The nurses' role in intra-abdominal pressure monitoring in the critical care setting

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STATEMENT OF AUTHENTICATION

The work presented in this thesis is to the best of my knowledge and belief original, except as acknowledged in the text. I hereby declare that I have not submitted this material in full or in part for a degree at this or any other institution.

Leanne Hunt

CERTIFICATE OF ORIGINAL AUTHORSHIP

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as part of the collaborative doctoral degree and/or fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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ABSTRACT

Intra-abdominal hypertension (IAH) and abdominal compartment syndrome (ACS) are increasingly recognised as complications for critically ill patients requiring accurate diagnosis and timely management. Increases in intra-abdominal pressure, beyond normal physiological parameters, can alter organ perfusion and as a consequence end organ function. The incidence of IAH is reported to be 50% of the critical care population. Of these 50%, 32.1% develop IAH and 4.2% develop ACS within the first 24 hours in the intensive care unit.

Intra abdominal hypertension and ACS can impact on the care of a range of critically ill patients. Preventing complications, secondary to IAH and ACS, is important to improving patient outcomes. Early detection and intervention of intra-abdominal hypertension and abdominal compartment syndrome has the potential to reduce time in critical care, overall length of hospital stays and improve patient outcomes. Nurses are responsible for measuring and reporting of intra-abdominal pressure measurements, yet there is limited literature specifically focusing on nurses' knowledge regarding IAH and ACS.

An essential component of this thesis was to address the following study aims; establish nurses' knowledge about intra-abdominal pressure measurement, IAH and ACS identification and management, and to assess, develop and refine strategies for intra-abdominal pressure measurement, IAH and ACS identification and management.

These aims were achieved through a series of discrete studies that were undertaken using methodological approaches consistent with the study questions. The studies undertaken were:

Study 1: *Management of intra-abdominal hypertension and abdominal compartment syndrome: a review.*

Study design: Integrative review

This study found that critical care nurses measure intra-abdominal pressure using the modified Kron technique and thus play an important role in recognising and managing IAH and ACS. Despite this role nurses' knowledge about IAH and ACS was poor.

Study 2: *Critical care nurses' knowledge of intra-abdominal hypertension and abdominal compartment syndrome.*

Study design: Survey design

This study found that inadequate or absent evidence based guidelines, policies and procedures and educational support are barriers to monitoring intra-abdominal pressure. This finding underscores the importance of supporting nurses to provide evidence based care.

Study 3: *A retrospective analysis of trauma patients requiring surgical intervention.*

Study design: Registry review

This study identified that trauma was often a pre-cursor to the development of IAH and ACS. The causes of IAH and ACS are multi-factorial highlighting the need for vigilance when monitoring trauma patients.

Study 4: *A comparison of fluid instillation volumes to assess intra-abdominal pressure using Kron's method.*

Study design: Prospective, alternate treatment allocation.

This study found that a volume of 10mL of fluid instilled into the bladder to measure intra-abdominal pressure showed agreement with the current World Society of Abdominal Compartment Syndrome recommendation to instil 25mL. A volume of 10mL of fluid instilled into the bladder showed no agreement with 0mL.

Study 5: *Reliability of intra-abdominal pressure measurements using the modified Kron technique.*

Study design: Prospective, convenience sample.

This study found a single intra-abdominal pressure measurement per measurement period was an accurate indicator of intra-abdominal pressure. Multiple intra-abdominal pressure measurements per measurement period are not necessary.

This thesis provides a unique contribution to the science of IAH and ACS management. Firstly, it has described the state of the science on accepted intra-abdominal pressure measurement techniques, IAH and ACS. Secondly, it has identified that there is a gap in critical care nurses' knowledge in the topic area. Thirdly it has identified that trauma patients are at risk of developing IAH and ACS, particularly in the presence of massive fluid resuscitation. Fourthly, this thesis has challenged current guidelines on intra-abdominal pressure measurement techniques. Fifthly, this thesis has identified the need for standardised practice guidelines and education to strengthen critical care nurses knowledge, skills and competence in assessing and recognising intra-abdominal hypertension and abdominal compartment syndrome.

Future research regarding the effects of intra-abdominal pressure and IAH in discrete patient populations, including post-operative cardiothoracic surgery and type ll respiratory failure patients, as well as alternative routes of measurement such as nasogastric measurement are needed. Nurses are well situated to diagnose IAH and management of ACS. Advancing the science of assessment, measurement and management are essential to improving outcomes for individuals with IAH and ACS.

PUBLICATIONS AND PRESENTATIONS

This thesis is presented as a series of five papers (4 published and 1 under review). I am the first author for each of these papers and had full responsibility for collecting and analysing the data reported in each paper. I prepared the drafts of each paper and my co-authors and supervisors provided leadership, direction and supervision. Co-author and supervisor contributions involved critical revisions to manuscripts for intellectual content. The analysis of all data was undertaken by me. This was then reviewed by my principal supervisor and discussed and confirmed by all authors.

PUBLICATIONS (International Refereed Journals)

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Hunt, L., Frost, S. A., Newton, P. J., Salamonson, Y., & Davidson, P. M. (2016). A survey of critical care nurses' knowledge of intra-abdominal hypertension and abdominal compartment syndrome. *Australian critical care*. DOI http://dx.doi.org/10.1016/j.aucc.2016.02.001.

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GLOSSARY AND ABBREVIATIONS

Abdominal compartment syndrome (ACS): A new or sustained IAP >20mmHg regardless of the abdominal perfusion pressure (APP) where a new organ dysfunction or failure is present.

Abdominal decompression: A surgical procedure to release the physical pressure within the abdomen.

Abdominal perfusion pressure (APP): MAP - IAP, indicates abdominal perfusion pressure.

APACHE II: Acute Physiology and Chronic Health Evaluation II. Is an intensive care unit scoring system used to categorise the severity of disease and thus the risk of death.

Bladder compliance: The relationship between the changes bladder volume to detrusor pressure.

Compartment syndrome: When a fixed compartment, defined by bone and myofascia, becomes subject to increased pressure and exceeds perfusion pressure.

Intra-abdominal hypertension (IAH): A sustained or repeated IAP ≥ 12mmHg.

Grade I, IAP 12–15 mmHg
Grade II, IAP 16–20 mmHg
Grade III, IAP 21–25 mmHg
Grade IV, IAP > 25 mmHg

Intra-abdominal pressure (IAP): The pressure concealed within the abdominal cavity.

Mean arterial pressure (MAP): is the average pressure during one cardiac cycle.

Modified Kron technique: Is the measurement technique considered the gold standard of intra bladder measurement of IAP.

Multi-organ failure (MOF): The progressive dysfunction of two or more organs resulting in an ability to maintain homeostasis. Typically a complication of sepsis.

Primary abdominal compartment syndrome: IAP ≥20mmHg secondary to injury or disease of the abdominopelvic region.

Recurrent abdominal compartment syndrome: Where IAH or ACS redevelops post their initial treatment.

Secondary abdominal compartment syndrome: IAP ≥20mmHg secondary to injuries that do not originate from the abdominopelvic region.

Septic shock: A condition caused by bacteraemia in the circulatory system. Characterised by persistent hypotension, reduced blood flow to organs, tissue and often organ dysfunction.

Trauma: An injury to living tissue caused by an extrinsic agent.

WSACS: World Society of Abdominal Compartment Syndrome

CHAPTER 1: INTRODUCTION

1.1 Background

This chapter provides the background for the series of studies presented in this thesis focusing on assessing intra-abdominal hypertension (IAH) and management of abdominal compartment syndrome (ACS). Firstly, the historical background and clinical challenges associated with IAH and ACS will be demonstrated, secondly the methodological approach and structure of the thesis will be presented, and finally the significance of this study will be discussed.

Intra-abdominal hypertension and abdominal compartment syndrome are increasingly recognised as complications for critical care patients requiring accurate diagnosis and timely management. Increases in IAP beyond normal physiological parameters can alter organ perfusion and as a consequence end organ function (Cheatham 2009, Cheatham 2010). The incidence of IAH is reported to be 50% of the critical care population. Of this 50%, 32.1% develop IAH and 4.2% develop ACS within their first 24 hours in the intensive care unit (ICU) (Malbrain, Cheatham et al. 2006, Kim 2012). This pathology is a frequent occurrence in critical care and it is essential for registered nurses to regularly monitor IAP and organ perfusion to predict adverse consequences and be proactive in the management of patients at risk (Spencer 2008, Cheatham 2009).

The concept of a compartment syndrome has long been recognised as a clinical phenomenon that occurs within the peripheral limbs (Lee 2012; Paula, 2014.

However, in the 1900s compartment syndrome was recognised as a phenomenon occurring within the abdomen. Compartment syndromes occur when a fixed compartment, defined by bone and myofascia, becomes subject to increased pressure which exceeds perfusion pressure. This increased pressure can potentially result in ischemia and organ dysfunction (Paula 2014).

In 1863 Marey followed by Paul Bert in 1870, identified the relationship of IAP to inspiratory and expiratory changes specifically showing the relationship of the type of respiration to intra-abdominal pressure (Coombs 1922). In 1873, Schatz and then Schroeder in 1886 suggested a connection between pregnancy and abdominal wall adjustment to accommodate changes in intra-abdominal pressure (Coombs 1922). Hasse in 1890, identified the relationship between inspiration, diaphragm flattening and intra-abdominal pressure. In the same year Heinricius found that there was a correlation between intra-abdominal pressure (27cm - 46cm) and decreased respiratory compliance. Emerson described the relationship of IAP to cardiac dysfunction in 1911. It was, Wendt in 1913 who for the first time identified that IAP was related to declining renal function (Coombs 1922, Saggi 2001).

In 1984, Kron and colleagues described the constellation of physical factors, known as ACS (Kron 1984). Since then the concept of IAP, IAH and ACS have become more accepted within the medical and nursing professions. In more recent times, Kron developed a simple measurement technique known as the "Modified Kron technique". This method of measurement has assisted in understanding the relationship between IAH, ACS and associated physiological impacts (Kron 1984, Iberti 1987, Iberti 1989, Saggi, Sugerman et al. 1998). The modified Kron technique is currently considered the gold standard for IAP measurements via the bladder (Kirkpatrick and Kimball 2013).

These advances in understanding of pathophysiology and sequelae have driven changes in diagnostic practices. As a consequence there is an increased awareness of IAH and ACS which has guided changes in treatment models for patients sustaining traumatic injury and those suffering from a critical illness (Malbrain 1999, Cheatham 2010).

Despite the increase in awareness and guideline recommendations, there remains some resistance to adopting regular screening and monitoring practices (Balogh and Leppaniemi 2009, Murcia-Saez 2010). Spencer, Kinsman & Fuzzard. (2008), surveyed 582 Australian critical care nurses. Of these 582 nurses, 62.1% (n=356) described their knowledge of ACS to be non-existent or limited. Within the same survey it was identified that there was a shortfall in nurses' knowledge in identifying patients in high risk groups and identifying the clinical manifestations of IAH and ACS (Spencer 2008).

1.2 Definition

Intra-abdominal pressure (IAP) is defined as the sustained pressure within the abdominal cavity (Kirkpatrick and Kimball 2013). The IAP can be measured using a variety of techniques. However, the World Society of Abdominal Compartment Syndrome (WSACS) endorses the Modified Kron Technique as the gold standard of measurement (Spencer 2008, Kirkpatrick and Kimball 2013).

The modified Kron Technique is an intra-bladder measurement where patient is placed in a supine position, a T-piece is connected to the urinary catheter, the urinary catheter drainage bag is clamped off, a pressure transducer is connected 25ml of water is instilled into the bladder via the urinary catheter. The transducer is placed at the sympysis pubis and a measurement is taken at end expiration (Kirkpatrick and Kimball 2013).

Figure 1.1: T-piece connection to urinary catheter

Figure 1.2: Urinary catheter drainage bag is clamped off and a pressure transducer is connected.

Figure 1.3: 25mL is instilled into the bladder via the urinary catheter

Intra abdominal hypertension is defined as the sustained or repeated pressure of ≥12mmHg. Abdominal compartment syndrome is a sustained or repeated pressure of >20mmHg, with or without an APP <60mmHg that is associated with a new organ dysfunction or failure (Kirkpatrick and Kimball 2013). A number of categories defines the severity of IAH: Grade I: IAP 12-15mmHg, Grade II: IAP 16-20mmHg, Grade III: IAP 21-25mmHg Grade IV: IAP > 25mmHg (Kirkpatrick and Kimball 2013).

Intra abdominal hypertension and ACS are further divided into primary or secondary origins. Primary IAH and ACS are conditions associated with injury or disease of the abdominopelvic region that often requires early surgical and/or radiological intervention. Secondary IAH and ACS refers to conditions arising outside the abdominopelvic region. The causes are diverse, intra-abdominal sepsis, peritonitis, cardiac arrest, thermal injuries and extra peritoneal trauma. The development of secondary IAH and ACS are related to shock requiring fluid resuscitation and is characterised by visceral, abdominal wall and retroperitoneal oedema. (Ball, Kirkpatrick et al. 2008, Kirkpatrick and Kimball 2013).

Recurrent IAH and ACS refers to IAH and ACS that redevelops following previous surgical or medical treatment of either condition (Kirkpatrick and Kimball 2013). Despite the fact that the bedside critical care nurse measures IAP there are few studies reflecting nurses' knowledge about IAP measurement, presentation or outcomes (Spencer 2008, Ejike 2010, Newcombe 2012).

As mentioned above, a study of Australian critical care nurses highlighted that the majority (n=356 or 62.1%) demonstrated limited knowledge. The same study identified that there was a shortfall of nurses knowledge not only in identifying patients in high risk groups but also and the clinical manifestations of IAH and ACS (Spencer 2008). These results are similarly reflected in international studies. Ejike et.al. (2010), surveyed 513 health care workers, 59.8% of these were paediatric registered nurses. The study demonstrated that 23% of participants were unaware of ACS, there were variances in measurement thresholds and there was a requirement for further education among health care workers.

The WSACS has commissioned a team of specialist critical care nurses, including Rosemary Lee, Leanne Hunt, John Gallagher and Kathleen Bombeke, to develop guidelines specifically related to the nursing management guidelines of IAH and the nursing management of the open abdomen. These guidelines were presented in 2015 at the WSACS conference in Ghent and are to be published on the WSACS website. This panel of experts identified that an educational package for critical care nurses' was necessary and one is currently being developed.

The modern intensive care unit (ICU) has developed significantly to allow for the improved detection and diagnosis of IAH and ACS. The difficulties in detection and diagnosis can be existing policies and procedures, clinician recognition of who requires monitoring, measurement techniques, and implementing appropriate interventions. Critical care nurses knowledge about IAH and ACS needs to be underpinned with appropriate education and practice guidelines. Without these educational standards presenting symptoms can be overlooked or misinterpreted as signs of other critical illness (Hunt 2016).

1.3 Problem statement

IAH and ACS can impact on the health outcomes of critically ill patients. Despite the fact that critical care nurses are responsible for measuring and reporting of IAP measurements, there is limited literature specifically focusing on registered nurses' knowledge regarding IAH and ACS. Furthermore, in spite of best practice guidelines, there is limited uptake of recommendations. The available evidence indicates that there are variances in knowledge regarding IAH and ACS definitions (Spencer 2008), IAP measurement techniques (Malbrain 2004, Malbrain 2006, Balogh, De Waele et al. 2007), the uptake of IAP monitoring the physiological impacts of IAH and ACS (Malbrain, Deeren et al. 2005, Malbrain, Cheatham et al. 2006, Malbrain 2008, Malbrain, De Laet et al. 2009). These knowledge gaps can lead to a delay in diagnosis, treatment, increased morbidity and mortality, increased health care cost and increased personal costs to the patient and their support system.

1.4 Study aims

This thesis addresses the scarcity of research by undertaking a series of discrete studies that address the following aims:

1. Define the pathophysiology, clinical manifestations and current treatment trends of IAH/ACS (Study 1, 2)
2. Discuss the state of the science and issues in implementations of best practice guidelines (Study 1,2)
3. Document the knowledge of critical care nurses and identify the barriers and facilitators to implementation of best practice guidelines (Study 2)
4. Refine the knowledge base of registered nurses' on best practice methods of assessment and identification of IAH/ACS (Study 5,6)

5. Identify consensus definitions and measurement of intra-abdominal hypertension and abdominal compartments (Study 1,5,6)
6. To identify the incidence of IAH and ACS, risk factors and mortality (Study 2,4,5,6)
7. Identify key area of future research to improve practice and patient outcomes. (Study 3,5,6)

1.5 Thesis structure

This thesis presents a series of discrete but linked studies that are organised in individual chapters. Each chapter outlines the methodological approach and provides an introduction and summary of each published study. Ethical issues, where appropriate to the study are addressed in each chapter and ethical approvals provided in Appendix 1.

- **Chapter 2 :Study 1**

  Hunt, L., Frost, S., Hillman, K., Newton, P., Davidson, P. (2014). Management of intra-abdominal hypertension and abdominal compartment syndrome: A review. *Journal of Trauma Management and Outcomes*. 8 (2). Online

  This study used an integrative literature review method to identify the evidence for the management of IAH and ACS. The study aims were to outline existing literature surrounding the etiology of intra-abdominal hypertension, IAP measurement strategies, manifestations of ACS and the importance of nursing observation, assessment and interventions. Establishing current research and practice is necessary to develop standards of care, to establish future research and improve patient outcomes

- ## Chapter 3: Study 2

Hunt, L., Frost, S., Newton, P., Salamonson, Y., Davidson, P. (2016). A survey of critical care nurses' knowledge of intra-abdominal hypertension and abdominal compartment syndrome. *Australian Critical Care.* [In press].

This survey was conducted among Australian critical care nurses. The aims were to assess the knowledge regarding current practice guidelines and identify barriers in recognising IAH and ACS and measuring IAP. The establishment of critical care nurses' knowledge regarding IAH and ACS establishes a platform for the development of specific education and practice guidelines.

- ## Chapter 4:Study 3

A retrospective analysis of trauma patients who require surgical intervention.

(Draft)

A retrospective analysis of trauma patients was conducted to document patients’ risk of developing IAH and ACS. The risk was measured against the mechanism of injury, type of injury and volume of intravenous fluid received.

- ## Chapter 5: Study 4

Hunt, L., Van Lunen, H., Alexandrou, E., Frost, S., Davidson, P., Hillman, K., D'Amours, S. (2012). A comparison of fluid instillation volumes to assess intra-abdominal pressure using Kron's methods. ***Journal of Trauma and Acute Care Surgery*****. 73(1):152-155.**

The WSACS suggests a standard protocol of 25mL sterile water instillation into the bladder to measure IAP. This study aimed to determine if a smaller volumes of instilled sterile water demonstrated comparable IAP measurements compared to the standard 25mL guidelines.

- **Chapter 6: Study 5**

Hunt, L., Frost, S., Alexandrou, E., Hillman, K., Newton, P., Davidson, P. (2014). Reliability of intra-abdominal pressure measurements using the modified Kron technique. ***Acta Clinica Belgica: International Journal of Clinical and Laboratory Medicine.*****70(2):116-120.**

Current WSACS guidelines recommend completing 1 IAP measurement 1 - 6 hours apart. This study aimed to assess the validity and reliability between 2 measurements within a single time period as an accurate indicator of a patients' clinical status.

- **Chapter 7: Conclusion**

This concluding chapter will integrate and synthesise the discrete studies and demonstrate the implications for policy, practice, education and research.

1.6 Significance and contribution of the thesis

This chapter has outlined that IAH affects organ function in critically ill patients and may lead to ACS. IAH and ACS can also occur in patients without abdominal conditions underscoring the importance of monitoring and assessment. IAP can be measured easily and reliably in patients through the bladder using simple tools and constitutes an important dimension of nursing assessment (Iberti 1987, Malbrain 2004, Syndrome. 2012, Hunt 2014). The adverse sequelae of an increased IAP are multiple, burdensome and costly, but renal dysfunction is of particular concern due to anatomical position and the adverse impact on health, particularly in critically ill patients.

Preventing ACS is an important dimension of improving health outcomes requiring an integrated, evidence based approach to improve the health outcomes and the quality of care. As IAP monitoring is a crucial step in managing IAH, reliable and valid means of measurement are required as well as strategies for implementation. As registered nurses are responsible for the monitoring and assessment of IAP it is important that they have the necessary knowledge, skills and attributes to perform assessment and implement evidence based strategies within the health care team.

This thesis advances the science by identifying the barriers and facilitators to evidence based care, assessing measurement strategies and identifying trends in individuals with IAH and ACS. The following chapter provides the background and context for the following studies through undertaking an integrated literature review outlining the pathophysiology, prevalence and burden of ACS.

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Chapter Two

Publication Title: Management of intra-abdominal hypertension and abdominal compartment syndrome: a review

This chapter introduces the article presented as an original reprint published in the *Journal of Trauma Management & Outcomes*.

Citation: Hunt, L., Frost, S. A., Hillman, K., Newton, P. J., & Davidson, P. M. (2014). Management of intra-abdominal hypertension and abdominal compartment syndrome: a review. *Journal of Trauma Management & Outcomes*, *8*(1), 1. (14577 views and 14 citations as of 16/7/16)

2.1 Introduction

The diagnosis of intra-abdominal hypertension (IAH) and abdominal compartment syndrome (ACS) are increasingly recognised as an important paradigm in caring for critically ill patients. This chapter reports on an integrative literature review and outlines the current science on intra-abdominal hypertension and abdominal compartment syndrome.

IAH and ACS can impact on organ perfusion and as a result end organ function and consequently can be life threatening to critically ill patients (Cheatham 2009, Cheatham 2010). As described in the previous chapter, the notion of IAH and ACS was recognised in the late 1800's and early 1900's however, the impact on patients physiological status has only been established in the past 15 - 20 years (Coombs 1922, Paula 2014).This increase has been, in-part, due to the improvement in diagnostic practices and changes in treatment paradigms in patients sustaining traumatic injury and those with critical illness (Malbrain 1999, Cheatham 2009).

Despite this increase in awareness and guideline recommendations there is limited research relating to the role of nurses when caring for patients with IAH or ACS and there remains some resistance to adopting regular screening and monitoring practices (Malbrain 2014). The pathology is a frequent occurrence in critical care patients and it is essential for nurses to regularly monitor intra-abdominal pressure (IAP) to predict adverse consequences and be proactive in the management of patients at risk (Spencer 2008, Cheatham 2009).

2.2 Summary of findings

A total of 53 papers were reviewed. Due to editorial restrictions the published manuscript figure 1 "flowchart of study selection process" appears to have a discrepancy with the total number of papers included in the literature review. The search originally included 814 articles, 226 duplicates, 214 did not meet the inclusion criteria and 374 were excluded based on the criteria documented in the literature review. Data derived from the retrieved material were discussed under the following themes: (1) aetiology of intra-abdominal hypertension; (2) strategies for measuring intra-abdominal pressure (3) the manifestation of abdominal compartment syndrome; and (4) the importance of nursing assessment, observation and interventions. Intra-abdominal pressure (IAP) and abdominal compartment syndrome (ACS) have the potential to alter organ perfusion and compromise organ function.

Critically ill patients, and more specifically patients suffering from trauma related events, were found to be at the highest risk of developing ACS. The review found that there are clear definitions and management guidelines for IAH and ACS developed by consensus methods and published by the WSACS (Kirkpatrick and Kimball 2013). The study identified the gold standard for IAP measurement is done via the bladder using the Modified Kron technique.

However, there are variances in the techniques used to measure IAP, providing justification and context for Studies 5 & 6 which are reported in Chapters 6 & 7.

2.3 Conclusion

Critical care nurses measure IAP using the modified Kron technique and thus play an important role in the recognising and managing IAH and ACS. Despite the importance of this role, this review identified that nurses' knowledge about IAH and ACS was limited. In order to develop and refine strategies for IAH and ACS management, a survey of critical care nurses' knowledge of intra-abdominal hypertension and abdominal compartment syndrome was undertaken in the Australian context. This study was undertaken with the support of the Australian College of Critical Care Nurses (ACCCN). ACCCN is a not for profit membership-based organisation representing over 2,300 nurses nationally. ACCCN's members work across the critical care clinical spectrum, principally in the area of intensive care, in clinical, educational, management, and research roles. It was considered that this platform would not only be a mechanism for engaging critical care nurses but also stimulating interest in this important area of patient management. The aims, method and results of this survey are outlined in Chapter 3.

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REVIEW Open Access

Management of intra-abdominal hypertension and abdominal compartment syndrome: a review

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Abstract

Patients in the intensive care unit (ICU) are at risk of developing of intra abdominal hypertension (IAH) and abdominal compartment syndrome (ACS).

Aim: This review seeks to define IAH and ACS, identify the aetiology and presentation of IAH and ACS, identify IAP measurement techniques, identify current management and discuss the implications of IAH and ACS for nursing practice. A search of the electronic databases was supervised by a health librarian. The electronic data bases Cumulative Index of Nursing and Allied Health Literature (CINAHL); Medline, EMBASE, and the World Wide Web was undertaken from 1996- January 2011 using MeSH and key words which included but not limited to: abdominal compartment syndrome, intra -abdominal hypertension, intra-abdominal pressure in adult populations met the search criteria and were reviewed by three authors using a critical appraisal tool. Data derived from the retrieved material are discussed under the following themes: (1) etiology of intra-abdominal hypertension; (2) strategies for measuring intra-abdominal pressure (3) the manifestation of abdominal compartment syndrome; and (4) the importance of nursing assessment, observation and interventions. Intra-abdominal pressure (IAP) and abdominal compartment syndrome (ACS) have the potential to alter organ perfusion and compromise organ function.

Keywords: Intra-abdominal pressure, Intra-abdominal hypertension, Abdominal compartment syndrome, Abdominal perfusion pressure

Background

The importance of the diagnosis and management of intra-abdominal hypertension (IAH) and abdominal compartment syndrome (ACS) is increasingly recognised. These conditions can alter organ perfusion and as a consequence end organ function. Complications resulting from IAH and ACS can be life threatening to critically ill patients [1,2]. Intra abdominal hypertension and ACS have been recognised since the 1800 s [1,2] however, it has only been the past 15 years that the physiological complications of IAH and ACS and the impact these can have on patients has been appreciated. Furthermore, there is limited data published specific to the nursing role in IAH and ACS.

The increase in awareness of IAH and ACS is due to improvements in diagnostic practices and changing treatment paradigms in patients sustaining traumatic injury and those with critical illness [2,3]. Despite the increase in awareness and guideline recommendations, there remains some resistance to adopting regular screening and monitoring practices [4,5]. Spencer et al. [6], in an Australian survey of 582 critical care nurses that the majority (356 or 62.1%) described their knowledge of ACS to be non-existent or limited. Within the same survey it was identified that there is a shortfall in nurses' knowledge in identifying patients in high risk groups and the clinical manifestations of IAH and ACS. The incidence of IAH in critical care patients is reported to be 50%, of these 50%, 32.1% develop IAH and 4.2% develop ACS within their first day of ICU [7,8]. The pathology is a frequent occurrence in critical care it is essential for nurses to regularly monitor IAP and organ perfusion to predict adverse consequences and be proactive in the management of patients at risk [2,6].

This review seeks to define IAH and ACS, identify the etiology and presentation of IAH and ACS, identify IAP measurement techniques, identify current management

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and discuss the implications of IAH and ACS for nursing practice.

Method

An integrative review is a method that permits the inclusion of a range of study designs to provide an inclusive evaluation [9]. This process is particularly informative in intervention development. Following consultation with a health care librarian, the electronic databases CINAHL, Medline, Embase and the Internet were searched databases were searched from 1996 to July 2013. Key word searches of the electronic databases included; abdominal compartment syndrome, abdominal pressure, peritoneal cavity, compartment syndrome, decompression surgery, practice guideline, multiple organ failure, abdominal injury, intensive care, critical illness, risk factors, treatment outcomes, intensive care unit, nursing, nursing care, intra-abdominal hypertension, intra-abdominal pressure, abdomen, critical care, critical illness, wounds and injuries nursing assessment, hypertension. Database searches were limited to the English language and humans. The reference lists of published materials were searched for additional literature. Journals held locally were hand searched for relevant articles. The World Wide Web was searched using Google Scholar and Yahoo search engines for peer reviewed related electronic documents. All abstracts were reviewed for relevance to the aims of the review.

Using the stated search strategy 514 articles were retrieved. Abstracts were reviewed for relevance to the review aims. Sixty five articles provided information describing the nursing role, the description of the assessment process, diagnosis and management of IAH and ACS (Figure 1). The results of the search were analysed by the authors using content analysis driven by the research questions and aims of the study.

A narrative review of the articles is presented and organised into the following themes: (1) Diagnosis of intra abdominal hypertension; (2) etiology of intra-abdominal hypertension; (3) strategies for measuring intra-abdominal pressure; (4) the manifestations of abdominal compartment syndrome; and (5) the importance of nursing assessment, observations and intervention.

Results

Diagnosis of intra abdominal hypertension

Intra-abdominal pressure is defined as the pressure created within the abdominal cavity the normal IAP for critically ill adults is 5–7 mmHg [10,11]. Intra-abdominal hypertension is a sustained or repeated IAP > than 12 mmHg [11]. There are various grades of IAH, Grade 1 IAP 12–15 mmHg, Grade 2 IAP 16–20 mmHg, Grade 3 IAP 21–25 mmHg and grade 4 an IAP > 25 mmHg [10-12]. The IAP measurement is completed twice over a period of 1 – 6 hours [13]. If IAP measurements are >12 mmHg but >20 mmHg the WSACS suggest IAP measurements

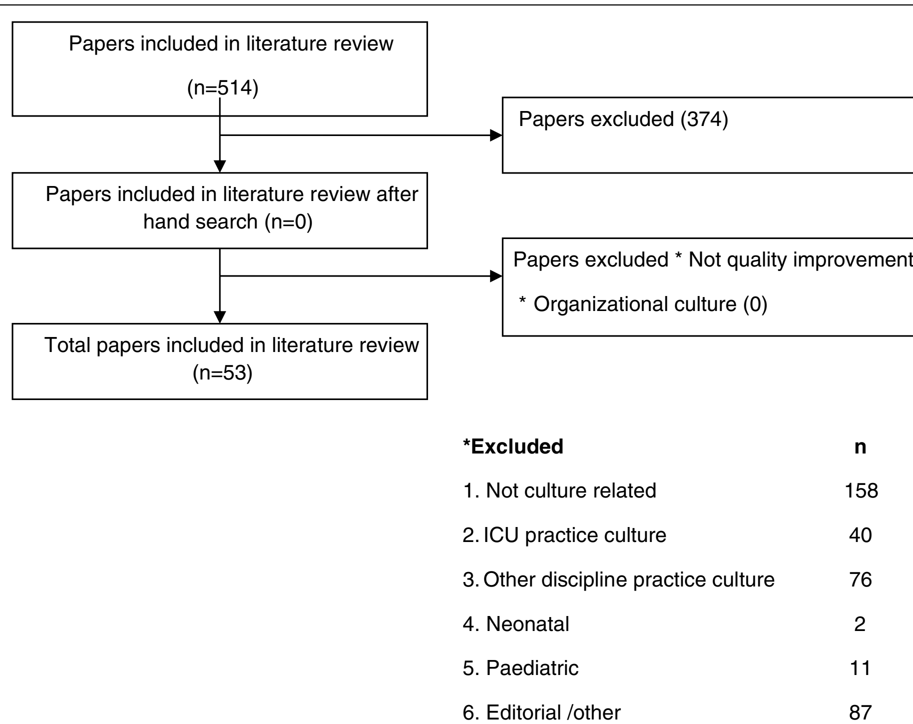

Figure 1 Flowchart of study selection process.

fourth hourly whilst the patient is critically ill, avoid excessive fluid resuscitation and optimize organ perfusion [10,11].

Etiology of intra abdominal hypertension

There are multiple physiological factors that have the potential to alter an individual's intra-abdominal pressures (IAP). These factors can be categorised as those that are related to;

1. A decrease in abdominal wall compliance.
2. An increase in intraluminal contents.
3. Capillary leakage or fluid resuscitation see Table 1.

Whilst there are no risk prediction models that will assist in identifying IAH or ACS, elevated peak ventilation pressures, decreased urine output, hypothermia, coagulopathy and acidosis have been described in several studies as the key indicators of an increased mortality [14-17]. These same studies suggest early recognition and management of hypothermia coagulopathy and acidosis could result in an overall reduction in in mortality [14-17].

Intra-abdominal pressure measurement

Measurement of IAP is simple, inexpensive, safe and accurate method in determining the presence of IAH. This measurement can guide patient management [2,10,18,19]. The WSACS has recommended the use of a standardised protocol despite this recommendation across centers there is minimal standardisation of the methods of assessment [7]. Techniques are influenced by measurement accuracy and reproducibility, budget constraints for equipment and staff training and ease of use of the chosen method of measurement [7].

Historically physical observation and measurement of abdominal girth were used to determine the presence of IAH. This method of measurement is inaccurate due to a high risk of variability and low inter-rater reliability [19,20]. A range of approaches to measure IAP include intra gastric, intra rectal, inferior vena cava and via a urinary indwelling catheter pressure monitoring systems [18,20].

The WSACS advocates the use of the modified Kron technique as the gold standard of IAP measurement [2,10,11]. The Kron method assesses the IAP via bladder pressure measurement using a maximum instillation of 25 ml of sterile saline [11]. The measurement is taken;

1. With the transducer zeroed and positioned in line with the iliac crest and mid-axillar.
2. With the patient in a supine position.
3. At end-expiration.
4. With an instillation volume of no greater than 25 mL of saline (for bladder technique).

Table 1 Physiological factors impacting on intra abdominal pressure (IAH)

Related to diminished abdominal wall compliance	• High BMI
	• Pregnancy
	• Mechanical ventilation
	• The use of PEEP or when auto PEEP is present
	• Basal pneumonia
	• Pneumoperitoneum
	• Abdominal surgery particularly with tight abdominal closures
	• Pneumatic anti shock garments
	• Prone positioning
	• Abdominal wall bleeding or abdominal hematoma
	• Burns with abdominal eschars
Related to increased intra-abdominal contents	• Gastro paresis
	• Gastric distension
	• Ileus
	• Volvulus
	• Bowel pseudo obstruction
	• Abdominal hematoma
	• Intra-abdominal or retroperitoneal hematoma
	• Damage control laparotomy
	• Liver dysfunction with ascites
	• Abdominal infection (peritonitis, pancreatitis)
	• Hemoperitoneum
	• Pneumoperitoneum
	• Major trauma
	• Excessive inflation during laparoscopy
	• Peritoneal dialysis
Related to capillary leak and fluid resuscitation	• Acidosis (pH below 7.2)
	• Hypothermia (core temp below 33°
	• Coagulopathy
	• Multiple transfusions/trauma (>10 units in 24 hours)
	• Sepsis, severe sepsis or bacteraemia
	• Septic shock
	• Massive fluid resuscitation (>5 L colloid or > L crystalloid in 24 hours in the presence of capillary leak and a positive fluid balance)
	• Major burns

5. 30–60 seconds after instillation to allow for bladder detrusor muscle relaxation (for bladder technique) [1,10-12,16,20-22].

The reliability of the intermittent measurement guidelines set down by WSACS has been challenged [22,23]. More recently, the technology of continuous IAP monitoring has been suggested to be superior to the intermittent technique [23]. The continuous method allows for continuous analysis of the IAP via the bladder and eliminates the risk of missing elevations in IAP due to timing, which can occur with intermittent techniques [10,13,24]. Continuous methods have been used via the gastric route and invasive direct measurements, but measurements using these techniques showed poor reproducibility [23,25]. However a recent study showed comparable results between the traditional Kron technique and continuous direct intra-abdominal technique [26]. The agreement of continuous bladder IAP measurements to the current gold standard of intermittent measurements is reliable [24,27,28]. The continuous IAP measurement technique requires insertion of the more expensive three way catheter, which could be the cause of its limited use [24,25].

There is also a range of opinions regarding the volume of fluid required to be instilled into the bladder to format an accurate pressure reading. Volumes as low as 2 ml have been used to measure IAP and results are comparable to the use of 25 ml of normal saline [29]. Fluid volumes above 25 ml have the potential to mislead treatment due to overestimation of the IAP [24,29,30]. Current guidelines suggest a maximum volume of 25 ml of fluid be instilled into the bladder for IAP measurement [11].

There are a select few patients in whom IAP measurement via the direct bladder method is not feasible. These include patients with a ruptured bladder, intra bladder hematoma, neurogenic bladder, recent bladder surgery and uro-genital anomalies [31-33]. As suggested by Malbrain et al. [11], the best technique to measure IAP is one critical care nurses will use in their nursing practice [19].

What is abdominal compartment syndrome

Abdominal compartment syndrome is defined as a sustained IAP greater than 20 mmHg with a new organ dysfunction or failure regardless of abdominal perfusion pressure (APP) [1,2,6,10,12,13,15]. For example, the development of renal failure, respiratory failure or an unexplained metabolic acidosis. The WSACS suggests using these absolute value as a guide when defining ACS recommending that if the patient exhibits signs of new organ dysfunction or failure that this is more clinically significant than an absolute value [10,11].

Abdominal compartment syndrome is further classified into three groups primary, secondary and recurrent ACS.

Primary ACS

Primary ACS occurs as a result of injury or disease to the abdominal or pelvic region that frequently requires early radiological or surgical intervention or, conditions that develop post abdominal surgery requiring surgical intervention [2,7,10,11]. Included in primary ACS are patients who are managed non-operatively for organ damage who then go on to develop ACS. This category can include patients with abdominal trauma, abdominal lesions, retroperitoneal hematoma and those associated with damage control during a laparotomy procedure [2,11,12,34].

Secondary ACS

Secondary ACS is an often unavoidable progression of the ICU patient's pathology and refers to conditions that do not originate from the abdominal or pelvic region [11]. Secondary ACS occurs in the absence of any abdominal injury. This can include patients who have sepsis, pancreatitis or have had excessive fluid resuscitation [2,10,13,35].

Recurrent ACS

Recurrent ACS is the reoccurrence of ACS after surgical or medical treatment of either primary or secondary IAH or ACS [2,10-12,34].

Abdominal perfusion pressure (APP)

The abdominal perfusion pressure (APP) has been identified as an indicator for adequate abdominal perfusion [10,36]. Abdominal perfusion pressure indicates the pressure available for perfusion of intra abdominal organs [10,12]. Abdominal perfusion pressure is calculated using the formula mean arterial pressure MAP – IAP [10,11]. Abdominal perfusion pressure has previously been suggested as a more accurate indicator of IAH severity and indicates the degree of abdominal tissue perfusion [36]. Malbrain and colleagues have also previously recommends that APP should be maintained between 50–60 mmHg for patients with IAH who do not require immediate intervention [8,10,19]. Cheatham et al. and Spencer et al. also suggest that patients with IAH who are unable to maintain an APP above 50 mmHg require surgical intervention [6,36]. More recent studies have suggested that patients with an APP greater than 60 MmHg have shown a reduction in the incidence of renal failure [2,6,10]. Despite these studies the WSACS 2013 consensus management statement could make no recommendations for the use of APP in the resuscitation or management of patients [11].

Indications for IAP monitoring

There is considerable debate regarding the applicability of absolute IAP ranges in the management of critically ill patients [4,6]. As suggested by multiple authors [4,6,8,10,18], an IAP >20 mmHg can cause significant physiological disturbance in critically ill patients. However, there are also patients with this same elevation in IAP that show no such derangement. Due to differences in clinical presentations there appears to be a lack of clinical awareness hence failure to recognise IAH and ACS [7,14,37]. The WSACS has developed definitive evidence based IAH assessment, IAH and ACS management algorithms and a non-operative management algorithm to improve awareness and management of patients at risk of IAH and ACS [10,11].

Identifying patients at risk is the initial step in the recognition and diagnosis of these pathologies [10]. It is essential that patients are screened for the presence of IAH or ACS upon admission to ICU and additionally in the presence of new or progressive organ failure [2,12,38]. The WSACS suggests assessment for risk factors of IAH and ACS on admission to ICU and for the duration of the patients critical illness [10]. Post assessment if there are two or more risk factors present or there is a new or progressive organ failure then a baseline IAP measurement should be taken then the assessment algorithm should be implemented [10]. If IAH is present medical management should be implemented to reduce IAP, measurements should be taken 4–6 hourly or continuously [10]. For patients with an elevated IAP monitoring should occur throughout the patients critical illness [10].

There are recognised independent risk factors for the development of IAH and ACS [10] (See Table 1). In addition to these independent risk factors IAP monitoring is also suggested for patients with open or blunt abdominal trauma, those who have a high body mass index (BMI), those who sustain burns, or hypotensive for whatever reason, those patients with mesenteric ischemia or patients with an elevated ICP [7,10].

Implications for nursing practice

In spite of the diverse literature discussing IAH and ACS, there is limited literature specific to the nursing care for patients with IAH or ACS. Patients with IAH or ACS will be most frequently encountered in ICU, high dependency units (HDU), coronary care units (CCU) and emergency departments (ED). Recently, it has been proposed to expand IAP and ACS monitoring beyond traditional critical care areas to enable early detection of the clinical deterioration in in susceptible patients thus improve patient outcomes [32,39].

The complex presentation of patients with IAH or ACS requires an advanced practice nurse's clinical expertise and vigilant monitoring is essential [6,21]. Advanced practice nurses possess superior assessment and decision making skills, critical thinking and communication expertise that is imperative in an often unpredictable critical care environment [40]. Advanced nursing practice allows expert nurses to demonstrate increased clinical discretion, responsibility and autonomy when recognising, assessing, and managing patients with IAH or ACS [41].

Specific nursing management is focused on assessing organ function, pain management, vital signs, perfusion to the lower extremities, assessment of wound drainage and output, ongoing assessment for reoccurrence of IAH or ACS and provision of support to patients and their families [6,42,43].

Organ function

Due to the adverse effects of IAH and ACS on patient morbidity and mortality (See Table 2), there is a need for advanced practice nurses to assess and manage patients using evidence based protocols [38].

Patients with ACS are often managed with pharmacological, technical, medical and surgical procedures [11,44,45]. Pharmacological support for patients with IAH or ACS is multi-faceted and entails active and precise fluid resuscitation to maintain adequate circulating volume without fluid overloading, medications to support cardiac output in the event of decompensation and antibiotics to treat infections [6,42,46-48]. In the context of a critical illness, technical support involves ventilator support, continuous renal replacement therapy (CRRT), invasive cardiac monitoring, arterial blood gas interpretation and intervention, blood glucose monitoring and treatment of electrolyte disturbances [6,42,49].

A non- surgical approach is generally used in patients with no abdominal injuries and may involve the insertion of a percutaneous drain for fluid removal [44,48,50,51]. Current guidelines suggest that when IAH or ACS has been established and intra peritoneal fluid has been confirmed percutaneous drainage should be undertaken as it may negate the need for decompressive laparotomy [11]. Other measures endorsed by the WSACS include the judicious use of fluids, endogastric tube insertion, laxative usage, pain relief and muscle relaxants [6,8,11,32,48,52]. Whilst other measures such as CRRT, diuretics and albumin are being used to manage patients the WSACS could make no recommendations regarding their use [11,49]. Another non-surgical approach to prevent and manage IAH and ACS is damage control resuscitation. Damage control resusitation is chacterised by permissive hypotension, limitation of crystalloid infusion and the administration of higher ratios of plasma and platelets to red blood cells [17,53]. The WSACS suggests a higher ratio of plasma and packed red blood cells as opposed to limited or no use [11].

Surgical management involves decompression of the abdomen [17,54]. Decompression occurs in cases of trauma with abdominal injuries or where the patient's clinical condition continues to deteriorate while using non-surgical management techniques. Decompression is aimed at restoring organ perfusion and ultimately organ function. Early surgical decompression of the abdomen is considered a therapeutic intervention and a definitive

Table 2 Adverse effects of intra abdominal hypertension (IAH) and abdominal compartment syndrome (ACS)

Cerebral	• An Increase in IAP forces the diaphragm up decreasing intra-thoracic space, increasing the intra-thoracic pressure.
	• Jugular venous pressure elevates.
	• Venous return decreases.
	• Intra cerebral pressure will increase.
	• Cerebral blood flow decreases.
Cardiac function	• An increase in IAP causes increased pressure on the inferior vena cava, intra abdominal circulation and perfusion.
	• Venous return is impaired and peripheral oedema occurs.
	• Increase in central venous pressure.
	• Increased pulmonary artery wedge pressures as the myocardium is placed under an increasing workload.
Respiratory function	• An increased in IAP forces the diaphragm up decreasing intra-thoracic space and restricts respiration.
	• Result in an increase in intra thoracic pressure particularly with mechanically ventilated patients.
	• Left uncorrected will result in a decrease in lung compliance, functional residual capacity a VQ mismatch and hypoxia.
Renal function	• Defined as oliguria and anuria despite aggressive fluid resuscitation.
	• Increase in abdominal pressure decreases renal blood flow coupled with a reduction in cardiac output.
	• The rennin angiotensin system is activated further adding to intra- abdominal pressure and cardiac workload.
Gastrointestinal function	• Increased intra- abdominal pressure results in an increase in vascular resistance and decreased cardiac output.
	• Results in a decrease in tissue perfusion.
	• Ultimately tissue ischemia.
Peripheral perfusion	• Increased intra- abdominal pressure is said to increase femoral venous pressure increase peripheral vascular resistance and reduce femoral artery blood flow by up to 60%.

treatment for ACS and is performed when ACS is unresponsive to medical treatment options [1,10-12,52]. This is recommended despite reported complications and 50% mortality rates [11,52]. Decompression often results in the abdomen being left open followed by other surgical procedures [6,10,15,32,55-57]. Presumptive decompression should be considered at the time of laparotomy for patients who demonstrate risk factors for ACS [7,58]. After a decompression procedure where the abdomen is left opened there is limited literature guiding definitive abdominal closure. It has been suggested that closure is possible within 5–7 days of decompression if the patient underwent early decompression prior to the development of significant organ injury [7,58]. However, optimal timing of closure is dependent upon normalisation of IAP [6].

Damage control laparotomy for trauma patients is used as a measure to control hemorrhage and restore metabolic function and is supported as a resuscitative procedure by the WSACS [11,17,59]. Current guidelines suggest this method should be used when the patient is physiologically fatigued with the abdomen to remain prophylactically opened to avoid IAH [11].

The role of the nurse is to assess, interpret and titrate therapy according to the patients' organ function [6,42]. Nursing care of the patient with an open abdomen involves the management of complex wounds, negative pressure systems, assessment of vascular supply to the wound, wound drainage, dressing integrity, patient positioning, and assessing for recurrence of ACS [6,42]. Unless contraindicated, nasogastric feeding should be considered to optimise gastrointestinal function [60,61].

Implications for further research

The research surrounding the care of the patient with IAP and ACS is limited and hence, further research is required. This research will;

1. Improve the body of knowledge about IAH and ACS within nursing.
2. Provide nurses with the knowledge to identify patients at risk.
3. Improve patient outcomes.

Intra-abdominal hypertension and ACS are potential life threatening conditions to critically ill patients. Critical care nurses have the ability to identify IAH and ACS, implement and evaluate management interventions. Nursing practice should be centered on evidence based practice guidelines [62]. Nurses should provide a standard of care in managing patients who are at risk of IAH and ACS from pre-hospital, emergency, operating theatre and intensive care areas.

Further research is required on the minimum volume of fluid needed to measure IAP via the intra bladder technique, the assessment of the reliability of a single IAP measurement, and a comparison of intra bladder and intra gastric IAP to establish the validity of an alternative route in measuring IAP.

Conclusion

The pathological characteristics of IAH and ACS have the potential to cause multi organ failure and subsequently increase patient mortality. Monitoring IAP and APP for signs of ACS has become an inexpensive and useful diagnostics tool for identifying complications. An integrated approach to screening and monitoring for IAH may improve patient outcomes and decrease hospital costs. Due to the high incidence of IAH and ACS, it is essential for critical care nurses to regularly monitor IAP and APP. Critical care nurses require advanced clinical practice, skills, knowledge and awareness of the pathological signs, symptoms and complications of IAH and ACS.

Key points

- Intra-abdominal hypertension (IAH) and abdominal compartment syndrome (ACS) occur frequently in critical care and can alter organ perfusion and end organ function.
- Measurement of Intra-abdominal pressure (IAP) is done via the bladder using the modified Kron technique.
- Abdominal compartment syndrome (ACS) is classified as an IAP greater than 20 mmHg with a new organ dysfunction.
- Critical care nurses play a significant role in the recognition and management of IAH and ACS.

Competing interests
The authors declare that they have no competing interests.

Authors' contributions
LH: Study design, data analysis and interpretation, manuscript preparation. SAF: Study design, interpretation of data, manuscript preparation. KH: Study design, interpretation of data, manuscript preparation. PJN: Interpretation of data, manuscript preparation. PMD: Study design, interpretation of data, manuscript preparation. All authors read and approved the final manuscript.

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Chapter Three

Publication title: A survey of critical care nurses' knowledge of intra-abdominal hypertension and abdominal compartment syndrome.

This chapter introduces the article presented as an original reprint published in *Australian Critical Care.*

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3.1 Introduction

As identified in chapter 2 the importance of IAP measurement and management of IAH and ACS has increased significantly over the past 20 years and has have become accepted practice within the area of critical care. Critical care nurses' play an important role in the measurement of IAP and the reporting and management of IAH an ACS (Kron 1984, Malbrain 1999, Thomas 1999, Malbrain 2004, Malbrain 2006). Both IAH and ACS are potentially life-threatening conditions. Therefore, it is necessary for critical care nurses to understand the factors that predispose patients to IAH and ACS, and to be vigilant when assessing patients to predict those patients at risk of these conditions and to manage patients appropriately (Lozen 1999, Hunt 2014).

Critical care nurses' knowledge about IAH and ACS needs to be underpinned with a comprehensive understanding of pathophysiology and related knowledge of evidence based clinical practice guidelines (Thomas 1999, Sugrue 2002, Kirkpatrick and

Kimball 2013, Hunt 2014). Without this fundamental knowledge and understanding, presenting symptoms can be overlooked or misinterpreted as signs of other critical illness (Spencer, Kinsman & Fuzzard, 2008).

3.2 Summary of findings

Eighty two critical care nurses (3.2%) responded to the survey distributed through the ACCCN membership list. Findings show that nurses overall knowledge about IAH and ACS was lower than anticipated. However, there was no correlation between this finding and years of experience. This had no correlation to years of experience or the possession of a post-graduate qualification. The findings of this study also demonstrated that nurses were carrying out IAP measurements but did not possess the knowledge underpinning the recognition of IAH and ACS. Critical care nurses were able to identify some obvious causes of IAH but were unable to identify less apparent causes. These findings corroborate the findings of (Diaz 2006, Spencer 2008, Ejike, Newcombe et al. 2010)

3.3 Conclusion

Critical care nurses' identified a lack of evidence-based guidelines, policies and procedures and educational support as barriers to monitoring IAP. This underscores the importance of supporting nurses to provide evidence based care. Providing expert clinical care is often dependant on pattern recognition and prior experience (Elstein,2002). Study 3, reported in Chapter 4 retrospectively analysed and documented the development of IAH and ACS outcomes in trauma patients over a 9 year period. Specifically analysis was completed on the mechanism of injury, type of injury and volume of intravenous fluid received, in relation to the patient's risk of developing abdominal compartment syndrome. Undertaking this method of assessment is critical in developing decision making models and providing information and resources to clinicians.

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Review Paper

A survey of critical care nurses' knowledge of intra-abdominal hypertension and abdominal compartment syndrome

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ABSTRACT

Background: Intra-abdominal hypertension and abdominal compartment syndrome are potentially life threatening conditions. Critical care nurses need to understand the factors that predispose patients to intra-abdominal hypertension (IAH) and abdominal compartment syndrome (ACS). Predicting and managing IAH and ACS are important to improve health outcomes.
Aim: The aim of this paper was to (1) assess the knowledge of Australian critical care nurses about current IAH and ACS practice guidelines, measurement techniques, predictors for the development of IAH and ACS and (2) identify barriers in recognizing IAH, ACS and measuring IAP.
Methods: Between October 2014 and April 2015 86 registered nurses employed in the area of critical care were recruited via the form to participate in an on-line, 19-item questionnaire. The survey was distributed to critical care nurses via the Australian College of Critical Care Nurses (ACCCN) mailing list and directly to intensive care units via The majority of participants were women (n = 62) all participants were registered nurses employed in critical care the response rate was 3.2%. The study design was used to establish demographic data, employment data, and individuals' knowledge related to IAH and ACS. Participants had the option to write hand written responses in addition to selecting a closed question response.
Results: The results showed that most survey participants were able to identify some obvious causes of IAH. However, less than 20% were able to recognize less apparent indices of risk. A lack of education related to IAP monitoring was identified by nearly half (44.2%) of respondents as the primary barrier to monitoring IAP.
Conclusion: Critical care clinicians' knowledge of IAH and ACS is generally low in the areas of presentation and outcomes of IAH and ACS requiring tailored and targeted educational interventions.

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Chapter Four

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4.1 Introduction

As discussed in the previous chapters, IAH and ACS are potentially life-threatening conditions. Trauma patients are at particular risk of developing these conditions due to factors such as massive haemorrhage, shock, acidosis, coagulopathy, decreasing splenic perfusion, tissue ischemia, decreased thoracic compliance, decreased ventilation and decreased oxygenation (Meldrum, Moore et al. 1997, Malbrain, Cheatham et al. 2006, Cheatham 2009, Malbrain & De laet 2009, Cheatham 2010, Kirkpatrick and Kimball 2013)

The risk of development of IAH and ACS in trauma patients is influenced by the type and severity of injury, the volume of fluid resuscitation and the delay to diagnosis and intervention. Therefore early identification and management of patients at risk of developing IAH or ACS can improve morbidity and mortality (Ertel 1998, Balogh, McKinley et al. 2003, Kirkpatrick and D'Amours 2008, Carr 2013, Kirkpatrick and Kimball 2013).

The literature review presented in chapter 2 identified patients who are critically ill as being at risk of developing IAH and ACS. Chapter 3 recognised the importance of existing guidelines for patients at risk of developing ACS and supporting nurses to provide evidence based care. This chapter discusses a registry review of trauma patients conducted to assess the mechanism of injury, type of injury and volume of fluid received in relation to the patient's risk of developing ACS signifying the importance of monitoring, intervention and evidence based guidelines.

4.2 Summary of findings

During a 9 year period in the study setting, 787 trauma patients received a laparotomy. Of these, 105 were considered at risk of developing ACS. Motor vehicle accident (MVA) represented the highest mechanism of injury in this group, and abdominal trauma was the most frequently occurring injury. Poly-transfusion has been found to cause significant physiological changes specifically abdominal oedema resulting in IAH or ACS (Holodinsky et.al. 2013, Iyer et.al. 2014).

4.3 Conclusion

This registry review identified that trauma was often a pre-cursor to the development of IAH and ACS and the factors impacting on the development of IAH and ACS were multi-factorial. This highlights the need for nurses to be vigilant when monitoring critical care patients. Chapter 6 reports the findings of a study (Study 5) challenging the current guidelines set by the WSACS for the measurement of IAP.

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Title: A retrospective analysis of trauma patients requiring surgical intervention

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Conflict of interest

No conflict of interest has been declared by the authors.

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Abstract

Background: Patients sustaining trauma are at an increased risk of intra-abdominal hypertension and abdominal compartment syndrome. This retrospective study aims to document the mechanism of injury, type of injury and volume of fluid received in relation to their risk of developing intra abdominal hypertension and abdominal compartment syndrome.

Aims: This retrospective study aims to document the findings of an existing trauma database. The mechanism of injury, type of injury and volume of fluid received, in relation to the patient's risk of developing intra abdominal hypertension or abdominal compartment syndrome.

Methods: This retrospective consecutive cohort study used a trauma database of an academic health centre. Data was collected over a 9 year period on, the number of trauma admissions, mechanism of injury, specific patient injuries, risk of developing intra abdominal hypertension and abdominal compartment syndrome and volume of fluid received.

Results: Over a 9 year period there were 31 819 trauma admissions recorded. Motor vehicle accidents were the most frequent mechanism of injury and abdominal injuries were the most frequently occurring injury. Patients who developed primary abdominal compartment syndrome (*n* = 4, 0.5%) received an average of 2.3L of fluid pre-hospital and 1.6L of fluid in emergency. Patients who developed secondary ACS (*n* = 8, 1%) received 1litre in the pre-hospital period and 2.4L of fluid in emergency. Patients identified at risk of developing IAH or ACS (*n* = 76, 9.6%) received 1.5L of fluid pre-hospital and 3L of fluid in emergency.

Conclusion: Abdominal trauma is associated with IAH and ACS. Excessive fluid resuscitation is associated with the development of IAH and ACS. However, fluid resuscitation is often a requirement for patient stabilisation and appropriate for the level of traumatic injury the patient has sustained. Clear and standardised guidelines are required for trauma data collection to enable more accurate analysis of patient information.

Keywords: Intra abdominal pressure, intra abdominal hypertension, abdominal compartment syndrome, trauma, fluid resuscitation

Intra abdominal hypertension (IAH) and abdominal compartment syndrome (ACS) are important predictors of patient outcomes. There is evidence that IAH and ACS contribute to patients' morbidity and mortality through the effects on end organ function secondary to pathophysiological changes (1-6). It has been shown that early identification and management of patients at risk of developing IAH or ACS can improve patient outcomes (7-9).

Patients who suffer trauma are at an increased risk of developing IAH and ACS (2, 3, 5, 10-12). The reasons for this increase in risk are multifactorial. Previous studies have suggested; type of injury (particularly blunt or penetrating abdominal trauma), severity of injury, volume of fluid resuscitation and the delay to diagnosis and intervention are major influences on the patients' development of IAH and ACS and associated morbidity and mortality (4, 5, 13-15).

The World Society of Abdominal Compartment Syndrome (WSACS) describes intra-abdominal pressure (IAP) as the pressure within the abdominal cavity. IAH is defined by a sustained or repeated IAP ≥ 12mmHg (5). IAH is divided into four categories; Grade I: IAP 12-15mmHg, Grade II: IAP 16-20mmHg, Grade III: IAP 21-25mmHg and Grade IV: IAP >25mmHg (5).

ACS is defined as a new or repeated intra-abdominal pressure (IAP) >20mmHg regardless of the abdominal perfusion pressure (APP) where a new organ dysfunction or failure is present (5). ACS is considered a serious condition and if left untreated can lead to deteriorating organ function and death (16).

Primary IAH and ACS are associated with any injury or disease in the abdominopelvic region. Common causes include abdominal trauma, abdominal surgery and acute pancreatitis (5).

Secondary IAH and ACS are conditions that do not have primary abdominopelvic involvement and can be caused by massive fluid resuscitation, positive fluid balance, hypotension and polytransfusion (5). Recurrent IAH or ACS is where IAH or ACS redevelops post initial treatment of either primary or secondary IAH or ACS (5).

Aim

This registry review aims to document the findings of an existing trauma database. The mechanism of injury, type of injury and volume of fluid received, in relation to the patient's risk of developing abdominal compartment syndrome.

METHOD

Institutional ethics approval was granted prior to the commencement of this review, HREC LNR/13/LPOOL/319 and HREC 2013000683. This retrospective review was conducted in a large metropolitan teaching hospital in the South West of Sydney that manages a variety of acute and chronic medical, surgical and trauma patients. The trauma database accessed specifically collected data on patients who had received damage control laparotomy as well as, the number of trauma admissions categorised as minor, major and deaths, the mechanism of injury, specific patient injuries, the patients pre-calculated risk of developing IAH/ACS, the volume and type of fluid received pre hospital, the volume and type of fluid received in emergency and complications the patient developed (specifically ACS).

This database covered a 9 year period, a different database with differing collection parameters was commenced after this 9 year period. Coding of patients injuries was done using the Injury Severity Score (ISS). The ISS is a severity score based on the anatomical findings identified in the Abbreviated Injury Score (AIS) and is said to predict morbidity, mortality and hospital stay (17).

The cohort of patient who were at risk of developing ACS were identified and included in the database if they had any of the following: haemorrhagic shock, packed red blood cells (PRBC) in emergency, initial PRBC >6 units or > 6 units PRBC before admission to ICU, crystalloid infusions: > 4 L in first 3 hours or 7 L in first 6 hours, shocked patient with retroperitoneal haematoma, pelvic fractures, multiple long bone fractures or vascular injuries.

Within this database IAH was defined as a pressure >15mmHg. ACS was defined as any IAP > 20 mmHg associated with progressive clinical organ dysfunction despite resuscitation, with improvement of physiological parameters following operative decompression. Clinical organ dysfunction was defined as urinary output less than 0.5/1 ml/kg/hr, or a Peak Airway Pressure (PAP) ≥45 cm H2O with PCO2 > 50mmHg, or PaO2/FiO2 < 150, or CI < 3 L/min/m^2. Primary ACS was considered to be ACS in the presence of an abdominal injury. Secondary ACS was considered to be ACS where no intra peritoneal pathology was identified.

Statistical analysis

Data was extracted from an existing trauma database and entered into the Statistical Analysis System (SAS). All data management and statistical analysis was performed using SAS.

Results

During a 9 year period there were 31 819 trauma admissions. Of these, 13 214 (42%) were considered major and 18605 (58%) were considered minor. The Institute of Trauma and Injury Management (ITIM) classifies traumas according to the calculated injury severity score (ISS). Patients with an ISS > 15 are considered serious to critically injured, and those with an ISS < 15 are considered to have moderate to minor injuries (18). The data was interrogated to specifically generate information and capture trauma patients who received a laparotomy (*n* = 787, 2.5%*)* and who were considered at risk of developing ACS (*n* = 105, 13.3%).

Demographically males represented 76% (*n* = 597) and females 24% (*n* = 187). Data was missing for 3 patients and was excluded from final analysis. The mean age of patients was 33 years. The mean ISS was 22 and ranged from 1-75.

The highest proportion of patients requiring a laparotomy post injury from either suspected or confirmed ACS were from motor vehicle accidents (MVA) (*n* = 310, 39%) followed by stabbings (*n* = 214, 27%) and pedestrians (*n* = 61, 8%). Mechanisms of injury and their relationship to the development of ACS is represented in table 1. Abdominal injury represented the most frequently occurring injury 88% (*n*=690) requiring laparotomy. Characteristics of patient injuries and their relationship to the development of ACS are represented in table 2.

Of the 390 (49.5%) patients who received intravenous fluids prior to hospital 8 (1%) developed ACS. Patients who did not developed ACS received an average of 1072.42L, those that developed ACS received 1187.50L of fluid pre hospital admission. A total of 529 (67.2%) patients received intravenous fluids in the emergency department. Patients who did not develop ACS received an average of 2102.66L, patients who developed ACS (*n*=8, 1%) received an average of 2.125L of intravenous fluid, as summarised in table 3. Some of these patients received intravenous fluids pre- hospital and in the emergency department.

Discussion

There are multiple factors that increase a trauma patient's risk of developing IAH and/or ACS. These can include the type of injury, mechanism of injury, or the delay to diagnosis and intervention. The relationship between trauma patients' abdominal injuries, fluid resuscitation and the development of IAH and ACS has been identified by the WSACS and other authors (2, 4). Ertel et al reported a 5.5% (*n* = 17) incidence of ACS occurrence specifically in patients who had pelvic and/or abdominal trauma (4). Meldrum reported an incidence of 14% (*n*=145) of acutely injured patients developed ACS. These results are consistent with the findings of our study. There are however other studies that report higher incidences of ACS among critical care patients (11, 26).

The mechanism of injury in patients is considered to be a practical guide to predicting injuries and useful to overall management of trauma patients (19).The mechanism of injury has also been used as a predictor of patient recovery and functionality (20).Within this study the mechanism of injury with the highest frequency was MVA 39% (*n* = 310). This category includes both drivers and passengers. Other studies have also identified the most common mechanism of injury as MVA (21-23). This has a close relationship to the increased frequency of male traumas identified in other studies (1, 2, 24-26). The Australian Bureau of Statistics identifies the cause of death related to MVA to be between 12% and 17% with male deaths contributing 9.0% - 12.8% over a 9 year period (27). This is identified as a common occurrence by other studies (28, 29).

Abdominal trauma has the potential to cause massive haemorrhage, shock, acidosis, coagulopathy, IAH and ACS decreasing splenic perfusion, tissue ischemia, decreased thoracic compliance and decreased oxygenation and ventilation (25). Abdominal trauma has been identified as the most frequently occurring injury in this study, 88% (*n*=690).These results are supported by other studies (2, 30, 31). The number of patients who were considered to be at risk of developing ACS in this study was 10% (*n*=76) and those who developed primary or secondary ACS was 1.5% (*n*=12). This supports the suggestion that there is a relationship between abdominal injury and the development of ACS. The number of patients who developed ACS was relatively low compared to other studies (11, 26). This could be attributed to the narrow scope of patients admitted into the study and the data parameters collected for the database.

The aim of fluid resuscitation in trauma patients is to restore and maintain systemic and microcirculation by restoring circulating volume (32). There has been increasing discussion regarding the volume of fluid administered to trauma patients. The WSACS guidelines state that polytransfusion is a risk factor in the development of intra-abdominal hypertension and abdominal compartment syndrome (5). Aggressive fluid resuscitation increases capillary hydrostatic pressure and decrease plasma oncotic pressure causing fluid to shift into the interstitium, this coupled with micro vascular capillary leak syndrome causes both peripheral and organ oedema (14, 15, 26, 32-34). Specifically, aggressive fluid resuscitation can cause abdominal oedema resulting in IAH and ACS (15). It has been suggested that aggressive fluid resuscitation reverses vasoconstriction of injured vessels, cause early clot dislodgement, dilutes coagulation factors, induces hypothermia and provokes visceral swelling impacting morbidity, mortality and hospital length of stay (14).

The WSACS definitions and clinical practice guidelines suggest the judicious use of fluids, correction of a positive fluid balance and avoiding a positive fluid balance after acute resuscitation in order to decrease the risk of IAP and ACS (5). Fluid resuscitation volumes identified as risk factors for IAH and ACS include multiple transfusions >10u packed cells in 24 hours and high volume of fluid resuscitation, >3500mL in 24 hours (14, 15, 35). The volumes of fluid received by patients in this study who developed primary ACS and secondary ACS was 3.9 L and 3.4 L of fluid respectively. These volumes are a measurement of pre-hospital and emergency department administration of fluids during the acute resuscitation phase not total volume received in 24 hours, suggesting that the total volume of fluid received in 24 hours could be higher.

Fluid resuscitation can also be considered a measure of a patient's hemodynamic status. Kirkpatrick et al. (2008), suggest that patients fall into 3 categories, responders, transient responders and non responders. Responders have a sustained response to fluid challenges do not generally require emergency intervention. Transient responders have initial improvement then deteriorate often require intervention but time can be taken to investigate the patient. Non responders do not respond to aggressive fluid resuscitation and require urgent intervention (14). Obtaining circulatory stability in unstable patients is essential to patient's outcome. In some cases the volume of fluid used is an indication of the severity of the abdominal injury and is therefore necessary for the level of injury and not the exclusive cause of IAH or ACS.

In 2014 Iyer et al studied 472 patients and identified that patients who developed IAH were resuscitated with greater quantities of fluids and had more positive fluid balances (26). Baldwin et al (2012) studied 100 patients and suggested that their studies relatively low IAP results were due to mean negative fluid balances. The authors also noted the correlation between elevated CVP and elevated IAP and suggested iatrogenic fluid overload has a relationship to elevated IAP. These findings are well supported by other studies. (5, 13, 19, 26, 36-38). These studies support the findings of our study, trauma patients who are resuscitated with larger volumes of fluid are at risk of developing IAH and ACS.

Limitations

There are several limitations to this study. Data was missing on 3 of the patients in the not at risk of ACS cohort and were excluded from final analysis. In this data base there were no records of arterial blood gasses, full blood count, coagulation profile, pulmonary artery wedge pressures or urine output. These measurements have been identified as useful clinical information in the management of trauma patients. The volumes of fluid calculated were for pre hospital and emergency departments' administration and are not reflective of intravenous fluid administration within a 24 hour period. The number of patients who developed primary or secondary ACS in this study was comparatively low. This could be due to the data parameters collected for the database. The data collected is "real world" data and may lack the same quality checks as administrative data.

Conclusion

Abdominal trauma is associated with IAH and ACS. Excessive fluid resuscitation is associated with the development of IAH and ACS. However, fluid resuscitation is often a requirement for patient stabilisation and appropriate for the level of traumatic injury the patient has sustained. Clear and standardised guidelines are required for trauma data collection to enable more accurate analysis of patient information.

Table 1

Mechanism ID by ACS

Frequency Percentage Row Pct

Table of Mechanism ID by ACS			
Mechanism ID	ACS		
	No	Yes	Total
MVA	303 38.50 97.74	7 0.89 2.26	310 39.39
Stabbing	214 27.19 100.00	0 0.00 0.00	214 27.19
Pedestrian	60 7.62 98.36	1 0.13 1.64	61 7.75
MBA	52 6.61 94.55	3 0.38 5.45	55 6.99
Gunshot	41 5.21 100.00	0 0.00 0.00	41 5.21
Fall	33 4.19 97.06	1 0.13 2.94	34 4.32
Other	25 3.18 100.00	0 0.00 0.00	25 3.18
Industrial	21 2.67 100.00	0 0.00 0.00	21 2.67
Assault	14 1.78 100.00	0 0.00 0.00	14 1.78
Cyclist	12 1.52 100.00	0 0.00 0.00	12 1.52
Total	775 98.48	12 1.52	787 100.00

Table 2

Characteristics of patient injuries

Frequency Percentage Row Pct

Table of injC_1 by ACS			
injC_1	ACS		
	No	Yes	Total
abdo	680 86.40 98.55	10 1.27 1.45	690 87.67
dermis	34 4.32 94.44	2 0.25 5.56	36 4.57
penetrating	34 4.32 100.00	0 0.00 0.00	34 4.32
extremities	12 1.52 100.00	0 0.00 0.00	12 1.52
head neck	7 0.89 100.00	0 0.00 0.00	7 0.89
thoracic	4 0.51 100.00	0 0.00 0.00	4 0.51
other	2 0.25 100.00	0 0.00 0.00	2 0.25
pelvis	2 0.25 100.00	0 0.00 0.00	2 0.25
Total	775 98.48	12 1.52	787 100.00

Table 3

Intravenous fluid administration

ACS=No

Variable	N	Mean	Std Dev	Median	Quartile Range	25th Pctl	75th Pctl
PreFluidVolume	382	1072.42	1133.01	800.0000000	900.0000000	500.0000000	1400.00
EDFluidVolume	521	2102.66	1516.35	2000.00	1800.00	1000.00	2800.00

ACS=Yes

Variable	N	Mean	Std Dev	Median	Quartile Range	25th Pctl	75th Pctl
PreFluidVolume	8	1187.50	1058.89	950.0000000	1900.00	250.0000000	2150.00
EDFluidVolume	8	2125.00	1073.71	1900.00	1150.00	1625.00	2775.00

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Chapter Five

Publication title: A comparison of fluid instillation volumes to assess intra-abdominal pressure using the Kron's method.

This chapter introduces the article presented as an original reprint published in the Journal *of Trauma and Acute Care Surgery*

Citation: Hunt, L., Van Luenen, H., Alexandrou, E., Frost, S. A., Davidson, P.M., Hillman, K., & D'Amours, S. (2012). A comparison of fluid instillation volumes to assess intra-abdominal pressure using Kron's methods. *Journal of Trauma and Acute Care Surgery*, *73*(1), 152 - 5. *(3 citations as of 16/7/16)*

5.1 Introduction

An elevated IAP is a prognostic indicator of abdominal function and marker of physiological status. Various methods have been used to measure IAP but the modified Kron method is considered to be the gold standard (Malbrain 2004; Ivaturyet.al., 2006; Malbrain & Deeran, 200; Chiumello et.al., 2007; Zengerink et.al.,2008; Kirkpatrick et.al., 2013).

Researchers have determined that increasing volumes of fluid instillation to measure IAP reduces abdominal compliance. More importantly excessive fluid instillation, particularly in the presence of poor abdominal compliance, can result in over estimation of the IAP and misclassification of patients into the IAH or ACS category (Ball and Kirkpatrick, 2006). Historically volumes of up to 300mL have been used to measure IAP (Malbrain & Deeren, 2006). The WSACS recommends the instillation of 25mL sterile saline to measure IAP (Ball and Kirkpatrick 2006).

5.2 Summary of findings

Thirty seven patients were enrolled into the study. The instillation of 10mL of fluid compared to the current standard of 25mL showed no significant difference in IAP measurement. Patients who had an IAP greater than 20mmHg showed the same IAP's using volumes of 10mL and 25mL. This is clinically significant as a patient with an IAP of 20mmHg is associated with new or worsening organ failure and is often an indicator for escalating management strategies (De Waele, Hoste & Malbrain, 2006; Ivatury et.al., 2006).

A volume of 0mL showed no agreement when compared with 25mL. The study determined that 95% of the population enrolled into this study had a normal IAP. The results demonstrate that some fluid is required to accurately measure IAP.

5.3 Conclusion

This outcomes of this study challenges the current guidelines developed by the WSACS and presents a novel method of assessment. The current recommendation by the WSACS is to instil 25mL of water into the bladder to measure IAP. This study demonstrated that volumes as small as 10mL could be used however, 0mL showed no agreement. Chapter 6 presents Study 5 which analyses the reliability between IAP measurements. This study is important in determining the reliability of a single IAP measurement as the measurement is used to guide patient management.

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A comparison of fluid instillation volumes to assess intra-abdominal pressure using Kron's methods

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BACKGROUND: Intra-abdominal pressure (IAP) measurement has become an important tool in the assessment of critically ill patients. The World Society of the Abdominal Compartment Syndrome consensus guidelines recommend using a maximum volume of 25 mL of sterile saline instilled into the bladder for intermittent IAP measurements. It is postulated that the volume of fluid instilled may have an impact on the estimation of IAP.

METHODS: This study sought to compare measured bladder pressures after the instillation of 25, 10, and 0 mL volumes of sterile saline using measurement analysis. Measurement was performed using the modified Kron technique, and treatment allocation was applied by prospective, alternate patient treatment allocation. Transvesical IAP measurements were undertaken using volumes from 0 mL to 25 mL. Recordings were taken with the catheter unclamped, clamped, 10 mL instillation, and 25 mL instillation. This measurement analysis was conducted in a mixed intensive care unit at a Level I trauma hospital over a period of 14 weeks. IAP measurements were performed on 37 patients with varying disease processes using 25, 10, and 0 mL of sterile saline instilled into the bladder.

RESULTS: Medical, surgical, and trauma patients were distributed equally across the treatment groups. Twenty-three patients were male, and the mean age was 58 years ± 18 years. The concordance correlation coefficient between 25 mL and 10 mL was 0.95. The concordance correlation coefficient between 25 mL and no fluid with an unclamped and clamped catheter was 0.55.

CONCLUSION: In a general intensive care unit population, measured intra-urinary bladder pressure measurements using a volume of 10 mL fluid instillation provides comparable results to using 25 mL fluid. (*J Trauma Acute Care Surg*. 2012;73: 152–155. Copyright © 2012 by Lippincott Williams & Wilkins)

LEVEL OF EVIDENCE: Diagnostic study, level II.

KEY WORDS: Intra-abdominal pressure; intra-abdominal hypertension; intra-abdominal compartment syndrome.

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Chapter Six

Publication title: Reliability of intra-abdominal pressure measurements using the modified Kron technique.

This chapter introduces the article presented as an original reprint published in *Acta Clinica Belgica: International Journal of Clinical and Laboratory Medicine.*

Citation: Hunt, L., Frost, S. A., Alexandrou, E., Hillman, K., Newton, P.J, & Davidson, P.M. (2014). Reliability of intra-abdominal pressure measurements using the modified Kron technique. *Acta Clinica Belgica: International Journal of Clinical and Laboratory Medicine. 70*(2), 116 - 120.

6.1 Introduction

Current practice guidelines developed by the WSACS recommend that a patient with an IAP greater than 12mmHg should have their IAP measured every four hours whilst critically ill (WSACS. 2010). The degree of agreement or reproducibility between measurements is important to consider as it may influence patient outcomes (Malbrain & Jones, 2006; De Waele, De laet & Malbrain, 2007; Kimball et.al.,2007). The current method of relying on a single IAP measurement may not accurately reflect a patients' clinical status (WSACS. 2010). This study investigated if multiple measurements within a time period may more accurately indicate a patients' clinical status

6.2 Summary of findings

Forty eight patients were enrolled into this study based on their risk of developing IAH or ACS. A total of two measurements were taken per patient within a single time period. Of the study participants 17 had an IAP less than 12mmHg, 26 had IAH and 5 had ACS. This is reflective of the critical care population (Pouliart & Huyghens, 2002; Malbrain et.al., 2004).

The study showed that there was no significant change in IAP between the two measurements and that a single IAP measurement is sufficient per time period in routine monitoring. The results of this study are supported by other studies (Kimball et.al.,2007). It was observed that fluid instillation in patients that have existing ACS and thus poor intrinsic abdominal compliance causes significant elevations in IAP.

6.3 Conclusion

Measurement of IAP and monitoring for signs of IAH and ACS are important in managing critically ill patients. A study assessing the reliability of a single IAP measurement was conducted to measure validity. The literature review (chapter 2) identified variances in measurement techniques. Chapter 3 has identified that there was a need for evidence based guidelines to support clinical practice; Chapter 5 challenged current WSACS guidelines that state 25mL of sterile saline is required to be instilled into the bladder for IAP measurement. This chapter has supported current WSACS practice guidelines demonstrating that measuring two IAP on a single patient produced comparable results therefore, it appears there is no advantage in doing two IAP measurements on a single patient. This has implications for nursing workload and patient comfort.

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Original Paper

Reliability of intra-abdominal pressure measurements using the modified Kron technique

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Objectives: Assessment of intra-abdominal pressure (IAP) and the likelihood of abdominal compartment syndrome using valid and reliable measures is an important tool in the assessment of critically ill patients. The current method of relying on a single IAP per measurement period to determine patient clinical status raises the question: is a single intermittent IAP measurement an accurate indicator of clinical status or should more than one measurement be taken per measurement period?
Methods: This study sought to assess the reliability of IAP measurements. Measurements were taken using the modified Kron technique. A total of two transvesical intra-abdominal pressure measurements were undertaken per patient using a standardized protocol. Recordings were taken at intervals of 5 minutes.
Results: The majority of participants (58%) were surgical patients. Thirty-two were males and the mean age was 58 years (SD: 16.7 years). The concordance correlation coefficient between the two measurements was 0.95. Both the scatter and Bland–Altman plots demonstrate that the comparisons of two measurements are highly reproducible.
Conclusion: The findings of this study suggest that conducting two IAP measurements on single patient produce comparable results; therefore, there appears to be no advantage in doing two IAP measurements on a single patient. The measurement of an IAP requires the implementation of a standardized protocol and competent and credentialed assessors trained in the procedure.

Keywords: Intra-abdominal hypertension, Abdominal compartment syndrome, Reliability, Variability, Validity

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Chapter 7

Conclusion: Implications for policy, practice, education and research

7.1 Introduction

As outlined in the previous chapters, there are deleterious effects of raised abdominal pressure (Cheatham & Safcsak ,2009; Cheatham & Safcsak, 2010). This thesis has followed a systematic approach in assessing and developing the knowledge base to assist critical care nurses in assessing and managing IAP, IAH and ACS. It has long been recognised that critical care nurses' are important in the measurement, interpretation and management of IAP. However, to date there has been limited research on critical care nurses' knowledge about IAP measurement techniques, and optimal strategies to identify patients at risk. Despite the availability of current practice guidelines nurses' knowledge concerning IAP measurement techniques and risk identification is documented by this thesis and other authors as being less than would be expected by a critical care nurse (Spencer, Kinsman & Fuzzard, 2008; Ejike et.al.; 2010, Hunt et. al, 2016).

This thesis has documented: firstly the level of knowledge about IAH and ACS by critical care nurses is limited; secondly, .the importance of nurses involvement in the measurement of IAP and the identification and management IAH and ACS; and thirdly despite the existence of practice guidelines current standards of practice are poorly recognised.

Prior to this research there were limited data on nurses knowledge of IAH and ACS, the importance of the critical care nurses role and the impact IAH and ACS could have on patient outcomes. Whilst the task of completing an IAP measurement can be perceived as a simple pattern recognition, the ability to analyse and act upon the IAP measurement is a complex decision making process (National Health Scheme, 2011). Critical care nurses, with the support of education and clinical practice guidelines, have the ability to systematically gather and analyse data, make judgements, make decisions and evaluate outcomes (National Health Scheme, 2011). It is crucial to patient outcomes that critical care nurses are knowledgeable and active participants in the clinical decision making process.

Preventing complications secondary to IAH and ACS is important to patient outcomes and quality improvement of health care organisations (Cheatham & Safcsak, 2010; Malbrain et.al., 2014). Early detection and intervention in the assessment of IAH and the management of ACS has the potential to reduce time in critical care, decrease hospital stays and improve patient outcomes, and critical care nurses are uniquely placed to participate actively in this process (Cheatham & Safcsak, 2010; Cheatham & Safcsak,2014; Malbrain et.al.,2014). Poor understanding by critical care nurses about IAP measurement techniques, patient presentation and the sequela associated with the development of IAH and ACS, particularly in critical care patients can impact patient outcomes. Clear guidelines and adequate educational support can mitigate some of this risk.

7.2 Research aim

The aim of this thesis has been to: establish nurses' knowledge about IAP measurement, IAH and ACS identification and management, assess, develop and refine strategies for IAP measurement and IAH and ACS identification and management.

7.3 Research objectives

To achieve this aim, this thesis addressed the seven objectives as described below:

1. Define the pathophysiology, clinical manifestations and current treatment trends of IAH/ACS (Study 1,2)

2. Discuss the state of the science and issues in implementations of best practice guidelines (Studies 1 and 2)

3. Document the knowledge of critical care nurses and identify the barriers and facilitators to implementation of best practice guidelines (Study 2)

4. Refine the knowledge base on best practice methods of assessment and identification of IAH/ACS (Studies 5 and 6)

5. Identify the consensus definitions and measurement of intra-abdominal hypertension and abdominal compartments (Studies 1,5 and 6)

6. To identify the incidence of IAH and ACS, risk factors and mortality (Studies 2,4,5 and 6)

7. Identify key area of future research to improve practice and patient outcomes. (Studies 3,5 and 6)

7.4 Synthesis of empirical findings based on the research objectives

The main empirical findings of this research were presented in chapters two through seven. These sections synthesize the empirical findings and addressed the research

objectives:

1. *Management of intra-abdominal hypertension and abdominal compartment syndrome: a review*: Critical care patients, more specifically trauma patients are at an increased risk for the development of IAH and ACS. The review found that there were clear definitions and management guidelines for the measurement of IAP and management of IAH and ACS. Despite these guidelines there are variances in measurement techniques and identification of patients at risk. Nurses are integral in the measurement, reporting and management of IAH and ACS, however their knowledge is limited.
2. *A survey of critical care nurses' knowledge of intra-abdominal hypertension and abdominal compartment syndrome:* Critical care nurses' general knowledge about IAH and ACS was limited; this had no correlation to years of experience or post graduate qualifications. This study found that nurses carry out IAP measurements but do not always possess the underpinning knowledge for identification and management of patients at risk. Identification of overt causes of IAH was reasonable but less apparent causes were not identified. This study demonstrates the need for education and support for critical care nurses to provide evidence based care.
3. *A retrospective analysis of trauma patients requiring surgical intervention:* This study found that patients sustaining traumatic injuries were at an increased risk of developing IAH and ACS due to the type of injury, severity

of injury, volume of fluid resuscitation administered and the delay to diagnosis and intervention. Patients who developed IAH or ACS had increased morbidity and mortality. Guidelines existed for fluid resuscitation in traumatic injuries however; clinical endpoints remain the absolute markers of fluid resuscitation. Early recognition of injury and early intervention and management of patients have the potential to improve patient outcomes.

4. *A comparison of fluid instillation volumes to assess intra-abdominal pressure using Kron's method:* The WSACS has developed practice guidelines for the measurement of IAP which suggest using 25mL of sterile water to measure IAP. A comparison of fluid instillation volumes showed that using 10mL of instilled fluid produced similar IAP measurements to using the recommended 25mL challenging current guidelines. A comparison of 0mL showed no agreement when compared to 25mL or 10mL.
5. *Reliability of intra-abdominal pressure measurements using the modified Kron technique:* The WSACS practice guidelines suggest doing an IAP 1-6 hours apart for patients with IAH. An assessment of the validity of a single IAP measurement showed that a single IAP measurement was reliable and multiple measurements within a single time period were not required. Furthermore, fluid instillation into patients who have a pre-existing ACS causes significant elevations in IAP due to poor intrinsic compliance.

7.5 Implications of the study findings

7.5.1. Policy

Policy is imperative to adopting a clear and consistent approach to practice. This thesis has been valuable in guiding policy development and contributes to the overall science of IAH and ACS, supports existing and future research to enhance future policy development.

Although a small study, the results of study 4 (chapter 5) has led Liverpool Hospital Intensive Care Unit to change its policy on the volume of fluid instilled into the bladder prior to IAP measurement. The thesis outcomes have assisted in supporting the need for the development of an educational package titled "Critical care nurse education package on IAH and ACS". I have been commissioned as the team leader of this development committee. The final package will be published on the WSACS website for general access.

7.5.2 Practice

This thesis has supported practice change through changes in measurement of IAP techniques. Liverpool Hospital Intensive Care Unit has changed its policy on the volume of fluid instilled into the bladder prior to IAP measurement as a result of study 4 (chapter 5). The thesis also supports current research, practice techniques and management of IAH and ACS in the critical care patient. Strategies for monitoring adherence to evidence based guidelines and strategies for implementing quality improvement strategies should be considered. Moreover, although clinical practice guidelines exist identifying strategies to implement evidence based practices through translational science methods should be considered.

7.5.3. Education

This thesis has underscored the importance of education in developing nursing competence and ensuring the quality of patient care (Thomas, 1999; Sugrue, 2002; Kirkpatrick et.al., 2013; Hunt et.al., 2014). The WSACS has commissioned expert critical care nurses for the development of "*Nursing management guidelines of IAP*", "Nursing management of the open abdomen" and an educational learning package. This project has the capacity to improve patient outcomes. My expertise as a critical care nurse, and the research I have undertaken through this thesis has seen me assigned as a team leader for the development and implementation of the "*Critical care nurse education package on IAH and ACS*". This is an international collaboration with members of the WSACS.

7.5.4 Research

This thesis has contributed to the current body of knowledge about IAH and ACS by assessing current practice and exploring novel measurement techniques. Significantly this thesis has identified that nurses' knowledge about IAP measurements and IAH and ACS is not adequate and access to evidence based education strategies is limited. This is particularly concerning as critical care nurses play a significant role in the monitoring, identification and management of patients.

Future research regarding the effects of IAP and IAH on particular patient cohorts is required.

Future research directions include;

a. *The incidence of IAH and ACS in type II respiratory failure;*

b. *The effects of mechanical ventilation pressures on intra-abdominal pressures;*

c. *Validation of the use of nasogastric route as a measurement of intra-abdominal pressure*.

These areas of research will be an important contribution to the management and outcomes of critical care patients and contribute to existing scholarly research.

7.6 Limitations

The results from the studies undertaken in this thesis need to be considered within the context of the study design chosen. Formost the small sample size within the survey of critical care nurses should be used as an indicator of knowledge within this sample group. The results, due to the small sample size are not generalisable across all critical care nurses

One of the studies used an existing data base for collection of data. This data base used parameters that were incongruent to the WSACS definitions of IAH and ACS. Whilst many scientific enquiries have used existing data bases they are subject to many confounders that could alter results (Murphy, 2013).

Despite the limitations the research contained within the thesis, there is a comprehensive rationale with supporting evidence regarding IAH and ACS

7.7 Conclusions

The importance and significance of IAH and ACS has increased since the 1980s largely to technological innovations in emergency abdominal surgery and trauma. However, many patients in the ICU, both adult and paediatric, are affected by IAH and ACS, particularly where there is massive fluid resuscitation. An essential first step in preventing adverse health outcomes is early recognition of IAH. The only way to accomplish this is through creating the awareness and priority of IAH as an important clinical condition, and then by monitoring IAP in patients who are at risk using standardised, valid and reliable measures.

This thesis has provided a unique contribution to the science of IAH and ACS management. Firstly, it has described the state of the science about accepted IAP measurement techniques, IAH and ACS. Secondly, it has identified that critical care nurses' knowledge is not adequate in the topic area. Thirdly, it has identified that trauma patients are at risk of developing IAH and ACS particularly in the presence of massive fluid resuscitation. Fourthly, this thesis has challenged current guidelines on IAP measurement techniques, and finally, this thesis has identified the need for standardised practice guidelines and education to strengthen critical care nurses' knowledge.

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