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PATIENT SAFETY AT EMERGENCY DEPARTMENTS – CHALLENGES WITH CROWDING, MULTITASKING AND INTERRUPTIONS

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PATIENT SAFETY AT EMERGENCY DEPARTMENTS – CHALLENGES WITH CROWDING, MULTITASKING AND INTERRUPTIONS

THESIS FOR DOCTORAL DEGREE (Ph.D.)

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“Don't raise your voice, improve your argument.”

Desmond Tutu, 2004

To Mathias and Bibbi

ABSTRACT

Several challenges with patient safety in the emergency department (ED) context have been previously identified, and some commonly mentioned are crowding, multitasking, and interruptions. The ED is a complex, high-risk work environment where multiple clinicians (physicians, registered nurses [RNs], and licensed practical nurses [LPNs]) are constantly working in parallel work processes, in an often crowded ED, while conducting tasks involving cognitively demanding decision-making processes. ED crowding has for the past 20 years been identified as a problem internationally, resulting in extended ED length of stay (LOS) and increased morbidity and mortality for patients. ED crowding is also considered to have negative effects on the clinicians' workload and work satisfaction.

Both multitasking and interruptions have been identified as risk factors for patient safety by having negative effects on a clinician's decision-making processes and thus increasing the risk of forgetting important details and events because of memory overload. However, information has been lacking about what specific work assignments ED clinicians conduct, and thus there is little information about the types of assignments they perform while multitasking and being exposed to interruptions. Further, because not all interruptions lead to errors and because they are not all preventable, a more refined account of interruptions is called for. Moreover, it seems that previous studies have not identified which specific factors influence the ED clinicians' perceptions of interruptions. The work environment has been referred to as a possible influencing factor, but specific details on the relationship between the work environment and negative effects from interruptions are pending.

The overall aim of the thesis was to describe ED crowding, and its influence on ED clinicians' work processes (activities, multitasking, and interruptions) and patient outcomes, from a patient safety perspective. The thesis addressed six research questions: 1) How has ED characteristics, patient case mix and occurrence of ED crowding changed over time? 2) What work activities are performed by ED clinicians? 3) What kind of multitasking situations are clinicians exposed to during ED work? 4) What kind of interruptions are clinicians exposed to during ED work? 5) How do ED clinicians perceive interruptions? 6) Is there an association between ED crowding and mortality for stable patients without the need for acute hospital care upon departure from the ED?

The data in the thesis were generated from two data collections: 1) registry data containing patient characteristics and measures of ED crowding (ED occupancy ratio [EDOR], ED LOS, and patient/clinician ratios) extracted from the patients' electronic health records (paper I and IV) and 2) observations and interviews with ED clinicians (physicians, RNs, and LPNs) (paper II and III). Nonparametric statistics were used in paper I and III, quantitative and

qualitative content analysis were used in paper II and III, and multivariate logistic regression analysis was used in paper IV.

The main results in the thesis are presented based on Asplin's conceptual model of ED crowding, from the aspect of input-throughput-output, and how parts of a sub-optimal throughput influence patient safety through ED clinicians' work processes and patient outcomes. During 2009 – 2016 there has been a change in patient case mix at the EDs at the study hospital, primarily with an increase in unstable patients (input) and a decrease in the number of patients admitted to in-hospital care (output). The median for ED LOS over the study period increased, and the largest increases occurred among the subgroups of unstable patients, patients ≥80 years of age, and those admitted to in-hospital care (throughput). Further, an increase in crowding, in terms of median EDOR and median patients per RN ratios, was identified, with an increase in EDOR from 0.8 in 2009 to 1.1 in 2016 and an average increase of 0.164 patients/RN/year (throughput). The ED clinicians' work assignments consisted of 15 categories of activities, and *information exchange* was found to be the most common activity (42.1%). In contrast, the clinicians only spent 9.4% of their activities on direct *interaction with patients and their families* (ED clinicians' work processes). The clinicians multitasked during 23% of their total number of performed activities, and there was an overall interruption rate of 5.1 interruptions per hour. The majority of the observed multitasking situations and interruptions in the ED clinicians' work occurred during demanding activities that required focus or concentration (ED clinicians' work processes). Finally, an association was identified between an increase in ED LOS and EDOR and 10-day mortality for stable patients without the need for acute hospital care upon departure from the ED (patient outcomes).

This thesis illustrates how a sub-optimal throughput, affected by conditions in both the input and output components, negatively influence the ED clinicians' work processes as well as patient outcomes.

LIST OF SCIENTIFIC PAPERS

I. Berg LM, Ehrenberg A, Florin J, Östergren J, Göransson KE. Significant changes in emergency department length of stay and case mix over eight years at a large Swedish university hospital. (International Emergency Nursing, 2018 Sep 3. pii: S1755-599X(18)30110-1. [Epub ahead of print]. https://doi.org/10.1016/j.ienj.2018.08.001

II. Berg LM, Ehrenberg A, Florin J, Östergren J, Göransson KE. An observational study of activities and multitasking performed by clinicians at two Swedish emergency departments. European Journal of Emergency Medicine. 2012; 19:246-51.

III. Berg LM, Källberg AS, Göransson KE, Östergren J, Florin J, Ehrenberg A. Interruptions in emergency department work: an observational and interview study. BMJ Quality and Safety. 2013; 22:656-63.

IV. Berg LM, Ehrenberg A, Florin J, Östergren J, A. Discacciati, Göransson KE. Associations between crowding and 10-day mortality among stable patients without need of acute hospital care upon departure from the emergency department. (Submitted manuscript)

CONTENTS

LIST OF ABBREVIATIONS

ACCI – Age-combined Charlson's Comorbidity Index

CDW – Central Data Warehouse

ED – emergency department

EDCS – the Emergency Department Crowding Scale

EDOR – the Emergency Department Occupancy Ratio

EDWIN – the Emergency Department Work Index

EHR – electronic health record

EMS – emergency medical services, i.e. ambulance or helicopter staffed by paramedics

LOS – length of stay

LPN – licensed practical nurse = assistant nurse

NEDOCS – the National Emergency Department Overcrowding Scale

OECD – the Organization for Economic Co-operation and Development

READI – the Real-time Emergency Analysis of Demand Indicators

RETTS – the Rapid Emergency Triage and Treatment System

RN – registered nurse

SEAL – the Skåne Emergency Department Assessment of Patient Load

WHO – the World Health Organization

DEFINITIONS

Adverse event – an injury or complication that is caused by medical management or interventions, rather than the underlying disease (1) p. 4

Crowding – a situation in which the identified need for emergency services outstrips available resources in the ED. This situation occurs in hospital EDs when there are more patients than staffed ED treatment beds and wait times exceed a reasonable period. Crowding typically involves patients being monitored in non-treatment areas (e.g., hallways) awaiting ED treatment beds or inpatient beds. Crowding may also involve an inability to appropriately triage patients, with large numbers of patients in the ED waiting area of any triage assessment category (2)

Disturbed work process – an interruption of a work process that is negatively perceived as being irrelevant, annoying, or delaying the ongoing work process (3) p. 3

Interruption – a break in the performance of a human activity initiated by a source internal or external to the recipient, with occurrence situated within the context of a setting or a location. This break results in the suspension of the initial task by initiating the performance of an unplanned task with the assumption that the initial task will be resumed (4) p. 38

Medical error/error – a failure made in the process of care that results in or has the potential to result in severe harm to patients (1) p. 4

Multitasking – managing multiple tasks at the same time (5) p. 1240

Patient safety – absence of preventable harm to a patient and reduction of risk of unnecessary harm associated with health care to an acceptable minimum (6)

Primary task – the ongoing task while being interrupted

Self-interruption – when an individual, independent of another person, suspends an activity to perform another activity; i.e. while walking, stops abruptly and talks to another person (7)

Undisturbed work process – an ongoing work process during which interruptions do not cause a negative perception (3) p. 3

PREFACE

The focus of this thesis is to investigate the challenges that emergency departments (EDs) face in terms of patient safety from the perspectives of how crowding influences ED clinicians' work processes and ED patients' outcomes. I have been working as a registered nurse at the ED at Karolinska University Hospital in Solna since 2003. I had worked for seven years on orthopedic and surgical wards before entering this position and was a fairly experienced nurse familiar with working in high-paced environments with severely sick patients. Still, to enter the ED context with its, from time to time, extremely high workload and never-ending inflow of patients with different priority levels and unknown complaints was a bit of a shock. I still remember how exhausted I was when ending my shifts during the first couple of weeks. A reflection I made quite soon was that I, on a daily basis, frequently multitasked and repeatedly got interrupted in my work assignments, which sometimes was alright and sometimes almost put me over the edge. Different colleagues also had different capacities to handle interruptions, and some did not seem to be bothered at all while others struggled considerably. Regardless, I surprisingly became used to the situation and actually found myself enjoying working in this alternating and challenging environment. Yet, I sometimes wondered if crowding and all of the interruptions and multitasking situations might have negative consequences for patient safety.

After working in the ED for some years, I felt a strong need for a change and wanted to develop professionally, preferably without having to leave the ED. Thus, I started to consider the possibility of conducting research in a clinical setting. In 2009, I heard about a project that would soon be starting at the clinic about multitasking. At that time, I asked if I could participate, a decision I have never regretted as it put me on the path to become a PhD student, which has opened so many doors and put me where I am today career wise. I will not deny that these past nine years from time to time have been extremely challenging. However, they have mostly been rewarding, providing me with insights about the academic world, the ED, my professional identity as a registered nurse, and not least about myself and the knowledge that I never give up when I have put my mind to something. Now, when I read my thesis and look back on what I have accomplished, I can see that I have contributed to a better understanding of the complex ED work environment and how parts of this complexity influence patient safety, especially concerning how a sub-optimal throughput, affected by conditions in both the input and output components, negatively influence the ED clinicians' work processes as well as patient outcomes. In my current position as Head of Nursing Development at the Functional Area of Emergency Medicine Solna, I have been able to use my research results to draw conclusions and make strategic decisions for the clinical setting. To see that my research has clinical influence on both patients and clinicians is extremely rewarding. Completing this thesis is not the end, it is only the beginning of my research career.

1 INTRODUCTION

For many people, health care is associated with safe institutions where people can get help, comfort and treatment when they are sick or injured. Still, large numbers of errors occur in health care. Studies have estimated that as many as 98,000 hospital deaths (many preventable) per year are related to health system errors in the USA (1). In a Swedish report from 2018, where health records from 77,000 in-hospital care episodes in somatic hospitals were audited, it was found that adverse events occurred in 8% of these in-hospital care episodes, equivalent to about 110,000 patients/year on a national level based on 1.4 million care events/year (8). These adverse events correspond to permanent injuries for approximately 2,800 patients/year and as contributing causes to death for 1,400 patients/year. Further, these adverse events were not only costly in terms of human lives and suffering, but they also added to the costs of health care (45% of the adverse events resulted in extra days in hospital care) (8). In turn, the occurrence of adverse events generates a loss of trust among the patients for the delivered quality of care.

1.1 PATIENT SAFETY

There is no globally established definition for patient safety; however, the World Health Organization (WHO) defines patient safety as the "absence of preventable harm to a patient and reduction of risk of unnecessary harm associated with health care to an acceptable minimum" (6). Further, inconsistent use of language has compromised the understanding of patient safety (9). For example, similar concepts are described by using different terms and some terms embrace several concepts (9), which makes it difficult to develop risk-reduction strategies, to perform evidence-based research, and to evaluate existing healthcare policies relevant to patient safety (10). The WHO's World Alliance for Patient Safety addressed this problem, and in 2009 it formed a drafting group for an International Classification for Patient Safety. Their work culminated in a conceptual framework consisting of the following ten high-level classes: incident types, patient outcomes, patient characteristics, incident characteristics, contributing factors/hazards, organizational outcomes, detection, mitigating factors, ameliorating actions, and actions taken to reduce risk (10). Commonly used concepts are medical error/error, i.e. a failure made in the process of care that results in or has the potential to result in severe harm to patients (1) and adverse event, i.e. an injury or complication that is caused by medical management or interventions rather than the underlying disease (1).

The interest in patient safety has evolved over the past 20 years, but safety culture has been of concern much longer within other high-risk areas, such as the aviation and nuclear industries (1). Patient safety culture is generally described in terms of being something that can be influenced to achieve safer care and might be explained through five central components (11):

1. Management – commitment to safety and prioritization
2. Safety system – safety policies, incident reporting
3. Risk perceptions and attitudes towards risk and safety
4. Work pressure – workplace and workload
5. Competence – selection and training of the workforce

Patient safety culture can be compared to the concept of patient safety climate because these terms are often used interchangeably. However, the studies of climate and culture in organizations ha different origins (12). Culture has been studied within anthropological research, most commonly with qualitative methods. The study of organizational climate has its origin in social psychology and is often studied using quantitative methods (13). Culture is more stable over time, whereas climate is assumed to be easier to influence and to change than culture (12). When the healthcare system started to develop a patient safety culture, much knowledge and solutions from the aviation industry were transferred into health care. However, these contexts are in many ways different, which makes comparisons problematic, and thus difficult to use the same safety strategies (14).

Safety-I and Safety-II are two common perspectives of safety within a system. They have different views on how safety can be achieved, but can be seen as complementary to one another (15) (Table 1).

Table 1. Overview of the Safety-I and Safety-II perspective. *

	Safety-I	Safety-II
Definition of safety	That as few things as possible go wrong.	That as many things as possible go right.
Safety management principle	Reactive, respond when something happens or is categorized as an unacceptable risk.	Proactive, continuously trying to anticipate developments and events.
View of the human factor in safety management	Humans are predominantly seen as a liability or hazard.	Humans are seen as a resource necessary for system flexibility and resilience.
Accident investigation	Accidents are caused by failures and malfunctions. The purpose of an investigation is to identify the causes.	Things basically happen in the same way, regardless of the outcome. The purpose of an investigation is to understand how things usually go right as a basis for explaining how things occasionally go wrong.
Risk assessment	Accidents are caused by failures and malfunctions. The purpose of an investigation is to identify causes and contributory factors.	To understand the conditions where performance variability can become difficult or impossible to monitor and control.

*Reproduced with permission from EUROCONTROL (16)

The central mechanism in the Safety-I perspective is related to the causality credo, i.e. adverse events are related to something that goes wrong and that can be "found and fixed". This is a linear way of thinking, and therefore linear accident models are often used in Safety-I for analysis. Examples of such models are Heinrich's "Domino Model" (17) and Reason's "Swiss Cheese Model" (18). Further, the Safety-I perspective is built on the assumption that a system can be decomposed into meaningful constituents and thus be understood (15).

In contrast, the mechanism in the Safety-II perspective is related to emergence rather than causality. Adverse events do not occur because of a single root cause that can be eliminated, but rather are transient phenomena or conditions that only exist at a particular point in time. In turn, these conditions could have emerged from other transient phenomena. Safety-II use nonlinear or systematic models to analyze accidents and to assess risks. This perspective assumes that risks occur because of coincidences, links, and resonances (15). Further, the

Safety-II approach believes that the same mechanisms are at play whether a situation goes right or wrong. Associated with the introduction of the Patient Safety Act (In Swedish: Patientsäkerhetslagen) (2010:659) in 2011, the Swedish healthcare system took a step away from the perspective that errors are dependent on individual recklessness (Safety-I). Instead, suggestions are that errors to a large extent are caused by faulty systems, processes, and conditions that cause clinicians to make mistakes, especially in judgments regarding diagnostic procedures and treatment decisions (Safety-II) (19, 20). However, according to a report from the Health and Social Care Inspectorate Swedish emergency departments (EDs) still have a long way to go before this approach is fully implemented (21). For example, the EDs' patient safety work is most often carried out by mangers and does not involve employees and/or patients and their next of kin, even if they indicate that they want to be involved. Further, incidence reporting is still at a premature level, lacking the system perspective and focusing too much on addressing mistakes rather than identifying deficiencies within the system, which maintains scapegoat-thinking (21). Further, it seems as though knowledge of how adverse events occur, as derived from incident reporting, stays on a micro-organizational level, meaning that the organization is looking for underlying causes in very close proximity to the adverse event and seeks to implement measures there. Also, the organizational memory of lessons learned from incidence reporting is weak and is connected to individuals within the organization. When these individuals leave the organization, the knowledge leaves with them (22).

1.2 CHALLENGES WITH PATIENT SAFETY IN THE ED

Several challenges with patient safety within the ED context are previously known within the research field. Some commonly mentioned are crowding (23-33), multitasking (34), and interruptions (34-36).

1.2.1 ED clinicians' work processes

Clinicians at Swedish EDs consist of physicians, registered nurses (RNs), and licensed practical nurses (LPNs). Some EDs have their own employed physicians; however, most EDs are staffed by physicians employed at other clinics than the ED at the hospital. These physicians are, in addition, often responsible for the care of in-hospital patients at wards while also working in the ED. RNs and LPNs are always employed by the EDs. Some of the ED physicians are specialized in emergency medicine, which is a relatively new medical specialty in Sweden. Since 2014, a nursing specialty in ED care for RNs has been established. However, it is not as common that RNs in the ED have a specialist degree, as it is for nurses working in the emergency medical services (EMS) or in intensive care units.

The ED clinicians' workload and work pace are often high and can change rapidly. One reason for such a situation is that the ED context is characterized by unpredictability as because patient attendance, presentation of patient symptoms, and the priority levels of patient conditions vary considerably (37). Another reason is the constant increase in the number of ED visits (38) and the lack of in-hospital beds that in turn leads to extended ED length of stay (LOS) (39). In addition, the ED clinicians are frequently exposed to interruptions (40-45). A reason for frequent interruptions is that EDs consist of multiple teams of clinicians, i.e. physicians, RNs, and LPNs, working in different flow processes. Examples of flow processes are triage, internal medicine patients, and orthopedic patients. These flow processes and team constellations are organized differently in each ED, although a commonality is that work is organized in temporarily assembled inter-professional teams without predetermined leadership. Several care processes, each one involving one unique patient, occur simultaneously within each flow process. The team members have responsibility for some, or all, of these care processes depending on the number of teams in each flow process. The priority levels of the care processes within each flow process often vary, generating a need for the team members to constantly prioritize among the care processes. Because not all team members are concurrently involved in the same care processes, there is often a need to interrupt one another. Further, team members from the different flow processes often need to interact with one another to finalize a specific care process. Apart from frequent interruptions, these parallel flow and care processes create a common need for the clinicians to multitask their assignments and cognitive processes.

Multiple tasks are undertaken by the ED clinicians, but there is little research about what specific work assignments the ED clinicians are conducting during their work. However, a systematic review conducted in 2018 reported that ED physicians spent around 25% – 40% of their time on direct face-to-face contact with the patient, 8% – 44% on communication, 10% – 28% on documentation, and 2% – 20% on administrative tasks (46). Many tasks carried out by clinicians in the ED involve decision-making processes, and studies have shown that ED clinicians are likely to make errors during their decision-making processes because of frequent interruptions (7, 34, 36, 42, 47). These situations are seen during the entire ED visit, from triage to discharge/admission and the consequences of such errors might be an actual or potential threat to patient safety (5, 7, 34-36, 42, 47-49). The ED environment, where decisions are made under time pressure and sometimes based upon incomplete information, is considered conducive to producing errors. In fact, EDs had the highest proportion of preventable errors among several different settings at 51 hospitals, with diagnostic errors being the most common (50).

This complex work environment puts considerable demands on the ED clinicians' capability to prioritize their work and make correct decisions without jeopardizing patient safety and quality of care. The work environment also puts demands on the clinicians to be flexible and

capable team workers. These contextual factors make the ED a high-risk environment (47, 51) and an increasing interest has turned towards the high-risk ED context. During the past years, at least two Swedish PhD theses on patient safety in the ED have been published (52, 53). Both theses identified the need to improve patient safety work in EDs, and these conclusions are supported in a recent report from the Health and Social Care Inspectorate in Sweden (21). The clinicians participating in the studies in the two theses considered interruptions, lack of communication, and crowding as patient safety risks (52, 53).

1.2.2 Crowding

ED crowding has for the past 20 years been identified as a problem internationally (54, 55). Already in 2001 did 91% of the EDs in the United States report that crowding was a major problem (56) and at least two international theses have been published on ED crowding since 2015 (57, 58). ED crowding is considered a threat to patient safety (21, 59, 60), resulting in extended ED LOS (23, 25, 30, 32, 61, 62) and increased morbidity (63, 64) and mortality (25-27, 30) for patients, and Sweden has seen an increase in both the number of ED visits (38) and ED LOS the last decade (39). Many international studies have focused on the group of critically ill patients and those in need of in-hospital admissions when investigating the effect of crowding (23, 24, 26, 28-33). Further, ED crowding is also considered to have negative effects on the clinicians' (physicians' and RNs') workload (21) and work satisfaction (65), and both high workload and crowding have been identified as reasons for high turnover rates for RNs (21). Finally, crowding contributes to stress (21) and increases the occurrence of multitasking and interruptions, and both stress and interruptions are known factors that decrease productivity and effectiveness (60, 66).

A basic challenge with the concept of crowding is that it has multiple meanings. For example, the terms crowding, and overcrowding are often used interchangeably to refer to the same condition. According to the WHO, overcrowding refers to the situation in which more people are living within a single dwelling than there is space for, so that movement is restricted, privacy is lost, hygiene is impossible, and rest and sleep are difficult (67). While population density is an objective measure of the number of people living per unit area, overcrowding refers to people's psychological response to density. However, definitions of crowding used in statistical reporting and for administrative purposes are based on density measures and do not usually incorporate people's perceptions of crowding. The common theme between different definitions is that ED crowding often is referred to as the result of the imbalance between demand and capacity occurring when the number of patients visiting the ED exceeds the expected number (2, 68-70).

Still, there is a lack of a standardized definition and systematic measurement of crowding in a health care context (71), which makes it difficult to compare the results of different studies and to obtain an overview of the magnitude of crowding. Medical associations from different countries have developed their own definitions of ED crowding (Table 2). However, the first part of a commonly used definition is: "*a situation in which the identified need for emergency services outstrips available resources in the ED*" (2), which is similar to the definition of a major incident. That is, ED crowding should not only be related to the sheer number of patients in the ED, but also to factors like the number of clinicians on duty, the distribution between triage acuity levels, the number of patients waiting to be seen by a physician, and the number of available in-hospital beds (72).

In the literature, several ED crowding indicators have been used for measuring crowding. Examples are the ED Occupancy Ratio (EDOR) (73), the ED work score to predict ambulance diversion (74), the ED work index (EDWIN) (75), the National ED Overcrowding Scale (NEDOCS) (76), the Real-time Emergency Analysis of Demand Indicators (READI) (77), the overcrowding hazard scale (31), the Emergency Department Crowding Scale (EDCS) (78), and the Skåne Emergency Department Assessment of Patient Load (SEAL) (79). ED LOS, i.e. the time interval from registration until the patient leaves the ED either as discharged or admitted to in-hospital care, is sometimes used as a measure of crowding (25, 30, 58) and sometimes as an effect of crowding (23, 32, 61). Among these measures, ED LOS and EDOR are the most commonly used. Further, LOS is used as a quality indicator in EDs, both in Sweden and internationally, with a goal that total LOS should not exceed 4 hours, although the suitability of a 4-hour target has been debated (80-82). EDOR is only a value of how many patients are present in the ED over a certain time period divided by the number of established treatment beds (fixed number) in the ED, with crowding defined as a ratio >1.0 (73). This way of measuring crowding does not take the patients/clinician ratio into consideration, which was the case in a large European study that identified that the 30-day mortality rate for in-hospital patients in surgical wards increased by 7% if the RNs' workload increased by one patient (83). Even if these figures are related to in-hospital patients, it is possible that a similar relationship regarding patients/RNs ratios exists in the ED.

Table 2. ED crowding definitions according to medical associations in different countries.

Country	Definition of crowding/overcrowding	Medical association
Australasia	"ED overcrowding refers to the situation where ED function is impeded primarily because the number of patients waiting to be seen, undergoing assessment and treatment, or waiting for departure exceeds either the physical bed and/or staffing capacity of the ED."	Australasian College for Emergency Medicine (68)
Canada	"Emergency department overcrowding is best defined as a situation in which the demand for emergency services exceeds the ability of a department to provide quality care within acceptable time frames.*" "* Time frames will generally be based on the Canadian Emergency Department Triage and Acuity Scale (CTAS)."	Canadian Association of Emergency Physicians/National Emergency Nurses Affiliation (69)
United Kingdom	"This is the situation where the number of patients occupying the emergency department is beyond the capacity for which the emergency department is designed and resourced to manage at any one time. This results in an inability to provide safe, timely and efficient care to those patients, and any subsequent patients who attend the department."	Royal College of Emergency Medicine (70)
United States	"A situation in which the identified need for emergency services outstrips available resources in the ED. This situation occurs in hospital EDs when there are more patients than staffed ED treatment beds and wait times exceed a reasonable period. Crowding typically involves patients being monitored in non-treatment areas (e.g., hallways) awaiting ED treatment beds or inpatient beds. Crowding may also involve an inability to appropriately triage patients, with large numbers of patients in the ED waiting area of any triage assessment category."	American College of Emergency Physicians (2)

1.2.2.1 A conceptual model of ED crowding as a theoretical framework

The problem with the meaning of the concept of crowding prompts the question if of whether we should develop and modify the concept of "ED crowding" or start fresh by defining ED crowding according to "demand and capacity"? Already in 2006 Asplin published a commentary where he established that the research agenda on ED crowding had stalled at a fundamental stage due to the inability to define and quantify crowding using common metrics derived and validated at multiple sites (84). He suggested that it was time for a paradigm shift concerning the phenomenon of ED crowding and asked whether, when trying to cope with ED crowding, organizations should start to define and measure what they want to happen instead of what they do not want to happen (84). This approach is similar to the previously mentioned perspectives on patient safety, that is Safety-I vs. Safety-II (15), as Safety-I looks at what goes wrong and Safety-II looks at what goes right. Thus, according to Asplin the focus should be on measuring patient flow instead of crowding when attempting to understand the problem with overfull EDs (84).

According to a conceptual model of ED crowding by Asplin et al. (85), the ED system can be divided into three main components: input (e.g. patient inflow, chief complaints, and acuity levels), throughput (e.g. staff levels, staff workload, and access to treatment beds), and output (e.g. access to in-hospital beds and access to transport service) (85). The input and output components are the most difficult for the ED itself to influence. Still, the component throughput component is to a large extent dependent on both input and output in order for the ED system to work smoothly. A sub-optimal output leads to situations where patients stay boarded in the ED, i.e. they need to remain in the ED while waiting for, for example, an in-hospital bed or transportation. This will eventually lead to a crowed ED, especially if the inflow of new patients is high.

A major plan to reform Swedish healthcare has been ongoing since the last decades, where one goal is to transfer some of the in-hospital care to clinics outside the hospitals so that as much health care as possible is delivered by care givers in the primary health care sector. The primary reason for this reform is to deliver care at the most effective level (86). One effort, as a part of the transition from in-hospital care to the provision of care outside the hospital, has been to reduce the number of in-hospital beds. This decrease of in-hospital beds has created a shortage of in-hospital beds at all Swedish hospitals (86, 87). Thus, Sweden is one of the countries in the Organization for Economic Co-operation and Development (OECD) with the lowest number of available in-hospital beds for somatic care in relation to its population (2.4 beds/1000 inhabitants in 2015 compared to the OECD average of 4.7 beds/1000 inhabitants) (88). These figures can be compared to Japan, which has the highest number of available in-hospital beds/1000 inhabitants among the OECD countries with 13.2 (88).

The numbers of patients seeking ED care are increasing each year, both in Sweden (38) and internationally (89). In Sweden, there were about 2 million ED visits to 62 hospital-based EDs with two or more somatic specialties in 2017 (90, 91). Approximately 40% of patients seeking ED care in Sweden are the group of elderly citizens (≥65 years of age), and this group is constantly increasing in numbers both in Sweden and internationally (92, 93). The prognosis is that by 2050, one of five persons will be 60 years or older, totaling 2 billion people worldwide, and that every fourth Swedish inhabitant will be over 65 years already in 2030 (92, 94). Furthermore, it has been reported that patients ≥80 years have more extended length of stay (LOS) in the ED than other age groups (39). Because these patients are often in need of in-hospital admission (92), it is likely that their extended ED LOSs are influenced by the previously mentioned reduction of in-hospital beds. A quarter to a half of people over 85 years are estimated to be frail, and frailty results in a vulnerability to sudden health status changes triggered by relatively minor stressor events (95). Thus, an extended LOS might comprise negative influences for this already vulnerable group.

Thus, this widely used model provides a framework for a better understanding of ED crowding because the ED cannot be seen as an isolated unit at the hospital. Figure 1 illustrates a modified version of Asplin's model in which also macro, meso, and micro perspectives, and examples of factors that specifically influence the Swedish ED system, have been added to the model. The macro, meso, and micro perspectives illustrates the difficulties for EDs to influence input, throughput, and output, since certain influencing factors have their origins already on a hospital or community level.

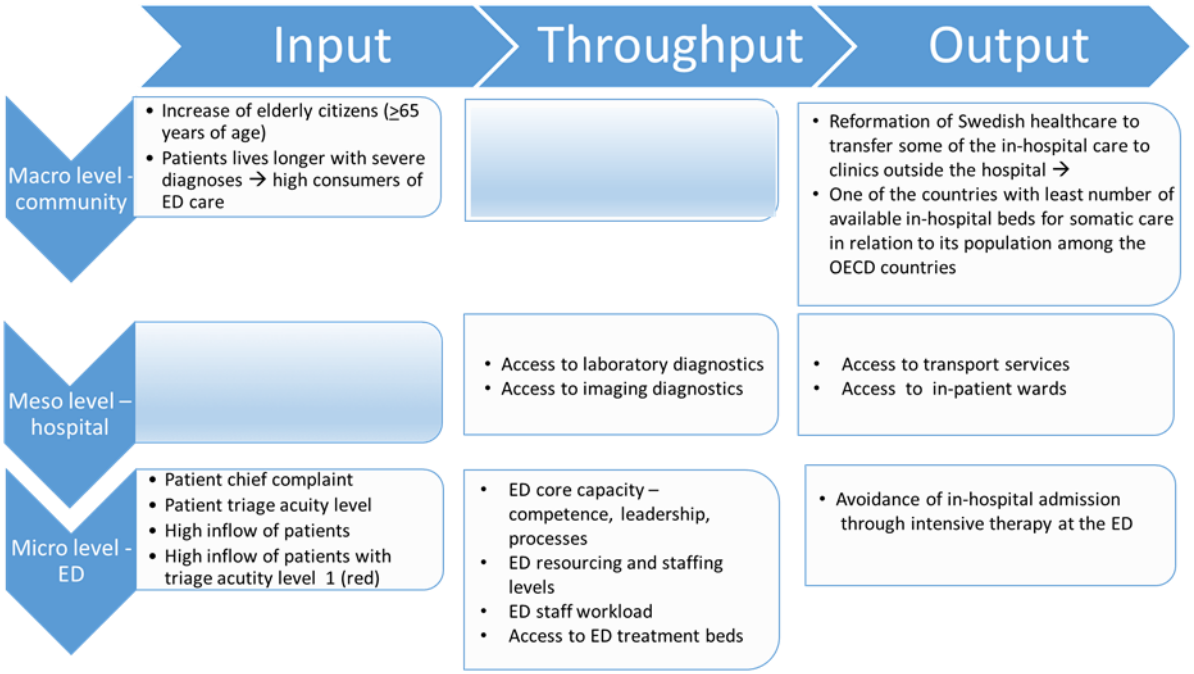

Figure 1. Examples of factors influencing the Swedish ED system based on Asplin's conceptual model of ED crowding.

1.2.3 Multitasking

Several assignments in the ED are undertaken by clinicians simultaneously with other assignments, and managing multiple tasks at the same time is commonly known as multitasking (5, 34, 47, 96-100). In this thesis, "*managing multiple tasks at the same time*" is used as the definition of multitasking (5). Multitasking occurs frequently in the ED (5, 34, 47, 96, 98-100), and ED clinicians need to master this skill to some extent. Polychronicity, i.e. the extent to which people in a culture prefer to be engaged in two or more tasks or events simultaneously and believe their preference is the best way to do things, can be assessed through psychometric measures such as the Inventory of Polychronic Values (101). However, one recent outcome study of multitasking and task errors by ED physicians did not find any effect of polychronicity on error rates (34).

Multitasking implies risks to patient safety in that it creates higher demands on the working memory (47, 102). A systematic review of time and motion studies conducted in 2018 revealed that the proportion of time spent on multitasking ranged from 10% to 23% (46). Another study reported that ED clinicians perceived cognitive demands, such as multitasking, to have the highest impact on the occurrence of errors, together with a poor patient safety climate (49). However, not many studies have been able to establish an association between multitasking and errors, but one study did find an association between multitasking and increased rates of prescribing errors (34). On the other hand, if a clinician chooses to stop an ongoing task when a new assignment is introduced, this is considered an interruption instead of multitasking.

1.2.4 Interruptions

Several synonyms and definitions of the concept of "interruption" have been used in acute care studies. In a review article based on 23 articles studying interruptions in health care, 18 different definitions for "interruption"' were identified (103). Different articles also use different synonyms for the concept of interruption, and some examples are presented in Table 3.

Table 3. Overview of different synonyms for the concept of 'interruption'.

Synonyms for interruption	Reference
Break-in-task	(5, 104, 105)
Disruption	(97, 98, 106-108)
Distraction	(43, 109, 110)
Disturbance	(111, 112)
Glitch	(113)
Self-interruption	(48)
Task switching	(98, 99)
Turn-taking interruption	(114)

Similar to the case for the concept of crowding, the lack of consensus on what defines an interruption in a health care context makes it difficult to compare and generalize results from different studies (103) and hinders a thorough understanding of the phenomenon of interruption (4). Brixey et al. identified a need to develop an accepted theoretical definition of interruption in a health care setting and conducted a concept analysis of the phenomenon of interruption (4). They systematically searched through dictionaries and the research literature from health care, as well as other disciplines such as aviation, human factors, nuclear power plants, management, psychology, and cognitive science, to find meanings of the phenomenon of interruption. Defining attributes, antecedents, and consequences related to interruptions identified in the concept analysis are presented in Table 4.

Finally, a definition of interruption was derived from the literature, which is also the definition used in this thesis:

"*An interruption is a break in the performance of a human activity initiated by a source internal or external to the recipient, with occurrence situated within the context of a setting or a location. This break results in the suspension of the initial task by initiating the performance of an unplanned task with the assumption that the initial task will be resumed*" (4).

A literature search of articles concerning interruptions in a health care setting was conducted by the author of this thesis in 2018 in order to determine if any additional views concerning the concept had been identified since Brixey and colleagues' concept analysis was published (4). Twenty-five additional scientific articles were identified (34, 36, 40-45, 97, 100, 107, 108, 110, 115-126), and all articles contained one or several of the above-mentioned defining attributes of an interruption. Thus, it seems as if the definition of an interruption developed by Brixey and colleagues is still relevant.

Table 4. Defining attributes, antecedents, and consequences of the phenomenon of interruption according to Brixey et al. (4).

	The phenomenon of interruption
Defining attributes	• Objective • Human experience • Intrusion of a secondary, unplanned and unexpected task • Discontinuity • Externally or internally initiated • Situated within a context
Antecedents	1) Intent to interrupt is formed by the initiator 2) Physical signs pass the threshold test of detection by the recipient 3) Sensory system of the recipient is stimulated to respond to the initiator 4) Interruption task is presented to the recipient 5) Interruption task is either accepted or rejected by the recipient
Consequences	• Both negative and positive impact on human task performance • Related to workplace satisfaction expressed by RNs and physicians • Increase in communication tasks for RNs and physicians because of the preference for synchronous communication channels • Psychological effects such as increased annoyance, anxiety, and stress • Some employees, especially managers, expect to be interrupted as part of the job

Interruptions, especially when ED clinicians are multitasking, are of special concern because might have a negative effect on the clinicians' working memory and activity performance, resulting in a risk of forgetting tasks and thus leading to errors (7, 48, 127). Such errors can occur in face-to-face situations and are related to the use of technical devices for communication (e.g., pagers and telephones) (5, 7, 48) or when preparing, administrating or prescribing medications (34, 36). Further, frequent interruptions during triage could lead to a prolonged triage duration and could affect both RNs concentration and patient care (42, 128, 129). Finally, interruptions that referred to parallel cases during patient care were associated with increased stress among ED clinicians (45).

Moreover, ED clinicians are not only being interrupted, but are also initiators of interruptions, most often towards others but also towards themselves (self-interruptions) (7). Senior clinicians and positions that have a central coordinating role at the ED seem to be exposed to interruptions to a higher degree (7, 47, 130).

A literature review of interruptions in EDs was conducted in 2009 (131). The conclusion of the review was that interruptions occurred as a result of communication that could either take place face-to-face or via technical devices (Figure 2). Interruptions were a risk factor for the origin of adverse events and their influence on patient safety. Another risk factor for adverse events was high workload, which also was a trigger for more frequent interruptions.

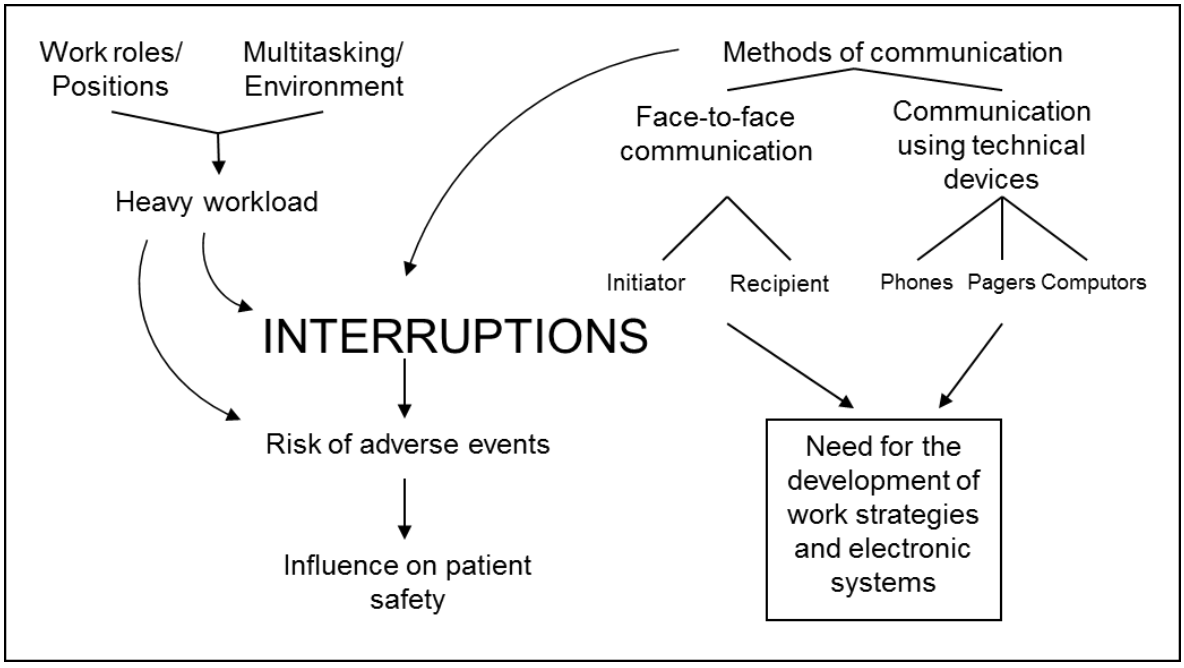

Figure 2. Indications of causes and effects of interruptions in the ED based on a literature review (131).

ED clinicians have been identified as particularly at risk of communication overload (130). Several studies have identified that communication traffic at the ED is higher than necessary, which results in an interruption-driven work environment contributing to inefficiency in work practice (5, 7, 127). Because the communication load in the ED is high, different ways of communication might be considered. Further, organizational, educational, and technological changes are needed to decrease the amount of interruptions and the sources of possible errors (5, 7, 127).

Studies on interruptions in health care have primarily focused on the negative outcomes of interruptions and the negative effects they might have on patient safety (103, 132). However, interruptions might also generate positive effects on patient safety (106, 122, 133). Hence, the need for a more nuanced picture of interruptions has been suggested by the authors of two reviews on interruptions in health care (103, 123). The assumption that interruptions negatively affect patient safety is based on evidence from experiments on cognition conducted in controlled laboratory settings showing that interruptions in mental processes can be linked to errors (134, 135). Further, this evidence from laboratory settings has been extrapolated to health care clinicians' assignments, leading to concerns that interruptions are contributing to errors in patient care without any concluding evidence that there are similarities between a laboratory setting and a clinical situation (132). Instead, three reviews on interruptions in health care concluded that there is a lack of evidence of the extent to which interruptions lead to errors (103, 123, 132). Only a few studies have found a positive association between interruptions and medical errors (34, 36, 136, 137) or adverse effects on clinicians' cognition and memory processes in health care settings (intensive care units and operating rooms) (116, 121, 138). It has also been emphasized that when an interruption creates an error, it is due to a series of events and part of a complex situation (103).

1.3 RATIONALE

The ED is a complex, high-risk work environment consisting of several known patient safety risks such as crowding, multitasking, and interruptions. However not many studies regarding these subjects have been conducted in a Swedish ED setting. Previous studies of ED crowding have focused either on how to define and measure crowding or on causes of, effects of, and solutions for crowding, primarily for the group of critically ill patients and those in need of in-hospital admissions. Further, to my knowledge, no previous studies have described the occurrence of crowding over time or differentiated ED LOS between the different triage acuity levels. Only one study, with a cross-sectional design, has tried to create an overview of the occurrence of crowding in 15 countries, although not from a longitudinal perspective. There is also a knowledge gap concerning the case mix of patients who present to the ED and the influence of ED crowding on patient outcomes for stable patients without the need for acute hospital care upon departure from the ED. Further, with a crowded ED comes high workloads for the ED clinicians, and multiple ED clinicians constantly work in parallel processes while performing tasks (activities) that often involve cognitively demanding decision-making processes. However, there is a lack of knowledge about what specific work assignments the clinicians carry out and hence the type of assignments they are performing while multitasking and being interrupted. Knowledge is also lacking about to what extent multitasking and interruptions occur, and the ED clinicians' perceptions of interruptions. Thus, based on the above-mentioned knowledge gaps regarding ED crowding over time, and its influence on patient outcomes and ED clinicians work assignments, this thesis addresses these perspectives using Asplin's conceptual model of ED crowding.

2 AIMS

The overall aim of the thesis was to describe ED crowding, and its influence on ED clinicians' work processes (activities, multitasking, and interruptions) and patient outcomes, from a patient safety perspective.

The specific research questions were:

- How has ED characteristics, patient case mix and occurrence of ED crowding changed over time? (paper I)
- What work activities are performed by ED clinicians? (paper II)
- What kind of multitasking situations are clinicians exposed to during ED work? (paper II)
- What kind of interruptions are clinicians exposed to during ED work? (paper III)
- How do ED clinicians perceive interruptions? (paper III)
- Is there an association between ED crowding and mortality for stable patients without the need for acute hospital care upon departure from the ED? (paper IV)

Table 5. Overview of the four papers.

Paper	Aim	Design and data collection method	Sample	Analysis method
I	To describe the longitudinal development of crowding and patient and ED characteristics at a Swedish university hospital over an 8-year period.	Descriptive, retrospective, longitudinal Registry data	ED visits with patients ≥18 years of age at a university hospital with EDs at two sites during 2009–2016 (N = 1,063,806)	Chi square test, Wilcoxon Rank Sum test and quantile regression analysis
II	To explore the type and frequency of activities and multitasking performed by ED clinicians (LPNs, RNs, and physicians)	Explorative Observations	18 clinicians (6 physicians, 6 RNs, and 6 LPNs) from two hospital-based EDs, including 9 from a university hospital and 9 from a medium-sized county hospital	Qualitative content analysis
III	To explore interruptions occurring during common activities of clinicians working in EDs	Explorative Observations and interviews	18 clinicians (6 physicians, 6 RNs, and 6 LPNs) from two hospital-based EDs, including 9 from a university hospital and 9 from a medium-sized county hospital	Chi square test and qualitative content analysis
IV	To describe the association between ED crowding and 10-day mortality for patients that were stable (low triage acuity levels) at ED arrival and without the need for acute hospital care upon departure from the ED	Descriptive, retrospective Registry data	ED visits by patients ≥18 years with triage level 3–5 discharged from the ED at a university hospital with EDs at two sites (N = 705,691) 2009–2016	Multivariate logistic regression analyses

3 MATERIAL AND METHODS

3.1 DESIGN

The thesis consists of four studies (papers I-IV). Papers I and IV used quantitative methodologies and had descriptive designs. Papers II and III used qualitative methodologies and had explorative designs. Descriptive and explorative designs were chosen because there was limited knowledge regarding the subjects of interest (139). Figure 3 illustrates the coherence among the papers.

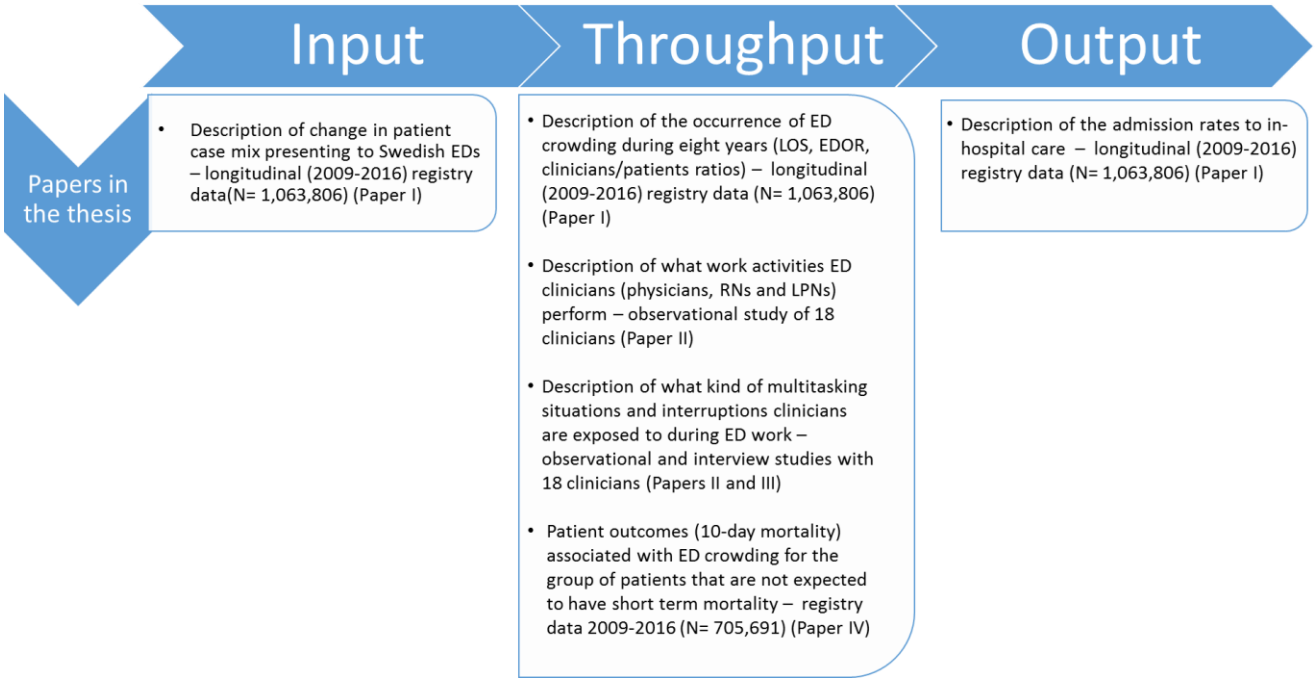

Figure 3. Overview of the four papers in relation to Asplin's conceptual model of ED crowding.

3.2 SETTING

The four studies in the thesis were conducted at two Swedish hospitals, including one university hospital and one county hospital. The university hospital is located on two sites and is one of six acute care hospitals in Stockholm County, which has approximately 2.3 million inhabitants in 2018. Both sites host their own EDs for adults with a range of 52,602 – 68,546 (site 1) and 63,357 – 72,638 (site 2) ED visits per year during the study periods. Until May 1, 2018, both EDs saw patients with internal medicine, surgical, orthopedic, neurological, and infectious conditions. Site 1, which is also a level one trauma center, also sees patients with on-going oncologic treatments and until October 1, 2018, patients with ear-nose-and throat complaints. The ED at the county hospital is one of two hospital-based EDs

in the county of Dalarna, which had approximately 285,724 inhabitants in 2017. The ED had a range about 49,000 – 58,000 ED visits/year during 2008 – 2012 (the period when the studies were conducted). The Rapid Emergency Triage and Treatment System (RETTS) is used at all three EDs (140). RETTS is a five-level triage scale descending from red (1) to blue (5), where red (1) represents the most urgent level, i.e. patients in need of immediate medical attention. Patients with triage acuity levels red (1) and orange (2) are classified as unstable, in contrast to the stable group consisting of levels yellow (3), green (4), and blue (5). During the time periods when the studies were conducted, about 90 clinicians were on duty over a 24-hour period at both EDs. The ED at the university hospital has its own employed physicians. The physicians at the county hospital ED are employed at, and belong organizationally to, other clinics (internal medicine and surgical units) and are, in addition, often responsible for in-hospital patients at wards during their ED rotations. The RNs and LPNs are all employed by the EDs.

Papers I and IV are based on data retrieved from the university hospital's central data warehouse (CDW) that contains patient data from the EDs at both sites. This data warehouse, in turn, retrieves information directly from the patient's electronic health record (EHR). Papers II and III were conducted at site 1 at the university hospital and at the county hospital.

3.3 DATA SETS

The four studies (papers I-IV) are based on two data collections; one extraction from a data source and one data collection with observations and interviews, which generated four data sets.

1. Registry data based on 1,063,806 ED visits (paper I)
2. Observational data of 18 ED clinicians at two Swedish EDs (papers II and III)
3. Observational and interview data from 18 ED clinicians at two Swedish EDs (paper III)
4. Registry data based on 705,691 ED visits (paper IV)

3.4 SAMPLE

3.4.1 Paper I

All ED visits by adults (≥18 years of age) at the university hospital during the period January 1, 2009–December 31, 2016 (N = 1,063,806) were included in the study. Exclusion criteria were patients with gynecological conditions because these sections of the EDs are staffed by their own clinicians and are thus not part of the regular EDs.

3.4.2 Papers II and III

The sample consisted of 18 clinicians divided into three groups (6 physicians, 6 RNs, and 6 LPNs), with 9 from the ED at site 1 at the university hospital and 9 from the ED at the county hospital. These groups of clinicians were selected because they constitute the teams in the different flow and care processes and all have different responsibilities and assignments related to their professions. The participants were recruited using purposeful sampling by two of the researchers working at both EDs. Variations in gender and length of work experience in the ED care were sought for. A minimum of 6 months' work experience in ED care was necessary for being included in the study. The work experience in ED care among the participants varied from 6 months to 30 years.

3.4.3 Paper IV

During the period 2009–2016, a total of 1,063,806 records relating to ED visits of patients ≥18 years of age at the university hospital were extracted (Figure 4). Inclusion criteria were patients triaged as stable (RETTS triage acuity levels 3–5) and without the need for acute hospital care upon departure from the ED (i.e. discharged or referred to geriatric care) (n = 705,813). The reason for including both patients discharged from the ED and those admitted to a geriatric hospital was that neither group is not in need of acute in-hospital care in our hospital setting. Exclusion criteria were patients triaged as unstable (RETTS triage acuity levels 1–2 or missing), admitted to in-hospital care or death before ED discharge (n = 357,993). Finally, after the manual audit explained in the paragraph below, a total of 705,691 ED visits were marked for the analyses, corresponding to 366,665 unique patients (mean of 1.9 visits/patient).

A manual audit of the patients' EHRs was conducted for the complete subset of ED visits relative to patients triaged as stable and without the need for acute hospital care upon departure from the ED and who died within 10 days (n = 737). The audit identified 79 (11%) ED visits that were excluded due to various reasons, mainly patients inaccurately included despite RETTS triage acuity levels 1–2, in-hospital admission, and patients with documentation of expected death within 10 days (terminal stage). The reason for this inaccurate inclusion was due to technical shortcomings in the EHR. Finally, some patients had multiple ED visits during the 10-day period before their date of death. In order to deal with the complexity of multiple visits in relation to death as an outcome measure, all ED visits in this time period were excluded apart from the earliest one in the time-frame of days 1–10 (n = 43). A total of 615 subjects were triaged as stable, were without the need for acute hospital care upon departure from the ED, and died within 10 days. The inclusion and exclusion process is visualized in Figure 4.

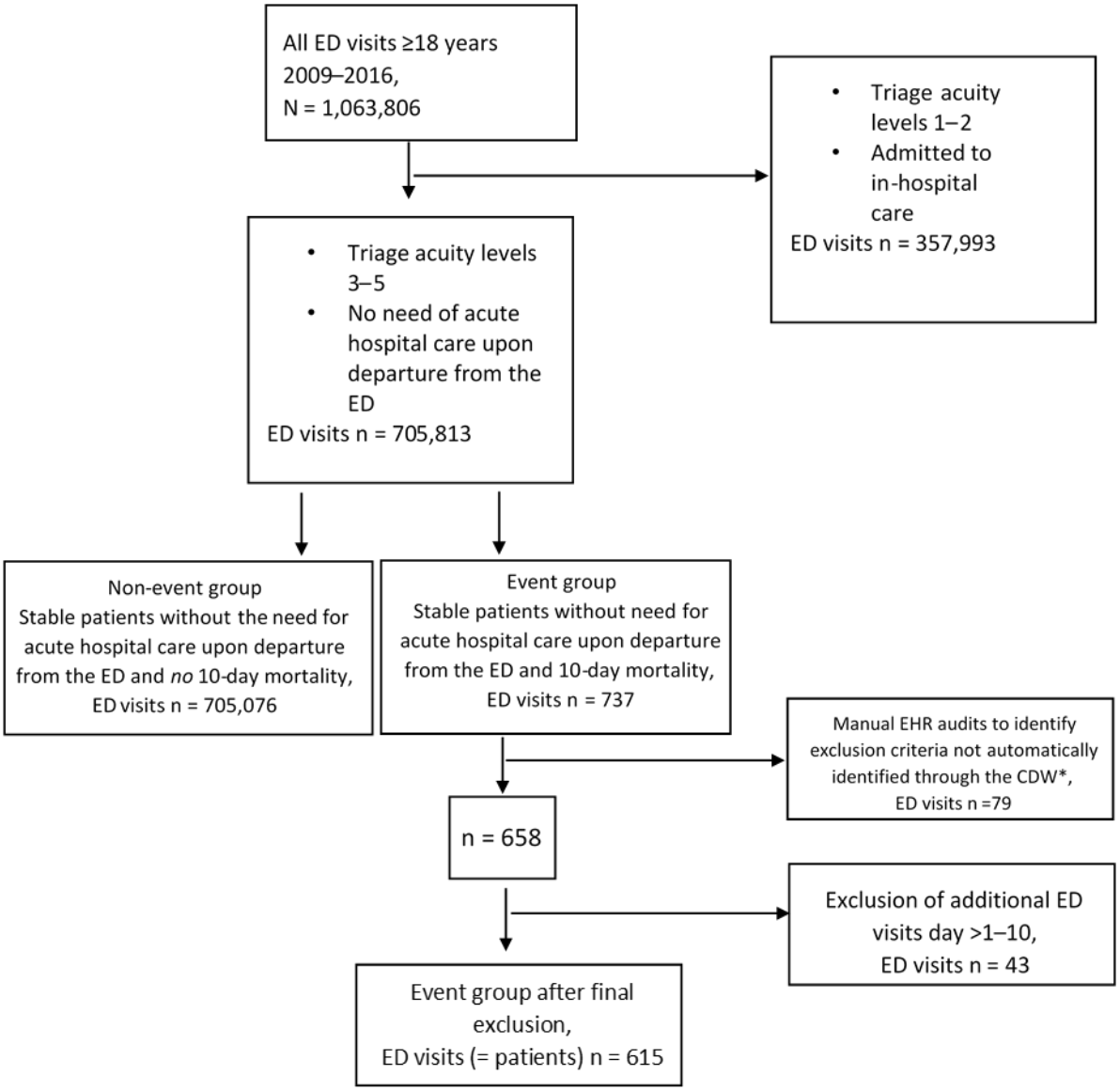

Figure 4. Flow chart describing the process for inclusion and exclusion of patient visits to ED care, 2009–2016.

3.5 DATA

3.5.1 Papers I and IV

All data in papers I and IV were based on registry data. Since 2009, all patient data from the EHR system are downloaded to a hospital CDW every 24 hours. The CDW also imports external information such as date of birth and death, gender, and the personal identity number from the Swedish Population Register every 24 hours. Thus, when the ED establishes an EHR for a patient, the system automatically retrieves information from the Swedish Population Register, and all previous hospital visits will appear. Further, the CDW makes it possible to retrospectively collect all information that can be retrieved from a patient's EHR from all ED visits at the hospital. In papers I and IV, information about EDOR and patients/clinician ratios was extracted in two-hour slots over 8 years, 2009–2016. The decision on two-hour time slots was based on the notion of investigating a shorter time frame than what had been investigated in previous research, one that might make sense in capturing the fluctuations in ratios from a clinical perspective, but at the same time creating a manageable amount of data.

The following variables were retrieved from the EHR through the CDW for each ED visit: the patient´s age, gender, chief complaint, arrival mode (with or without EMS, i.e. ambulance or helicopter), triage acuity level, Age-Combined Charlson's Comorbidity Index (ACCI)(141), ICD 10-codes (paper IV), date and time of arrival/discharge from the ED, admittance to in-hospital care (paper I), date of death, and site (paper IV). Further, the ED crowding variables ED LOS (extracted from the CDW through time stamps for "time of arrival at the ED", which are automatically entered when establishing an EHR and time stamps for "time of discharge from the ED", which are manually entered when the patient leaves the ED), EDOR (extracted from the CDW through automatically entered information about the number of patients present in the ED at a given time slot divided by the number of established treatment beds (a fixed number), which was added manually to the algorithm by the research group), ratios of RNs/physicians per patient (i.e. number of unique caregivers responsible for each patient during a patient ED visit, presented for each profession separately) (paper I) and ratios of patients per RN/physician (i.e. number of patients that each unique clinician is responsible for in a given time slot, extracted from the CDW through unique identity codes for each clinician, manually entered to the EHR, and presented for each profession separately)(papers I and IV) were calculated for each patient visit. A register, including personal numbers for paper IV, was established for this research project.

In paper IV, both ACCI and the number of ED visits within the previous year were used as measures of co-morbidity. ACCI was retrieved from the CDW. The algorithm used ICD-10 codes and age in the patients' EHRs to calculate an ACCI-point for each patient visit. Because the university hospital's two ED sites have catchment areas with varying

socioeconomic groups, we conditioned the regression models on ED site to adjust for socio-economic status.

The two variables related to ratios and ACCI were created by the research group. All variables used in papers I and IV have been validated by the author of the thesis together with a systems scientist at the Department of E-Health and Strategic IT at the university hospital. For example, parts of the extracted data manually entered in the EHR have been compared to actual patient information in the EHR in order to validate the programming codes for extraction. The extraction of data and validation of the variables have been discussed continuously within the research group during the validation process.

3.5.2 Papers II and III

The data in papers II and III were collected through non-participatory semi-structured observations followed by short semi-structured interviews with the clinicians observed. The observations covered day, evening and night shifts, Mondays to Thursdays, and different points in time (from 8:00 am to 03:00 pm), as well as different weekdays to achieve variation of possible working conditions, e.g. workloads. The participants were followed unobtrusively (shadowed) in their work for 2 hours each (36 hours in total) by two researchers concurrently. The researchers worked as a pair during the observations in order to maximize the capture of events of interest in the fast-paced environment. A paper-based semi-structured data collection protocol was used for documenting the observed events on a minute-to-minute basis (see Appendix 1). Because no previous data collection protocol existed that was suitable for the specific purpose of the study, a protocol was developed by the research team based on a previous study within the research field in question (142). The observations had an inductive approach, and no predefined categories were used to describe the participants' assignments, and instead the observers used their own words to describe what they observed.

Almost immediately after the observations, a short (approximately 15 minutes) semi-structured interview was conducted with each clinician. This interview session was done to capture the participants' own perceptions of interruptions during the 2 hours of observation. All interviews were tape-recorded and transcribed verbatim.

3.6 DATA ANALYSIS

All categorical variables were presented as frequencies and percentages (papers I–IV) and continuous data as medians (IQR) due to lack of a normal distribution of the data (paper I). P-values were two-sided and statistical significance was set at $p < .05$ (papers I and IV).

3.6.1 Paper I

Non-parametric analyses were used. Chi-square tests were used to investigate differences in proportions of ED visits for males vs. females and age groups 18–79 years vs. ≥80 years in relation to triage levels. The Wilcoxon Rank Sum test was used when investigating differences in the distribution of ED LOS for the same age and gender groups as well as for triage levels. Quantile regression analysis was used to model the trend in median ED LOS, EDOR, and the patients per RN/physician and physicians/RNs per patient ratios over time. The analyses were based on ED visits and not on unique patients (N = 1,063,806), except for EDOR, which was based on 2-hour time slots (N = 35,064), i.e. 12 slots for each date during the period 2009–2016.

3.6.2 Papers II and III

Qualitative content analysis was used for data analyses in papers II and III (143). The observational and interview data were analyzed inductively (143), and quantitative content analysis (143) was also performed for countable data, such as the amount of multitasking and the number of interruption events. Non-parametric statistics (chi-square analysis) was used in paper III. In this thesis, the analyses have focused on the manifest content (143) and as little interpretation as possible of the text has been aimed for.

3.6.2.1 Observations

The data from the observations at both hospitals were combined and analyzed together. The qualitative analysis was performed in three steps (143). First, the two separate observation protocols generated for each clinician by the two observers were transcribed into one electronic document in which every observed task was registered on a minute-by-minute basis. During this phase, the observed tasks from the two protocols were combined, and if differences in the documented observed tasks occurred, both were noted. Thus, the registered observed tasks in the observation protocols were seen as condensed textual units. Second, the condensed textual units were aggregated through a combination with the location and person involved with the observed task, and this formed a code. In the third and final phase of the analysis, the categories, also referred to as activities, emerged (Table 6).

Table 6. Examples of inductive content analysis of the observations in paper II.

Time **Hour: minute**	**Observed activity/ Condensed textual unit**	**Location and other person involved in observed activity**	**Code**	**Category**
20: 56-57	Answers a question	Nurse's desk/RN	Provides an answer to a request at the nurse's office	*Information exchange*
20: 57-58	Printing labels with patient identity	Nurse's desk	Printing labels with patient identity at nurse's office	*Administration*
20: 58-59	Looking at the patient tracking system	Triage desk	Checks out the patient tracking system in the triage	*Information seeking*
20:59-00	Seeks patient for examination and to obtain medical history	Patients examination room/Patient/ Relative	Performs patient assessment in patient's examination room	*Patient/family-nurse/doctor interaction*

To achieve credibility in every phase of the analysis, four of the researchers independently carried out analyses on sub-sets of the data (139). Discrepancies were discussed until consensus was achieved.

The quantitative analysis was conducted by counting all observed activities, category by category. For paper II, the subject of interest was how these activities were exposed to multitasking situations, and the multitasking that was performed in each activity was counted and calculated as a relative frequency. Finally, frequencies for both activities and multitasking were reported for each group of clinicians (i.e. RNs, LPNs, and physicians) to determine whether differences existed between these groups. In paper III the subject of interest was how the same activities were exposed to interruptions. Thus, frequencies of how often interruptions occurred in each activity were counted, and the locations in the EDs where these interruptions occurred were identified. Further, the type of clinicians involved in the interruption, whether or not an activity was resumed after the interruption, and whether the observed clinician was involved in self-interruptions or was the recipient of an interruption were registered. Non-parametric statistics (Chi-square test) were used to analyze differences in being a recipient of an interruption or causing self-interruptions for each category of clinicians.

3.6.2.2 Interviews

The interview data from both hospitals were also analyzed as one data set using inductive qualitative content analysis (143). Initially, the interviews were read through several times to get a sense of the whole. Next, the text was divided into textual units, which were condensed and coded. The codes consisted of a few words that summarized the core meaning of the textual unit. All codes that dealt with the same content were organized into sub-categories and categories (143). The result was structured into three separate areas – locations in the ED where interruptions occurred, clinicians' need to interrupt someone else, and clinicians' perceptions of interruptions. Examples of the analysis of the third area are shown in Table 7. The data were analyzed primarily by the two first authors of paper III (LMB and ASK). Consensus was reached through repeated discussions in the research group until agreement about the categories was obtained.

Table 7. Examples of inductive content analysis of the interviews in paper III.

Textual unit	Condensation	Sub-category	Category
"I guess it was someone who asked me something."	Occasional questions	Infrequent communicative interruptions	Undisturbed work process
"There are other days when there are significantly more calls on the pager than today, and then it (disturbance) becomes obvious. There are usually many more pagings than there were today."	Many pagings are disturbing	Frequent communicative interruptions	Disturbed work process
"No, normal (amount of interruptions). The phone rings, people ask you questions, but it isn't something I am disturbed by."	Questions and phone calls part of the normal work environment	Expectations of the work environment	Undisturbed work process
"I get disturbed by having to wait for the person who will help me make a decision. Yes, one gets disturbed by waiting."	Disturbed by waiting	Waiting	Disturbed work process

3.6.3 Paper IV

Mortality within 10-days for the group of stable patients without the need for acute hospital care upon departure from the ED was used as the outcome measure. Information about date of death was automatically imported from the Swedish Population Register to the EHR and collected through the CDW for the study.

Multivariable conditional logistic regression models, conditioning on EDs as fixed effects, were used to estimate odds ratios (ORs) and 95% confidence intervals (CIs) in order to analyze the association of ED LOS (<1 hour, 1–<2 hours, etc., until >8 hours), EDOR (quartiles), patients/RN ratio (1–<5, 5–<10, 10–<15, >15), and patients/physician ratio (1–<3, 3 – <6, 6–<9, >9) with 10-day mortality. The four crowding variables were analyzed using separate models. All models used ED visits as the unit of analysis. Clustered robust standard errors were employed to account for the potential correlation in the outcome at the patient level because a single patient could contribute to the analyses with repeated ED visits. Models were adjusted for the following potential confounders: age (18–39, 40–64, 65–79, and >80 years), gender, triage acuity level (3–5), number of ED visits during the previous year (0, 1, 2, ≥3), ACCI, arrival with EMS transport (yes/no), arrival time of day (daytime [7 a.m.–3:59 p.m.], evening [4 p.m.–8:59 p.m.], night [9 p.m.–6:59 a.m.]) and chief complaint (top three/others). Missing values on the potential confounders were treated as separate categories.

3.7 RESEARCH ETHICHS

3.7.1 Papers I and IV

The Regional Ethical Review Board in Stockholm gave their approval to conduct the studies for papers I and IV (Dnr:2016/1164-31), and permissions from the managers of the EDs were obtained. De-identified data were extracted from the CDW, and the code key was kept at the Department of E-Health and Strategic IT. However, for the event group the Swedish personal identity numbers were obtained to facilitate EHR audits. Finally, all data are presented at the group level.

3.7.2 Papers II and III

Approval from the Regional Ethical Review Board in Stockholm was obtained (Dnr: 2009/1413-31/4 and 2012/2237-32), and the managers at both EDs gave their permission before conducting the data collection. Participation in the studies was voluntary, and the participants could decline further participation in the studies at any time without having to justify their decision. Before the interviews, the participants signed a written informed consent. Information to the patients about the observations conducted in 2009 was posted in the waiting rooms of the EDs and in the assessment rooms. Some of the observed activities were patient-related, and in these cases the patients were verbally informed of the reason for the researchers' presence and were asked for their approval. The observers sometimes decided to refrain from following the observed clinician into the assessment rooms in order to protect the patient's integrity.

4 RESULTS

The main results in the thesis are presented based on Asplin's conceptual model of ED crowding, from the aspect of input-throughput-output, and how parts of a sub-optimal throughput influence patient safety (Figure 5).

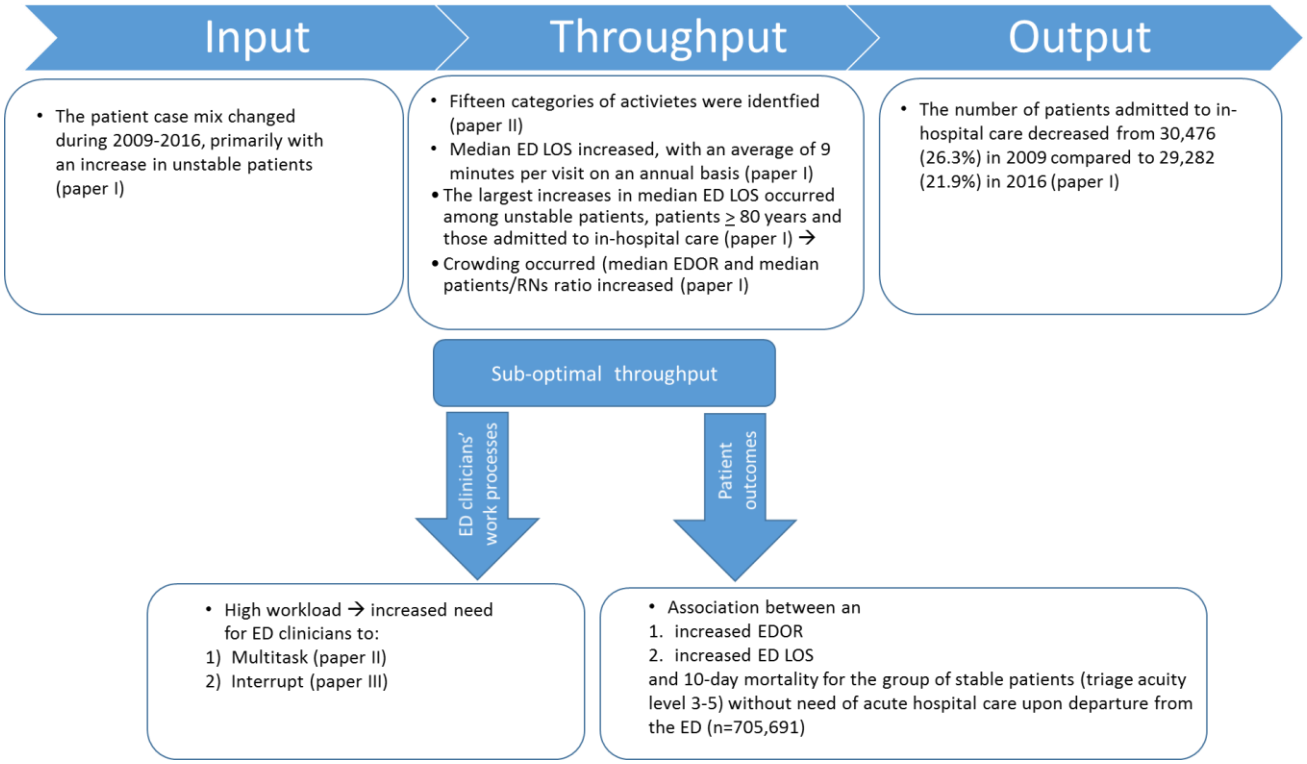

Figure 5. The main results in the thesis in relation to Asplin's conceptual model of ED crowding.

4.1 INPUT AND OUTPUT (PAPER I)

Input and output are components in the ED system that are difficult for the ED itself to influence, and these involve factors such as patient case mix presenting to the ED and access to in-hospital beds, both of which have impacts on the throughput phase.

A total of 1,063,806 eligible ED visits were made to the hospital's ED during 2009 – 2016 (paper I) (Table 8). Most variables were constant over time, however, the number of ED visits in 2009 was 17,377 fewer than in 2016. During the study period, there was a constant increase in patients triaged as unstable in their health condition (triage acuity levels 1–2), and a decrease in those triaged as stable (triage acuity levels 3–5). In 2009, 14.9% of the patients were triaged as unstable compared to 20.2% in 2016 ($p < 0.001$). Further, patients ≥80 years of age were represented more in the triage acuity levels 1–2 compared to patients aged 18–79 (29% vs. 16%, $p < 0.001$). Finally, the proportion of ED visits leading to in-hospital care decreased each year, from 26.3% in 2009 to 21.9% in 2016 ($p < 0.001$).

Table 8. Demographic ED data for the participating EDs at a Swedish university hospital during the study period.

	2009	2010	2011	2012	2013	2014	2015	2016
Number of ED visits (n)	116,080	125,967	136,128	139,085	136,171	140,004	137,184	133,457
Patients' age (years) median (IQR)	51 (34, 68)	51 (34, 68)	51 (34, 68)	51 (34, 68)	51 (34, 68)	50 (34, 69)	51 (34, 69)	50 (33, 68)
Sex female, n (%) [a)]	58,411 (50.3%)	63,912 (50.8%)	69,393 (51.0%)	71,176 (51.2%)	69,499 (51.0%)	71,432 (51.0%)	69,824 (50.9%)	67,332 (50.5%)
Prevalence of top three chief complaints (dyspnea, chest pain and stomach pain), n (%)	24,652 (21.2%)	29,242 (23.3%)	32,220 (23.7%)	33,420 (24.0%)	32,849 (24.1%)	34,597 (24.7%)	33,615 (24.5%)	32,404 (24.3%)
Arrival with EMS [d)] transport, n (%)	24,236 (20.9%)	26,491 (21.1%)	29,241 (21.5%)	30,391 (21.9%)	30,598 (22.5%)	30,844 (22.0%)	30,797 (22.4%)	27,904 (20.9%)
Triage acuity level [b) c)], n (%)								
1 (red)	5,549 (4.8%)	5,574 (4.4%)	6,047 (4.4%)	7,188 (5.2%)	7,733 (5.7%)	8,088 (5.8%)	7,298 (5.8%)	7,768 (5.7%)
2 (orange)	11,750 (10.1%)	14,089 (11.2%)	15,665 (11.5%)	16,897 (12.1%)	16,293 (12.0%)	17,641 (12.6%)	18,506 (13.5%)	19,245 (14.4%)
3 (yellow)	29,323 (25.3%)	34,825 (27.7%)	37,658 (27.7%)	44,964 (32.3%)	47,530 (34.9%)	52,774 (37.7%)	55,532 (40.5%)	55,392 (41.5%)
4 (green)	41,999 (36.2%)	45,248 (36.0%)	51,425 (37.8%)	46,711 (33.6%)	41,545 (30.5%)	40,192 (28.7%)	35,054 (25.6%)	28,001 (21.0%)
5 (blue)	25,487 (22.0%)	24,235 (19.3%)	23,502 (17.3%)	21,002 (15.1%)	20,897 (15.3%)	18,851 (13.5%)	17,328 (12.6%)	19,939 (14.9%)
ACCI [e)] -point median (IQR)	0 (0,3)	0 (0,3)	0 (0,3)	0 (0,3)	0 (0,3)	0 (0,3)	0 (0,3)	0 (0,3)
Time of arrival, n (%)								
Day (7 a.m. – 3:59 p.m.)	67,744 (58.4%)	72,443 (57.6%)	77,774 (57.1%)	79,245 (57.0%)	77,652 (57.0%)	79,522 (56.8%)	77,207 (56.3%)	75,276 (56.4%)
Evening (4 p.m. – 8:59 p.m.)	27,732 (23.9%)	29,629 (23.6%)	32,179 (23.6%)	32,971 (23.7%)	31,953 (23.5%)	33,179 (23.7%)	32,880 (24.0%)	31,946 (23.9%)
Night (9 p.m. – 6:59 a.m.)	20,604 (17.7%)	23,625 (18.8%)	26,175 (19.2%)	26,869 (19.3%)	26,566 (19.5%)	27,303 (19.5%)	27,097 (19.8%)	26,235 (19.7%)
Admitted to in-hospital care, n (%)	30,476 (26.25%)	33,784 (26.88%)	35,426 (26.02%)	35,102 (25.24%)	32,963 (24.21%)	33,677 (24.05%)	32,006 (23.33%)	29,282 (21.94%)

a) 3,733 missing during the entire study period
b) Based on the five-level triage scale RETTS© where triage level '1 (red)' represents the most urgent level, i.e. in need of immediate medical attention
c) 18,531 missing during the entire study period
d) Emergency Medical Services, i.e. ambulance or helicopter staffed by paramedics
e) Age-Adjusted Charlson Co-Morbidity Index, points on a scale from 0–34

4.2 THROUGHPUT (PAPERS I-IV)

In this section, events that occur during the throughput phase will be described. For example, the occurrence of ED crowding, the constitution of the ED clinicians' work processes, and how a sub-optimal throughput might influence patient safety.

4.2.1 The occurrence of ED crowding (paper I)

During the study period, the median ED LOS increased by an average of 9 minutes per visit on an annual basis (95% CI: 8.8–9.1, p <0.001) (Figure 6). The median LOS for all ED visits increased by 59 minutes from 2009 to 2016 (175 min vs. 234 min). Also, there was an increased median ED LOS for patients ≥80 years compared to the age group 18–79 years (248 min vs. 190 min, p <0.001).

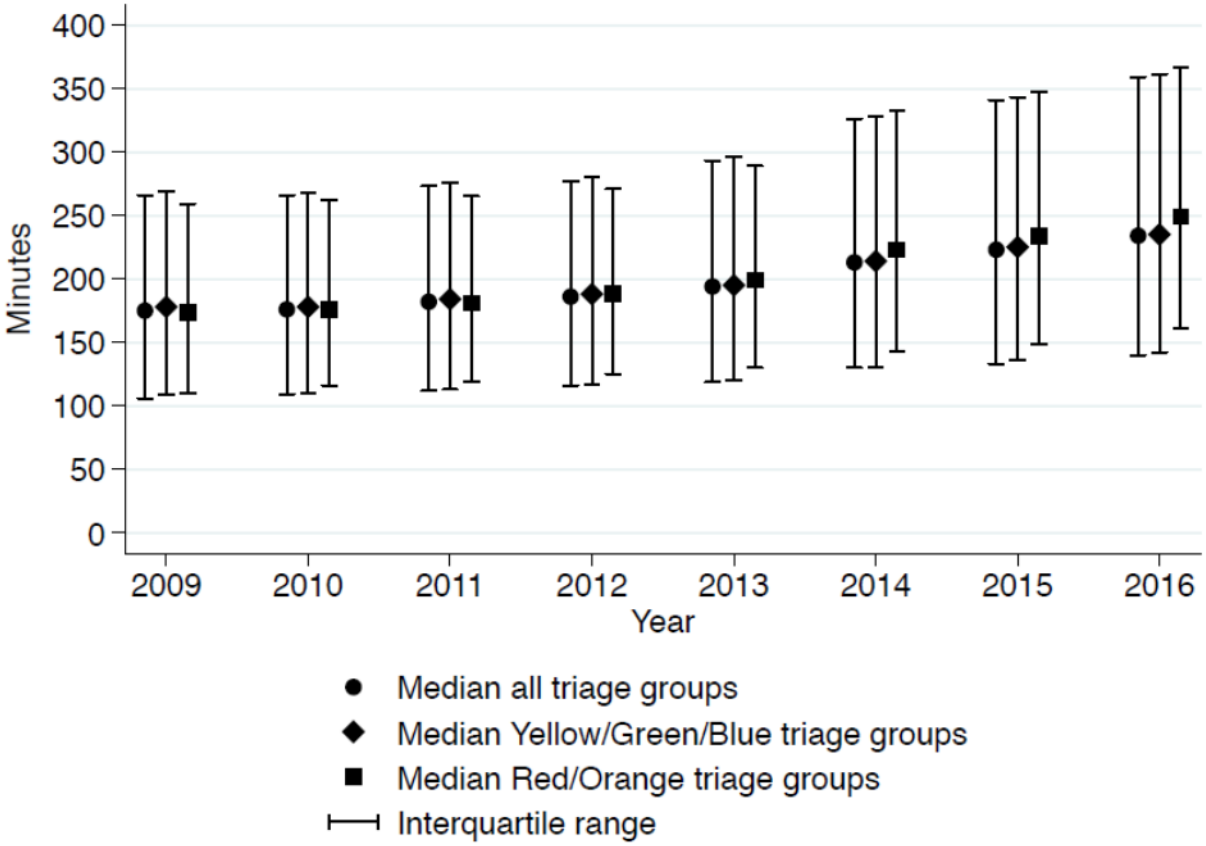

Figure 6. Median ED LOS in minutes grouped as unstable (triage acuity level 1-2 red/orange) and stable (triage acuity level 3-5 yellow/green/blue) patients.

Further, there was a trend of an average increase of 11.6 minutes/year (95% CI: 11.2–11.9, p <0.001) in median ED LOS for the group of unstable patients over the study period compared to the group of stable patients, which increased by an average of 8.7 minutes/year (95% CI: 8.5–8.8, p <0.001) (Figure 6). The largest increase was identified for patients triaged in the second most urgent triage acuity level (level 2), with an average increase in median ED LOS by 11.8 minutes/year (95% CI: 9.4–10.6, p <0.001). The smallest average increase median ED LOS, 1.5 minutes/year (95% CI: 1.2–1.8, p <0.001), was identified for patients triaged as level 5, i.e. the least urgent triage acuity level. Furthermore, patients with triage level 5 had a median ED LOS of 124 minutes compared to 159 minutes for triage level 1.

The median ED LOS for the group of admitted patients was 95 minutes longer in 2016 than in 2009 compared to the median ED LOS for the for the group of patients that were discharged, which was 54 minutes longer (Figure 7).

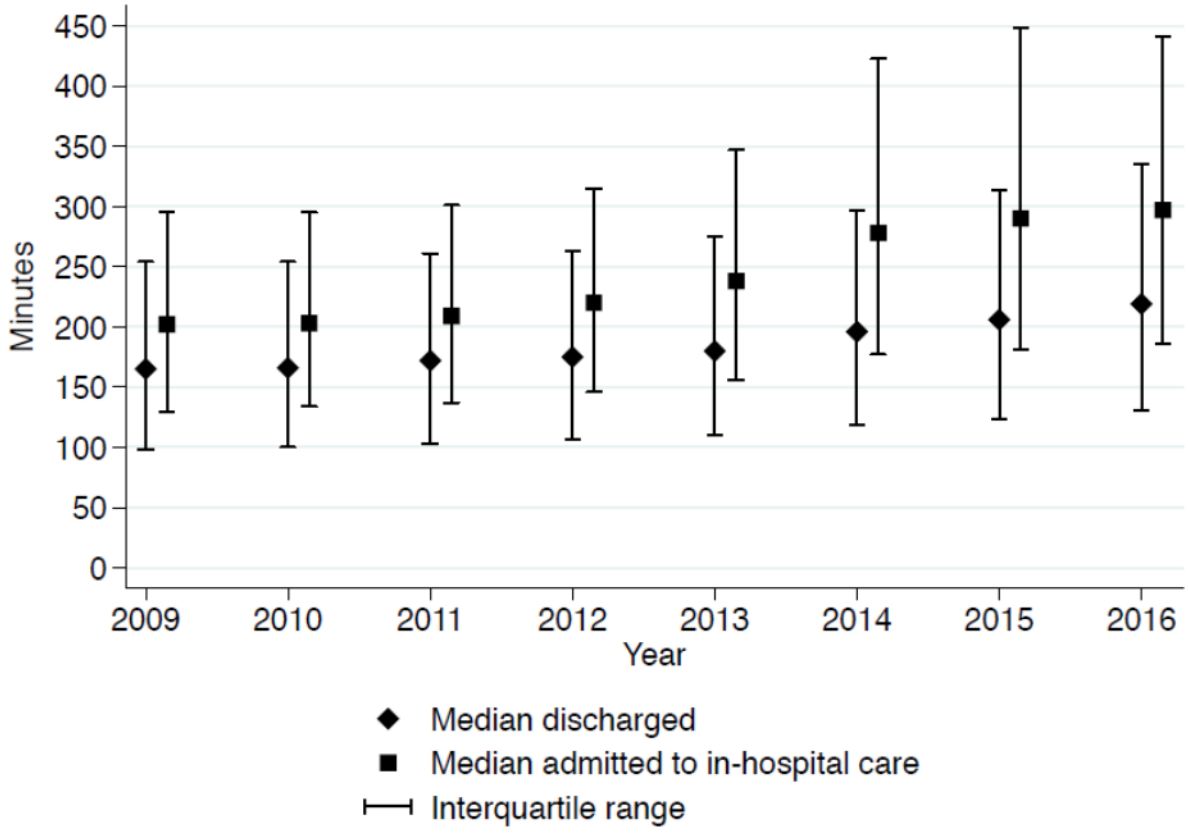

Figure 7. Median ED LOS in minutes grouped as patients discharged from the ED and patients admitted to in-hospital care.

Thus, when testing for trends in median ED LOS over the study period for the two subgroups of those discharged or admitted to in-hospital care, an average increase of 7.7 minutes/year (95% CI: 7.5–7.9, p <0.001) for the patients discharged from the ED was found. This was compared to the group of patients admitted, which increased their median ED LOS by an average of 15.5 minutes/year (95% CI: 15.2–15.8, p <0.001).

The median and the 25th and 75th percentiles for three of the four crowding ratios were stable over the study period. Only the median patients per RN ratio increased, with an average increase of 0.164 patients/RN/year (95% CI 0.162–0.167; p <0.001) (Figure 8). Furthermore, the median (50th percentile) for EDOR during the study period increased from 0.8 in 2009 to 1.1 in 2016, which was an increase of 0.04/year (95% CI 0.040–0.047; p <0.001).

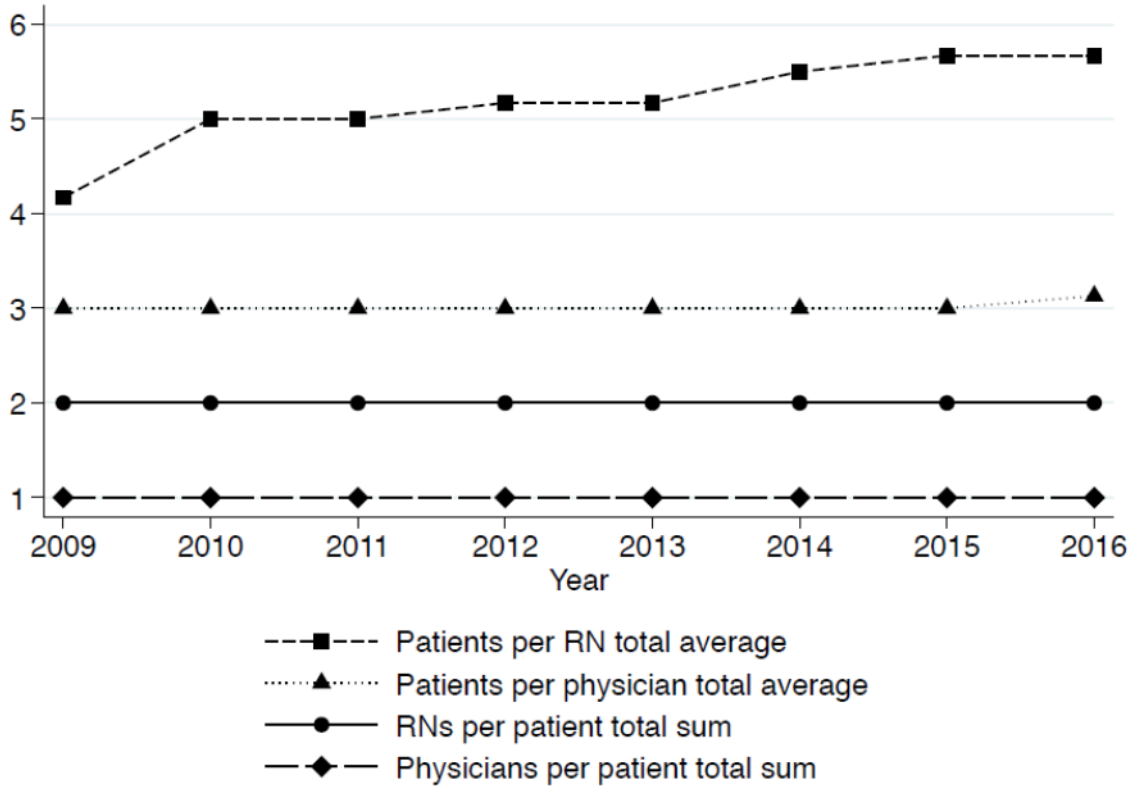

Figure 8. Crowding ratios in ED visits from 2009–2016, reported as medians.

4.2.2 ED clinicians' work processes (papers II and III)

During the throughput phase, the ED clinicians conducted several different activities. From 1,882 observed activities, 15 categories could be identified (paper II). All three groups of clinicians performed similar kinds of activities with a few exceptions, but the content and focus differed (Table 9).

Table 9. Activities (n = 1,882) carried out by ED clinicians (n = 18) presented in descending order in relation to the total number of activities.

Categories of activities	Physician n (%)	RN n (%)	LPN n (%)	Total n (%)
Information exchange	239 (46.2)	326 (43.1)	228 (37.4)	793 (42.1)
Information seeking	81 (15.6)	120 (15.9)	42 (6.9)	243 (12.9)
Patient/family – nurse/doctor interaction	39 (7.5)	62 (8.2)	75 (12.3)	176 (9.4)
Administration	36 (7.0)	64 (8.5)	33 (5.4)	133 (7.1)
Documentation	41 (8.0)	43 (5.7)	35 (5.7)	119 (6.3)
Transportation	20 (3.9)	30 (4.0)	67 (11.0)	117 (6.2)
Break	18 (3.5)	41 (5.4)	45 (7.4)	104 (5.5)
Maintenance	1 (0.2)	21 (2.8)	47 (7.7)	69 (3.7)
Patient data analysis	26 (5.0)	18 (2.4)	13 (2.1)	57 (3.0)
Preparation of medical-technical tasks	0 (0.0)	5 (0.7)	16 (2.6)	21 (1.1)
Organizational planning	14 (2.7)	3 (0.4)	3 (0.5)	20 (1.1)
Surveillance	1 (0.2)	9 (1.2)	0 (0.0)	10 (0.5)
Miscellaneous	1 (0.2)	5 (0.7)	4 (0.7)	10 (0.5)
Preparation of medication	0 (0.0)	7 (0.9)	0 (0.0)	7 (0.4)
Assistance	0 (0.0)	1 (0.1)	2 (0.3)	3 (0.2)
Total	517 (100)	755 (100)	610 (100)	1,882 (100)

RN: registered nurse, LPN: licensed practical nurse

RNs were the only group of clinicians that performed activities in all 15 categories. *Information exchange* (asking for or giving information through interaction with another clinician) was the most common category of activity, and this represented 42.1% of all activities. *Information exchange* most often involved face-to-face encounters. The activity *patient/family–nurse/doctor interaction* (e.g., communicating with a patient/next of kin, examining a patient, bedside nursing, administrating medication) only totaled to 9.4% of the observations.

The whole group of clinicians multitasked during 23% of their total number of performed activities. Among the three groups of clinicians, RNs most often multitasked their activities: 28% for RNs vs. 23% for physicians and 16% for LPNs. The two most commonly conducted activities, *information exchange* and *information seeking*, were the two activities most often exposed to multitasking, representing 61% of all multitasking situations.

Of the 1,882 activities observed, 184 (10%) were interrupted, which yielded a mean rate of 5.1 interruptions per hour. Interruptions were observed during 12 of the previously identified 15 categories of activities (Table 10). Most commonly, interruptions were observed during *information exchange* (20%), but the activity most exposed to interruptions in relative terms was *preparation of medication* (29%).

Table 10. Frequency of interruptions in 12 categories of activities as presented by groups of ED clinicians (n = 18) in relation to the total number of interruptions.

	Frequency of interruptions for each category of activity		**Frequency of interruptions for the three groups of clinicians**			
Categories of activities	**Frequency of observed activities n**	**Frequency of interruptions per each category of activity n (%)**	**Physicians n (%)**	**RNs n (%)**	**LPNs n (%)**	**Total n (%)**
Preparation of medication	7	2 (28.6)	0 (0.0)	2 (4.0)	0 (0.0)	2 (1.1)
Documentation	119	32 (26.9)	24 (32.9)	4 (8.0)	4 (6.6)	32 (17.4)
Patient/family – nurse/doctor interaction	176	34 (19.3)	10 (13.7)	5 (10.0)	19 (31.1)	34 (18.5)
Preparation of medical-technical tasks	21	4 (19.0)	0 (0.0)	3 (6.0)	1 (1.6)	4 (2.2)
Administration	133	21 (15.8)	4 (5.5)	8 (16.0)	9 (14.8)	21 (11.4)
Patient data analysis	57	8 (14.0)	2 (2.7)	1 (2.0)	5 (8.2)	8 (4.3)
Transportation	117	12 (10.3)	4 (5.5)	3 (6.0)	5 (8.2)	12 (6.5)
Organizational planning	20	2 (10.0)	1 (1.4)	0 (0.0)	1 (1.6)	2 (1.1)
Information seeking	243	23 (9.5)	10 (13.7)	9 (18.0)	4 (6.6)	23 (12.5)
Maintenance	69	5 (7.2)	0 (0.0)	1 (2.0)	4 (6.6)	5 (2.7)
Information exchange	793	37 (4.7)	14 (19.2)	14 (28.0)	9 (14.8)	37 (20.1)
Break	104	4 (3.8)	4 (5.5)	0 (0.0)	0 (0.0)	4 (2.2)
Total	1882	184 (100)	73 (100)	50 (100)	61 (100)	184 (100)

RN: registered nurse, LPN: licensed practical nurse

There were 73 interruptions identified for physicians, 50 for RNs, and 61 for LPNs. Collectively, the clinicians were more often recipients of interruptions (63%) than causing self-interruptions (37%) ($p<0.001$). The most common way to be interrupted was by face-to-face interaction with another clinician (51%). Most interrupted activities, 161 (87.5%), were resumed shortly after the interruption.

In the interviews, some respondents used the terms interruption and disturbance (and variations of these terms such as interrupted, disturbed, and disturbing) as representations of the same concept, whereas others distinguished between interruptions and disturbances. Further, regardless of the terms used (interruption or disturbance), data from the interviews revealed that interruptions were not always perceived as a negative event, i.e. some interruptions were actually expected and seen as normal events during ED work.

The respondents' perceptions of interruptions were categorized as either an *undisturbed work process* or a *disturbed work process* (Figure 9).

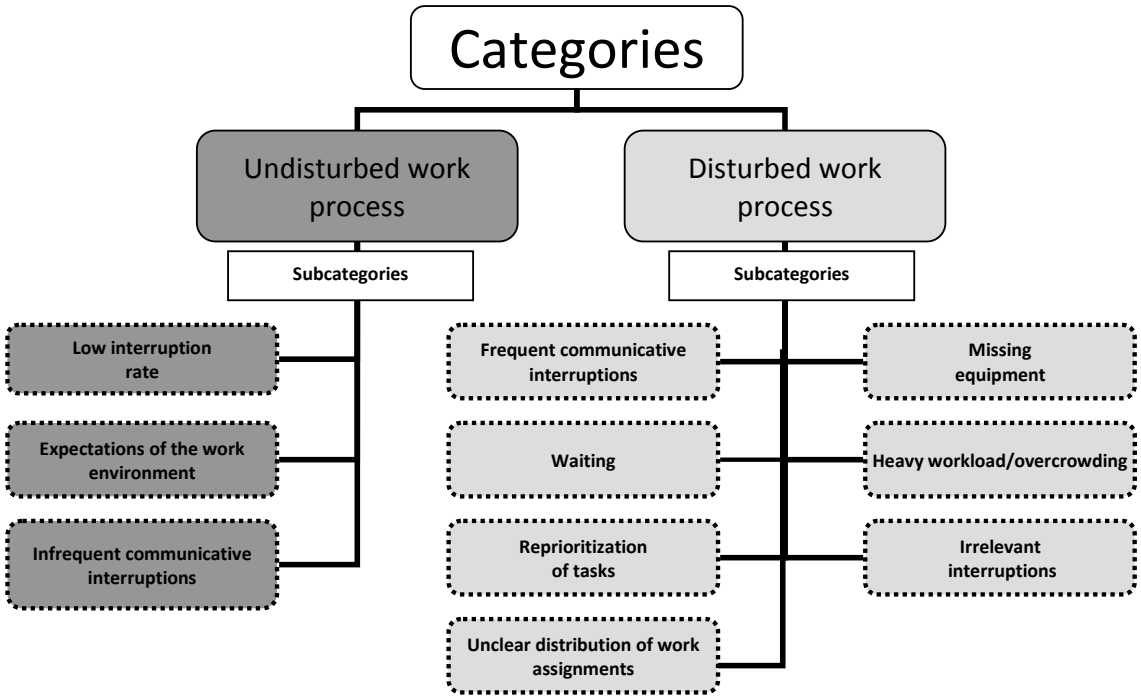

Figure 9. The ED clinicians' perceptions of interruptions identified during the interviews in paper III.

The most common reasons for respondents not to perceive an interruption as a negative event (*undisturbed work process*) were related to their own expectations of the work environment or to whether the rate of interruption was perceived as low. The respondents' perceptions in the subcategory *expectations of the work environment* often consisted of thoughts about being interrupted as a natural part of their professional role. An example was: "That's the job at the ED; it is always decisions and you are always interrupted… something happens in between" (10: senior physician). Another perception in the subcategory *expectations of the work environment* was that interruptions were commonplace events. An example was: "It's so commonplace; this is happening every day, so I don't think of it as an interruption" (2: senior LPN). If the interruption occurred with low frequency (*low interruption rate*), it was not considered a negative event for the ongoing work.

The primary reason for perceiving an interruption as a negative event (*disturbed work process*) was respondents' exposure to *frequent communicative interruptions*, mostly by colleagues, pagers, or phones. An example was: "There are days when there are significantly more calls on the pager than today, and then it (the disturbance) becomes obvious. There are usually many more pagings than there were today" (1: senior physician). Another reason for perceiving an interruption as a negative event was if the interruption was perceived as *irrelevant*. "When you get disturbed by what I think is an irrelevant interruption, it is often from wards. Pagings of a non-urgent character that can wait" (7: junior physician). Having to *wait* for someone else to get on with the tasks at hand was a further reason for the interruption to be perceived to cause a disturbed work process. "I get disturbed by having to wait for the person who will help me make a decision. Yes, one gets disturbed by waiting" (16: junior physician). Furthermore, *missing equipment* was another reason for being negatively influenced by an interruption because this made the respondent to feel disturbed in the work process "The boxes I brought in when we were inserting the catheter had not been properly filled, so then I had to go out and get more equipment. It is disturbing because you have to interrupt what you are doing in there" (14: junior LPN).

4.2.3 Association between ED crowding and 10-day mortality (paper IV)

The entire sample in paper IV consisted of 705,691 ED visits over 8 years (Table 11). The gender distribution was similar within the group of stable patients without the need for acute hospital care upon departure from the ED with 10-day mortality (event group) and the group with no 10-day mortality (non-event group). However, the event group had larger proportions of patients aged ≥80 years (51.4% vs. 7.7%), triaged with higher (i.e. yellow) acuity level (63.3% vs. 35.6%), and arriving with EMS transport (59.7% vs. 11.0%). Finally, the ACCI median IQR was higher for the patients in the event group compared to those in the non-event group (6 vs. 0), indicating that the patients in the event group had higher co-morbidity, for example, cancer and cardiovascular diseases.

Table 11. Characteristics and 10-day mortality of patients triaged as stable on admission to ED care during 2009 – 2016 (ED visits n = 705,691).

	Stable patients without the need for acute hospital care upon departure from the ED and without 10-day mortality	Stable patients without the need for acute hospital care upon departure from the ED with 10-day mortality	Total
Number of ED visits (n)	705,076	615	705,691
Patients' age, n (%)			
18-39	279,234 (39.6)	15 (2.4)	279,249 (39.6)
40-64	261,279 (37.1)	100 (16.3)	261,379 (37.0)
65-79	110,252 (15.6)	184 (29.9)	110,436 (15.6)
80+	54,311 (7.7)	316 (51.4)	54,627 (7.7)
Sex, n (%)			
Female	365,880 (51.9)	299 (48.6)	366,179 (51.9)
Male	336,421 (47.7)	316 (51.4)	336,737 (47.7)
Missing	2,775 (0.4)	0 (0.0)	2,775 (0.4)
Triage acuity level, n (%) [a)]			
3 (yellow)	251,242 (35.6)	389 (63.3)	251,631 (35.7)
4 (green)	288,452 (40.9)	172 (28.0)	288,624 (40.9)
5 (blue)	165,382 (23.5)	54 (8.8)	165,436 (23.4)
Number of ED visits in the previous 365 days, n (%)			
0	472,621 (67.0)	379 (61.6)	473,000 (67.0)
1	133,963 (19.0)	121 (19.7)	134,084 (19.0)
2	47,854 (6.8)	64 (10.4)	47,918 (6.8)
3+	50,638 (7.2)	51 (8.3)	50,689 (7.2)
ACCI [b)] -point median (IQR)	0 (0-1)	6 (4-8)	0 (0-1)
Arrival with EMS [c)] transport, n (%)			
Yes	77,554 (11.0)	367 (59.7)	77,921 (11.0)
No	627,522 (89.0)	248 (40.3)	627,770 (89.0)
Time of arrival, n (%)			
Day (7 a.m. - 3:59 p.m.)	419,371 (59.5)	389 (63.3)	419,760 (59.5)
Evening (4 p.m. – 8:59 p.m.)	160,156 (22.7)	137 (22.3)	160,293 (22.7)
Night (9 p.m. - 6:59 a.m.)	125,549 (17.8)	89 (14.5)	125,638 (17.8)
Chief complaint, n (%)			
Top three (dyspnea, chest pain or stomach pain)	144,765 (20.5)	131 (21.3)	144,896 (20.5)
Others	509,910 (72.3)	417 (67.8)	510,327 (72.3)
Missing	50,401 (7.1)	67 (10.9)	50,468 (7.2)

a) Based on the five-level triage scale RETTS© where triage level '1 (red)' represents the most urgent level, i.e. in need of immediate medical attention
b) Age-Adjusted Charlson Co-Morbidity Index, points on a scale from 0–3
c) Emergency Medical Services, i.e. ambulance or helicopter staffed by paramedics

The proportions of patients with ED LOS >4 hours and with EDOR in the second, third, or fourth quartile were higher in the event group than in the non-event group ($p<0.0001$ and $p = 0.0003$ respectively) (Table 12).

Table 12. Crowding measures and 10-day mortality for patients (n = 705,691) admitted to ED care during 2009 – 2016.

	Stable patients without the need for acute hospital care upon departure from the ED and without 10-day mortality	Stable patients without the need for acute hospital care upon departure from the ED with 10-day mortality	Total	Un-adjusted Odds ratio (OR)	95% Confidence Interval	Overall p-value for each crowding measure
ED LOS (hours)%						p<0.0001
<1	68,091 (9.7)	12 (2.0)	68,103 (9.7)	1.00		
1 – <2	127,560 (18.1)	41 (6.7)	127,601 (18.1)	1.82	0.96 – 3.47	
2 – <3	145,976 (20.7)	86 (14.0)	146,062 (20.7)	3.34	1.83 – 6.12	
3 – <4	121,427 (17.2)	82 (13.3)	121,509 (17.2)	3.83	2.09 – 7.02	
4 – <5	88,343 (12.5)	101 (16.4)	88,444 (12.5)	6.49	3.57 –11.80	
5 – <6	58,736 (8.3)	71 (11.5)	58,807 (8.3)	6.86	3.72 –12.65	
6 – <7	37,507 (5.3)	67 (10.9)	37,574 (5.3)	10.14	5.48 –18.74	
7 – <8	22,936 (3.3)	53 (8.6)	22,989 (3.3)	13.11	7.01 –24.54	
8+	34,222 (4.9)	102 (16.6)	34,324 (4.9)	16.91	9.30 –30.76	
Missing	278 (0.0)	0 (0.0)	278 (0.0)			
Mean EDOR during ED visit, n (%)						p = 0.0003
1st quartile (0.04 – 0.94)	176,331 (25.0)	109 (17.7)	176,440 (25.0)	1.00		
2nd quartile (0.94 – 1.25)	179,216 (25.4)	160 (26.0)	179,376 (25.4)	1.44	1.13 – 1.84	
3rd quartile (1.25 – 1.54)	175,192 (24.8)	181 (29.4)	175,373 (24.9)	1.67	1.32 – 2.12	
4th quartile (1.54 – 3.11)	174,061 (24.7)	165 (26.8)	174,226 (24.7)	1.53	1.20 – 1.95	
Missing	276 (0.0)	0 (0.0)	276 (0.0)			
Patients/RN ratios, n (%)						p<0.0001
1 – <5	280,959 (39.8)	286 (46.5)	281,245 (39.9)	1.00		
5 – <10	355,382 (50.4)	303 (49.3)	355,685 (50.4)	0.84	0.71 – 0.98	
10 – <15	57,602 (8.2)	23 (3.7)	57,625 (8.2)	0.39	0.26 – 0.60	
15+	7,609 (1.1)	2 (0.3)	7,611 (1.1)	0.26	0.06 – 1.04	
Missing	3,524 (0.5)	1 (0.2)	3,525 (0.5)			
Patients/physician ratios, n (%)						p = 0.012
1 – <3	222,419 (31.5)	216 (35.1)	222,635 (31.5)	1.00		
3 – <6	357,649 (50.7)	308 (50.1)	357,957 (50.7)	0.89	0.75 – 1.06	
6 – <9	53,482 (7.6)	29 (4.7)	53,511 (7.6)	0.56	0.38 – 0.82	
9+	4,549 (0.6)	1 (0.2)	4,550 (0.6)	0.23	0.03 – 1.61	
Missing	66,977 (9.5)	61 (9.9)	67,038 (9.5)			

The multivariable adjusted logistic regression showed that there was an association between the increase in both ED LOS and EDOR and 10-day mortality after adjusting for potential confounders (Table 13 and Figures 10 and 11). In other words, patients triaged as stable when arriving at the ED and without the need for acute hospital care upon departure from the ED had a higher risk of 10-day mortality when the ED LOS and EDOR increased. In contrast, there was no significant association between patients/RN ratios or patients/physician ratios and 10-day mortality (Table 13).

Table 13. Adjusted odds ratios (95% CI) for 10-day mortality within the group of stable patients (RETTS triage acuity levels 3 – 5) without the need for acute hospital care upon departure from the ED (n = 705,691).

Independent variables	Adjusted Odds ratio (OR) *	95% Confidence Interval	Overall p-value for each crowding measure
ED LOS (hours)			p<0.0001
<1	1.00 (reference)		
1 – <2	1.33	0.69 – 2.57	
2 – <3	1.85	0.99 – 3.46	
3 – <4	1.69	0.90 – 3.19	
4 – <5	2.30	1.23 – 4.31	
5 – <6	2.05	1.07 – 3.90	
6 – <7	2.67	1.40 – 5.09	
7 – <8	2.99	1.55 – 5.77	
8+	3.10	1.64 – 5.86	
EDOR (n)			p = 0.010
1st quartile (0.04 –0.94)	1.00 (reference)		
2nd quartile (0.94 – 1.25)	1.43	1.10 – 1.87	
3rd quartile (1.25 – 1.54)	1.59	1.21 – 2.10	
4th quartile (1.54 – 3.11)	1.48	1.11 – 1.98	
Patients/RNs ratio (n)			p = 0.440
1 – <5	1.00 (reference)		
5 – <10	0.94	0.79 – 1.11	
10 – <15	0.72	0.46 – 1.11	
15+	0.63	0.15 – 2.55	
Patients/physicians ratio (n)			p = 0.245
1 – <3	1.00 (reference)		
3 – <6	0.93	0.78 – 1.11	
6 – <9	0.70	0.47 – 1.05	
9+	0.32	0.05 – 2.31	

* Odds ratios were adjusted for age, gender, triage acuity level, number of ED visits during the previous year, ACCI, arrival with EMS transport, arrival time of day, chief complaint and ED site.

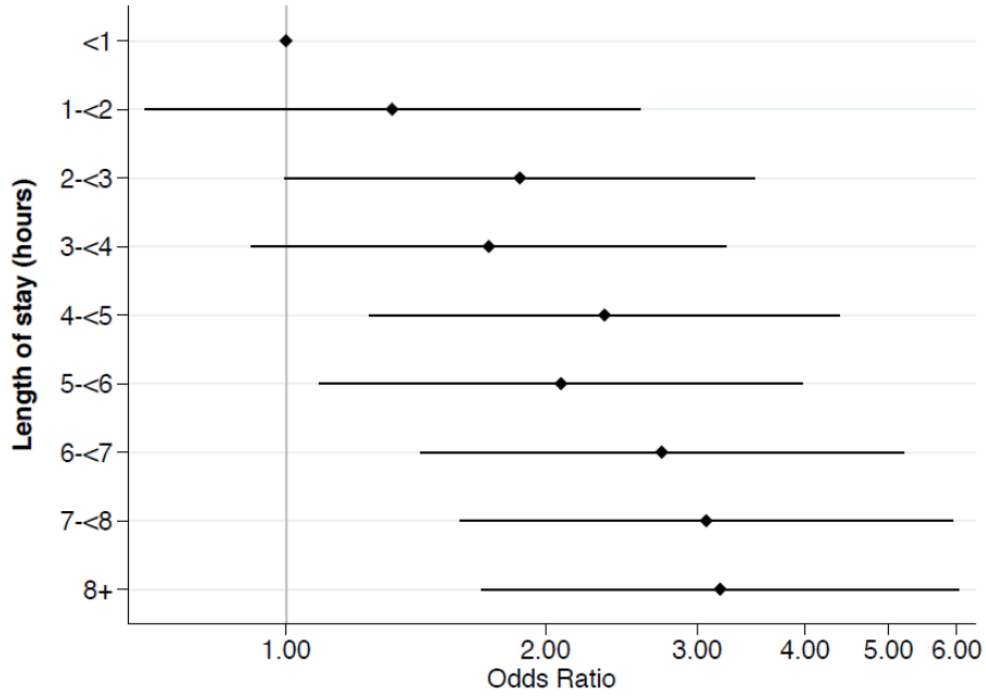

Figure 10. Adjusted odds ratio (95% CI) for 10-day mortality within the group of stable patients without the need for acute hospital care upon departure from the ED (n = 705,691) in relation to ED LOS.

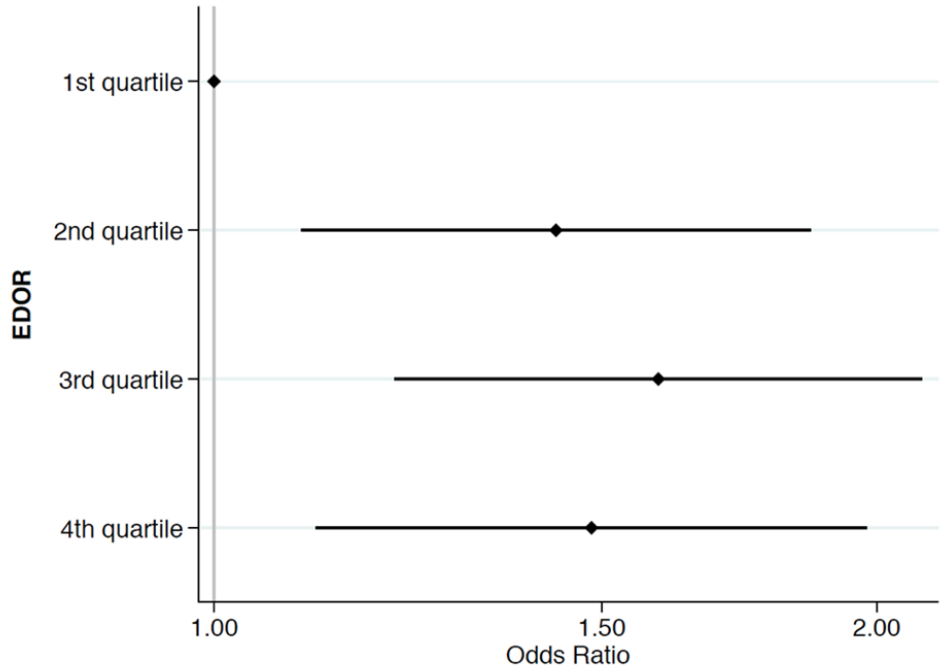

Figure 11. Adjusted odds ratio (95% CI) for 10-day mortality within the group of stable patients without the need for acute hospital care upon departure from the ED (n = 705,691) in relation to EDOR.

5 DISCUSSION

To summarize the main results, during 2009 – 2016 there has been a change in patient case mix at the EDs at the study hospital, primarily with an increase in unstable patients (input) and a decrease in the number of patients admitted to in-hospital care (output). The median for ED LOS over the study period increased, and the largest increases occurred among the subgroups of unstable patients, patients ≥80 years of age, and those admitted to in-hospital care (throughput). Further, an increase in crowding, in terms of median EDOR and median patients per RN ratios, was identified, with an increase in EDOR from 0.8 in 2009 to 1.1 in 2016 and an average increase of 0.164 patients/RN/year (throughput). The ED clinicians' work assignments consisted of 15 categories of activities, and information exchange was found to be the most common activity (42.1%). In contrast, the clinicians only spent 9.4% of their activities on direct interaction with patients and their families (ED clinicians' work processes). The clinicians multitasked during 23% of their total number of performed activities, and there was an overall interruption rate of 5.1 interruptions per hour. The majority of the observed multitasking situations and interruptions in the ED clinicians' work occurred during demanding activities that required focus or concentration (ED clinicians' work processes). Finally, an association was identified between an increase in ED LOS and EDOR and 10-day mortality for stable patients without the need for acute hospital care upon departure from the ED (patient outcomes). The discussion is presented in relation to Asplin's conceptual model of ED crowding (Figure 12).

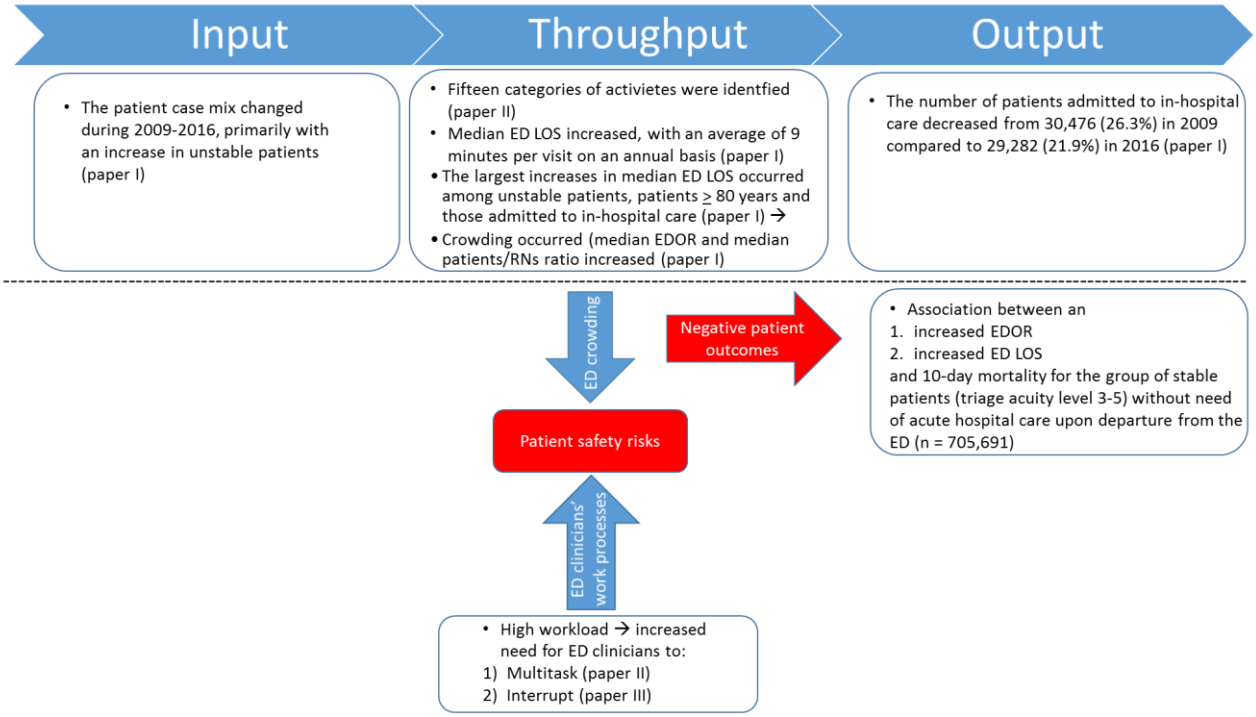

Figure 12. Challenges with patient safety in the ED in relation to Asplin's conceptual model of ED crowding.

5.1 CHALLENGES WITH PATIENT SAFETY IN THE ED IN RELATION TO ASPLIN'S CONCEPTUAL MODEL OF ED CROWDING

Increased ED LOS and EDOR are both indicators of a sub-optimal ED throughput (paper I). Both conditions involve a large number of patients present in the ED, which causes an increased workload for the clinicians. This, in turn, influences the ED clinicians' work processes negatively. For example, a high workload creates an increased need to multitask (paper II) and interrupt (paper III), both of which are known to affect patient safety negatively (34). Although, negative patient outcomes as a direct result of multitasking and interruptions are difficult to measure. However, one way to measure patient outcomes is the association between crowding indicators and short-term mortality (paper IV).

5.1.1 ED crowding

During the period 2009–2016 the proportion of unstable patients increased (input, Figure 12), indicating that patients seeking ED care might have been more severely ill when arriving at the ED in 2016 than in 2009. Furthermore, because patients ≥80 years were represented to a greater extent in this group, the data in paper I suggest that the group of vulnerable and frail patients in the ED has increased. Despite this, the proportion of in-hospital admission decreased during the study period (output, Figure 12), and the yearly increase in median LOS for patients who were admitted was twice as high as for patients who were discharged (throughput, Figure 12). The increased median LOS for all ED visits (72 minutes during the study period) is consistent with figures from annual Swedish reports since 2011 of waiting times at five Swedish EDs (39, 144). However, the accumulated increase of median ED LOS during the reviewed periods was about 50 minutes. Also, median for EDOR increased from 0.8 in 2009 to 1.1 in 2016 and has not been < 1.0 on an annual basis since 2012 (throughput, Figure 12).

The groups of patients especially exposed to increased LOS were the most vulnerable and frail patients, i.e. the unstable patients and patients ≥80 years of age (paper I) (throughput, Figure 12). Previous studies report that increased ED LOS for elderly patients is well known (39, 61, 145). The prolonged stay in the ED might be caused by the fact that unstable and older patients more often need admission to in-hospital care and, therefore, need more extensive investigations, such as radiology and inter- professional consultations, in the ED before a treatment plan is set.

Both fewer admissions and increased ED LOS as well as EDOR are closely related to the availability of in-hospital beds, and the findings indicate that the EDs have an output problem related to the number of beds. A major plan to reform Swedish healthcare has been ongoing since the last decades, where one goal is to transfer some of the in-hospital care to clinics

outside the hospitals. One part of the transition from in-hospital care to the provision of care outside the hospital has been to reduce the number of in-hospital beds. Such decrease, together with other changes in the health care setting, such as staffing wards with RNs, has created a shortage of available in-hospital beds at all Swedish hospitals and has created an output problem for Swedish EDs (86, 87). This is one of the causes for ED crowding, and Swedish healthcare organizations have tried to deal with the lack of available in-hospital beds in different ways. Within the Stockholm region, one solution that affects input is that as much care as possible should be delivered by care givers in the primary health care network. The primary reason is to deliver care at the most effective level (86). This solution is primarily for patients among the lowest triage levels and who are considered stable. A throughput strategy has been to create fast tracks within the EDs for these patients if they still need ED care (146), a solution recognized by the Swedish National Board of Health and Welfare to affect LOS in a positive way (39). However, none of these solutions are targeting output. The results in paper I show that patients with the second most urgent triage level (level 2) have increased their median LOS by 94 minutes during the study period compared to an increase of 12 minutes for the patients with the least urgent triage level (level 5). Thus, according to these findings, this previously mentioned focus on input and throughput primarily seems to benefit the group of patients with the lowest urgency, which is the group with the least need of ED care.

The groups of patients that have the longest median ED LOS (unstable and ≥80 years of age) often have greater care needs compared to those with the lowest triage levels and <80 years of age. This increased care need creates a greater workload for the ED clinicians, even if the patients per clinician ratios have been stable over the years apart from patients/RN. Also, unstable and older patients more often require admission to in-hospital care. The increase in ED LOS for patients that need to be admitted creates boarding and turns the EDs into a kind of short stay in-hospital wards, without having the necessary structure or work processes for it, e.g. lack of alarm functions in the corridors and equipment in the rooms. This result of boarding creates patient safety risks, such as medication errors, and potential lack of nursing care regarding risks for, e.g. pressure ulcer, malnutrition, urine retention, and fall injuries. This is stressful for the clinicians because the EDs are not designed, dimensioned, or staffed for such a mission (39, 147). These factors combined might create a perception among clinicians that the EDs are crowded even when EDOR is <1, in the sense that there is more to do during a shift. One way to take this perception into consideration is to include the clinicians' perception of workload into a crowding measurement tool. One Swedish measure of crowding has taken this perspective into consideration by, in addition to using crowding data accessible via the computerized ED patient log system, by having ED clinicians assess their workload by answering the question, "How would you assess the overall workload in the ED during the previous hour?" on a scale from 1 to 6, with 6 representing a very high level of workload (79). Even if previous studies have found significant correlations between ED clinicians' perceptions of crowding and scores that indicate crowding according to tools

predicting crowding, such as EDWIN, NEDOCS, and the ED work score to predict ambulance diversion (74-76), it is difficult to measure the actual workload in a more objective way without implementing valid tools for patient classification, such as the Jones Dependency Tool (148). This kind of tool must also be supported by the IT systems for extraction of data.

5.1.2 ED clinicians' work processes

As previously mentioned, ED clinicians are often simultaneously involved in different flow and care processes but still frequently need to interact with one another. Through the observations in paper II, it was found that almost 50% of all activities performed by the ED clinicians were related to communication (mostly through face-to-face interactions) (throughput, Figure 12). This result is consistent with results from other studies, which have found that the most common reason for interruption in health care is communication, either face-to-face or through technical devices (7, 40, 44, 47, 49, 105, 118, 126, 130, 142). One way to reduce the number of interruptions through face-to-face encounters is to find better ways to communicate, such as through technical solutions (e.g., chat functions). However, in a literature review, it was shown that technical solutions to improve communication adopted for the ED setting were lacking (131). To use chat functions or text messages would be a way for the recipients to take control over the situation because they would not need to address the message immediately but wait until they are ready for communication.

Further, a high workload created a need for the ED clinicians to multitask and interrupt each other (paper II and III) (ED clinicians' work processes, Figure 12). The whole group of clinicians multitasked during 23% of their total number of performed activities and a systematic review of time and motion studies conducted in 2018 revealed that the proportion of time spent on multitasking ranged from 10% to 23% (46). Further, the mean interruption rate was 5.1 interruptions per hour, which is similar to findings in other studies (41, 42, 43, 45). However, rates over 11 interruptions per hour have been found in some studies (40, 44). Multitasking, and interruptions are both known threats to patient safety (5, 7, 34-36, 42, 47-49). The activity *preparation of medication*, although rarely observed, was the most interrupted activity in relative terms. This is a particular patient safety risk, since studies have shown that ED clinicians are likely to make errors during situations that need focus and concentration because of frequent interruptions (7, 34, 36, 42, 47).

However, the respondents in the interviews in paper III did not perceive all interruptions to cause a disturbed work process. The Safety-II perspective of patient safety refers to a resilient system, i.e. a system that is able to adjust its functioning prior to and following a disturbance (15). Within resilience engineering, safety is studied from the perspective of successful

performance within a system and learns from that (15). According to the literature not all interruptions lead to error, and not all interruptions are preventable. On the contrary, some interruptions can actually be seen as promoting patient safety, for example information leading to better handling of patient care management or aiming to prevent errors (103, 122, 123, 125, 149-152). It has been suggested that health care shows gaps in the caring process and that clinicians constantly need to be able to bridge these gaps in order to improve and maintain the quality of care, for example, during shift handovers and when shifting attention between patients (153). In order to bridge these gaps, it is necessary to understand how success usually happens. By observing how clinicians successfully deal with interruptions, it might be possible to better understand the relationship between interruptions and cognitive and social processes. Artifacts used by the clinicians to manage the effect of interruptions might be useful in designing new technological products. Grundgeiger and colleagues also states in their literature review that IT systems could help clinicians to execute plans (e.g., through electronically accessible work lists or cues on a display to remind the clinicians that certain tasks need to be carried out). However, these systems need to be tested for their potential to cause additional interruptions, i.e. they might produce the direct opposite than the intended effect (103).

5.1.3 Patient outcomes

Several studies have used short-term mortality as an outcome measure when studying EDOR (26, 27, 33), and increased ED LOS (25, 30), but these studies do not present consistent results, and both associations (25-27, 30), and no associations (33), have been reported. However, most studies have focused on critically ill patients and those in need of acute in-hospital admission (23, 24, 26, 28-33), and, to my knowledge, only two studies have also included discharged patients (25) or both groups (27).

The group of stable patients without the need for acute hospital care upon departure from the ED, i.e. patients who are not expected to die shortly after discharge, has not been a common study object of interest, even when such studies have been called for (33). However, one study based on Medicare claims showed that 12,375 (0.12%) out of 10,093,678 discharged patients died within 7 days, despite no diagnosis of a life-threatening illness recorded in their claims (154). No explanation for this association was identified. In a Canadian study (25), discharged patients from all triage acuity levels, i.e. both patients who were assessed as unstable and stable at ED arrival, were investigated with regards to short-term mortality following the ED visit. Despite exclusion of the group of unstable patients in paper IV, the results in that paper are consistent with the results published by Guttmann and colleagues (2011) concerning the association between increased LOS and short-term mortality.

Thus, the results in paper IV indicate that the association between increased ED LOS as well as EDOR and short-term mortality cannot be explained by patients being assessed as unstable when arriving at the ED (patient outcomes, Figure 12). Still, through the EHR audits it was identified that many of the patients with 10-day mortality had high co-morbidity, e.g. cancer in a palliative stage or severe heart failure. However, patients with documented expected short survival, such as "discharged with hospital-based home care services in order to die at home", were excluded in paper IV. The question arises as to why these stable patients died so shortly after the ED visit. Was there something that the clinicians did, or more likely failed to do, to the patients during their ED visits that contributed to the outcomes? It is previously known that ED crowding has negative effects on patients' medical outcomes, for example, adverse cardiovascular outcomes (e.g., cardiac arrests, heart failures, dysrhythmias, etc.) (64), and time until treatment for patients with time-sensitive conditions such as pneumonia (63). Crowding is also associated with delays in analgesic treatment (155), and increased frequency of medication errors (e.g., incorrect doses, frequencies, durations, routes, and administrate contraindicated medications) by pharmacists (156). Recently, outcomes specifically related to nursing have been identified. In studies conducted in medical and surgical wards, 74% of the RNs in Sweden and 86% of the RNs in the UK reported that necessary nursing care was left undone on their last shift due to lack of time (157, 158). Further, associations between care left undone and RN staffing were found in several studies (157-159). Also, an association between care left undone and 30-day mortality has been identified, where care left undone mediates the relationship between RN staffing and patient mortality (159). Even if these studies were conducted at in-hospital wards, it is likely that the same associations exist in the ED, even if the results from the patients/clinician ratios in paper IV were not significant. For example, in paper II we found that only 8.2% of the RNs, 9.4% of the LPNs, and 7.5% of the physicians' activities were spent on direct patient care (*patient/family–nurse/doctor interaction*).

5.2 METHODOLOGICAL CONSIDERATIONS

5.2.1 Papers I and IV

All data were retrieved from the patients' EHR through the CDW, and to ensure internal validity the author of this thesis validated all extracted variables together with a systems scientist from the university hospital. All variables that are manually entered into the EHR, such as chief complaint, arrival mode, and triage acuity level, have a potential risk of being less valid than those that are automatically imported from the Swedish Population Register, such as age, gender, and date of death. To ascertain the quality of the manually entered data in the EHR, part of the extracted data was compared to actual patient information in the EHR in order to validate the programming codes for extraction. The author's knowledge of the clinical setting and of how patient data are registered in the EHR made it possible to take both the validity and reliability of the data into consideration and to identify potential sources of error for further scrutiny.

The structure of the CDW caused some challenges in identifying ED visits that should be excluded according to the exclusion criteria. In the event group (n = 737), 79 (11%) ED visits were manually excluded for reasons presented in the methods section. Despite repeated efforts, we were unable to determine why 11% of the patient visits in the event group were included, despite fulfilling the exclusion criteria of being triaged as unstable (triage acuity level 1–2) or requiring in-hospital admission. Hence, it cannot be ruled out that a similar proportion of inaccurately included visits occurred in the entire study group. This might have led to the non-event group potentially consisting of patients who were allocated to high triage acuity levels or who were admitted to in-hospital care, and this is a limitation because the two groups (event vs. non-event) might not be as homogenous as expected. The extraction of data, the validation of the data quality, and the EHR audit were discussed continuously within the research group during the validation process.

There were also some challenges regarding the development of the crowding variables that concern ratios. For example, each individual clinician was only counted once, even if the clinician was registered as involved in care on more than one occasion during a patient's ED visit (paper I). This might have affected the clinicians per patient ratios in that some of the extracted ratios were slightly lower than the actual ratios. Another limitation related to the ratios is that data were collected in 2-hour intervals, which leads to some potential lack of detail that might have been detected using, for example, a 30-minute interval (paper I). However, we still think that it has been possible to capture possible fluctuations concerning ratios, and since the study spreads over 8 years, it would be difficult to handle the amount of data that would be produced at a lower level of abstraction than 2 hours.

Regarding external validity, the organization was essentially unaltered with regard to staffing and how ED work was organized during the study period. Thus, the results are likely to be generalizable to other EDs in a similar health care context because the demographic in Stockholm is similar to the rest of the country, apart from a slightly lower proportion of citizens ≥65 years of age in Stockholm. Also, Swedish ED care is publicly organized and tax-funded, and thus is similarly configured across in the entire country. The choice of 10-day mortality as the outcome measure, instead of the more commonly used 7-day mortality, made it possible to capture more events of short-term mortality, but made it a bit more difficult to compare the results to other studies. However, there is no consistent way of presenting mortality in the literature.

5.2.2 Papers II and III

Credibility, dependability and transferability need to be considered to achieve trustworthiness in a qualitative study (139). The credibility of the findings in this thesis is perceived to be high considering the variation in observation periods, clinical roles, and participants' age, gender, and level of ED work experience. Further, the fact that no relevant data were excluded and that no irrelevant data were included strengthens the credibility of the findings in this thesis. Also, one way to increase this aspect of credibility is to present representative quotations from the interviews, which has been done in papers II and III. Another way is to seek agreement from other researchers, and in both papers independent analysis of all data was conducted by several researchers, which also strengthens the credibility of the studies. Dependability was likely achieved in that both data collections were conducted over a limited period. Moreover, continuous discussions were held among the members of the research group concerning the design of the studies and the execution of the observations and interviews. To assure transferability, the settings, samples, inclusion and exclusion criteria, data collections and analysis processes have been described as vigorously as possible in both papers in order to make it possible for others to evaluate the applicability to other contexts. Also, the fact that both observations and interviews were conducted at a university hospital and a county hospital transferability to other Swedish EDs possible because these are all typically hospital-based EDs in Sweden. Further, appropriate quotations from the interviews are used to clarify the results for the readers' scrutiny of the applicability to other settings.

A main challenge with this study was observing the various activities in the complex and dynamic environment of the ED. The observed activities varied in complexity, from very general to highly detailed, with many of these activities carried out as comprehensive processes (e.g., drawing blood from a patient or bladder catheterization). Teamwork during data collection in conjunction with the use of a semi-structured data collection protocol strengthened the possibility to maximize the capturing of observed activities. All performed major activities were probably captured, which is indicated by the fact that the same observed activities were most often noted by the two observers. Further, on the few occasions when differences in observations occurred, the observers supplemented each other, suggesting the credibility of identifying all ongoing activities. Towards the end of the data collection phase, the observers captured no additional types of activities, suggesting that no additional activities would have been detected even if further observations had been conducted.

The two members of the research group that conducted the data collection were both RNs working at one of the participating EDs, and thus there was the risk that the RNs' pre-understanding might have influenced the observations as well as the analysis. On the other hand, because the researchers were familiar with the work context at each ED, it might have been easier to capture details of the respondents' activities and interruptions during the

observations thus contributing to a deeper understanding of the subject matter. The presence of the two observers was a way of minimizing the potential bias effect while simultaneously increasing the possibility to capture complex work processes. The presence of the observers did not seem to affect the ED clinicians' performance because the clinicians only seemed to be aware of the observers during the first 15 minutes of the observation periods.

Another limitation was that some multitasking might have been performed internally as cognitive events and hence thus not visible to the observers. One way to capture such processes would have been to use the concurrent or retrospective think-aloud technique (139, 160). It also cannot be ruled out that a longer observational time period have changed the proportion of multitasking and interruption events in the activities. Also, there might be seasonal differences not captured by this study. Further, sometimes the observers chose not to observe situations when the clinician was examining or treating a patient in order to maintain the patient's integrity. However, in these situations the observers waited for the clinician just outside the door to the assessment room until the session ended. The observers would thus have noticed potential multitasking events as well as interruptions that might have occurred, apart from interactions with other people inside the room.

The interviews with the clinicians were conducted immediately after the observation was finalized. The clinicians were still on duty and might have felt time pressure by having to leave their assignments and thus might have wanted to terminate the interview as quickly as possible. The time factor might have had a negative effect on the richness of the data, but the intention was to minimize the time between the 2-hour observation period and the interviews so that the clinicians could reflect upon their perceptions of the interruptions that had occurred.

Using both observations and interviews in the data collection strengthened the credibility and dependability of the studies. This triangulation made it possible to look at the same situations from two perspectives, which provided a deeper understanding of the phenomenon in question. Finally, the inductive approach in the data collection process (161-163) resulted in more detailed information about type of ED activities than in previous studies, which used either a deductive or a combination of inductive and deductive methods.

6 CONCLUSIONS

This thesis illustrates how a sub-optimal throughput, affected by conditions in both the input and output component, negatively influence the ED clinicians' work processes as well as patient outcomes.

Over the eight years there was an increase in unstable patients seeking ED care, at the same time as there was a decrease in number of patients admitted to in-hospital care. These changes contributed to ED crowding (depicted as increased median ED LOS and EDOR), which made the throughput phase sub-optimal. This thesis contributes with new knowledge on differentiated ED LOS for patients with different triage acuity levels. The longitudinal study shows a trend of increasing ED LOS in general, but especially increasing ED LOS for patients with high care needs, which in turn influences the ED clinicians' workload. Also, crowding influenced the ED clinicians' work processes in terms of an increased need to multitask their work activietes and interrupt each other. Finally, ED crowding also influenced patient outcomes, as an association was identified between increased ED LOS and EDOR and 10-day mortality among patients with stable triage levels without the need for acute hospital care upon departure from the ED.

7 CLINICAL IMPLICATIONS

The identified difference between ED LOS for patients with different triage acuity levels has made it possible to show that there was an increased ED LOS over eight years for patients with high care needs, which in turn influences the ED clinicians' workload. This should be considered when planning the ED staffing. Further, patient safety risks, in terms of short-term mortality, were identified with extended ED LOS or during ED crowding. ED managers and clinicians need to be aware of, and take appropriate measures to decrease these risks. Finally, to be able to create a better work environment that promotes patient safety, the focus should be on reducing interruptions that are perceived as negative events by ED clinicians. One solution could be to raise clinicians' awareness of the risks involved with interruptions. Another solution is to reduce the total communication load at the ED by developing better technical solutions for communication, for example through chat functions. This knowledge needs to be taken into consideration when planning for the organization of ED work.

8 FUTURE RESEARCH

Further research is called for to identify causation behind the association between increased ED LOS and EDOR and increased 10-day mortality. One way could be to combine registry data with questionnaires on the nursing care that is left undone. To be able to identify an association between the patients/clinician ratios and short-term mortality, it is probably more suitable to use a prospective study design instead of a retrospective design. Another way of measuring the patient load on the clinician level could be to use a variation of EDOR, where the number of patients present in the ED at a certain time is divided by the number of clinicians on duty instead of divided by the number of treatment beds.

To confirm the connection between multitasking and interruptions and negative outcomes for patient safety is a considerable methodological challenge. One reason is that it is difficult to find suitable outcome measures. Another reason is the difficulty in studying the effects of interruptions in an active and complex ED context. However, one way to determine a potential relationship between disturbing interruptions and negative outcomes could be to study the phenomenon in a controlled environment, for example, by using standardized simulated scenarios in which clinicians are exposed to interruptions in situations where interruptions are perceived as disturbing and measure outcomes such as the extent of adherence to the ABCDE approach (Airway, Breathing, Circulation, Disability, and Exposure) and physical effects on stress biomarkers.

9 SVENSK SAMMANFATTNING

Bakgrund

Flera patientsäkerhetsutmaningar på akutmottagningar har påvisats i forskningen och några vanligt förekommande är crowding, multitasking och avbrott. Akutmottagningsverksamheten kännetecknas till stor del av oberäknelighet, både vad gäller antal sökande patienter och allvarlighetsgraden av deras sökorsaker, vilket stundtals leder till hög arbetsbelastning för akutmottagningspersonalen. Personalen (läkare, sjuksköterskor och undersköterskor) utför ofta arbetsuppgifter simultant (multitasking) och de utsätts frekvent för avbrott av kollegor, patienter och närstående. Denna komplexa arbetsmiljö leder till att akutmottagningen är klassad som en högriskmiljö. Akutmottagningspersonalen består av ett stort antal kliniker som konstant arbetar i parallella flödes- och vårdprocesser, inte sällan på en akutmottagning som är överbelastad (crowded), och många av de arbetsuppgifter akutmottagningspersonalen utför innehåller komplicerade beslutsfattandeprocesser som kräver stor koncentration. Crowding anses vara ett hot mot patientsäkerheten på akutmottagningar och det finns indikationer för att akutmottagningscrowding skapar ett dysfunktionellt sjukvårdssystem. Det finns dock svårigheter med att jämföra inverkan av crowding på olika, i övrigt jämförbara, vårdinrättningar då det inte finns någon konsensus rörande hur man mäter crowding. Ett vanligt förekommande mått är antalet patienter som vistas på akutmottagningen i förhållande till mottagningens antal fasta behandlingsplatser med crowding definierat som värden >1 (EDOR). Även faktorer som antal medarbetare i tjänst, fördelningen mellan patienternas triagenivåer, antal patienter som väntar på att träffa läkare och antalet tillgängliga slutenvårdsplatser bör vägas in när man mäter crowding. Inget av dessa mått mäter däremot den faktiska belastningen som crowding har på medarbetarna som vårdar patienterna. Akutmottagningscrowding leder bland annat till längre vistelsetider för patienterna på akutmottagningen och ett flertal studier har identifierat en association mellan akutmottagningscrowding och både ökad morbiditet och mortalitet. Crowding har även visat sig ha negativa effekter på akutmottagningspersonalens arbetsbelastning och arbetstillfredsställelse. Slutligen bidrar crowding till stress hos akutmottagningspersonalen samt ökar förekomsten av multitasking och avbrott i deras arbetsprocesser; båda kända faktorer för minskad produktivitet och effektivitet.

Multitasking och avbrott har identifierats som potentiella patientsäkerhetsrisker, till stor del på grund av deras negativa effekter på akutmottagningspersonalens arbetsminne vilket i sin tur leder till risker för att arbetsuppgifter glöms bort eller utförs felaktigt. Dock saknas det i litteraturen information om vilken specifik typ av arbetsuppgifter medarbetarna utför under tiden de multitaskar och avbryts. Vidare saknas det även en nyanserad bild av avbrott, då inte alla avbrott är undvikbara och de flesta inte leder till att fel uppstår. Med stor sannolikhet är en stor del av avbrotten nödvändiga och gynnsamma för patientsäkerheten och vissa avbrott för arbetsprocesser framåt. Tidigare studier har inte heller undersökt akutmottagningspersonalens uppfattningar om avbrott.

Syfte

Det övergripande syftet med avhandlingen, som består av fyra delarbeten, är att beskriva akutmottagningscrowding och dess påverkan på akutmottagningspersonalens arbetsprocesser (aktiviteter, multitasking och avbrott) och patientutfall. Avhandlingen har studerat sex forskningsfrågor:

- Hur har akutmottagningskaraktäristikan, case mixen av patienter och akutmottagningscrowding förändrats över tid? (delarbete I)
- Vilka arbetsuppgifter (aktiviteter) utför akutmottagningspersonalen? (delarbete II)
- Vilken typ av multitasking utsätts akutmottagningspersonalens arbetsuppgifter för? (delarbete II)
- Vilken typ av avbrott utsätts akutmottagningspersonalens arbetsuppgifter för? (delarbete III)
- Hur uppfattar akutmottagningspersonal avbrott? (delarbete III)
- Finns det en association mellan akutmottagningscrowding och mortalitet för gruppen stabila patienter som är utan behov av akutsjukvård när de lämnar akutmottagningen? (delarbete IV)

Avhandlingens specifika syften är:

Delarbete I: att beskriva utvecklingen av crowding samt akutmottagnings- och patientkaraktäristika över tid.

Delarbete II: att undersöka vilken typ och frekvens av aktiviteter och multitasking som utfördes av akutmottagningspersonal.

Delarbete III: att undersöka vilka avbrott som förekom av dessa aktiviteter samt hur dessa avbrott uppfattades av akutmottagningspersonalen.

Delarbete IV: att beskriva associationen mellan akutmottagningscrowding och 10-dagarsmortalitet för gruppen av patienter som är stabila (triagenivå 3–5) vid ankomst till akutmottagningen och som inte är i behov av akutsjukvård när de lämnar akutmottagningen.

Material och metod

Data till de fyra delarbetena i avhandlingen består av två datainsamlingar, vilket sammantaget resulterade i fyra dataset:

1) Registerdata baserat på 1,063,806 akutmottagningsbesök (delarbete I)
2) Observationer och intervjuer med 18 kliniker (6 läkare, 6 sjuksköterskor och 6 undersköterskor) (delarbete II)
3) Observationer och intervjuer med 18 kliniker (6 läkare, 6 sjuksköterskor och 6 undersköterskor) (delarbete III)
4) Registerdata baserat på 705,691 akutmottagningsbesök (delarbete IV)

Delarbete I och IV har båda en kvantitativ och deskriptiv ansats och är baserade på journaldata som är uthämtad från ett centralt datalager tillhörande ett universitetssjukhus med akutmottagning på två siter. Detta datalagar hämtar i sin tur data direkt från patientens elektroniska journal. Både delarbete II och III har en kvalitativ och explorativ ansats och data till dessa studier är baserat på observationer och intervjuer som utfördes på två svenska akutmottagningar för vuxna, varav den ena var en av akutmottagningssiterna vid ovan nämnda universitetssjukhus och den andra den på ett länssjukhus.

I delarbete I inkluderades alla akutmottagningsbesök med vuxna ($\geq$ 18 år) patienter under tidsperioden 1 januari 2009 – 31 december 2016 (N=1,063,806). Till delarbete IV valdes en subgrupp av dessa besök ut, nämligen de akutmottagningsbesök med patienter som var stabila (triagenivå 3–5 enligt RETTS) vid ankomst till akutmottagningen och som inte var i behov av akutsjukvård (dvs. skrevs ut till hemmet eller geriatrisk avdelning) när de lämnade akutmottagningen (n=705,813). Exklusionskriterium var vårdtillfälle med patient som var instabil (triagenivå 1–2), blev inlagd inom akut somatisk slutenvård eller avled under akutmottagningsbesöket (n=357,993). De vårdtillfällen som uppfyllde inklusionskriterierna ovan och som avled inom tio dagar från att de lämnade akutmottagningen utgjorde händelsegruppen (n=737). För denna grupp gjordes en manuell journalgranskning, vid vilken ytterligare 79 vårdtillfällen exkluderades och till slut togs även alla akutmottagningsbesök under perioden dag >1–10 efter indexbesöket bort från denna grupp (n=43). Till slut återstod 705,691 akutmottagningsbesök (motsvarande 366,665 unika patienter) för analys, varav den slutliga händelsegruppen (triagenivå 3–5 vid ankomst, ej i behov av akutsjukvård när de lämnade akutmottagningen, avliden inom tio dagar efter utskrivning) utgjorde 615 patienter och icke-händelsegruppen (triagenivå 3–5 vid ankomst, ej i behov av akutsjukvård när de lämnade akutmottagningen, ej avliden inom tio dagar efter utskrivning) utgjorde 705,076 vårdtillfällen.

För delarbete II och III gjordes ett ändamålsenligt urval av informanter för att få en variation av bl.a. ålder, kön och erfarenhet. Två observatörer skuggade varje informant under två timmar. Observatörerna använde ett semi-strukturerat datainsamlingsprotokoll (Appendix 1) för att bl.a. notera vilken typ av arbetsuppgifter (aktiviteter) som utfördes och hur dessa aktiviteter utsattes för multitasking och avbrott. Direkt efter observationen utfördes en kort intervju för att fånga informantens uppfattning om multitasking och avbrott under observationstiden.

Variabler som uthämtades för delarbete I och IV var ålder, kön, sökorsak, ankomstsätt, triagenivå, inläggning inom slutenvård eller ej (enbart delarbete I), ACCI, tid och datum för ankomst/utskrivning från akutmottagningen samt ICD-koder och datum för död (enbart delarbete IV). Fyra olika crowdingvariabler uthämtades; vistelsetid på akutmottagningen (ED LOS), EDOR, antal unika sjuksköterskor/läkare per patient (enbart delarbete I) och antal patienter per unik sjuksköterska/läkare. Icke parametrisk statistisk användes för att analysera delarbete I och III och all observations- och intervjudata (delarbete II och III) analyserades induktivt och kvantitativa och kvalitativa innehållsanalyser gjordes. I delarbete IV gjordes multivariabla logistiska regressionsmodeller, med död inom tio dagar som utfallsmått och ovan nämnda crowdingmått som oberoende variabler.

Resultat

Huvudfynden i avhandlingen har satts i relation till Asplins konceptuella modell av akutmottagningscrowding och placerats in i modellens tre processer input-throughput-output. Ineffektivitet i throughput-processen har studerats noggrannare utifrån ett patientsäkerhetsperspektiv, genom att undersöka hur ökad crowding influerar akutmottagningspersonalens arbetsprocesser och hur den är associerad med utfallet för en subgrupp av patienter.

Input och output

År 2009 var akutmottagningsbesöken 17,377 färre jämfört med 2016.Vidare skedde under studieperioden 2009–2016 en förändring av case mixen av patienter på akutmottagningen, främst genom en ökning av andelen instabila (triagenivå 1–2) patienter (14.9 % 2009 vs. 20.2 % 2016, $p < 0.001$). Samtidigt skedde en minskning i andelen inläggningar till akut somatisk slutenvård, från 26.3 % till 21.9 % ($p < 0.001$) (delarbete I).

Throughput

Femton kategorier av aktiviteter identifierades under observationerna av akutmottagningspersonalen (läkare, sjuksköterskor och undersköterskor) och den vanligast förekommande aktiviteten var *informationsutbyte*, som uppgick till 42.1 % av de 1882 observerade aktiviteterna (delarbete II). Enbart 9.4 % av alla utförda aktiviteter som akutmottagningspersonalen utförde ägnades åt direkt *interaktion med patient och/eller närstående*. Under studieperioden 2009–2016 ökade medianvistelsetiden på akutmottagningen (ED LOS) och den största ökningen skedde bland vårdtillfällen med patienter som var instabila, 80 år och äldre eller blev inlagda inom akut somatisk slutenvård. Även crowdingvariabeln EDOR ökade, från en median på 0.8 2009 till 1.1 2016, samt crowdingvariabeln ’antal patienter per unik sjuksköterska’, med en genomsnittlig medianökning av 0.164 patienter/sjuksköterska/år (delarbete I). I delarbete II och III undersöktes hur crowding influerar akutmottagningspersonalens arbetsprocesser. Den vanligaste förekommande aktiviteten *informationsutbyte* var också den som oftast utsattes för multitasking och avbrott (delarbete II och III). Vidare visade observationerna att akutmottagningspersonalen multitaskade 23 % av sina utförda aktiviteter (delarbete II), medan tio procent av alla observerade aktiviteter avbröts, vilket gav en total genomsnittlig avbrottsfrekvens på 5.1 avbrott per timme (delarbete III). Majoriteten av alla multitaskingsituationer och avbrott skedde i arbetsuppgifter (aktiviteter) som krävde fokus och koncentration (delarbete II-III). Vid intervjuer med akutmottagningspersonalen efter observationstillfällena uppdagades det att informanterna inte alltid uppfattade avbrott som negativa, utan den uppfattningen var relaterad till om deras arbetsprocess blev störd eller inte (delarbete III). I delarbete IV, där inverkan av crowding på patientutfall undersöktes, identifierades att en ökad vistelsetid på akutmottagningen (ED LOS) samt ökad EDOR båda är associerade med en ökad 10-dagarsmortalitet för gruppen patienter som var stabila vid ankomst till akutmottagningen och som inte var i behov av akutsjukvård när de lämnade akutmottagningen.

Slutsats

Resultaten illustrerar den negativ inverkan en sub-optimal throughput-fas, påverkad av förutsättningar i både input- och outputfaserna, har på akutmottagningspersonalens arbetsprocesser och på patientutfall.

De förändringar som framförallt påverkade input- och outputfaserna var att det skedde en förändring av case mixe:en av patienter på akutmottagningen, framförallt genom en ökning av instabila patienter samtidigt som det skedde en minskning av antalet inläggningar till slutenvården. Dessa förändringar bidrog till akutmottagningscrowding, i form av ökad medianvistelsetid på akutmottagningen (ED LOS) och EDOR, vilket i sin tur ledde till en

sub-optimal throughput-fas. Det var dock inte bara en generell trendökning medianvistelsetiden, utan den skedde framförallt för den grupp av patienter som har ett högt vårdbehov, vilket i sin tur påverkar akutmottagningspersonalens arbetsbelastning. Vidare influerade crowding personalens behov av att multitaska sina aktiviteter och avbryta varandra. Crowding influerade även utfallet för patienter, då en ökad vistelsetid på akutmottagningen (ED LOS) samt ökad EDOR båda var associerade med en ökad 10-dagarsmortalitet för gruppen patienter som var stabila vid ankomst till akutmottagningen och som inte var i behov av akutsjukvård när de lämnade akutmottagningen.

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11 REFERENCES

1. Kohn LT, Corrigan, J.M., Donaldson, M.S. . To err is human: Building a safer health system. Washington DC: National Academy Press; 1999.

2. ACEP Crowding Resources Task Force. Responding to Emergency Department Crowding: A Guidebook for Chapters Dallas, TX, USA: American College of Emergency Physicians; 2015 [Available from: http://www.emdocs.net/edcrowding/.

3. Berg LM, Kallberg AS, Goransson KE, Ostergren J, Florin J, Ehrenberg A. Interruptions in emergency department work: an observational and interview study. BMJ quality & safety. 2013;22(8):656-63.

4. Brixey JJ, Robinson DJ, Johnson CW, Johnson TR, Turley JP, Zhang J. A concept analysis of the phenomenon interruption. Advances in Nursing Science. 2007;30(1):E26-42.

5. Chisholm CD, Collison EK, Nelson DR, Cordell WH. Emergency department workplace interruptions: are emergency physicians "interrupt-driven" and "multitasking"? Academic Emergency Medicine. 2000;7(11):1239-43.

6. The World Health Organization. Patient safety - definition 2018 [Definition of patient safety]. Available from: http://www.who.int/patientsafety/about/en/.

7. Brixey JJ, Tang Z, Robinson DJ, Johnson CW, Johnson TR, Turley JP, et al. Interruptions in a level one trauma center: a case study. International Journal of Medical Informatics. 2008;77(4):235-41.

8. The Swedish Association of Local Authorities and Regions. Skador i vården – utveckling 2013 - 2017 (Adeverse events in the health care sector - the development during 2013-2017). Swedish Association of Local Authorities and Regions; 2018 2018-06-18.

9. Runciman W, Hibbert P, Thomson R, Van Der Schaaf T, Sherman H, Lewalle P. Towards an International Classification for Patient Safety: key concepts and terms. International journal for quality in health care : journal of the International Society for Quality in Health Care. 2009;21(1):18-26.

10. World Alliance For Patient Safety Drafting Group, Sherman H, Castro G, Fletcher M, Hatlie M, Hibbert P, et al. Towards an International Classification for Patient Safety: the conceptual framework. International journal for quality in health care : journal of the International Society for Quality in Health Care. 2009;21(1):2-8.

11. Flin R, Mearns K, O'Connor P, Bryden R. Measuring safety climate: identifying the common features. Safety Science. 2000;34(1-3):177-92.

12. Danielsson M. Patient Safety - Cultural Perspectives [Doctoral]. Linköping, Sweden: Linköping University, Sweden; 2018.

13. Haukelid K. Theories of (safety) culture revisited - An anthropological approach. Safety Science. 2008;46(3):413-26.

14. Pronovost PJ, Goeschel CA, Olsen KL, Pham JC, Miller MR, Berenholtz SM, et al. Reducing health care hazards: lessons from the commercial aviation safety team. Health Aff (Millwood). 2009;28(3):w479-89.

15. Hollnagel E, Woods DD, Leveson N, editors. Resilience engineering: concepts and precepts. Burlington: Ashgate Publishing; 2006.

16. Hollnagel E, Leonhardt J, Licu T, Shorrock S. From Safety-I to Safety-II: A White Paper: European Organisation for the Safety of Air Navigation (EUROCONTROL); 2013 [Available from: https://www.eurocontrol.int/sites/default/files/content/documents/nm/safety/safety_whitepaper_sept_2013-web.pdf.

17. Heinrich HW. Industrial Accident Prevention. New York: McGraw-Hill Book Company; 1931.

18. Reason J, editor. Human error. New York: Cambridge University Press 1990.

19. Printezis A, Gopalakrishnan M. Current pulse: can a production system reduce medical errors in health care? Quality Management Health Care. 2007;16(3):226-38.

20. Simpson RL. Patient and nurse safety: how information technology makes a difference. Nursing administration quarterly. 2005;29(1):97-101.

21. The Health and Social Care Inspectorate. Hur står det till med våra akutmottagingar? (How are our emeregency departments doing?). The Health and Social Care Inspectorate; 2015. Report No.: IVO 2015-76.

22. Wrigstad J. The inside of a paradigm. An expedition through an incident reporting system. [Doctoral]. Lund, Sweden: Lund Universit; 2018.

23. Chiu IM, Lin YR, Syue YJ, Kung CT, Wu KH, Li CJ. The influence of crowding on clinical practice in the emergency department. The American journal of emergency medicine. 2018;36(1):56-60.

24. Goulet H, Guerand V, Bloom B, Martel P, Aegerter P, Casalino E, et al. Unexpected death within 72 hours of emergency department visit: were those deaths preventable? Crit Care. 2015;19:154.

25. Guttmann A, Schull MJ, Vermeulen MJ, Stukel TA. Association between waiting times and short term mortality and hospital admission after departure from emergency department: population based cohort study from Ontario, Canada. Bmj. 2011;342:d2983.

26. Jo S, Jeong T, Jin YH, Lee JB, Yoon J, Park B. ED crowding is associated with inpatient mortality among critically ill patients admitted via the ED: post hoc analysis from a retrospective study. The American journal of emergency medicine. 2015;33(12):1725-31.

27. Jo S, Jin YH, Lee JB, Jeong T, Yoon J, Park B. Emergency department occupancy ratio is associated with increased early mortality. The Journal of emergency medicine. 2014;46(2):241-9.

28. Mathews KS, Durst MS, Vargas-Torres C, Olson AD, Mazumdar M, Richardson LD. Effect of Emergency Department and ICU Occupancy on Admission Decisions and Outcomes for Critically Ill Patients. Critical care medicine. 2018.

29. McCarthy ML, Zeger SL, Ding R, Levin SR, Desmond JS, Lee J, et al. Crowding delays treatment and lengthens emergency department length of stay, even among high-acuity patients. Annals of emergency medicine. 2009;54(4):492-503 e4.

30. Paton A, Mitra B, Considine J. Longer time to transfer from the emergency department after bed request is associated with worse outcomes. Emerg Med Australas. 2018.

31. Sprivulis PC, Da Silva JA, Jacobs IG, Frazer AR, Jelinek GA. The association between hospital overcrowding and mortality among patients admitted via Western Australian emergency departments. The Medical journal of Australia. 2006;184(5):208-12.

32. Sun BC, Hsia RY, Weiss RE, Zingmond D, Liang LJ, Han W, et al. Effect of emergency department crowding on outcomes of admitted patients. Annals of emergency medicine. 2013;61(6):605-11 e6.

33. Verelst S, Wouters P, Gillet JB, Van den Berghe G. Emergency Department Crowding in Relation to In-hospital Adverse Medical Events: A Large Prospective Observational Cohort Study. The Journal of emergency medicine. 2015;49(6):949-61.

34. Westbrook JI, Raban MZ, Walter SR, Douglas H. Task errors by emergency physicians are associated with interruptions, multitasking, fatigue and working memory capacity: a prospective, direct observation study. BMJ quality & safety. 2018;27(8):655-63.

35. Henneman EA, Marquard JL, Nicholas C, Martinez V, DeSotto K, Scott SS, et al. The Stay S.A.F.E. Strategy for Managing Interruptions Reduces Distraction Time in the Simulated Clinical Setting. Crit Care Nurs Q. 2018;41(2):215-23.

36. Westbrook JI, Woods A, Rob MI, Dunsmuir WT, Day RO. Association of interruptions with an increased risk and severity of medication administration errors. Arch Intern Med. 2010;170(8):683-90.

37. Sheehy SB. Emergency Nursing - Principles and Practice. 4th ed. St Louis: Mosby; 1998.

38. The National Board of Health and Welfare. Väntetider och patientflöden på akutmottagningar (Waiting times and patient flows at emergency departements) - Report December 2015. The National Board of Health and Welfare; 2015 2015-12-15.

39. The National Board of Health and Welfare. Väntetider och patientflöden på akutmottagningar (Waiting times and patient flows at emergency departements) - Report February 2017. The National Board of Health and Welfare; 2017 2017-02-15.

40. Blocker RC, Heaton HA, Forsyth KL, Hawthorne HJ, El-Sherif N, Bellolio MF, et al. Physician, Interrupted: Workflow Interruptions and Patient Care in the Emergency Department. The Journal of emergency medicine. 2017;53(6):798-804.

41. Forsyth KL, Hawthorne HJ, El-Sherif N, Varghese RS, Ernste VK, Koenig J, et al. Interruptions Experienced by Emergency Nurses: Implications for Subjective and Objective Measures of Workload. Journal of emergency nursing: JEN : official publication of the Emergency Department Nurses Association. 2018.

42. Johnson KD, Motavalli M, Gray D, Kuehn C. Causes and occurrences of interruptions during ED triage. Journal of emergency nursing: JEN : official publication of the Emergency Department Nurses Association. 2014;40(5):434-9.

43. Kosits LM, Jones K. Interruptions experienced by registered nurses working in the emergency department. Journal of emergency nursing: JEN : official publication of the Emergency Department Nurses Association. 2011;37(1):3-8.

44. Ratwani RM, Fong A, Puthumana JS, Hettinger AZ. Emergency Physician Use of Cognitive Strategies to Manage Interruptions. Annals of emergency medicine. 2017;70(5):683-7.

45. Weigl M, Beck J, Wehler M, Schneider A. Workflow interruptions and stress atwork: a mixed-methods study among physicians and nurses of a multidisciplinary emergency department. BMJ open. 2017;7(12).

46. Abdulwahid MA. Understanding better how emergency doctors work. Analysis of distribution of time and activities of emergency doctors: a systematic review and critical appraisal of time and motion studies. Emergency medicine journal : EMJ. 2018;[Epub ahead of print].

47. Laxmisan A, Hakimzada F, Sayan OR, Green RA, Zhang J, Patel VL. The multitasking clinician: Decision-making and cognitive demand during and after team handoffs in emergency care. International Journal of Medical Informatics. 2007;76(11-12):801-11.

48. Brixey JJ, Robinson DJ, Tang Z, Johnson TR, Zhang J, Turley JP. Interruptions in workflow for RNs in a Level One Trauma Center. AMIA Annual Symposium Proceedings. 2005:86-90.

49. Coiera EW, Jayasuriya RA, Hardy J, Bannan A, Thorpe ME. Communication loads on clinical staff in the emergency department. Medical Journal of Australia. 2002;176(9):415-8.

50. Leape LL, Brennan TA, Laird N, Lawthers AG, Localio AR, Barnes BA, et al. The nature of adverse events in hospitalized patients. Results of the Harvard Medical Practice Study II. N Engl J Med. 1991;324(6):377-84.

51. Croskerry P, Sinclair D. Emergency medicine: A practice prone to error? Cjem. 2001;3(4):271-6.

52. Burström L. Patient Safety in the Emergency Department - Culture, Waiting and Outcomes of Efficiency and Quality [PhD]. Uppsala, Sweden: Uppsala University, Sweden; 2014.

53. Källberg A-S. Patient Safety in the Emergency Department - Errors, Interruptions and Staff Experience [PhD]. Solna, Sweden: Karolinska Institutet, Stockholm, Sweden; 2015.

54. Pines JM, Hilton JA, Weber EJ, Alkemade AJ, Al Shabanah H, Anderson PD, et al. International perspectives on emergency department crowding. Academic emergency medicine : official journal of the Society for Academic Emergency Medicine. 2011;18(12):1358-70.

55. Stead LG, Jain A, Decker WW. Emergency department over-crowding: a global perspective. International journal of emergency medicine. 2009;2(3):133-4.

56. Derlet RW, Richards JR, Kravitz RL. Frequent Overcrowding in U.S. Emergency Departments. Academic Emergency Medicine; 2001.

57. Cheng IS. Emergency department crowding and hospital patient flow : influential factors and evidence-informed solutions [Doctoral]. Stockholm, Sweden: Karolinska Institutet; 2016.

58. van der Linden C. Emergency Departement Crowding - factors influencing flow: University of Amsterdam; 2015.

59. Boyle A, Beniuk K, Higginson I, Atkinson P. Emergency department crowding: time for interventions and policy evaluations. Emerg Med Int. 2012;2012:838610.

60. Kocher KE, Asplin BR. Emergency department crowding 2.0: coping with a dysfunctional system. Annals of emergency medicine. 2012;60(6):687-91.

61. Perdahl T, Axelsson S, Svensson P, Djarv T. Patient and organizational characteristics predict a long length of stay in the emergency department - a Swedish cohort study. European journal of emergency medicine : official journal of the European Society for Emergency Medicine. 2015.

62. van der Linden N, van der Linden MC, Richards JR, Derlet RW, Grootendorst DC, van den Brand CL. Effects of emergency department crowding on the delivery of timely care in an inner-city hospital in the Netherlands. European journal of emergency medicine : official journal of the European Society for Emergency Medicine. 2016;23(5):337-43.

63. Bernstein SL, Aronsky D, Duseja R, Epstein S, Handel D, Hwang U, et al. The effect of emergency department crowding on clinically oriented outcomes. Academic emergency medicine : official journal of the Society for Academic Emergency Medicine. 2009;16(1):1-10.

64. Pines JM, Pollack CV, Jr., Diercks DB, Chang AM, Shofer FS, Hollander JE. The association between emergency department crowding and adverse cardiovascular outcomes in patients with chest pain. Academic emergency medicine : official journal of the Society for Academic Emergency Medicine. 2009;16(7):617-25.

65. Eriksson J, Gellerstedt L, Hilleras P, Craftman AG. Registered nurses' perceptions of safe care in overcrowded emergency departments. Journal of clinical nursing. 2017.

66. Bellow AA, Jr., Gillespie GL. The evolution of ED crowding. Journal of emergency nursing: JEN : official publication of the Emergency Department Nurses Association. 2014;40(2):153-60.

67. World Health Organization. Overcrowding - making a difference 2003 [Available from: http://www.who.int/ceh/indicators/overcrowding.pdf.

68. Australasian College for Emergency Medicine (ACEM). Statement on emergency department overcrowding 2011 [Available from: https://acem.org.au/getmedia/dd609f9a-9ead-473d-9786-d5518cc58298/S57-Statement-on-ED-Overcrowding-Jul-11-v02.aspx.

69. Canadian Association of Emergency Physicians/National Emergency Nurses Affiliation. Joint Position Statement on emergency department overcrowding. Cjem. 2001;3(2):82-8.

70. The Royal College of Emergency Medicine. Tackling Emergency Department Crowding 2015 [Available from: https://www.rcem.ac.uk/docs/College%20Guidelines/5z23.%20ED%20crowding%20overview%20and%20toolkit%20(Dec%202015).pdf.

71. Hwang U, Concato J. Care in the emergency department: how crowded is overcrowded? Academic emergency medicine : official journal of the Society for Academic Emergency Medicine. 2004;11(10):1097-101.

72. Tadjerbashi K, Khoshnood A, Nordberg M, Ekelund U. ["Overload of the emergency department" - a Swedish definition is needed]. Lakartidningen. 2012;109(16):792-3.

73. McCarthy ML, Aronsky D, Jones ID, Miner JR, Band RA, Baren JM, et al. The emergency department occupancy rate: a simple measure of emergency department crowding? Annals of emergency medicine. 2008;51(1):15-24, e1-2.

74. Epstein SK, Tian L. Development of an emergency department work score to predict ambulance diversion. Academic emergency medicine : official journal of the Society for Academic Emergency Medicine. 2006;13(4):421-6.

75. Bernstein SL, Verghese V, Leung W, Lunney AT, Perez I. Development and validation of a new index to measure emergency department crowding. Academic emergency medicine : official journal of the Society for Academic Emergency Medicine. 2003;10(9):938-42.

76. Weiss SJ, Derlet R, Arndahl J, Ernst AA, Richards J, Fernandez-Frackelton M, et al. Estimating the degree of emergency department overcrowding in academic medical centers: results of the National ED Overcrowding Study (NEDOCS). Academic emergency medicine : official journal of the Society for Academic Emergency Medicine. 2004;11(1):38-50.

77. Reeder TJ, Garrison HG. When the safety net is unsafe: Real-time assessment of the overcrowded emergency department. Academic Emergency Medicine. 2001;8(11):1070-4.

78. Asplin BR RK, Flottemesch TJ, et al. Is this emergency department crowded? A multicenter derivation and evaluation of an emergency department crowding scale (EDCS). . Academic emergency medicine : official journal of the Society for Academic Emergency Medicine. 2004;11:484-5.

79. Wretborn J, Khoshnood A, Wieloch M, Ekelund U. Skane Emergency Department Assessment of Patient Load (SEAL)-A Model to Estimate Crowding Based on Workload in Swedish Emergency Departments. PloS one. 2015;10(6):e0130020.

80. Campbell P, Boyle A, Higginson I. Should we scrap the target of a maximum four hour wait in emergency departments? Bmj-British Medical Journal. 2017;359.

81. The National Board of Health and Welfare. Väntetider vid sjukhusbundna akutmottagningar (Waiting times at hospital-based emergency departements) - Report December 2013. The National Board of Health and Welfare; 2013 2013-12-11.

82. The National Board of Health and Welfare. Uppföljning av väntetider vid sjukhusbundna akutmottagningar - delrapport april 2013 (Follow-up on waiting times at hospital-based emergency departments - progress report April 2013). Socialstyrelsen; 2013.

83. Aiken LH, Sloane DM, Bruyneel L, Van den Heede K, Griffiths P, Busse R, et al. Nurse staffing and education and hospital mortality in nine European countries: a retrospective observational study. Lancet. 2014;383(9931):1824-30.

84. Asplin BR. Measuring crowding: time for a paradigm shift. Academic emergency medicine : official journal of the Society for Academic Emergency Medicine. 2006;13(4):459-61.

85. Asplin BR, Magid DJ, Rhodes KV, Solberg LI, Lurie N, Camargo CA, Jr. A conceptual model of emergency department crowding. Annals of emergency medicine. 2003;42(2):173-80.

86. The County Council auditors in Stockholm County Council. Framtidens hälso- och sjukvård - planering och genomförande 2016 (Future healthcare - planning and implementation 2016). 2016 December 2016. Report No.: Projektrapport nr 12/2016.

87. The Swedish Association of Local Authorities and Regions. Ingen på sjukhus i onödan - Hur kan vi tillsammans minimera överbeläggningar och utlokaliseringar för patientens bästa (Nobody in hospital unnecessarily - How can we minimize extra admissions overcapacity and relocations for the patient's best). Swedish Association of Local Authorities and Regions; 2016 2016-09-14.

88. The Swedish Association of Local Authorities and Regions. Statistik om hälso- och sjukvård samt regional utveckling 2015 - Verksamhet och ekonomi i landsting och regioner (Statistics on healthcare and regional development 2015 - Function and economics in county councils and regions). The Swedish Association of Local Authorities and Regions; 2016.

89. Schuur JD, Venkatesh AK. The growing role of emergency departments in hospital admissions. N Engl J Med. 2012;367(5):391-3.

90. The National Board of Health and Welfare. Statistik om väntetider och besök vid sjukhusbundna akutmottagningar 2017 (Statistics on waiting times and visits at hospital-based emergency departments 2017). 2018 2018-09-18. Report No.: Art.nr: 2018-9-18.

91. The National Board of Health and Welfare. Tillgänglighet i hälso- och sjukvården (The availability to healthcare). The National Board of Health and Welfare; 2018.

92. The Swedish Council on Health Technology Assessment. Omhändertagande av äldre som inkommer akut till sjukhus – med fokus på sköra äldre, en litteraturöversikt (Care of elderly who arrive urgently to hospital - focusing on fragile elderly people, a literature review). The Swedish Council on Health Technology Assessment; 2013. Report No.: 221.

93. United Nations Population Fund. United Nations Population Fund - Ageing 2018 [Available from: https://www.unfpa.org/ageing.

94. World Health Organization. Global strategy and action plan on ageing and health 2016-2020. 2017. Report No.: 978-92-4-151350-0.

95. Clegg A, Young J, Iliffe S, Rikkert MO, Rockwood K. Frailty in elderly people. Lancet. 2013;381(9868):752-62.

96. Forsberg HH, Athlin AM, von Thiele Schwarz U. Nurses' perceptions of multitasking in the emergency department: Effective, fun and unproblematic (at least for me) - a qualitative study. Int Emerg Nurs. 2014.

97. Kalisch BJ, Aebersold M. Interruptions and multitasking in nursing care. Jt Comm J Qual Patient Saf. 2010;36(3):126-32.

98. Skaugset LM, Farrell S, Carney M, Wolff M, Santen SA, Perry M, et al. Can You Multitask? Evidence and Limitations of Task Switching and Multitasking in Emergency Medicine. Annals of emergency medicine. 2016;68(2):189-95.

99. Walter SR, Li L, Dunsmuir WTM, Westbrook JI. Managing competing demands through task-switching and multitasking: a multi-setting observational study of 200 clinicians over 1000 hours. BMJ quality & safety. 2014;23(3):231-41.

100. Weigl M, Muller A, Holland S, Wedel S, Woloshynowych M. Work conditions, mental workload and patient care quality: a multisource study in the emergency department. BMJ quality & safety. 2016;25(7):499-508.

101. Bluedorn AC, Bluedorn AC, Kalliath TJ, Strube MJ, Martin GD. Polychronicity and the Inventory of Polychronic Values (IPV): The development of an instrument to measure a fundamental dimension of organizational culture. 1999;14(3-4).

102. Li SY, Magrabi F, Coiera E. A systematic review of the psychological literature on interruption and its patient safety implications. J Am Med Inform Assoc. 2012;19(1):6-12.

103. Grundgeiger T, Sanderson P. Interruptions in healthcare: theoretical views. Int J Med Inform. 2009;78(5):293-307.

104. Chisholm CD, Dornfeld AM, Nelson DR, Cordell WH. Work interrupted: a comparison of workplace interruptions in emergency departments and primary care offices. Annals of emergency medicine. 2001;38(2):146-51.

105. France DJ, Levin S, Hemphill R, Chen K, Rickard D, Makowski R, et al. Emergency physicians' behaviors and workload in the presence of an electronic whiteboard. International Journal of Medical Informatics. 2005;74(10):827-37.

106. Potter P, Wolf L, Boxerman S, Grayson D, Sledge J, Dunagan C, et al. Understanding the cognitive work of nursing in the acute care environment. J Nurs Adm. 2005;35(7-8):327-35.

107. Weigl M, Muller A, Zupanc A, Glaser J, Angerer P. Hospital doctors' workflow interruptions and activities: an observation study. BMJ quality & safety. 2011;20(6):491-7.

108. Wiegmann DA, ElBardissi AW, Dearani JA, Daly RC, Sundt TM, 3rd. Disruptions in surgical flow and their relationship to surgical errors: an exploratory investigation. Surgery. 2007;142(5):658-65.

109. Colligan L, Guerlain S, Steck SE, Hoke TR. Designing for distractions: a human factors approach to decreasing interruptions at a centralised medication station. BMJ quality & safety. 2012;21(11):939-47.

110. Healey AN, Primus CP, Koutantji M. Quantifying distraction and interruption in urological surgery. Qual Saf Health Care. 2007;16(2):135-9.

111. Andersson AK, Omberg M, Svedlund M. Triage in the emergency department--a qualitative study of the factors which nurses consider when making decisions. Nurs Crit Care. 2006;11(3):136-45.

112. Hwang LY, Huang S, Hsiao SH, Wang MW. [Noise reduction at an emergency intensive care unit of medical center in southern Taiwan]. Hu Li Za Zhi. 2004;51(1):58-69.

113. Morgan L, Robertson E, Hadi M, Catchpole K, Pickering S, New S, et al. Capturing intraoperative process deviations using a direct observational approach: the glitch method. BMJ open. 2013;3(11).

114. Alvarez G, Coiera E. Interruptive communication patterns in the intensive care unit ward round. International Journal of Medical Informatics. 2005;74(10):791-6.

115. Cole G, Stefanus D, Gardner H, Levy MJ, Klein EY. The impact of interruptions on the duration of nursing interventions: a direct observation study in an academic emergency department. BMJ quality & safety. 2016;25(6):457-65.

116. Collins S, Currie L, Patel V, Bakken S, Cimino JJ. Multitasking by clinicians in the context of CPOE and CIS use. Stud Health Technol Inform. 2007;129(Pt 2):958-62.

117. Edwards A, Fitzpatrick LA, Augustine S, Trzebucki A, Cheng SL, Presseau C, et al. Synchronous communication facilitates interruptive workflow for attending physicians and nurses in clinical settings. Int J Med Inform. 2009;78(9):629-37.

118. Fairbanks RJ, Bisantz AM, Sunm M. Emergency department communication links and patterns. Annals of emergency medicine. 2007;50(4):396-406.

119. Fong A, Ratwani RM. Understanding Emergency Medicine Physicians Multitasking Behaviors Around Interruptions. Academic emergency medicine : official journal of the Society for Academic Emergency Medicine. 2018;25(10):1164-8.

120. Jeanmonod R, Boyd M, Loewenthal M, Triner W. The nature of emergency department interruptions and their impact on patient satisfaction. Emergency medicine journal : EMJ. 2010;27(5):376-9.

121. Liu D, Grundgeiger T, Sanderson PM, Jenkins SA, Leane TA. Interruptions and blood transfusion checks: lessons from the simulated operating room. Anesth Analg. 2009;108(1):219-22.

122. Myers RA, McCarthy MC, Whitlatch A, Parikh PJ. Differentiating between detrimental and beneficial interruptions: a mixed-methods study. BMJ quality & safety. 2016;25(11):881-8.

123. Rivera-Rodriguez AJ, Karsh BT. Interruptions and distractions in healthcare: review and reappraisal. Qual Saf Health Care. 2010;19(4):304-12.

124. Weigl M, Muller A, Vincent C, Angerer P, Sevdalis N. The association of workflow interruptions and hospital doctors' workload: a prospective observational study. BMJ quality & safety. 2012;21(5):399-407.

125. Westbrook JI, Coiera E, Dunsmuir WT, Brown BM, Kelk N, Paoloni R, et al. The impact of interruptions on clinical task completion. Qual Saf Health Care. 2010;19(4):284-9.

126. Woloshynowych M, Davis R, Brown R, Vincent C. Communication patterns in a UK emergency department. Annals of emergency medicine. 2007;50(4):407-13.

127. Brixey JJ, Robinson DJ, Turley JP, Zhang J. Initiators of interruption in workflow: the role of MDs and RNs. Information Technology in Health Care 2007;130:103-9.

128. Johnson KD, Alhaj-Ali A. Using Simulation to Assess the Impact of Triage Interruptions. Journal of Emergency Nursing. 2017;43(5):435-43.

129. Johnson KD, Gillespie GL, Vance K. Effects of Interruptions on Triage Process in Emergency Department: A Prospective, Observational Study. J Nurs Care Qual. 2018;33(4):375-81.

130. Spencer R, Coiera E, Logan P. Variation in communication loads on clinical staff in the emergency department. Annals of emergency medicine. 2004;44(3):268-73.

131. Berg LM. Interruptions in Emergency Department Work - Causes and Effects. A literature review. [Bachelor of Science]: Dalarna University; 2009.

132. Hopkinson SG, Jennings BM. Interruptions during nurses' work: A state-of-the-science review. Res Nurs Health. 2013;36(1):38-53.

133. Henneman EA, Blank FS, Gawlinski A, Henneman PL. Strategies used by nurses to recover medical errors in an academic emergency department setting. Applied Nursing Research. 2006;19(2):70-7.

134. Einstein GO, McDaniel MA, Williford CL, Pagan JL, Dismukes RK. Forgetting of intentions in demanding situations is rapid. J Exp Psychol Appl. 2003;9(3):147-62.

135. Eyrolle H, Cellier JM. The effects of interruptions in work activity: field and laboratory results. Appl Ergon. 2000;31(5):537-43.

136. Drews FA, editor The freqency and impact of task interruptions on patient safety in the ICU. Human Factors and and Ergonomics Society 51st Annual Meeting; 2007; Baltimore, Maryland, USA.

137. Westbrook JI, Gosling AS, Coiera EW. The impact of an online evidence system on confidence in decision making in a controlled setting. Medical Decision Making. 2005;25(2):178-85.

138. Grundgeiger T, Sanderson P, MacDougall HG, Venkatesh B. Interruption management in the intensive care unit: Predicting resumption times and assessing distributed support. J Exp Psychol Appl. 2010;16(4):317-34.

139. Polit DF, Beck CT. Nursing Research - Generating and Assessing Evidence for Nursing Practice. 10th ed. Philadelphia, USA: Wolters Kluwer Health / Lippincott Williams & Wilkins; 2017.

140. Wireklint SC, Elmqvist C, Parenti N, Goransson KE. A descriptive study of registered nurses' application of the triage scale RETTS(c); a Swedish reliability study. Int Emerg Nurs. 2018.

141. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. Journal of chronic diseases. 1987;40(5):373-83.

142. Brixey JJ, Robinson DJ, Turley JP, Zhang J. The roles of MDs and RNs as initiators and recipients of interruptions in workflow. Int J Med Inform. 2010;79(6):e109-15.

143. Krippendorff K. Content analysis: an introduction to its methodology. Second ed. Thousand Oaks, California, USA: Sage Publications, Inc.; 2004.

144. The National Board of Health and Welfare. Väntetider vid sjukhusbundna akutmottagningar (Waiting times at hospital-based emergency departments). The National Board of Health and Welfare; 2011 2011-03-30.

145. Kreindler SA, Cui Y, Metge CJ, Raynard M. Patient characteristics associated with longer emergency department stay: a rapid review. Emergency medicine journal : EMJ. 2016;33(3):194-9.

146. The Swedish Council on Health Technology Assessment. Triage och flödesprocesser på akutmottagning (Triage and patient flow processes in the emergency department). The Swedish Council on Health Technology Assessment; 2010 2010-03-24.

147. The Health and Social Care Inspectorate. I väntan på vårdplats - Om patientsäkerhet på akutmottagningar (While waiting for an in-hospital admisson - about patient safety in emergency departments). The Health and Social Care Inspectorate; 2018 March 2018. Report No.: IVO 2018-2.

148. Gary Jones RE, Robert Crouch. Emergency Nursing Care Principles and Practice. London: Greenwich Medical Media Limited; 2003.

149. Berg LM, Florin J, Ehrenberg A, Ostergren J, Djarv T, Goransson KE. Reasons for interrupting colleagues during emergency department work - A qualitative study. Int Emerg Nurs. 2016.

150. Berg LM, Kallberg AS, Ehrenberg A, Florin J, Ostergren J, Djarv T, et al. Factors influencing clinicians' perceptions of interruptions as disturbing or non-disturbing: A qualitative study. Int Emerg Nurs. 2016.

151. Coiera E. The science of interruption. BMJ quality & safety. 2012;21(5):357-60.

152. McGillis Hall L, Pedersen C, Hubley P, Ptack E, Hemingway A, Watson C, et al. Interruptions and pediatric patient safety. J Pediatr Nurs. 2010;25(3):167-75.

153. Cook RI, Render M, Woods DD. Gaps in the continuity of care and progress on patient safety. Bmj. 2000;320(7237):791-4.

154. Obermeyer Z, Cohn B, Wilson M, Jena AB, Cutler DM. Early death after discharge from emergency departments: analysis of national US insurance claims data. Bmj. 2017;356:j239.

155. Mills AM, Shofer FS, Chen EH, Hollander JE, Pines JM. The association between emergency department crowding and analgesia administration in acute abdominal pain patients. Academic emergency medicine : official journal of the Society for Academic Emergency Medicine. 2009;16(7):603-8.

156. Kulstad EB, Sikka R, Sweis RT, Kelley KM, Rzechula KH. ED overcrowding is associated with an increased frequency of medication errors. The American journal of emergency medicine. 2010;28(3):304-9.

157. Ball JE, Griffiths P, Rafferty AM, Lindqvist R, Murrells T, Tishelman C. A cross-sectional study of 'care left undone' on nursing shifts in hospitals. Journal of advanced nursing. 2016;72(9):2086-97.

158. Ball JE, Murrells T, Rafferty AM, Morrow E, Griffiths P. 'Care left undone' during nursing shifts: associations with workload and perceived quality of care. BMJ quality & safety. 2014;23(2):116-25.

159. Ball JE, Bruyneel L, Aiken LH, Sermeus W, Sloane DM, Rafferty AM, et al. Post-operative mortality, missed care and nurse staffing in nine countries: A cross-sectional study. International journal of nursing studies. 2017.

160. Göransson KE, Ehnfors M, Fonteyn ME, Ehrenberg A. Thinking strategies used by Registered Nurses during emergency department triage. Journal of advanced nursing. 2008;61(2):163-72.

161. Brixey JJ, Robinson DJ, Johnson CW, Johnson TR, Turley JP, Patel VL, et al. Towards a hybrid method to categorize interruptions and activities in healthcare. International Journal of Medical Informatics. 2007;76(11-12):812-20.

162. Chisholm CD, Weaver CS, Whenmouth L, Giles B. A Task Analysis of Emergency Physician Activities in Academic and Community Settings. Annals of emergency medicine. 2011.

163. Hobgood C, Villani J, Quattlebaum R. Impact of emergency department volume on registered nurse time at the bedside. Annals of emergency medicine. 2005;46(6):481-9.

12 APPENDIX 1. DATA COLLECTION PROTOCOL OBSERVATIONS

Data collector: ____________________

Date of observation: ____________________

Start of observation: ____________________

End of observation: ____________________

Observed clinician: ____________________

Physician/RN/LPN: ____________________

Level of competence: ____________________

Place of observation: ____________________

Row No	Performed assignment by the clinician	Start time for the assignment	Involved in the assignment, person, place	Interruption Y = Yes N=No	Who or what interrupts	Recipient or Initiator of interruption	End time for the assignment	Break-in-task? X=Yes	Observed error? X=Yes
1									
2									
3									
4									
5									