulse oximetry was not in use for the two missing SpO₂ measurements. The median documented SpO₂ was 98% (IQR 97 – 100%). There were four documented hypoxaemic episodes in three patients, as shown in Table 6.4: Patient 10 had two hypoxaemic episodes and Patients 5 and 9 had one hypoxaemic episode each. During all of these hypoxaemic episodes the documented SpO₂ was 94% for all patients.
## OXYGEN THERAPY MANAGEMENT

Table 6.4 Documented and observed oxygen saturation per patient

<table>
<thead>
<tr>
<th>Patient</th>
<th>SpO₂</th>
<th>20 mins</th>
<th>40 mins</th>
<th>60 mins</th>
<th>80 mins</th>
<th>100 mins</th>
<th>120 mins</th>
</tr>
</thead>
<tbody>
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<td>100</td>
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<td>97</td>
</tr>
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<td>99</td>
<td>99</td>
<td>93*</td>
<td>92*</td>
<td>97</td>
</tr>
<tr>
<td></td>
<td>Observed</td>
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<td>100</td>
<td>100</td>
<td>94*</td>
<td>92*</td>
<td>98</td>
</tr>
<tr>
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<td>98</td>
<td>94*</td>
<td>92*</td>
<td>98</td>
</tr>
<tr>
<td></td>
<td>Observed</td>
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<td>100</td>
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<td>94*</td>
<td>96</td>
<td>92*</td>
</tr>
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</tr>
<tr>
<td></td>
<td>Observed</td>
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</tr>
<tr>
<td></td>
<td>Observed</td>
<td>100</td>
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</tr>
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<tr>
<td></td>
<td>Observed</td>
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<tr>
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</tr>
<tr>
<td></td>
<td>Observed</td>
<td>98</td>
<td>96</td>
<td>100</td>
<td>100</td>
<td>99</td>
<td>100</td>
</tr>
</tbody>
</table>

Note. *hypoxaemia = SpO₂ less than or equal to 94%.
The nursing observation charts were also examined to determine if the oxygen flow rate or oxygen delivery device was changed in response to a documented hypoxaemic episode. For the three patients (Patients 5, 9 and 10) who had documented hypoxaemic episodes, Patient 10 was receiving oxygen by nasal prongs and had the oxygen flow rate increased from 2 litres per minute to 3 litres per minute in response to a SpO$_2$ of 94%. Hypoxaemia was documented in Patient 10 at 01:00 hours, the change in oxygen flow rate was observed to have occurred at 01:40 hours however the change in oxygen flow rate was not documented until 02:00 hours. There was no change to the oxygen flow rate for Patients 5 and 9 and there were no changes to oxygen delivery devices for Patients 5, 9 or 10 following documentation of hypoxaemia.

Observed SpO$_2$ measurements were examined to identify episodes of hypoxaemia and to enable comparison of documented and observed hypoxemia. There were 90 observed SpO$_2$ measurements; pulse oximetry was not in use for the missing six SpO$_2$ measurements. The median observed SpO$_2$ was 97% (IQR 95 – 98%). There were 20 observed hypoxaemic episodes in 10 patients (Table 6.4). Of these, Patient 8 had five hypoxaemic episodes (SpO$_2$ values of 90%, 91%, 91%, 93% and 94%). Patient 10 had four hypoxaemic episodes (SpO$_2$ values of 93%, 94%, 90% and 86%), Patients 2 and 3 each had two hypoxaemic episodes (SpO$_2$ values of 93% and 92% for Patient 2 and 94% and 92% for Patient 3) and five patients (Patients 5, 6, 7, 11, and 12) each had one hypoxaemic episode. The lowest observed SpO$_2$ was 86% for one episode in Patient 10. All patients experienced hypoxaemic episodes while they were receiving supplemental oxygen.
OXYGEN THERAPY MANAGEMENT

The nursing observation charts were also examined to determine if the oxygen flow rate or oxygen delivery device had been changed in response to an observed hypoxaemic episode. Of the ten patients in whom a hypoxaemic episode was observed, only Patient 10 had their oxygen flow rate increased from 2 litres per minute via nasal prongs to three litres per minute via nasal prongs: this was the same patient referred to in the above discussion about documented hypoxaemia. There were no changes to the oxygen flow rates for the other nine patients who had observed episodes of hypoxaemia. Further, there were no changes to oxygen delivery device for any of the ten patients in whom an episode of hypoxaemia was observed.

There are 45 sets of documented and observed SpO₂ data and yet, 32 sets of data (71%) had different measurements. On 24 occasions the documented SpO₂ value was higher than the observed SpO₂ (documented SpO₂ range of 1-8% higher), on 13 occasions the documented and observed SpO₂ were the same, and on eight occasions the documented SpO₂ value was lower than observed SpO₂ (documented SpO₂ was 1% lower for each instance), as shown in Table 6.4. The largest discrepancy between documented and observed SpO₂ was for Patient 10 where the documented SpO₂ was 94% and the observed SpO₂ was 86%. There were six episodes where observed hypoxaemia was documented as a normal SpO₂ in five patients. Patients 3, 7, 10 and 12 each had had one episode of observed hypoxaemia that was documented as a normal SpO₂ (Patient 3 had a documented SpO₂ of 99% and an observed SpO₂ of 92%, Patient 7 had a documented SpO₂ of 97% and an observed SpO₂ of 93%, Patient 11 had a documented SpO₂ of 98% and an observed SpO₂ of 94% and Patient 12 had a documented SpO₂ of 95% and an observed SpO₂ of 92%. Patient 8 had two episodes of
observed hypoxaemia where the documented SpO2 was normal: (a) documented SpO2 was 98% and the observed SpO2 was 91% and (b) documented SpO2 was 99% and the observed SpO2 was 94% (Table 6.4).

Documented and observed SpO2 measurements were examined to identify and compare episodes of hypoxaemia that were, and were not, documented. As discussed above, all SpO2 measurements were documented on the nursing observation charts hourly with no documentation of SpO2 at any other time during the observation periods. There were four hypoxaemic episodes documented in three patients however there were 20 observed episodes of hypoxaemia in ten patients. Four of these episodes of hypoxaemia were both documented and observed in three patients (Patients 5, 9, and 10). However, nine hypoxaemic episodes observed in five patients (Patient 2, 3, 6, 8, and 10) were not documented. Of the hypoxaemic episodes that were observed but not documented, three occurred in Patient 8 (observed SpO2 of 90%, 91% and 93%), and two occurred in Patient 2 and Patient 10 (observed SpO2 of 92% and 93% for Patient 2 and 90% and 93% for Patient 10). Patients 3 and 6 both had one hypoxaemic episode (observed SpO2 of 94% for Patient 3 and 93% for Patient 6) that was not documented. The lowest observed SpO2 that was not documented was 90%, occurring once in Patients 8 and 10.

**Documented and observed tachypnoea**

*Documented respiratory rate* measurements from the hourly entries of the nursing observation chart were examined to identify episodes of tachypnoea (defined as a respiratory rate greater than 24 breaths per minute). All respiratory rate measurements
were documented on the nursing observation charts hourly: all entries were made on the hour and there was no documentation of respiratory rate at any other time during the observation periods. There were 48 documented respiratory rate measurements recorded. The median documented respiratory rate was 19.5 breaths per minute (IQR 18 – 22 breaths per minute). There were six documented tachypnoeic episodes in four patients, as shown in Table 6.5. Patient 10 had three documented tachypnoeic episodes (respiratory rate measurement of 26 breaths per minute for each episode) and Patients 1, 6 and 15 each had one documented tachypnoeic episode in which the respiratory rate was 26 breaths per minute.
### OXYGEN THERAPY MANAGEMENT

Table 6.5 Documented and observed respiratory rates per patient

<table>
<thead>
<tr>
<th>Patient</th>
<th>Respiratory rate</th>
<th>20 mins</th>
<th>40 mins</th>
<th>60 mins</th>
<th>80 mins</th>
<th>100 mins</th>
<th>120 mins</th>
</tr>
</thead>
<tbody>
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<td>26*</td>
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<td>24</td>
<td>22</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Observed</td>
<td>26*</td>
<td>24</td>
<td>24</td>
<td>20</td>
<td>22</td>
<td>18</td>
</tr>
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<td>P2</td>
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<tr>
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</tr>
<tr>
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<td>Documented</td>
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<td>20</td>
<td>20</td>
<td>26*</td>
<td>26*</td>
</tr>
<tr>
<td></td>
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<td>22</td>
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</tr>
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* tachypnoea (respiratory rate greater than 24 breaths per minute).
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The nursing observation charts were also examined to determine if the oxygen flow rate or oxygen delivery device was changed in response to a documented tachypnoeic episode. Of the four patients (Patients 1, 6, 10 and 15) who had a documented tachypnoeic episode, Patient 10 had their oxygen flow rate increased from 2 litres per minute via nasal prongs to 3 litres per minute via nasal prongs. There were no changes to the oxygen flow rates for Patients 1, 6 and 15 and there were no changes to oxygen delivery devices for Patients 1, 6, 10 and 15 following documentation of tachypnoea.

Observed respiratory rate measurements were examined to identify episodes of tachypnoea and to enable comparison of documented and observed tachypnoea. There were 96 observed respiratory rate measurements recorded. The median observed respiratory rate was 21 breaths per minute (IQR 19 – 22 breaths per minute). There were 12 observed tachypnoeic episodes in five patients (Patients 1, 6, 10, 11 and 15) (Table 6.5). Of these, Patient 10 had six tachypnoeic episodes (respiratory rate values of 33, 26, 25, 28, 26 and 28 breaths per minute). Patient 15 had three tachypnoeic episodes (respiratory rate values of 26, 26 and 26 breaths per minute). Patients 1, 6 and 11 each had one tachypnoeic episode with respiratory rate values of 26, 26 and 25 respectively. The highest observed respiratory rate was 33 breaths per minute for one episode in Patient 10. All patients experienced observed tachypnoeic episodes while they were receiving supplemental oxygen.

The nursing observation charts were also examined to determine if the oxygen flow rate or oxygen delivery device had been changed in response to an observed
tachypnoeic episode. For the five patients (Patients 1, 6, 10, 11 and 15) who had an observed tachypnoeic episode, only Patient 10 had their oxygen flow rate increased from 2 litres per minute using nasal prongs to 3 litres per minute. Patient 10 was the same patient referred to in the above discussion about documented tachypnoea. There was no change to the oxygen flow rate for Patients 1, 6, 11 and 15 and there were no changes to oxygen delivery devices for Patients 1, 6, 10, 11 and 15 following documentation of tachypnoea.

There are 48 sets of documented and observed respiratory rate data and yet, 32 sets of data (67%) had different measurements. On eight occasions the documented respiratory rate was higher than the observed respiratory rate (documented respiratory rate ranged from 1-4 breaths per minute higher than observed), on 16 occasions the documented and observed respiratory rate measurements were the same, and on 24 occasions the documented respiratory rate was lower than the observed respiratory rate (documented respiratory rate ranged from 1-7 breaths per minute lower than observed respiratory rate), as shown in Table 6.5. The largest discrepancy between documented and observed respiratory rate was for Patient 4 where the documented respiratory rate was 14 breaths per minute and the observed respiratory rate was 21 breaths per minute. There were three episodes of observed tachypnoea that were documented as normal respiratory rate in two patients (Patient 11 had a documented respiratory rate of 22 breaths per minute and an observed respiratory rate of 25 breaths per minute, Patient 15 had a documented respiratory rate of 24 breaths per minute and observed respiratory rate of 26 breaths per minute) on two occasions, as shown in Table 6.5.
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Documented and observed respiratory rate measurements were examined to identify and compare episodes of tachypnoea that were, and were not, documented. As discussed above, all documented respiratory rate measurements were documented on the nursing observation charts hourly with no documentation of respiratory rate at any other time during the observation periods. There were four episodes of tachypnoea that were both documented and observed in two patients (Patients 1 and 10). However, there were five observed tachypnoeic episodes in three patients (Patients 6, 10 and 15) that were not documented. Patient 10 had three tachypnoeic episodes (observed respiratory rate measurements of 26, 26 and 26 breaths per minute) and Patients 6 and 15 had one tachypnoeic episode each (observed respiratory rate value of 26 breaths per minute) that was not documented. The highest observed but not documented respiratory rate was 28 breaths per minute for one episode for Patient 10. All three patients (Patients 6, 10 and 15) that had an episode of observed but not documented tachypnoea had at least one observed and documented episode of tachypnoea made on their nursing observation chart.

During each observation period the researcher kept field notes to help to describe the interactions between intensive care patients and intensive care nurses. In the section to follow, a description of the observed nurses’ activities that assisted and hindered oxygen therapy effectiveness is provided.
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Nurses’ activities that assisted or hindered oxygen therapy effectiveness

The findings presented in the following sections describe nurses’ observed oxygen therapy practice. Analysis of the textual data obtained from the field notes identified two broad themes related to impact of nurses’ activities on the effectiveness of oxygen therapy:

• Activities that promoted effective oxygen therapy
• Activities that hindered effective oxygen therapy

A description of each theme will now be presented.

Theme 1: Activities that promoted effective oxygen therapy

Over the 16 hours of observation, the researcher observed the intensive care nurses performing therapeutic activities that promoted effective oxygen therapy. The activities included positioning the patient to optimise lung expansion and assisting the patients to complete deep breathing and coughing exercises. Positioning of patient allows for the abdominal contents to fall away from the diaphragm and permits full expansion of the chest wall during inspiration (Stiller, 2000). Nurses 5, 7, 9, 11 and 12 were observed to re-position the patient for the purposes of improved oxygenation and gas exchange. Deep breathing and coughing exercises are taught to patients to improve oxygenation and maintain respiratory function (Stiller, 2000). Twelve intensive care nurses (Nurses 1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 13, and 16) were observed to help their patient perform chest physiotherapy maneuvers e.g. encouraging and assisting the patient to perform deep breathing and coughing exercises. During deep breathing and coughing exercises the nurse instructs the patient to take slow breaths, and then to hold
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the breath for a few seconds at the end of inspiration. Holding the breath in at end of inspiration increases intra-pleural pressure and reopens collapsed alveoli, thereby increasing the number of alveoli that can participate in gas exchange (Stiller, 2000).

Nurse 7 was observed providing help to his patient for the purposes of deep breathing and coughing exercises, the patient was resting in bed during this time.

“The nurse asks the patient to take some deep breaths. The patient complies but appears to be taking shallow breaths initially. The patient is helping and pulls on the bed rails to help sit herself forward.” (Nurse 7)

Additionally, the analysis of the field notes identified that seven intensive care nurses (Nurses 2, 4, 6, 7, 11, 13 and 16) provided verbal reassurance and encouragement to the patient to foster compliance with oxygen therapy. Nurse 2 was overheard to explicitly instruct the patient to take a couple of deep breaths and was observed to provide a rolled-up towel to act as a brace while the patient complied with the request.

“Shortly after movement the patient’s SpO2 drops. The nurse is heard to instruct the patient to deep breathe and cough and to also take a couple of deep breaths. Comment by patient to nurse is that it hurts to breathe deep. Nurse provides patient with rolled-up towel. Patient places towel to chest.” (Nurse 2)
Theme 2: Activities that hindered effective oxygen therapy

In contrast to the activities that promoted effective oxygen therapy, the researcher observed nursing actions that were deemed to hinder effective oxygen therapy. These activities included: a failure to increase the oxygen flow rate despite the patient becoming hypoxaemic; a decrease in the oxygen flow rate despite the patient’s SpO₂ decreasing from 100% to 93% when the patient was transferred from a chair to the bed; and the removal of the face mask in order to provide mouth care resulting in a fall of SpO₂ from 100% to 92%. The provision of mouth care to patient participant lasted two minutes and after replacing the face mask three minutes passed before the observed SpO₂ returned to 100%.

Episodes of suboptimal monitoring and documentation of SpO₂ and respiratory rate were observed in this study. For example, one nurse had documented a SpO₂ reading for the 01:00 hour mark of the observation period, despite the patient not having a pulse oximetry device in place for the preceding 20 minutes. The following is an extract of the event involving Nurse 4.

“To assist with eating the pulse oximetry device is removed by the patient. In response to the monitors alarm sounding to indicate a failed SpO₂ reading, the nurse silences the alarm. The pulse oximetry probe was off for a total of 1 hour and 25 minutes.” (Nurse 4)

During the documentation period involving Patient 10, despite tachypnoea and hypoxaemia being documented on the nursing observation chart, Nurse 10 did not
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change the patient’s oxygen delivery device despite the availability of oxygen delivery devices in the patient’s bed space. The additional oxygen delivery devices that were available for use for this patient were capable of providing higher oxygen flow rates than the nasal prongs the patient was wearing throughout the observation period.

“Patient currently tachypnoeic with a respiratory rate >30/minute for periods of 1-2 minutes. Although currently on nasal prongs, there is a high-flow oxygen therapy device set-up in the patient’s bed space. There is also a previously used face mask oxygen delivery device in the bed bay. This would suggest that previously the respiratory requirements or oxygen demands of this patient have required high-flow therapy.” (Nurse 10)

Summary of key findings

The key findings of Study Three were that observed respiratory dysfunction (hypoxaemia and / or tachypnoea) affected the majority of patients in this study, yet few patients had their respiratory dysfunction documented on the nursing observation chart. Documented SpO₂ (median SpO₂ 98%) tended to be higher than observed SpO₂ (median SpO₂ 97%). Documented respiratory rate measurements (median 19.5 breaths per minute) tended to be lower than observed respiratory rate measurements (median 21 breaths per minute). All episodes of respiratory dysfunction occurred while patients were receiving supplemental oxygen and few changes to oxygen flow rates or oxygen delivery devices by intensive care nurses were made. Additionally, no hypoxaemic or tachypnoeic episodes occurring during the hour (therefore not coinciding with the routine hourly documentation practices) were documented.
The following chapter is Chapter Seven. The purpose of Chapter Seven is to draw together and discuss the research findings in relation to the overall research aim. In addition, the clinical implications of the findings are discussed and recommendations for nursing practice, policy development and nursing education are presented.
Chapter 7: Discussion and conclusion

It is recognised that management of oxygen therapy for patients at risk of respiratory dysfunction is primarily undertaken by nurses, is multi-factorial and often carried out in complex clinical settings. The aim of the three studies presented in this thesis was to investigate, in detail, the management of oxygen therapy for patients at risk of respiratory dysfunction. Those three studies identified three key factors known to impact on effective oxygen therapy: (a) the selection and use of an oxygen delivery device, (b) the experience, including patient’s experience of receiving oxygen therapy and nurses’ experience managing oxygen therapy, and (c) how oxygen therapy is managed and documented in clinical practice.

In order to appropriately investigate the complexity of oxygen therapy management, three sequentially linked studies, situated within a modified World Health Organisation patient safety conceptual framework, were completed (Runciman et al., 2009; Runciman et al., 2010). The three major objectives of this study were to investigate:

- The clinical efficacy and user-friendliness of oxygen delivery devices
- Patients’ and nurses’ perceptions of oxygen therapy
- How intensive care nurses’ manage and document oxygen therapy for patients at risk of respiratory dysfunction

The findings of the three studies reported in this thesis fill gaps in the literature by providing overarching information about perceptions and practice. Most previous
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Studies have tended to investigate factors that impact on oxygen therapy in isolation, without an overarching in-practice approach. In this chapter, the implications of these findings in relation to how intensive care nurses manage oxygen therapy and the conceptual framework that underpinned the research are considered. The significance of these research findings in relation to nursing practice, policy development, nursing education and avenues for future research are discussed.

**Outcomes of the research**

Four major findings arising from the research are reported in this thesis. Study One (Part A) confirmed that nasal prongs, face mask and nasopharyngeal oxygen catheter devices were effective at maintaining an SpO₂ greater than 95% with no evidence of patients altering their respiratory rate to compensate for a change in oxygen supply between devices. Face masks, which use a higher oxygen flow compared to nasal devices, were deemed by patients to be the least comfortable device. In part B of that study, it was shown that patients’ and nurses’ have clear perspectives on oxygen therapy. Importantly, patients wanted to receive oxygen via nasal prongs or nasopharyngeal oxygen catheter as these devices were the most comfortable, permitted ease of eating, drinking and talking. Conversely, nurses reported using measures of a patient’s SpO₂ and respiratory rate as drivers for their oxygen therapy decisions. Nurses preferred to use the face mask as their first choice for oxygen supplementation because of the ability to provide high oxygen flow rates. However, differences in patients’ and nurses’ perspectives of oxygen therapy may compromise the effectiveness of oxygen therapy with patients resistive to using a face mask. In the second study, results showed that episodes of respiratory dysfunction were common among post-operative patients in
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the intensive care environment. This study showed there were few alterations made to
the type of oxygen delivery device used, or changes to oxygen flow rates in response
respiratory dysfunction. The third study also revealed that what nurses documented in
the intensive care environment including oxygen saturation and respiratory rate
measures did not reflect patient status and some nursing actions hindered effective
oxygen therapy. For example, in one observation period, despite the patient
experiencing tachypnoea and hypoxaemia, the intensive care nurse did not change
oxygen therapy despite the availability of a range of oxygen delivery devices in the
patient’s bed space. In addition, although for only a short period of time, a drop in
oxygen saturation was observed when the intensive care nurse removed the patient’s
face mask to provide mouth care. These findings suggested that the intensive care
environment did not protect the patient from suboptimal oxygen therapy management.

Collectively, the findings of the three studies revealed a need for health care
professionals to review oxygen device selection in specific clinical settings, the
importance of involving patients in decisions about their care and the need to
appropriately document patient status and response to oxygen therapy. Additionally,
there is a need to further understand and implement strategies to assist in the selection of
oxygen delivery devices, engagement of patients and accurate documentation of all
aspects of oxygen therapy to optimise patient safety. Further, it may be useful to
develop patient-centred practice guidelines or local protocols related to oxygen therapy.
Clinical efficacy and user-friendliness of oxygen delivery devices

The effectiveness of nasal prongs, face mask and nasopharyngeal oxygen catheter to maintain a normal SpO₂ together with the absence of indicators of respiratory dysfunction (hypoxaemia, tachypnoea and bradypnoea) confirmed in Study One, concur with what other studies have shown. Study One showed that these devices were safe and effective at providing low-level oxygen supplementation for the assessment period. Other studies comparing nasal prongs and face mask (Ayhan et al., 2009; Nolan et al., 1993; McBrien & Sellers, 1995; Stausholm et al., 1995) or face mask and nasopharyngeal oxygen catheters (Eastwood et al., 2004) have shown equivalence in maintaining a normal SpO₂ when the device was correctly positioned. These previous studies compared devices in isolation or they only compared two devices. The significance of the current study is that it is the first study to simultaneously compare three devices (nasal prongs, nasopharyngeal oxygen catheter and face mask) to determine the implications of device selection in adult patients.

The findings of Study One, and those of others (Ayhan et al., 2009; Bolton & Russell, 2001; McBrien & Sellers, 1995; Stausholm et al., 1995), support the use of nasal devices in preference to face mask. Ensuring that oxygen is administered in a timely and appropriate way using the right device is an important aspect of patient care. By selecting the appropriate oxygen delivery device a number of outcomes can be predicted, including: more efficient use of resources (i.e. oxygen, oxygen therapy equipment and nursing time), providing treatment tailored to better meet patient needs, healthcare cost savings, and increased patient satisfaction and compliance with oxygen therapy (Ayhan et al., 2009; Bolton & Russell, 2001; Eastwood et al., 2007). The use of
nasal devices can overcome the disadvantages associated with the face mask, which are reported to include claustrophobic sensations in some patients, frequent device removal and impaired eating and drinking (Barnes, 2000; Eastwood & Dennis, 2006; Macmarek et al., 2005).

Impact of patients’ and nurses’ perceptions on effective oxygen therapy

Part B of Study One is one of only a few studies that have explored the patient and nurse experience of oxygen therapy application and management and the factors that either assist or hinder patient compliance with oxygen therapy (Ayhan et al., 2009; Bolton & Russell, 2001; Nolan et al, 1993; Sasaki et al., 2003; Stausholm et al 1993). This study showed that nurses’ need to listen to and understand the patient experience of oxygen therapy and any past experiences. When nurses involve the patient in their own care and selection of oxygen delivery device, interruptions to oxygen therapy may be minimised and adverse events related to hypoxaemia could be avoided.

In Study Two it was found that a majority of intensive care nurses would choose the face mask as their delivery device of choice but patients preferred nasal prongs. A difference in preferred delivery device has implications for oxygen therapy effectiveness and highlights a deficiency in the inclusion of the patient in care decisions. Nurses’ preference for face masks was due to perceptions that masks are safer as they deliver higher oxygen flow rates than nasal devices (Nerlich 1997; McConnell 1997). Continued unnecessary face mask use may pose an unnecessary clinical risk by (a) impairing communication leading to misunderstanding between nursing staff and patient, and (b) increased risk of device removal due to discomfort; both instances may
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increase the risk of a respiratory related adverse event. When managing oxygen therapy, nurses should be mindful of the advantages and disadvantages associated with device selection and use and the implications for patient compliance with therapy.

It was hypothesised that device comfort would be the main factor for patient compliance with oxygen therapy. Previous researchers have also identified the device comfort has a direct impact on a patient’s acceptance of a device and compliance with therapy (Nolan et al., 1993; Sasaki et al., 2003; Stausholm et al., 1995). It is also acknowledged that patient anxiety and discomfort wearing oxygen devices may lead to non-compliance and increased interruptions to oxygen therapy (Eastwood, Gardner, O’Connell, 2007). There is evidence that when patients are involved in their own care, the risk of adverse events is reduced because the patient feels engaged with, and therefore complies with, treatment interventions (Arbuthnott & Sharpe, 2009; ACSQHC, 2011).

In terms of patient functional status, for example being able to eat and drink during oxygen therapy, patients preferred the nasal devices. Reasons indicated by patients for their preference for nasal devices to the face mask were: comfort, nasal prongs were more likely to stay correctly positioned compared with the face mask, and the oxygen flow associated with the nasal devices caused less drying of the mouth and nose than the higher oxygen flow of the face mask. Because individual patients have particular oxygen therapy requirements, further exploration as to how nurses can best individualise patient care and tailor therapy to achieve satisfactory blood oxygen levels and to optimise patient comfort and compliance is warranted. Other researchers have
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demonstrated that nasal prongs are more likely to remain in situ than face mask and are therefore more likely to maintain adequate saturation (Nolan et al., 1993). The removal of oxygen therapy devices interrupts oxygen delivery, and places the patient at risk of hypoxaemia. Consequently, nurses need to be aware of any activity that may interrupt oxygen delivery and actively engage in strategies to prevent hypoxaemia; these may involve including the patient in conversations about oxygen therapy device selection and the need for compliance with therapy.

Nurses management and documentation oxygen therapy for patients at risk of respiratory dysfunction

The findings of studies Two and Three are consistent with other research on the management of oxygen therapy for patients at risk of respiratory dysfunction, evaluation of the oxygen management practices among nurses (Considine et al., 2006; Cook et al., 1996; Wong et al., 2000); and literature on patient compliance and comfort with oxygen therapy (Bolton & Russell, 2001; Stausholm, et al., 1995). The findings concur with previous research that shows deficiencies in perceptions of the clinical significance of an elevated respiratory rate (Cretikos et al., 2008; Hogan, 2006; Quach et al., 2008), and the documentation of vital signs for hospitalised patients (Helliwell et al., 2002; McGain et al., 2008).

The studies reported in this thesis showed a majority of the episodes of hypoxaemia and tachypnoea were not documented on the nursing observation chart. Failing to document abnormal vital signs occurring within-the-hour may miss subtle trends and variations that trigger early interventions to address worsening physiology.
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This calls into question the value of the nursing observation chart and how to best document the care and clinical status of intensive care patients. Evidence from published studies arising from the adverse events literature has clearly identified that documented abnormal vital signs almost always precede adverse events, such as cardiac arrest (Buist et al., 1999; Harrison et al., 2006). It is foreseeable that technological advancements in physiological patient monitoring will provide access to real time data to optimise the ability of nurses to respond to the early signs of clinical deterioration.

The discrepancy between observed and documented SpO2 and respiratory rate is of particular concern. This raises questions about the actual function of the nursing observation chart and its role as a mode of communication. For example, documented SpO2 was higher than observed and documented respiratory rate was lower than observed. Discrepancies in the documentation of SpO2 have important implications related to the content of oxygen in arterial blood. The non-linear relationship between the partial pressure of arterial oxygen (PaO2) and SpO2 means that a small decrease in SpO2 can result in a large decrease in PaO2 (O’Driscoll et al., 2008). Likewise, recording a lower than actual respiratory rate is problematic, as an elevated respiratory rate is a clinically significant indicator of physiological deterioration (Cretikos et al., 2008; Hogan, 2006; Quach et al., 2008).

Inaccurate or incorrect documentation of vital signs on nursing observation charts raise issues of clinical risk. It is well known that an elevated respiratory rate is linked to worsening respiratory function or is representative of derangement in another body system (Cretikos et al., 2008). Inaccurate documentation of vital signs may be
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reflective of a cognitive disposition of nurses to ‘ascertainment bias’ (Croskerry, 2002; Croskerry, 2003). ‘Ascertainment bias’ occurs when the nurse’s thinking is pre-shaped by what the nurse specifically hopes to find (Croskerry, 2002). For example, the nurse may record SpO₂ and respiratory rate that are suggestive of an improving patient, when in actuality the patient’s physiological state may be deteriorating. Consequently, there is risk of other nurses, doctors, or physiotherapists making a diagnostic error by either failing to appreciate the true extent of a clinical problem or not identifying a clinical problem that exists (Szaflarski, 1997). Appropriate monitoring and accurate documentation of measures of SpO₂ and respiratory rate should limit the risk of diagnostic errors (under-diagnosing a potential or existing clinical problem; diagnosing a clinical problem that does not exist) being made by other intensive care healthcare professionals.

Alarmingly, all episodes of respiratory dysfunction identified in the current research occurred while the patient was receiving supplemental oxygen. Few patients had their episode of respiratory dysfunction treated, either by an increase in the oxygen flow rate or a change in the oxygen delivery device despite being situated in the intensive care unit and having close physiological monitoring in place. A failure to intervene appropriately to signs of clinical deterioration may reflect a lack of clinical knowledge or evidence to support nurses’ practice of oxygen therapy. Several researchers have identified that current oxygen therapy practices are suboptimal, with oxygen being administered incorrectly at times (Cook et al., 1996; Wong et al., 2000). These investigators have attributed suboptimal oxygen therapy management to a variety of causes, including failure to administer prescribed treatment (Kor & Lim, 2000;
Howell, 2001), failure to monitor blood oxygen levels appropriately (Cook et al., 1996), and lack of knowledge about the physiological and pharmacological principles of oxygen therapy (Brokalaki et al., 2004a; Cooper, 2002). While the objective of the research reported in this study was not to assess the appropriateness of nursing practice, the findings presented are consistent with findings from earlier research about suboptimal nursing practices (for example, the nurse who described cutting the mask in two). Therefore, there is a need to critically examine the traditional practices of hourly documentation and enhance physiological monitoring systems in order to facilitate responsiveness to clinical deterioration and optimise patient safety.

**Comparison between the conceptual framework and the research findings**

The World Health Organisation International Classification for Patient Safety (ICPS) underpinned the conceptual framework used to support the research reported in this thesis (Runciman, et al., 2009). Given the strong relationship between respiratory dysfunction, the intensive care context and respiratory related adverse events, selecting a conceptual framework situated in patient safety and clinical risk was appropriate.

The conceptual framework used for this thesis (Runciman, et al, 2009) identified key components known to influence oxygen therapy management for patients at risk of respiratory dysfunction. The conceptual framework developed consisted of a central component and four key components. The central component was ‘oxygen therapy management of oxygen therapy for patients at risk of respiratory dysfunction’. Informed by the findings of the literature review, the four key components that bespoke the central component were: (a) contributing factors to the pathophysiology of respiratory
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dysfunction and the administration of oxygen therapy, (b) patient characteristics, (c)
nurse characteristics, and (d) monitoring and management considerations in when caring
for patients at risk of respiratory dysfunction and receiving oxygen therapy in the
intensive care unit. Each component consisted of factors associated with respiratory
dysfunction and the management of oxygen therapy in clinical practice. A simplified
conceptual framework of oxygen therapy management for patients at risk of respiratory
dysfunction is shown in Figure 7.1.

Figure 7.1 Simplified conceptual framework of the key factors that influence oxygen
therapy management for patients at risk of respiratory dysfunction.

There was strong evidence to support the contention that oxygen therapy
management for patients at risk of respiratory dysfunction is complex and multi-
factorial. Specifically, intensive care patients are at risk of respiratory dysfunction and
remain at risk even when receiving supplemental oxygen. When positioned correctly, nasal prongs, face mask and nasopharyngeal oxygen catheter devices were all shown to maintain an oxygen saturation at or greater than 95%, thus suitable for use in clinical practice. Further, differences between patients’ and nurses’ perceptions of oxygen do influence the effectiveness of oxygen therapy.

‘Nurse characteristics’ was clearly supported by the research findings as an important component of the conceptual framework. Specifically, nurses used physiological measures (e.g. oxygen saturation and respiratory rate) as determinants of therapeutic effect of oxygen therapy and incorporated clinical knowledge of oxygen therapy and respiratory dysfunction into their practice. Nurses were observed to manage other care activities to minimise interruption to oxygen therapy and therefore optimise the effectiveness of oxygen therapy. Additionally, nurses were also observed to educate patients about their oxygen therapy as an additional means to optimise oxygen therapy effectiveness and patient compliance with therapy. Detailed information about the type and timing of education nurses use to educate patients about oxygen therapy is however lacking and therefore remains a research gap that warrants investigation. Crucially, the ritualistic approach to documentation (e.g. the on-the-hour recording of vitals signs) did not accurately reflect the patient’s overall clinical status. There was failure to document important abnormalities of RR and oxygen saturation, so the vital sign observation chart often gave a false impression of physiological stability. Evaluation of how intensive care nurses’ can best use current documentation systems associated with the recording of oxygen related variables warrants detailed investigation.
‘Patient characteristics’ was also supported as a critical component of the conceptual framework. Patient’s experiences of oxygen therapy do affect their compliance with therapy and compliance remains a major factor in oxygen therapy effectiveness. Patients linked compliance with oxygen therapy to comfort of the oxygen delivery device and the ability to perform normal daily activities such as talking and eating, while receiving oxygen therapy. The new knowledge of patients’ experiences of oxygen therapy generated in this study has provided additional evidence to support nurses’ management of oxygen therapy. Importantly, patient’s experiences of oxygen therapy influence its effectiveness and the results of this study highlight that incorporating the patient and their preferences into oxygen management decisions will decrease clinical risk of respiratory dysfunction by optimizing compliance with oxygen therapy.

‘Monitoring and management considerations in the intensive care’ was confirmed by the research findings as an essential component of the conceptual framework. Nurses provided physiological monitoring, respiratory assessment and implemented therapeutic interventions related to oxygen therapy for intensive care patients. Nonetheless, the intensive care environment did not always protect patients from experiencing episodes of respiratory dysfunction. Thus, two factors associated with the ‘monitoring and management considerations in the intensive care’ remain underexplored. Firstly, there were episodes where documentation of oxygenation and respiratory rate was inaccurate, the reasons for which remain unclear. Secondly, reasons behind why intensive care nurses failed to appropriately alter oxygen flow rates or change oxygen delivery devices in response to signs of respiratory dysfunction also
remains undetermined. Extensive exploration of intensive care nurses’ make clinical
decision-making associated with the management and documentation of oxygen therapy
now warrants investigation.

Comparisons between the conceptual framework and the research findings
confirm the strong interplay between key components associated with oxygen therapy,
and the effectiveness of oxygen therapy cannot be strongly aligned to one dominant component. Furthermore, comparisons between the conceptual framework and the research findings have identified three new gaps in the literature. Firstly, knowledge of how nurses recognise and respond to the early signs of respiratory dysfunction remains unclear. Secondly, knowledge of how nurses select and use of oxygen delivery devices remains poorly understood. Thirdly, knowledge of to best monitoring and document oxygen saturation and respiratory rate to facilitate the early recognition of respiratory dysfunction is lacking. Collectively, the research findings together with the identified gaps in the literature can now inform the development of other conceptual frameworks and support future investigations into oxygen therapy management for patients at risk of respiratory dysfunction.

Strengths and limitations of the research

This study makes an important contribution to the understanding of the interplay
of factors that impact on nurses’ management of oxygen therapy for patients at risk of respiratory dysfunction. The major strengths of the research included the capture of robust and verifiable outcomes (SpO₂, respiratory rate, oxygen flow rate), the self-reported data from patients and nurses about their perceptions of oxygen therapy and the
examination of what oxygen therapy management and documentation as it occurred in clinical practice. The above sections have discussed the research findings and illustrated the relationship between the research findings and those of other investigators. Like all research designs there are a number of limitations that should be acknowledged and considered when interpreting the research findings and designing future studies.

**Sampling limitations**

For the research findings to be applicable to a broader range of intensive care patients and nurses, the sample should accurately represent the larger study population (Endacott & Botti, 2007). The three studies were conducted within a single healthcare organisation, located in the Eastern suburbs of Melbourne, Australia. Inherent to this setting are cultural and socio-economic characteristics’ at the societal level and nursing culture and educational norms at the unit level. Nonetheless, the reported participant characteristics are nonetheless likely to be consistent with the characteristics of other intensive care patients and intensive care nurses in other Australian settings. Furthermore, given the frequent use of oxygen therapy, the common use of nasal prongs, face mask and nasopharyngeal oxygen catheter, applicability of the research findings to other intensive care units is likely.

**Limitations of the data collection methods**

*Limitations of randomised crossover trials*

The main limitations associated with the conduct of randomised crossover trials are the possibility of carry-over and order related effects (Sibbald & Roberts, 1998). By convention a ‘washout’ period lessens the impact of any carry-over effect, yet for Study
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One (Part A) interrupting the delivery of oxygen to patients would have been a threat to patient safety. In lieu of a washout period of ‘no oxygen’ the study procedure included a 10-minute period between oxygen administration and outcome measurement for each device. To minimise order related effects three trial arms were used and patients were randomly allocated to each trial arm using a permuted block randomisation procedure. While the potential of carry-over and order and effects was recognised a priori, a parallel trial would have trebled the number of patient participants, prolonged the duration of the study, and prevented patients from trialing all three devices.

Limitations of face-to-face interviews

A major limitation of conducting face-to-face interviews is interviewer bias, in which the interview technique, verbal and non-verbal behaviours of the interviewer may affect participant’s responses (Polit & Hungler, 1997; Sim & Wright, 2000). To minimise the effect of interviewer bias, a single researcher using a purposefully developed interview schedule conducted all interviews. Additional strategies used by the researcher to reduce the effect of interviewer bias included establishing rapport with the participants, defining the topic areas at the commencement of the interview and following the interview schedule (Ivey, 1994). To facilitate a friendly, polite and productive interview, patient interviews were conducted at the patient’s bedside and nurse interviews were conducted in a quiet location and at time convenient to nurse participants.
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Limitations of medical record audits

In this research, the medical records of 210 cardiac surgical patients spanning a period of three years were reviewed and assessed using a pre-established data collection tool. However, like other retrospective studies, retrospective medical record audits are limited by the nature of the data available and that no causal relationship can be made, as documentation does not thoroughly reflect patient care (Gearing et al., 2006; Hess, 2004). In particular, perceived inaccuracies in documentation could be explained by other factors, which were not addressed in this thesis. For example, it may have been possible that the nurse-to-patient ratio for some cardiac surgical patients during the immediate post-operative was 1:2. Thus, it is likely that ongoing respiratory assessment of the cardiac surgical patients was occurring but without documentation. Nonetheless, by evaluating oxygen delivery device use, clinical indicators of respiratory dysfunction and exploring relationships between those variables with outcomes, valuable insights into oxygen therapy management in the intensive care unit has been achieved. Other limitations of data extracted from medical records include incomplete documentation, missing records, unrecoverable information and variation in use of medical/nursing abbreviations (Gearing et al., 2006). Thus, the documented values obtained in this research may have underestimated what is likely to be happening and may not be reflective of the lowest SpO₂ or the highest respiratory rate experienced by cardiac surgical patients.

Limitations of clinical practice observation

The major limitation of observational data collection is observational bias such as the ‘Hawthorne effect’ (Whitehead & Annells, 2007), in which the behaviours of
those being observed may have changed. Participants in this study knew that they were being observed due to the presence of the researcher. To minimise the ‘Hawthorne effect’, participants were informed of the broad aims of the study and were told that the researcher was seeking to observe how patient care was being delivered in the intensive care unit. The researcher adopted a ‘pure observer’ role to avoid disrupting patient care (Mulhall, 2003; Polit & Hungler, 1997). In addition, the researcher sat at a desk located close to the patient’s bed location. By being close to participants it was possible for the researcher to observe and record nurse-patient interactions without impacting on participant behaviour.

In summary, there were some limitations inherent to research design that related to participant sampling and the individual data collection methods that were used. However, by using different data collection methods a detailed evaluation of how nurses’ managed oxygen therapy for patients at risk of respiratory dysfunction was achieved. Therefore, while the limitations impact on the generalisability of the research findings to other settings and patient populations, they do not prevent the value of the data and the contribution to the understanding of the interplay between factors that influence the management of oxygen therapy in the intensive care setting.

**Significance of the research findings**

In response to identified complexities associated with the management of oxygen therapy for intensive care patients, intensive care nurses must remain diligent and engaged with their practice of oxygen therapy. Improvements in the selection of oxygen delivery devices and the tailoring of the device to match the clinical condition and
activity of the patient are needed. Documentation systems need to be reviewed in order
to appropriately match the acuity, complexity and pace of contemporary intensive care
unit practice. Educational interventions to improve nurses’ knowledge and competence
in oxygen management and documentation are indicated. In addition, specific
interventions to promote and facilitate the use of evidence-based practice by intensive
care nurses, development of a framework that includes intensive care nurses in
educational interventions, the development of integrated educational pathways and the
writing of unit-based protocols is warranted (Eastwood et al, 2008; Thomson, Angus, &
Scott, 2000). Importantly, to contribute to effective and efficient patient care, changing
clinical practice to incorporate the best available evidence will required a multi-factorial
approach that combines education, local champions, decision support tools and clinical
reminders (Bhattacharyya, Reeves, Garfinkel, & Zwarenstein, 2006; Eastwood et al.,
2008; Titler & Everett, 2001).

Constructive feedback to intensive care nurses, while emphasising the positive
aspects (promoting patient comfort with oxygen therapy, correct fitting of oxygen
delivery devices, and the appropriate timing on nursing care interventions) of current
oxygen management practices, should stress the importance of diligently documenting
oxygen saturation and respiratory rate. Significantly, the research findings presented in
the these studies provides evidence from which future observational and interventional
studies aimed at improving nurses’ management of oxygen therapy and the rapid,
accurate detection and management of respiratory dysfunction, in particular hypoxaemia
and tachypnoea, in the intensive care unit, can be conducted.
While the aim of the current research was not to investigate how intensive care nurses make oxygen management decisions, variability in the documentation, monitoring and delivery of low-flow oxygen therapy suggests disparity in clinical decision making. Variability in oxygen therapy practice among intensive care nurses is likely to continue until there is evidence from clinical trials to support development of clinical practice guidelines with clear recommendations for practice. Future research should address this issue by developing and trialing an ‘evidence-based guideline’ on the management of oxygen therapy.

Implications of research findings for future research

Throughout the discussion in this chapter, the implications of the research findings for future research have been illustrated. They highlight the need for strategies to assist healthcare professional to judiciously select the most appropriate oxygen device, involve patients in their care decisions, and the need to align care documented with care that is provided. Significantly, the research findings provide evidence from which future observational and interventional studies aimed at improving patient safety and outcomes associated with oxygen therapy management can be conducted. It is important that future studies be conducted in order to:

- Better understand how intensive care nurses manage oxygen therapy for a wider variety of intensive care patients
- Identify the decision-making processes of intensive care nurses so that quality improvement initiatives target specific and modifiable areas of practice
- Inform the development and integration into practice of clinical practice guidelines for the management oxygen therapy in the intensive care setting
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- Improve methods of monitoring and documenting vital signs while intensive care patients receive oxygen therapy

Conclusion

Nurses play a vital role in the management of oxygen therapy for patients at risk of respiratory dysfunction. How nurses recognise and respond to signs of respiratory dysfunction has the potential to reduce the incidence of respiratory related adverse events. Using a series of linked studies situated within a clinical risk and patient safety framework, it was possible to explore the complexity of oxygen therapy management for patients at risk of respiratory dysfunction. Overall, the research findings revealed a need for health care professionals to review the way in which oxygen devices are selected, the importance of involving patients in decisions about their care, and the need to appropriately document care that is provided. Importantly, the research findings provide a better understanding of the factors that impact intensive care nurses’ management of oxygen therapy in daily practice. These findings can be used to inform future interventions to improve oxygen therapy management aimed at optimising patient safety and outcomes.
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Appendix A – Ethical approval documents from Deakin University

MEMORANDUM

TO: Mr Glenn Eastwood
   Nursing
   Melbourne

FROM: Secretary, Deakin University Human Research Ethics Committee (DU-HREC)

DATE: 30 June 2005

SUBJECT: PROJECT: EC 122-2005
          (Please quote this project number in future communication.)
          A RANDOMISED CONTROL TRIAL EVALUATING THE EFFICACY OF THREE
          LOW-FLOW OXYGEN THERAPY DEVICES

This application was considered at the DU-HREC meeting held on
27 June 2005.

APPROVAL HAS BEEN GIVEN FOR GLENN EASTWOOD, UNDER THE SUPERVISION OF
PROF BEV O'CONNELL, SCHOOL OF NURSING, TO UNDERTAKE THIS PROJECT FROM
29 JUNE 2005 TO 31 DECEMBER 2006.

The approval given by the Deakin University Human Research Ethics Committee is given
only for the project and for the period as stated in the application and approval. It is your
responsibility to contact the Secretary immediately should any of the following occur:
- Serious or unexpected adverse effects on the participants
- Any proposed changes in the protocol, including extensions of time.
- Any events which might affect the continuing ethical acceptability of the project.
- The project is discontinued before the expected date of completion.
In addition you will be required to report on the progress of your project at least once every
year and at the conclusion of the project. Failure to report as required will result in suspension
of your approval to proceed with the project.

Victoria Emery
Secretary, DU-HREC
(03) 9251 7123

Signature Redacted by Library
MEMORANDUM

TO: Mr Glenn Eastwood
Nursing
Melbourne

FROM: Executive Officer, Deakin University Human Research Ethics Committee (DU-HREC)

DATE: 5 March 2007

SUBJECT: PROJECT: EC 122-2005 (Please quote this project number in future communication.)
A RANDOMISED CONTROL TRIAL EVALUATING THE EFFICACY OF THREE LOW-FLOW OXYGEN THERAPY DEVICES

Interim approval for modifications to this project, received on 19 November 2006, was ratified by DU-HREC at meeting 1/07 held on 19 February 2007.

APPROVAL HAS BEEN GIVEN FOR GLENN EASTWOOD, UNDER THE SUPERVISION OF PROF BEV O'CONNELL, SCHOOL OF NURSING, TO CONTINUE THIS PROJECT AS MODIFIED TO 29 JUNE 2008.

The approval given by the Deakin University Human Research Ethics Committee is given only for the project and for the period as stated in the approval. It is your responsibility to contact the Secretary immediately should any of the following occur:
• Serious or unexpected adverse effects on the participants
• Any proposed changes in the protocol, including extensions of time.
• Any events which might affect the continuing ethical acceptability of the project.
• The project is discontinued before the expected date of completion.
• Modifications are requested by other HRECs.

In addition you will be required to report on the progress of your project at least once every year and at the conclusion of the project. Failure to report as required will result in suspension of your approval to proceed with the project.

Silvia Rametta
On behalf of DU-HREC
(03) 9251 7123
MEMORANDUM

TO: Prof. Bev O'Connell
    School of Nursing, Melbourne
cc: Glenn Eastwood

FROM: Deakin University Human Research Ethics Committee (DU-HREC)

DATE: 5 August 2008

SUBJECT: Project EC 122-2005  (Please quote this project number in future communication.)
A Randomised Control Trial evaluating the efficacy of three low-flow oxygen therapy devices

The modification to this project was ratified at the DU-HREC meeting held on 4 August 2008

Approval has been given for Glenn Eastwood under the supervision of Prof. Bev O’Connell, School of Nursing, to continue this project as modified to 29 June 2008.

The approval given by the Deakin University Human Research Ethics Committee is given only for the project and for the period as stated in the approval. It is your responsibility to contact the Executive Officer immediately should any of the following occur:
• Serious or unexpected adverse effects on the participants
• Any proposed changes in the protocol, including extensions of time.
• Any events which might affect the continuing ethical acceptability of the project.
• The project is discontinued before the expected date of completion.
• Modifications are requested by other HREC's.

In addition you will be required to report on the progress of your project at least once every year and at the conclusion of the project. Failure to report as required will result in suspension of your approval to proceed with the project.

DU-HREC may need to audit this project as part of the requirements for monitoring set out in the National Statement on Ethical Conduct in Human Research (2007)

Vicky Bates, Secretary
On behalf of DU-HREC
03 9251 7052

Signature Redacted by Library
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Appendix B – Ethical approval documents from Epworth Healthcare

HUMAN RESEARCH ETHICS COMMITTEE
CERTIFICATE OF APPROVAL

Project Title: A clinical trial evaluating the efficacy of three oxygen therapy devices

Investigators: Mr Glenn Eastwood, Professor Bev O'Connell, Associate Professor Anne Gardner, Dr Benno Ihle

Epworth Study No: 30405

HREC Meeting Date: 4 May 2005

Board of Management Approval: 25 May 2005

Denis R Hogg
Chief Executive

TERMS AND CONDITIONS OF APPROVAL:
The Principal Investigator is required to notify the Human Research Ethics Committee of:
1. Any changes to the protocol which occur after approval has been given, together with ethical implications for the consideration of the Committee;
2. Any change in personnel advised in relation to the carrying out the research;
3. Adverse effects experienced by the subjects of the study;
4. Any unforeseen events;
5. The Committee must be advised if the project is cancelled or postponed;
6. A progress report must be submitted to the Committee on completion of the study or every twelve months from the date of approval.

Researchers are asked to confirm acceptance of these conditions on the attached copy of this certificate.

I, ........................................, accept the terms and conditions set out above.

Signature of Researcher: ........................................ Date: ........................................

Signature Redacted by Library

Signature Redacted by Library
27 December 2006

Mr Glenn M. Eastwood  
c/o Epworth Eastern Hospital, ICU.  
1 Arnold Street  
Box Hill VIC 3128

Dear Glenn,

Re: Epworth Study No. 30405: *A clinical trial evaluating the efficacy of three oxygen therapy devices*

Thank you for your submission of amendments to your above study to the Epworth Healthcare Human Research and Ethics Committee.

They were pleased to approve your amendments at their meeting on the 6th of December 2006.

Thank you for keeping the committee informed of the progress of your study.

Yours sincerely,

Louise Grey  
HREC Coordinator  
Epworth Hospital, SLP

Signature Redacted by Library
15 May 2008

Mr Glenn M. Eastwood
c/o Epworth Eastern Hospital, ICU.
1 Arnold Street
Box Hill VIC 3128

Dear Glenn,

Re: Epworth Study No. 30405
A Clinical Trial Evaluating the Efficacy of Three Oxygen Therapy Devices

Thank-you for your letter dated the 10th April 2008 to request an extension to the above study to include the following:

Mapping of Oxygen Administration to Patients Following Cardiac Surgery in the Intensive Care Unit (ICU)

The Committee approved the extension to this study at their meeting on the 7th May 2008.

Please contact me if you have any queries.

Kind regards,

[Signature Redacted by Library]

Louise Grey
HREC Coordinator
Epworth HealthCare
66 Bridge Rd.
Richmond VIC 3121
Dear Patient,

My name is Glenn Eastwood. I am a student enrolled in the Doctor of Philosophy course in the School of Nursing, Deakin University. With Professor Bev O’Connell as the Principal Investigator, I will be working with a team of researchers from the university and the hospital. The other team members are Associate Professor Anne Gardner (Deakin University), and Dr Benno Ihle (Epworth Hospital).

You are invited to participate in a research project about oxygen therapy in the intensive care unit (ICU). This study investigates how we administer oxygen to patients and whether we can give it in a more comfortable and efficient manner. We also wish to identify factors that assist or hinder the use of oxygen therapy devices from both the patients’ and nurses’ perspective.

We need to know more about low-flow oxygen therapy devices in the ICU as comfort with the device, compliance with therapy and satisfactory blood oxygen levels are all vital aspects of oxygen therapy. Although this research may not benefit you directly, your participation in this study is likely to lead to improved decisions about modes of oxygen therapy, provide greater choice of device and increase patient comfort.

If you choose to participate, you will be asked to use and give us your opinion on three (3) low-flow oxygen therapy devices. The devices are: a soft nasopharyngeal oxygen catheter, nasal prongs, and an oxygen face mask. The nasopharyngeal oxygen, involves the insertion of an oxygen catheter through a nostril and into the back of your nose. Nasal prongs are short tubes placed at the base of the nose. Face masks are semi-rigid plastic masks that cover the nose and mouth. These three devices will be randomly allocated to you. We will measure the amount of oxygen required by each device to provide you with a safe level of oxygen.

After receiving oxygen by each device you will be asked to indicate how comfortable you found each device to be. Examples of the questions you will be asked are: Which device do you feel made your
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breathing easier and why? Did you experience any difficulties with receiving oxygen by the three devices? After a period of two hours I will return to re-assess comfort of your current oxygen therapy device and ask you similar questions as I did earlier. At a separate time I will ask the nursing staff similar questions concerning low-flow oxygen therapy and low-flow oxygen therapy devices.

To help us describe the patients that participate in this study we will retrieve information about you from your medical record and audiotape the interview for analysis purposes. It is anticipated that the first part of the study will last approximately 30 minutes. The second part is conducted two hours after the first part. It is anticipated that the second part of the study will last approximately 5 minutes.

Risks associated with this study include a failure to achieve adequate oxygen saturations, bleeding from the nose following insertion of the oxygen catheter, and drying of the mouth and nose associated with oxygen flow. These risks will be minimized by continuous monitoring of your blood oxygen levels, insertion of the oxygen catheter by an experienced nurse, and asking you to tell us of any discomfort experienced in relation to the oxygen flow.

Your participation in this main study is voluntary and you are free to withdraw at anytime. Where possible, we will provide information about this study to your relative or significant other so that they can assist you with the consent process and provide us with any information where necessary on your behalf. In addition, the doctor in charge of this ICU is aware of the study and has agreed to you being approached to participate. Should you decide to withdraw from the study your present and future care will not be affected. If you choose to withdraw we will only retain minimum demographic data about you.

To ensure confidentiality you will be assigned a code and this code kept in a code book accessed by the Principal Investigator. These codes will be used to identify you. All data will be recorded in a coded manner. When the study is complete all written material will be kept in a secure location at Deakin University for a period of 7 years. Results will be published in nursing journals and presented at professional conferences. Although no published information will identify you directly, at your request we will be happy to provide you with a summary of the overall results.

This study has been approved by Epworth Hospital Ethics Committee and the Deakin University Ethics Committee. If you would like to discuss the study further, please ring the Principal Investigator, Professor Bev O’Connell on (03) 9594 4240 or Mr Glenn Eastwood on (03) 9508 1905.

Should you have any concerns about the conduct of this research study, please contact Ms Louise Grey, Epworth Hospital Human Research Ethics Committee Coordinator, Tel. (03) 9426 6218.

Alternatively, you may contact the Executive Officer, Human Research Ethics, Deakin University, on Tel: (03) 9251 7123 or E-mail: research-ethics@deakin.edu.au Please quote project no. EC 122-2005.
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Patient Consent Form

1. **INVESTIGATOR:**
   I, ............................................................................................................................... have fully explained the aims, risks and procedures of the research study to ..............................................................

   **Signed:**........................................................................................................... Date: ................................

2. **THE PERSON GIVING CONSENT:**
   I, ............................................................................................................................... (print name)

   of ..........................................................................................................................

   agree to take part in the research study described in the Patient Information Statement, being conducted by ...........................................

   and who has fully explained the research study to me and given me a copy of the Patient Information Statement.

   I understand that

   - I am free to withdraw from the study at any time and any information obtained from me will not be used other than demographic data and the reason why I withdrew from the study.

   - my clinical status is paramount, any deterioration in my oxygenation will be immediately detected, measures to correct the deterioration implemented, and I will be withdrawn from the study.

   - as a participant I will be allocated a code, that my name and address will be kept separately from it and, any information that I provide will not be made public in any form that could reveal my identity to an outside party i.e. that I will remain fully anonymous.

   - aggregated results will be used for research purposes and may be reported in scientific and academic journals

   In this study I wish to

   (please tick)

   □ Fully participate □ Only provide demographic data □ Not provide any data at all

   **Signed:**........................................................................................................... Date: ................................

   **Signature of Witness:** ................................................................................. Date: ................................

   **Name and Address of Witness:** .................................................................
3. INDEPENDENT CONTACT PERSON

Should you have any concerns about the conduct of this research study, please contact Ms Louise Grey, Epworth Hospital Human Research Ethics Committee Coordinator, Tel. (03) 9426 6218.

Alternatively, you may contact the Executive Officer, Human Research Ethics, Deakin University, on Tel: (03) 9251 7123 or E-mail: research-ethics@deakin.edu.au Please quote project no. EC 122-2005.
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Appendix D – Randomised crossover trial and participant interview data

NURSE PARTICIPANT

Nurse Code Identification Number: _______    Study Date: ___/___/___

Age (in years):   □ 20-30    □ 31-40    □ 41-50    □ 51-60    □ 61-70    □ 70+

Gender:         □ male     □ female

Current clinical position: □ RN    □ CCRN    □ CNS (ICU)    □ ANUM    Other ______

Employment status: □ Full-time □ Part-time □ Casual


Critical care qualification: □ No qualification □ Certificate □ Graduate Cert.

□ Postgraduate Dip. □ Postgraduate Deg.

Critical care experience (in years): □ 0-4 □ 5-8 □ 9-12 □ 13-16 □ 17+

Q.1 – What patient factors do you feel influence the compliance with low-flow oxygen therapy devices such as nasal prongs and face masks?
Response:

Q.2 – How do you promote patient compliance with low-flow oxygen therapy?
Response:

Q.3 – What criteria do you use to select a low-flow oxygen device?
Response:

Q.4 – What criteria do you use to change a patient from one low-flow oxygen therapy device to another?
Response:

Q.5 – What low-flow oxygen therapy device do you find user friendly and why?
Response:

Thank-you for your participation in this study.
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PATIENT PARTICIPANT

Patient Code Identification Number: ____________

Patient Unit Record (UR) number: ____________

Study Date: ___/___/___ Date of ICU admission: ___/___/___

D.O.B ___/___/___ Gender: □ male □ female

Reason for admission to ICU:
□ Cardiovascular □ Respiratory □ Renal □ General-Surgical
□ Neurological □ Orthopaedic □ Sepsis □ Other ____________

Apache II Score: _____ SAPS II Score: ____ Hb level____

Assessment of Orientation in Person, Time and Place

Ask patient: Correct Incorrect
What is your name? □ □
What is the year? □ □
What is the month? □ □
Where are you? □ □

Anatomical position of patient during study:
□ Sitting-out-of-bed
□ In-bed (□ lateral □ supine □ semi-recumbent)
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Low-flow Oxygen Therapy Devices

<table>
<thead>
<tr>
<th>Patient randomized to: □ Arm 1 □ Arm 2 □ Arm 3</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Low-Flow Oxygen Therapy Device</th>
<th>NP</th>
<th>NPO</th>
<th>FM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time commenced oxygen therapy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time to achieve target SpO₂ (mins)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxygen saturation ≥ 95% reached</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxygen flow rate to achieve SpO₂</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiration rate once target SpO₂ reached</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note.* NP Nasal prongs; NPO Nasopharyngeal Oxygen; FM Semi-rigid plastic face mask

Comfort with oxygen therapy device:
(Patient to complete)

1. How comfortable did you find the nasal prongs?

______________________________________________________________________________

Most uncomfortable Most comfortable

2. How comfortable did you find the nasopharyngeal oxygen catheter?

______________________________________________________________________________

Most uncomfortable Most comfortable

3. How comfortable did you find the face mask?

______________________________________________________________________________

Most uncomfortable Most comfortable
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Semi-Structured Questions:

Q.1 – Which device did you feel made you breathing easier and why?
Response:

Q.2 – Did you experience any difficulties when receiving oxygen by these three devices?
Response:

Q.3 – In what ways did the oxygen devices impact on your ability to perform the activities you wanted to do?
Response

Q.4 – How long do you think you need to assess the comfort of the device you are wearing?
Response

2 hour follow-up:

Mode of oxygen therapy  □ NPO  □ NP  □ FM  □ Other: ______

How comfortable did you find – (the current oxygen therapy device)?

_________________________________________________________

Most uncomfortable  Most comfortable

Q. Over the last two hours, do you think the current oxygen therapy device has enabled you to do the activities that you wanted to?

_________________________________________________________

Thank-you for your participation in this study.
Dear Colleague,

My name is Glenn Eastwood. I am a student enrolled in the Doctor of Philosophy course in the School of Nursing, Deakin University. With Professor Bev O’Connell as the Principal Investigator, I will be working with a team of researchers from the university and the hospital. The other team members are Associate Professor Anne Gardner (Deakin University), and Dr Benno Ihle (Epworth Hospital).

You are invited to participate in a research project about oxygen therapy in the intensive care unit (ICU). This study investigates how we administer oxygen to patients and whether we can give it in a more comfortable and efficient manner. We also wish to identify factors that assist or hinder the use of oxygen therapy devices from both the patients’ and nurses’ perspective.

The purpose of the research study is to examine the usefulness of three oxygen therapy devices (e.g. face masks) used in the Intensive Care Unit (ICU). We also wish to identify factors that assist or hinder the use of oxygen therapy devices from both the patients’ and nurses’ perspective. We need to know more about low-flow oxygen therapy devices in the ICU as comfort with the device, compliance with therapy and satisfactory blood oxygen levels are all vital aspects of oxygen therapy. Although this research may not benefit you directly, your participation in this research is likely to lead to improved decisions about modes of oxygen therapy, provide greater choice of device, and increase patient comfort.

If you agree to participate, you will be asked a series of open-ended questions that focus on low-flow oxygen therapy in the ICU setting. Examples of the questions you will be asked are: Which device do you find user friendly and why? What criteria do you use to select a low-flow oxygen therapy device? It is anticipated that the time required to complete the interview schedule will be approximately 30 minutes. Your participation in this research study is voluntary and you are free to withdraw at anytime. Should you withdraw from the study we will retain only minimum demographic data and the reason why you withdrew. To ensure confidentiality you will be assigned a code and this code kept in a code book accessed by the Principal Investigator. These codes will be used to identify you. All data will be recorded.
in a coded manner. When the study is complete all written material will be kept in a secure location at
Deakin University for a period of 7 years. Results will be published in nursing journals and presented at
professional conferences. Although no published information will identify you directly, at your request
we will be happy to provide you with a summary of the overall results.

This research study has been approved by Epworth Hospital Ethics Committee and the Deakin University
Ethics Committee. If you would like to discuss the study further, please ring the Principal Investigator,
Professor Bev O’Connell on (03) 9594 4240 or Mr Glenn Eastwood on (03) 9508 1905.
Should you have any concerns about the conduct of this research study, please contact Ms Louise Grey,
Epworth Hospital Human Research Ethics Committee Coordinator, Tel. (03) 9426 6218.

Alternatively, you may contact the Executive Officer, Human Research Ethics, Deakin University, on Tel:
(03) 9251 7123 or E-mail: research-ethics@deakin.edu.au Please quote project no. EC 122-2005.
OXYGEN THERAPY MANAGEMENT

Nurse Consent Form

1. **INVESTIGATOR:**

   I, .............................................................. have fully explained the
   aims, risks and procedures of the research study to ..................................................

   Signed: .......................................................... Date: ................................

2. **THE PERSON GIVING CONSENT:**

   I, ..............................................................

   (print name)

   of ..............................................................

   agree to take part in the research study described in the Nurse Information Statement, being
   conducted by ........................................

   and who has fully explained the research study to me and given me a copy of the Nurse Information
   Statement.

   I understand that

   - I am free to withdraw my consent at any time during the study in which event my
     participation in the study will immediately cease and any information obtained from me will not
     be used other than demographic data and the reason why I withdrew from the study.
   - any information that I provide will not be made public in any form that could reveal my
     identity to an outside party i.e. that I will remain fully anonymous.
   - as a participant I will be allocated a code and that my name and address will be kept
     separately from it.
   - aggregated results will be used for research purposes and may be reported in scientific
     and academic journals.

   In this study I wish to

   (please tick)

   □ Fully participate    □ Only provide demographic data    □ Not provide any data at all

   Signed: .......................................................... Date: ..............................

   Signature of Witness: .......................................................... Date: ..............................

   Name and Address of Witness: ..........................................................
INDEPENDENT CONTACT PERSON

Should you have any concerns about the conduct of this research study, please contact Ms Louise Grey, Epworth Hospital Human Research Ethics Committee Coordinator, Tel. (03) 9426 6218.

Alternatively, you may contact the Executive Officer, Human Research Ethics, Deakin University, on Tel: (03) 9251 7123 or E-mail: research-ethics@deakin.edu.au Please quote project no. EC 122-2005.
Appendix F – Medical record audit data collection form

EPWORTH HOSPITAL & DEAKIN UNIVERSITY

A Clinical Trial Evaluating The Efficacy Of Three Low-flow Oxygen Therapy Devices

Patient Code Identification Number: __________ (Review Date: ___/___/___)

Age: _______ years  Gender: □ male  □ female

DRG: □ F07Z  □ F03Z  □ F04A  □ F04B  □ F05A  □ F05B  □ F06A  □ F06B

Apache II score: ________  Apache III score: ________

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Appendix G – Clinical practice observation data collection form

Data collection tool

Date of observation: __ / __ / __ Code Number: ________

Patient gender: □ Male □ Female Nurse:Patient ratio: □ 1:1 □ 1:2 □ 1:3

Time of observation: □ 08:00 – 10:00 □ 12:00 – 14:00 □ 14:00 – 16:00
□ 16:00 – 18:00

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## Chart Review

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OXYGEN THERAPY MANAGEMENT

Nurse demographic data

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Gender:  
- male  
- female

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<th>CCRN</th>
<th>CNS (ICU)</th>
<th>ANUM</th>
<th>Other</th>
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Employment status:  
- Full-time  
- Part-time  
- Casual

General nursing qualification:  
- Hosp. cert.  
- Nursing Dip.  
- Nursing Deg.

Critical care qualification:  
- No qualification  
- Certificate  
- Graduate Cert.  
- Postgraduate Dip.  
- Postgraduate Deg.

Critical care experience (in years):  
- 0-4  
- 5-8  
- 9-12  
- 13-16  
- 17+

Nurse demographic data

<table>
<thead>
<tr>
<th>Age (in years):</th>
<th>20-30</th>
<th>31-40</th>
<th>41-50</th>
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Gender:  
- male  
- female

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Employment status:  
- Full-time  
- Part-time  
- Casual

General nursing qualification:  
- Hosp. cert.  
- Nursing Dip.  
- Nursing Deg.

Critical care qualification:  
- No qualification  
- Certificate  
- Graduate Cert.  
- Postgraduate Dip.  
- Postgraduate Deg.

Critical care experience (in years):  
- 0-4  
- 5-8  
- 9-12  
- 13-16  
- 17+

Patient demographic data

| DOB: |     /     /     | Gender:  
|------|----------------|-------|-------|-------|-------|-----|

Gender:  
- male  
- female

Days in ICU: ______

- Cardiovascular  
- Respiratory  
- Renal  
- General-Surgical

- Neurological  
- Orthopaedic  
- Sepsis  
- Other ______

Concurrent nacrotic analgesic infusion:  
- No  
- Yes  

Type: _____________

Patient demographic data

| DOB: |     /     /     | Gender:  
|------|----------------|-------|-------|-------|-------|-----|

Gender:  
- male  
- female

Days in ICU: ______

- Cardiovascular  
- Respiratory  
- Renal  
- General-Surgical

- Neurological  
- Orthopaedic  
- Sepsis  
- Other ______

Concurrent nacrotic analgesic infusion:  
- No  
- Yes  

Type: _____________