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IMMEDIATE DECISION-MAKING AND INFORMATION NEEDS IN INTENSIVE CARE COORDINATION

by

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To the real world professionals, ICU Charge Nurses and Physicians in Charge who participated in my study

and

To the two men of my life, Olli and Ville

Heljä Lundgrén-Laine
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ABSTRACT

The aim of this study was to develop a theoretical model for information integration to support the decision making of intensive care charge nurses, and physicians in charge – that is, ICU shift leaders. The study focused on the ad hoc decision-making and immediate information needs of shift leaders during the management of an intensive care unit's (ICU) daily activities. The term 'ad hoc decision-making' was defined as critical judgements that are needed for a specific purpose at a precise moment with the goal of ensuring instant and adequate patient care and a fluent flow of ICU activities. Data collection and research analysis methods were tested in the identification of ICU shift leaders' ad hoc decision-making. Decision-making of ICU charge nurses (n = 12) and physicians in charge (n = 8) was observed using a think-aloud technique in two university-affiliated Finnish ICUs for adults. The ad hoc decisions of ICU shift leaders were identified using an application of protocol analysis. In the next phase, a structured online questionnaire was developed to evaluate the immediate information needs of ICU shift leaders. A national survey was conducted in all Finnish, university-affiliated hospital ICUs for adults (n = 17). The questionnaire was sent to all charge nurses (n = 515) and physicians in charge (n = 223). Altogether, 257 charge nurses (50%) and 96 physicians in charge (43%) responded to the survey. The survey was also tested internationally in 16 Greek ICUs. From Greece, 50 charge nurses out of 240 (21%) responded to the survey.

A think-aloud technique and protocol analysis were found to be applicable for the identification of the ad hoc decision-making of ICU shift leaders. During one day shift leaders made over 200 ad hoc decisions. Ad hoc decisions were made horizontally, related to the whole intensive care process, and vertically, concerning single intensive care incidents. Most of the ICU shift leaders' ad hoc decisions were related to human resources and know-how, patient information and vital signs, and special treatments. Commonly, this ad hoc decision-making involved several multiprofessional decisions that constituted a bundle of immediate decisions and various information needs. Some of these immediate information needs were shared between the charge nurses and the physicians in charge. The majority of which concerned patient admission, the organisation and management of work, and staff allocation. In general, the information needs of charge nurses were more varied than those of physicians. It was found that many ad hoc decisions made by the physicians in charge produced several information needs for ICU charge nurses. This meant that before the task at hand was completed, various kinds of information was sought by the charge nurses to support the decision-making process. Most of the immediate information needs of charge nurses were related to the organisation and management of work and human resources, whereas the information needs of the physicians in charge mainly concerned direct patient care. Thus, information needs differ between professionals even if the goal of decision-making is the same. The results of the international survey confirmed these study results for charge nurses. Both in Finland and in Greece the information needs of charge nurses focused on the organisation and management of work and human resources. Many of the most crucial information needs of Finnish and Greek ICU charge nurses were common.

In conclusion, it was found that ICU shift leaders make hundreds of ad hoc decisions during the course of a day related to the allocation of resources and organisation of patient care. The ad hoc decision-making of ICU shift leaders is a complex multi-professional process, which requires a lot of immediate information. Real-time support for information related to patient admission, the organisation and management of work, and allocation of staff resources is especially needed. The preliminary information integration model can be applied when real-time enterprise resource planning systems are developed for intensive care daily management.

Keywords: charge nurse; coordination; critical care; decision-making; information need; information integration; intensive care; intensivist; physician in charge

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VÄLITÖN PÄÄTÖKSENTEKO JA TIEDONTARPEET TEHOHOIDON KOORDINOINNISSA
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TIIVISTELMÄ

Tutkimuksen tarkoituksena oli kehittää teoreettinen tiedon integraatiomalli tukemaan teho-osaston vastaavien sairaanhoitajien ja tehohoitolääkärien päätöksentekoa. Tutkimuksessa tarkastellaan ad hoc -päätöksentekoa ja välittömiä tiedontarpeita päivittäisen toiminnan johtamisessa. Termillä 'ad hoc -päätöksenteko' tarkoitetaan kriittisiä päätöksiä, joita joudutaan ratkaisemaan välittömästi tiettyä tilannetta varten. Päätösten tavoitteena on varmistaa potilashoidon välitön, asianmukainen ja sujuva toiminta. Tutkimuksessa testattiin aineiston keruun ja analysoinnin menetelmiä teho-osaston vuoron vastaavien ad hoc -päätösten tunnistamisessa. Teho-osaston vastaavien sairaanhoitajien (n = 12) ja tehohoitolääkärien (n = 8) päätöksentekoa havainnoitiin ääneenajattelun tekniikalla kahdella aikuisten teho-osastolla. Ad hoc -päätösten analysointiin sovellettiin protokolla analyysia. Tutkimuksessa kehitettiin strukturoitu kyselylomake, jolla arvioitiin teho-osaston vuoron vastaavien välittömiä tiedontarpeita päätöksentekotilanteissa. Kansallinen kysely toteutettiin kaikilla Suomen yliopistollisten sairaaloiden aikuisten teho-osastoilla (n = 17). Kysely lähetettiin vastaaville sairaanhoitajille (n = 515) ja tehohoitolääkäreille (n = 223). Kyselyyn vastasi 257 (50 %) vastaavaa sairaanhoitajaa ja 96 (43 %) tehohoitolääkäriä. Kolmannessa vaiheessa toteutettiin kyselyn kansainvälinen testaus kuudellatoista kreikkalaisella teho-osastolla. 50 kreikkalaista teho-osaston vastaavaa sairaanhoitajaa 240:stä vastasi kyselyyn (21 %).

Ääneenajattelun tekniikka ja protokolla analyysi soveltuivat teho-osaston vuoron vastaavien ad hoc -päätöksenteon tunnistamiseen. Teho-osaston vuoron vastaavat tekivät vuorokauden aikana yli 200 välitöntä ratkaisua vaativaa ad hoc -päätöstä. Ad hoc -päätöksiä tehtiin horisontaalisesti koko tehohoitoprosessiin liittyen sekä vertikaalisesti yksittäisen tilanteeseen liittyen. Eniten päätöksiä tehtiin henkilökuntaresursseihin ja tieto-taitoon, potilaan tilanteeseen ja vitaalielintoimintoihin sekä erikoistoimenpiteisiin liittyen. Tyypillisesti ad hoc -päätöksenteko sisälsi useita moniammatillisia päätöksiä, jotka liittyivät toisiinsa (a bundle of ad hoc decisions) ja joihin tarvittiin erilaisia tietoja. Osa välittömistä tiedontarpeista oli yhteisiä vastaaville sairaanhoitajille ja tehohoitolääkäreille. Suurin osa yhteisistä tiedontarpeista liittyi potilaan tulotilanteeseen, työn organisointiin ja henkilöstöresursointiin. Vastaavien sairaanhoitajien tiedontarpeet olivat moninaisemmat kuin tehohoitolääkärien. Moni tehohoitolääkärin tekemä ad hoc -päätös tuotti vastaavalle sairaanhoitajalle useita tiedontarpeita. Tämä tarkoitti, että ennen kuin kyseessä oleva toiminta voitiin suorittaa loppuun, vastaava sairaanhoitaja etsi erilaista tietoa päätöksenteon tueksi. Suurin osa vastaavien sairaanhoitajien tiedontarpeista liittyi työn organisointiin ja henkilöstöresursointiin, kun taas tehohoitolääkärien tiedontarpeet liittyivät välittömään potilashoitoon. Tiedontarpeet eroavat ammattilaisten välillä, vaikkakin päätöksenteon tavoite on sama. Kansainvälisen kyselyn tulokset vahvistivat tutkimustuloksia vastaavien sairaanhoitajien tiedontarpeiden osalta. Sekä Suomessa että Kreikassa vastaavien sairaanhoitajien tiedontarpeet painottuivat työn organisointiin ja henkilöstöresursseihin. Monet kriittisistä tiedontarpeista olivat yhteisiä suomalaisille ja kreikkalaisille sairaanhoitajille.

Yhteenvetona voidaan todeta, että teho-osaston vuoron vastaavat tekevät satoja resursointiin ja potilashoidon organisointiin liittyviä ad hoc -päätöksiä vuorokauden aikana. Teho-osaston vuoron vastaavien ad hoc -päätöksenteko on kompleksinen, moniammatillinen prosessi ja päätöksenteon tukesi tarvitaan paljon välitöntä tietoa. Reaaliaikaista tietoa tarvitaan erityisesti potilaan tulotilanteessa, työn organisoinnissa ja henkilöstöresursoinnissa. Tutkimuksessa esitettävää alustavaa tiedon integraatiomallia voidaan soveltaa, kun reaaliaikaisia toiminnanohjausjärjestelmiä kehitetään tehohoidon päivittäisen toiminnan johtamiseen.

Avainsanat: koordinointi; päätöksenteko; tehohoito; tehohoitolääkäri; tiedon integrointi; tiedontarve; vastaava sairaanhoitaja; vastaava lääkäri

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II Lundgrén-Laine H, Kontio E, Perttilä J, Korvenranta H, Forsström J, Salanterä S. Managing daily intensive care activities: An observational study concerning ad hoc decision-making of charge nurses and intensivists. Critical Care 2011, 15:R188. http://ccforum.com/content/15/4/R188.

III Lundgrén-Laine H, Kontio E, Kauko T, Korvenranta H, Forsström J, Salanterä S. National survey focusing on the crucial information needs of intensive care charge nurses and intensivists: same goal, different demands. BMC Medical Informatics and Decision Making 2013, 13:15. doi:10.1186/1472-6947-13-15.

IV Lundgrén-Laine H, Kalafati M, Kontio E, Kauko T, Salanterä S. 2012. Crucial information needs of ICU charge nurses in Finland and Greece. Nursing in Critical Care 2013, doi: 10.1111/nicc.12004

1 INTRODUCTION

Intensive care has rapidly become a standard of care in most modern hospitals worldwide. Before the 1970s it was rather uncommon that critically ill patients were treated in hospitals in discrete units. Today, the care of critically ill patients is delivered by an educated staff with adequate skills, expertise, and sophisticated technical resources, in a specially designated hospital area. In addition, international consensus guidelines for intensive care organisation are ratified by the societies of intensive care, and recommendations for intensive care coordination are stated based on experienced experts' opinions. These guidelines and recommendations include definitions and objectives of intensive care, minimum standards for good quality of care related to functional and activity criteria, and architectural standards for planning the highest level of intensive care. (Ferdinande 1997, Brilli et al. 2001, Haupt et al. 2003, Valentin & Ferdinande 2011, Thompson et al. 2012).

It has been estimated that medical care and national health expenditures account for over 10% of the gross domestic product in many countries. Intensive care costs are reported to represent around 13–25% of hospital costs, and nearly 1% of the gross domestic product (Graf et al. 2005, Moreno et al. 2010). In Finland, the costs of intensive care have been found to be slightly lower, and the median cost per intensive care unit (ICU) survivor was about 9,600 euros in 2011. The annual costs of Finnish intensive care were slightly over 142 million euros in 2011. The estimated cost of one ICU survivor in 2012 was under 15,000 euros. In addition, it has been estimated that after five years of survival the mean cost per life year and per quality-adjusted life year of an ICU patient amounts to a total cost of about 20,000 euros (Kari 2003, Parviainen et al. 2004, Finnish Intensive Care Consortium 2013).

Recent nationwide outcome studies conducted in Finland related to severe sepsis (The Finnsepsis Study), acute respiratory failure (The Finnali Study), out-of-hospital cardiac arrest (The Finnresusci Study), and acute kidney injury (The Finnaki Study) have also shown that ICU patient outcomes are good, and that the highest level care can be cost effective (Karlsson et al. 2009, Linko et al. 2010, Vaara et al. 2012, Vaahersalo et al. 2013). The cost-utility for one quality-adjusted life year of patients with severe sepsis or acute respiratory failure varied between 1,400–2,100 euros, which can be considered reasonable. Thus, compared to international ICU patient outcomes and costs, Finnish intensive care is on a good level. The mean hospital mortality rate for Finnish ICU patients was 18.4% during the years 2001–2008, increasing slightly with older age groups (Reinikainen 2012). According the benchmarking data of the Finnish Intensive Care Consortium (2013) mortality in intensive care was approximately 6 %, and the overall hospital mortality of ICU patients was about 11 %, in 2012. The database includes nearly 90 % of Finnish ICUs for adults.

According to recent studies, and the trends found in patient demographics worldwide, the burden of critical illnesses and demand for critical care among adults seems to be increasing (Adhikari et al. 2010, Rhodes et al. 2011, Reinikainen 2012). This means that

if we are aiming to maintain high quality ICU care and good patient outcomes the whole ICU care process should be considered more broadly, including both the coordination and delivery of care, as well as prolific technology support for managerial decision-making. In addition, it is obvious that the roles of ICU shift leaders will change when the complexity of care and the rate of information transfer increase together with ever-larger ICUs (Miller & Buerhaus 2013).

Leadership, team-based decision-making and information management in complex organisations have become important issues when successful units with growing demands have been studied. These issues are also strongly emphasised when model components and allocation of resources for magnet hospitals are evaluated (ANCC 2013). Management of daily activities in modern-day ICUs is a demanding task that involves complex coordination of both human and material resources. Every day ICU shift leaders, charge nurses, and physicians in charge are in a critical position, working as frontline managers when coordinating these complex care processes. Team-based management including open communication, effective leadership, and concerted coordination of work with shared visions has been found to enhance the outcomes of ICU patients as well as staff well-being (Sirio & Rotondi 1999, Reader et al. 2009). In addition, the more complex and critically ill patients are, the more intradisciplinary team work seems to impact on patient outcomes (Baggs et al. 1999).

Due to the nature of intensive care, most of the ICU shift leaders' duties are very time-critical, and include shared and overlapped tasks and decisions made by intradisciplinary professionals with varied information needs. In ICUs, most of the charge nurses and physicians in charge are designated as shift leaders based on their previous experience. In Finland, the managerial education of nurses is incorporated into their basic education, or managerial education as an update to the basic education is offered by various organisations. However, Finnish ICU charge nurses do not have any specific managerial education to support them in leading unit shifts. A uniform managerial education of Finnish physicians who work in ICUs is offered by universities, and this education is combined into the post-specialist education of intensive care medicine. Managerial education for intensivists is also offered by international organisations related to specific intensive care training programs (e.g. ESICM). Thus far managerial education related to ICU shift leading is not commonly carried out within multi-professional groups.

Optimal patient care in ICUs requires fluent, multi-professional coordination of activities and ruling of the overall picture during rapidly changing situations. Therefore, various kinds of immediate information are needed in every shift, for multiple decisions, when the care of the most critically ill patients are planned and delivered. In many writings and presentations, intensive care coordination has been likened to air traffic control, or to other complex contexts. However, in ICUs technological support for shift leaders' decision-making and information management is far from ideal when compared, for example, to air traffic control systems where it is possible to control simultaneous activities in real time. In addition, most of the information systems developed for intensive care only focus on direct patient care coordination. Information acquisition, retrieval, exchange, and archiving are fairly well supported in these systems, but the support for managerial decision-making is almost completely lacking, or the information

needed is saved in diverse systems together with paper-based notes and memos. Thus a major part of the ICU shift leaders' work is based on their memory.

There are many reasons why research and development related to the support of ICU shift leaders' decision-making has been hindered. Firstly, most of the patient cases in intensive care are not standardised, and every situation has the potential to suddenly change from a normal case to the most serious incident. Furthermore, difficulties in measuring the ongoing decision-making of an expert in real clinical situations have complicated the research, and there is a lack of international research concerning the decision-making and information needs of ICU shift leaders. However, different information needs of ICU shift leaders and effects of different organisational settings should be expounded before information technology designers are able to build suitable systems for ICU management. In addition, understanding the collaborative nature of ICU work is essential when future information systems are developed (Reddy et al. 2002).

The care of critically ill patients in ICUs constitutes a crucial component of hospital care, and thus there is a constantly growing pressure for large units. In future ICUs, the timely management and organisation of ICU daily activities, and a fluent flow of managerial information, will be crucial when patient outcomes, quality issues, and costs of care are considered. In this study, immediate decision-making and information needs of Finnish ICU shift leaders, charge nurses, and physicians in charge, were investigated during the management of ICU daily activities. In addition, information needs of Greek ICU charge nurses were also explored.

In this study, the title 'charge nurse' refers to a registered nurse who is responsible, and accountable, for nursing care within an ICU during his or her ICU shift. She or he will hold the position of a shift-specific leader in the unit, and will be responsible for a team of nurses, and coordinating nursing activities, in order to ensure a high quality of nursing care in every situation. The title 'physician in charge' refers here to a physician who is a specialist in the field of clinical practice, who works full-time or is regularly on duty in the ICU, and is responsible and accountable for patient care within an ICU during his or her shift. This individual also holds the position of a shift-specific team leader in the unit, and is responsible for coordinating patient care activities in order to ensure a high quality of care in every situation. The title 'ICU shift leader' refers to both charge nurses and physicians in charge.

The study was conducted in three phases during the years 2007–2012. All the study phases were studied within the highest-level ICUs for adults in university affiliated hospitals. The aim of the study was to produce a model for information integration to support the ad hoc decision-making and immediate information needs of intensive care charge nurses and physicians in charge during the management of an ICU's daily activities. The ultimate goal of the study was to set out the groundwork for an information integration tool that is obviously needed by the ICU shift leaders in critical care settings. It can be hypothesised that combining and supporting the access of crucial information needs of ICU shift leaders will have an effect on the coordination of activities, enhancing future ICU patient care quality and safety.

2 REVIEW OF THE LITERATURE

The literature review consists of four main areas. Firstly, the roles of ICU shift leaders, charge nurses and physicians in charge, are discussed. Secondly, the literature search is targeted to cover the managerial decision-making related to coordination of ICU daily activities, and the concept of an ad hoc decision is described. In addition, the combination of a think-aloud technique and protocol analysis in decision-making research is reviewed. Thirdly, information needs of ICU shift leaders are explored. Lastly, an overview of the supporting information integration tools developed for ICU shift leaders is provided.

The aim of the literature review was to present a comprehensive overview of the relevant literature related to ICU shift leaders' managerial decision-making, their immediate information needs during the coordination of daily activities, and how these decisions are currently supported by technology. The database search was carried out through several phases with different combinations of keywords, as described in Figure 1. The scientific literature related to the research topics proved to be very scattered and the relevant literature was searched for both systematically and manually. The main concepts of the study were used as keywords for the database search separately. In

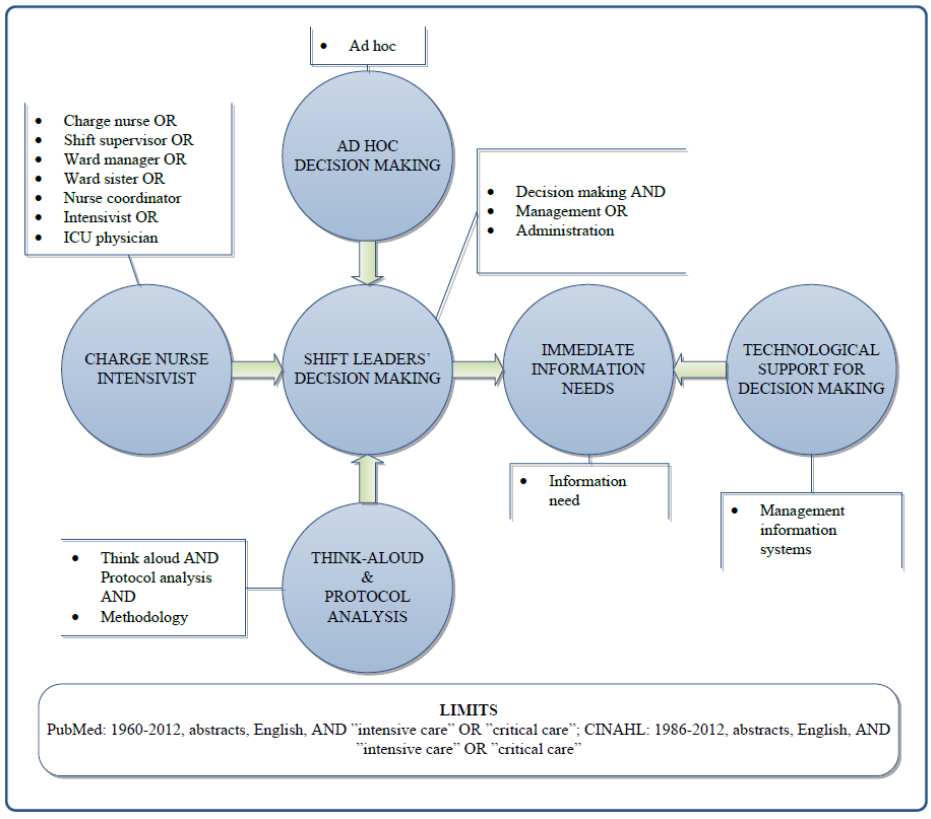

Figure 1. Literature searches conducted from PubMed and CINAHL with keywords and limits used.

addition, evidence of comprehensive intervention studies or randomised controlled trials related to this research area is lacking. A literature search was conducted in two databases: PubMed (Medline), and CINAHL (Ebsco). In PubMed the search was limited to the years 1960–2012, to also cover the early stages of intensive care. Search in CINAHL was limited to the period of 1981–2012, to cover the whole database. The searches were limited to studies published in the English language and research conducted in intensive care/critical care. In addition a Finnish database, Medic, and a union catalogue of Finnish University Libraries, Linda, was explored to identify intensive care related articles and doctoral theses published in Finland. On the basis of these database searches, the concept of ad hoc decision-making was dissociated from concepts related to heuristic and intuitive decision-making. Ad hoc decision-making was defined using an internet search and dictionaries. A supplementary manual search was conducted in the reference lists of the articles.

2.1 ICU shift leaders: charge nurses and physicians in charge

Care coordination in ICUs is a complex process that involves coordination of both resources and of patient care. The leadership and management of the daily care activities of intensive care units are usually shared between the nurse and the physician in charge. The main tasks of the ICU shift leaders are ensuring the smooth flow of activities, and a consistent quality of care by coordinating unit resources and ensuring the knowledge and skill levels of the personnel. Critical incident studies conducted in ICUs have shown that multidisciplinary teamwork in shift leading has a great impact on, for example, patient safety and unit efficiency (Reader et al. 2006, Pronovost et al. 2006). Collaboration and shared responsibility in shift leading presumes a dedication of leaders to the coordination of and communication in all aspects of unit management; meaning that setting goals, organising human resources, and coordinating daily activities are negotiated together (Brilli et al. 2001, Salas et al. 2007, Reader et al. 2009). In the following chapters, the role and tasks of ICU shift leaders are discussed further.

2.1.1 The definition and the role of an ICU charge nurse

The title of charge nurse is defined by the Medical Dictionary (www.medical-dictionary.thefreedictionary.com) and Oxford English Dictionary (www.oed.com) as ‘The nurse assigned to manage the operations of the patient care area for the shift. Responsibilities may include staffing, admissions and discharge, and coordination of activities in the patient care area’, and ‘A nurse who has charge of a ward in an infirmary or hospital’. Wikipedia (www.en.wikipedia.org) defines the role as follows: ‘The charge nurse is the nurse, usually assigned for a shift, who is responsible for the immediate functioning of the unit. The charge nurse is responsible for making sure nursing care is delivered safely and that all the patients on the unit are receiving adequate care. They are typically the front-line management in most nursing units. Some charge nurses are permanent members of the nursing management team and are called shift supervisors’. In the scientific literature, the title of charge nurse is used inconsistently, and the absence of an agreed uniform role is evident. In many studies the title ‘charge nurse’ refers to different levels of nursing managers (Platt & Foster 2008), or the title has been used only for male

counterparts as a synonym for female ward sisters (RCN 2009, Bradshaw 2010). Several similar kinds of titles are found within the literature referring to a charge nurse, such as charge nurse managers (McCallin & Frankson 2010), ward sister or ward manager (Lewis 1990, Willmot 1998, Fabray & Luck 2000, Bradshaw 2010), shift leaders or team leaders (Endacott 1999, ACCCN 2003), nurse coordinators or clinical coordinators (ACCCN 2003, Gurses et al. 2009), or senior nurses (Platt & Foster 2008). Sometimes the traditional term sister is also used to refer to a charge nurse.

An unambiguous definition, or an officially qualified title, for a charge nurse was not found in the previous literature. In this study, the title 'charge nurse' refers to a registered nurse who is responsible, and accountable, for nursing care within an ICU. This individual will hold the position of a shift-specific leader in the unit, is responsible for a team of nurses, and coordinating nursing activities, in order to ensure a high quality of nursing care in every situation.

Together with the above-mentioned inconsistencies with the title, the role and tasks of charge nurses seem to be various (Krugman & Smith 2003, Sherman 2005, McGilton et al. 2009, Bradshaw 2010, McCallin & Frankson 2010). In clinical settings, charge nurses share the unit leader position together with unit head nurses or nurse managers by coordinating the activities of the staff and patient care around the clock. The assignment of a charge nurse is to direct nursing staff and manage the work system during a particular shift, and be committed to providing appropriate care for ICU patients. The work of charge nurses has been likened to the work of air traffic controllers (Sherman et al. 2011, Wilson et al. 2011). As such, the role is described as a complex mixture of clinical care and managerial duties, including several tasks such as maintaining the quality of patient care, ensuring the availability of an adequate nursing staff with appropriate skill levels, and supporting interactions and activities between team members as well as effective and efficient operation of the units (Fabray & Luck 2000, Connelly et al. 2003a, Isaacson & Stacy 2004, Bondas 2006, Locke et al. 2011). Compared to the first-line nurse managers or head nurses, charge nurse can be counted as a front-line manager who is working at the interface of health care management and actual clinical care delivery (Connelly et al. 2003b, RCN 2009, Sherman et al. 2011).

The content areas of competences regarding intensive care nursing education and staffing are defined by the critical care associations (ACCCN 2003 & 2006, EfCCNa 2004 & 2007, WFCCN 2005a & 2005b). These statements include recommendations for ICU leadership and management. It is emphasised that on each shift in an ICU there should be a designated nurse in charge, who is responsible for the smooth flow of the activities throughout the shift. In Finland, the basic ICU competencies and educational requirements for graduating nursing students were recently evaluated by Lakanmaa (2012), also covering the areas of leadership and management. However, the qualifications, educational requirements, or competencies for ICU post-registration nurses who work as charge nurses are not officially defined. It seems that most charge nurses are designated as shift leaders based on their skills and knowledge, working experience, or their own interests, without a formal managerial education (Hughes & Kring 2005, Wojciechowski et al. 2011); notwithstanding this fact, they represent the nurse leadership positions on a 24/7 basis.

2.1.2 The definition and the role of a physician in charge

In closed model ICUs, intensivists or ICU physicians with different special post-training act as primary care physicians. Commonly, both administrative and managerial duties are also combined in their work (Marchan et al. 2010). The role of the ICU physician has been precisely defined by the Society of Critical Care Medicine in 1992: these definitions were later revised, for example by Brilli et al. in 2001 and by the Leapfrog consortium in 2010. According to these definitions, an ICU physician should have the medical training and skills to manage multiple vital health problems related to cardiovascular, respiratory, neurologic, and renal systems; endocrine, gastrointestinal, pharmacologic and hematologic disorders; infectious diseases; and the nutritional needs of ICU patients. In addition, he or she should manage several unit-specific procedures vital for seriously ill patients. However, the responsibilities of an ICU physician related to management are only briefly described in these definitions. An ICU physician is expected to deliver a good quality and human care with efficient use of unit resources, and their administrative duties include, for example: admission and discharge decisions, development and implementation of treatment protocols, directing performance improvement activities, maintaining up-to-date equipment and techniques, gathering unit-based data, interdisciplinary cooperation, and budgeting (Brilli et al. 2001).

In this study, the title of 'physician in charge' refers to a certified senior physician who is specialised in the field of clinical practice (critical care, internal medicine, anesthesiology, or surgery), who works full-time or is regularly on duty in the ICU, and is responsible and accountable for patient care within an ICU during his or her shift. This individual holds the position of a shift-specific team leader in the unit, and is responsible for coordinating patient care activities in order to ensure a high quality of care in every situation.

Most of the studies assessing the role of an ICU physician in charge have concentrated on the full-time presence of a specialised physician in the ICU, or closed units run by an intensivist versus open ICUs, and how this impacts on patient outcomes such as mortality, morbidity, postoperative complications, or length of stay (e.g. Brown & Sullivan 1989, Carson et al. 1996, Hanson et al. 1999, Pronovost et al. 1999, Uusiaro et al. 2003, Fuchs et al. 2005, Garland et al. 2011, Wallace et al. 2012). It has been shown that patient outcomes improve when ICUs are directed by intensivists, compared to open units which are run by different specialists. However, the mechanism explaining this association is not clear (Gajic & Afessa 2009).

In a Finnish study by Uusiaro et al. (2003) the effects of admission and discharge times of emergency patients (n = 23,134) on ICU and hospital mortality were analysed. Additionally, the risk of death during the ICU in-patient time was investigated for weekdays and weekends, as well as office and out-of-office hours (n = 15,978). The results of the study revealed that weekend admissions were associated with increased ICU mortality, and a patient's risk of dying in the ICU was higher during out-of-office hours. The explanatory variables (severity of disease, intensity of care, and care restrictions) did not explain the findings. The researchers suggested that the study findings could be explained with the lack of 24-hour intensivist coverage, the lack of in-depth patient knowledge during out-of-office hours, or the defective database

related to part of the patients' information. In a recent study by Wallace et al. (2012) the relationship between night-time intensivist coverage and the hospital mortality of ICU patients was investigated within an extensive database including over 65,000 patients. Reduced mortality was found in units which had a low-intensity physician staffing model. However, no relationships were found among those units that already used a high-intensity physician model, and where intensivists had the primary responsibility for coordination. In these above-mentioned studies, organisational characteristics might have had an effect on outcomes but these factors were not considered. The managerial duties of ICU physicians in charge and critical interfaces with other team-related activities might be important factors for patient outcomes. However, this point of view has received less attention in the scientific literature (Reader et al. 2009).

2.2 Decision-making of ICU shift leaders

2.2.1 Managerial decision-making of ICU shift leaders

ICU nurse–physician collaboration in decision-making has been promoted since the early 1980s by several national groups aiming to improve patient care (e.g. NIH 1983), but little scientific evidence exists for these recommendations. Only a few studies have shown that collaborative decision-making between ICU nurses and physicians improves patient care in ICUs (Knaus et al. 1986, Brown & Sullivan 1989, Mitchell et al. 1989, Baggs et al. 1999). Decision-making related to immediate care must often be made quickly, in response to the changing condition of the ICU patient, and thus fluent collaboration between different professional groups is needed. This clinical decision-making is usually supported by patient information systems that are designed to provide detailed individual, patient-focused information (Miller et al 2010a). However, decision-making concerning direct patient care is impossible to complete in everyday situations if managerial decisions are made inaccurately or are delayed.

Managerial decision-making in hospitals can be considered on three different levels: strategic, tactical, and operational (Winter et al. 2001). Arising from the acute, fast-paced, and collaborative nature of intensive care work, managerial decision-making in ICUs is a complex task. Many, and varied, multi-professional managerial decisions are made during the running of daily activities; ICU shift leaders' duties and tasks are a mixture of direct patient care, supervision of care, and managerial work. Therefore, their decisions result in both clinical and managerial orders to support patient care and ICU workflow. It seems that these shift-based managerial decisions made by charge nurses and physicians in charge are diffused to different levels, and thus management occurs on an operational level, as well as on a tactical level. A proportion of managerial decisions concern more long-term goals and consequences, such as the planning of special treatments or admission of elective patients; whereas part of the activities have to be completed immediately, ad hoc, and are always managed on a day-to-day or an hour-to-hour basis, like daily shift allocation.

Miller et al. (2010a) have produced an integrated multidisciplinary model of ICU care coordination including four layers of decision-making: 1. Unit resource coordination;

2. Care coordination; 3. Patient care coordination; and 4. Patient care delivery. This model is also applicable to managerial decision-making. The first layer, unit resource coordination, represents decision-making related to the optimal resource allocation. The second layer, care coordination, refers to pooling optimal resources to patient needs. The third layer, patient care coordination, concerns the care needs of a single patient; and the fourth layer, patient care delivery, involves direct patient care. Multidisciplinary decision-making occurs both vertically, up and down the levels, as well as laterally, within each level. In the same study by Miller et al. (2010a) the decision-making and information management of charge nurses occurred mainly at the unit level involving preparation, planning, execution, and team assessment, whereas the physicians' decision-making was more connected to the other three levels. Shared decision-making between charge nurses and physicians was found in relation to ICU admissions, discharges, and patient transfers.

2.2.2 Ad hoc decision-making of ICU shift leaders

The term 'ad hoc' derives from Latin, meaning 'for this'. According to the Oxford English Dictionary (www.oed.com) the verb 'ad hoc' means to act or respond to a specific need or demand, for a particular purpose, as necessary, rather than in accordance with a general policy or rule, or long-term strategy. Acting on an ad hoc basis can also mean to improvise. As an adjective it means that something is done for a particular purpose, in response to a specific need or demand, rather than in accordance, for example with a general policy or rule. In Wikipedia (www.wikipedia.org) the term 'ad hoc' is defined as a problem or task that is specifically designed for certain situation and it is non-generalisable or non-adaptable to other purposes.

A suitable scientific definition for the term 'ad hoc decision-making' was not identified. However, in the literature related to the mechanical engineering design, the term has been defined as a decision-making process which is done within a short time limit and without a structured approach. Ad hoc decision-making therefore depends on the problem, person, social context, and time available for the decision-making. When making ad hoc decisions people are determining the most important criteria, and if their idea meets these criteria then they usually make their judgement. (Ullman 2006.) Currently in ICU settings, most of the ad hoc decisions during the daily care management are made by shift leaders, without any specific criterion, and managerial judgements are based primarily on the shift leader's own experiences, coordination skills, and memory capacity.

Ad hoc decision-making can be enlarged to include intuition or heuristic decision-making, as described in the nursing and medical literature. However, situations in shift leading differ from actual patient care situations, where intuitive or heuristic decision-making is usually present. Intuitive decision-making is connected to expert nursing, tacit knowledge, and holistic understanding in complex and unpredictable situations, when part of the required information is missing and rapid decision-making is needed (Dreyfus & Dreyfus 1985, Benner 2001). Heuristics is based on cognitive psychology, and in a recent study by Gigerenzer and Gaissmaier (2011) was defined as follows: 'a strategy that ignores part of the information, with the goal of making decisions more quickly, frugally, and/or accurately than with more complex methods.' In ad hoc decision-making

information should not be omitted, but instead the access to this existing information should be supported.

In this study, the term 'ad hoc decision-making' was operationalised through the protocol analysis in the first study (Papers I, II) using the different verbalisation levels. In the survey phase (Papers III, IV) the term was connected to the immediate information needs of ICU shift leaders that should always be available for each shift leader in every situation. Most of the situations in shift leading where a smooth flow of activities and ad hoc decision-making is needed are known in advance, like admissions or discharges. These decisions are impossible to conduct without a certain amount of proper immediate information; although all information will never be accessible, and intuitive or heuristic decision-making is still needed in complex situations. In this study, the term 'ad hoc decision-making' was defined as critical judgements that are needed for a specific purpose at a precise moment, with the goal of ensuring instant and adequate patient care and a fluent flow of ICU activities. (Lundgrén-Laine et al. 2011.)

2.2.3 Revealing the decision-making of ICU shift leaders

A direct measurement of on-going human cognition is difficult to demonstrate with classical methods used in decision-making research such as introspection, observation, or interviews. Strictly speaking, a real-time decision-making process in humans can only be described using magnetic resonance imaging, or using response tests with reaction time measures (e.g. Do Lam 2012, Oberauer & Hein 2012). A think-aloud technique combined with protocol analysis is one analysis method which is able to reveal at least a subset of the thoughts heeded while a person is completing a particular task.

The think-aloud technique is a research method in which participants verbalise their thoughts while performing tasks or solving problems. The direct verbalisation during the performance reflects the information attended by the person during that moment. (Ericsson & Simon 1993, Charters 2003.) The basis of this method is in cognitive psychology and information processing research, where the relationships between thoughts and words have been studied as an 'inner speech' from as early as the 1960s by Vygotsky, in order to investigate the inter-relationship of language development and thoughts. In information processing theory, thinking aloud is considered as an approach to use introspection in a more reliable way when the information processes of a human are objectively investigated. Human information management is described as an information process where an information stimulus enters into the short-term memory through the working memory, and finally ends up in the long-term memory. The working memory processes visual and verbal representations with a limited capacity, and operates when information has to be accessed, retained, updated, or manipulated for an immediate response. It is anticipated that with the think-aloud technique a researcher is able to gain an insight into the working memory and immediate awareness of a participant (Newell & Simon 1972, Ericsson & Simon 1993, Charters 2003, Linden 2007). The process of performing a study with this think-aloud technique is described in more detail in Paper I (Lundgrén-Laine et al. 2010).

In the context of clinical decision-making the term protocol usually means a certain linear process used, for example, to manage ventilation weaning, medication

administration, or wound care. Here, protocol analysis refers to a verbalisation process, which is viewed as a step-by-step progression of a participant's performance, revealing the information they are concentrating on during their tasks (Jones 1989, Ericsson & Simon 1993). The leaning towards using protocol analysis in information processing theory was initially developed by Ericsson & Simon in 1984, when they provided a detailed and systematic description of three levels of verbalisation. They demonstrated that verbalisations were produced based on memory functions, and the content of the working memory could be revealed by analysing the levels of these verbalisations. In this analysis, the first and the second level verbalisations are considered as reliable because they are assumed to be connected to the working memory. It is further assumed that at these verbalisation levels the sequence of heeded information is not connected to the long-term memory (Ericsson & Simon 1993, Yang 2003). First level verbalisations are direct articulations during a performance, with no further processing needed by the participant. On the second level, information might not have any verbal codes, and concepts are more abstract. In this case, the focus of information remains the same, but the person has to describe and explain the content of her or his thoughts (Ericsson & Simon 1993, Nielsen et al. 2002, Yang 2003). On the third level, the thinking processes are no longer essential for the immediate performance, and thinking is connected to previous experiences and long-term memory.

The combination of a think-aloud-technique and protocol analysis is widely used in usability testing (e.g. van den Haak et al. 2003, Wu et al. 2008, Li et al. 2012). However, in health-care research these methods are rarely used together (e.g. Simmons et al. 2003). In Paper I (Table 1, p. 567), a literature search was conducted on those articles that discussed the combination of a think-aloud technique and protocol analysis form a methodological point of view. Eight articles were found, only three of which were carried out in a real context. In ICU settings the think-aloud technique has been applied (Aitken 2000, Aitken & Mardegan 2000, Aitken 2003, Aitken et al. 2008, Aitken et al. 2011), but the combination of the think-aloud technique and protocol analysis is infrequently used in acute care settings. Both methods have only been used together a few times when clinical decision-making of bedside nurses has been studied. Fisher & Fonteyn (1995) used the combination of these methods when they investigated reasoning strategies of ICU nurses related to the evaluation of a patient's status. Hoffman et al. (2009) studied the differences between novice and expert nurses and how they collected and used cues during decision-making while caring for ICU patients. No articles were identified which related to both these methods and the decision-making of ICU shift leaders.

2.3 Information needs of ICU shift leaders

2.3.1 Information need

Previous studies have explored the concept of information needs and defined the term information need as 'a recognition that your knowledge is inadequate to satisfy a goal that you have, within the context or situation in which you find yourself at a specific point in time' or 'an expression of missing information needed to perform a particular task' (Case 2002, Timmins 2006, Ormandy 2011). In the field of information science, information

needs are considered from three perspectives: knowing, know how, and to know how to act in work situations when decisions have to be made. In addition, it is supposed that information needs are always connected to four key theoretical dimensions: goals, context, situation, and time, which all have an influence on the information needs of an individual (Dervin 1999, Miranda & Tarapanoff 2008).

In this study, the four key theoretical dimensions were:

1. Goal → Fluent flow of daily activities
2. Context → The highest-level ICUs for adults
3. Situation → Decision-making and information needs during the management of daily activities
4. Time → Ad hoc decision-making and immediate information needs

Furthermore, the information needs of ICU shift leaders were connected to their ad hoc decision-making, and the terms immediate information need and crucial information need were used interchangeably.

2.3.2 Information needs of charge nurses

According to the literature search, previous research concerning the information needs of ICU charge nurses is very limited and mainly discussed in trade papers. Most of a charge nurse's work occurs at a unit level, and their information needs are mainly associated with resource management. Compared to ICU physicians, their involvement in patient related decision-making is rather minor (Miller et al. 2010a). Nurse coordinators' information needs during the coordination of care within trauma hospitals were studied by Gurses et al. (2009). Nurse coordinators gathered and combined different kinds of information to support their work. These information needs included summary information about patients, such as reason for admission, the attending physician, staffing levels for the last 12 hours, available beds, and patient isolation information. The information needs of nineteen ICU nurses were studied in three clinical practice settings in a recent study by Koch et al. (2012). They found that the most frequent tasks of an ICU nurse were communication, medication management, and patient awareness tasks such as patient assessment or note recording. Unavailable and indiscriminate information cause perceptional challenges, and nurses have to combine multiple pieces of information from several sources. It is also found that ICU nurses' information needs are related to patient-specific, social, and logistic issues (McKnight 2006).

Furthermore, information needs and communication patterns of charge nurse have been studied in other settings, for example in operating rooms (Moss & Xiao, 2004, Moss et al. 2001), where it was found that communication between staff is mainly face to face, and information needs related to patient tracking, patient status, and equipment management are emphasised by charge nurses. More specifically, difficult managerial decisions made by ward charge nurses were evaluated in Fabray's and Luck's study (2000). The most difficult of these decisions concerned overall dependency of patients, bed occupation, throughput of patients, imbalance of actual and required staff hours, rate

of emergency admissions, dealing with admission and discharge documentation, level of support services, number of registrars, incidence of escorting patients, and staff sickness rates. The researchers concluded that technological applications would support different immediate information needs and the coordination of care, but that multidisciplinary development is still needed.

2.3.3 Information needs of physicians in charge

The information needs of physicians in charge are a poorly investigated aspect in the area of intensive care. In a study from the early 1980s patient information systems were only able to provide less than 50% of the important data needed by ICU physicians. Most of this important data concerned a patient's laboratory results, and clinical observations. However, other data such as clinical guidelines and procedures were also needed, but not easily provided by the existing systems (Bradshaw et al. 1984). Information needs of ICU physicians have been studied in order to develop a novel user interface for modelling the critical illness of ICU patients in a recent study by Herasevich et al. (2010). The core information needed by ICU physicians covered: patient demographics; patient admission characteristics, such as mechanical ventilation; basic monitored variables, like heart rate and central venous pressure; diagnostics and laboratory tests; interventions such as vasopressors; and patient outcomes, such as length of stay and ICU readmission. No other studies were identified in the literature search related to the information needs of ICU physicians in charge.

2.3.4 Shared information needs of ICU shift leaders

The unmet information needs of ICU shift leaders could result in irreversible consequences to the entire care process, and may have an impact on patient outcomes. Previous studies have shown that patient mortality is associated with delays in ICU admissions, readmissions, unplanned night discharges, and poorly organised transfers between hospital units (Goldfrad 2000, Simchen et al. 2007, Chen 2009). Typically, therefore, shift leaders in ICUs must use, and combine, a variety of sources to obtain the information needed for ad hoc decisions when care activities are coordinated. In this study, 'shared information needs of ICU shift leaders' are defined as immediate information needs involving both charge nurses' and physicians' requirements for their ad hoc decision-making in order to manage the fluent flow of ICU activities.

ICU research concerning information needs has mainly focused on individual needs, or information needs of patients and family members, rather than information needed by multi-professional experts. Only a few studies have been published investigating multidisciplinary information needs in ICU settings (Randolph & Kane 1998, Reddy et al. 2002, Miller et al 2010a). This is notable because information needs might differ between the ICU professionals, as was shown by Miller & Sanderson (2005), who found that nurses and physicians focused on the same patient information but for different reasons.

In the database search, a few articles discussing ICU staff information needs were found; however, none of these articles were strictly focused on ICU shift leaders'

information needs. The shared information needs of ICU personnel were investigated in a preliminary study by Randolph & Kane (1998) in order to install a web-enabled bedside patient application in one ICU. The information needs of ICU staff were not questioned, but the researchers made an observational inventory of these information requirements; papers, electronic documents, manuals, hand-outs, and patient charts used by clinicians. Altogether, 71 different categories of information were identified covering laboratory and diagnostic results, documents related to care summarisations, follow-up data, and frequent reports across patients such as equipment supply lists or use of medications. Some of these information needs regarded ICU specific information, and others related to hospital-wide information. Reddy et al. (2002) observed the information needs of patient-care teams in two 10-bed open surgical ICUs in the USA. During a three-month period they identified over 1500 questions made during patient morning rounds. Questions were classified into seven major categories: plan of care, patient specific, organisation, medication, teaching, further details related to deeper information, and miscellaneous questions that could not be categorised. Plan of care, patient specific data, and medication questions comprised 70% of the information needs of the ICU team. It is also noteworthy that nearly 20% of the questions concerned organisational issues, related for example to resource allocation or care protocols, and these were asked to all team members. According the study results, organisational issues seemed to play an essential role in the functioning of a successful ICU team. Miller et al. (2010a) found that multidisciplinary information is needed in relation to both patients and resources. However, an overload of information, and gaps between different information, might result in serious consequences to patient outcomes. Common for all of these study findings conducted in ICU settings was a high prevalence of organisational information needs for shared decision-making. Similar findings have been found in other settings, namely emergency departments and coronary care units (Currie et al. 2003, Reddy & Spence 2008). The main concepts and definitions are summarised in Table 1.

Table 1. The main concepts of the study and definitions used.

Main concepts	Definitions
Charge nurse	'A registered nurse who is responsible, and accountable, for nursing care within an ICU. He or she will hold the position of a shift-specific leader in the unit, is responsible for a team of nurses, and coordinating nursing activities, in order to ensure a high quality of nursing care in every situation.'
Physician in charge	'A certified senior physician who is specialised in the field of clinical practice, who works full-time or is regularly on duty in the ICU, and is responsible and accountable for patient care within an ICU during his or her shift. This individual holds the position of a shift-specific team leader in the unit, and is responsible for coordinating patient care activities in order to ensure a high quality of care in every situation.'
ICU shift leader	Both charge nurses and physicians in charge.
Ad hoc decision-making	'Critical judgements that are needed for a specific purpose at a precise moment, with the goal of ensuring instant and adequate patient care and a fluent flow of ICU activities.'
Immediate information need	'Immediate information needs that are required for a specific purpose at a precise moment, with the goal of ensuring instant and adequate patient care and a fluent flow of ICU activities.' Immediate information need and crucial information need were used interchangeably.'

2.4 Information integration tools developed to support decision-making and information needs of ICU shift leaders

For shift leaders it is most important that they are easily able to monitor and assess the rapidly changing situations in their units, in order to support their staff and facilitate the smooth running of activities through intra-group coordination (Lewis 1990, Wears et al. 2007). Thus, shift leaders spend a significant amount of time seeking information in ICUs, resulting from the nature of intensive care.

The first clinical information systems were introduced in ICUs in the early 1970s in the USA (Varon & Marik 2002). Since then the spread of intensive care information systems has been vast, replacing handwritten patient flow sheets, and the first paperless ICU was described by Hammond et al. as early as 1991. However, most of the information systems developed for intensive care are patient care systems, which are stand-alone systems offering information related to a single patient, but which are not integrated with other systems used in the unit or at a hospital level. Compared to bedside workers, shift leaders in ICUs need different kinds of information for their decision-making: indicators that describe and integrate the performances and situations in their units. However, it seems that at the moment commercial information systems used in ICUs are still too inflexible for managerial data extraction (Colpaert et al. 2010).

The defects of information systems have forced clinicians to create their own information tools to support their information integration. Clinician-designed information tools are usually created only for temporal use from highly selected bundles of information derived from multiple sources (Gorman et al. 2000). Information tools can be informal papers, sticky notes, to do lists, single-use worksheets, or different kind of artefacts (status boards) which help clinicians to create an overall picture of the current situation. The basic idea behind these user-designed information tools is that they support the mobile work of shift leaders by being either portable, rapidly accessible integration tools, or by combining the most important ward-organisational information on a daily basis. In addition, these process-oriented tools are found to be better than many current electronic information systems in providing at-a-glance representations of the information needed immediately, and in supporting the continuity and coordination of care. (Hammond et al. 1991, Gorman et al. 2000, Ash et al. 2001, Gurses & Xiao 2006, Gurses et al. 2009.) A remarkable problem with these user-designed information tools is that they are usually disposable. Thus, the information gathered with these tools cannot be analysed retrospectively and the organisational relevance of this information remains unrecognised. (Miller 2013.)

Gorman et al. (2000) investigated paper-based information tools in ICU settings, and found that different kinds of tools were developed for different professionals. However, they were all actively created to support problem solving, task performances or maintaining situation awareness. These tools were physical representations—highly selective collections of information including data from different levels. In addition, all of the tools were very context specific, task oriented, and redundant in that way that all information included could be found elsewhere. Wears et al. (2007) described the status boards of an emergency department and a general paediatric ward and found

six properties to explain why user-developed information tools were workable. The boards were flexible, and their reconfiguration was easy with the use of new notations, colours, or symbols. In addition, boards were seen as ecological and locally owned, supporting the work of front-line workers at the unit level. These boards were widely accessible, to inform all the unit workers, representing each unit's own informal style. Furthermore, the boards were easy to use for everybody, requiring no other skills than writing. Most of the computer-based tools developed to the same purpose have not succeeded in gaining these characteristics, except in the sense of their wide availability.

Only a few studies were found in the literature search which described the development and implementation of integration platforms/dashboards/data warehouses, or evaluated the used of these in adult ICU settings. Most of these studies were published in conference proceedings, presenting the early phases of a system's development. Examples of such systems include: a real-time ventilator management dashboard, to support ventilator care and infection prevention (Starmer & Giuse 2008); ICU data warehouse development (de Mul et al. 2010); an advanced patient monitoring system (Heldt et al. 2006); and information technology implementation and adaptation rates in Flemish ICUs (Colpaert et al. 2010). All of these systems were built up for clinical information integration, rather than to support the managerial decision-making in the ICUs.

Pervasive computing systems have been piloted in other settings, namely in an operating ward and in an emergency department (Hansen & Bardram 2007, Wong et al. 2009), using location tracking systems, touch sensitive systems, and mobile devices to enhance the coordination of work. Through these systems clinicians were able to obtain information about the unit's activities and the location of staff, current scheduling, a list of operating rooms, isolation information, and each patient's length of stay. In addition, these systems enabled a video link, and the ability for staff to call or send messages to each other. Most of the users evaluated that the system increased the efficiency of their work.

In addition, two articles described requirements for information integration systems. Ho et al. (2007) observed 13 multidisciplinary rounds in 10-bed paediatric intensive care units, and determined how computers may be used to support professionals' information integration. They presented several physical, social, and supporting artefact requirements for computerised platforms. Most importantly for these kinds of platforms was the facility to combine individual information needs ('bundling') with visualisations of the data. Miller et al. (2010b) presented broader design principles for integrated information systems: in addition to data entry, systems should support intradisciplinary interactions and decision-making processes, information flows, and practices. The information needs of ICU shift leaders and their support tools found from the literature are summarised in Table 2.

Table 2. Information needs of ICU charge nurses, physicians in charge, shared information needs of ICU shift leaders, and support tools found from the literature search.

	Information related to patients	Information related to staff	Information related to material	Other information
Information needs of ICU charge nurses (Ref. Fabray and Luck 2000, Gurses et al. 2009, Koch et al. 2012, McKnight 2006, Miller et al. 2010a, Miller & Buerhaus 2013, Moss & Xiao 2004, Moss et al. 2001)	Admissions Reason for admission Patient isolation information Number of patients (patient tracking) Patient status Overall dependency of patients Throughput of patients Admission and discharge documentation Incidence of escorting patients	Attending physician Staffing levels for the last 12 hours Imbalance of actual and required staff hours Number of registrars Staff sickness Rate of emergency services Level of support services	Available beds Bed occupation Equipment management	
Information needs of ICU physicians in charge (Ref. Bradshaw et al. 1984, Herasevich et al. 2010)	Patients' laboratory results Clinical observations Mechanical ventilation Basic monitored variables Patients' diagnostic results Interventions Patient outcomes			Clinical guidelines and procedures
Information needs of ICU shift leaders (Ref. Miller et al. 2010a, Miller & Sanderson 2005, Randolph & Kane 1998, Reddy et al. 2002)	Patient admission Laboratory and diagnostic results Care summarisations Follow-up data Medication Plan of care Patient specific data	Staff resources	Equipment supply lists	Care protocols

Support tools

Clinical information systems, handwritten patient flow sheets, informal papers, sticky notes, to do lists, single-use worksheets, status boards, platforms / dashboards / warehouses / pervasive computing systems (in their preliminary phase)

(Ref. Colpaert et al. 2010, Gorman et al. 2000, Hammond et al. 1991, Hansen & Bardram 2007, Heldt et al. 2006, Ho et al. 2007, Miller et al. 2010b, Miller & Buerhaus 2013, Starmer & Giuse 2008, de Mul et al. 2010, Varon & Marik 2002, Wears et al. 2007, Wong et al. 2009)

2.5 Conclusions from the literature review

Coordination of care in ICUs is a complex process with many time-critical interventions, external influences, overlapping activities, and multidisciplinary, shared tasks (Rothen 2010); this requires rapid decision-making from shift leaders in every situation. A fluent coordination of both resources and patient care is thus needed. The shift-based management of daily care coordination in ICUs is usually shared between charge nurses and physicians in charge. The assignments of charge nurses and physicians in charge occur at the interface of care management and care delivery. Many of the decisions related to daily-care coordination have to be made on ad hoc-bases without delay, and easily accessible information is needed to support this decision-making. The aim of this literature search was to gain a comprehensive overview of the scientific literature presenting ICU shift leaders' decision-making and immediate information needs related to the daily care coordination, and how this is currently supported by technology. The literature search revealed a lack of research related to all of these topics. However, a few aspects can be highlighted concerning the existing evidence, which are presented in the following chapter, along with the gaps in the current literature.

2.5.1 What is already known?

- ICU charge nurses and physicians in charge are sharing shift-specific leadership, and are responsible for coordinating daily activities and ensuring a high quality of care. However, the role of a charge nurse as a shift leader is more ambiguous than the role of an ICU physician in charge. In addition, managerial education related to ICU shift leading is not commonly carried out within multi-professional groups.

- Multidisciplinary shift leading in ICUs has an influence on patient outcomes. It has been shown to reduce adverse events and critical incidents, patient mortality, and patient length of stay. Furthermore, it enhances unit efficiency on the whole.

- Managerial decision-making of ICU shift leaders occurs on both tactical and operational levels. Shared decision-making of ICU shift leaders is related to ICU admissions, discharges, and patient transfers.

- Directly measuring ongoing cognitions (vs. ad hoc decision-making) is difficult without complex and expensive methods.

- A think-aloud technique combined with protocol analysis has been used in studies investigating humans' ongoing thinking during a performance. These methods are mainly used together in usability testing.

- Even in the same situation, with common goals, the information needs of nurses and physicians differ. In addition, the information needs of ICU shift leaders are poorly evaluated in the scientific literature.

- Organisational information needs are emphasised in shared decision-making within ICU settings.

- Managerial information needs are poorly supported by existing information systems. This has forced clinicians to create their own information tools to support information integration.

2.5.2 What are the gaps in the existing knowledge?

- The distribution of decision-making between ICU charge nurses and physicians in charge is not clear when the shift-specific coordination of daily care is managed.
- ICU shift leaders' managerial decision-making is an unexplored area in ICU research and the ad hoc decision-making of ICU shift leaders has not been explored in previous studies. To our knowledge, this is the first research in Finland to study both charge nurses and physicians in charge together. In addition, a comparison of ICU charge nurses' information needs in different countries has not been previously conducted.
- A think-aloud technique combined with protocol analysis has not been previously applied in the identification and analysis of ICU shift leaders' decision-making
- The information needs of ICU charge nurses and physicians in charge is a poorly investigated area in an ICU settings. No previously developed instrument measuring the immediate information needs of ICU shift leaders was identified.
- It is not known what the mechanisms or factors are that explain the association between multidisciplinary shift leading and better ICU outcomes. The decision-making of ICU shift leaders, and how information integration and support for information access could impact on patient outcomes, has not been evaluated.

3 AIMS OF THE STUDY

The aim of this study was to produce a preliminary model for information integration to support the ad hoc decision-making and immediate information needs of intensive care charge nurses and physicians in charge during the management of an ICU's daily activities. The following detailed research tasks and questions were postulated:

Task 1: To test methods to identify and analyse the ad hoc decision-making of ICU charge nurses and physicians in charge during the management of daily activities (Paper I and II).

- How does the think-aloud technique lend itself to the identification of ad hoc decision-making by ICU shift leaders?
- How does the protocol analysis lend itself to in the analysis of ad hoc decision-making by ICU shift leaders?

Task 2: To identify the ad hoc decision-making of ICU charge nurses and physicians in charge during the management of daily activities (Paper II).

- What are the ad hoc decisions of ICU charge nurses during the management of daily activities?
- What are the ad hoc decisions of physicians in charge during the management of daily activities?
- What are shared ad hoc decisions of ICU shift leaders during the management of daily activities?

Task 3: To develop and test an instrument for evaluating the immediate information needs of ICU charge nurses and physicians in charge during the management of daily activities. (Paper III).

Task 4: To evaluate the immediate information needs of ICU charge nurses and physicians in charge during the management of daily activities (Papers III and IV).

- What are the immediate information needs of ICU charge nurses during the management of daily activities?
- What are the immediate information needs of physicians in charge during the management of daily activities?
- What are the immediate information needs of ICU shift leaders during the management of daily activities?

Task 5: To combine the knowledge of the earlier phases to develop a preliminary model for ICU shift leaders' immediate information needs.

4 MATERIAL AND METHODS

4.1 Settings and sampling

Study phases, tasks, design, settings, sampling, methods, data, and expected outcomes are summed up in Table 3, page 35. In the first phase of the study (Task 1 and 2), the think-aloud method and protocol analysis were tested in order to identify the ad hoc decision-making of ICU shift leaders during the management of daily activities. The first phase of the study was conducted in two of the largest university-hospital ICUs for adults in Finland from 25th April to 23rd June 2007 (Papers I and II). The study units were chosen based on their similar organisational characteristics, however they also represented different regions of Finland. Both of the ICUs were mixed medical-surgical and closed-model units managed by full-time intensivists. Both of the units had a full-time intensivist with 24-hour coverage, but out-of-office hours (4p.m. to 8a.m.) and weekends were covered by physicians in charge at the unit. Together the ICUs took care of over 4,000 patients annually, with 24 and 22 beds. More detailed characteristics of the ICUs are presented in Paper II (p. 2). The daily activities of the ICUs were coordinated and managed by the charge nurses and physicians in charge. Both of the ICUs used the same patient information system (Centricity™ Critical Care). Altogether, 20 ICU professionals, consisting of six charge nurses and four physicians in charge equally from both ICUs, were observed for the study. A purposeful sample was used for the observation to establish a good cooperation with our participants. Since the main target was to identify ad hoc decision-making of ICU shift leaders, ICU charge nurses and physicians in charge who had at least 5–10 years of experience working in a position of responsibility in intensive care were recruited. The ICU managers were asked to assess who of the charge nurses and physicians in charge in their unit could be capable and competent to undertake the study before asking for approval from the participants themselves. The inclusion criteria for the study participants were as follows: voluntary, willing, capable, and competent in thinking aloud. The competence of the participants in thinking aloud was evaluated by the ICU managers, using their perceptions related to the participants' working experience, capacity to control complex situations, and capability to verbalise their thinking spontaneously.

The third research (Phase II) task was to develop an instrument for evaluating the immediate information needs of ICU shift leaders during the management of daily activities. The term 'ad hoc' was operationalised through protocol analysis (Papers I, II), and the questionnaire was developed based on the results of the first study phase. The development and the content of the questionnaire are described in more detail in section 4.2.2 and in Papers III and IV.

The fourth research task (Phase III) was to evaluate the immediate information needs of ICU charge nurses and physicians in charge during the management of daily activities. Firstly, a nationwide survey was conducted between September and November 2009 (Paper III) in Finland. The inclusion criteria for the study units were that: (i) they can provide comprehensive care for critically ill adult patients; (ii) they have a designated

full-time physician and senior nurse, who are responsible for the overall management of the staff and the standards of clinical service provision; and (iii) they have an academic teaching mission. The survey covered all the highest level ICUs for adults (n = 17) in Finnish university-affiliated hospitals. The speciality areas of these ICUs differed, including ten mixed medical-surgical units, three postoperative units, three surgical units, and one ICU for burns. All of the units were close model units, and they had an appointed charge nurse and physician in every shift. A cross-sectional survey design was used, and all of the ICU charge nurses (n = 515) and physicians in charge (n = 223) working in the 17 study units during data collection were recruited for the study.

Table 3. Phases, tasks, design, settings, sampling, methods, data, and expected outcomes of the study.

	Task	Design	Setting	Sampling	Methods and data	Expected outcomes
Phase I 2007–2008	1 & 2	Observational study	Two highest level ICUs for adults in Finland	ICU charge nurses (n = 12), physicians in charge (n = 8)	Think-aloud technique 92 hours of think-aloud	Identification of ad hoc decisions of ICU shift leaders
Phase II 2009	3	To develop an instrument for evaluating immediate information needs of ICU charge nurses and physicians in charge during the management of daily activities				
Phase III 2009–2012	4	Cross-sectional national and international surveys	All Finnish highest level ICUs for adults (n = 17) Greek highest level ICUs for adults (n = 16)	All eligible Finnish ICU charge nurses (n = 515) and physicians in charge (n = 223) during data collection All eligible Greek ICU charge nurses (n ~ 240) and physicians in charge (n = NA) from study units during data collection	A structured online survey, 122 statements regarding immediate information needs Altogether 403 responses of ICU shift leaders Finnish charge nurses, n = 257 Finnish physicians in charge, n = 96 Greek charge nurses, n = 50	Identification of immediate information needs of ICU shift leaders
	5	To develop a preliminary model for ICU shift leaders' immediate information needs.				

NA; Not available

The study was extended with an international survey. The same survey that was first implemented in Finland was translated into Greek, and conducted in Greece between April and June 2010. A cross-sectional survey design was also used, and all eligible Greek ICU charge nurses and physicians in charge from 16 different ICUs were recruited. The inclusion criteria for the Greek ICUs were the same as in Finland. The estimated number of Greek charge nurses at the time of the data collection was about 240, but the number of physicians in charge was unknown. The demographic data of the study participants are presented in Table 6 in page 52. The final phase of the study combined the knowledge gained from the earlier phases for the preliminary information integration model.

4.2 Data collection

Data for the study were collected using two different data collection methods: observational study with a think-aloud technique (Phase I), and a structured online questionnaire (Phase III).

4.2.1 Think-aloud technique (Papers I and II)

A think-aloud technique was used for data collection to identify ad hoc decisions made by the ICU shift leaders during the management of daily activities. The think-aloud technique was chosen because it enables rich and in-depth data collection when complex environments are investigated. This technique has been found to be an appropriate method for investigating and revealing complex cognitive processes in real-life situations (Ericsson & Simon 1993, Kushniruk 2001). However, it is quite rarely used in ICU settings, and most of the studies that have used the technique have concentrated on clinical work (Aitken 2000, Aitken & Mardegan 2000, Aitken 2003, Aitken et al. 2008, Hoffman et al. 2009, Aitken et al. 2011).

A think-aloud technique consists of asking people to verbalise their thoughts while performing tasks or solving problems. It has been postulated that by thinking aloud, the study participants are also making interpretations, and the main task of the researcher is to objectively observe these interpretations (van den Haak et al. 2003). Both observation and audio- or videotaping of study participants can be combined when using this method (Ericsson & Simon 1993, Jones 1989). The think-aloud technique can be applied both concurrently and retrospectively. In the concurrent technique, the participants are asked to verbalise their thoughts as they are performing their tasks, whereas in the retrospective technique, the verbalisations occur after the performance. Videotaping is usually used when a retrospective approach is applied (van den Haak et al. 2003). In this study a concurrent think-aloud technique was used, and the data collection was performed during the participants' performance with a portable MP3 player. Recording was suspended during breaks. Videotaping was planned and tested, but in the early stages it became clear that this would not elicit enough new information. One reason for not using the video camera was that the aim of the observation was to reveal the most immediate decisions related to the management of daily activities in the unit, not the interpretations of the study participants. Another reason was the transient nature of the shift leaders' work as 'floating' staff members.

A sample size of 20 participants was decided, and altogether 12 charge nurses and eight physicians in charge were observed. In previous research, relatively small sample sizes have been used with a think-aloud technique; some scholars have suggested using a sample size as small as five for stable results. However, such small sample sizes have also been criticised (e.g. Nielsen 1994, Lewis 1994, Yang, 2003). In this study, a larger sample size was considered on the basis of the nature of intensive care, and the hypothesis was that performances in intensive care would be extremely complex and varied. More important than the sample size for a study using the think-aloud technique are the heterogeneous sample of participants, the skills of participants in verbalisation, the applicability of those skills to thinking aloud (Caulton 2001, Fonteyn et al. 1993, Hall et al. 2004, van den Haak et al. 2003, van Someren et al. 1994), as well as the saturation of the data, which was taken into account in this study.

The charge nurses and physicians in charge at two of the highest level Finnish ICUs were observed equally. The observations were conducted during different eight-hour shifts (15 morning shifts, four evening shifts and one night shift) and during different days of the week, including three weekend shifts. Each participant was individually followed by the principal investigator, familiar with intensive care, from the beginning of the shift. The role of the researcher was to remind participants to talk aloud during the observations. If the participant was silent while performing his/her duties, he/she was reminded to keep talking. Some supportive questions were also asked by the observer such as, 'what are you thinking?' and 'what are you doing?' during the observations. Otherwise, the working situations and conversations were kept as normal as possible. Altogether, 92 hrs of thinking aloud data was recorded, constituting 212 pages of text for analysis (size A4).

4.2.2 Online survey (Papers III and IV)

In phase II, a structured online questionnaire (Webropol®) was developed, based on the results of the first study (Paper II). Before the final survey, 13 people with experience in nursing, medicine, or computer science evaluated the clarity of the questions, the intelligibility of the concepts, and the scale used. The survey was also piloted in a mixed medical 12-bed ICU with similar kinds of organisational characteristics as the units from phase one. In addition, the technology of the online program and the time of responding were tested before the final survey. Four of the questions were omitted because they were too similar, but only minor revisions were made to the phrasing and clarity of the questions in light of the evaluation. There were no technological problems with the program, and the average time needed to complete the questionnaire was under 20 minutes.

The questionnaire comprised two parts: (i) the demographics of the respondents including education, gender, age, ICU working experience, charge-position frequency, and two background questions concerning the name of the hospital and the number of ICU beds; and (ii) 122 statements regarding information needs related to the daily activities of the ICU. The statements of the questionnaire were derived from our observation study where each ad hoc decision found referred to several immediate information needs, which altogether constituted 122 immediate information needs. The statements of the questionnaire were divided into six dimensions. These dimensions were: patient admission (Statements 1-21); organisation and management of work (Statements 22-81); allocation of staff (Statements 82-99); special treatments (Statements 100-104); material resources (Statements 105-111); and patient discharge (Statements 112-122). With each statement the necessity of the information needed was measured on a rating scale from 0 meaning completely unnecessary to 10 meaning absolutely necessary. All statements were in the same format, such as 'immediate information about a patient's name is…' or 'immediate information about real-time workload at the unit is…'. The questionnaire was translated from Finnish into both English and Greek.

Prior to the start of the survey, each local ICU management was informed. In Finland, the managers of the units, department head nurses, and medical officers acted as study coordinators and provided the e-mail addresses of the shift leaders. Each participant received a personal online survey link. In Greece, the assigned coordinators were contacted from each participating ICU, and were given an open link to the survey.

Coordinators then passed on the direct link to eligible participants in their units. In both countries the participants responded anonymously, and two reminders were sent to non-responders. The survey was not dependent on a certain web browser and participants were able to suspend their answering, and then later continue. All participants were given an information letter. In Finland, answering the survey was considered as informed consent to participate. In Greece, a consent form was provided for each participant.

4.3 Data analysis

4.3.1 Protocol analysis (Papers I and II)

In the first phase of the study (Papers I and II), an application of protocol analysis (Ericsson & Simon 1993) was used to identify the ad hoc decisions of ICU shift leaders. Firstly, audiotaped think-aloud data were listened to, and saved into the waveform audio file format in Windows Media Player immediately after each observation. Secondly, the data were transcribed in authentic form (*txt), and parts of the data that were not related to the focus of our study questions were omitted. Finally, all the data were put into a computer-assisted qualitative software program, NVivo 7®, which was used to support the coding and analysis of the data.

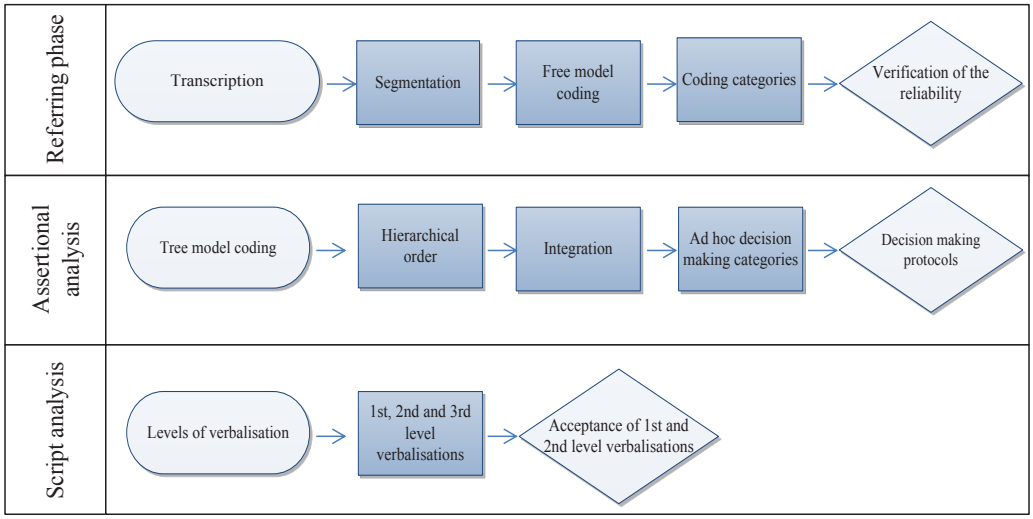

Figure 2. Analysis of verbalisations through the three phases.

Analysis of verbalisations was performed through the three phases used in protocol analysis (Ericsson & Simon 1993, Fonteyn et al. 1993): (i) referring phase analysis, (ii) assertional analysis, and (iii) script analysis (Figure 2, see also Paper I). The referring phase includes identification and definition of concepts with information on which participants are concentrating while performing their tasks (see Simmons et al. 2003). The objective of the referring phrase analysis was to isolate the information that participants concentrated on while performing their tasks. Thus first, the transcribed verbal protocols were divided into segments, each corresponding to one sentence, clause, or word. The data coding was then

started with free-model coding in order to identify all utterances of ICU shift leaders that included decision-making. A 'decision' was defined as choosing between alternatives and making a choice of action (Baron 2000, Thompson & Dowding 2002). The segments were encoded inductively, related to the information contained in them representing different decision-making categories (An example: includes a decision → yes [not enough nurses] → about what → Human resources). A coding scheme was developed by the principal researcher. Secondly, the reliability of coding was ensured by two independent coders through a coding scheme, which defined how the elements of the decisions could be identified. The data of ICU charge nurses and physicians in charge were coded separately. The reliability of the coding was good, constituting high intercoder agreement percentages, 97% for the data from the physicians in charge and 91% for the charge nurses' data. Consistency of the coding for each coding category was also good (Cohen's κ values 0.90–1.0).

Table 4. Coding categories, categories for ad hoc decisions, and dimensions of immediate information needs (See also Papers I, II, and III, Lundgrén-Laine & Salanterä 2010, Lundgrén-Laine et al. 2011, Lundgrén-Laine et al. 2013a and 2013b).

Coding categories	Ad hoc decision-making categories	Dimensions of immediate information needs
1. Administrative data	1. Adverse events	1. Allocation of material resources
2. Admission	2. Diagnostics	2. Allocation of staff
3. Adverse events	3. Human resources and know-how	3. Organisation and management of work
4. Diagnosis	4. Material resources	
5. Discharge	5. Patient admission	4. Patient admission
6. Human resources	6. Patient discharge	5. Patient discharge
7. Know-how of personnel	7. Patient information and vital signs	6. Special treatments
8. Laboratory tests	8. Special treatments	
9. Material resources		
10. Medication		
11. Patient information and vital signs		
12. Radiology and imaging		
13. Special treatments		

Merged categories:
Coding categories → Ad hoc decision-making categories:
Administrative data, Human resources, Know-how of personnel → Human resources and know-how;
Admission →Patient admission;
Diagnosis, Laboratory tests, and Radiology and imaging → Diagnostics;
Medication → Special treatments
Discharge → Patient discharge
Ad hoc decision-making categories → Dimensions of immediate information needs:
Adverse events, diagnostics, and patient information and vital signs → Organisation and management of work;
Human resources and know-how → Allocation of staff, and Organisation and management of work;
Material resources → Allocation of material resources.

The next phase of the coding was assertional analysis, which refers to evaluating the relationships between different categories. The coding was continued with tree-model coding, where each decision was organised hierarchically, and finally decision-making categories with close contents were integrated (see merged categories in Table 4, Categories for ad hoc decisions). Definitions of ad hoc decision-making categories, and related examples, are presented in Paper II (p.6). The last phase of the protocol analysis is a script analysis, which is used to describe the overall reasoning processes of the participants. In this study, it was applied in order to identify the levels of verbalisations in segments under the coded categories. These levels were analysed through the three levels

used within protocol analysis (Paper I and II). Only first- and second-level verbalisations were considered reliable because these levels are assumed to reveal the content of the short-term working memory (Ericsson & Simon 1993). The levels of the verbalisations are discussed in more detail in the Results section (Think-aloud technique) and in Paper I.

4.3.2 Statistical analysis

In the first phase of the study, the study population comprised 20 ICU professionals. Twelve charge nurses and eight physicians in charge were observed equally from two of the largest university hospitals in Finland. The study units were chosen based on their similar organisational characteristics. The sample size was considered on the basis of the complex and varied nature of intensive care performance. The saturation of the data was evaluated after each observation. Inclusion criteria of the study units and participants are discussed in chapter 4.1. Categories of ad hoc decisions (Table 4) and descriptive statistics were used to summarize the data (Table 5). The statistical analysis of the data was performed using SAS 9.2 (SAS 2004).

Table 5. Measured variables, sub-variables, and statistical methods used in different study tasks.

	Measured variables	Sub-variables	Statistical methods used
Tasks 1 & 2	**Ad hoc decisions** of ICU - charge nurses - physician in charge - shift leaders*	Eight categories: 1. Human resources and know-how 2. Material resources 3. Patient admissions 4. Patient information and vital signs 5. Special treatments 6. Diagnosis 7. Adverse events 8. Patient discharges	• Frequency • Coding frequencies of ad hoc decisions • Percent • Inter-rater reliability • Observation times
Task 3 & 4	**Statements of the survey; Information needs of ICU** - charge nurses - physician in charge - shift leaders*	122 statements divided into six dimensions 1. Allocation of material resources 2. Allocation of staff 3. Organisation and management of work 4. Patient admission 5. Patient discharge 6. Special treatments Age Number of ICU beds Intensive care experience Shift leader acting frequency	• Frequencies • Means • Medians • Standard deviations • Sum-variables; Cronbach's α • Confirmatory factor analysis; Kaiser's MSA • Pearson's chi-square • Mann-Whitney U • Kolmogorov-Smirnov • Correspondence analysis

* Shift leaders: both charge nurses and physicians in charge
The level of statistical significance of 5% was used throughout the analysis.

Related to the ad hoc decisions found in the first phase of the study, the online questionnaire was developed to evaluate the immediate information needs of ICU shift leaders during the management of the unit's daily activities. Each ad hoc decision discerned in the previous study phase was connected to the information needs in the moment; altogether this constituted 122 statements related to the immediate information needs of ICU shift leaders. The study participants of the nationwide survey comprised 515 ICU charge nurses and 223 physicians in charge from the 17 study units. All of the

charge nurses and physicians in charge during data collection were recruited for the study. The international survey participants included 50 Greek charge nurses. The Greek ICUs had the same inclusion criteria as in Finland, and all eligible ICU charge nurses during the data collection time were also recruited.

The statements from the survey were divided into six dimensions (Table 4, Dimensions of immediate information needs). In the analysis, median values were used because the distributions of data were distorted. The 10-point scale was divided into three sections related to the median (median lower that 5, 'not important'; median 5–8, 'important', and median 9–10, 'absolutely important'). The responses with a median of 9–10 were included in the analysis. In addition, a cut-point of 70% was used to identify the most crucial shared information needs of the shift leaders. This means that if 70% of the respondents rated a statement as 9 or 10, then it was considered to be the most crucial information need.

Sum-variables were constructed from six dimensions, and Cronbach's α scores were calculated for each dimension to certify the internal coherence reliability of the scales. Confirmatory factor analysis with iterated principal factor analysis was used to describe how well the dimensions explained the content of the information needs of shift leaders. Appropriateness of the factor model was verified with the overall Kaiser's MSA (a measure of sampling adequacy). Values of 0.8 or 0.9 are considered good, and over the acceptable level (SAS 2004). Pearson's chi-square test was used to determine the differences between the individual responses of the charge nurses and physicians in charge. Non-parametric tests (Mann-Whitney U median test and Kolmogorov-Smirnov test) were used to reveal the differences between the sum-variables, and the classifying variables of education and in-charge position frequency. Correspondence analysis was also performed, to visualise the interactions between the six dimensions and the differences between nurses and physicians in charge. For the subsequent analysis, the respondents were divided into four groups, depending on their age and work experience.

4.4 Ethical questions

All study phases were conducted in accordance with Finnish national legislation and research ethical principles (Medical Research Act 488/1999, Academy of Finland 2003, WMA Declaration of Helsinki 2004, National Advisory Board on Research Ethics 2009, Medical Research Act 794/2010, TENK 2012). For the study tasks 1 and 2, approval was received from the nursing research governance committees of the hospital districts and the medical officers of the hospitals. The participants were recruited by the principal investigator after the ICUs managers' assessment of who, out of the charge nurses and physicians in charge in their unit, would be capable and competent in the study. Both a written information sheet, including a description of the think-aloud technique, and verbal information were provided to the participants before the observation. A written consent form was obtained from each participant.

Each participant was individually followed by the principal investigator, familiar with intensive care, from the beginning of their shift. The role of the researcher was to remind participants to talk aloud during the observations. If the participant was silent while

performing his/her duties, he/she was reminded to keep talking. Some supportive questions were also asked by the observer such as, 'what are you thinking?' and 'what are you doing?' during the observations. Otherwise, the working situations and conversations were kept as normal as possible. The confidentiality and anonymity of the study participants and data, as well as professional security, were ensured throughout the study. No data are personally identifiable. Withdrawal from the study was possible at any time.

The combination of the think-aloud technique and protocol analysis is an innovative and rarely used research method in health care; hence, the lack of research evidence impacted on the ethical questions during the research process. More research is needed to support the ethical aspects and recommendations when these methods are applied in real clinical contexts. In this study, the observation of participants especially raised a few ethical questions related to the recording of speech. The participants wore an MP3 recorder during their entire shift, and the recording was only suspended during breaks. Thus during the observations it was impossible to control what would be recorded onto the MP3 file. All other conversations and private information concerning the patients, families, or other staff members were fully deleted during transcription. The data was only listened to, and transcribed by, the principal researcher and its safety and confidentiality was ensured with passwords. Videotaping of observations was also planned and tested, but not used after considering the ethical aspects related to the acute settings. Much of the shift leaders' work occurs at the bedside and near patients, which would have complicated the observations and the settings of the study.

Permissions to conduct the survey were obtained from each hospital's district authority from five university hospitals. An ethical statement for the study was conferred before the pilot study by the Ethical committee of the hospital district of South West Finland (Satakunta Central Hospital, 9§, 29.4.2009). Before the data collection, the local ICU management was informed about the survey and the researcher personally contacted all unit managers. In Finland, the managers of the units, department head nurses, and medical officers acted as study coordinators and provided the e-mail addresses of the shift leaders. Email addresses of the participants were managed only by the principal researcher, and were only used for the purposes of the study. An invitation letter was sent to each participant, which included a personal online survey link. Answering the survey was considered as informed consent to participate. In Greece, the consent form, participant information letter, and a direct link to the survey were provided by unit coordinators, who were informed in cooperation with local partners. Coordinators then passed on the direct link to eligible participants in their units. In every phase, the study participants were informed that they had a right to withdraw from the study at any time, for any reason. In both countries two reminders were sent to non-responders.

The survey was not dependent on a certain web browser and participants could suspend the survey, and continue it later. The respondents were able to respond to the survey anonymously. The survey did not include any personal or sensitive questions, and questions did not break the vow of silence of the professionals. All responses were gathered in an online system (Webropol®) with protected password access, only accessible to the principal researcher.

5 RESULTS

The main findings of the study are reported in five parts, according to the research tasks and questions. Firstly, the applicability of the think-aloud technique and protocol analysis in the identification and analysis of ICU shift leaders' ad hoc decisions is discussed (Phase I, Papers I and II). Secondly, the ad hoc decision-making of ICU shift leaders is described (Phase I, Paper II). Thirdly, the evaluation of the instrument developed is presented; and then the information needs of ICU shift leaders are discussed (Phase III, Papers III and IV). Finally, as a summary, a preliminary model for an ICU information integration platform is introduced. More detailed study results are presented in the original papers I–IV.

5.1 Applicability of a think-aloud technique and protocol analysis in the identification of ICU shift leaders' ad hoc decisions (Paper I, II)

The first research task was to test methods to identify and analyse the ad hoc decision-making of ICU charge nurses and physicians in charge during the management of daily activities.

Think-aloud technique

A concurrent think-aloud technique was found to be applicable for the identification of the ad hoc decision-making of ICU shift leaders, as it was shown to reveal the cognitive behaviour and information stored in the working memories of the study participants in the present moment. Practice and warm-up tasks were not carried out before the observation sessions but participants were asked to consider an orientation session, and they were provided with an example related to the thinking aloud process, e.g.: 'I am thinking about the admission of a new patient. I need to know how many beds we have available and how many nurses we have on the next shift'. During the observations participants were asked to verbalise their thoughts, and their speech was recorded with a portable MP3 player as they coordinated the daily activities of the ICU. All the participants, 12 charge nurses and eight physicians in charge, were voluntary, capable, and competent for the task. None of the participants withdrew from the study during the observations and all observations were conducted according the study plan: i.e. during different eight-hour shifts and days of the week, individually with each participant. The final recording time used in the data analysis varied from two to six hours per participant. The duration of the recording time depended on the participant's work situation and the intensity of the shift. The mean duration of the think-aloud data was four hours and 40 minutes. Altogether, 92 hours of data was recorded.

The think-aloud technique was easy to carry out for the participants, who represented experienced ICU charge nurses and physicians in charge with work experience from five to 32 years. All of the participants were able to speak their thoughts aloud and link their thinking processes with their performances in the present. No special warm-

up tasks were needed. The small, portable nature of the recorder contributed to the fact that most of the participants actually forgot about the recording after a while. One of the advantages of the think-aloud technique was that it combined subjective introspection and objective observation. In addition, the researcher's knowledge of the context area and concepts facilitated the used of this technique. This was especially important in the transcription phase when special concepts were connected to certain situations, and afterwards when ad hoc decisions were combined with information needs.

Protocol analysis

The goal of the analysis was to identify ICU shift leaders' decisions that were needed immediately for a specific purpose at a precise moment during the management of ICU activities. Protocol analysis was found to be applicable for the analysis of ICU shift leaders' ad hoc decision-making. It was possible to reveal the verbal processes, and the step-by-step progression of a participant's thought pathways during the performance, through verbalisation and by applying protocol analysis. Three different verbalisation levels used in protocol analysis were applied in order to find thinking processes which were essential for the immediate performance. It can be hypothesised that most of the ad hoc decisions of ICU shift leaders that are made in different and varying situations in a clinical context are based on the information stored in the working memory. The verbalisation levels of protocol analysis could thus be applied to reveal this information. First level, direct verbalisations and second level, more abstract and encoded but focused verbalisations, were considered as ad hoc decisions. More detailed examples of the levels of verbalisations and data analysis are presented in Paper I.

5.2 The ad hoc decision-making of ICU shift leaders during the management of daily activities (Paper II)

The second research task was to identify the ad hoc decision-making of ICU charge nurses and physicians in charge during the management of daily activities. Firstly, this ad hoc decision-making by shift leaders is discussed. Secondly, ad hoc decision-making of charge nurses and physicians in charge are described separately.

ICU shift leaders made a great number of complex ad hoc decisions during the management of daily activities. Altogether, 907 ad hoc decisions made by the charge nurses and physicians in charge were identified. This breaks down to nearly 240 ad hoc decisions per day, or ten ad hoc decisions per hour. The entire patient care process from admission to discharge was covered by the ICU shift leaders' ad hoc decisions. Eight decision-making categories were identified: 1. adverse events, 2. diagnostics, 3. human resources and know-how, 4. material resources, 5. patient admission, 6. patient discharge, 7. patient information and vital signs, and 8. special treatments (see Table 4 and Paper II, Table 3, p. 6). These eight categories were divided into two different types of decision-making: process-focused, and situation-focused. The process-focused (horizontal) decision-making of ICU shift leaders represented ad hoc decision-making that was related to permanent events. In addition, these decisions

were made concerning the entire unit, and they affected the workflow of the whole ICU. Processed-focused decision-making is thus represented with human resources and know-how, and material resources. The situation-focused (vertical) ad hoc decision-making concerned incidents that occurred at a certain moment. Typically they concerned one patient or were single incidents. Situation-focused decision-making is thus represented through adverse events, diagnostics, patient admissions, patient discharges, patient information and vital signs, and special treatments (see Figure 3). Most of the ad hoc decisions of ICU shift leaders were process-focused decisions, and belonged to the category of human resources and know-how (32%). Situation-focused ad hoc decisions related to patient information and vital signs (27%) and special treatments (19%) were the next most commonly made. Fewer ad hoc decisions were made related to diagnostics (9.5%) and patient discharge (6.4%). The most rare ad hoc decisions concerned patient admissions (3.5%), material resources (2.4%), and adverse events (0.1%). The categories of ad hoc decision-making are described in Table 6 below (see also Paper II, with for more detailed descriptions).

Table 6. Categories, amounts, coding frequencies of ad hoc decisions, number of ad hoc decisions, inter-rater reliability values and observation times (see also Paper II, Table 3, p. 6., Lundgrén-Laine et al. 2011).

Categories of ad hoc decisions	Shift leaders*	Physicians in charge (*n* = 8)	Charge nurses (*n* = 12)
Process-focused, *n* (%)			
1. Human resources and know-how	**291 (32.1%)**	NF[a]	**291 (63%)**
2. Material resources	22 (2.4%)	NF[a]	22 (4.8%)
Situation-focused, *n* (%)			
3. Patient admissions	32 (3.5%)	3 (0.7%)	29 (6%)
4. Patient information and vital signs	**246 (27%)**	**174 (39%)**	**72 (16%)**
5. Special treatments	**171 (19%)**	**147 (33%)**	24 (5%)
6. Diagnostics	86 (9.5%)	**86 (19%)**	
7. Adverse events	1 (0.1%)		1 (0.2%)
8. Patient discharges	58 (6.4%)	34 (8%)	24 (5%)
IRR[b] (%)/Cohen's κ		97.0/0.92 to 1.0	91.0/0.90 to 1.0
Total ad hoc decisions, *n*	**907**	**444**	**463**
Total observation time, hours	92	30	62

* Shift leaders: both physicians in charge and charge nurses; [a]NF = Not Found; [b]IRR = inter-rater reliability

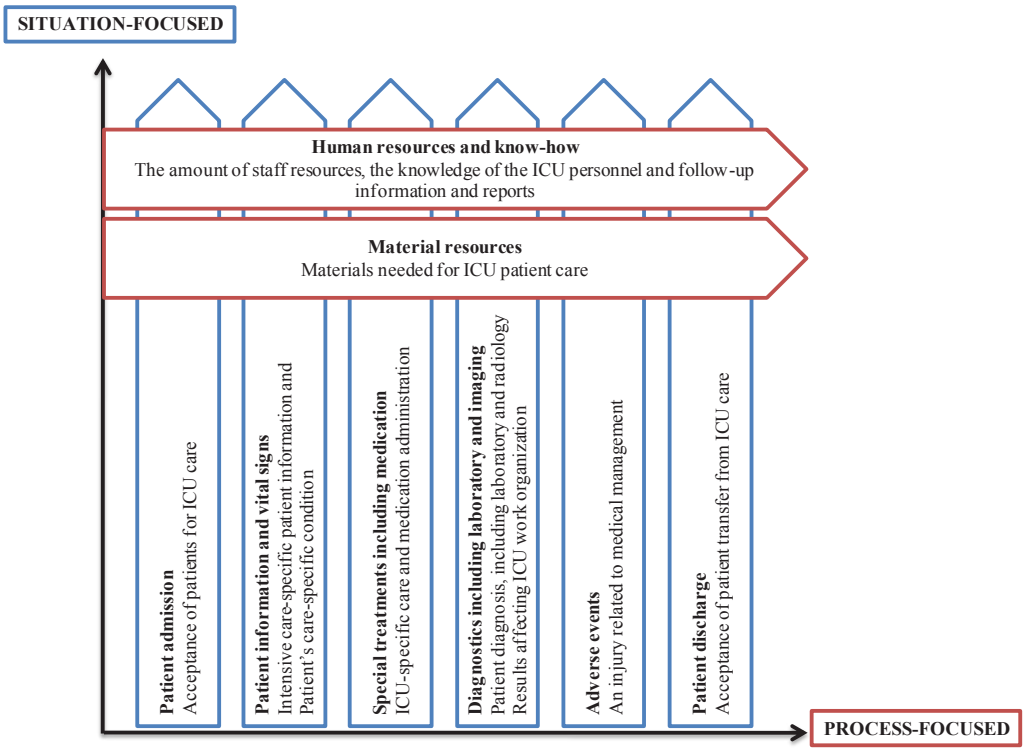

Figure 3. Named categories of ad hoc decisions related to process-focused (horizontal) and situation-focused (vertical) decision-making (Modified from Paper II, Figure 1, p. 5 in Lundgrén-Laine et al. 2011).

Human resources and know-how

The main objective for these ad hoc decisions was to manage the number of ICU personnel, to ensure sufficient and appropriate resources, or to compensate for the know-how levels required in order for patient care to be ensured in all situations, around the clock. In addition, many of these ad hoc decisions dealt with the different kinds of follow-up data needed for a unit's statistics or research, such as day situation reports for the chief nursing officer, or planned training sessions on the unit.

Patient information and vital signs

These ad hoc decisions covered very intensive care, specific patient information, and the present condition of a patient fulfilling the criteria for essential ICU care such as the mode of isolation, patient care intensity, or changes required immediately for the care plan. Most of these ad hoc decisions were also connected to other ad hoc decisions, such as those related to admissions or discharges.

Special treatments

These ad hoc decisions dealt with ICU-specific care, and the administration of medication. ICU-specific care is defined as the treatments that were only possible to perform under intensive care circumstances. Medication administration concerned all patient medication that required intensive monitoring.

A bundle of ad hoc decisions

Most of the ad hoc decisions made by the ICU shift leaders were not isolated decisions concerning only one judgment, but were event-based, complex combinations of several decisions including both process-focused as well as situation-focused decisions, which were made by both the physicians in charge and charge nurses. In addition, this ad hoc decision-making was not a linear process; instead it varied between decision makers, and in often rapidly changing situations. Ad hoc decision-making was thus a multidisciplinary process in which the roles of shift leaders were not well defined. Typically, one ad hoc decision made by either of the shift leaders created a bundle of ad hoc decisions and information needs which were needed to complete a task (Figure 4).

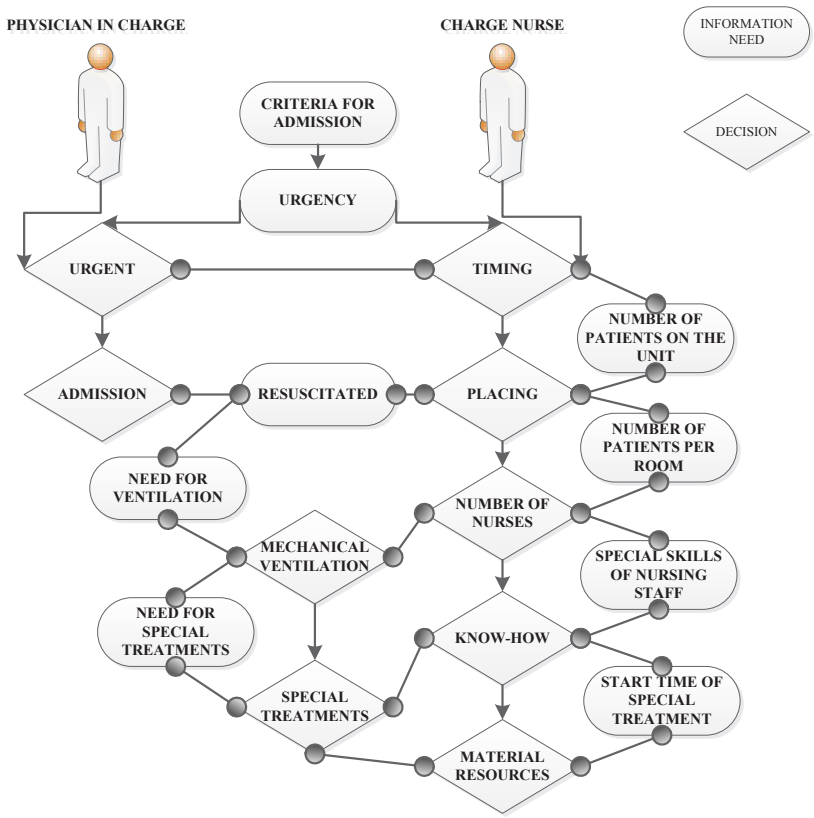

Figure 4. A simplified example of an ad hoc decision-making bundle, and information needs, during patient admission.

5.2.1 Ad hoc decision-making of charge nurses (Paper II)

Twelve ICU charge nurses were observed, during a total of 62 hours, and in total 463 ad hoc decisions were identified in the analysis. The amount of ad hoc decisions breaks down to almost 39 immediate decisions per charge nurse during one eight-hour shift. Most of the ad hoc decisions of charge nurses were process-focused, and related to human resources and know-how (63%) and material resources (5%). This process-focused decision-making represented horizontal ad hoc decision-making. It was connected to more permanent events

and decisions concerned the entire unit which had an effect on the work flow of the whole ICU. Charge nurses made all the ad hoc decisions related to human resources and know-how found in the analysis. However, these decisions were typically made in coordination with other ICU colleagues, or were negotiated in multidisciplinary teams before individual judgments were made. All ad hoc decisions about material resources and adverse events were also identified from the data sets of the charge nurses. More detailed examples of the ad hoc decisions of charge nurses are presented in Paper II.

5.2.2 Ad hoc decision-making of physicians in charge (Paper II)

Eight physicians in charge were observed for a total of 30 hours, and in total 444 ad hoc decisions were identified in the analysis. The number of decisions per participant was approximately 56 ad hoc decisions per physician in charge during one eight-hour shift. According to the analysis, the ad hoc decision-making of the physicians in charge was situation-focused (vertical), concerning mainly single incidents that occurred at a certain moment. The ad hoc decisions identified were related to diagnostics (19%), patient admission (0.7%), patient discharge (8%), patient information and vital signs (39%), and special treatments (33%) (Table 4). Most of the ad hoc decisions of the physicians in charge dealt with patient information and vital signs, such as the removal of a patient from isolation, a patient's hemodynamical problems, urgent changes in a patient's care plan, or the need for mechanical ventilation. Almost 40% of these ad hoc decisions concerned patient information and vital signs. The next largest group of ad hoc decisions by the physicians in charge was related to special treatments like specific consultations immediately needed, the starting of a haemodialysis, pacemaker placement, or medications that required intensive monitoring such as sedatives or inotropes. One-fifth of all the ad hoc decisions by the physicians in charge were related to diagnostics, or laboratory and radiology results. Fewer than 10% of their ad hoc decisions concerned the acceptance of a patient transfer from ICU care. More detailed examples of the ad hoc decisions made by the physicians in charge are presented in Paper II.

5.3 Evaluation of the instrument developed to measure the immediate information needs of ICU shift leaders

An instrument to measure the immediate information needs of ICU charge nurses and physicians in charge during the management of daily activities was not found from the previous literature. Therefore, the third research task was to develop this instrument, based on the results of the first study (Paper I, II, and III). The survey was first conducted in Finland, and included all charge nurses and physicians in charge from the highest level ICUs; after which, it was then also carried out in 16 Greek ICUs fulfilling the same inclusion criteria as the Finnish units.

The sampling included 738 Finnish ICU charge nurses (n = 515) and physicians in charge (n = 223). The response rate was 50% (n = 257) for the charge nurses and 43% (n = 96) for the physicians in charge, comprising an overall response rate of 47.8% (n = 353). The mean age of the charge nurses was 43 years (SD, 8.6), and the mean age of the physicians in charge was 43 years (SD, 7.3). Most of the charge nurses were

female (85%) and had an average of 15 years of ICU experience (SD, 7.9; range, 1–35). Both genders were equally represented among the physicians in charge (51% male, 49% female), with an average of 10 years of ICU experience (SD, 7; range 0–30). Most charge nurses reported working in a charge position on average once a week, or two–three times a month, whereas the physicians in charge reported that they worked in a charge position more often than once a week or two–three times a month.

Only seven responses were received from the Greek physicians in charge, and due to the subsequent poor representativeness, those responses were omitted from the study analysis. Fifty Greek ICU charge nurses responded to the questionnaire resulting in a response rate of about 21%. The mean age of the Greek charge nurses was 43.7 years (SD = 5.8), ranging from 26 to 53 years. Most Greek charge nurses were female (62% vs. 38%). The mean work experience of the respondents was 10.7 years with a range of one to 27 years. In Greece most of the respondents (46%) worked as a charge nurse more often than once a week.

The consistency of the instrument was evaluated with Cronbach's alpha scores. Almost all of the alpha scores for each of the six dimensions were excellent: patient admission (.87), organisation and management of work (.97), allocation of staff resources (.96), allocation of material resources (.91), special treatments (.87), and patient discharge (.90). The structure of the questionnaire was evaluated with a confirmatory factor analysis, and the total explanatory power was 64.5%, and can be considered as good. Further development and testing of the instrument was not considered in this study. The demographic data of both the Finnish and Greek participants are presented in Table 7.

Table 7. Demographic data of the participants in phase III. (See also Papers II and IV, Lundgrén-Laine et al. 2011, Lundgrén-Laine et al. 2013a)

	Finnish CN (%)	**Greek CN (%)**	**Finnish Ph IC (%)**
n	257	50	96
Sex			
Male	38 (15)	19 (38)	49 (51)
Female	219 (85)	31 (62)	47 (49)
Age, years			
Min, max	25, 61	26, 53	29, 63
Mean, SD	43, 8.6	37, 5.8	43, 7.3
Not reported	1	3	
Age groups			
25–34	(20)	(36)	(10)
35–44	(39)	(55)	(46)
45–54	(32)	(9)	(36)
55–63	(9)	-	(8)
Experience in ICU years			
Min, max	1, 35	1, 27	0, 30
Mean, SD	15, 7.9	10.7, 6.3	10, 6.6
Not reported			2
Shift leader's duties			
More than once a week	(24)	(46)	(29)
On average one a week	(26)	(12)	(23)
2–3 times a month	(28)	(20)	(33)
Less often	(22)	(22)	(15)

CN; Charge Nurse, **Ph IC**; Physicians in Charge

5.4 Information needs of ICU shift leaders (Paper III, IV)

The fourth research task was to evaluate the immediate information needs of ICU shift leaders during the management of daily activities. Firstly, the shared information needs of ICU shift leaders are described. Secondly, the information needs of charge nurses and physicians in charge are separately discussed.

A total of 57 information needs of ICU shift leaders were identified as crucial, out of 122 needs. These information needs covered all six dimensions: patient admission, organisation and management of work, allocation of staff resources, allocation of material resources, special treatments, and patient discharge. Twenty-two of these were shared multi-professional crucial information needs. This means that 70% of all respondents had evaluated this information need as absolutely necessary for his/her ad hoc decision-making (median 9–10). Most of these needs were related to patient admission, organisation and management of work, or resource allocation (Paper III, Table 2). Nearly 90% of all ICU shift leaders reported that immediate information about the need to isolate the patient, the death of a patient, and planned special treatments were absolutely necessary for their ad hoc decision-making during the management of daily activities. The most emphasised shared crucial information needs were related to direct patient care, such as the need to isolate the patient (mean 9.7, SD 1.2), the death of a patient (mean 9.4, SD 1.5), planned special treatments (mean 9.4, SD 1.4), a patient's need for mechanical ventilation (mean 9.3, SD 1.5), special treatments given to patients (mean 9.2, SD 298 1.7), the number of patients in the unit (mean 9.2, SD 1.8), and the method of patient isolation (mean 9.2, SD 1.8).

When ICU shift leaders' shared information needs were analysed, the highest factor loadings were for: information needs concerning staffing level on the current shift (0.77), staff resources that could be released for transport (0.77), number of staff per patient (0.71), patient admitted to the ICU (0.65), a significant change in the patient's condition during a shift (0.63), staff skills and knowledge (0.61), and the need to isolate the patient (0.60).

The crucial information needs of ICU charge nurses and physicians in charge differed, especially among issues involving allocation of staff (p-value < 0.05), allocation of material resources ($p = < .0001$), and patient discharge ($p = < .0001$). The largest difference between the charge nurses and physicians in charge was related to information about the skills mix of the nursing staff, the number of staff working on the next shift, and the skills mix of the current shift. All of this information was greatly emphasised by the charge nurses, but was not crucial for the physicians in charge. Statistically significant associations between working experience, or shift leader acting frequencies, and crucial information needs were not identified.

5.4.1 Information needs of charge nurses (Paper III, IV)

Compared to the physicians in charge, a higher number of crucial information needs were stressed by the Finnish charge nurses. Finnish ICU charge nurses evaluated 40 most crucial information needs as being absolutely necessary. The analysis revealed that the majority of the most crucial information needs for charge nurses were related to

the organisation and management of work, and allocation of staff resources (Paper III, Figure 2). The most crucial information needs of ICU charge nurses were: the need to isolate the patient (99%), planned special treatments (91%), the number of patients in the unit (91%), staff skills and knowledge (87%), staffing levels on the current shift (87%), and staff sick leave (85%). The results were verified by the international survey with Greek charge nurses. Altogether, 20 of the most crucial information needs were evaluated as being absolutely necessary by the charge nurses, in both countries (Paper IV, Figure 1). In the Finnish data, a statistically significant difference was found between the number of ICU beds (bed numbers <10 or 10–15, and ICUs with bed numbers >20, $p = 0.003$ and 0.01). The number of ICU beds also seems to impact upon information needs related to special treatments and patient discharge. In addition, the responses of charge nurses with 5–10 years of work experience differ from those with other levels of work experience in questions relating to the dimension of organisation and management of work ($p = 0.02$).

5.4.2 Information needs of physicians in charge (Paper III)

The physicians in charge emphasised nine of the most crucial information needs, all of them relating to direct patient care under the dimensions of patient admission, organisation and management of work, and special treatments (Paper III, Figure 2). The most crucial of which were: the need to isolate the patient (91%), the death of a patient (86%), the criterion/criteria for a patient's admission to the ICU (79%), planned special treatments (79%), the patient's need for mechanical ventilation (76%), special treatments given to patients (such as kidney replacement treatments or counter pulsator) (75%), the method of patient isolation (74%), the urgency of the patient's condition (73%), and scheduled dates for surgery or procedures (72%). Statistically, these crucial information needs were not significantly associated with age, length of working experience, or the shift leader acting frequencies of the physicians in charge.

5.4.3 A preliminary information integration model for ICU shift leaders' immediate information needs

Based on the study results (task 5) a preliminary information integration model for ICU shift leaders' immediate information needs is presented in Figure 5.

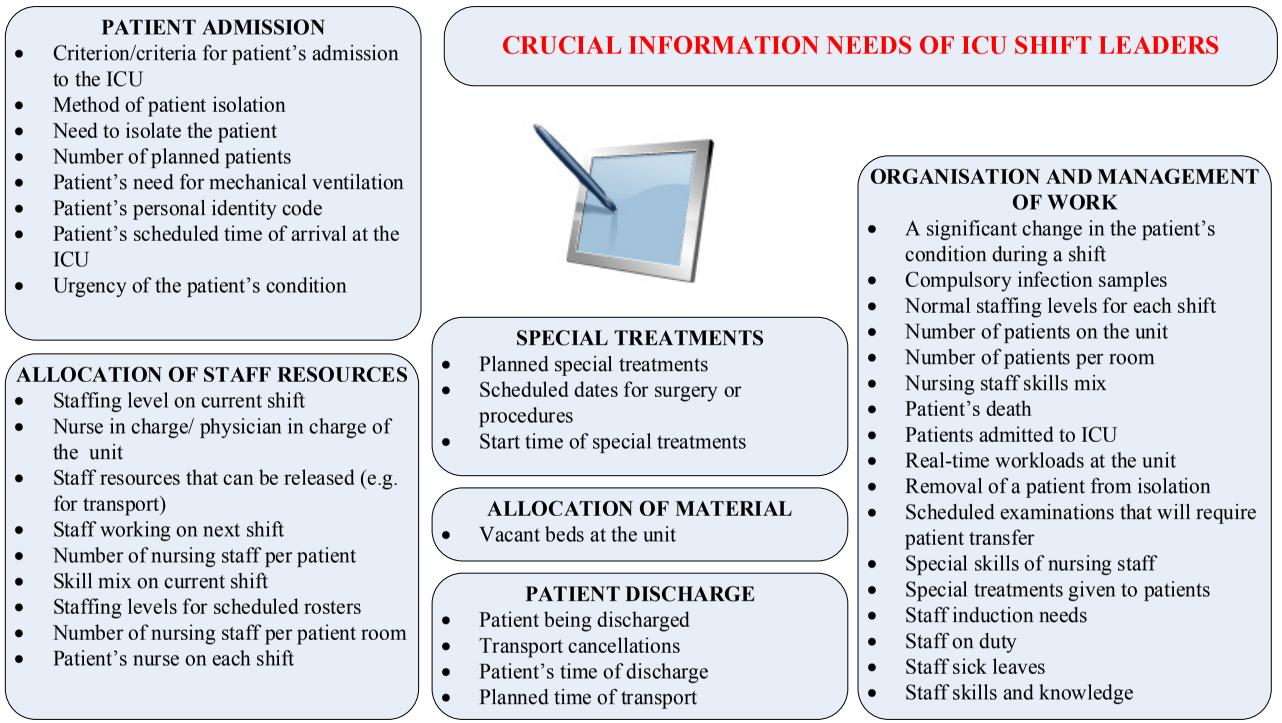

Figure 5. An information integration model for ICU shift leaders' immediate information needs, divided according to the dimensions of immediate information needs (Table 4).

6 DISCUSSION

In this section, the main results and strengths of the study, the limitations of the study, the validity and reliability of the study, and the implications for the future are discussed.

6.1 Main results and strengths of the study

The strengths of the study lie in the study methods used and the novel approach to ad hoc decision-making. By combining a think-aloud technique with protocol analysis it was possible to reveal the decision-making and information needs of participants, rather than just the external information observed by the researcher, or findings revealed through the interviews. The knowledge revealed in this study can be considered as information that has been given meaning and understanding through the thoughts of the participants. The main results of the study are presented according to the research tasks. It was found that a think-aloud technique can be carried out in a real clinical context, even in fast-paced units such as ICUs, when participants are performing their tasks. Furthermore, this study showed that a think-aloud technique combined with protocol analysis is an applicable research method when the ad hoc decision-making of ICU shift leaders are identified in real, clinical contexts. By using the verbalisation levels of protocol analysis it is possible to reveal the ad hoc decisions of ICU shift leaders.

This study showed that ICU shift leaders make numerous ad hoc decisions when managing the daily activities of their units. However, these multi-professional decisions differ between charge nurses and the physicians in charge. In addition, most of these ad hoc decisions are not isolated, but complex combinations of several ad hoc decisions (or a bundle of ad hoc decisions) made by the physicians in charge and the charge nurses. The ad hoc decisions of ICU shift leaders constitute various immediate information needs. Also, information needs differ between charge nurses and physicians in charge – that is, for the same task charge nurses and physicians in charge need different kinds of immediate information. In general, immediate information needs are not significantly associated with age, length of working experience, or the shift leader acting frequencies of either the charge nurses or the physicians in charge. Most of the crucial information needs include basic information related to the organisation and management of work and allocation of staff resources. The need for real-time information support is obvious in ICU settings.

No previously developed instrument measuring the immediate information needs of ICU shift leaders during the management of an ICU's activities was identified. Based on the study results (Papers I and II) a structured online questionnaire was developed. This survey was conducted in Finland, covering all the highest-level ICUs for adults and all of the charge nurses and physicians in charge working in the study units during the data collection. The instrument was also tested internationally. To our knowledge, this study is the first to describe a multi-professional model for ICU shift leaders' information integration.

A preliminary information integration model for ICU shift leaders' immediate information needs was produced. The model includes the crucial multi-professional information needs that are immediately required during the management of an ICU's daily activities in order to ensure instant and adequate patient care and a fluent flow of activities.

6.2 Study results and existing evidence

Related to the previous research, the topic of this study seems to be a significantly under-researched area in the context of ICUs: in previous results, none of the studies had presented the multi-professional ad hoc decision-making and immediate information needs of ICU shift leaders, or integrated information models used to support the decision-making of charge nurses and physicians in charge. Currently, we do not know how shift leaders' information needs, once identified and integrated, will shape information exploitation, patient care quality and outcomes, or safety issues in ICU settings.

Although the nurse–physician collaboration in ICUs has been promoted from the early 1980s little scientific literature exists that is related to the shared decision-making of ICU shift leaders. In addition, shared decision-making and intradisciplinary teamwork are found to be essential components when characteristics and outcomes of magnet hospitals are described (ANCC 2013). In a study by Miller et al. (2010a) it was found that charge nurses' decision-making concerned different areas than that of physicians during care coordination. Most of the shared decisions were related to ICU admissions, discharges, and patient transfers. In their study, the multidisciplinary decision-making was described as occurring both vertically, up and down the different decision-making levels, as well as laterally within each level. In this study, the differences between charge nurses and physicians in charge were also identified. The decisions shared between charge nurses and physicians were connected to patient admissions, patient information and vital signs, special treatments, and patient discharges including transfers. The decision-making process was described here with two different types of decision-making: process-focused (horizontal), and situation-focused (vertical).

Previous research related to ICU shift leaders' information needs was not identified. Most of the studies concerning information needs in ICU settings are focused on the individual needs of a professional, or information needs of patients and family members (e.g. Herasevich et al. 2010, Chatzaki et al. 2012, Koch et al. 2012). However, many of the crucial information needs found in this study were supported by the previous results presented in single studies (Table 7).

The results of this study showed that neither ICU working experience nor shift leader acting frequencies are significantly associated with crucial information needs. However, separate analyses revealed a statistically significant difference between both the number of ICU beds and the length of ICU experience of charge nurses (5–10 years), and information needs under the dimension of organisation and management of work. Associations with the number of beds might result from the complexity of ICU care in bigger units or in speciality areas of a certain unit. The duration of experience of charge

nurses might reflect different decision-making processes in more experienced nurses. However, these associations were not evaluated in more detail. It can be hypothesised that combining crucial information needs presented in this study will have an effect on the coordination of work, and ICU patient care quality and safety, if shift leaders' decision-making and access to crucial information is adequately promoted. This hypothesis is already supported by the previous international consensus guidelines and studies that have defined quality factors for ICUs, and have investigated certain single factors during care that influence the outcome of critically ill patients. A few examples of these studies are shown in Table 8, below.

Table 8. Quality factors or ICU patient outcomes that support the relevance of found crucial information needs of ICU shift leaders.

A crucial information need of ICU shift leader found in this study (Dimension of immediate information need, Table 4)	**Supportive data reference**	**Significance or patient outcome**
Criterion/criteria for patient's admission to the ICU (Patient admission)	Task Force on Guidelines. Crit Care Med 1999;27:633–638.	Consensus guidelines for admission criteria based on expert opinion and the relevant literature.
	Cavallazzi et al. Association between time of admission to the ICU and mortality. Chest 2010;138:68–75.	Outcomes: Patients admitted to an ICU over a weekend have a higher risk of death than patients admitted during weekdays.
Method of patient isolation, or need to isolate the patient (Patient admission)	Pearson et al. 2009. Review of the Infection Control Literature. National Health and Medical Research Council by The Joanna Briggs Institute.	Recommendations: ICU specific isolation precautions and other infection control strategies should be defined.
Patient need for mechanical ventilation (Patient admission)	Task Force on Guidelines. Crit Care Med 1999;27:633–638.	Admission criteria: Patients with respiratory failure requiring ventilator support.
Urgency of the patient's condition (Patient admission)	Duke et al. Survival of Critically Ill Medical Patients is Time-Critical. Crit Care Resusc 2004; 6:261–267.	Outcomes: Increasing lead-time is associated with an increased mortality-risk for ICU patients with acute respiratory or renal failure.
Normal staffing levels for each shift, real-time workloads at the unit, and staffing levels on current shift (Organisation and management of work; Allocation of staff resources)	Kane et al. The Association of Registered Nurse Staffing Levels and Patient Outcomes Systematic Review and Meta-Analysis. Med Care 2007;45:1195–1204.	Outcomes: Lower nurse staffing or increased workload are associated with adverse ICU patient outcomes, hospital related mortality, length of stay, failure to rescue, and hospital-acquired pneumonia.
Nursing staff skills mixes, number of nursing staff per patient, and skill mix on current shift (Allocation of staff resources)	Penoyer DA. Nurse staffing and patient outcomes in critical care: A concise review. Crit Care Med 2010;38:1521–1528.	Recommendations: Ventilated patients should have a minimum of one nurse to one patient and the ICU nurse-patient ratio should not go below one nurse to two patients.
Start time of special treatment (Special treatments)	Bray et al. Standards for nurse staffing in critical care units determined by: The British Association of Critical Care Nurses, The Critical Care Networks National Nurse Leads, Royal College of Nursing Critical Care and In-flight Forum. BACCN 2010;15:109–111.	Outcomes: Early institution of renal replacement therapy in critically ill patients with acute kidney injury may benefit survival.

(Continue)

A crucial information need of ICU shift leader found in this study (Dimension of immediate information need, Table 4)	Supportive data reference	Significance or patient outcome
(Continue)		
Vacant beds at the unit (Allocation of material)	Karvellas et al. A comparison of early versus late initiation of renal replacement therapy in critically ill patients with acute kidney injury: a systematic review and meta-analysis. Crit Care 2011;15R72.	Outcomes: A significant association between the number of ICU beds available and ICU admission and patient goals of care among hospitalised patients with acute vital problems.
Patient being discharged, and patient's time of discharge (Patient discharge)	Stelfox et al. Intensive Care Unit Bed Availability and Outcomes for Hospitalized Patients With Sudden Clinical Deterioration. Arch Intern Med. 2012;172:467–474.	Discharge criteria: Patient's physiologic status is stabilised enough, there is no need for ICU monitoring and care or when patient's physiologic status is deteriorated and no other active interventions are planned.
	Task Force on Guidelines. Crit Care Med 1999;27:633–638.	
	Laupland et al. Hospital mortality among adults admitted to and discharged from intensive care on weekends and evenings. J Crit Care 2008;23:317–324.	Outcomes: Discharge from ICU at night is associated with mortality.

6.3 Main limitations of the study

This study has some limitations that need to be taken into account when considering the study, and the generalisability of the results. The first limitation concerns the methods – the think-aloud technique and protocol analysis – used in this study. The combination of these methods is infrequently used in real clinical contexts, both in acute health care settings and in ICUs. More scientific research in complex clinical settings is needed to confirm the methodological basis of the methods. The second limitation is related to the information need instrument developed in this study. This was the first time the instrument was tested both nationally and internationally, in Finnish and Greek highest-level ICUs. Although the validity and reliability of the questionnaire was found to be good, the questions should be reconsidered in more detail when using the instrument in other settings. In addition, generalising from the international survey results is not possible because of the low number of Greek study participants. The third limitation concerns the selection of study units. The main survey was only conducted in one country, and included only the highest-level ICUs. In international settings many factors, such as geographical location, cultural elements, specialisation of units, and staff structure or responsibilities, may affect what is categorised as the most crucial information for each unit. However, the majority of the most important multi-professional information needs found in this study were not ICU specific, but basic information related to the activities of the units. Thus, it can be hypothesised that this information is likely to be generalisable for other health care settings. The limitations of the study's different phases are also discussed in Papers I-IV.

The study's limitations related to validity and reliability are discussed in more detail in the following sections.

6.4 Validity and reliability

6.4.1 Validity and reliability of the study samples and data collection

In the first study (Paper I and II), a purposeful sample of 12 charge nurses and eight physicians in charge who had at least five or ten years of experience in ICU work was used. The participants were chosen equally from two university-level ICUs for adults that fulfilled the study inclusion criteria (see 4.1) and represented the highest level of units with similar kinds of organisational characteristics. Studies using a think-aloud technique in ICU settings have focused on in-depth data, and thus the sample sizes of these studies have been relatively small (e.g. Aitken 2000, Aitken 2003, Aitken et al. 2008, Hoffman et al. 2009, Aitken et al. 2011). A homogeneous sample and the characteristics of the participants, such as verbalisation skills, have been emphasised in these kinds of studies; furthermore, it is expected that the study participants understand the focus of the study, and are able to express their thoughts during the performance (Fonteyn et al. 1993, van den Haak et al. 2003, van Someren et al. 1994, Parahoo 2006.). The study sample was homogenous because all of the participants have previous experience of in-charge working. All of them were voluntary, willing, capable, and competent in thinking aloud. Furthermore, the nature of critical care was taken into account when the sample size was decided. Therefore, 20 participants were chosen in order to obtain extensive and saturated data.

Data collection was carried out during different eight-hour shifts including morning, evening, night, and weekend shifts. All the observations were conducted by the same researcher. It has been advised that before think aloud sessions, short mental warm-up tasks would be useful (Ericsson & Simon 1993); however, the literature does not contain any detailed guidelines for this (van Someren et al. 1994). In this study, written and oral instructions for thinking aloud were provided, and participants were asked to imagine how they would familiarise an incoming employee with their tasks as they were performing them. The situation during the observations was kept as normal as possible, and the presence of the researcher was not highlighted (e.g. by using hospital work wear). Two of the participants seemed to feel somewhat uncomfortable at the beginning of the observations, which might be considered as a disadvantage. However, all the observations succeeded, and saturation of data occurred.

A national and an international survey were conducted during the research task four (Papers III and IV). All the study units had same inclusion criteria (see 4.1). The respondents represented all five university-hospitals in Finland, and all ICU charge nurses and physicians in charge who were eligible during the data collection were recruited. The response rate of Finnish participants was 47.8%, varying from 50% (charge nurses) to 43% (physicians in charge). From Greece, a response rate of 21% was achieved. The response rate of the study is an important factor when reliability of the study results is evaluated. Suggested minimal levels of response rates have varied between 50–80%, depending on whether a survey was aimed at measurement on an individual or organisational levels. Response rates have been found to be about 50% when on an individual level, whereas on an organisational level they have been about 35%. In addition, response rates to online surveys have declined, as has happened previously

with postal surveys (Sheehan 2001, Burns & Grove 2005, Baruch & Holtom 2008). The response rates of this study related to the Finnish respondents can be considered to be on a satisfactory level. However, the response rates of Greek participants were lower. Thus, the generalisability of the results is limited. Furthermore, the lack of official statistics of all ICU professionals in both countries, in Finland and in Greece, is a significant limitation when scientific studies are made.

6.4.2 Validity and reliability of the think-aloud technique and protocol analysis

The validity of a think-aloud technique has been found to be good when performances of people have been studied in simulated, retrospective experiments. Validity is tested by, for example, comparing eye movement data during the task to the retrospective reports after the performance. Furthermore, the complexity of the task does not reduce the validity (Ericsson & Simon 1993, Guan et al. 2006). However, the validity of a concurrent think-aloud process is difficult to evaluate. In this study, the validity of the think-aloud technique could have been tested by using retrospective reporting or, for example, comparing data collected by two different observation methods. On the other hand, when using a concurrent think-aloud process, the participants are able to express their thoughts immediately: a longer time span between a performance and the recall of it might weaken its validity (Crisp 2008). The validity of the think-aloud technique in this study was ensured by choosing participants who fulfilled the inclusion criteria of the study, and who were highly experienced in their work. The study environment and the tasks were familiar to the participants, and the research subject was strictly defined to ad hoc decisions. The validity of the think-aloud technique was also verified through the protocol analysis, and the information needs derived from the ad hoc decisions identified in the analysis. According to this study the following pros and cons of using a think-aloud technique in ICU settings can be postulated:

Pros:

- A concurrent think-aloud technique is applicable when decision-making of experienced ICU charge nurses and physicians in charge are observed in real, clinical situations.
- With a think-aloud technique it is possible to reveal cognitive behaviour and information stored in the working memory of the decision makers, in the present moment, in an ICU setting.
- A think-aloud technique can be used to reveal the tacit knowledge of ICU charge nurses and physicians in charge.
- A think-aloud technique is a cheap research method which can be applied within complex environments such as ICUs.
- Prior knowledge of the context area and concepts used by the study participants facilitates the application of a think-aloud technique.
- A think aloud-technique is an easy method to learn for the study participants.

Cons:

- A think-aloud technique is a time-consuming method both for the participants and the researcher.
- The think-aloud technique is conditional on good quality recording and file uploading.
- With a think-aloud technique and traditional recording it is possible to identify only one decision thought-path at a time.
- The use of the think-aloud technique in real, clinical contexts might not be possible in all situations from an ethical point of view.
- When using concurrent think-aloud techniques without videotaping, it is impossible to verify the situation after the performance.

Shorter observation sessions could also have worked as well as longer sessions. In this study only one participant was shadowed during one eight-hour shift. However, current modern technology enables simultaneous observations that may reveal better multiple decisions and the information needs of multi-professional participants in the present moment (see Westbrook & Ampt 2009, Ballerman et al. 2011).

In previous research, several problems related to reliability have been found when a think-aloud study is combined with protocol analysis. Examples of these problems are a limited engagement, or unsuccessful study environments (Defeng 2004). The reliability of the study method was supported by the careful planning of the data collection. The inclusion criteria of the participants were defined, and the capability and competence of the participants was also assessed by the unit managers. All participants had at least five years of experience in critical care, and could be considered expert in their field. Before the observation sessions all the participants were given written and oral instructions about thinking aloud, and the role of the researcher was explained. Study participants were asked to think about how they would familiarise a colleague with their work tasks, and were reminded to keep talking. Since acute clinical settings cannot be predetermined or structured beforehand, the situations during the observations were kept as standard and usual as possible, for example all normal communications related to working situations were permitted. The sample size was considered large enough in order to gain a saturated data. The saturation of the data was evaluated after each observation, when the transcription was completed.

The reliability of the protocol analysis should be evaluated throughout its different levels and phases. An objective analysis requires the recognition and sharing of preconceptions by the researcher as well as a predefined, consistent, and repeatable coding. The reliability of the coding can be improved with two or more coders, by assessing intercoder reliability (Graneheim & Lundman 2004, Burla et al. 2008). Another coder was used in the study analysis when ad hoc decisions were clustered into different coding categories. Intercoder agreement percentages (97%) and the consistency of coding were assessed with Cohen's κ values (0.92–1.0).

6.4.3 Validity and reliability of the information need instrument

The validity suggests the degree to which a questionnaire measures the phenomenon under investigation. Typically, the validity of the study instrument is evaluated through three approaches: content, construct, and criterion validity. (Parahoo 2006.)

With content validity the representativeness of the statements in the questionnaire is evaluated (Parahoo 2006). The content validity of the study questionnaire was verified in three ways. Firstly, the information-need statements of the questionnaire were based on the think-aloud data and ad hoc decisions made by the ICU professionals. All of the concepts used in these statements were derived from the clinical reality of the ICU professionals. Secondly, the clarity of the questions, the intelligibility of the concepts, and the scale used, were evaluated by 13 people with experience in nursing, medicine, and computer science. Thirdly, the survey was piloted in a mixed medical 12-bed ICU by 16 charge nurses and five physicians in charge. Professionals in the pilot unit evaluated the relevancy and clarity of the questions. Based on the pilot survey four of the questions were omitted because they were too similar to another question, but only minor revisions were made to the phrasing and clarity of the questions. One part of the content validity is face validity, which can be assumed to be a more subjective way to assess the validity of the instrument (Redsell et al. 2004). The face validity of the questionnaire was evaluated by two nurse scientists from Great Britain and Greece, both with former experience of intensive-care nursing. In addition, the technology of the online program and the time for responding were tested before the final survey.

Construct validity describes how well a questionnaire is able to measure a particular construct (Parahoo 2006). Previous research did not include a validated instrument to measure ICU shift leaders' information needs: therefore, the questionnaire was specifically designed for this study. The construct validity of the questionnaire and the structure of the six dimensions of daily ICU activities were assessed by confirmatory factor analysis. The factor analysis supported the six dimensions, and the total explanatory power was 64.5%. The overall Kaiser's MSA was used to verify the appropriateness of the factor model—the overall MSA-value was excellent (0.93). The criterion validity of the instrument can be assessed through comparison when the same data is collected by another questionnaire. In this study, such comparison was not possible because a specific instrument measuring the information needs of ICU charge nurses and physicians in charge was not found in the previous literature.

The reliability of the questionnaire was tested with Cronbach' s α, and the scores for each dimensions were as follows: patient admission (.87), organisation and management of work (.97), allocation of staff resources (.96), allocation of material resources (.91), special treatments (.87) and patient discharge (.90). High α-values reflect that the items of the questionnaire based on the ad hoc decisions of ICU shift leaders were consistent. However in the future, the structure and the number of the questions should be reconsidered in more detail.

6.4.4 Validity and reliability of the study results

The validity and reliability of the study results can be considered by the credibility, objectivity, reflexivity, and the transferability of the study findings. Credibility is used

to assess the truth value of the study results, and the believability of the findings. Objectivity means that the researcher tries to prevent any bias by not letting their own subjective opinions influence the data collection or analysis. Reflexivity means that the researcher continuously, during the research process, reflects on his or her own values, preconceptions, or behaviour which can affect the interpretation of the findings. Transferability refers to the generalisation of the study results to other contexts (Miles & Huberman 1994, Malterud 2001, Parahoo 2006).

The credibility of the information need statements of the study questionnaire was tested in three phases before the final survey (by 13 evaluators, in the pilot ICU, and by two international evaluators). Only minor revisions to the phrasing and clarity of the questions were needed. The survey was sent to all Finnish charge nurses and physicians in charge working at the 17 study units during data collection. Information need statements in the questionnaire covered the whole ICU patient care process from admission to discharge and the total explanatory power was high (64.5 %), reflecting that the dimensions used in the questionnaire covered the phenomenon under investigation. The findings were nationally coherent in both professional groups of charge nurses and physicians in charge. The results of the charge nurses were also verified by the international survey in Greece.

Objectivity of the study was considered in every phase of the data collection and analysis. The basics of the think-aloud technique were adhered to during the data collection and the voice of the participants was respected in the analysis. The objectivity of the study was strengthened by another coder during the analysis phase. Protocol analysis is described explicitly and in detail in Paper I and II, and in the summary. Using a think-aloud technique enhanced the reflexivity of the findings because only the direct verbalisations of the participants were used, and the interpretations of the researcher related mainly to the level of the verbalisations. Transferability of the study findings is possible, but restricted to similar kinds of settings to first level ICUs. The generalisation of the findings might also be dependable on geographical locations, and cultural elements of the organisation, or specialisation of units, and staff structure. On the other hand, international criteria for the highest levels of ICU care are similar, despite the different diagnoses of ICU patients. Cultural differences between Finnish and Greek health care systems are discussed in Paper IV.

In the following sections, the implications for practice, administration, education, and research will be discussed.

6.5 Implications for the future

6.5.1 Implications to practice

The information integration model (Figure 5) developed for ICU shift leaders' immediate information needs can be used as a preliminary model when real time information management tools are designed to support managerial decision-making in ICUs. The results of the study are generalisable for ICUs with similar characteristics as those used

here: closed, highest level ICUs for adults; a designated full-time physician and senior nurse who are shift-based, and responsible for overall management of staff; units can provide comprehensive care for critically ill adult patients; and units have the academic teaching mission. In addition, the results of the international study (Paper IV) indicated that a major proportion of the information needs of charge nurses are also generalisable in similar international settings. These findings are also supported by a recent study by Miller & Buerhaus (2013). However, different organisational structures and differences in clinical roles should be taken into consideration when study results are applied in this way.

For intensive care practice, the most emphasised issues according to the study results are related to organisational and staff related information such as staffing levels, skills mix, or the know-how levels of the staff. In future ICUs, this information should be immediately accessible at the point of coordination, when it is needed. Also, the general professional competence (see Lakanmaa 2012) of ICU shift leaders, including more than working experience alone, should be defined and evaluated. With modern information technology, for example, the know-how levels and competence areas of ICU personnel could be connected directly to the personal data of ICU nurses and physicians. This information is essential when daily care coordination is managed and evaluated.

6.5.2 Implications for administration and information technology developers

Regarding administration, the information integration model makes the implicit decision-making of ICU shift leaders an explicit activity, which can be used as part of quality management. Making the processes of shift leading more transparent might also create new knowledge that facilitates the delivery of good quality care. Currently, it is impossible to follow up the process of managerial decision-making and coordination of care from the shift leaders' point of view in real time, or if it is possible, then only single pieces of information are accessible. In addition, it is impossible to discover breaks or gaps in the information flow of ICU shift leaders. There is no 'minimum standard' for the quality of ICU shift leading. The work in ICUs is highly variable, and constant changes produce different information needs in different situations. The study findings showed that information needs also differ between professionals: referring to the previous literature and the study findings, the roles of ICU shift leaders should thus be clarified.

Furthermore, it has been suggested that clinical information systems should be designed in close cooperation with the end users and vendors. Administrators will have a critical role in this cooperation as they direct the technology development projects in their organisations. New systems should be flexible, in the way that they can provide the maximum freedom for users in restructuring and reconfiguring data in different situations (Gurses et al. 2009). In addition, new systems should be mobile devices, supporting not just access to information but, most of all, the integration of real-time information when it is needed. The real challenges for information technology developers are how to configure and combine the crucial multi-professional information needs of ICU shift leaders from disparate sources, and how this is supported in real time. Better information integration between the operational and tactical levels, and the sophisticated enterprise resource planning systems near patient care delivery, are greatly needed to support

shift leaders' work. This demand is highly relevant in many other health care settings, including ICUs. This will require close collaboration between practices, administrations, information system units, and vendors.

6.5.3 Implications for education

The basic elements of ICU shift leader's work should be taught during post-qualification education. Statistically significant associations between experience or shift leader acting frequencies and information needs were not found. However, one of the study findings was that over one-quarter of the charge nurses worked as shift leaders two or three times a month, or less often. Similar findings also concerned the physicians in charge; over 30% of them worked as shift leaders two or three times a month, and 15% less often. Thus it can be argued that standardised and ongoing education could especially support those charge nurses and physicians who work quite infrequently as shift leaders. In addition, in ICUs the education of shift leaders—both nurses and physicians should be an essential part of updating the training of experienced professionals. In an ICU setting, the roles and functions of nurses and physicians in charge are not always completely clear. As in Fackler et al.'s study (2009) it is difficult to recognise where a charge nurse's role ends and the role of the physician in charge begins. Education related to ICU shift leading could be organised on a multi-disciplinary basis, including the evaluation of competence levels required for the role of the shift leaders. Furthermore, educational simulation models could be a useful method to support ICU shift leading tasks (Boyle & Kochinda 2004).

6.5.4 Implications for research

This study showed that ICU shift leaders' decision-making and information needs are an under-researched area, both in nursing science and in medicine. Based on this study the following aspects for future research are postulated:

- Ad hoc decision-making needs to be studied in other settings, internationally, and in lower level ICUs, in which organisational and cultural factors may differ.
- The ad hoc decision-making of ICU professionals should be studied simultaneously, in order to reveal the entire decision-making process enacted between shift leaders. In this study, each participant was individually followed during the observation. However, it was found that the decision-making process was composed of a bundle of ad hoc decisions, and decision-making by both charge nurses and physicians in charge was needed to complete tasks. More advanced recording methods during the think-aloud technique and observation will also be needed (see e.g. Ballermann et al. 2011).
- More research is needed about the information needs of ICU shift leaders both internationally and in other settings, such as in lower level units. The questionnaire developed in this study needs to be tested and validated. The questionnaire is translated from Finnish into English and Greek. Further translations need to be culturally validated.

- In the future, the information integration model developed in this study needs to be implemented and tested in a clinical context. A think-aloud technique and protocol analysis could be applied to usability testing of the model. Both concurrent and retrospective techniques could be tested separately, or in parallel.
- After implementation, the effectiveness of the model for patient care quality, patient outcomes, and patient safety should be tested.

7 CONCLUSION

This study presents a novel and innovative approach for exploring the decision-making and information needs of ICU shift leaders. To our knowledge, this study is the first to describe a multi-professional model for ICU shift leaders' information integration, and thus contributes to the field of knowledge related to ICU organisational research. This study added new knowledge to the existing knowledge base by revealing the ad hoc decision-making, and exploring the immediate information needs, of ICU shift leaders during shift-specific care coordination. In addition, an instrument regarding the information needs of ICU shift leaders was developed and tested, and a preliminary information integration model for ICU shift leaders' information needs was also developed. Based on the study results, the following conclusions can be drawn:

1. A think-aloud technique combined with protocol analysis is an applicable research method for identifying the ad hoc decision-making of ICU shift leaders during the management of daily activities. By using the verbalisation levels of protocol analysis it is possible to reveal the ad hoc decisions of ICU shift leaders. However, more research and further applications of these methods are needed when real clinical contexts are studied.

2. Shared ad hoc decisions of ICU shift leaders are connected to intensive-care specific patient information, human resources, know-how levels of the professionals, and ICU-specific treatments. Most ad hoc decisions by ICU charge nurses are related to organisational issues, whereas ad hoc decisions of the physician in charge are more connected to patient-specific information. Ad hoc decisions of ICU shift leaders during daily-care coordination create several multi-professional information needs, thus support for real time information access in fast-paced intensive care settings is needed.

3. A nationwide survey regarding the immediate information needs of ICU shift leaders was conducted. The survey was also tested in Greece, with a smaller sample size of ICU charge nurses. The reliability and validity of the instrument was found to be good. In the future, expanding the survey to include lower-level ICUs, international participants, or other acute health care settings would be of interest.

4. Care coordination within ICUs is a multi-professional, collaborative process. The majority of the immediate information needs of ICU shift leaders focus on the organisation and management of work, patient admission, and allocation of staff resources. However, even when coordinating the same activity the information needs of charge nurses and physicians in charge differ. This should be taken into account when information integration systems are developed to support ICU shift leaders during the coordination of care. In the future, an information integration model of ICU shift leaders should be implemented in a clinical context, and the effectiveness of information integration for patient care quality should be tested with outcomes research.

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