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ADVERSE EVENTS FOLLOWING SURGERY OF THE HIP

Martin Magnéli

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Adverse events following surgery of the hip

THESIS FOR DOCTORAL DEGREE (Ph.D.)

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For Sara, Frans, Ebbe and Harry

ABSTRACT

Introduction

An adverse event (AE) is when a patient is harmed in healthcare. There are many different definitions of AEs and internationally, many different definitions are used. It may seem obvious that the healthcare should not harm the patients, but nevertheless, over one million patients die each year because of AE following surgical care, globally.

This thesis is dedicated to study AEs following acute and elective hip surgery. It consists of four different papers from two studies: The fast-track study and the VARA (Validation of Register Data After Hip Arthroplasty)-study. The overall aim of this thesis was to compare two fast-track systems for hip fracture patients, to validate an instrument for measuring AEs following hip arthroplasty surgery, to study AE claims and to create a new model for measuring AEs following hip arthroplasty surgery.

Paper I, the fast-track study

The aim of this paper was study if the implementation of a new fast-track system for hip fracture patients could reduce the time from arrival at the hospital to the commencement of surgery. We included 415 consecutive hip fracture patients participating in two parallel fast-track systems in this prospective cohort study. Main outcomes were time to surgery and the proportion of patients that underwent surgery within 24 hours, secondary outcomes were number of AEs and mortality. The patients in the improved fast-track group had in mean three hours shorter time to surgery and there were a 13-percentage difference in the proportion of patients operated within 24 hours.

The VARA-study papers II to IV

Paper II

The aim of this paper was to validate a Swedish instrument for measuring AEs following hip arthroplasty surgery and to calculate the incidence of AEs. In this Swedish multicentre study we included 2,000 acute and elective hip arthroplasty patients and performed retrospective record review (RRR) on all medical records, on all admissions and unplanned out-patient visits within 90 days after surgery. The results were used for validation of the AE measure instrument. The instrument is based on diagnosis codes in the patient register. We also calculated the adjusted cumulative incidence of AEs. The 30-day sensitivity was 6% and specificity 95% for the AE measure instrument. The adjusted cumulative 30-day incidence was 28% for all patients, and 51% and 17% for the acute and the elective patients, respectively.

Paper III

The aim of this paper was to study the proportion of patients with an AE from paper II that also had an accepted claim from the mutual insurance company of the county councils (Löf).

The patients in the VARA-study were matched against Löf's records and the proportion of patients with a major preventable AE that had an accepted claim was calculated. The proportion was 7%. 94% of the claims were approved and received compensation. The proportion of accepted claims was higher for the elective patients compared with the acute patients.

Paper IV

The aim for this paper develop a new model to predict AEs following hip arthroplasty surgery. The dataset from the VARA-study was used to train and evaluate different statistical models for predicting AEs. Different machine learning models including neural networks were used. The best performing model was a logistic regression model including the variables age, length of stay for the primary admission, number of readmissions and accident and emergency department (A&E) visits. It was compared with the AE measure instrument from paper II, a model based on diagnosis codes. The new model had two to three times better sensitivity and the same specificity as the diagnosis code-based model.

Conclusions

Paper I

An improved fast-track system that bypasses the A&E could reduce the time to hip fracture surgery by 3 hours and the proportion of patients who underwent surgery within 24 hours. The fast-track system could be performed in a safe way but did not affect mortality or the number of AEs.

Paper II

The cumulative incidence of AEs following hip arthroplasty surgery was high, and the instrument based on administrative data with diagnosis codes could not measure this incidence with any convincing accuracy. Furthermore, the incidence of AEs was much higher for the acute patients than the elective patients, and only approximately half of the identified AEs had a correct diagnosis code.

Paper III

The proportion of accepted claims for AEs following hip arthroplasty is very low in Sweden, even for obvious and serious AEs such as periprosthetic joint infection. The proportion of accepted claims is higher for elective than acute patients. Whether the healthcare system fails to inform patients about their rights to file a claim for compensation or the patients are informed but choose not to file a claim is unknown.

Paper IV

A prediction model for AEs following hip arthroplasty surgery based on administrative data without diagnosis codes is more accurate than a model based on diagnosis codes. In addition to the accuracy variables such as LOS, readmissions, gender and age are robust and objective and, therefore, not prone to bias in a manner similar to diagnosis codes.

LIST OF SCIENTIFIC PAPERS

The fast-track study

I. **'Straight to bed' for hip-fracture patients: A prospective observational cohort study of two fast-track systems in 415 hips.**
Martin Eriksson, Paula Kelly-Pettersson, André Stark, Anna K. Ekman, Olof Sköldenberg

Injury, International Journal of the Care of the Injured; 43 (2012) 2126-2131

The VARA-study

II. **Validation of adverse events after hip arthroplasty: a Swedish multicentre cohort study.**

Martin Magnéli, Maria Unbeck, Cecilia Rogmark, Ola Rolfson, Ami Hommel, Bodil Samuelsson, Kristina Schildmeijer, Desirée Sjöstrand, Max Gordon, Olof Sköldenberg

BMJ Open. 2019 Mar 7;9(3):e023773

III. **Only 7% of preventable major adverse events after hip-arthroplasty surgery are filed as claims. A multi-centre cohort study on 1998 patients.**

Martin Magnéli, Maria Unbeck, Bodil Samuelsson, Cecilia Rogmark, Ola Rolfson, Max Gordon, Olof Sköldenberg

Manuscript accepted for publication in Acta Orthopaedica

IV. **A model for predicting adverse events following hip arthroplasty surgery using administrative data without ICD-codes.**

Martin Magnéli, Maria Unbeck, Cecilia Rogmark, Olof Sköldenberg, Max Gordon

Manuscript

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LIST OF ABBREVIATIONS

A&E = Accident and Emergency department

AI = Artificial Intelligence

AE = Adverse Event

AO = Arbeitsgemeinschaft für Osteosynthesefragen

ASA = American Society of Anesthesiologists

DOAC = Direct Oral AntiCoagulants

GTT = Global Trigger Tool

ICD = International Classification of Diseases

LOS = Length Of Stay

Löf = Landstingens ömsesidiga försäkringsbolag (The mutual insurance company of the county councils)

NPR = National Patient Register

PJI = Periprosthetic Joint Infection

RRR = Retrospective Record Review

SHAR = Swedish Hip Arthroplasty Register

SSI = Surgical Site Infection

WHO = World Health Organization

INTRODUCTION

Hip arthroplasty

The first known extensive surgery of the hip was performed in 1821 by Anthony White in London, England. The operation was an excision arthroplasty where the head of the femur was removed. The patient survived 12 years after the surgery (1). The first hip arthroplasty was performed by Professor Glück in 1891 (2). The implant consisted of an ivory ball replacing the femoral head. Glück performed many hip arthroplasties, which were successful in the short term but ultimately failed due to aseptic loosening or postoperative infection. The next big step in the evolution of hip arthroplasties was the Austin Moore arthroplasty, which consisted of a large metal head connected to a stem that was placed in the femoral shaft (3).

The father of the modern total hip arthroplasty is John Charnley (4). He started to develop a metal stem that was cemented in the femur with acrylic bone cement and hinged against a polyethylene cup replacing the acetabulum. The success of this concept was the low friction achieved by the small diameter metal head against the polyethylene. John Charnley was knighted for his contributions to humanity in 1977. The total hip arthroplasty has been declared the operation of the century (5).

The modern hip arthroplasty can be divided in the hemi and total arthroplasty. The hemiarthroplasty is a surgical implant that replaces the proximal part of the femur (Figure 1). A stem is inserted in the diaphysis of the femur and a steel ball replaces the native femoral head. The steel head articulates against the native acetabulum. This type of arthroplasty is most commonly used to treat hip fracture patients because it is a shorter and less extensive type of surgery with a low rate of dislocation.

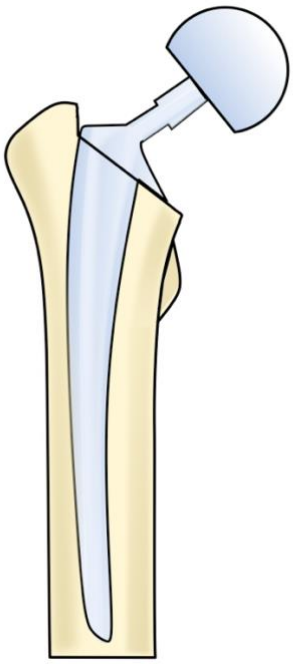


Figure 1, Hemi arthroplasty.

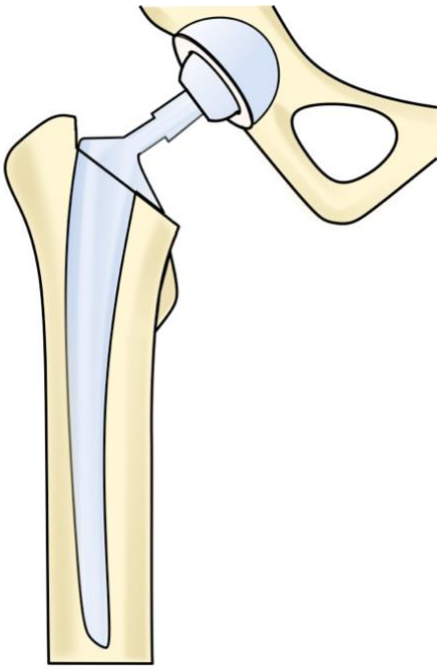


Figure 2, Total arthroplasty.

The total arthroplasty replaces both the proximal part of the femur and the acetabulum. The design can be seen as an extension of the hemiarthroplasty with a stem inserted in the diaphysis of the femur. Instead of a steel ball of the same size as the native femoral head, a smaller head is articulated against a plastic liner that is either cemented directly in the acetabulum or in a metal cup that is inserted in the acetabulum (Figure 2). Total hip arthroplasties are used for the treatment of both degenerative joint diseases and hip fractures.

Osteosynthesis

Fracture surgeries have been performed since the middle ages. In 1928, a humerus dated between 1150 to 1527 with a healed fracture was found in an abbey in Varnhem, Sweden (6). The fracture had been internally fixated with a copper plate wrapped around the fracture and riveted together. The aseptic properties of the copper prevented infection, and the fracture had healed, demonstrating that the patient had survived the surgery for a period of time.

In more recent times, the term osteosynthesis (union of a fracture with implants) was proposed by Albin Lambotte in the early 20th century. Lambotte performed the first known modern internal fixation of a tibia fracture with a homemade metal plate. Lambotte was a skilled surgeon and constructor of both surgical implants and violins! Further progress in the treatment of fractures was made by Gerhard Kuntscher, who invented and explored the potential of intramedullary nails. His method was first met with scepticism in his native Germany, but during World War 2, he could develop and practise his techniques during his placement at the warfront in Finland. Since then, intramedullary nailing has become one of the mainstays of modern fracture surgery.

In 1949, Robert Danis published “Théori et pratique de l’ostéosynthèse”, a seminal work declaring that the main principles for internal fixation are early mobilization of the affected limb, complete restoration of the bone shape and direct bone union without the formation of a callus. This work was highly influential on Muller, who started the Arbeitsgemeinschaft für Osteosynthesefragen (AO) group. The AO group is now the world’s leading institution on fracture surgery (7).

Hip fractures

In Sweden and similar countries, the most common reason for hip fractures is low energy trauma in elderly patients. The mean age for the Swedish hip fracture patient is 82 years (8), and 18,000 patients sustain a hip fracture every year in Sweden. Hip fractures are more common in women (8–11). The one year mortality rate following a hip fracture ranges from 21 to 38% (12–16). A hip fracture is defined as a fracture in the upper quarter of the femur. The fractures can be further divided based on their anatomical location, and treatment is determined after this classification. Fractures are divided into cervical fractures, trochanteric and subtrochanteric fractures based on their anatomical location (Figure 3). The grade of dislocation of cervical fractures are commonly classified with the Garden classification (17). Garden classification is based on the anteroposterior hip radiographs and consists of four stages from undisplaced to totally displaced (Figure 4).

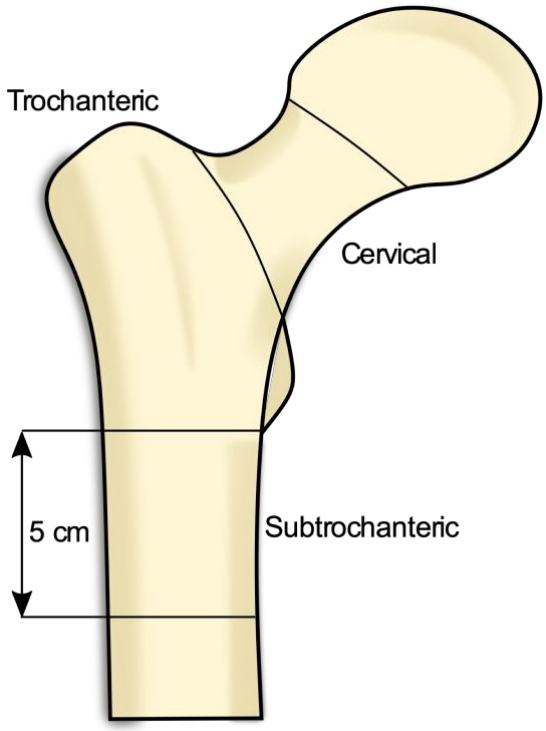


Figure 3, Classification of hip fractures.

Osteosynthesis with screws, plates, and intramedullary nails are an effective way to treat hip fractures. Osteosynthesis is the most common treatment option for per and subtrochanteric fractures as well as undisplaced femoral neck fractures (Garden I & II) (8). The displaced femoral neck fractures (Garden III & IV) are often treated with total or hemiarthroplasty, depending on the age and condition of the patient. Younger patients more often receive a total arthroplasty and older patients often receive a hemiarthroplasty (18,19).

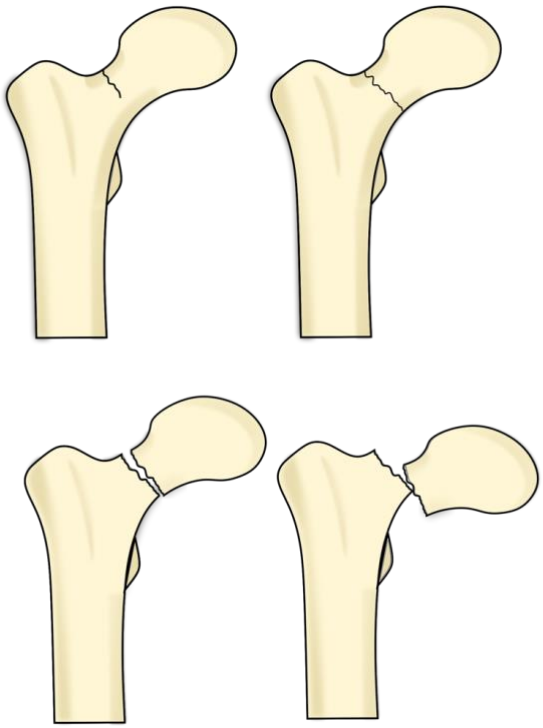


Figure 4, The Garden classification of femoral neck fractures. Clockwise from top left: Garden I to IV.

The impact of waiting time to surgery on hip fracture patients

One of the key modifiable risk factors for hip fracture patients is the waiting time to surgery (20,21). This factor have been studied by numerous studies, but there remains no consensus concerning the optimal cut-off (22–27). Internationally, recommendations varies, and 24 hours is recommended in Sweden (28), 36 hours in the United Kingdom (29) and 48 hours in Canada (30) and the United States (31).

Surgery within 24 hours is a significant cut-off for the 30 day mortality (32,33) but not the 12-month mortality with a significant cut-off of 48 hours (34). When comparing in-hospital mortality, a 24-hour cut-off was associated with lower mortality compared with 48 hours and 12 hours had the lowest mortality rate. Time to surgery also has an impact on adverse events (AEs). Both 24 and 48-hour cut-offs have been reported to have lower rates of different AEs (22,32,35). In addition, there is no evidence that early surgery has any other negative effects (22).

Fast-tracks for hip fracture patients

The concept of fast-tracks in clinical pathways first evolved for myocardial infarcts, a diagnosis for which time is of the essence (36). The aim of the fast-track is to reduce the time from arrival at the hospital to the correct intervention. The success of myocardial infarct fast-tracks have spread to other diagnoses such as stroke (37,38) and also to hip-fractures (39).

The hip process

In 2006, the first fast-track system for managing hip-fracture patients was implemented at Danderyd hospital. The aim for this system was to reduce the waiting time from hospital admission to surgery and to reduce the time spent in the accident and emergency department (A&E). Hip-fracture patients represent an elderly and fragile group, and waiting on a hospital gurney can cause pressure ulcers within 30 minutes (40). The conventional way of managing hip-fractures is that the physician in the A&E examines the patient, ordinates the radiographic examination. After the radiographic examination the patient is transferred to back to the A&E and further to the ward (Figure 5, A).

In the hip process fast-track system, patients with a suspected hip fracture are transferred from the radiology department to the ward (Figure 5, B). After implementation of the hip process, the proportion of patients who had surgery within 24 hours rose from approximately 50 to 75%.

The Ambulance process

During early 2010, a new, improved fast-track system was introduced. It was named the Ambulance process, in which the ambulance personnel transported the patient directly to the radiology department, bypassing the A&E. The ambulance personnel followed a check list when they encountered a patient with a shortened and externally rotated leg and pain from

the hip or groin. If there were doubts concerning the diagnosis or if the patient had multiple fractures, prior surgery of the injured hip, head trauma or life-threatening conditions such as acute myocardial infarction or stroke, the fast-track was abandoned and the ambulance followed their usual protocol.

When the patient was assessed in the radiology department, personnel from the ward met up with the patient and brought a hospital bed for transport to the ward. The on-call physician met up with the patient at the ward (Figure 5, C).

Reducing the time to surgery could possibly reduce AEs.

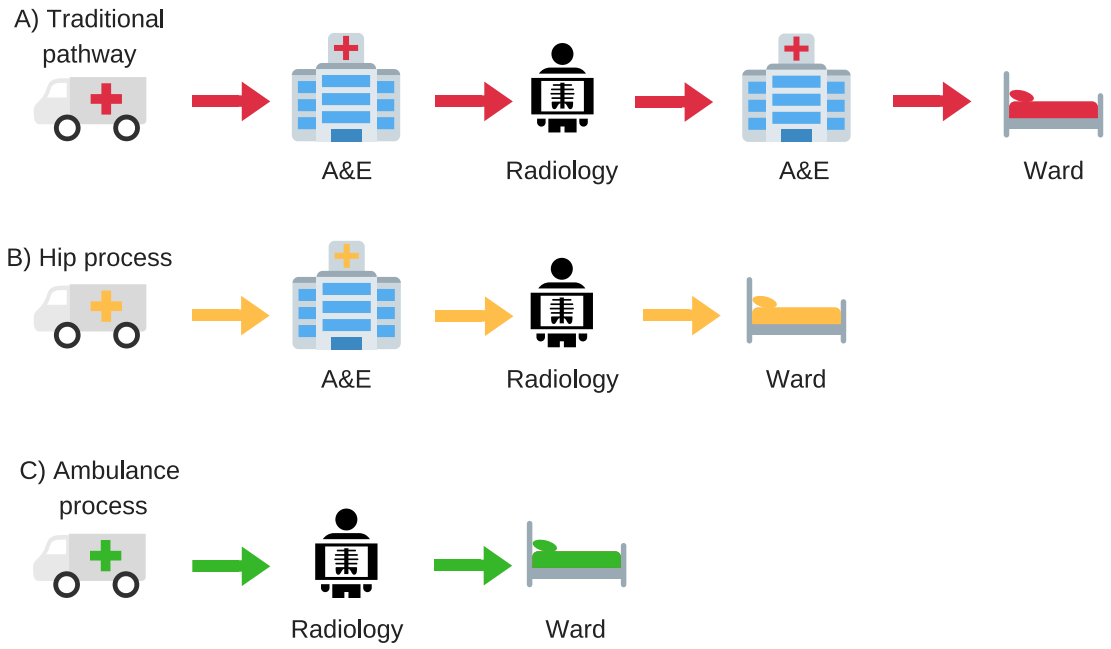


Figure 5, different clinical pathways for hip fracture patients.

Adverse events

Hippocrates, born approximately 460 BC on the Greek island of Kos, is widely known as the father of modern medicine (41).

He was one of the first people to realize that diseases are not caused by gods or superstition but by something found in the natural surroundings. He is famous for coining the Hippocratic oath, which contains principles for persons that practice medicine. The Hippocratic oath is the earliest expression of medical ethics in the western world. It contains the phrase, “Primum non nocere”, “first do no harm”, which could be considered as an early expression of thoughts on AEs.

During the 19th and 20th centuries, healthcare made huge leaps. More advanced surgery could be performed with the aid of ether narcosis developed by the dentist William T. G. Norton in 1846 (42). The discoveries of antiseptic treatment of wounds and surgical instruments with phenol by Joseph Lister in 1867 further enhanced the results after surgery (43).

When the results after surgery improved radically, surgeons started to question themselves when their results sometimes failed. A pioneer in the field of patient safety was Ernest Amory Codman, a surgeon based in Boston (44).

Codman was not only a brilliant shoulder surgeon but also among the first to evaluate the long-term outcomes of patients and to study how different AEs affect the end result. His discoveries led to the world's first mortality and morbidity conference. Like those of many others who are ahead of their time, his work conflicted with his peer's opinions, and he left Massachusetts General Hospital to start his private hospital named The End Result Hospital in 1911.

The range of AEs is vast, with many different definitions and even a nomenclature that is not global or consistent. AEs have many synonyms, such as harm, medical errors, iatrogenic illnesses, critical incidents, mistakes, slips, violations or complications, to mention a few (45). However, the essence of all these synonyms is that the healthcare caused suffering for a patient, which conflicts with the statement, "First do no harm".

Adverse events in orthopaedic surgery

One of the most important publications on patient safety is "To err is human" by the Institute of Medicine (46). Based on studies from hospitals in Utah and Colorado the extrapolated calculated annual death caused by AEs in the USA was 44,000 and based on studies from New York it was 98,000. This publication had a massive impact on patient safety and on the number of published articles concerning patient safety (47).

AE rates in orthopaedic surgery in most studies range from 4.1 to 13.7 (48–53), with the exception of two studies with a rate of 33 and 47 (54,55).

In orthopaedic surgery, studies on AEs have mostly been focused on AEs related to the surgical procedure or implant. Unbeck et al. found the AE rate at our orthopaedic department at Danderyd Hospital to be 16% in a study including 395 patients (56), and that most AEs did not relate to the skill of the surgeon nor the anaesthetist, but rather to the orthopaedic care processes outside the operating room (57). The risk of an AE is higher for trauma patients than for elective patients with a complication rate of 11.4% versus 4.1% (58). Comorbidities can be used as a predictor for AEs. Hip fracture patients with the American Society of Anesthesiologists (ASA, a six point assessment score that developed in the forties as a simple categorization tool for a patient's physiological status to be used for estimating risk connected with surgery (59)) classification 3 to 4 have a 4 to 7 times increased risk of sustaining an AE than those with ASA class 2 (60). The most frequent and important AEs after hip fracture surgery are cognitive and neurological events, cardiopulmonary events, thromboembolism, gastrointestinal bleedings, urinary tract complications, perioperative anaemia, electrolytic and metabolic events and pressure ulcers (61).

Dislocation of the arthroplasty

Dislocation occurs when the head of the arthroplasty extends beyond the cup or the acetabulum (Figure 6), a very painful condition for the patient, who often needs to visit the A&E. The reduction is often performed in the operating room. Dislocation is primarily an early AE, but it can also occur several years after the operation (62). Late dislocations can be caused by wear of the acetabular liner. Other causes of dislocation are poor placement of the implant and other implant factors such as the head size and stem neck angle (63–65).

Patient factors can also influence the risk of dislocation. The greatest patient related risk factor is operation due to hip fracture (66). Another important risk factor is alcohol abuse (67). The reported dislocation rate for the hip fracture patient is between 2 and 16% (68–70). For patients with total hip arthroplasty, the reported dislocation rate is between 2 and 22% (71,72).

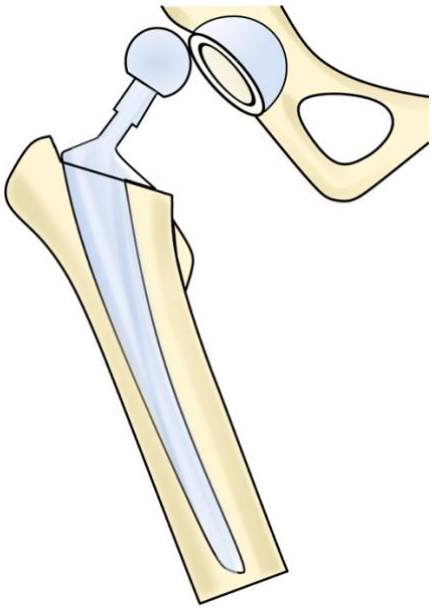


Figure 6, A dislocated total arthroplasty

Surgical site infection

Human skin is colonized with bacteria that can potentially cause wound and soft tissue infections. The definition of a surgical site infection (SSI) must therefore have infection symptoms in addition to the presence of bacteria (73). Superficial SSIs are most common, but the infection can spread deeper and cause a periprosthetic joint infection (PJI). The Musculoskeletal Infection Society created a definition of PJI in 2011, which has been commonly used worldwide (74):

1) There is a sinus tract communicating with the prosthesis; or
2) A pathogen is isolated by culture from at least two separate tissue or fluid samples obtained from the affected prosthetic joint; or
3) Four of the following six criteria exist:

a) Elevated serum erythrocyte sedimentation rate (ESR) and serum C-reactive protein (CRP) concentration,
b) Elevated synovial leukocyte count,
c) Elevated synovial neutrophil percentage (PMN%),
d) Presence of purulence in the affected joint,
e) Isolation of a microorganism in one culture of periprosthetic tissue or fluid, or
f) Greater than five neutrophils per high-power field in five high-power fields observed from histologic analysis of the periprosthetic tissue at 9,400 magnification.

PJIs are almost always in need of surgical treatment and long periods of antibiotic treatment. A PJI can cause great suffering for the affected patient, and many times there is a need for revision surgery in either one or two stages. Between the first and second surgery, the patient is without any implant in the hip. The incidence of PJI after total hip arthroplasty is between 0.2 to 1.6% (75,76). Infections can also be early or late. The most common bacteria in periprosthetic infections are Coagulase Negative Staphylococcus and *Staphylococcus aureus* (77–79).

Measuring adverse events

Structured record review

A structured retrospective record review (RRR) is the most used and therefore most studied method for identifying AEs (80,81). The medical records, including all professionals' notes, are reviewed, and with the use of predefined screening criteria or triggers, AEs are identified. All AE data in this thesis were collected using the structured record review. In paper I, we reviewed the records in a structured way but did not use any specific method, and in papers II to IV, we used the Swedish version (82) of the Global Trigger Tool (83).

Global Trigger Tool

The use of "triggers", which can be described as clues for possible AEs, was introduced by Jick in 1974 (84). This concept was taken further by Classen who used computer software to screen medical records for triggers (85,86). The "flagged" medical records were reviewed manually, searching for AEs. This tool was effective but expensive and required customized computer software for database linkage. Based on Classen´s electronic method the Institute for Healthcare Improvement (IHI) developed a tool for manual record review using triggers, the GTT in 2000 (83). The Swedish adaptation of the GTT named Markörbaserad journalgranskning was developed by the Swedish Association of Local Authorities and Regions (82).

The mutual insurance company of the county councils (Löf)

Löf ("Landstingens Ömsesidiga Försäkringsbolag", "The mutual insurance company of the county councils") insures all publicly financed healthcare in Sweden and is owned by the 21 Swedish regions (87). Löf received more than 17,000 claims for compensation in 2018, of

which 28% concerned AEs caused by orthopaedic care. Löf compensates approximately 40% of the filed claims (87).

Filing a claim is free of charge. The claim to Löf must have been done within three years after the AE was noticeable and a maximum of ten years after contact with the healthcare. Löf can compensate for the loss of income, other expenses, pain and suffering.

The Swedish patient insurance system is regulated by the Swedish Patient Injury Act (88), and the first paragraph states that all healthcare providers must have insurance that covers AEs. The 6th paragraph states the six criteria for an AE to be compensated.

Machine learning

Arthur Samuel published the first paper containing the term machine learning in 1959 (89), the quote "Machine Learning is the field of study that gives computers the ability to learn without being explicitly programmed" is often credited to Samuel, but it has not been published. In his paper, he gazed into the future and predicted "Programming computers to learn from experience should eventually eliminate the need for much of this detailed programming effort".

During the fifties, he developed a computer programme that enabled the computer to learn how to play checkers instead of programming it how to play. This process has evolved into neural networks, artificial intelligence and the subfield of statistical learning.

Statistical and machine learning methods

Bootstrap sampling is a resampling method that was described in 1979 by Bradley Efron (90). Bootstrap samples are smaller samples of the same size that are repeatedly drawn, with replacement from a larger sample (91). Bootstrapping can be used for measures of accuracy, such as variance, bias and confidence intervals. Many other statistical learning methods incorporate some form of resampling method.

Logistic regression is a method for modelling binary outcomes that is credited to David Cox in 1958 (92). Logistic regression is common in medical research (93). Logistic regression models are based on linear regression. The model includes the mathematical constant e (Euler's number) that is raised to the power of a linear model. Linear regression predicts a value of a predictor modelled on the input variables, and logistic regression predicts the probability that a given input belongs to a certain class (91). Splines are mathematical functions that are used to bend a model curve so that it better fits the data, and often used with logistic regression models.

Decision trees can be used for both regression and classification problems. The advantages of Trees are that they are easy to explain, especially graphicly, and that they are intuitive because of the resemblance to human decision-making. Decision trees suffer from high variance. If the data that are used to create the model are divided in two equal parts and used to create two separate models, the results will differ (94).

Random Forests are a machine learning model invented by Leo Breiman and is based on decision trees (95). It includes bootstrap sampling to generate multiple decision trees, each based on a sample of the data. The randomness in the model is derived from that when a decision tree is about to make a split, only a random sample of the variables (often the size of the square root of the total number of variables) are selected and used. It may seem strange discard so much data, but because so many trees are grown all variables will be used and the strong variables will be represented because the end result is the mean classification from all trees (91).

Support vector machines use hyperplanes to separate classes in feature space. A hyperplane in two dimensions is a straight line. In figure 7, the two classes, grey and yellow, can be separated. However, real data are almost never separable, and classes overlap. This is handled by the use of the Kernel trick. This is a way to transform hyperplanes into nonlinear decision boundaries (Figure 8). If a hyperplane in three dimensions resembles a flat paper, it would be a scrunched up paper after the application of the Kernel trick.

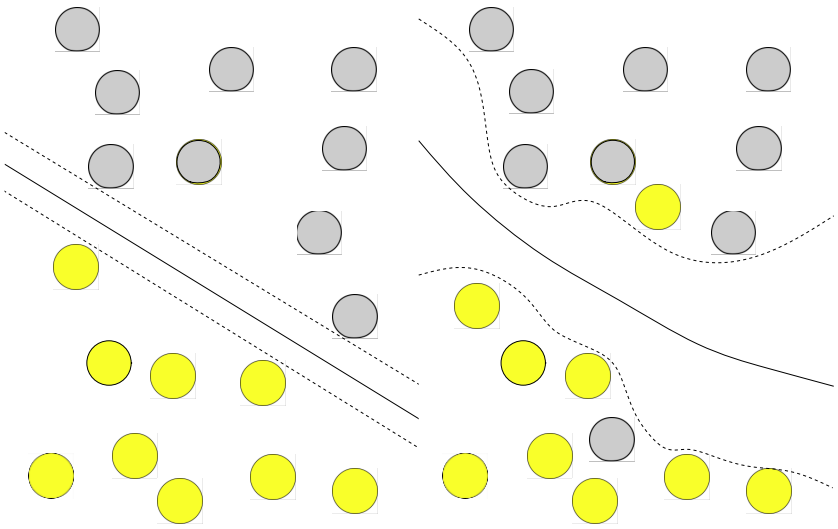


Figure 7, Separating hyperplane. **Figure 8, Nonlinerar separator.**

Neural networks are networks of interconnected nodes that are inspired by the human nervous system (91). The input variables are filtered through one or more hidden layers of neurons and end up in an output layer that generates the result (Figure 9). The first neural network was developed in 1958, but they were not popular because of the limited capacity of early computers (96). Deep neural networks (with many hidden layers) are referred to as “deep learning” or “artificial intelligence” and have been very successful in image translation in recent years (97).

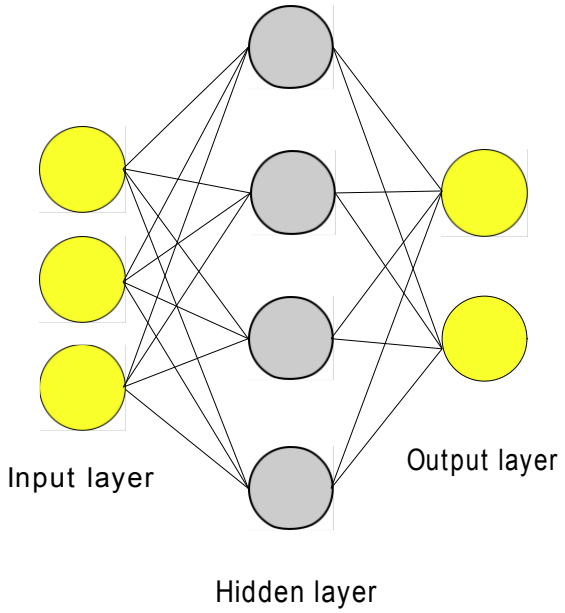


Figure 9, A simple neural network with one hidden layer.

AIMS

The overall aim of this thesis was to compare two fast-track systems, validate an instrument for measuring AEs and AE claims, and create a model for measuring AEs following hip surgery.

Specific aims

Paper I

To study if the implementation of a new fast-track system for hip fracture patients could reduce the time from arrival at the hospital to the commencement of surgery.

Paper II

To validate an instrument for measuring AEs following hip arthroplasty surgery and to calculate the incidence of AEs.

Paper III

To study the proportion of patients that sustained an AE that filed a claim to the mutual insurance company of the county councils (Löf).

Paper IV

To develop a new model for measuring AEs following hip arthroplasty based on administrative data without diagnosis codes.

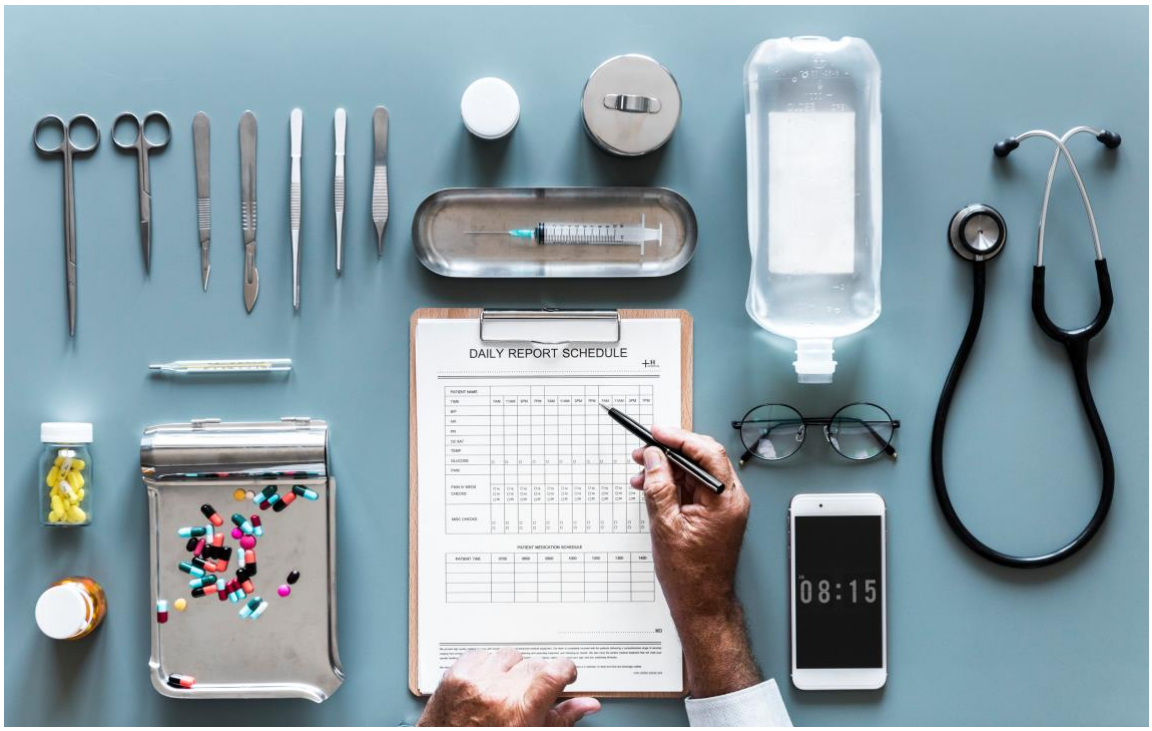
METHODS

Cohorts

This thesis is based on two main studies: the fast-track study and the VARA (Validation of Register Data After Hip Arthroplasty)-study.

The Q-Hip cohort, paper I

The Q-Hip ('Improved Quality of Care for Hip Fracture Patients') cohort is a prospective cohort of hip fracture patients treated at Danderyd hospital between April 2010 to January 2011. The cohort consisted of patients included in one of the two different fast-track systems for hip fracture patients in parallel operations, the hip process and the ambulance process. We included 415 consecutive patients (Figure 10) and performed a structured record review of all medical records up to 90 days after surgery.



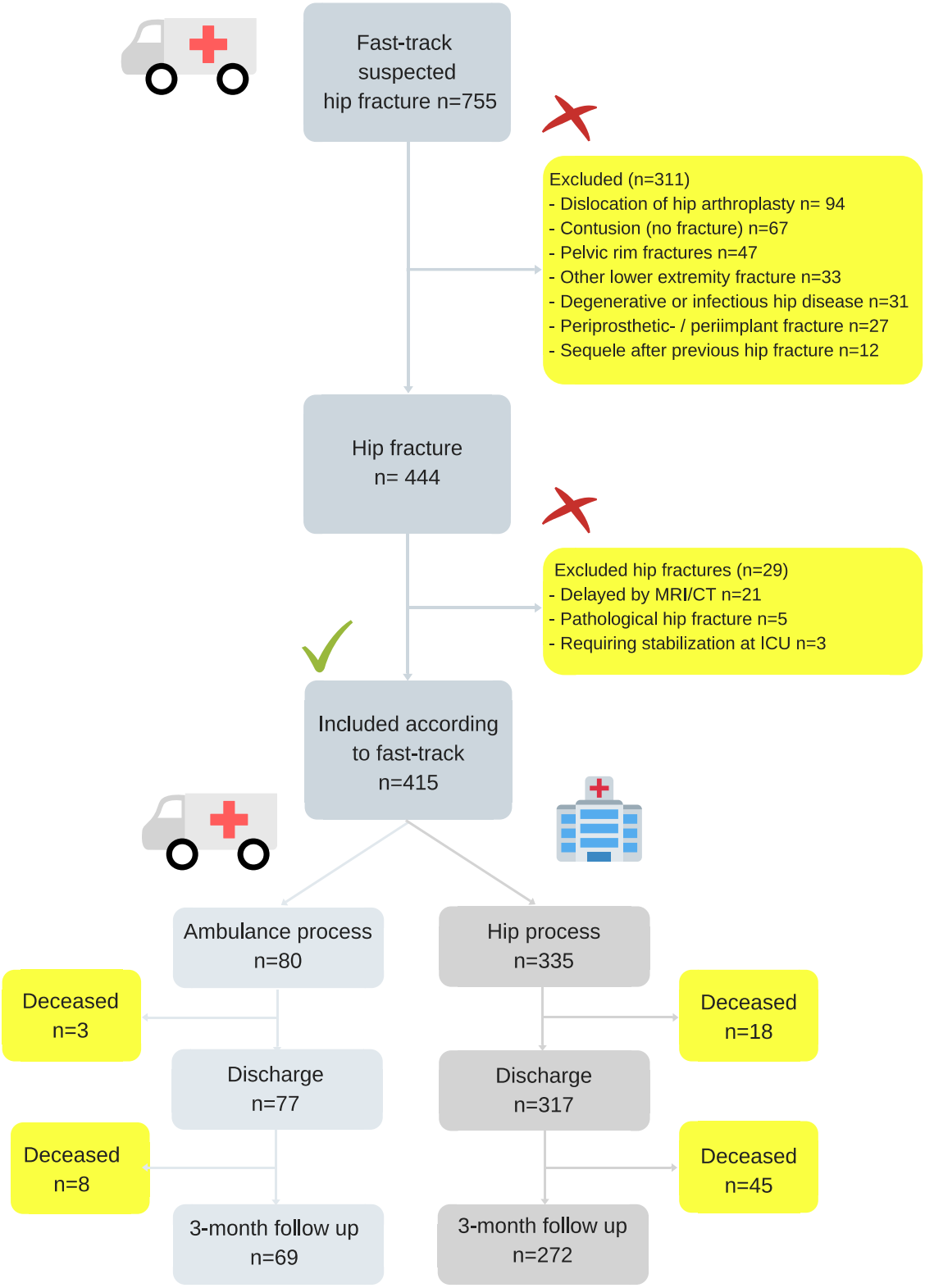


Figure 10, Flowchart of patients in paper I

The VARA-cohort, papers II to IV

The VARA-cohort is a multicentre retrospective cohort designed to validate the Swedish Hip Arthroplasty Register's (SHAR) instrument for measuring AEs after hip arthroplasty. Papers II to IV are all based on this cohort and referred to as the VARA-study. By performing retrospective RRR using the Swedish adaptation of the Global Trigger Tool (GTT) (82) on the medical records of all patients in the cohort, we would obtain the best available results for the incidence of AEs within 90 days after surgery.

The study population consisted of 21,774 patients aged >18 years and registered for a hip arthroplasty in the SHAR between 2009 and 2011 in four major regions in Sweden. Both total and hemi arthroplasties were included in the cohort. Because validation was the main objective, a random sample would only contain 2 to 30% of records with AEs, and the study cohort would be too large to use RRR as the measurement method for AEs. To avoid extensive RRR, we used a weighted sample. The idea was to increase the selection of patients who have sustained an AE. By identifying patient groups with a higher risk of having sustained an AE, we could draw more samples from these groups and increase the probability of selecting these patients.

A longer length of stay is a risk factor for AEs (98–101), and therefore, sampling was performed from three different percentiles for length of stay (0-55%, 56-80%, 81-100%), and more samples were drawn from the higher percentile groups. Readmissions are also a risk factor for AEs (102,103). We created two groups with readmissions within 30 and 90 days after surgery. The five groups were further divided in the case of an international classification of diseases (ICD)-code (104) indicating an AE in the NPR or not. The set of ICD-codes were similar to the set of codes used in the instrument that was validated in paper II. More samples were drawn from the groups that had an ICD-code. This procedure was repeated for both acute and elective patients, resulting in a total of 20 groups (Table 1).

Table 1, Selection groups used for the weighted study cohort

With a predefined ICD-10 code indicating an AE in the NPR

		Acute admissions		Elective admissions	
		Population N	Study cohort n (%)	Population N	Study cohort n (%)
Percentiles of length of stay	0 - 55%	194	11 (5.7)	95	22 (23.2)
	56 - 80%	148	16 (10.1)	58	33 (56.9)
	81 - 100%	302	25 (8.3)	235	49 (20.9)
Readmission	2 - 30 days	274	98 (35.8)	356	196 (55.1)
	31 - 90 days	199	98 (49.3)	204	195 (95.6)

Without a predefined ICD-10 code indicating an AE in the NPR

		Acute admissions		Elective admissions	
		Population, N	Study cohort n (%)	Population, N	Study cohort n (%)
Percentiles of length of stay	0 - 55%	2 859	44 (1.5)	9 769	86 (0.9)
	56 - 80%	1 167	65 (5.6)	2 070	131 (6.3)
	81 - 100%	766	97 (12.7)	1 781	197 (11.1)
Readmission	2 - 30 days	294	147 (50.0)	337	295 (87.5)
	31 - 90 days	341	66 (19.4)	325	129 (39.7)
Total		6 544	667 (10.2)	15 230	1333 (8.8)

AE = adverse event

ICD-10 = the 10th revision of the International Classification of Diseases

NPR = National Patient Register

Cross-linking and data collection

The VARA-cohort was sampled from a study population registered in the Swedish Hip Arthroplasty Register (SHAR). A statistician at the National Board of Health and Welfare performed the crosslinking of the Swedish personal numbers and operation dates from the SHAR with data from the National Patient Register (NPR). Data on the date and type of surgery from the SHAR was combined with NPR data on the admissions that made the index admission and the registered ICD-codes from these admissions.

In addition, we received data from all readmissions and outpatient visits from the NPR for all patients at 90 days after surgery. The personal identity numbers were used to match the NPR data, and a timeline was created with all admissions, readmissions and outpatient visits for each patient. The timelines were used to guide the RRR and ensured that no admissions or outpatient visits were missed.

We performed RRR with GTT on the primary admissions, all readmissions and unplanned outpatient hospital visits (A&E visits) within 90 days after surgery. All discovered AEs were registered in a database and used in papers II to IV (Figure 11).

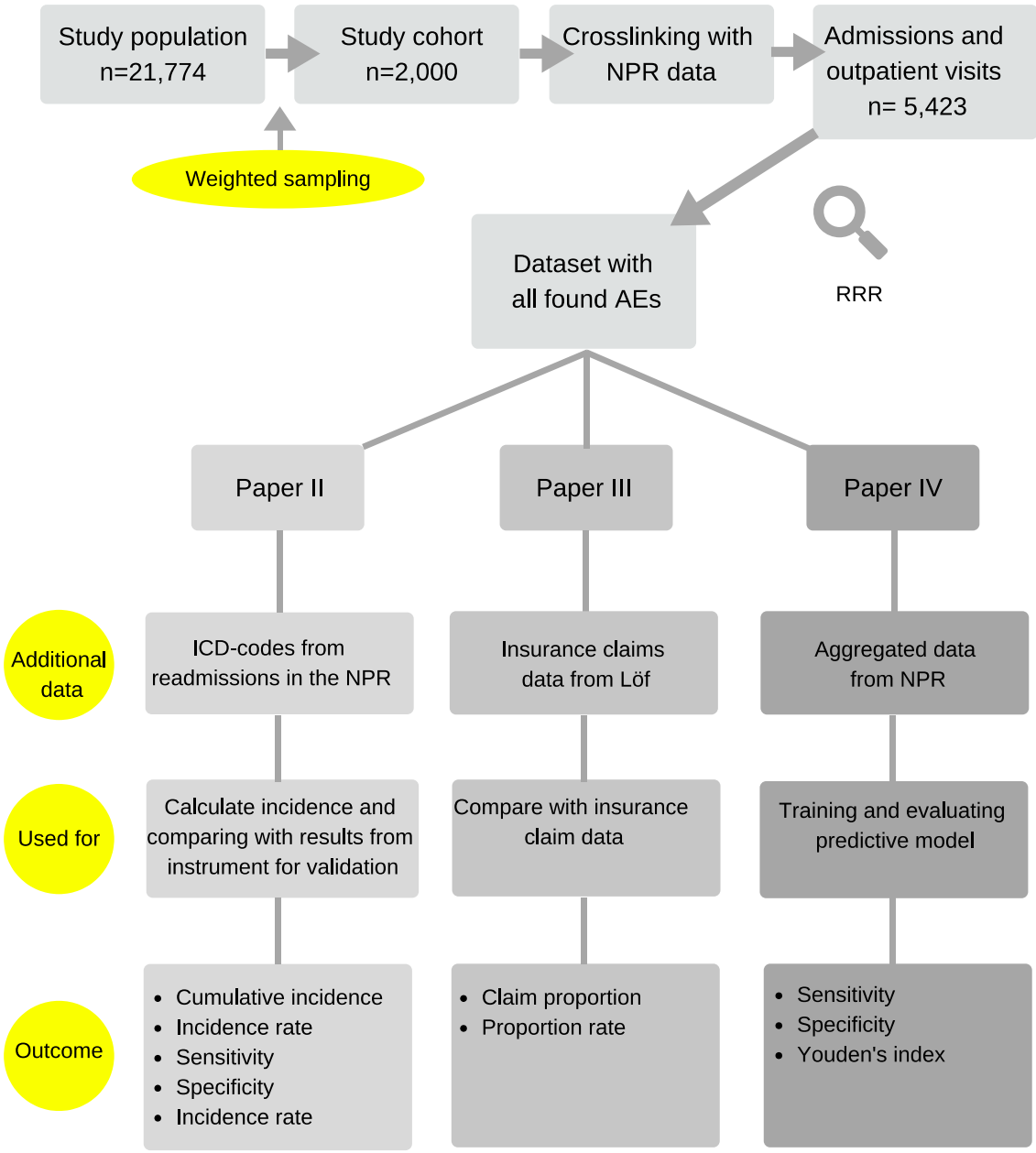


Figure 11, Outline of the papers in the VARA-study

The results from the RRR in the VARA-study were used in papers II to IV.

Paper II

The found AEs were used to calculate the adjusted 90-day cumulative incidence and the incidence rate. The results were used as gold standard during the validation of the instrument. The instrument result was generated with ICD-codes registered in the NPR.

Paper III

The results were used to calculate the rate of accepted filed claims. All patients with a preventable AE were compared with Löf data, and the rate was calculated.

Paper IV

The results and patient data were used to train and evaluate a predictive model.

Data sources

In the fast-track study, the data sources consisted of the admission register from Danderyd Hospital that was used to follow all patients with a suspected hip fracture. The data on time to surgery was a comparison with the time registered at arrival at the A&E and the time registered in the hospital operation planning software named Orbit. Patient data, data on AEs and reasons for delay were available in the electronic medical records.

The VARA-study was based on three data sources, the Swedish Hip Arthroplasty Register, National Patient Register, Löf and patient's records.

The Swedish Hip Arthroplasty Register (SHAR)

The SHAR was founded in 1979, in which orthopaedic units participate voluntarily. It has been supported by the Swedish Association of Local Authorities and Regions since 1989. The completeness of the register is approximately 98% (105). The SHAR supplied the source population from which the samples were drawn for the VARA-cohort, and data on the primary surgery date, hospital and type of surgery.

The National Patient Register

The National Patient Register (NPR) collects data on all Swedish admissions and outpatient visits. The NPR was founded in 1964 and has had total national coverage since 1987 (106,107). NPR supplied data on all admissions and unplanned outpatient visits from the primary admission to 90 days after surgery, which included the admission date, discharge date, and primary and secondary diagnoses determined with ICD-10 codes. NPR also supplied the aggregated data used in paper IV.

Global Trigger Tool

The GTT is a two stage procedure (83). In stage 1, all medical records were reviewed, including notes from different professionals (Figure 12). The records were screened for any of the 38 predefined triggers that indicated a potential AE. All records with a potential AE were forwarded to review stage 2.

All identified triggers deemed as positive for a potential AE were assessed in stage 2. Each potential AE was then assessed regarding causation. If healthcare was deemed to contribute to the occurrence, is was classified as an AE, and the AE was classified according to several variables.

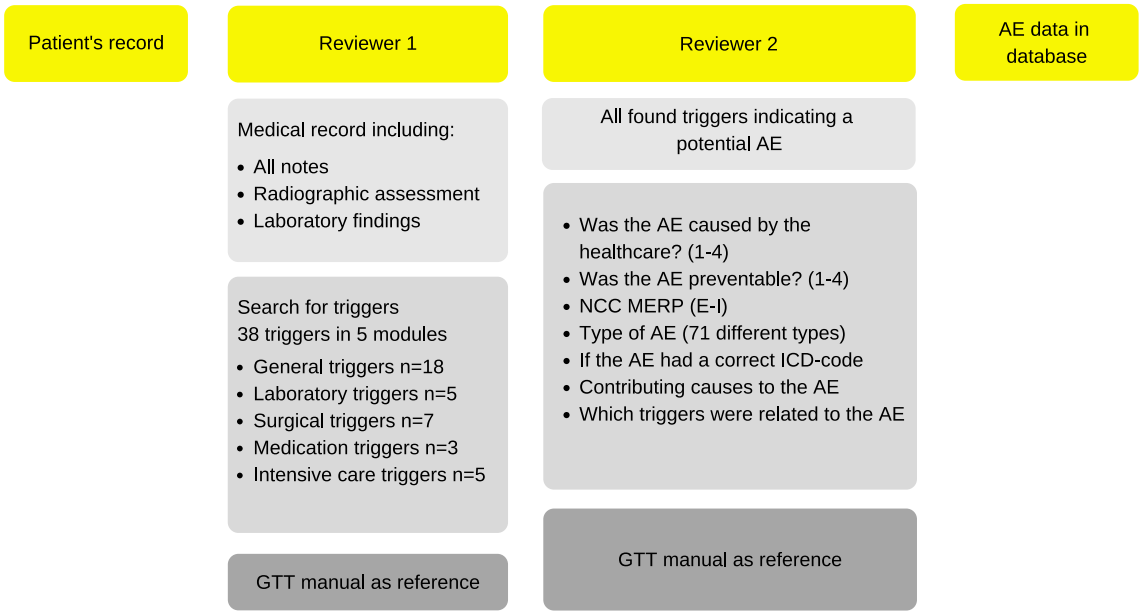


Figure 12, The Global Trigger Tool method

The mutual insurance company of the county councils (Löf)

Löf supplied the data on claims in paper III. Review of the claims data was performed at Löf. A reviewer collected the data on the date of the claim, reimbursement and level of disability.

Scales and measures used in the structured retrospective record review

ASA Physical Status Classification System

The Physical Status Classification System, used in paper I to control for confounding in the multivariable logistic regression model, was developed by the American Society of Anaesthesiologists (ASA) (108).

The score consists of six classes, where 1 corresponds to a healthy patient, 4 to a patient with severe systematic disease that is a constant threat to life, 5 to a moribund patient and 6 to a brain-dead patient.

Short Portable Mental Status Questionnaire (SPMSQ)

Commonly known as the Pfeiffer test in Sweden, this 10-question form is used to perform a quick assessment of a patient's cognitive function (109).

Each question gives one point if answered correctly. A result of 8 to 10 suggests an intact cognitive function, a result of 6 to 7 mild impairment, a score of 3 to 5 moderate impairment and a score of 0 to 2 a severe impairment of cognitive function.

NCC MERP

The severity of the AEs in the VARA-study was evaluated using a slightly modified version of the National Coordinating Council for the Medication Error Reporting and Prevention (NCC MERP) index (108). Categories E to I were included, and the categories indicated the following: E) contributed to or resulted in temporary harm, F) contributed to or resulted in temporary harm that required outpatient or inpatient care or prolonged hospitalization, G) contributed to or resulted in permanent harm, H) required intervention necessary to sustain life within 60 minutes and I) contributed or resulted in the patient's death.

Pressure ulcer categorization

We used the definition by the European Pressure Ulcer Advisory Panel (EUPAP) for classification of pressure ulcers in all papers (110). It contains four categories where category one is a non-blanchable area with redness of intact skin and category four is full thickness tissue loss with exposed bone, tendon or muscle.

Definitions

In paper I, we used the WHO definition: an AE is any unfavourable or unintended sign including an abnormal laboratory finding, symptom or disease associated with the use of a medical treatment or procedure, regardless of whether it is considered related to the medical treatment or procedure (81). A serious AE was defined as any medical occurrence that results in death, is life-threatening, requires hospitalization, prolongs an existing hospitalization or results in persistent or significant disability or incapacity.

In papers II to IV, we defined an AE as suffering, physical harm or disease, as well as death related to the index admission and as a condition that was not an inevitable consequence of the patient´s disease or treatment.

Based on the terminology in the Swedish Patient Safety Act (111), a preventable AE was defined as an event that could have been prevented if adequate actions had been taken during the patient's contact with healthcare.

The AEs classified as NCC MERP F or higher were defined as major AEs.

The index admission was defined as the orthopaedic admission when the patient had hip arthroplasty surgery. If the patient was discharged directly to a geriatric or rehabilitation clinic, this admission was also included in the index admission.

Outcomes

Paper I

Primary outcomes: Time from arrival at the hospital to the start of surgery and proportion of patients who underwent surgery within 24 hours.

Secondary outcomes: AEs, serious AEs, mortality both during the hospital stay and within 90 days, length of stay, and reasons for delay over 24 hours.

Paper II

Primary outcomes: The 30 and 90-day adjusted cumulative incidence, sensitivity and specificity of the AE measurement instrument.

Secondary outcomes: Rate of AEs with a correct ICD-code and incidence rate.

Paper III

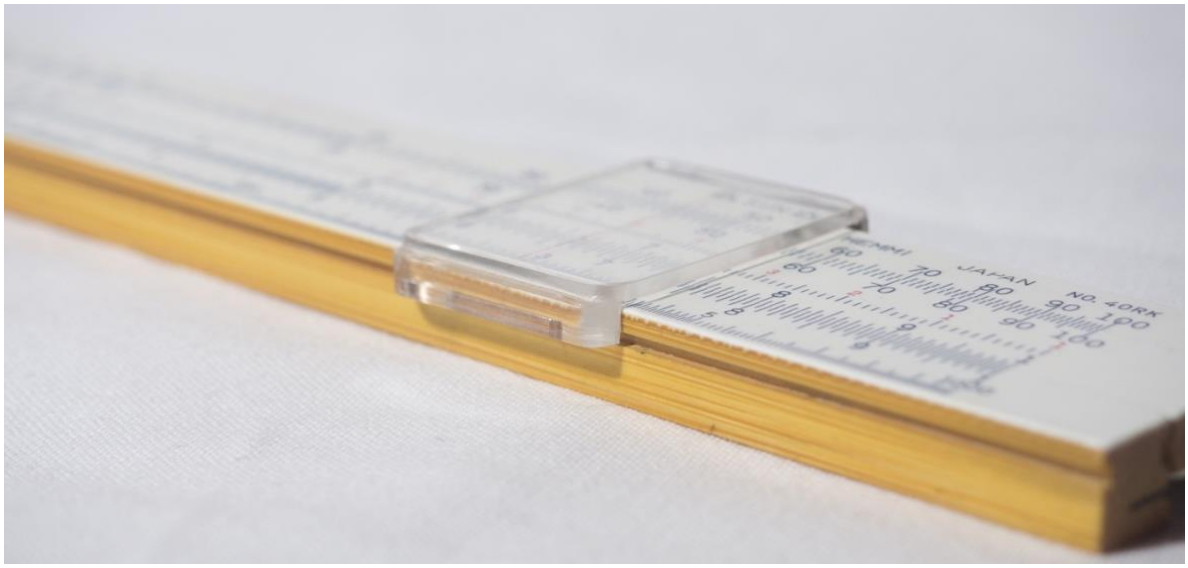
Primary outcomes: Adjusted 90-day proportion of accepted patient claims to Löf.

Secondary outcomes: Mean compensation.

Paper IV

Primary outcomes: Sensitivity, specificity and Youden's index.

Secondary outcomes: None.



Statistical methods

An overview of the statistical methods used in papers I to IV is shown in Figure 13.

Statistical method	Paper I	Paper II	Paper III	Paper VI
• Student's T-test	x	-	-	-
• Chi-square test	x	-	-	-
• Kolmogorov-Smirnov	x	-	-	-
• Levene's test	x	-	-	-
• Logistic regression	x	-	-	x
• Cohen's kappa	-	x	x	-
• Bootstrap samples	-	x	x	-
• Mixed effect models	-	-	x	-
• Cross-validation	-	-	-	x
• Random forest	-	-	-	x
• Support vector machines	-	-	-	x
• Neural networks	-	-	-	x
• Youden's index	-	-	-	x

Figure 13, Table of statistical methods used in the thesis

Definitions and measures

Cumulative incidence or risk proportion is a measure of how many patients that is affected by a disease or other often negative events (112). In the VARA-study we used this definition:

$$cumulative\ incidence\ = \frac{number\ of\ patients\ with\ an\ AE\ during\ a\ timeframe}{total\ number\ of\ patients}$$

Sensitivity or true positive rate are used for measure the precision of tests (112). Often used for clinical test, but also for predictive models. In the VARA-study we used this definition:

$$sensitivity = \frac{patients\ with\ AE\ and\ positive\ test}{all\ patients\ with\ AE}$$

Specificity or true negative rate is also a measure of precision (112). We used this definition:

$$specificity = \frac{patients\ without\ AE\ and\ negative\ test}{all\ patients\ without\ AE}$$

Youden's index is a single number measure for test precision (113), used in paper IV. It is defined as:

$$sensitivity\ +\ specificity\ -\ 1$$

A receiver operating characteristic (ROC) curve is created by plotting sensitivity and specificity for different thresholds of a test (114). It is often used for determining optimal

thresholds for tests, both in medicine and machine learning. The area under the ROC-curve (AUC) is the best single number measure to evaluate predictive models (115).

Paper I

We tested the normality and homogeneity of the data variance with the Kolmogorov-Smirnov and Levene's test. To test the difference in primary and secondary end-points in the two groups, we used the independent Student's t-test for continuous variables and the Chi square test for categorical variables. To evaluate differences between the intervention and control group association with surgery within 24 hours and to control for possible confounding factors, we used a multivariate logistic regression model. We used the following variables: gender, age at surgery, cognitive, ASA classification and type of surgery. We considered a P-value < 0.05 to be statistically significant.

Paper II

To calculate the cumulative incidence in the population, the result had to be adjusted according to the sampling table. In each sample group, the number of patients with an AE was divided by the total number of patients in the sample group to determine the incidence in that sample group. The incidence was multiplied by the population group size divided by the total population, and the results from all groups were added together to derive the adjusted cumulative incidence. This procedure was repeated for the 30 and 90-day incidence and for preventable and major preventable AEs. Bootstrap samples (n=3,000 for all AEs and preventable AEs and n=1,500 for major AEs) were used to calculate the 95% confidence intervals.

The incidence rate was calculated by taking the total sum of the identified AEs within 30 days after surgery for each selection group, dividing it by the sample group size and then multiplying it by the group proportion. The sum was the incidence rate in AEs/person-month. We used Cohen's Kappa (116) for the inter-rater reliability between the primary reviewers.

The adjusted sensitivity and specificity were calculated for both 30 days and 90 days. The sensitivity and specificity were calculated in each sample group and followed the same procedure as the adjusted cumulative incidence.

We compared the positive test results from NPR with both the results from all identified AEs from the RRR and from the AEs identified during readmissions.

Paper III

The adjusted proportion of accepted claims for preventable major AEs and the proportion ratio were calculated using the same method used to calculate the adjusted cumulative incidence in paper II. We used a customized bootstrap method with 20,000 samples. The 95% confidence interval was the 2.5^{th} and 97.5^{th} percentiles from the 20,000 samples. The same method was used to calculate the proportion ratio (proportion for elective patients/ proportion for acute patients). For all patients, we pooled the groups together, and for the acute and elective proportions, we used the separated groups.

To predict accepted claims, we used a mixed effect logistic regression model with age, gender, NCC MERP and acute or elective surgery type as fixed effects and selection group as the random effect.

Paper IV

Dataset

The AE data set from paper II was used to train different machine learning models to predict AEs based on patient variables. The dataset was supplemented with aggregated data from the Swedish National Board of Health and Welfare. Each hospital type (university, county, district or private) contained the 50th, 75th, 90th and 95th percentile, mean and standard deviation of the length of stay (LOS), which was further divided into the age of the patient, year, gender and fracture status. We matched each patient with the aggregated data, and each patient had percentiles for patients with the same gender, age, fracture status and operation in the same type of hospital during the same year as the additional variables.

Training and selection of models

Before the training of the models, we split the dataset randomly. One-third of the patients served as a holdout set that we only used in the final test of the best performing model. The remaining two-thirds of the patients were used as a training set for training and fine tuning of the models. For all trainings, we used 10-fold cross-validation. The training data were randomly split into 10 parts, and the model was trained on 9/10 of the set and evaluated on the remaining 1/10th to estimate the prediction error without using the holdout set. The outcomes were the sensitivity, specificity and AUC for all models. We tested the following models: random forests, logistic regression with and without natural splines, support vector machines and neural networks with three different structures (shallow = three layers, deep = seven layers and wide = three layers) (Figure 14).

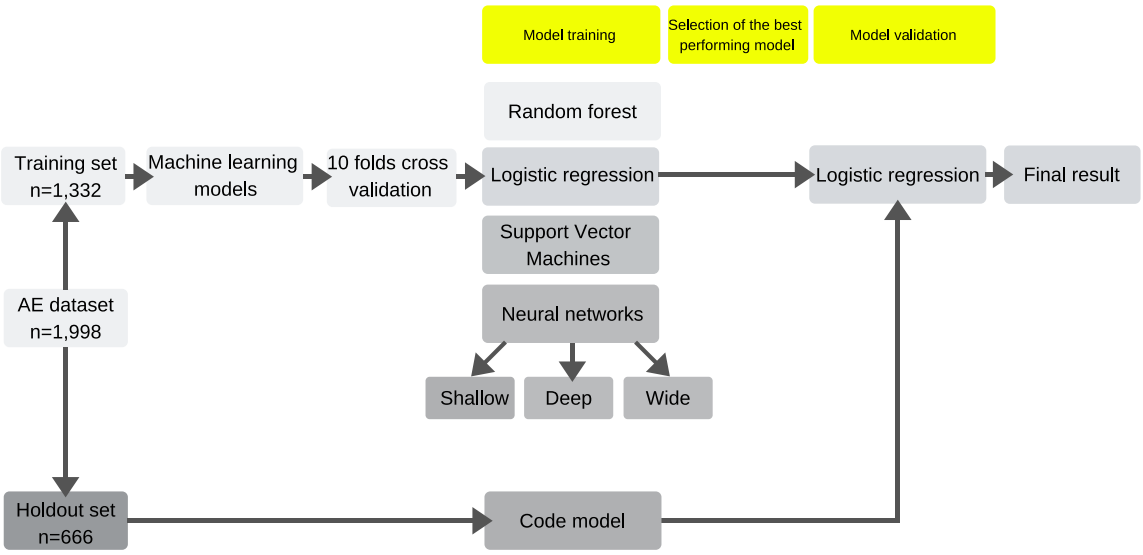


Figure 14, Flowchart of the model training and selection in paper IV

We started the training with a dataset that included all the variables. The importance of the different variables was evaluated by the generated importance in the output from the random forest model, and using the rms package with the lrm function for logistic regression models, we tested the relative importance of the different variables with the Chi-Square test. We removed the least important variables and retrained the model that continued to improve. In the end, only age, the length of stay during the orthopaedic admission, the number of readmissions, and the number of A&E visits were used and had the best results.

Overfitting occurs when a model is too flexible and will fit the training data very well, but if it is used for unknown data, the fit will not be as good. We controlled overfitting by first training the model on a portion of the training data and thereafter evaluating the model on the same data and on the remaining data. If there was a large discrepancy between the results, we concluded that there was some overfitting in the model.

Validation of the models

In the final test, we used the whole training set to train the model, and the trained model was used for prediction for the holdout set. We could not use AUC as a measure for the comparison with the code-based model, because a receiver operating curve cannot be derived from a model that yields the result in form of a four-way table. Instead we chose Youden's index (113) as a substitute. We made a prediction for each selection group. The sensitivity and specificity in the groups were multiplied by the group proportion (group size in population/total population) and summed, which yielded the adjusted sensitivity, specificity and Youden's Index. We did not use cross-validation in the final model. For the code-based model, the sensitivity, specificity and Youden's index were calculated using the same method applied for the training data.

Software

In paper I, we used PASW Statistics software for Windows (SPSS Inc., Chicago, IL, USA) to perform all statistical analyses. In papers II to IV, we used R. (R. C. Team, R: A Language and Environment for Statistical Computing. Vienna, Austria, 2013.) We used the dplyr package to manage and cross-link datasets in papers II to IV. We used the boot package for bootstrap samples in papers II & III. In studies II & III, we calculated Cohens Kappa (116) using the irr package. In paper IV, we used the randomForest and ranger packages for random forests and bagging. We used the TensorFlow with Keras API for neural networks and the e1071 package for support vector machines. All tables were created using the htmlTable package.

ETHICAL CONSIDERATIONS

All studies had ethical approval: paper I received approval from the local ethics committee in Stockholm, Dnr: 2009/1657-31/2 with amendment: 2010/685-32, and papers II to IV received ethical approval from the local ethics committee in Gothenburg, Dnr: T732-13 with amendment: 516-13.

We received ethical approval to perform a record review without any consent from the patients. The VARA-study, because it was a register-based study with 2,000 patients, would have been impossible to execute if informed consent had been required. All the heads of the departments that treated the patients gave their permission to perform the record review. Throughout this project, data were treated with confidentiality and were kept encrypted or in safe storage at the Danderyd hospital central server. All results were compiled and reported in such way that no individuals could be recognized. All studies were conducted according to the principles of the Declaration of Helsinki.

RESULTS

In this section, the main findings from the respective papers origin from the two studies are presented.

The fast-track study, paper I

After exclusion of patients who did not have a hip fracture, had a pathological fracture, were medically unfit or had a delay in their diagnosis, the final cohort consisted of 415 patients (intervention group n=80 and control group n=335).

The patients in paper I consisted of a majority of females, and the intervention group consisted of more females than the control group (Table 2). Otherwise, there were no major differences between the groups.

The time to surgery had a mean duration that was 3 (95% confidence interval 1 to 5) hours shorter in the intervention group and a 13 percent difference in the proportion of patients who underwent surgery within 24 hours. The probability of surgery ≤ 24 h remained in favour of the intervention group after adjustments for several possible confounders. We found no difference in mortality or length of stay between the groups (Table 3).

Table 2, Demographics of the fast-track study

	Ambulance process (n=80)	Hip process (n=335)
Age[a]	85 (58-103)	82 (32-102)
Female[b]	65 (81)	227 (68)
Dementia or SPMSQ <3[b]	43 (54)	190 (57)
ASA classification[b]		
1-2	33 (41)	110 (33)
3-4	47 (59)	225 (67)
Type of fracture[b]		
Femoral neck fracture	40 (50)	186 (56)
Trochanteric fracture	33 (41)	118 (35)
Subtrochanteric fracture	7 (9)	31 (9)
Type of Surgery[b]		
Arthroplasty	24 (30)	112 (33)
Cannulated screws	13 (16)	57 (17)
Sliding hip screw	12 (15)	48 (14)
Intramedullary nail	31 (39)	117 (35)

[a] mean (range)
[b] n (%)
SPMSQ = Short portable mental status questionnaire
ASA = American Society of Anaesthesiologists Physical Status Classification System

Table 3, Main outcomes of the fast-track study

	Ambulance process (n=80)	Hip process (n=335)	p-value
Time to surgery (hours)[a]	18 (4-47)	21 (4-72)	0.035
Surgery within 24 hours[b]	70 (88)	250 (75)	0.015
Delays > 24 hours[c]			
Administrative	5 (50)	59 (69)	0.2
Medical	5 (50)	26 (31)	0.2

[a] Mean (range), P-value derived from the Student's t-test
[b] n (%), P-value derived from the Chi-square test
[c] n (%), 10 patients were delayed in the Ambulance process and 85 in the Hip process group. P-value derived from the Chi-square test

The VARA-study, papers II to IV

Of the 2,000 included patients in the VARA-cohort, two were excluded. The cohort consisted of one-third acute patients and two-thirds elective patients. The acute patients had a median age that was 11 years older and 6 percent more females than the elective patients (Table 4).

Table 4, Demographics of the VARA-study

	Total n= 1,998	Acute n= 667	Elective n= 1,331
Female n=	1,250 (63%)	444 (67%)	806 (61%)
Male n=	748 (37%)	223 (33%)	525 (39%)
Age, median†	77 (68-84)	84 (79-89)	73 (64-80)
LOS, median†	7 (4-13)	14 (9-20)	5 (4-8)
Type of Hospital n=			
University	630 (32%)	295 (44%)	335 (25%)
Central County	556 (28%)	180 (27%)	376 (28%)
County	531 (27%)	109 (16%)	422 (32%)
Private	281 (14%)	83 (12%)	198 (15%)

†, Interquartile range

Adverse event results

We found 2,116 AEs of different severity in 1,171 (59%) patients (Figure 15). Of these, 1,605 (76%) AEs in 975 (49%) patients were classified as preventable, and 1,066 (50%) in 744 (37%) patients were deemed as major preventable.

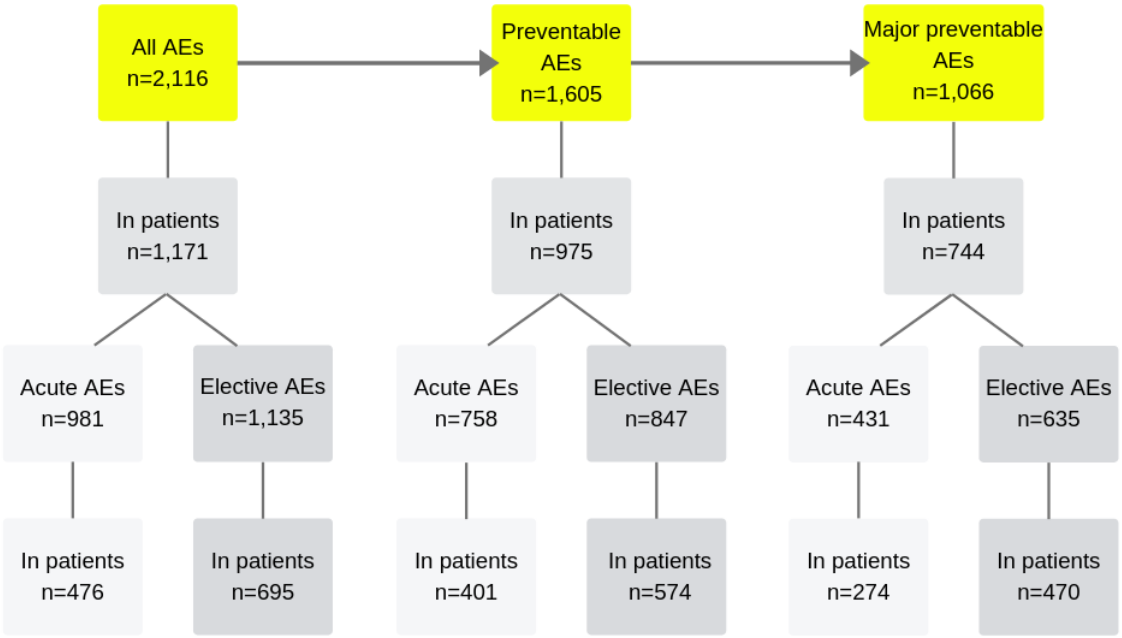


Figure 15, Flowchart of different categories of AEs

AEs occurred most frequently on the day of surgery and the following days (Figure 16). AEs were most common during the index admission, and there were more AEs during the index admission than during the readmissions within 30 and 90 days together (Figure 17). The majority of the AEs during the index admission did not have a correct ICD-code, and the majority of the AEs during readmissions had a correct ICD-code.

The median age of the acute patients who sustained an AE was 85 years and for the elective patients 75 years (Figure 18). The median age of the acute patients who did not sustain an AE was 83 years and for the elective patients 71 years (Figure 19).

We found that 10% of the total arthroplasties consisted of acute patients and 90% of elective patients (Figure 20). The hemi arthroplasties consisted of 8% elective patients and 92% acute patients. The odds ratio for an acute patient sustaining an AE compared with an elective was 2.3. The odds ratio of sustaining an AE for a hemiarthroplasty patient compared with a total arthroplasty patient was 2.5.

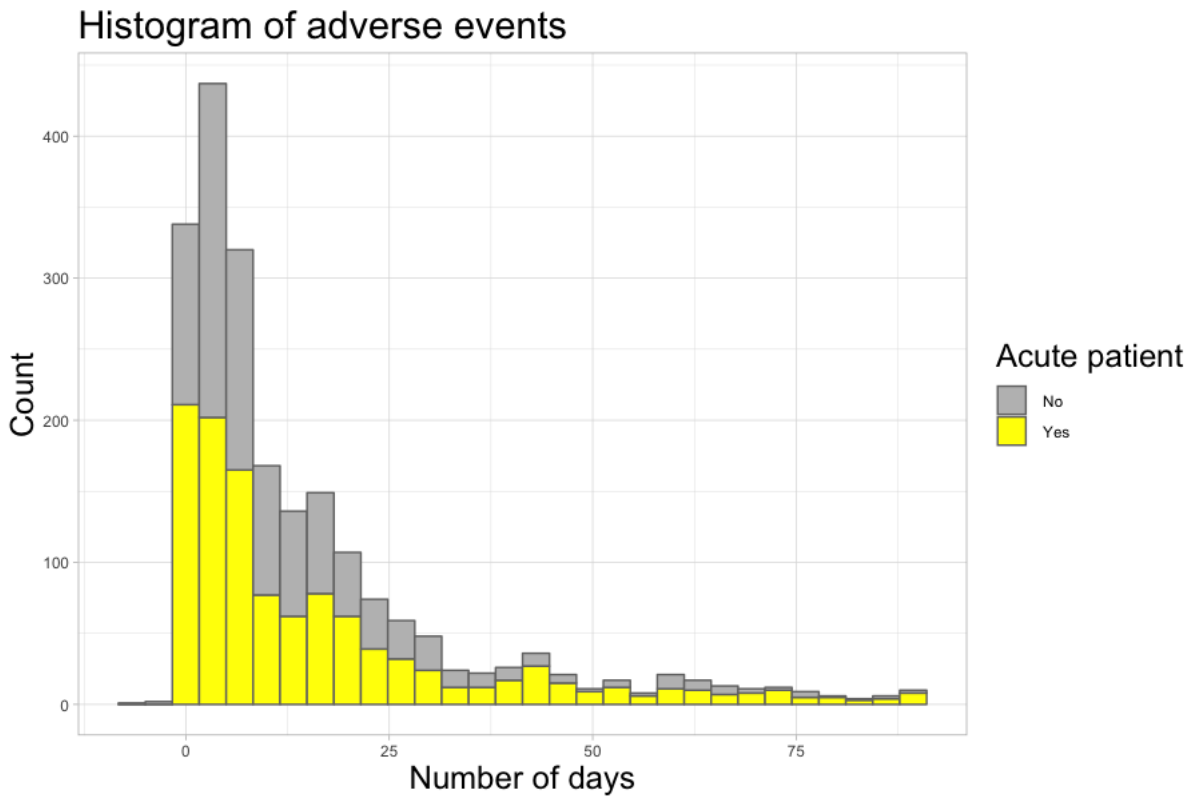


Figure 16, Distribution of AEs for acute and elective patients over time

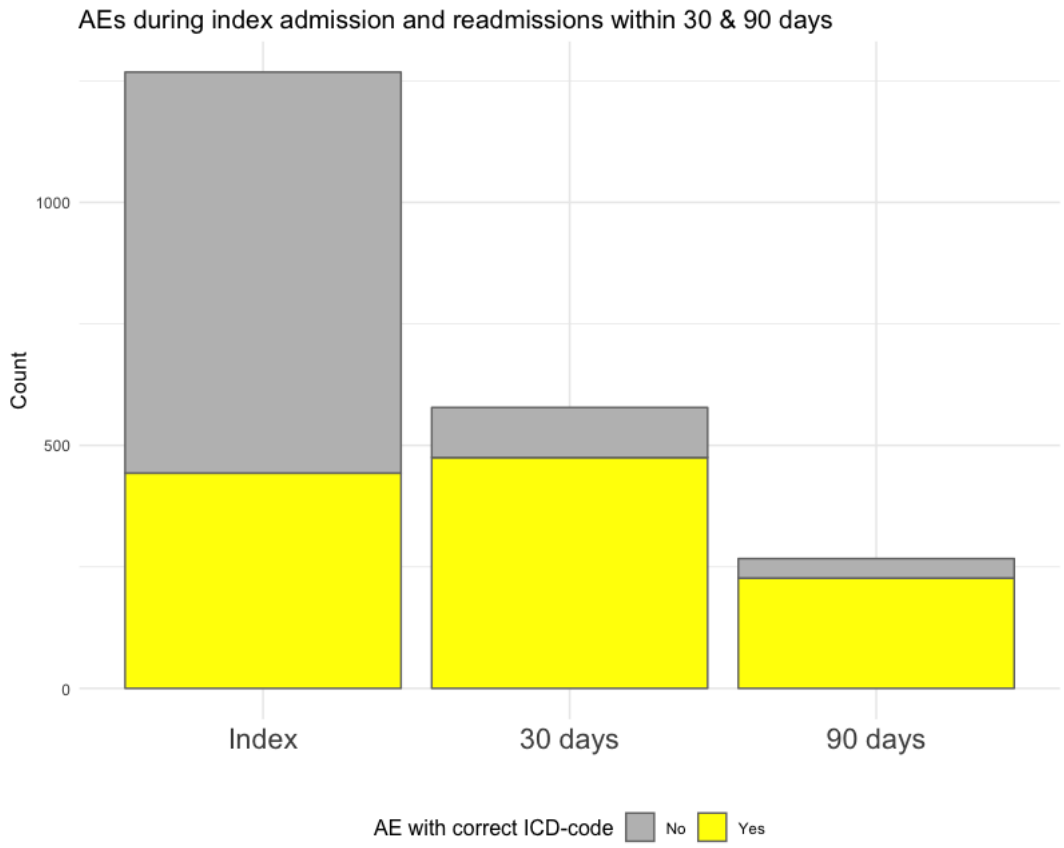


Figure 17, Distribution of AEs during index admission and readmissions

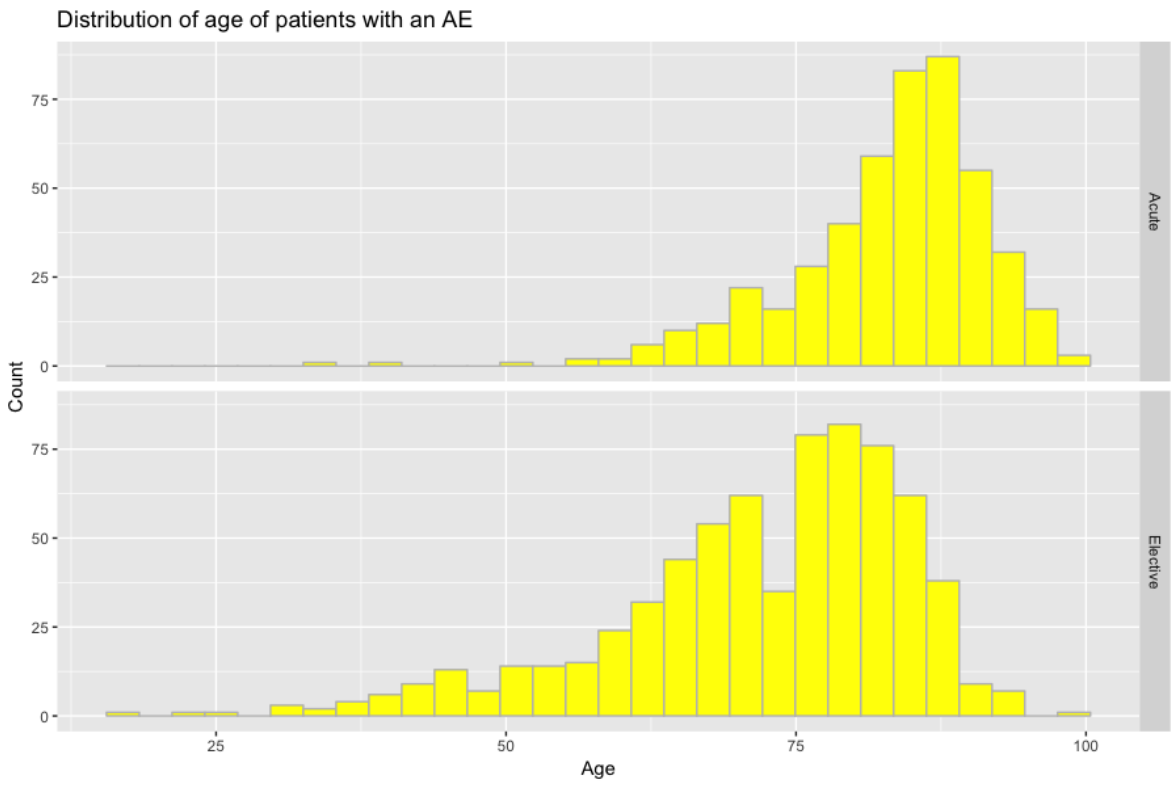


Figure 18, Distribution of age for patients with an AE

Figure 19, Distribution of age for patients without an AE

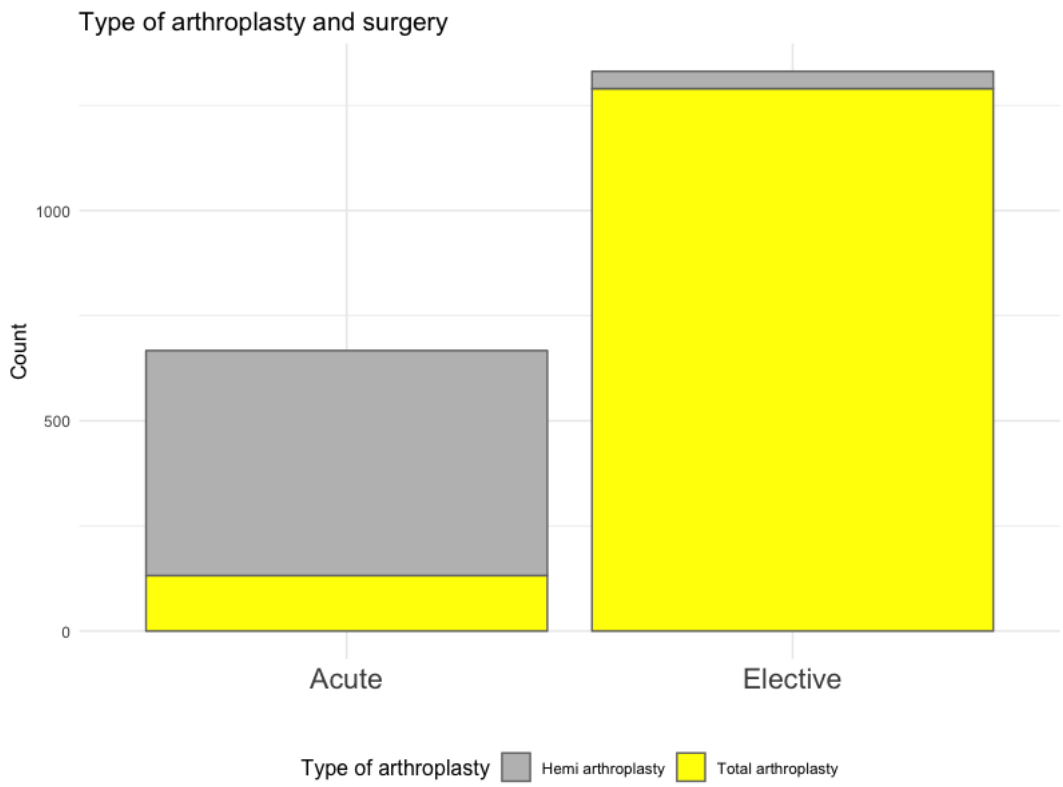


Figure 20, Proportion of hemi and total arthroplasties

Type of adverse events

The most common group of AEs was infections followed by AEs related to the surgical procedure, pressure ulcers and thromboembolic (Table 5). The most common individual AE was distended bladder followed by PJI and dislocation.

Table 5, Adjusted cumulative incidence of different AEs

	Adjusted cumulative incidence	LL	UL
Iatrogenic infections	0.123	0.112	0.133
AEs related to the surgical procedure	0.070	0.053	0.085
Pressure ulcers	0.040	0.030	0.055
Thrombosis or embolus	0.023	0.016	0.035
Distended bladder	0.030	0.018	0.040
PJI	0.017	0.013	0.020
Dislocation	0.016	0.013	0.018

LL = lower 95% confidence interval
UL = upper 95% confidence interval
PJI = periprosthetic joint infection
AE = adverse event

Examples of adverse events found in medical records

"Now on arrival at the A&E also had chills. Has been at the general practitioner for control, where this was noted and that the wound has slipped slightly and c-reactive protein was 60. Therefore, the patient was sent here with suspicion of prosthetic infection."

– from the admission note of a PJI patient.

"Underwent surgery 3 weeks ago with a total plastic right hip due to a dislocated collum femoris fracture. When she got up from sitting and went into the hall, she became dizzy and felt that she might faint. She didn't, but she fell on the floor and then experienced pain in the right hip, right femur."

– from the admission note of a periprosthetic fracture.

"The night up to yesterday, the patient has fallen at the geriatric clinic, on the way up to the toilet itself. The patients received an x-ray today, and the X-ray shows that the prosthesis is fully dislocated cranially. There is also a 1.5-cm-long boney fragment corresponding to the joint socket, which could represent a turned corner of the cranial acetabulum."

– from the admission note of a patient with a dislocated hemi arthroplasty and acetabular fracture.

Paper II

The adjusted sensitivity and specificity for all AEs were 6% (95% confidence interval 5 to 7) and 95% (94 to 97) at 30 days, and 15% (8 to 24) and 92% (90 to 94) at 90 days, respectively. The instrument had higher sensitivity but lower specificity for the acute patients compared with the elective patients.

The acute patient had higher adjusted cumulative incidence than the elective patients (Table 6).

Table 6, Adjusted cumulative incidence of adverse events

	All patients	Acute patients	Elective patients
All AEs			
Incidence 30 days	28 (25-32)	51 (44-60)	17 (14-21)
Incidence 90 days	30 (26-34)	52 (45-60)	19 (15-23)
Preventable AEs			
Incidence 30 days	22 (19-26)	41 (35-47)	14 (11-18)
Incidence 90 days	23 (20-27)	41 (36-48)	15 (12-19)
Major AEs			
Incidence 30 days	13 (11-16)	21 (18-26)	10 (8-13)
Incidence 90 days	15 (12-17)	22 (19-26)	12 (9-15)

All results are in %, 95% confidence interval in brackets

AEs = adverse events

Paper III

There were 144 claims from the patients in the study cohort, of which 68 concerned AEs that originated from the index admission in this study (Figure 21). One claim was not detected by the RRR. Six claims originating from index admissions were excluded from the analysis due to their debut after the study's inclusion period (4 PJIs and 2 dislocations). Four patients had their claims declined by Löf because they were not deemed to be preventable AEs. The declined claims included a PJI due to haematogenous spread, a perioperative fracture, pain and numbness of the hands and lengthening of the operated leg. The analysis thus included 58 accepted claims from 57 patients. The rate of accepted claims was 94% (58/62). All accepted claims except one were defined as major AEs. The elective patients had 93% of the accepted claims and the acute 7%.

The proportion of accepted claims for the preventable AEs was 6% (95% confidence interval 0 to 33) and 7% (95% confidence interval 0 to 34) for the major preventable AEs. The proportion was larger for the elective patients at 12% (95% confidence interval 0 to 33) compared with 0.2% (95% confidence interval 0.2 to 0.4) for the acute patients. The proportion ratio for elective/acute was 60 (95% confidence interval 3 to 440). The most commonly accepted AE was PJI (36/58).

In the mixed effects logistic regression model used to analyse if any patient factors could be used as a predictor for which patients that are likely to have an accepted, claim the elective patients had higher a odds ratio. However, the confidence intervals were wide, and none of the patient factors were a statistically significant predictor.

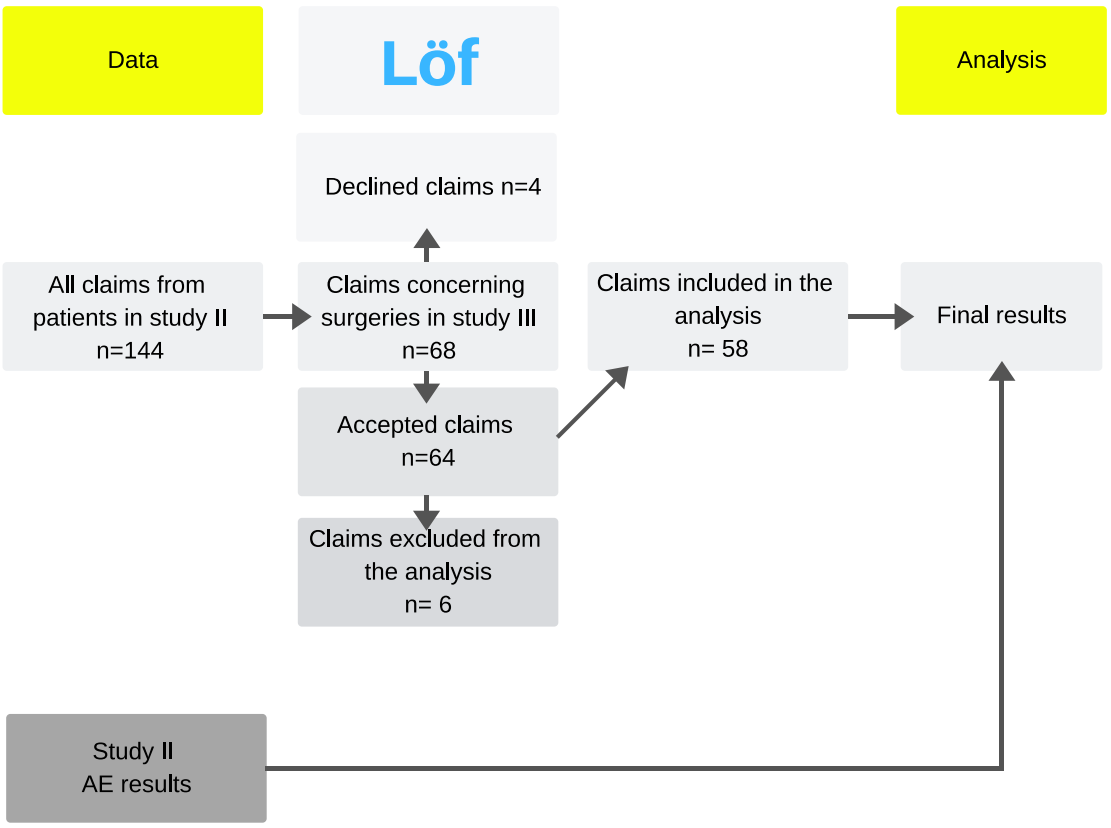


Figure 21, Flowchart of the study process for paper III

Paper IV

There was no substantial difference between the performance of different models during the training. The model that had the best precision and the fastest computing time was the logistic regression with two natural splines for age, which was chosen for use in the final testing. The variables used in the final models were LOS for the orthopaedic admission, number of readmissions, number of unplanned outpatient visits and age.

The new model had higher precision for all, acute and elective patients, both for 30 and 90 days. Both models had a higher sensitivity and lower specificity for the acute patients compared with the elective patients, which was also true when comparing all three types of patients at 30 and 90 days.

Patients with an LOS of 5 days had the lowest relative risk for sustaining an AE (Figure 22). For patients with an LOS of 10 days, the relative risk was 2.1 (95% confidence interval 1.6 to 2.6); and for patients with an LOS of 16 days, it was 3.1 (95% confidence interval 2.3 to 4.1).

Patients with an age of 63 years had the lowest relative risk for sustaining an AE (Figure 23). Patients with an age of 79 years had an relative risk of 2.0 (95% confidence interval 1.6 to 2.5)), and those aged 87 years had an relative risk of 3.1 (95% confidence interval 2.4 to 3.9).

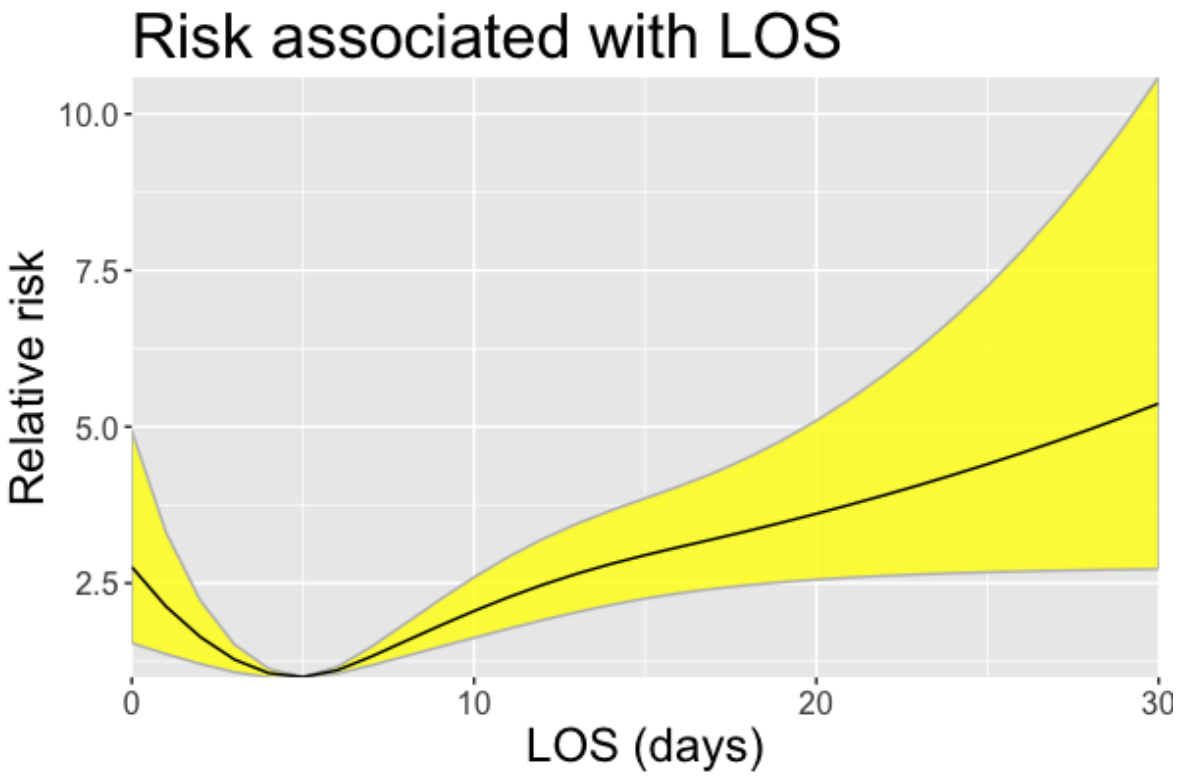


Figure 22, Plot of the relative risk in association with the length of stay (LOS), with the 95% CI shown in yellow.

Figure 23, Plot of the relative risk in association with age, with the 95% CI shown in yellow.

DISCUSSION

This thesis is dedicated to the study AEs. AEs are a global problem, and despite advances in all aspects of healthcare, the incidence of AEs is appallingly high. A patient has a one in 300 risk of being harmed during healthcare compare with a one in a million risk of being harmed during a plane flight. The risk of being harmed is even higher during hospital care, during which one in ten patients is harmed during the hospital stay. The global 1-year incidence of a disabling AE following surgical procedures is seven million, of which more than one million patients die (117).

The risk of sustaining an AE following surgery of the hip is probably more dependent on the type of patient more than the surgical procedure itself. In the fast-track study, we studied the most fragile patient hip surgery patient group, hip fracture patients. In the VARA-study, we studied AEs following hip arthroplasty surgery, a patient group consisting of younger and healthier elective patients with degenerative joint disease and acute patients with hip fracture. The different papers from two different studies in this thesis examine different aspects of AEs.

The fast-track study, paper I

Fast-track, a method for reducing AEs following hip fracture surgery?

In paper I, we addressed whether an improved fast-track system for hip fracture patients could reduce the time to surgery and whether this had an effect on mortality and the incidence of AEs. We found that the time to surgery could be reduced and a trend towards a lower AE incidence in the Ambulance process group.

Since the publication of paper I, several studies have addressed the timing of surgery for hip fracture patients, and convincing evidence are now available demonstrating that a shorter waiting time to surgery is associated with a better outcome. In their study, described 42,000 patients, of whom the patients who underwent surgery within 24 hours had a 5.8% 30-day mortality rate, compared to 6.5% (33). A meta-analysis of 190,000 patients comparing early surgery with late and mixed cut-offs of 24 and 48 hours showed that early surgery was associated with lower mortality and pressure ulcers (23). A third study on 47,000 patients and a cut-off of 48 hours did not reveal any differences in 30-day mortality but a difference in hospital acquired pneumonia and pressure ulcers, in favour of the early group (118).

A study by Kelly-Pettersson et al. approached timing in a new way and examined the possibility of a cut-off time (119). They observed a 12% increase in risk for serious AEs for every 10 hours of waiting time, and their results suggested that a definitive cut-off for AEs might not exist and that the relationship between time and AEs is in fact linear. Fast-tracks for hip fracture patients have been implemented in other hospitals in Sweden. A randomized controlled study comparing a fast-track identical to the Ambulance process and a traditional clinical pathway was conducted in southern Sweden in 2016 (120). They found that the fast-track could reduce the time to radiographic examination but not to surgery. They did not find any differences in LOS, postoperative AEs or mortality between the groups. The mean time

to surgery was 18 hours in both groups, which is equivalent to the Ambulance process patients in our study and 4 hours less than the national mean of 22 hours (8).

The Ambulance process is no longer active at Danderyd hospital because the ambulance company no longer wanted to participate. After termination of the Ambulance process, the Hip process was the option until a new modified fast-track named the Hip alarm was implemented. This fast-track system resembles a trauma alarm because a suspected hip fracture patient is examined and prepared in the trauma room and subsequently transferred to radiology and the ward.

The reasons for a delay more than 24 hours in the fast-track study was caused equally by administrative and medical reasons in the Ambulance group and two-thirds administrative in the other group. After publication of paper I, the broad introduction of direct oral anticoagulants (DOAC) has been one of the major reasons for delayed surgeries, because unlike warfarin, there is no available antidote as cheap and reliable as vitamin K. When a DOAC-treated patient is admitted, the DOAC concentration is monitored until it is safe to perform spinal anaesthesia. Of the DOACs, only dabigatran has an antidote (121) and is seldom used except in exceptional cases.

Although we could not confirm that the fast-track could reduce AEs, the fast-track was beneficial for the patients. The A&E is a stressful environment for an elderly injured patient, and surgery is the most effective pain relief for hip fractures (35,122)

The VARA-study, papers II to IV

Studies on measuring AEs

In the VARA-study, we used RRR with GTT to measure and characterize AEs following both acute and elective hip arthroplasty surgery. To our knowledge, this is the first study to achieve this goal. The VARA-study is dedicated to the measurement of AEs and to compare our results with other studies, it is important to consider the following factors:

1. The definition of AEs used in the study.
2. The method for measuring AEs.
3. The time frame for measuring AEs.

We used a wide definition of AEs, which means we found more AEs compared with studies that used a narrower definition and thereby “missed” events that would have been considered AEs in the VARA-study. The rationale for our definition was that we wanted to identify as many AEs as possible to display the whole spectrum of the AE problem. The most time-consuming part of the study was in obtaining and reviewing the medical records, and there would have been a small difference in effort using a narrower definition. In this way, we identified all possible AEs, and a narrower definition could subsequently be applied by removing AEs. This procedure was applied in all VARA-papers by utilizing the NCC MERP index. In the VARA-study, we used RRR with GTT to measure and characterize AEs

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We used RRR, the AE measure method that identifies the most AEs (56,123,124) and, therefore, generates a higher incidence compared with other methods such as clinical incident reporting systems or administrative systems. AE rates from studies using the GTT methodology cannot be compared without considering the completeness of the medical records, the experience of the review teams, inclusion criteria, other definitions and different interpretation of reviewers (125).

We used a time frame of 90 days after surgery, which means that we would measure all short and midterm AEs, but not long-term AEs such as aseptic loosening and PJIs from haematogenous spread.

Paper II

In paper II, we validated the AE measure instrument used by the SHAR and the Swedish Association of Local Authorities and Regions and calculated the adjusted cumulative incidence of AEs. The AE incidence was much higher for the acute patients with a hip fracture, and we can conclude that acute surgery is a risk factor for sustaining AEs. The obvious difference between these two groups was age. The median age of the elective patients was ten years younger than the acute patients. We did not have any data on comorbidities in our study. Age and health are closely related to each other, and health declines with age (126). Hip fractures are more common in patients with a worse health status and comorbidities (127–129). Cognitive impairment or dementia is the most common comorbidity in hip fracture patients. In addition to being the most common, it is probably the comorbidity that contributes to the most AEs for hip fracture patients.

The most common AE was dislocation. Age is a known risk factor for dislocation (130), and a high ASA score (can be used as a proxy for comorbidities) is also a known risk factor (131). Patients with cognitive impairment experience problems following instructions in restrictions of the operated leg and receive less rehabilitation and physiotherapy (132,133). The elderly patients' weaker musculature that leads to inferior control over the operated leg may increase the risk of dislocation, providing a probable explanation for the increased risk. This phenomenon could also explain the increased risk of falling and sustaining fractures and wounds, which was a common AE in the VARA-study. Falls have also been shown to be more common in the elderly population (134). Considering that a fall is probably the cause of the fracture in the first place, the risk that the patient will fall after the surgery seems impending. Moreover, patients with cognitive impairment have a higher risk of falls (135).

Nosocomial infections were also a common AE. Age is a risk factor for all types of infections including PJI (136,137). The decreasing capacity of the ageing immune system has been suggested as the main reason for the increased susceptibility. The cognitive function of the patient affects the capacity to follow instructions for surgical wounds which increases the SSI risk for patients with cognitive impairment (138).

Osteoporosis is more common in elderly patients, particularly in hip fracture patients. Osteoporosis increases the risk for perioperative fractures during the insertion of arthroplasty components. Arthroplasty surgery with cemented stems have a lower risk for perioperative fractures compared with cementless stems and is therefore more common for hip fracture surgery. Patients who have sustained an interoperative periprosthetic fracture have a higher risk for revision surgery (139)

The cemented arthroplasties are, however, associated with another lethal AE. If bone cement is applied with a high pressure technique, the increased pressure on the bone marrow can release a fat embolus, resulting in patient death (140–142)

The prevention of AEs is one of the most important aspects of AEs. A successful prevention intervention for AEs can result in a real difference and avoid suffering and death of the patients. Unfortunately, the most common AEs discussed above do not have a quick-fix solution, and there is weak evidence for interventions for preventing AEs (53).

An exception is urinary retention, with a distended bladder that is also more common in elderly patients (143). This is one of the AEs that can be prevented with correct monitoring. If the patients are scanned frequently, the patients with urine retention can be treated with urine catheters before the bladder is distended.

Paper III

In paper III, we studied the proportion of patients in paper II who sustained a major preventable AE and had an accepted claim from Löf, and we found that the proportion was merely 7%. We can conclude that claims to Löf is not a reliable measure for AEs following hip arthroplasty in Sweden. The rate of accepted claims was 94%, so the reason for the low proportion of accepted claims was that very few patients had filed a claim. The acute patients

had a higher incidence of major preventable AEs, yet the proportion of accepted claims was sixty times higher for the elective patients. Kasina et al. also found that acute hip arthroplasty patients have lower probability of filing an insurance claim for AEs (144).

Orthopaedics is the speciality which is the cause of most claims to Löf (87), and orthopaedics also have been the cause of most sentinel events (major AEs leading to death or serious injury for the patient) (145). Patients claims to Löf for AEs caused by orthopaedic surgery have been studied, and similar to our results infection was the most common reason for claims (146). The rate of accepted claims ranges from 55 to 96% (144,146,147)

We identified age as one of the key factors for hip fracture patients with a much higher AE incidence than elective patients. There is a reason to suspect that age as well as cognitive status are important factors related to the low proportion of accepted claims for acute patients. Older patients have less probability of filing an insurance claim (148–150). The prevalence of pre fracture cognitive impairment for hip fracture patients was 28% in a cohort study of patients aged over 65 years (151), and another study of hip fracture patients aged over 68 years found a prevalence of 85% and 62 for the control group (152). It seems plausible to conclude that patients with cognitive impairment do not have the capacity to file a claim themselves. However relatives can file claims for patients.

The finding that only 7% of the major preventable resulted in accepted claims can be considered an expression of the low awareness of AEs in both healthcare professionals and patients. I believe it is common that neither realize that an AE has occurred. The high prevalence of cognitive impairment supports this theory.

My personal experience is that the knowledge of Löf and the patient injury act is poor among healthcare professionals and almost non-existent among patients. Considering such knowledge among people, since the Patient Safety Act (111) was enacted in 2011, who have a legislated obligation to inform patients about Löf when a preventable AE occurs is low, few patients will receive the information to which they are entitled, which I think is reflected in the results.

There should be no reason that so few patients filed a claim. There are no negative effects for a patient to file a claim. The application can be performed online or on paper, and there is no cost of filing a claim. Before the introduction of the current no-fault system in 1975, the patient was obligated to prove negligence on the part of the healthcare to receive compensation, and sometimes patients sustained major AEs where fault could not be proved and the patient did not receive compensation (45). The system is also blame-free, and the healthcare provider responsible for any AEs will not suffer any consequence if Löf accepts an AE claim (153). In this way, patients do not need to worry about a strained relationship with their healthcare provider.

Paper IV

In paper IV, we created a new predictive model for predicting AEs following hip arthroplasty surgery. We found that a model based on patient-related variables, age, LOS and number of readmissions was superior based on ICD-codes, the instrument we validated in paper II.

In paper II, we found that only half of the found AEs had a correct ICD-code, and there was a wide range of correct code rates when comparing different types of AEs. Maass et al. (154) also found a sensitivity varying from six to 100% and a very high specificity for administrative data.

The evident danger with ICD-code-based measures of AEs is that the healthcare provider responsible for the AE is also responsible for registering the codes that are used for measurement. If economic compensation is based on such measures there is an imminent risk that the ICD-codes for an AE will not be correctly registered. This type of manipulation of administrative data is called DRG-creep (155).

The key to creating an unbiased measure for AEs is to use variables that cannot be subjective or altered. LOS represents such a variable. The LOS is calculated from admission and discharge dates, and it is completely objective in the absence of tampering these dates. Age is also a completely objective and robust variable. Another advantage of these variables is that they are easy to measure and easily available from administrative data.

Over time, LOS has decreased in general (156–158). This is also true for hip arthroplasty patients (Figure 24) and even outpatient surgery is now performed (159,160). In Sweden, there is a general shortage of hospital beds, which leads to a high motivation to discharge patients as soon as possible. When there is suspicion that a patient might have an incipient infection or other suspicious condition, it is common practise that the patient will stay for another day for expectancy and more tests, among other assessments. If the patient develops a serious condition, LOS will be affected. The compressed LOS is the reason that it can be used as a proxy for AEs.

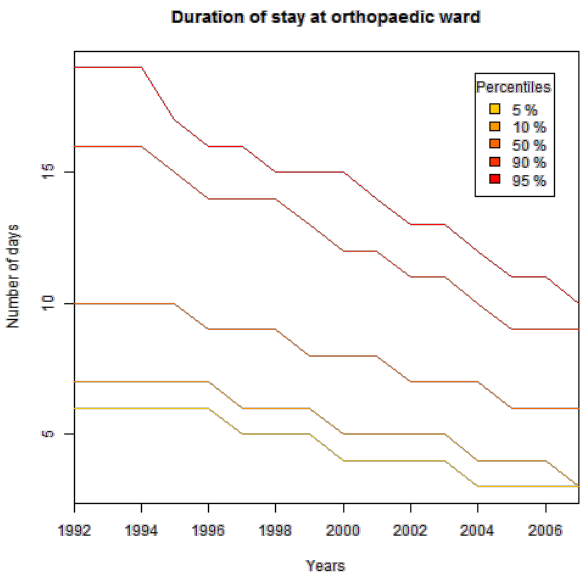

Figure 24, Trend of LOS over time for total hip arhroplasty patients. Datasource: Swedish Hip Arthroplasty register.

The other risk factors for AEs that are related to the patient and not the admission that we discussed above are not easily available from administrative data. Comorbidities are complex and difficult to register and measure (161). The ASA-classification (59) could be a single measure for health and comorbidities and health. However, it is not objective, and the inter-rater reliability ranges from fair to moderate agreement (162,163).

In addition, the ASA class is not registered in, for example, the NPR and must be collected from medical records or operation planning systems.

Machine learning methods in orthopaedics have recently received attention (164), especially the use of deep neural networks known as AI, which have been successfully used in the interpretation of orthopaedic trauma radiographs (165). In paper IV, better precision than conventional methods was not achieved, which may due to the absence of more complex structures in this dataset.

The future of predicting AEs may reside in AI models that are trained to abstract data from medical records. Rajkomar et al. (166) succeeded in creating a model that can interpret written text and find patterns in electronic medical records. The whole electronic medical record is fed into the model, which has the advantage of removing all bias introduced by researchers attempting to identify important variables. Another example of the advances in AI methods for text interpretation and generation is GPT-2. GPT-2 is an unsupervised language model that was trained to predict the next word in 40 GB of Internet text (167). The

The model performed so well that the creators, OpenAI, a nonprofit AI research organization, went in opposition to their principles and did not release the trained model to the public.

It seems like the original idea behind an automated AE measure that led to the GTT will be realized in the not-so-distant future.

Methodological discussion

The fast-track study

The strengths of the fast-track study included a large consecutive cohort and the prospective data collection with a well-documented method (80,81). This was the first study that compared two fast-tracks operating in parallel.

The fast track-study was not conducted as a random controlled trial, which is the preferred study design for intervention studies because it removes selection bias by creating two random groups and, therefore, provides the strongest level of evidence. A prospective cohort study was chosen because the Ambulance process was only operated by one ambulance company, and there was a need to acquire evidence that the fast-track was effective and safe. The prospective cohort study could start almost directly after implementation of the fast-track. A randomized study would remove all possibilities of selecting younger and healthier patients for the Ambulance group. However, when comparing the two groups, there were no major differences in age, ASA classification or comorbidities.

The trend of lower AE rates for patients in the Ambulance process might not just be a trend, and there is a risk that a type II error was committed. If the study cohort had been bigger, it might have provided the power to prove this secondary endpoint.

We used RRR to record all AEs in this thesis. Despite being the method that identifies the most AEs, it has several limitations. The possibility of identifying an AE is completely dependent on the quality of the documentation in the medical records. AEs that occurred but were never documented in text or in ICD-codes can never be identified. The experience of the review team will affect the number of identified AEs, as experienced teams find up to double the number of AEs than inexperienced teams (168,169). Assessing AEs is not objective, even if there is a study-specific manual with exact AE definitions, which was used in the VARA-study. Causality and preventability can be difficult to determine and can be subject to hindsight bias. Hindsight bias or "knew it all along" bias (170) is defined as people who tend to perceive events that have already occurred as more predictable than those that have in fact happened. We measured the inter-rater reliability of the RRR and obtained κ values of 0.65 to 0.97, which correspond to strong to almost perfect agreement.

The VARA-study

The strengths of the VARA-study included the large cohort and multicenter design. The Swedish personal number allowed us to trace all readmission from the NPR. This in combination with the use of RRR with the GTT methodology enabled us to identify as many AEs as possible.

In the VARA-study, we used the weighted sample instead of a random sample. Using a weighted sample has the advantages of sampling more patients who have sustained AEs than a random sample. Thus, we could record more AE data with less RRR. The dataset would also be more balanced between patients with and without AEs, which is an advantage when creating the prediction model in paper IV. Alternately, we would have to use resampling to create a weighted dataset and select more patients with an AE.

The weighted sample had to be taken into account when performing the statistical analysis. We used bootstrap sampling to calculate the confidence intervals in papers II to III. In paper III, we were faced with a methodological problem in which some of the sampling groups had no accepted claims, and we could not use Poisson regression as planned. Therefore, we attempted to employ a combined method utilizing Poisson regression for the groups that had claims and $(1-\text{max risk})^{n=0.05}$ for the groups without claims, which simplifies to $\text{max risk}=1-0.05^{1/n}$ for the upper 95% CI limit. This strategy was derived from the rule of three, which can be used to estimate upper confidence interval limits (171). We also used a customized bootstrap sample method that yielded both upper and lower confidence interval limits. The results from the two methods were similar, and therefore, chose the bootstrap method.

In paper IV, we attempted to use the ICD-codes in the logistic regression model without any success. This information seemed to be provided in the other variables, and the model had lower precision. Since the specificity of the ICD-codes was high and therefore did not classify

many cases as false positives, we attempted to create a model in which the cases that were classified as negative by the new model but as positive by the ICD-model were reclassified as positive, which also did not improve the precision of the model.

Final words

AEs are a major challenge for future healthcare. This thesis has explored different aspects of AEs, including the following:

- An intervention to prevent AEs
- Evaluation of methods to measure AEs.
- Collected data on AEs.
- Studied insurance claims for AEs.
- Developed a new measure for AEs.

There is an evident need for actions to reduce the number of AEs, and this topic is beyond the scope of this thesis. That the healthcare would cause zero AEs is an interesting thought which I believe might be impossible, because after all, “to err is human”.

But…

> “The seemingly impossible is possible”

– Hans Rosling

And…

> ”It is the highest form of self-respect to admit our errors and mistakes and make amends for them. To make a mistake is only an error in judgement, but to adhere to it when it is discovered shows infirmity of character”

– Dale Turner

CONCLUSIONS

Paper I

An improved fast-track system that bypasses the A&E could reduce the time to hip fracture surgery by 3 hours and the proportion of patients who underwent surgery within 24 hours. The fast-track system could be performed in a safe way but did not affect mortality or the number of AEs.

Paper II

The cumulative incidence of AEs following hip arthroplasty surgery was high, and the instrument based on administrative data with ICD-codes could not measure this incidence with any convincing accuracy. Furthermore, the incidence of AEs was much higher for the acute patients than the elective patients, and only approximately half of the identified AEs had a correct ICD-code.

Paper III

The proportion of accepted claims in Sweden after hip arthroplasty is very low, even for obvious and serious AEs such as periprosthetic joint infection. The proportion of accepted claims is higher for elective than acute patients. Whether the healthcare system fails to inform patients about their rights to file a claim for compensation or the patients are informed but choose not to file a claim is unknown.

Paper IV

A prediction model for AEs following hip arthroplasty surgery based on administrative data without ICD-codes is more accurate than a model based on ICD-codes. In addition to the accuracy variables such as LOS, readmissions, gender and age are robust and objective and, therefore, not prone to bias in a manner similar to ICD-codes.

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Maria Unbeck

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SAMMANFATTNING PÅ SVENSKA

”Primum, non nocere” är latin och kan översättas till ’först av allt, inte skada’. Denna berömda fras brukar tillskrivas Hippokrates, känd som läkekonstens fader. Frasen är ett uttryck för tidig medicinsk etik, att de som utövar medicin inte ska riskera att skada en patient och då är det ibland bättre att avstå från en åtgärd som riskerar att göra situationen värre.

När sjukvården orsakar en patient lidande kallas detta för en skada. Det finns många olika definitioner på skador och internationellt används många olika begrepp. I denna avhandling har vi använt den engelska termen adverse event. På svenska definieras vårdskada i patientsäkerhetslagen. En vårdskada är lidande, psykisk eller kroppslig skada, sjukdom eller dödsfall som kunnat undvikas om adekvata åtgärder vidtagits. Det är undvikbarheten som är skillnaden mellan en skada och en vårdskada.

Detta kan tyckas självklart att sjukvården inte ska skada patienter, men trots detta avlider årligen över en miljon patienter på grund av skador i orsakade av kirurgiska vårdtillfällen i världen.

Denna avhandling handlar om skador på patient efter höftkirurgi. Höftkirurgi är vanligt och görs i huvudsak av två anledningar.

1. På grund av höftfraktur. Cirka 18000 personer bryter årligen höften i Sverige. Typpatienten är en äldre benskör kvinna som faller i samma plan. Höftfrakturpatienter är en gammal och skör patientgrupp och dödligheten efter en fraktur är hög.
2. På grund av degenerativ ledsjukdom. Artros kallas ofta för ledförslitning och är en sjukdom som gör att ledbrosket i höften tunnas ut och tillslut är det ben som går mot ben i leden. Detta är mycket smärtsamt. Artros orsakar smärtor och nedsatt rörlighet.

Höftfrakturer opereras med skruvfixation av frakturen eller ersättning av leden med en konstgjord höftled, en höftprotes. Höftproteser används även för att behandla höftartros.

Avhandlingen är uppdelad i fyra artiklar.

Artikel I

I denna artikel studerade vi införandet av ett nytt snabbspår för höftfrakturpatienter på Danderyds sjukhus. I det nya snabbspåret fördes patienterna direkt till röntgenavdelningen istället för till akutmottagningen som i det gamla snabbspåret. Patienterna lades direkt i en sjukhussäng och sedan till avdelningen. I denna prospektiva observationsstudie samlade vi data på 415 patienter med höftfraktur och ingick i något av de två snabbspåren. Skillnaden i tid till operation var i medel tre timmar kortare och 13 procentenheter fler patienter blev opererade inom 24 timmar i det nya snabbspåret. Det fanns en trend att de drabbades av färre skador.

Slutsats: Det nya snabbspåret gjorde att patienterna blev opererade tidigare och att snabbspåret var säkert då ingen patient skadades.

Artikel II

Det finns ett svenskt instrument för att mäta skador efter höftprotesoperation. Det är baserat på diagnoskoder som registreras i patienters utskrivningsanteckning från återbesök inom 90 dagar. Denna information registreras i patientregistret. Detta instrument används av både Sveriges Kommuner och Landsting samt Svenska Höftprotesregistret. Detta instrument har aldrig validerats och dess validitet är okänd. I denna multicenterstudie utförde vi retrospektiv strukturerad journalgranskning med hjälp av Markörbaserad journalgranskning på 2000 patienter som opererats med höftprotes. Alla skador registrerades och resultatet jämfördes med instrumentet. Vi beräknade även andelen patienter som fick en skada.

Instrumentet upptäckte och klassificerade 6% av de patienter som fick en skada, instrumentets sensitivitet. 95% av de som inte fick en skada klassificeras rätt av instrumentet, dess specificitet. 28% av patienterna fick en skada inom 30 dagar efter operation. Av de patienter med akut operation fick 51% en skada och 17% av patienterna med planerad operation fick en skada inom 30 dagar.

Slutsats: Instrumentet är inte tillförlitligt för mätning av skador efter höftprotesoperation.

Artikel III

Patientskadelagens första paragraf säger att alla vårdgivare måste ha en försäkring som försäkrar patienterna mot skador. All offentligt finansierad sjukvård i Sverige försäkras av Löf (Landstingens ömsesidiga försäkringsbolag). Den som skadas i hälso- och sjukvården har rätt att ansöka om ersättning från Löf. Sjukvården har enligt patientsäkerhetslagen en skyldighet att snarast upplysa patienter som fått en skada som bedöms som undvikbar, dvs en vårdskada, om att de drabbats av en vårdskada och att de har möjlighet att begära ersättning enligt patientskadelagen.

I denna studie studerade vi hur många av de patienter i artikel II som drabbades av en allvarlig vårdskada som hade en godkänd ansökan hos Löf. 7% av de som drabbats hade en godkänd ansökan. Djup protesinfektion var den vanligaste skadan som godkändes. 94% av ansökningarna godkändes.

Slutsats: Endast en bråkdel av de vårdskadorna sökte och fick ersättning av Löf.

Artikel IV

Mätinstrumentet för skador i artikel II är baserat på diagnoskoder och har låg precision. Diagnoskoder är subjektiva och kan påverkas eftersom de även används för ekonomisk ersättning. Målet med denna studie var att utveckla en ny modell för att mäta skador efter höftprotesoperation.

Vi använde datasetet från artikel II för att träna olika maskinlärningsmodeller. En logistisk regressionsmodell hade precision och var snabbast. Denna nya modell baseras på variablerna patientens ålder, vårdtid, akutbesök och antal återinläggningar. Den nya modellen hade två till tre gånger högre sensitivitet och samma specificitet som diagnoskodmodellen.

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