TURUN YLIOPISTON JULKAISUJA
ANNALES UNIVERSITATIS TURKUENSIS

SARJA - SER. D OSA - TOM. 1083

MEDICA - ODONTOLOGICA

INFORMATION MANAGEMENT FOR TACTICAL DECISION-MAKING IN THE CARDIAC CARE PROCESS

by

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TURUN YLIOPISTO
UNIVERSITY OF TURKU
Turku 2013

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ISBN 978-951-29-5456-8 (PRINT)
ISBN 978-951-29-5457-5 (PDF)
ISSN 0355-9483
Painosalama Oy – Turku, Finland 2013

To Juha, Juuso and Joonas

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ABSTRACT

The aim of this study was to create a content model for supporting tactical decision-making with information management in cardiac care processes. The research had three phases. In Phase I, a literature review of enterprise resource planning (ERP) systems in healthcare environments was conducted (n=9). In Phase II, a qualitative approach involving the critical incident technique was used to identify critical information and information flow in cardiac care processes. The data of successful and unsuccessful incidents in cardiac care processes were collected in two phases with semi-structured questionnaires (50 respondents) and interviews (n=10) from registered nurses, ward sisters and health managers. Phase II studied tactical decision-making, as well as available and lacking information in cardiac care processes. The data was collected with semi-structured interviews from health management experts such as physicians, head nurses and nursing directors (n=14). Finally, in Phase III, the possibility for using machine-learning methods to predict the patients' acuity, based on previously assigned acuity scores and textual nursing notes (n=132 053 care days), was studied.

The results of Phase I show that most commonly, ERP systems are used for the management of materials in health care. ERP systems are also used in health care for clinical data management, financial data management and human resource management. However, ERP systems are not strongly connected with the actual care processes. Still, the identified critical information categories in Phase II were incidents relating to the care process, management and clinical care. In addition, the tactical decisions in cardiac care were classified into process- or resource-related decisions. Most of the information used in these decisions was retrieved manually, but also partly from information systems. A lot of information was lacking due to non-integrated or even non-existing information systems, resulting in difficulties in information utilization in tactical decision-making. Phase III then showed the power of such integrated information. Based on electronic nursing notes and the patient's acuity score of the previous day, it was possible to predict the patient's acuity for the next day and thus provide valuable information, for example for tactical decision-making in human resource allocation.

We can conclude that cardiac care processes contain critical information about the process itself, as well as management and clinical care. Tactical decisions are made relating to human resources, material resources and work loads. Tactical decision-making requires the collection of necessary information from several sources, but most of this information is not integrated or is manually recorded. Machine-learning methods provide possibilities for predicting a patient's acuity and provide useful information for human resource allocation. Finally, the created content model of the information needed in cardiac care processes provides a relevant design for future ERP systems.

Keywords: cardiac care process, tactical decision-making, information management, enterprise resource planning, electronic documentation, patient classification

Elina Kontio
TIEDONHALLINTA TAKTISESSA PÄÄTÖKSENTEOSSA SYDÄNPOTILAAN HOITOPROSESSISSA
Hoitotieteen laitos, lääketieteellinen tiedekunta, Turun yliopisto, Suomi

TIIVISTELMÄ

Tutkimuksen tarkoituksena oli kehittää sydänpotilaiden hoitoprosessin taktista päätöksentekoa tukeva tiedolla johtamisen sisältömalli. Tutkimusprosessi jaettiin kolmeen vaiheeseen. Vaiheessa yksi tarkasteltiin terveydenhuoltoon implementoituja toiminnanohjausjärjestelmiä analysoimalla aiheesta julkaistuja tutkimuksia (n=9). Vaiheessa kaksi kartoitettiin ensin sydänpotilaiden hoitoprosessin kriittisiä tietoja ja tiedon kulkua kriittisten tapahtumien tekniikalla sydänpotilaita hoitavilta sairaanhoitajilta ja osastonhoitajilta (n=50) weppikyselylomakkeella ja haastattelemalla osastonhoitajia, ylihoitajia ja osastonlääkäreitä (n=10) onnistuneista ja epäonnistuneista sydänpotilaiden hoitotapahtumista. Toisessa vaiheessa kartoitettiin myös sydänpotilaiden hoitoprosessissa tehtäviä taktisia päätöksiä sekä kyseisten päätösten taustalla olevan tiedon olemassaoloa ja kertymistä haastattelemalla osastonhoitajia, ylihoitajia ja osastonlääkäreitä (n=14). Vaihe kolme tarkasteli sydänpotilaiden hoitoprosessista tehtyjen elektronisten kirjausten (n= 132 053 hoitopäivää) ja aikaisempien hoitoisuusluokitusten ennustamisvoimaa koneoppimisen menetelmin.

Ensimmäisen vaiheen tulosten mukaan terveydenhuollossa käyttöönotettujen toiminnanohjausjärjestelmien yleisin sovellusalue oli materiaalihallinta. Järjestelmiä oli sovellettu myös taloushallintaan, kliinisen tiedon hallintaan ja henkilöstötiedon hallintaan. Järjestelmät olivat vain vähän varsinaiseen hoitotyöhön kytkeytyneitä. Kuitenkin sydänpotilaan prosessiin liittyviksi tärkeiksi tiedon luokiksi muodostuivat prosessiin liittyvät tapahtumat, johtamisen tapahtumat ja kliiniseen hoitamisen liittyvät tapahtumat. Taktiset päätökset ryhmiteltiin prosessia koskeviin ja resursseja koskeviin päätöksiin. Päätöksissä hyödynnettävä tieto olivat useimmiten manuaalista, mutta osin tietoa saatiin myös tietojärjestelmistä. Puuttuvia tietoja oli paljon johtuen monista integroitumattomista tai kokonaan puuttuvista tietojärjestelmistä, jonka vuoksi tiedon keruu ja systemaattinen käyttö taktisen päätöksenteon tukena oli vaikeaa. Vaihe kolme osoitti kuitenkin tietojen integroinnin voiman. Sähköisten kirjausten ja edellisen päivän hoitoisuusluokitusten avulla pystyttiin ennustamaan seuraavan päivän hoitoisuutta, jolla voi olla merkitystä ennakoitaessa henkilöstöresurssin määrää.

Yhteenvetona voidaan todeta, että sydänpotilaiden hoitoprosessi sisältää kriittistä tietoa prosessista, johtamisesta ja kliinisestä hoitamisesta. Näiden tietojen pohjalta tehdyt taktiset päätökset liittyvät henkilöstöresursseihin, materiaaliresursseihin ja työnmäärään. Päätöksenteon taustalla oleva tieto kertyy useasta eri lähteestä, mutta tiedot eivät ole integroituneita ja saattavat olla myös manuaalisia. Koneoppimisen menetelmin olisi mahdollista ennustaa potilaiden hoitoisuusluokitusta ja hyödyntää tätä tietoa henkilöstöresurssien hallinnassa. Tutkimuksessa esitettävää sisältömallia sydänpotilaan hoitoprosessin tarvitsemasta tiedosta voidaan soveltaa, kun reaaliaikaisia toiminnanohjausjärjestelmiä kehitetään.

Avainsanat: sydänpotilaan hoitoprosessi, taktinen päätöksenteko, tiedolla johtaminen, toiminnanohjausjärjestelmä, elektroninen kirjaaminen, hoitoisuusluokitus

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LIST OF ABBREVIATIONS

HIS = Hospital Information Systems

PCS = Patient Classification System

OPC = Oulu Patient Classification

ERP = Enterprise Resource Planning

AMI = Myocardial Infarction

STEMI = ST Elevation Myocardial Infarction

CCU = Critical Care Unit

PCI = Percutaneous Coronary Intervention

ACS = Acute Coronary Syndrome

MRP = Material Requirement Planning

MRP II = Manufacturing Resource Planning

HSSG = Hospital Systems Study Group Classification

LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following publications, which are referred to in the text with Roman numerals I – IV.

I. Kontio E, Lundgren-Laine H, Kontio J, Korvenranta H & Salanterä S. 2013. Enterprise resource planning systems in healthcare: A qualitative review. Int. J. of Information Systems in the Service Sector. In press.

II. Kontio E, Lundgren-Laine H, Kontio J, Korvenranta H & Salanterä S. 2011. Critical incidents and important information in the care processes of patients with cardiac symptoms. Journal of Nursing Management, 19, 209 – 217.

III. Kontio E, Lundgren-Laine H, Kontio J, Korvenranta H & Salanterä S. 2013. Information utilization in tactical decision making of middle management health managers. CIN: Computers, Informatics, Nursing, 31(1), 9-16.

IV. Kontio E, Airola A, Pahikkala T, Lundgren-Laine H, Junttila K, Korvenranta H, Salakoski T & Salanterä S. 2013. Predicting patient acuity from electronic patient records. Submitted.

1 INTRODUCTION

In health care, process development is a current topic as health care is transforming from being functional to process based. This transformation emphasizes the need for real-time information in decision-making. Relevant ICT technologies exist to collect and provide the required information, but the challenge is to define in detail the meaningful and critical information needed in a care process. The healthcare sector is not alone with these needs, as virtually every sector of contemporary society could improve their information management solutions. However, it seems that the healthcare sector has lagged behind other industries in implementing information systems (Shortliffe, 2005). Although there are many information systems in use in health care, the integration between these systems is very scarce. Typical ways information systems are used in health care include managing clinical and administrative operations. Most often, healthcare organizations use information systems for clinical purposes to improve patient care. (Bose, 2003.) These hospital information systems (HIS) are the core support for decision-making in health organizations. This decision-making support could be further improved with an integrated hospital information system that standardizes, integrates and organizes all the information available in different health information systems through an accessible and secure repository, and then conveniently distributes this information for decision-making (Canela-Soler et al., 2010). This kind of integrated information is necessary for the organization to plan, manage and evaluate, and therefore to provide managers with a decision tool for strategic and tactical decision-making in the short and medium terms (Canela-Soler et al., 2010). These integrated health information systems can be called enterprise resource planning (ERP) systems, like in many other sectors.

In Europe, cardiovascular diseases are the main causes of illness and death, and they are responsible for 23% of all disease burdens. Cardiac disease is the single most common cause of death in the European region of the World Health Organization (WHO). In the European Union (EU) one in six deaths in men and one in seven deaths in women are due to cardiac disease. (Allender et al., 2008). In Finland, cardiac disease is the cause of about 20% of all hospital stays. (National Cardiovascular Disease Register, 2009). In this study, the term ‘cardiac patients’ is used to include all patients presenting to the hospital with ischaemic cardiac symptoms.

The cardiac care process is very similar all around the world, typically including ambulatory care services (e.g. outpatient clinics, primary care services, radiology), emergency care services (e.g. hospital emergency departments, ambulances, trauma centers), operational care services (e.g. operating theaters, surgical daycare centers, anesthesia facilities), inpatient care services (e.g. intensive care units, general nursing wards), home care services (e.g. medical care at home, housekeeping support, personal hygiene assistants) and residential care services (e.g. nursing homes, rehabilitation clinics). In this study, we focus on the parts of the cardiac care process that occur within a hospital: emergency, operational and inpatient. A key issue in cardiac care is the timely and efficiently functioning of these care processes.

The origins of this research are in the idea of creating an ERP system for process-based activities. The main aim of this research is to build a content model that can support information management and enable the utilization of real-time and reliable information in decision-making during the care process continuum. The goal is that information production and collection can support management, especially information-based management and steering, at a tactical level. This research envisions an integrated health information system, that is an ERP system, that would help integrate the clinical, administrative, and financial processes in health care through a common technical architecture, and provide a decision support infrastructure for clinical and administrative decision-making. However, the design of an integrated health information system must not only provide the technical infrastructure that can support myriad applications, but must also integrate the system's applications in order to collect data that are accurate, complete, and stored in compatible formats (Grimson et al., 2000).

2 LITERATURE REVIEW

The literature review for this study consists of definitions for the main concepts of the study and an assessment of previous empirical studies concerning tactical decision-making in cardiac care processes, while paying special attention to information management with ERP and patient classification.

The database searches covered publications from 1990 to 2013 and were limited to studies that included abstracts. The searches were based on the PubMed and EBSCO databases as well as manual searches. The manual search included articles found in the reference lists of the examined articles from the databases and related literature. The database searches focused on the main concepts of the study and issues concerning tactical decision-making and information management in cardiac care processes with an ERP system. We conducted these searches using keywords, mesh terms and word-stems. The search terms were used alone and interchangeably, see Figure 1.

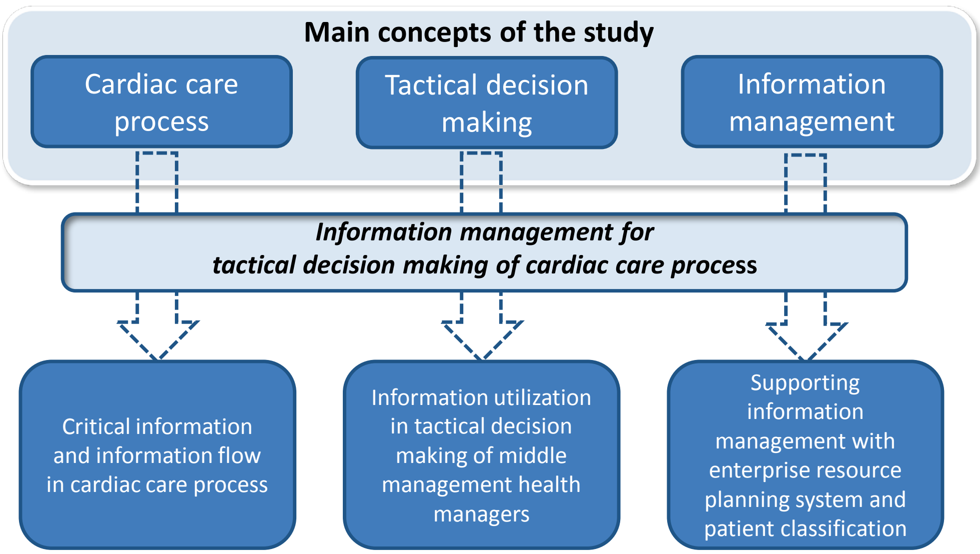

Figure 1. Search areas in database searches from PubMed and EBSCO, 1990–2013.

2.1 Main concepts of the study

The main concepts of this study are as follows:

1) the cardiac care process
2) tactical decision-making
3) information management

We defined these main concepts by referring to dictionary definitions, existing literature and existing concept analyses. We also defined the related concepts.

Cardiac here means that the patient has ischaemic coronary symptoms. A cardiac care process is defined here as a care process in which the multidisciplinary team is more or less organized and involved. Furthermore, the care process is supported by clinical pathways; that is, the care processes are discussed thoroughly and (re)designed. (Vanhaecht et al., 2009a.) The term clinical pathway is internationally accepted in all settings of healthcare management; however, there is no single, widely accepted definition of a clinical pathway (De Bleser et al., 2006). Based on a concept analysis by De Bleser et al., a clinical pathway is a method of patient-care management for a well-defined group of patients. A clinical pathway explicitly states the goals and key elements of care based on Evidence Based Medicine (EBM) guidelines, best practice and patient expectations by: facilitating communication, coordinating roles and sequencing the activities between the multidisciplinary care team, patients and their relatives; documenting, monitoring and evaluating variances; and providing the necessary resources and outcomes. Furthermore, the aim of a clinical pathway is to develop the quality of care, reduce risks, increase patient satisfaction and improve the efficient use of resources. (De Bleser et al., 2006.) Although all patients undergo a certain care process, the care of some patients is directed by a clinical pathway, while for other patients it is not. In designing a clinical pathway, the multidisciplinary team should endeavour to make the care process as transparent and standardized as possible (Lodewijckx et al., 2012). Clinical pathways, however, do not guarantee that a care process will be perfectly organized. There may still be room for improvement, and bottlenecks may still occur. Also, care processes not supported by a clinical pathway could still be organized in an appropriate way. Therefore, evaluating how clinical pathway methodology affects the organization of care processes is essential. (Vanhaecht et al., 2006.)

Tactical decision-making is one part of the managerial decision-making process. Managerial decision-making can be divided into strategic, tactical and operational (Hulshof et al., 2012; Winter et al., 2001). Strategic managerial decision-making focuses on far-reaching decisions, such as organizational goals, strategies, mission, policies and objectives and addresses structural decision-making. Furthermore, this strategic level has a long planning horizon and is based on forecasts and comprehensive information. Tactical managerial decision-making translates strategic decisions into guidelines that facilitate operational activities. Tactical decision-making focuses on medium-range decisions and addresses the organization of the operations of a healthcare delivery process. Many of these decisions are concerned with the timely and efficient procurement, allocation, and distribution of resources (e.g. funds, supplies, volunteers) through a supply chain. Operational managerial decision-making focuses on daily, routine decisions involving short-term decision-making, which are designed on the individual patient level and the individual resource level. The operational level includes offline and online decision-making, where the offline reflects the decisions made in advance and the online the real-time reactive decision-making in response to events that cannot be planned in advanced. (Hans et al., 2012; Hulshof et al., 2012.) This study focuses on tactical managerial decision-making.

Decisions in tactical information management address short- and medium-range plans, schedules, and budgets. They also specify policies, procedures, and business objectives for the subunits of an organization. Furthermore, resource allocation and the monitoring of the performances of organizational subunits, including departments, divisions, process teams, project teams, and other workgroups, are aspects of tactical decision-making. (Heller et al., 1988; Winter et al., 2001.) Tactical planning of resources in hospitals concerns elective patient admission planning and the intermediate-term allocation of resource capacities. Its main objectives are to achieve equitable access for patients, to meet production targets, to serve the strategically agreed number of patients, and to use resources efficiently. (Hulshof et al., 2013.) For example, tactical decision-making in a perioperative unit might include decisions on hiring more staff to extend hours, expanding the capacity of operating rooms, purchasing crucial equipment, increasing the block time of a surgical group or building a free-standing facility (Dexter et al., 2005a). The objective of capacity allocation is to trade off surgical and postsurgical resources (Dexter and Traub, 2002; Guerriero and Guido, 2011; Testi and Tanfani, 2009) in order to maximize the contribution margin per hour of surgical time (Cardoen et al., 2010).

In an emergency care service, tactical decisions include patient-routing related decisions (eg. to minimize patient waiting time, maximize patient throughput and increase staff utilization) (Brailsford et al., 2004; Jun et al., 1999). Furthermore, tactical decision-making in an emergency care service includes decisions related to admission control (Brailsford et al., 2004) and staff-shift scheduling (Ernst et al., 2004).

In inpatient care services, tactical decision-making is related to, for example, bed reallocation (Harper and Shahani, 2002; Vissers, 1998), temporary bed capacity changes (Harper, 2002a), admission control (Adan et al., 2009; Harper, 2002a; Vissers et al., 2007) and staff-shift scheduling (Burke et al., 2004; Ernst et al., 2004).

Information management (IM) is the collection and management of information from one or more sources, and the distribution of that information to one or more audiences. This sometimes involves those who have a stake in, or a right to, that information. Management means the organization of, and the control over, the structure, processing, and delivery of information. (Oxford Reference, 2009.) Information management describes the role of technology in healthcare systems (Howcroft and Mitev, 2000) and management of clinical decision support (Celler et al., 2003). Information management in hospitals is the sum of all management activities in the hospital that transpose the potential contribution of information processing to translate the hospital’s strategic goals into the hospital’s success (Winter et al., 2001). Information management can be defined as: “The economic, efficient and effective coordination of the production, control, storage, retrieval and dissemination of information from external and internal sources, in order to improve the performance of the organization” (White, 1985). In this study, the definition of information content is included in the Information Management concept.

These varying definitions of information all emphasize the importance of information management. Information management is a response to an information explosion, and the resultant increasing complexity of the decision-making aiming to control it by improving the flow, the control, the analysis and the synthesis of information for decision makers (Rowley, 1998). Information management supports the exploitation of information to achive organizational objectives (Cronin and Davenport, 1991). As mentioned, one essential part of information management is to improve the flow of information. Information flow is understood as “links, channels, contact, flow of communication to pertinent people or groups in the organization” (Glaser and Zamanou, 1987).

Information can be viewed and defined in many different ways. One common definition is that information is seen as a resource (Cronin and Davenport, 1991; Eaton and Bawden, 1991). It is a resource that healthcare managers must manage effectively, like any other resources such as human, material and financial resources (Heathfield and Louw, 1999). Other definitions of information also exist: for example, information can be defined by its function, as organized data or knowledge that provides a basis for decision-making (Shortliffe et al., 1990). Information can also be seen as useful data or as a thing (Buckland, 1992; Lester, 1992; Senn, 1990). Furthermore, information has been described as subjective knowledge (Court, 1997; Ingerwesen, 1996), as a commodity (Braman, 1989; Choo, 2006; Lord and Maher, 1990) and as a constitutive force in society (Braman, 1989).

2.2 Information management for tactical decision-making of cardiac care processes

This chapter consists of a description of studies concerning tactical decision-making in health care, studies concerning the cardiac care process and clinical pathway, and studies concerning information management in health care.

During our search of the existing literature, we found several studies concerning managerial clinical or operational decision-making in health care (Bailey, 2006; Buckingham and Adams, 2000; Culyer, 2005; Hudak et al., 1997; Lapaige, 2009; Lundgren-Laine et al., 2013; Maddux et al., 2008; O'Brien-Pallas and Hayes, 2008; Pudil and Paterson, 1998; Rosen, 2000; van Loon et al., 2013). Furthermore, we found some studies concerning managerial tactical decision-making in health care (Dexter et al., 2005b; Dexter et al., 2007b; Hulshof et al., 2013; Meslin et al., 1997; O'Brien-Pallas and Hayes, 2008), but none of these focused on the care process and none were conducted with cardiac patients.

2.2.1 Critical information and information flow in a cardiac care process

A cardiac care process is one good example in health care where information management and efficient information flow is essential. This information flow can be connected with critical/clinical pathways, which are care plans that detail the essential steps in patient care with a view to describing the expected progress of the patient. The literature suggests that the use of critical pathways reduces the cost of care and the length of patient stay in hospital. These pathways also have a positive impact on outcomes, such as increased quality of care and patient satisfaction, improved continuity of information, and better patient education. (Renholm et al., 2002.) Critical/clinical pathways define how patient information flows in care processes, including in identification and documentation structures (Newman 1995; Fuss & Pasquale 1998).

The importance of critical or clinical pathways can be seen from the numerous studies in health care. There are studies on Chronic Obstructive Pulmonary Disease (COPD) (Lodewijckx et al., 2012; Lodewijckx et al., 2011; Vanhaecht et al., 2010b), different kinds of fractures (Leigheb et al., 2012; Vanhaecht et al., 2012), total knee arthroplasty (Segal et al., 2011), total joint replacement (Vanhaecht et al., 2010a), joint arthroplasty (Van Herck et al., 2010), joint replacement (Barbieri et al., 2009), gastrointestinal surgery (Lemmens et al., 2008), and obstetric care (Sarrechia et al., 2012; Vanhaecht et al., 2005). Critical or clinical pathways in cardiac care processes have also been studied: see “Effects of care pathways on the in-hospital treatment of heart failure: a systematic review” by (Kul et al., 2012).

Critical or clinical pathways have also been studied from the viewpoint of management and task organization. The results of these studies show that the use of pathways resulted in better interprofessional teamwork (Deneckere et al., 2013; Deneckere et al., 2012a; Deneckere et al., 2012b; Deneckere et al., 2011), higher levels of organized care (Deneckere et al., 2013; Vanhaecht et al., 2009b), and lower risks of burnout (Deneckere et al., 2013) in acute healthcare teams.

Furthermore, the clinical pathways and care processes of cardiac care patients have been studied from various medical viewpoints (Cheung et al., 2010; Grimm and Maisch, 2006; Murphy et al., 2007; Yan et al., 2011; Zhang et al., 2009). These studies have identified many benefits of such clinical pathways. Yan et al. (2011) studied the outcomes of management participation in revising operating procedures of a cardiac catheterization clinical pathway. Their study showed significant improvements with the revised operating procedures: that is, nursing care completion rates, mean lengths of hospital stay, diagnosis numbers, surgical treatment numbers, and numbers of complications or comorbidities. Furthermore, medical utilization was also significantly lower ($p < .05$). The reorganizing of the operating procedures (clinical pathway) involves organization itself, procedural flows and performance management. As a result, the hospital finances and medical care quality also improved significantly. Cheung et al. (2010) studied the primary percutaneous coronary interventions of a new management programme for patients with ST elevation myocardial infarction (STEMI), with a focus on door-to-treatment time. They concluded that a well-organized and systematic clinical pathway is a prerequisite for a centre providing a timely and effective primary percutaneous coronary intervention service for patients with STEMI. Zhang et al. (2009) evaluated the impact of different clinical pathways on the reduction of reperfusion delay and subsequent improvement in outcomes in patients with STEMI. Their study showed that a clinical pathway bypassing the critical care unit (CCU) or cardiac ward admission correlated with rapid reperfusion, smaller infarct size, and improved short-term survival for patients with STEMI undergoing primary percutaneous coronary intervention (PCI). Murphy et al. (2007) examined the feasibility of reducing a post-operative stay through the implementation of a fast-tracked, goal-directed clinical pathway for elective open aortic surgery. Their results show that the introduction of a goal-directed pathway can reduce the length of a post-operative stay in patients undergoing aortic surgery. Grimm and Maisch (2006) studied the effects of a clinical pathway in acute coronary syndrome including different care protocols for different types of cardiac symptoms. Their results indicated that a clinical pathway leads to a remarkable improvement in clinical decision-making in the emergency rooms of hospitals and reduces the door-to-intervention time considerably.

Cardiac patients' medical treatment and clinical pathways are demanding and require prompt identification, as early treatment of patients with an acute coronary syndrome (ACS) is crucial for decreasing morbidity and mortality (Steurer et al., 2010). The cardiac care process is based on extensive research, and has been trialed (e.g.Amsterdam et al., 2002; Aronow, 2013; Banai et al., 2013; Eisenberg et al., 2013; Ezekowitz et al., 2013; Mrdovic et al., 2013; Palmerini et al., 2013; Stahrenberg et al., 2013; Zegre Hemsey et al., 2013). However, the relationship between patient care and care process management, as well as between critical information flow and management, is problematic due to the lack of integrated information systems.

2.2.2 Information utilization in tactical decision-making of middle management health managers

Health managers in secondary health care require certain types of information to make timely, evidence-based decisions.

Information technology is playing an increasingly important role in the support of advanced medical and healthcare services. When applying information technology to health care, one of the focus areas should be to support decision-making processes because decision-making in a critical sector such as health care must be effective and efficient. Information technology is changing the behavioral model of the decision-making process of healthcare managers by increasing performance and providing timely access to necessary information. (Jbilou et al., 2009.) In addition, information technology challenges the traditional decision-making process and modifies the management profession (Tamburis, 2006).

Information technology has been shown to facilitate information management, knowledge sharing, and the creation of new knowledge in organizations (Beamish and Armistead, 2001). However, little information is available about the information needs and sources of health care's middle management. Various authors have extensively explored various professional perspectives (e.g. that of doctors, nurses, pharmacists, dentists) (Fenton and Gamm, 2007; Hurley et al., 2007; Song et al., 2010), but few have studied the perspectives of managers and decision makers (England and Stewart, 2007). In one notable exception, the perceptions of nurse managers on the use of electronic information systems in their daily work were studied. That study showed that the current electronic information systems do not offer valid and accurate information for daily management in nursing. (Lammintakanen et al., 2010.) Studies have also shown that it is important to understand work-related information needs in the context of the work roles within which they arise (Lammintakanen et al., 2010; MacDonald et al., 2008). However, few studies have described the use of information by healthcare decision makers that would identify decision situations, information preferences and the challenges faced in information access and usage (Lammintakanen et al., 2010; MacDonald et al., 2008). In addition, the types of information required by decision makers in an organization are directly related to their management level and the amount of structure in their decision-making situations (O'Brien and Marakas, 2008). More research is needed on the information that is available, the information that is required, and the information that is missing from the perspective of a tactical decision maker in health care.

Arman et al. (2009) have studied what health managers do and what characterizes their use of time. Based on that study, it seems that health managers spend most of their time undertaking information-related activities (such as touring a ward or an office to discover the current status of events), which comprised on average one-third of their total working time.

An anesthesiologist’s tactical decision-making in an operating room has been studied in Dexter et al.’s studies (Dexter et al., 2005a; Dexter et al., 2005b; Dexter et al., 2007a; Dexter and Traub, 2002; Dexter et al., 2007b). These studies investigated whether anesthesiologists, without prompting, tend to make managerial decisions to increase the clinical work per unit time of the sites to which they are assigned during their scheduled time present. Based on these studies, it appears that clinicians tend to make decisions that increase the clinical work per unit time at each moment in each OR, even when doing so resulted in an increase in overutilized OR time, higher staffing costs, unpredictable work hours, and/or mandatory overtime (Dexter et al., 2007b). Such efforts to work quickly cannot be explained as a consequence of efforts to reduce waiting times for both surgeons and patients. Rather, the heuristic followed is consistent with increasing the personal clinical work per unit time at each assigned anesthetizing location. (Dexter et al., 2007a.) Furthermore, another study showed that groups of surgeons can be excluded from consideration at the tactical stage (e.g. surgeons who need intensive care beds or those with below average contribution margins per OR hour). Lower and upper limits for the future demand of OR time by the remaining surgeons are estimated in ORs, meaning that initial OR allocations can be accomplished with only partial information of future workloads. Once the new ORs open, operational decision-making based on OR efficiency is used to fill the OR time and adjust staffing. Surgeons who were not allocated additional time at the tactical stage were provided increased OR time through operational adjustments, based on their actual workload. (Dexter et al., 2005b).

2.2.3 Supporting information management with enterprise resource planning systems and patient classification

Although the information technology dimension in knowledge and competence management has not been intensively studied (Alavi and Tiwana, 2005), it is evident that technology supports information management, knowledge and competence sharing and the creation of new knowledge in organizations (Beamish and Armistead, 2001). One of the problems of information management is that organizations typically view information technology projects too narrowly and invest in individual systems to support operations of specific functional areas (Laughlin, 1999). This has led organizations to have multilayered systems that often use different platforms, and these systems do not share information between functional areas. In addition, such non-integrated systems lead to data redundancies (Markus et al., 2000).

Enterprise resource planning (ERP) is defined as a business philosophy to achieve effective business value creation and enhance operational excellence with internal and external customer intimacy through an integration of activities, processes and functions. ERP is configured by a system that integrates flows of information, materials, and monetary transactions. ERP evolved from material requirement planning (MRP), followed by manufacturing resource planning (MRP II) and then expanded to ERP II, which integrates supply chain management (SCM) and customer relationship management. Recent ERP systems provide management with tangible and intangible advantages and strategic competitiveness, as well as new business values through business process innovation (Davenport, 1998; Klaus et al., 2000; Motwani et al., 2002).

The fundamental idea of an ERP system is that it answers the need for the integration of fragmented information while also providing integrated comprehensive software, which can be used to manage and coordinate all the business functions within an organization. These sets usually include mature applications and tools for different business functions. An ERP system can deliver data across all business functions in real time. Typically, it includes various modules such as materials management, quality management, human resources, project management, financial and accounting, and sales and distribution. (Boykin, 2001; Chen, 2001; Nah et al., 2001.) Furthermore, the whole system is usually based on a central database (Shehab et al., 2004).

An ERP system has also been proven to enable organizations to achieve decision support benefits such as improved knowledge processing, enhanced decision-making reliability, and a better ability to gather corporate evidence to support the decisions made (Holsapple and Sena, 2001). However, there is very limited systematic evidence on the precise role of ERP systems in health care.

One of the key questions in a care process continuum is how to know, or to predict, the next steps in it. Being able to predict the care needs of patients would help in reducing the constantly rising costs of health care. The ability to predict the patients' care needs, or acuity, would provide a powerful tool for healthcare managers to allocate resources. The enormous amount of stored data in health care provides a rich environment to use information technology and computational intelligence techniques to produce estimates and predictions of the care process. One possible tool that can provide detailed clinical data for forecasting and real-time human resource allocation is the Patient Classification System (PCS). Patient classification can be determined by methods and processes that are used to identify, validate and monitor the needs of an individual patient (De Groot, 1989a; De Groot, 1989b; Huhkabay and Skonieeczny, 1981). Furthermore, the PCS provides information for human resource administration, accounting, budgeting and other functions of management (Alward, 1983; De Groot, 1989a). A PCS assesses and classifies patients according to their acuity – that is, their need for care – as well as the nursing activities that are necessary to fulfill those care needs during a certain time period (De Groot, 1989a).

PCSs were first introduced in the 1960s in the USA. The goal of these systems was to match the available nursing resources with the patients' care requirements (Alward, 1983). Today, PCSs play an important role in supporting nurse managers' decision-making in organizing the care process and resources. The PCSs provide methods to determine, validate and monitor individual patient care requirements over time. They are used to enable more rational and effective planning of nursing staff requirements for patients' individual needs. In addition, the PCSs provide information to determine the different resources consumed, assist in the budget planning of nursing services and assist in the evaluation of the quality of care provided (Alward, 1983; De Groot, 1989a). The main purpose of patient classifications is to help nursing management with the proper allocation of nursing resources. In addition, patient classifications are used to optimize available resources, provide estimations of nurse-to-patient ratios and to demonstrate the results achieved (De Groot, 1989a; Giovannetti, 1984).

Nowadays, numerous patient classifications are in use all over the world. In Finland, one of the most widely used classifications is the Oulu Patient Classification (OPCq), which was developed on the basis of the HSSG Hospital Systems Study Group classification (HSSG) from 1991 to 1993 at Oulu University Hospital (Giovannetti, 1984; Goldstone et al., 1983; Kaustinen, 1995; Partanen, 2002). The reliability and validity of the OPCq has been previously tested (Fagerstrom, 2009; Fagerstrom and Engberg, 1998; Fagerstrom et al., 2000). Using the OPCq and nurse resource registry, it is possible to calculate nursing intensity points per one working shift. Nursing intensity depends on the patients' care needs and also indicates the nursing workload caused by these care needs. The OPCq classification is based on the principles of nursing presented in the quality control programme and in Roper's model of nursing (Oulun yliopistollinen keskussairaala, 1994).

The patients are scored for the OPCq once a day: there is a classification manual available to support this scoring. The OPCq score does not describe how nurses have filled their day with different tasks, but how they have answered the patients' needs with the different processes and interventions of nursing work (Hoffman, 1989; Kaustinen, 1995; Rainio and Ohinmaa, 2005).

The OPCq (Kaustinen, 1995; Oulun yliopistollinen keskussairaala, 1994) consists of six nursing care subsections: 1) planning and coordination of care; 2) breathing, blood circulation and symptoms of disease; 3) nutrition and medication; 4) personal hygiene and excretion; 5) activity, movement, sleep and rest; 6) teaching, guidance in care and follow-up care, and emotional support. Each of these subsections is graded by the nurse on a scale from A to D according to the patient's need for care: A = 1 point, B = 2 points, C = 3 points and D = 4 points. This means that the possible range of summarized OPCq scores varies from 6 to 24 – the higher the score, the higher the nursing-care intensity of the patient (Rainio and Ohinmaa, 2005). Based on the OPCq score the patients are classified into five different categories: category I 6–8 points, category II 9–12 points, category III 13–15 points, category IV 16–20 points and category V 21–24 points. These categories have been established by using weighting coefficients in each category. The purpose of the weighting coefficient is to make these five categories of the OPCq comparable (Fagerstrom, 1998; Fagerstrom et al., 1999; Fagerstrom et al., 2000). Previously, nursing intensity has been studied concerning the association between nursing intensity, work-environment intensity, and nursing resources with patient satisfaction in outpatient departments. This study concluded that the patients were predominantly satisfied but special attention should be paid to the information given to patients. (Salin et al., 2012.)

In recent years, the feasibility of the automated analysis of EPRs has been the subject of several research studies. Computational methods from the area of computer science known as machine learning have proven to be invaluable in this context, as they allow for the automated detection of statistical patterns in large quantities of data, and numerous methods have been developed for dealing with numerical, structured and textual data. Such data analysis methods may be applied in order to automatically extract, summarize and visualize information contained in existing EPRs, for assisting medical professionals in filling in new records, or for making predictions about the future health of patients based on their existing records. Examples of these applications include an automated diagnosis assignment based on the patient's documentation (Aronow et al., 1995; Suominen et al., 2008; Wang et al., 2012), the segmentation of unstructured nursing narratives into categories such as breathing, blood circulation and pain (Ginter et al., 2009; Hiissa et al., 2007), and quality-of-life predictions for patients (Pakhomov et al., 2008). For a more thorough overview of these applications, see Demner-Fushman (Demner-Fushman et al., 2009).

2.3 Conclusions from the literature review

Cardiac care is a demanding and challenging process. The efficient management of this process requires real-time information of the process and of its participants. The aim of this literature search was to gain a comprehensive overview of the scientific literature presenting information on tactical decision-making in cardiac care processes from a managerial viewpoint. The literature review showed many recognized aspects and challenges in the management of the cardiac care process, especially from the point of view of tactical decision-making. At the same time, the literature review also highlighted the lack of existing research on this topic by revealing a lack of studies about tactical decision-making and its needs in cardiac care processes. Some key elements for the content of information management could be further defined. Furthermore, the literature review supported the need to create a content model for the ERP system.

2.3.1 What is already known?

- Existing information systems do not support the managerial information needs in cardiac care processes well.
- Necessary information is scattered in various information systems and the integration of these systems is missing.
- There are hospital information systems (HIS) that support decision-making in healthcare organizations. These systems are typically used to manage clinical and administrative operations. In addition, healthcare organizations use information systems for clinical purposes to improve patient care.
- Decision-making could be further supported with an integrated hospital information system that standardizes, integrates and organizes all the information available in different health information systems through an accessible and secure repository, and which conveniently distributes this information for decision-making.
- There is a need for an information system that integrates the information for decision-making and that provides a decision tool for planning, managing, evaluating and conducting strategic and tactical decision-making in short and medium terms.

2.3.2 What are the gaps in the existing knowledge?

- What is the current state-of-the-art of ERP systems in health care? The literature review did not show real and comprehensive evidence on ERP systems in health care.
- What are the critical points in a cardiac care process where support for information management is needed? The literature review did not provide evidence on the critical information in cardiac care processes.
- What tactical decisions are made in a cardiac care process? Based on the literature review there is lack of information about what tactical decisions are made and from where the information for these decisions should come.
- To what degree is it possible to predict patients’ acuity based on previously assigned acuity scores and/or textual nursing notes? The literature review did not provide previous methods to predict patients’ acuity.

3 AIM OF THE STUDY

The aim of this study was to create a content model for supporting tactical decision-making with information management in cardiac care processes.

The research questions were as follows:

1. What is the current state-of-the-art of ERP systems in health care?
2. What are the critical points in a cardiac care process where support for information management is needed?
3. What tactical decisions are made in a cardiac care process?
    a. What information is available?
    b. What information is missing?
4. To what degree is it possible to predict patients' acuity based on previously assigned acuity scores and/or textual nursing notes?

4 MATERIAL AND METHODS

The answers to the research questions were researched in three phases with four different study designs (Figure 2).

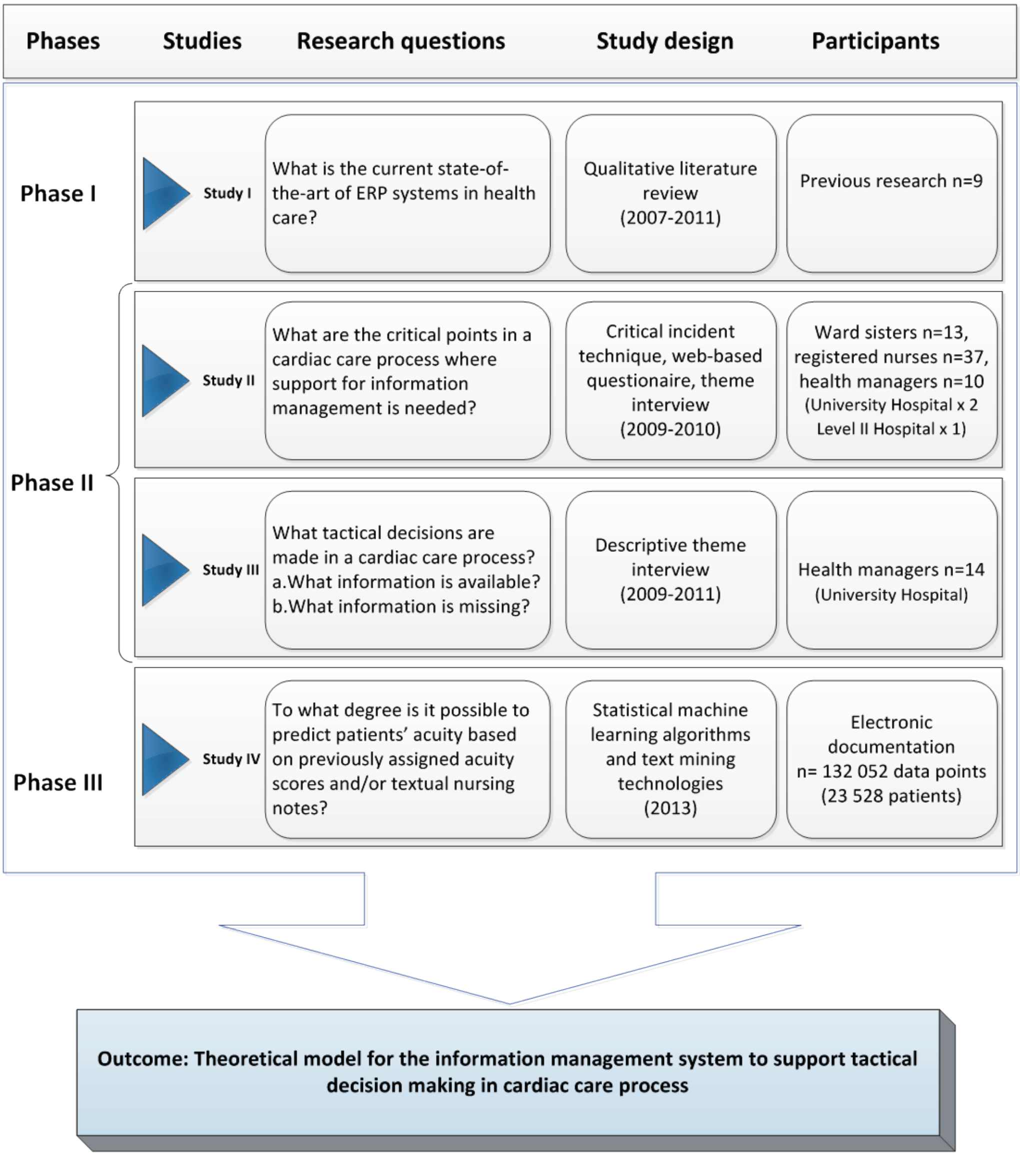

Figure 2. Four research questions, study designs and participants.

4.1 Study subjects, designs and data collection

Phase I

In Phase I (2009), a literature review of ERP systems in healthcare environments was conducted. This review was based on database searches from the following databases: PubMed, Emerald, CSA Engineering Research Database, ScienceDirect, ISI Web of Knowledge and Cinahl. The database searches covered the period from January 2000 to April 2009. The inclusion criteria of the studies accepted into the review were that they addressed ERP integration in health care. Many of the studies were descriptive pilot studies with single cases. There were 15 case studies (Epstein and Dexter, 2000; Feied et al., 2000; Gupta et al., 2004; Harper, 2002b; Larios et al., 2000; McGinnis et al., 2004; Paré, 2002; Perjons et al., 2005; Ramani, 2004; Ramani, 2006; Ruland, 2001; Salaway and Burris, 2001; Sia et al., 2002; Stefanou and Revanoglou, 2006; Trimmer et al., 2002a), two review studies (Feied et al., 2004; van Merode et al., 2004) and two Delphi studies (Ammenwerth et al., 2001; Ammenwerth and Reinhold, 2000).

Fourteen of the studies concentrated on the situation after the implementation of healthcare information systems. All of these studies were case studies (Feied et al., 2000; Gupta et al., 2004; Harper, 2002b; Larios et al., 2000; McGinnis et al., 2004; Paré, 2002; Perjons et al., 2005; Ramani, 2004; Ramani, 2006; Ruland, 2001; Salaway and Burris, 2001; Sia et al., 2002; Stefanou and Revanoglou, 2006; Trimmer et al., 2002a). Only one case study had its origin before the implementation of a healthcare information system (Epstein and Dexter, 2000). Four other studies focused on the situation before the implementation of a healthcare information system. These studies were reviews (Feied et al., 2004; van Merode et al., 2004) and Delphi studies (Ammenwerth et al., 2001; Ammenwerth and Reinhold, 2000).

The case studies ranged from single-case settings to multiple-case settings. The cases ranged from a single hospital to a country-wide national healthcare system. Seven of the single-case studies worked with a single hospital and one with a blood bank (Gupta et al., 2004).

Phase II

In Phase II, Study I (2010), a qualitative approach involving the critical incident technique was used. The data were collected in two phases with semi-structured questionnaires (50 respondents) and interviews (n=10) from registered nurses, ward sisters and health managers from selected hospitals.

In the first phase, 13 ward sisters and 37 registered nurses were recruited as informants for this phase of the study with purposive sampling. The rationale to use purposive sampling was based on the belief that the researchers' knowledge about populations could be used to choose sample members (Polit and Beck, 2012) and thus to choose the informants who would be able to provide the necessary data (Parahoo, 2006; Patton, 1990; Polit and Beck, 2012). The informants (n=50) were selected from different types of hospital wards to ensure a comprehensive view of the whole care process of cardiac patients. All the informants had experience in cardiac care, volunteered for the study and were willing to share their experiences. In this phase, data collection was done with a semi-structured online web questionnaire. The researcher e-mailed information explaining the purpose of the research, the voluntary nature of participation, and the confidentiality of the data to the ward sisters who delivered the same information to the selected registered nurses. The researcher also provided a definition of a critical incident – a significant successful or unsuccessful incident that occurred during the cardiac care process.

In addition to the five demographic variables (current position, education, type of unit, work experience after graduation, work experience in current position) we asked the respondents to describe the following:

- A successful cardiac care process, with an example.
- An unsuccessful cardiac care process, with an example.

In the second phase, the data were collected from interviews of ten managerial experts in one University hospital in Finland. The interviews were conducted to enrich and confirm the data collected in the first phase. The individuals interviewed were purposefully selected, they gave their time voluntarily, and represented a multi-professional managerial perspective. The interviewees were all experts in cardiac care with 6 to 15 years of work experience in managerial positions. The interviews were recorded, and they lasted from 45 minutes to 2 hours. The structure of the interview followed the structure of the questionnaire used in the first phase. During the interview, the researcher asked additional questions to clarify the critical incidents.

In Phase II, Study II, theme interviews (Polit and Beck, 2012) were used to collect the data. The interview themes included the following:

- What decisions do healthcare managers make?
- What information is available to them when making their decisions?
- What information do they lack in their decision-making process?

The possible interviewees were chosen with purposive sampling, as in Phase II. In total, 40 health management experts from one university hospital in Finland were invited to participate in the study. This hospital was selected because it had a project that focused on the development of the cardiac care process. The chosen experts were also working in the cardiac care process. They had experience in both clinical and managerial roles, were working in an improvement project to develop the cardiac care process, and were middle managers who made tactical decisions in their daily work. Finally, 14 experts were willing to participate in the study. The participants represented different positions: six physicians, six head nurses and two nursing directors with work experience in managerial positions varying from 2 to 15 years. The interviews were recorded and they lasted between 45 minutes and 2 hours.

Phase III

In Phase III, the original data consisted of 23,528 electronic patient records of patients with any type of heart problem that were admitted to a university hospital between 2005 and 2009. The data was collected from five different information systems: it consisted of text data from electronic patient records, patient administration systems (e.g. admission, discharge and transfer information), patient classification systems, text data from the radiology system and text data from the patology system.

The inclusion criteria were:

- Diagnosis: ICD 10: I20-I25, I27, I30-I52, R00, R01
- Date of birth: 23 September 1901 – 21 October 2009
- Admitted into hospital between 2005–2009
- Length of hospital stay >1 day.

The study was conducted with a data set consisting of electronic nursing narratives and the associated Oulu Patient Classification (OPCq) acuity. The data was pre-processed using a morphological analyzer of the Finnish language and transformed into a numerical representation using the word vector space model prevalent in the field of information retrieval. The data was trained with mathematical models for predicting OPCq scores using the regularized least-squares (RLS) algorithm, a state-of-the-art method widely used in the areas of statistics and machine learning (Hoerl and Kennard, 1970). The mathematical models were used to study to what extent prediction is possible using different information sources such as previously assigned scores, and/or textual records.

The data were further processed in order to link together the daily acuity scores and the corresponding nursing documentation, since these data came from different information systems. For each two consecutive days of a hospital stay for the patient, a data point consisting of the text for the previous and following day, and the associated acuity scores, was formed. After this pre-processing, the dataset consisted of 132,053 data points. Finally, the data set was randomly divided into three portions, following standard experimental methodology in machine learning: a training set, a validation set and a test set, consisting of 79,878, 25,657 and 26,518 data points, respectively. The division was done on the level of the patients, meaning that there was no overlap between the patients in the three sets.

4.2 Data analyses

Phase I

In Phase I, initial searches identified 135 articles. First, these articles were analyzed on the basis of their titles and abstracts by five reviewers, leading to the rejection of 95 articles. A large number of articles were rejected at this stage because the original search criteria boundaries were purposefully set quite wide. The relevant references were identified and the full texts acquired.

Second, three reviewers examined the full texts and compiled the lists of studies to be included and excluded. At this stage, 25 articles were excluded for different reasons, such as the article being a technical report, the article having nothing to do with ERP, the design of the article not being relevant, the article not having been published internationally or the article being a duplicate.

Third, the included articles were studied for quality appraisal. Two reviewers independently read the identified papers to assess their quality, leading to the rejection of six articles due to rigor, credibility or relevance.

Finally, nine articles were accepted for deeper analysis. These selected studies were analyzed with the thematic synthesis technique (Thomas and Harden, 2008). Thematic analysis is a method that is often used to analyze data in primary qualitative research. The selected papers were qualitative studies and therefore this method was appropriate. The studies were evaluated relating to their exactness, credibility and relevance using the Critical Appraisal Skills Programme (Critical Appraisal Skills Programme, 2006). Not every study met all the critical appraisal criteria. In fact, some weaknesses were identified in every study. However, these weaknesses were not of sufficient magnitude to preclude the inclusion of any of the studies that met the majority of the review criteria.

In this evaluation, the characteristics of each study were described. Then, statements concerning the usage, views, experiences and implementation challenges of ERP systems were inductively identified. All relevant statements were extracted and entered into a database for analysis. After which, the statements were summarized and grouped under thematic headings describing the topic in question in the statement cluster. Finally, these thematic headings were grouped into broader generic themes.

Phase II

In Phase II, Study II, the data were analyzed inductively (Polit and Beck, 2012). The basic unit of analysis followed Norman et al.'s (1992) preference for "critical happenings," which are defined as "events which are experienced as meaningful to the respondent involved in the care processes of cardiac patients." According to Norman et al. (1992), each 'critical happening' consists of an event and its related "meaning"

(Cox et al., 1993); in this study, 'events' pertained to aspects of cardiac patients' care processes.

The collected questionnaire and interview data were saved into a qualitative data analysis program, NVivo® (Bazeley, 2007). The information concerning the critical incidents was read several times in their entirety in order for the researchers to become immersed in the data. Using these data, major successful and unsuccessful important events in the care process of cardiac patients – i.e. incidents – were identified and described.

During the analysis, the identified incidents were categorized. In the beginning, there were a large number of incident categories. During the analysis, these incident categories were further categorized, and by the end of the analysis three main categories were identified: 'process-related incidents', 'managerial incidents', and 'clinical incidents'. As a result of this continuous categorization, each main category was also assigned a number of subcategories.

In Phase II, Study III, the data were analyzed inductively with thematic content analysis, which is similar to content analysis but also involves more explicit qualitative analysis of the meaning of the data context (Polit and Beck, 2012).

The collected data were transcribed and transferred into NVivo®. The primary researcher (EK) read the answers several times in their entirety to become immersed in the data. Interview transcripts were coded and analyzed using inductive coding to identify categories and themes regarding decision-making, information needs and the challenges of decision-making and lack of information. First, free-model coding was used to identify the decisions that were made by middle managers. Then, the decisions were hierarchically organized into clusters (tree-model coding). In the next phase, the hierarchical categories were compared, and those with close contents were integrated. Then, the analysis was independently reviewed by another researcher to enhance the validity. The content analysis theme coding was performed by the primary researcher (EK) and then assessed by another researcher, who read the answers independently and coded them according to the established themes. Finally, the coding was agreed, and the main classes were confirmed.

Phase III

In order to transform the data into a format amenable for machine-learning based analysis, the textual records were first lowercased, tokenized, and the words were reduced to their base forms using the FinTWOL morphological analyzer. A number of common Finnish stop words were removed from the texts, and after this the 10,000 most commonly occurring tokens were retained and the rest of the tokens were filtered out. Finally, the textual records were mapped into numerical vectors using the standard vector-space model with tf-idf weighting.

The models were trained on the training set, the regularization parameter was chosen from an exponential grid, and the selected parameter was the one that provided the best performance on the validation set. Finally, the model was used to make predictions on the test set, and the final performance was computed by comparing the predicted and true intensity scores of the test set. The same procedure was performed for each of the considered feature sets and for each category of nursing intensity scores, separately. We considered both the regression setting where the aim was to predict the scores exactly and the ranking setting where our aim was to order the patients from those needing the most care to those needing the least.

We considered a number of different feature sets for training the models, corresponding to the different available information sources:

- "PScore" the acuity scores assigned to the patient on the previous day,
- "PText", the free text nursing notes written about the patient on the previous day,
- "Text", the textual nursing notes written about the patient on the same day as the acuity scores are assigned.

The experiments where "PText" and/or "PScore" were used for making predictions corresponded to the setting where our aim was to predict the acuity scores for the following day. Experiments where the "Text" features were also used corresponded to a setting where we had already recorded the nursing notes for the same day that we wanted to give the acuity scores.

4.3 Ethical questions

The research was conducted according to established Finnish national legislation and research ethical guidelines (Academy of Finland, 2003; Burns et al., 2011; Medical Research Act 488/1999; Medical Research Act 794/2010; WMA Declaration of Helsinki, 2004). The ethical discussion in this study concerns the process of obtaining the necessary permissions to carry out the different study phases and to use the electronic documents.

Permission to conduct the research was obtained from the nursing research governance committees of the hospital districts and the medical officers of the hospitals (Phase II & III). In Phase III, the research data contains patient documentation, which was anonymized. This research phase was granted the approval of the ethical committee of the hospital district (number 12/2009).

In the qualitative review (Phase I), the ethical questions were ensured by treating the existing researches fairly and accurately. In addition, the review did not raise any ethical questions that needed to be addressed.

In the semi-structured online web questionnaire (Phase II), all responses were gathered in an online system (Webropol®) with protected password access, only accessible to the principal researcher. In the questionnaires, cover letters were attached in which the participants were informed about the purpose of the study and the principles of anonymity, confidentiality and voluntary participation. The letters included the researcher's contact information and the supervisors' names and affiliations. The online web questionnaire was not dependent on a certain web browser and participants could suspend the survey, and continue it later. The survey did not include any personal or sensitive questions, and the questions did not require the professionals to break their vow of confidentiality.

During the interviews (Phase II), the participants were informed both orally and in writing that participation was voluntary and that they had the right to withdraw at any time. Written informed consent was obtained from all participants, and withdrawal from the study was possible at any time. The researcher interviewed the participants personally and also transcribed all the interviews. The confidentiality and anonymity of the study participants and data, as well as professional security, were ensured throughout the study.

In the document analysis (Phase III), the research data contained anonymized patient documentation. The data was processed as a large group of patients, rather than from the viewpoint of a single patient. Ethical concerns in this study deal with the process of obtaining the necessary permissions to carry out the research and to use the electronic documents. In addition, this study follows the security procedures designed for accessing patient data (Berman, 2002). When using Finnish patient records in research, the researcher must follow the general laws in Finland, such as the Medical Research Act 488/1999 (Medical Research Act 488/1999), the Medical Research Decree 986/1999 (Statutes of Finland, 1999a), the Personal Data Act 523/1999 (Statutes of Finland, 1999b), the Act on the National Personal Data Registers for Health Care 556/1989 (Act on the National Personal Data Registers for Health Care 556/1989, 1989) and the Act on the Status and Rights of Patients 785/1992 (Act on the Status and Rights of Patients 785/1992, 1992). These laws were followed carefully.

5 RESULTS

This chapter presents the results of the study. Only the main findings according to the research task are introduced, while the more detailed results are presented in the original papers I-IV.

5.1 Enterprise resource planning systems

As on outcome of the literature review (Paper I and summary) there are very few ERP systems implemented in healthcare environments – or at least there are very few ERP systems which have been presented, studied and reported in academic journals.

ERP systems are used in health care for materials management, clinical data management, financial data management and human resource management. However, the analyzed studies showed that the usage of ERP systems currently does not cover all of these areas. Most commonly, ERP systems are used for materials management. Only a few studies showed that ERP systems are used for clinical data management; therefore, the ERP systems are not strongly connected with the actual care processes. The ERP systems in the studied cases mostly focused on the supportive and administrative processes. (Paper I)

Altogether, the studies showed several positive implications of the ERP systems for processes, financial issues and information. The ERP systems improved process management and quality. Furthermore, the ERP systems provided better control for financial and costs/revenue management. Finally, the availability and quality of information was improved with the ERP systems. (Paper I)

The benefits of the ERP system was also reflected in information availability and quality. For example, the case studies reported reduced numbers of data entry errors (quality) and real-time updating of patient records (availability). These reflections on information bring changes in processes or working practices that are more substantial than replacing paper with an electronic document. The changed information provides the impetus for further substantial changes to processes and financial issues. All of the above also reflect on decision-making. There were many examples of this transition: for example, the appraisal and review of clinical paths became possible, processes became more stable, costs were better controlled and costs were saved, or the pharmacy was better managed. All these changes also have reflections on patient care such as delivery and coordination of care for individual patients. Unfortunately, only a few of the reviewed articles were ready to analyze the impact of ERP systems all the way through a patient's care. In fact, the reviewed studies only provided experiences and views of ERP systems in health care for information and transition. (Paper I)

5.2 Information supported cardiac care processes

The second research question focused on information support in cardiac care processes (Phase II). In this phase, we described the critical points in a cardiac care process where support on information management is needed. The cardiac patient care process was presented with 70 successful and 85 unsuccessful incidents. These incidents described the cardiac care process from emergency care to discharge in specialized health care. (Paper II)

Incidents relating to the care process, management and clinical care proved critical when analyzed from the viewpoint of information flow. In the care process, problems in data flow affected the continuance of care in the emergency unit, intensive care unit or cardiac care unit, and during discharge. At the same time, the result showed that information flow was successful from the emergency unit to the angiography unit with manual handouts and oral information. One of the biggest unsuccessful incidents in the care process was that the existing agreed-care assessment criteria or urgency rating scale was not followed. (Paper II)

In the emergency and angiography units, several critical managerial incidents were emphasized. These were a lack of required experts, non-functionality of the process, and problems in patient logistics due to the lack of resources, but also due to the lack of real-time information flow. On the other hand, the multi-professional structure of the care team was recognized as a successful managerial incident. (Paper II)

Patient education was also identified as a critical incident. These clinical-care related incidents occurred in every phase of the cardiac care process: the patient was not informed of his/her sickness, the patient did not receive information and also the patient's relatives were not informed. On the other hand, the incidents showed that the care personnel's interest in the patients was evident. (Paper II)

The analysis of the decisions and the information used in the cardiac care process showed that the information systems produce a significant amount of information, but at the same time much of that information only exists in manual format, and that some of this manual information flows through the care process by the means of oral reports between the units. (Paper II)

Based on the analyzed successful and unsuccessful incidents, a theoretical model of important information content for the care process of cardiac patients was presented in Paper II (Figure 3). The model shows how identified, important incidents and different care process phases are connected. For example, a 'managerial incident' focusing on ordering transfer transportation is critical in the emergency phase, and a 'process-based incident' focusing on viewing the availability of beds is critical throughout the care process.

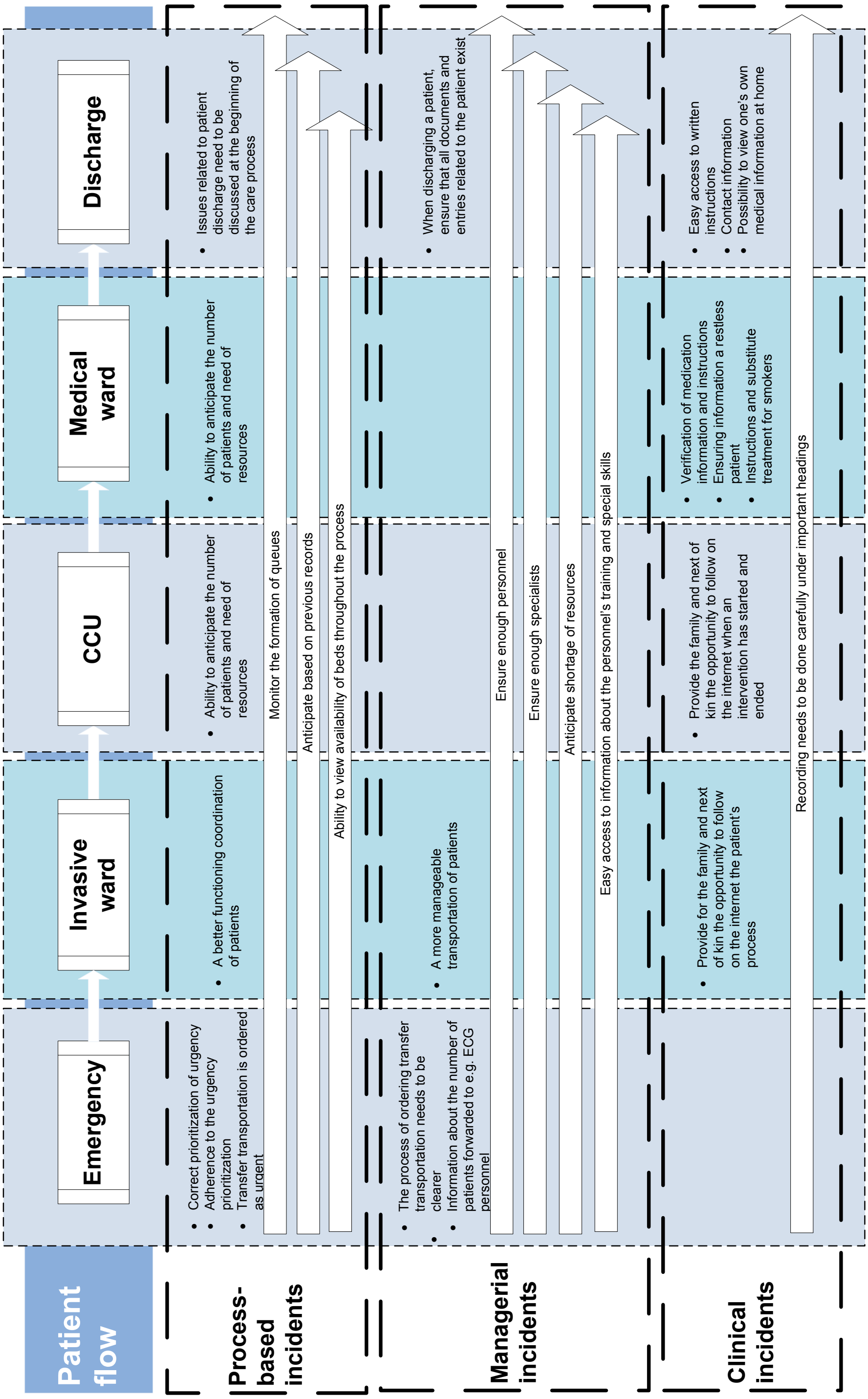

Figure 3. A Premodel of important information content for the care processes of patients with cardiac symptoms (Paper II) (Kontio et. al 2011)

5.3 Decision-making in cardiac care processes

In the second research phase, in Study II (Paper III), the tactical decisions that middle managers make, the information that is available, and the information that is missing were identified, using the cardiac care process as an example (Figure 4). The results of this study show that the tactical decision makers made a variety of different decisions during the cardiac care process. These decisions were categorized into process decisions and resource decisions. Process decisions were further categorized into work management decisions. Similarly, resource decisions were categorized into human resource and material resource decisions. The respondents gathered the information for these decisions from several information sources. However, for several decisions sufficient knowledge support was lacking as these decisions were based on manually collected data that was usually outdated and dependent on memory and various unreliable sources. In addition, even when the data existed it was seldom provided in real time and it was not accessible throughout the care process. (Paper III)

Two categories of available information were identified in this study: human-created manual information, such as staff recruiting information, and information-system-created information, such as patient classification (Figure 4). In addition to the available information, *missing information* or *information coming too late* or *lacking at all* in tactical decisions categories were also identified in this study. The respondents described several reasons for these problems in information management. (Paper III)

The information system provides reports about sick-leave statistics, the number of nursing staff per patient, overtime work, unit material lists, etc. However, the decision maker has no possibility to use this information in real-time; in addition, it is not possible to combine information from two or more information systems. Furthermore, there is a lot of information based on tacit knowledge stored in manual notebooks, for example information about the personnel’s skills and competences. (Paper III)

Work management related decisions were decisions about work-flow planning, for example. These decisions included planning and reporting, where information such as sick leave, overtime work and replacement staff usage were required. The decision maker received this information from information systems, but not in real-time. In addition, the decision maker had to manually combine information from different information systems. Furthermore, the decision maker did not have direct access to all information; instead she or he had to request the needed information, for example from the human resource department. And finally, the decision maker had no information available on the workloads of different units and the information on replacement staff usage was delayed. Workload related decisions include decisions about patient flow management, prioritizing and cardiac patients’ special situations. In patient flow management decisions, information on the amount of planned, elective patients and patient transportation was used. However, the decision maker did not have real-time information concerning patient flow or bottlenecks. (Paper III)

Human resource related decisions were decisions concerning staff recruiting, staff continuing education and staff allocation. In staff recruiting decisions, health managers used the same information of overtime-work and sick-leave statistics that they used for the work flow planning decisions. However, the decision maker did not have information on the required competences of the replacement staff and which replacement staff had these necessary skills. For decisions related to staff continuing education, health managers used information about available continuing education from information systems, but they also used information about the staff's continuing education participation history and the staff's education needs. The health managers created this information based on their own manual handouts. For staff allocation decisions, the health managers used information about the staff's special skills, and that information was based on manual notebooks. In addition, health managers used information about a patient's special treatments, scheduled dates for procedures, a unit's situation and number of patients on the unit. However, all this information was oral. They did not have the information available on staffing levels on current shifts, resources that could be released and the staff working on the next shifts. Furthermore, they did not have information about staff competences or knowledge development. (Paper III)

Material resource related decisions contained decisions about material logistics and material ordering. The decision makers had information on unit materials, but they did not have information on where the unit's equipment was. For material ordering decisions, health managers received estimated information about consumption, but they did not receive information about the financial situation of the materials budget. (Paper III)

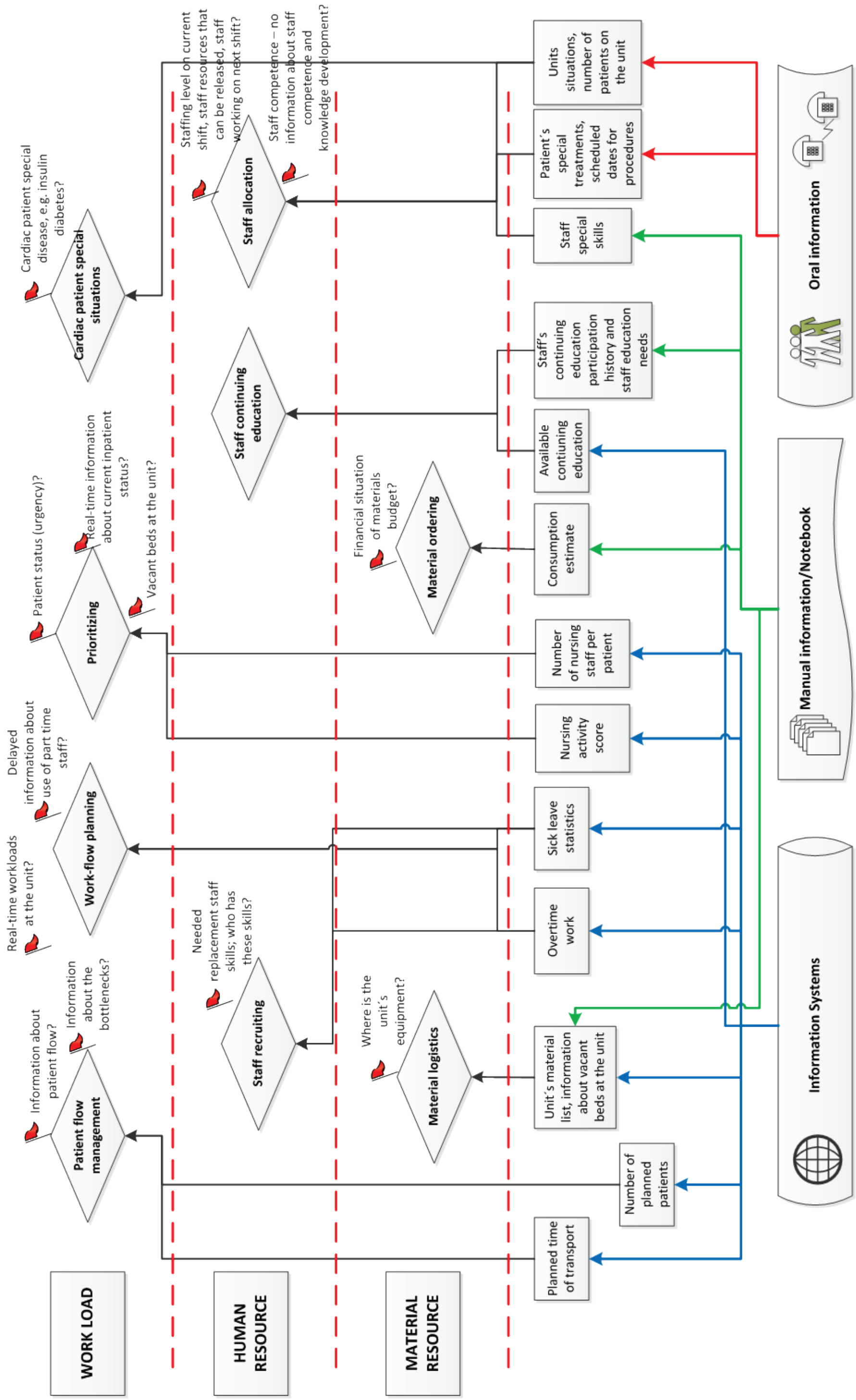

Figure 4. Information utilization in a cardiac care process. (🚩 = missing information)

5.4 Predicting patient acuity

The results for the regression experiments, where we tried to predict the scores exactly, are presented in Table 1, Figure 5 and Figure 6. The results are presented separately for the different combinations of features, and for the overall acuity score as well as the six acuity sub-categories.

Table 1. Mean absolute errors of the regression results.

(Cat1 = planning and coordination of care, Cat 2 = breathing, blood circulation and symptoms of disease, Cat 3 = nutrition and medication, Cat 4 = personal hygiene and excretion, Cat 5 = activity, movement, sleep and rest, Cat 6 = teaching, guidance in care and follow-up care, emotional support.)

Features	Acuity	Cat.1	Cat.2	Cat.3	Cat.4	Cat.5	Cat.6
PScore	0,488	0,475	0,415	0,445	0,455	0,462	0,427
PText	0,474	0,474	0,401	0,439	0,445	0,440	0,423
PScore & PText	0,445	0,449	0,369	0,398	0,410	0,411	0,400
Text	0,470	0,454	0,398	0,429	0,431	0,430	0,418
PScore & Text	0,430	0,429	0,366	0,397	0,395	0,401	0,394

First, we consider the problem in which our aim is to predict the scores for the following day, in which case we only have access to the "PScore" (the acuity scores assigned to the patient on the previous day) and "PText" (the free text nursing notes written about the patient on the previous day) features. Interestingly, the text recorded for the previous day proves to be more informative than the recorded scores, as in each case they enable more accurate predictions than do the scores. These two information sources complement each other, in all cases using both the previous scores and the text results in fewer errors than using either of them separately (Figure 5).

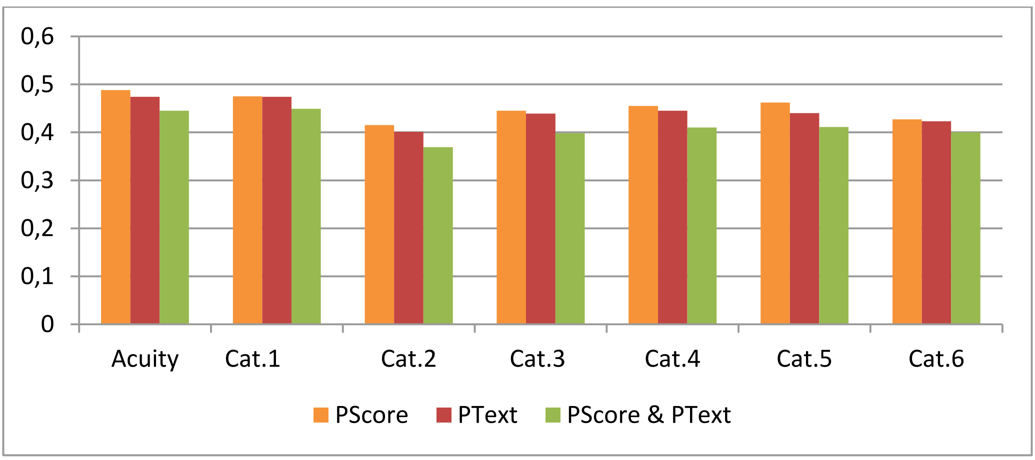

Figure 5. Mean absolute errors of the regression results with previous day information.

If we had access to the “Text” features, recording the nursing notes for the same day on which the score is to be given, the errors were even lower, but not dramatically so. Of the six sub-categories, category 1 (planning and coordination of care) proves to be the most difficult to predict in each case, while category 2 (breathing, blood circulation and symptoms of disease) proves to be the most easy to predict.

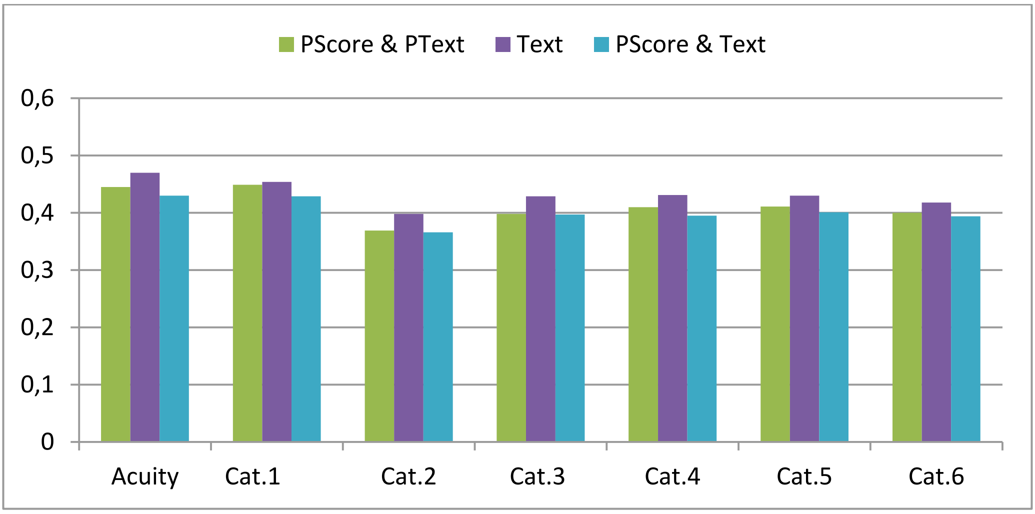

Figure 6. Mean absolute errors of regression results with nursing notes for the same day.

In Figure 7, we present the C-index for each category. In all the cases, the results are much better than the random performance 0.5, meaning that the models do have predictive powers. The overall trends are the same as for the regression experiment: the text proves to be more informative than the previous scores, combining them leads to the best models, and using the text from the same day allows for better prediction than the texts recorded on the previous day. Category 1 is again the most difficult one to predict, also in terms of the C-index; however, the easiest in this case is category 4 (personal hygiene and excretion).

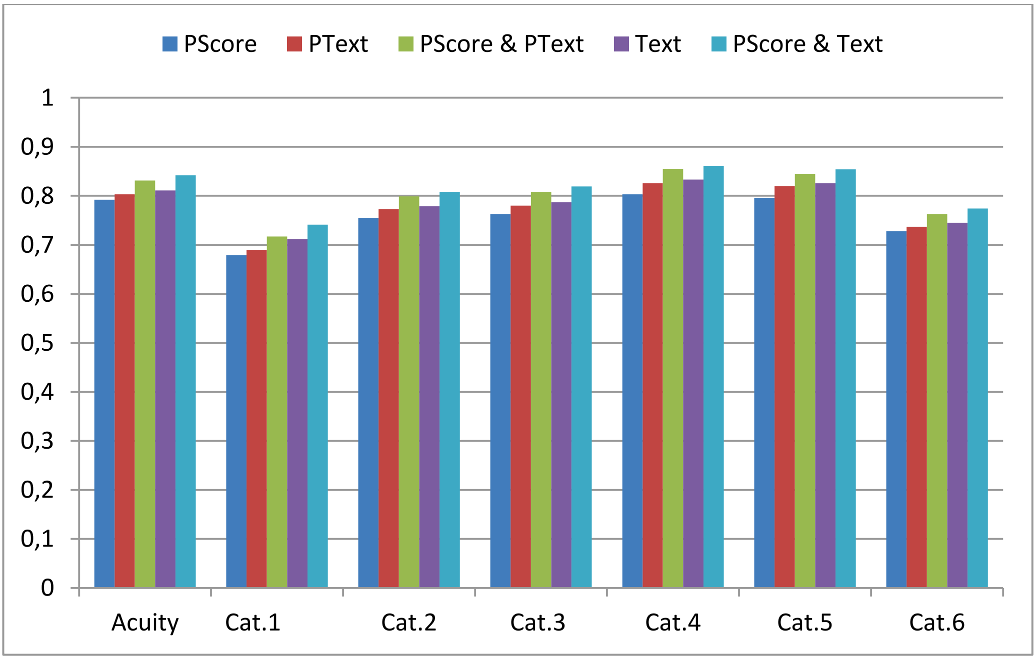

Figure 7. Ranking results (C-index).

5.5 Summary of the results

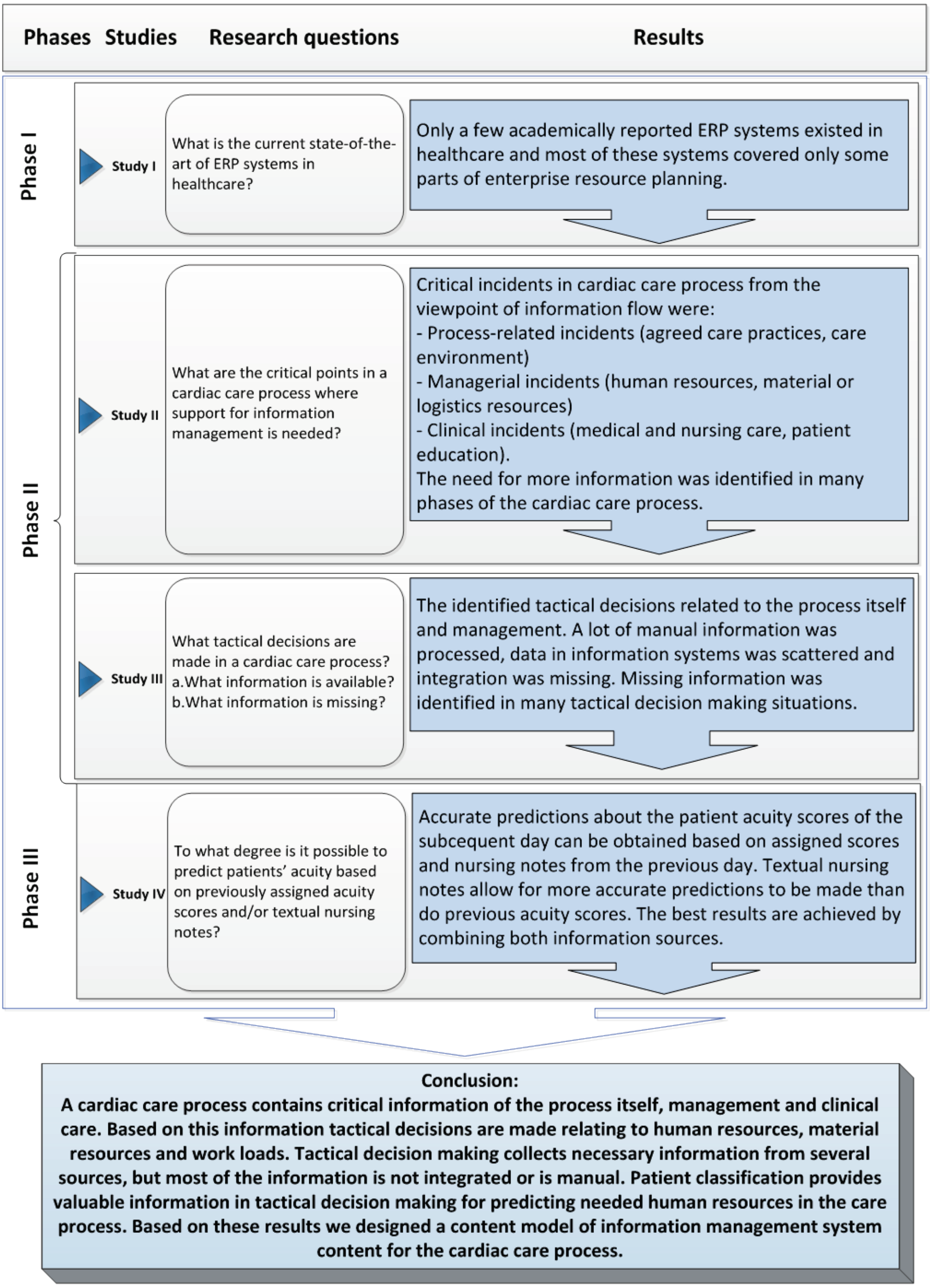

Figure 8. Summary of the results.

Based on this summary the following content model is introduced (Figure 9).

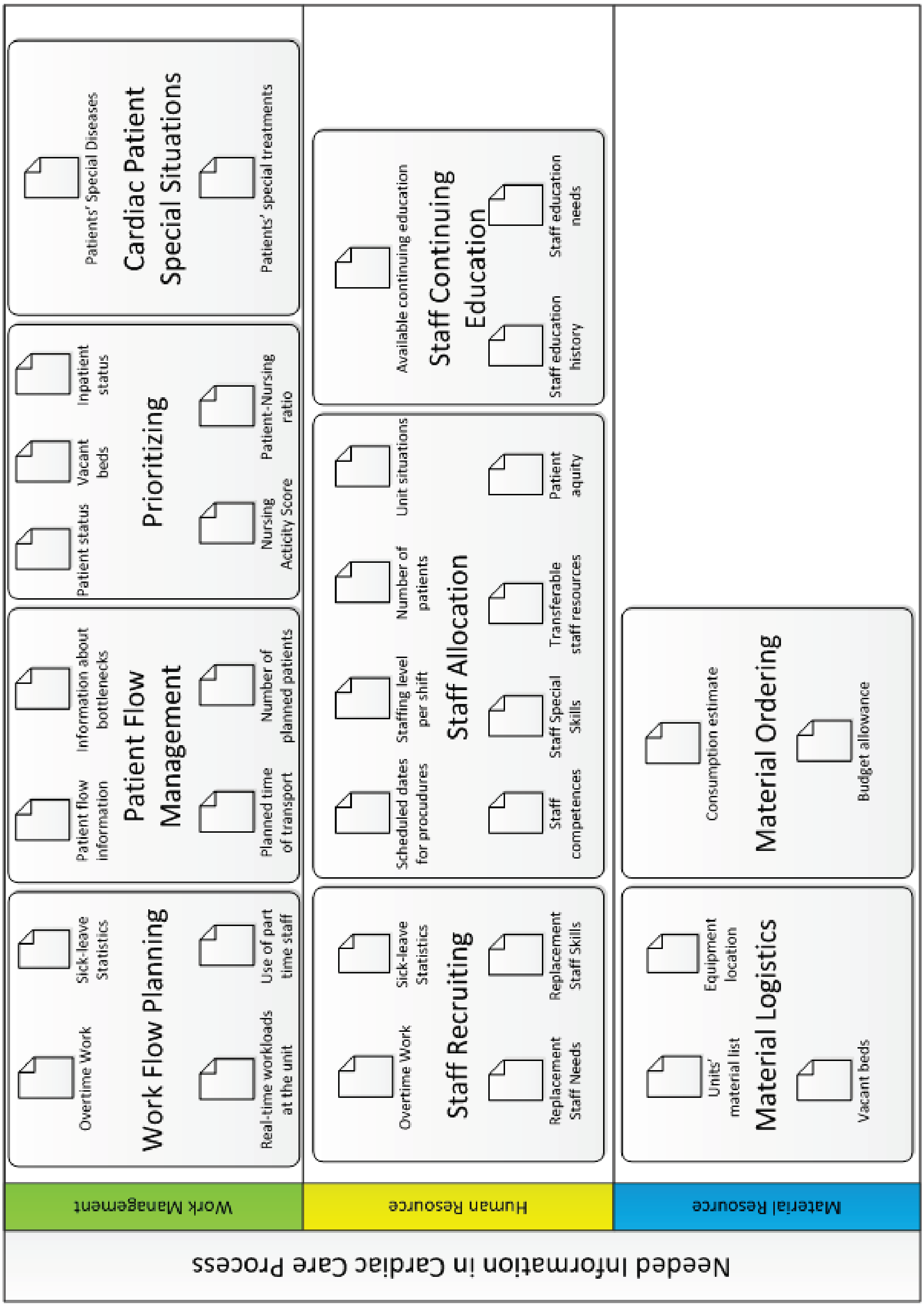

Figure 9. Content model of information management system for the cardiac care process.

6 DISCUSSION

The aim of this study was to create a content model for supporting tactical decision-making with information management in the cardiac care process.

This chapter discusses the strengths and limitations of the study and its main findings in relation to the previous literature. The validity and reliability of the qualitative research phases are examined through the concept of trustworthiness (credibility, transferability, dependability, confirmability) (Guba and Lincoln, 1989; Polit and Beck, 2012). The discussion continues with an evaluation of the validity and reliability of the quantitative study. The challenges for validity and reliability are also described in detail in the sub-studies (Papers I – IV). In addition, some conclusions are drawn and suggestions for nursing administration and for nursing research are presented.

6.1 Strengths and limitations of the study

The most important criteria in assessing the quality of a study are its validity and reliability (Polit and Beck, 2012). Validity is a measure of the truth and accuracy of a study in relation to the phenomenon of interest, while reliability represents the consistency of the measurement. The reliability and validity of this study have been ensured during the different research phases in multiple ways, for example through triangulation (Burns and Grove, 2009). The research phases also form a coherent and logical whole (see Figure 3.) However, there are some critical observations related to the data and the research process. The research was conducted, and the data collected, from a Finnish healthcare environment. This connects the study strongly to the Finnish healthcare system and cardiac care in Finland. A more international study might have provided additional viewpoints to the results and perhaps would have strengthened the conclusions and generalizations. However, the Finnish research setting did provide adequate sample sizes. Furthermore, this research utilizes mainly qualitative methods, naturally providing qualitative results. Only in the final part of the study are some quantitative results provided.

The main challenge to the study's validity was that this topic was novel and not previously studied in depth. This affected the research design phase, and sample outlining, limiting and defining were needed.

6.1.1 Trustworthiness of qualitative data

In this chapter, the trustworthiness (credibility, transferability, dependability, confirmability) of the qualitative research phases – i.e. the literature review, critical incident data and interview data – are examined. Trustworthiness in qualitative research refers to methodological soundness and adequacy (Shenton, 2004). In this study, trustworthiness was assessed in terms of credibility, transferability, dependability and confirmability, as further explored below (Guba, 1981; Polit and Beck, 2012; Shenton, 2004).

The credibility criterion involves establishing that the results of qualitative research are credible or believable from the perspective of the participant in the research (Guba and Lincoln, 1989). In this study, the credibility was enhanced by using data and method triangulation in order to gain a thorough picture of tactical decision-making in a cardiac care process (Polit and Beck, 2012). The results of the literature review (Paper I), the critical incidents data (Paper II) and the interviews from the cardiac care experts (Papers II, III) revealed both complementary and concordant elements that strengthen the credibility of this research.

Credibility was also increased in various ways within the different phases of the research. For example, in Paper II interviews were conducted to enrich and confirm the data collected. Furthermore, to enhance credibility and consistency, part of the interviewees were the same in Paper II and Paper III. On the other hand, the interviewees provided closely similar answers, which at the same time increased the credibility of the interviewees and saturated the data. Credibility was also enhanced by the researcher's personal knowledge and experience of the context of the study and cardiac care: this experience was useful throughout the process, but particularly in interviewing the participants and asking follow-up questions (Shenton, 2004). On the other hand, this pre-understanding may also bias the research (Miles and Huberman, 2001).

The credibility of the research could have been further enhanced by studying the experiences of the patients in the cardiac care process. However, the patients' ability to evaluate and analyze the management of the cardiac care process might have been limited and thus their input to the main purpose of this research might have been very narrow. However, the patients' viewpoints have been considered in another research of our university's research group (Rahkonen, 2010).

Transferability refers essentially to the generalizability or transferability of the data; that is, the extent to which the findings can be transferred to other settings or groups (Polit and Beck, 2012). In this study, the data were collected from an electronic database (Paper I) and from specialized health care in Finland (Paper II, III). The results must thus be viewed critically because the data for the study were collected from just a few hospitals, and only from Finland. Cardiac care processes, however, are quite common throughout the Finland.

One central transferability issue concerns the recruitment of informants (Shenton, 2004). The informants for the critical incidents data (Paper II) and interviews (Papers II, III) were selected on the basis of a set of inclusion criteria. The original papers, as well as the current synthesis, describe the inclusion criteria as well as the background data of the participants in the study so that the reader can critically assess the transferability of the findings to other similar situations (Polit and Beck, 2012). The interview participants were purposefully selected, multi-professional managerial experts with extensive work experience in cardiac care.

The informants were motivated to participate in this study, and they described cardiac care processes and information utilization very well. However, due to the small sample size the results cannot be generalized to represent the whole study population. On the other hand, the main purpose of this study was to gain in-depth information about the phenomena under investigation rather than to generalize the findings for a particular target population (Burns and Grove, 2009; Polit and Beck, 2012).

The **dependability** of the results from the literature review (Paper I), critical incidents in the cardiac care process (Paper II) and interviews (Papers II, III) are enhanced by the inclusion of a transparent description of the research strategies and the procedures for the analysis (Polit and Beck, 2012). The results of each part of the study have been evaluated in a multi-professional research group and the results of the analysis were always based on the opinions of several researchers. Furthermore, the data were analyzed logically, and the transcribed data were classifying with NVivo analysis software. It is possible that the researcher's experience of cardiac care has influenced both the course of the interviews and the process of data analysis. This is typical of all qualitative research, but it is important that it is recognized (Polit and Beck, 2012). To keep this influence of the researcher's advance understanding and attitude to a minimum, the progress of the analysis was constantly reviewed by a second researcher, who also critically examined the categories abstracted from the analyses. Investigator triangulation was used in order to make the categorized process less subjective (Cohen 1960, Polit & Beck 2004). In Paper I, the review for the study was carried out by five persons, who read and extracted the articles. All the search strategies, as well as the inclusion and exclusion criteria employed, are described in Paper I. Furthermore, the same articles are available for any other research group applying the same criteria. Data extraction was first done independently, by five evaluators, and then also collectively. In the event of discrepancies, discussions were held until a common understanding was reached. Altogether, the evaluators agreed on most studies and only a few studies needed closer discussion. Additional discussion was needed, for example, with a study containing an interesting technical detail of a healthcare IS, but less information related to the purposes of this review.

Confirmability refers to the degree to which the results could be confirmed or corroborated by others (Shenton, 2004). Here, the confirmability was assured by documenting the procedures for checking and rechecking the data throughout the study. The associations between the data and the results are reported in the original papers (Papers I, II, III) so that the reader can follow the researcher's reasoning, based on the excerpts and the categories extracted from them (Polit and Beck, 2012). Protection against research bias in all the original papers comes from the peer review process in scientific journals, to which all these papers were subject, and all the papers being published in international scientific referee journals honestly and openly.

6.1.2 Validity and reliability related to the quantitative study

In the third research phase (Paper IV), the data collection was carried out through a larger research project called "Clinical language management for improvement of utilization and usability of patient journals." The data consisted of textual electronic patient narratives and the associated OPCq acuity.

A morphological analyzer of the Finnish language was used to pre-process the data and the vector space model, prevalent in the field of information retrieval, was used to transform the pre-processed data into numerical representation. The mathematical models for predicting OPCq scores used the regularized least-squares (RLS) algorithm, a state-of-the-art method widely used in the areas of statistics and machine learning (Hoerl and Kennard, 1970). The RLS algorithm and the vector space model are one of the most widely applied algorithms in the area of machine learning. For example, they have previously been used for automated analysis of electronic patient records for automated classification of intensive care nursing narratives (Hiissa et al., 2007).

The pre-processed and transformed data were further processed in order to connect the daily acuity scores and the corresponding nursing documentation. This processing created a dataset consisting of 132,053 data points. Finally, the data set was randomly divided into three portions, following standard experimental methodology in machine learning: a training set, a validation set and a test set, consisting of 79,878, 25,657 and 26518 data points, respectively. This division was done on the level of the patients, meaning that there is no overlap between patients in the three sets.

The predictive accuracy of the developed model was evaluated on a large independent test set representing more than 25,000 ward days. The results demonstrated that the models were indeed able to make accurate predictions on this data. The predicting tools used in this study improve the utilization possibilities of the free-form textual patient documentation significantly, as our results showed. These tools should be directly applicable for Finnish hospitals using the same kind of electronic patient record system and recording practices, and treating similar types of patients as those comprising our data.

However, these results cannot be directly generalized to other hospitals using different types of recording practices. The trained models may, in settings where the data differs from the type of data that was used for training them, either perform worse than was observed in our experiments, or not work at all if the differences are large enough. However, the general machine-learning framework considered in this work should also be applicable for other types of electronic patient record systems, even across languages. The RLS algorithm and the vector space model can easily be used to model other types of textual or structured patient data and coding systems.

6.2 Discussion of the results

This research provided new information on tactical decision-making by describing the tactical decision-making process and decisions in a cardiac care process. Process-based organization needs, and benefits from, an ERP system (Botta-Genoulaz and Millet, 2006; Kueng, 2000) that provides real-time data of the processes for the decision makers (van Merode et al., 2004). This research provided new insight into what information cardiac care experts see as critical. Furthermore, this research revealed the information that is totally missing, and the information that is not available in the real-time cardiac care process for the decision maker. To succeed in the care processes, the information flow must be effective between different hospital wards and units. This is especially important when moving towards process-based organization (Vera and Kuntz, 2007). In addition, the information must be available in all the different phases of the process. The nurse managers should be able to see and analyze process-related, managerial and clinical information at the same time (Heathfield and Louw, 1999). This emphasizes the need for a comprehensive hospital information system such as an ERP system, where these elements should be available (Bose, 2003). Unfortunately, at the moment this is rarely the case, although there are studies that confirm the benefits of ERP systems for process performance, including:

- better information management, when all administrative functions are integrated into a single system (Botta-Genoulaz and Millet, 2006),
- better efficiency and reduced operational, labor and inventory costs (Pan and Pokharel, 2007),
- increased communication between departments (Stefanou and Revanoglou, 2006).

To support cardiac care process performance this study provided categories of important information for successful multi-professional and managerial decision-making, and for improving single points of action in the care process. Furthermore, this study provided knowledge about tactical decision-making – the decisions tactical decision makers make, the information that they use and have available and the information they are lacking. The results showed that there is a great deal of information available regarding the cardiac care process for tactical decision-making. However, this information is scattered, and most of this information is human-created, manual information. Furthermore, this information is seldom available in real time and is not accessible throughout the care process. Bose (2003) reached similar conclusions when envisioning a knowledge-management enabled health management system that would help to integrate clinical, administrative and financial processes in health care. Unfortunately it is not enough to focus only on information – fluent management of the care process requires more than that. Nurse managers need a more comprehensive picture of the care process and the information necessary to establish a reliable, effective and efficient flow of information. The results of Study IV showed, for example, the possible use of existing information to improve tactical decision-making with predicting tools. A high quality flow of information also presents challenges for organization – the importance of documentation has to be understood and managed well.

The results of this research show that the care process, from emergency to discharge, would benefit from information and decision support for administration staff, experts, patients and their relatives. These different stakeholders identified the critical information from their different perspectives. For the administration, human resource planning and other information related to resource allocation was critical. For experts, the following were identified as critical information:

- information about patient flow,
- information about patient transportation,
- information about patient waiting times,
- medication information,
- alert systems concerned with correct medication, and
- information about missing documentation.

These results are similar to Ruland's (2001) study on the development of a decision support system.

Critical information for patients included information about length of stay, discharge information before discharge, home-care regimens and the possibility of looking at one's own patient records during and after care. Furthermore, critical information for the patients' families or companions was information about waiting times, care processes and length of stay.

Clinical information of cardiac patients' EPRs can be used to predict the patients' OPCq acuity scores for the following day. The textual nursing notes and previously assigned acuity scores can be utilized to predict the different sub-categories of patients' acuity of the next day through the application of machine-learning techniques. Our study showed that it is possible to obtain accurate predictions about the patients' acuity scores. Based on the several experiments of this study we have shown that:

- It is possible to make accurate predictions about the value of the acuity scores of the subsequent day based on assigned scores and nursing notes from the previous day.

- Making predictions for the same day leads to good results, but having the access to the nursing notes for the same day boosts predictive performance even further.

At the moment, nurses define the patients' acuity scores and input them manually into the patient classification system once a day. A reliable patient acuity predicting system could decrease the nurses' workload for these tasks, freeing them to perform actual patient care. A reliable predicting tool would influence the whole care process and would improve efficient information utilization for tactical decision-making, such as human resource allocation.

In fact, it seems that there is room for a collective and supportive information system in cardiac care. Ideally, an information system such as an ERP system in a hospital could cover all the phases of the process and could support management with necessary information. Several previous studies have reached similar conclusions (Botta-Genoulaz and Millet, 2006; Stefanou and Revanoglou, 2006; Trimmer et al., 2002b). Some research has even described steps that have already been taken in this direction, such as Martin et. al. (2007) whose study showed that activities in the development of information systems facilitated the flow of information between different healthcare providers, social welfare institutions and other agencies.

This research designed a content model for an information management system for the cardiac care process (Figure 9). This model shows that an organization could benefit from an ERP system that integrates information from several resources and provides information in real time for tactical decision-making. Our model provides support for improving managerial decision-making with information technology, as Holsapple and Sena (2001) also suggest in their study. In practice, this model provides a starting point for analyzing the requirements for a possible information system for multi-professional and managerial decision-making.

6.3 Suggestions for nursing administration

Information management and utilization will be one of the key issues in the future for organizations that are moving to a process-based organization model. This study proved that information management with enterprise resource planning is a viable option for supporting tactical decision-making. In practice, a real enterprise resource planning system using this preliminary content model could be developed, tested and further improved in clinical settings. Based on the results of this study, we make the following suggestions for nursing administration:

1. Improve information support in the cardiac care process:
    - Renew information management architecture and reporting facilities serving the new organization model
    - Improve reporting with real-time information and monthly reports
    - Utilize the information relating to patient flow and human resources

2. Provide tools for tactical decision-making in the cardiac care process:
    - Support enterprise planning with a desktop tool
    - Support decision-making using the information in the information systems (for example provide information on staff allocation needs based on the patient flow estimates)
    - Improve information management in the human resource system to enable easy access and administration of personnel information to unit managers

6.4 Suggestions for nursing research

Even though supporting tactical decision-making with information management has been possible for a period of time, the scientific creation and evaluation of information management systems in health care has been scarce. The development of information management systems in health care is needed and future research should look at the collection, mining and systematic use of information from different perspectives. Based on the results of this study, we make the following suggestions for nursing research:

1. Define the content of the information management systems in health care

This study created a preliminary model for the content of an information management system for the cardiac care process. This preliminary model should be further evaluated, improved and validated.

2. More analysis on information management in the cardiac care process

This study showed the vast amount of information and the complexity of the information in the cardiac care process. It also described the flow and management of information in a cardiac care process. There is a clear need for this analysis to be further deepened and information management and information utilization should thus be studied in more depth. For example, the use of patient-related information during discharge and patient education could still be improved in the cardiac care process.

3. Information needs in tactical decision-making

As this study showed, supporting tactical decision-making and the possibility of information management have not been widely evaluated by earlier studies. The model presented in this study is an opening into that evaluation, as it could also be tested in other patient processes. In addition, the information needs in tactical decision-making should be further studied in other care processes.

7 CONCLUSION

This study presents a novel and innovative approach for exploring information management possibilities in tactical decision-making in cardiac care processes. To our knowledge, this study is the first to describe tactical decision-making in a care process from the viewpoint of information management. The abstraction level of described tactical decision-making concepts is high, which ensures transferability to other care processes. Thus, the results of tactical decision-making in the cardiac care process may be useful, and transferrable, elsewhere.

A cardiac care process contains critical information of the process itself, its management and clinical care. Based on this information, tactical decisions are made relating to human resources, material resources and workloads. Tactical decision-making collects necessary information from several sources, but currently most of this information is scattered, not integrated, or is manual. As the study results show, comprehensive single information systems integrating ERP systems are unusual in health care.

This tactical decision-making process suffers from a lack of information, such as patient flow, bottlenecks or patient status. In addition, information related to human resource management – that is, real-time workloads, staffing levels on current shifts or staff working on the next shift – is not available. The study results confirmed that better management of all information in a cardiac care process would improve tactical decision-making by providing real-time information, more efficient management of human resources and increased personnel satisfaction and, finally, better care for the patients. Improved information management helps identify the bottlenecks in the care process and provides the possibility to influence them. A good example of improved process management with better management of information is the application of acuity scores introduced in Phase 4 of this study. This study showed that it is possible to make reasonable predictions about the value of the acuity scores of the subsequent day based on assigned scores and nursing notes from the previous day and use this information for real-time human resource allocation.

To summarize, based on this research it is evident that in a cardiac care process a lot of information is utilized and processed, but this information does not yet fully serve and support tactical decision-making. In addition, there is room for a real-time integrated information system targeted at tactical decision-making.

ACKNOWLEDGEMENTS

This study was carried out at the Department of Nursing Science, University of Turku. During the process I have been privileged to collaborate with many supportive, encouraging and intelligent people in the Department of Nursing Science. In particular, I respectfully thank Professor Helena Leino-Kilpi PhD, the Head of the Department, for giving me the opportunity to do this research.

I wish to express my deepest gratitude to my great supervisors, Professor Sanna Salanterä, PhD, RN, and Docent Heikki Korvenranta, PhD, MD, for their belief in me and for their guidance and support during the research process. Sanna, you have always been there for me; I thank you for your spirit, innovativeness, trust and our happy moments together. As you have always taught me – the most important things during doctoral studies are love, passion and a willingness for adventures. During this process, all these feelings have indeed been needed. Heikki, thank you for connecting me to process development; I am very grateful that you provided me with this viewpoint on the development of a new hospital. Your innovation has inspired my research work.

The official reviewers, Professor Arja Häggman-Laitila and Professor Leena Paasivaara, I thank for their careful review and constructive criticism regarding ways to improve this dissertation.

My warmest thanks go to all the cardiac care experts who have given their valuable time in different phases of my study. Without your input this research would never have been finished.I would also like to express my warmest thanks to my follow-up group, Liisa Iire PhD and Professor Reima Suomi PhD. Your broad experiences in administrative healthcare and management, your in-depth evaluations, and your positive criticism made it possible for me to carry out this research.

I owe my special thanks to my best scientific colleague, my dear friend Heljä Lundgrén-Laine PhD, for sharing the same enthusiasm as me. It is a pleasure to work with such a good friend, as you are. I would like to thank all of my research and collaboration partners in the IKITIK group. It has been a great privilege for me to get to know you all. I am especially grateful to Antti Airola PhD, Tapio Pahikkala PhD, Juho Heimonen, and Professor Tapio Salakoski PhD, for their machine learning and statistical expertise during this research. I would also like to thank Kristiina Junttila PhD, for your expertise. There is indeed power in a multiprofessional work.

I own my sincere thanks to the R&D Manager, Aulikki Holma and all my colleagues at the Turku University of Applied Sciences. You have supported me in many different ways during this research process.

I would like to thank Suzanne Collins for your excellent help in the English language.

I am much obliged to all my great friends and neighbours for sharing their joys and sorrows with me. You have shared many experiences with me during the past years. I would like to thank you Sanna Kauhanen, Pia Viljamaa and Tanja Lehtiö for many delightful and memorable trips in Europe. I especially want to thank all our sport friends for many enjoyable “Young Finland Association” moments.

My special thanks go to the “VIISAAT” group, my dear fellow post-graduate students, Anna Axelin PhD, Katja Heikkinen PhD, Riitta-Liisa Lakanmaa PhD, Heljä Lundgrén-Laine PhD, Marita Ritmala-Castren, and Sanna-Mari Pudas-Tähkä, for sharing the joys and sorrows, for laughing and working together, and for the feeling that you are always there. I could never have kept my sanity over these years without the support, reality checks and joy you have brought into my life.

I would like to extend a special thanks to my mother Leena, and my father Juhani. I am deeply grateful to my parents for all of their love and support, but most of all for teaching me to value learning, hard work and persistence.

Finally, I want to extend my deepest and loving thanks to the three men of my life, my dear husband and soul mate Juha, and our beloved sons Juuso and Joonas. Without your support and understanding this work would never have been completed. Juha, you have been ”more than a husband”, as you were also one of my co-authors, which I gratefully and proudly acknowledge. I see it as gift that love and science are shared within our family.

This study was financially supported by the Finnish Work Environment Fund, European Social Fund / Innowell project, Finnish Foundation of Nursing Education, and the Academy of Finland, which is also gratefully acknowledged.

Halikko, June 2013

Elina

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