



TUOMAS HUTTUNEN

# Surgical Treatment of Upper Limb Fractures

An evidence-based approach



ACADEMIC DISSERTATION

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UNIVERSITY OF TAMPERE

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OF TAMPERE

ACADEMIC DISSERTATION

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## LIST OF ORIGINAL PUBLICATIONS

- I Huttunen, TT., Kannus, P., Pihlajamäki, H., Mattila, VM. Pertrochanteric fracture of the femur in the Finnish National Hospital Discharge Register: validity of diagnosis, procedural coding, and external cause for injury. *BMC Musculoskeletal Disorders* 2014 Mar 24; 15(1):98.
- II Huttunen, TT., Kannus, P., Lepola, V., Pihlajamäki, H., Mattila, VM. Surgical treatment of clavicular fractures in Finland – A register based study between 1987 and 2010. *Injury* 2013; 44(12):1899-903.
- III Huttunen, TT., Launonen AP., Pihlajamäki, H., Kannus, P., Mattila, VM. Trends in the surgical treatment of proximal humeral fractures – a nationwide 23-year study in Finland. *BMC Musculoskeletal Disorders* 2012 Dec 29; 13:261.
- IV Huttunen, TT., Kannus, P., Lepola, V., Pihlajamäki, H., Mattila, VM. Surgical treatment of humeral-shaft fractures: a register-based study in Finland between 1987 and 2009. *Injury* 2012; 43(10):1704-08
- V Mattila, VM., Huttunen, TT., Sillanpää, P., Niemi, S., Pihlajamäki, H., Kannus, P. Significant change in the surgical treatment of distal radius fractures: a nationwide study between 1998 and 2008 in Finland. *Journal of Trauma* 2011; 71(4):939-42



## ABBREVIATIONS

AO	Arbeitsgemeinschaft für Osteosynthesefragen
EBM	Evidence-based medicine
EBMWG	Evidence-Based Medicine Working Group
CF	Clavicle fracture
CI	Confidence interval
DASH	Disabilities of the Arm, Shoulder and Hand
DRF	Distal radius fracture
HSF	Humeral shaft fracture
ICD	International Classification of Diseases
NHDR	Finnish National Hospital Discharge Register
NOMESCO	Nordic Medico-Statistical Committee
PHF	Proximal humeral fracture
PPV	Positive predictive value
PRWE	Patient-Rated Wrist Evaluation
RCT	Randomised controlled trial
STAKES	National Research and Development Centre for Welfare and Health
THL	National Institute for Health and Welfare, Helsinki, Finland
WHO	World Health Organization





## ABSTRACT

The purpose of this thesis study was to investigate the trends and incidence rates of operative treatment of upper limb fractures in Finland. A further purpose of the study was to evaluate the reliability of the Finnish National Hospital Discharge Register.

The thesis consists of five separate studies. The first part of the thesis evaluated the reliability of the Finnish National Hospital Discharge Register. The study population consisted of all adult patients diagnosed with a pertrochanteric hip fracture in three Finnish hospitals between 2008 and 2010. Accuracy of diagnosis as well as accuracy and coverage of procedural coding and external cause of injury were assessed. The following four studies were based on data obtained from the Finnish National Hospital Discharge Register. The second study assessed the trends and incidence rates of surgically treated clavicle fractures consisting of all surgically treated adult patients with a clavicle fracture in Finland between 1987 and 2010. The third and fourth studies assessed trends and incidence rates of surgically treated humeral fractures. The study population consisted of all surgically treated adult patients with a fracture of proximal part or shaft of the humerus in Finland between 1987 and 2009. The fifth study assessed trends and incidence rates of surgically treated distal radius fractures. The study population consisted of all surgically treated patients 20 years and older with a distal radius fracture in Finland between 1998 and 2009.

In the first part of this thesis, the accuracy of diagnosis in the Finnish National Hospital Discharge register was 96%, coverage of external cause of injury was 95% and accuracy 90%. The coverage of procedural coding was 98% and accuracy 88%.

According to the results of this thesis, surgical treatment of common upper limb fractures has increased markedly. As with other upper limb fractures in this thesis, the rate of surgically treated clavicle fractures increased between 1987 and

2010. The magnitude of the change that was observed in this study was surprising; the overall incidence rate of clavicle fractures increased about ninefold. The change was even stronger in men under 60 years of age, where the incidence of surgical activity increased almost elevenfold. The rate of proximal humeral fractures that were surgically treated between 1987 and 2009 nearly quadrupled. The continuous increase in the surgical activity coincided with the actual fracture rate remaining quite constant, indicating that an increasing proportion of fractures are being treated surgically. The increase in the rate of surgical treatment, especially in plating was greatest in women older than 60 years of age. Between 1987 and 2009 the number and incidence rate of surgically treated humeral shaft fractures increased significantly, especially in older women. There was a clear shift towards plating, mostly at the expense of nailing, in the surgical treatment of humeral shaft fractures. Between 1998 and 2008 the incidence rate of surgically treated distal radius fractures doubled. A clear change in the type of surgical technique was also evident, as plating surpassed external fixation as the most popular procedure. These changes were especially notable in older women.

According to the first study, the Finnish National Hospital Discharge Register is a very reliable source of information, and can be used on assessing trends in the surgical treatment of fractures.

For one reason or another, surgical treatment of common upper limb fractures has increased markedly during recent years. Concerning distal radius, and proximal as well as humeral shaft fractures, plate fixation has increased, thus diminishing the rate of other surgical techniques. Current scientific evidence on the treatment of these upper limb fractures does not support the changes observed in this thesis. There is an urgent and evident need for more high-quality prospective research comparing non-operative and surgical treatment of these fractures. Additionally, different surgical methods need to be compared in a high-quality setting before major changes in the treatment protocols of common injuries are adopted.

# TIIVISTELMÄ

Tämän väitöskirjatutkimuksen tarkoitus oli selvittää, miten tavallisten yläraajamurtumien ja leikkaushoidon insidenssi on kehittynyt Suomessa viimeisten vuosikymmenten aikana. Toisena tavoitteena oli arvioida kansallisen hoitoilmoitusrekisterin luotettavuutta epidemiologisessa tutkimuksessa.

Tutkimus koostuu viidestä erillisestä osatyöstä. Ensimmäisessä osatyössä pyrittiin arvioimaan hoitoilmoitusrekisterin luotettavuutta lonkkamurtumapotilailla erityisesti toimenpidetekoodien osalta. Ensimmäisen osatyön aineisto koostui kolmeen eri sairaalaan vuosien 2008 ja 2010 välisenä aikana trokanteerisen reisiluun yläosan murtuman vuoksi joutuneista potilaista. Luotettavuutta arvioitaessa selvitettiin diagnoosin, toimenpidetekoodin ja ulkoisen tapaturman syyn käytön tarkkuutta ja lisäksi toimenpidetekoodin ja ulkoisen syyn käytön kattavuutta. Neljän seuraavan osatyön aineistona käytettiin valtakunnallista hoitoilmoitusrekisteriä. Toisessa osatyössä selvitettiin solisluun murtumien leikkaushoidossa tapahtuneita muutoksia. Tutkimusaineisto koostui kaikista vuosien 1987 ja 2010 välisenä aikana solisluun murtuman vuoksi leikkaushoidetuista aikuispotilaista. Kolmannessa osatyössä selvitettiin olkaluun yläosan murtumien leikkaushoidon esiintyvyydessä tapahtuneita muutoksia. Tutkimusaineisto koostui kaikista vuosien 1987 ja 2009 välisenä aikana olkaluun yläosan murtuman vuoksi leikkaushoidetuista aikuispotilaista. Neljännessä osatyössä tutkittiin olkaluun varren murtumien leikkaushoitojen esiintyvyydessä tapahtuneita muutoksia vuosien 1987 ja 2009 välisenä aikana. Tutkimusaineisto koostui kaikista olkaluun varren murtuman vuoksi leikatuista aikuispotilaista. Viidennessä osatyössä tutkittiin distaalisen varttinäluun murtuman leikkaushoitojen esiintyvyydessä tapahtuneita muutoksia. Tutkimusaineisto koostui kaikista Suomessa vuosien 1998 ja 2008 välissä varttinäluun murtuman vuoksi leikatuista aikuispotilaista.

Ensimmäisessä osatyössä arvioitiin hoitoilmoitusrekisterin luotettavuutta ja todettiin, että diagnoosin tarkkuus oli 96%, ulkoisen syyn kattavuus oli 95% ja tarkkuus 90%. Toimenpidekoodin kattavuus oli 98% ja tarkkuus 88%. Tutkimuksen perusteella kansallista hoitoilmoitusrekisteriä voidaan pitää erittäin luotettavana tiedonlähteenä tehtäessä tapaturmiin ja leikkaushoitoihin kohdistuvaa epidemiologista tutkimusta.

Väitöstutkimuksen perusteella voidaan lisäksi todeta, että yleisimpien yläraajan murtumien leikkausmäärät ovat lisääntyneet merkittävästi viime vuosina. Solisluun murtumien leikkaushoito lisääntyi vuosien 1987 ja 2010 välisenä aikana. Solisluun leikkausmäärien kasvu oli yllättävän voimakasta; aikuisten solisluun murtumien leikkaushoidot lisääntyivät yli yhdeksänkertaisesti ja alle 60-vuotiaiden miesten leikkausmäärät lisääntyivät lähes yksitoistakertaisesti. Olkaluun yläosan murtumien leikkausmäärät lähes nelinkertaistuivat vuosien 1987 ja 2009 välisenä aikana. Leikkaushoidon määrän kasvu on tapahtunut aikaan, jolloin itse olkaluun yläosan murtumien esiintyvyys on pysynyt melko tasaisena, mikä voi viitata leikkaushoidon suosion kasvuun konservatiivisesti hoidettujen potilaisiin verrattuna. Muutokset olivat selkeimmät vanhempien naisten osalta. Olkaluun varren murtumien leikkaushoito lisääntyi selkeästi vuosien 1987 ja 2009 välisenä aikana, etenkin vanhempien naisten osalta. Murtuman hoidossa aiemmin yleisimmin käytetty naulaus väheni levytysten lisääntyessä. Distaalisen varttinäluun leikkausmäärät kaksinkertaistuivat vuosien 1998 ja 2008 välisenä aikana. Lisäksi havaittiin, että leikkaustavoissa tapahtui selkeä muutos; murtumien leikkaushoito levyttämällä lisääntyi huomattavasti ulkoisen kiinnityksen vähentyessä. Muutokset olivat selkeimpiä vanhempien naisten osalta.

Yleisimpien yläraajamurtumien leikkaushoitojen esiintyvyys on lisääntynyt Suomessa viime vuosina huomattavasti. Distaalisen varttinäluun ja olkaluun yläosan ja varren murtumien osalta levytysleikkaukset ovat syrjäyttäneet muita leikkaustekniikoita. Nykyinen tutkimustieto ei tue näiden yläraajan murtumien osalta havaittua muutosta, etenkin vanhempien potilaiden osalta. On ilmeistä, että jatkossa tullaan tarvitsemaan korkealaatuista kliinistä tutkimusta, jossa verrataan konservatiivista hoitoa leikkaushoitoon. On myös välttämätöntä, että eri leikkaustekniikoita verrattaessa käytetään parhaita ja luotettavimpia tutkimusasetelmia parhaan leikkaustekniikan selvittämiseksi.

# 1. INTRODUCTION

Upper limb fractures are common injuries encompassing nearly 60% of all adult fractures.(Court-Brown and Caesar, 2006) As such, these injuries pose a considerable strain on our health-care system. Most upper limb fractures are traditionally good candidates for conservative treatment and are usually treated by primary immobilization.(Bucholz et al., 2006) During recent years, reports have been published indicating that injuries such as proximal humeral or distal radial fractures have been increasingly the target of surgical treatment.(Koval et al., 2008, Bell et al., 2011, Wilcke et al., 2013) However, the amount of high quality scientific evidence suggesting that a change in a more surgically active direction is lacking. Although common injuries, upper limb fractures have not been researched thoroughly in a high-quality setting. Because of the lack of clear evidence, it seems that treatment policies of common injuries vary between different orthopaedic trauma centres. (Chung et al., 2009, Bell et al., 2011)

The Finnish National Hospital Discharge Register (NHDR) provides for an excellent source of information as all surgically treated patients in Finland are recorded into the database.(Sund, 2012) The register contains a multitude of variables that can be used in epidemiological research. Together with the Official Statistics of Finland, the register allows true national population-based rates of surgical treatments to be assessed.

The validity of the NHDR has been evaluated previously and the reliability in respect to diagnosis has proved to be excellent.(Sund, 2012) However, there is only one previous study assessing the reliability of diagnosis, external cause of injury and procedural coding in the same study in recent years.(Sund et al., 2007) With

administrative hospital registers, a high level of validity is needed for the findings of research reports based on the register to be reliable.

This study aimed at increasing our knowledge of the trends in the surgical treatment of common upper limb fractures during recent years in Finland. There are no large population scale studies evaluating the rates of surgical treatment of these fractures. Additionally, proportions of different surgical procedures in the treatment of these fractures have not previously been studied on a national level. Assessing trends in surgical approaches adds to our understanding of the implementation of scientific evidence in clinical practice on a national level. Monitoring changes in current surgical practice enables us to critically appraise whether a certain trend is justified according to the best scientific evidence available. Additionally, the reliability of data sources such as hospital discharge register needs to be evaluated and a high rate of validity should be demanded. Therefore this study also aimed at assessing the reliability of the NHDR in respect to diagnosis, external cause of injury and procedural coding.

## 2. REVIEW OF THE LITERATURE

### 2.1 Bone tissue

Mature bone is made of bone marrow lined with endosteum, which is surrounded by the actual bone tissue and periosteum. Bone is a type of connective tissue with a matrix made of an organic and an inorganic component. (Ross and Pawlina, 2011) The matrix forms the bulk of bone tissue with the remainder made up of cells and blood vessels. (Ross and Pawlina, 2011) Most of the organic part of bone matrix consists of collagen, primarily of type I and to a lesser degree of types III, V, X and XII. (Buckwalter et al., 1996b) In addition to providing reinforcement to the structural integrity of bone, collagen also provides elasticity in bone. (Browner, 2009, Ross and Pawlina, 2011) The remainder of the organic matrix includes proteins such as proteoglycan, glycosaminoglycan, osteocalcin and sialoprotein. (Buckwalter et al., 1996b) The inorganic matrix of bone consists mostly of hydroxyapatite ( $\text{Ca}_{10}[\text{PO}_4]_6[\text{OH}]_2$ ) and serves two functions: while it gives bone its stiffness and strength it also provides a reservoir of important electrolytes for the body such as calcium, phosphorus and magnesium. (Buckwalter et al., 1996b, Buckwalter et al., 1996a, Ross and Pawlina, 2011)

The actual bone tissue can be divided into two separate types: cortical and cancellous bone. They have an identical composition but differ in density; cortical bone is much more dense or less porous than cancellous bone. This ultimately leads to cortical bone having greater compressive strength than cancellous bone. The bulk of the human skeleton consists of cortical bone and in long bones such as femur, clavicle or humerus the diaphysis or shaft is rich in cortical bone provides resistance to torsion and bending. Metaphyseal and epiphyseal parts of bones however are rich in cancellous bone with porous structure that allows greater deformation, providing



a needed distribution of load adjacent to joints. Over time the structure of bone tissue on human skeleton is altered in response to loading, as depicted by Wolff, and additionally in response to hormonal changes, injuries and immobilization. (Bucholz et al., 2006) Cancellous bone with its greater porosity has more inner surface area than cortical bone and as such cancellous bone has more area covered with cells in close proximity of blood vessels. Therefore, cancellous bone has a higher metabolic activity rate and changes as well as fracture healing occur more rapidly than in cortical bone. (Buckwalter et al., 1996b)

Both cortical and cancellous bone tissue consists of woven or lamellar bone. Woven bone forms the skeletal structures of the growing embryo and is slowly replaced by mature bone in the developing skeleton. Woven bone is rare in the maturing skeleton after the age of four to five years of age, but can be seen in response to injury, metabolic or malign disease or inflammation. In contrast to lamellar bone, woven bone is rich in osteocytes and cells, and extracellular matrix has a less organized structure. The irregular structure, with a high concentration of cells and water, makes woven bone more flexible and it has weaker tensile and compressive strength than lamellar bone. Lamellar bone is highly organized and consists of densely packed collagen fibre both intra- and extracellularly. The lamellae in lamellar bone organize into cylindrical form where the collagen fibres interconnect the adjacent lamellae. The collagen mesh, acting like ferroconcrete, provides additional strength into the structure. (Buckwalter et al., 1996b, Buckwalter et al., 1996a, Ross and Pawlina, 2011)

## **2.2 Fracture healing and basis for fracture fixation**

Fractures can be classified according to their shape and anatomical presentation (Bucholz et al., 2006, Browner, 2009). A closed fracture occurs without affecting the overlying soft tissue, whereas an open or compound fracture communicates with the surface of the skin. A splintered fracture is called comminuted and displaced if the fractured bone fragments are not aligned. Fracture can also be angulated in response to torque forces created by muscles that are attached to fractured bone fragments and pulling them apart. Bone, unlike many other tissues, has an efficient and unique ability to repair itself. (Bucholz et al., 2006, Robbins et al., 2010, Ross and Pawlina, 2011)

After sustaining a fracture, the induction of self-repair in bone is almost concurrent with the insult. The healing consists of three phases, a sequence of inflammation, repair and remodelling (Einhorn, 2005, Bucholz et al., 2006, Browner, 2009, Robbins et al., 2010). The period of inflammation begins as the fractured site is rapidly filled with blood, resulting in hematoma formation. (Buckwalter et al., 1996a, Browner, 2009) A blood clot fills the space between and around the bone fragments. In response to the injury in the tissues, the inflammatory cells and platelets release a broad spectrum of cytokines, activating in turn the osteoprogenitor cells in the periosteum, medullary cavity and surrounding soft tissues. (Buckwalter et al., 1996a, Browner, 2009, Robbins et al., 2010) In response to the inflammatory mediators, blood vessels dilate and plasma is pooled, resulting in local oedema. (Robbins et al., 2010) After the initial inflammatory response subsides, a fibrin mesh is formed, isolating the site and also providing an initial supporting structure for the chondrocytes, fibroblasts and newly forming capillary vessels. (Robbins et al., 2010) The period of repair is initiated as multipotent mesenchymal cells migrating through blood circulation start forming the initial fibrous tissue at the fracture site. (Einhorn, 1998, Einhorn, 2005) As early as 72 hours after the injury, the migrated cells start to proliferate, and mononuclear cells differentiate into osteoclasts and multipotent mesenchymal cells into chondroblasts, osteoblasts, osteocytes and bone lining cells. (Einhorn, 1998, Einhorn, 2005) Newly formed chondroblasts and osteoblasts start producing extracellular matrix, resulting in fracture callus consisting of fibrous tissue; cartilage first and later on woven bone. (Einhorn, 2005) Cartilaginous tissue formation starts after the first week after the injury and continues until 4 to 5 weeks after the injury. (Einhorn, 1998) After 5 weeks newly forming woven bone emerges. As mentioned before, woven bone has an unorganized extracellular matrix that gradually, as the healing and ossification proceeds, becomes more and more organized especially in respect to collagen fibrils and their orientation. (Einhorn, 1998) Initially, the callus can be divided into soft and bony callus. (Einhorn, 1998, Einhorn, 2005, Robbins et al., 2010) Soft callus consists primarily of cartilage and fibrous tissue whereas hard callus gradually replaces the cartilaginous softer callus with mature bone, a process also called endochondral or secondary ossification. (Einhorn, 2005, Ross and Pawlina, 2011) As the mineralization of callus proceeds, stiffness and stability of the fracture increases. The process continues until the fractured site is bridged with new bone, resulting in clinical union of the fracture. (Bucholz et al., 2006, Browner, 2009) In the last phase of remodelling, woven bone is turned into lamellar bone and excess callus is resorbed partly in response to increasing tensile and loading

forces of the bone.(Buckwalter et al., 1996a, Bucholz et al., 2006) Bone repair can also occur without a formation of callus when fractures are stabilized and fractured parts are aligned and in contact.(Einhorn, 2005) This ability of bone healing, also called intramembranous or primary ossification, is utilized in fracture surgery, but is dependent of absolutely rigid fracture fixation.(Bucholz et al., 2006, Ross and Pawlina, 2011) Primary ossification occurs when osteoclasts and osteoblasts from the adjacent bone tissue and newly forming blood vessels traverse the fracture line and directly initiate new bone formation.(Einhorn, 1998, Ross and Pawlina, 2011) In case of a gap between the fragments, osteoblasts migrate into the gap, forming woven bone and, with progressive remodelling, lamellar bone.(Buckwalter et al., 1996a, Bucholz et al., 2006)

An occurrence where bone heals in a deformed way or there is marked angulation or shortening after healing, is called malunion. A non-union is a situation when the fracture gap is not bridged by new bone, resulting in an unstable bone. Delayed union is simply a bone healing slower than is characteristic for a certain type of bone. Time to union (or delayed union) is dependent on the bone in question: for instance, wrist fractures heal more rapidly than fractures of the femur.

Several different techniques and fixation devices to treat different types of fractures have been developed over the years.(Bucholz et al., 2006) The different types of fixation techniques rely on a different approach and also a different biological process of healing.(Bucholz et al., 2006, Browner, 2009)

When external fixation device is used, pins are attached to the proximal and distal side of the fracture. An external fixator is then used to bridge the pins to form an external support for the fracture.(Bucholz et al., 2006, Browner, 2009) With external fixation, bone healing occurs after secondary or endochondral ossification.(Bucholz et al., 2006) As the external fixator provides for stability but allows for relative movement facilitating the normal bone healing, even large fracture gaps can be treated.(Bucholz et al., 2006) The basis of open reduction and internal fixation relies on four principles: anatomic reduction, rigidity of internal fixation, atraumatic surgical technique and early pain-free motion of the injured site.(Allgower and Spiegel, 1979) Locking compression plates allow for an anatomic reduction and compression of the bone fragments to bridge the fracture gap. Fracture healing after internal fixation occurs by primary ossification, which necessitates anatomic reduction and absolute rigidity of the fixation.(Bucholz et al., 2006) In contrast to normal fracture healing, callus formation after internal fixation has been seen as a sign of instability. Fracture fixation using intramedullary techniques such as intramed-

ullary nails provides for an internal fixation using closed technique.(Bucholz et al., 2006, Browner, 2009) The basis of the technique is less traumatic for soft tissues than open reduction and internal fixation as a smaller surgical exposure is needed. Opposite to the rigid fixation associated with open reduction and internal fixation, intramedullary fixation allows for some movement between the bone fragments. (Bucholz et al., 2006, Browner, 2009) Therefore, bone healing after intramedullary fixation relies on secondary or endochondral ossification: fracture healing occurs after callus formation.(Bucholz et al., 2006)

## 2.3 Definition of evidence-based medicine

Although apparently used already in 1990 as a part of the application material for the internal medicine residency program at McMaster University, the term evidence-based medicine (EBM) was first described in the literature in 1991, when Gordon Guyatt raised the question of whether the authority-based decision-making in medical education and practice should be questioned.(Guyatt, 1991) In a subsequent defining article, published in the Journal of the American Medical Association in 1992, a multidisciplinary Evidence-Based Medicine Working Group (EBMWG) introduced the path for the future.(Guyatt, 1992) The original introducers of EBM probably did not dare to contemplate, how profound a change in the practice of medicine they had started. More than a decade later, in 2007, the British Medical Journal proposed EBM as one of the 15 most important milestones next to, for instance, the discovery of DNA structure and antibiotics.(Godlee, 2007)

The ideas suggested by the original EBMWG were manifold. Traditionally medical science and especially the practice of medicine have revolved around authorities (masters) that the students (apprentices) look up to. An important part of the new way of thinking was to lessen the emphasis on relying on authorities such as clinical expertise and textbooks, and to accentuate the role of scientific literature on decision-making. New skills and knowledge for clinicians were seen as a necessity: understanding rules of evidence to be able to critically evaluate causation, diagnostic testing and treatments. This was not all new, though; understanding the underlying physiological and pathophysiological basis of disease was seen as important, especially when pondering whether certain research findings could be applied to an individual or generalized from one population to another. The above-mentioned EBMWG also pointed out that the “new way of thinking” did not try to downplay

the importance of clinical expertise, basic sciences in medicine or traditional teaching of clinical skills. The idea was to refine the traditional skills and add in a new way of critical thinking. An important part of implementing a new approach such as EBM is teaching. In the original paper, the authors from McMaster University presented the curriculum outline of their internal medicine program, where residents were “exposed” to EBM schooling on a weekly basis. A variety of problems that had arisen after the introduction of the evidence-based approach were also recognized in the original article: some authorities in their respective fields had found the authority-diminishing thinking to be threatening, the implementation of a critical appraisal of literature was found to be time-consuming, especially if the area of interest was lacking in high-quality research. The new way of thinking was also met with a certain amount of scepticism. (Guyatt, 1992)

The advocates of EBM from McMaster University followed with a series of articles aimed at familiarizing clinicians with reading scientific articles with the idea of answering defined questions that had arisen from clinical work. A critical evaluation of articles boiled down to three fundamental questions: Are the results of the study valid? What are the results? Can the results be applied to another population? (Guyatt and Rennie, 1993, Oxman et al., 1993) The EBM method starts by learning to ask questions related to patient work and then defining the problem or issue. In the next phase one needs to study the literature at hand and find the best evidence by going through all the relevant articles and critically assessing their results. In the last phase, after careful review and finding relevant and valid information, one needs to consider whether the results can be applied to the problem at hand and possibly generalized. (Sackett, 2000) In a later article of the series on EBM methodology, patient-related factors such as values and choices related to patient care decisions were discussed; after assessing the best evidence for a well formulated question, good care crystallizes in clinical skills, humanism and social responsibility. (Guyatt et al., 2000) As each patient is unique with his or her beliefs and values, the choice of treatment relies on the skills of the treating physician to find the best treatment for an individual. (Sackett, 2000)

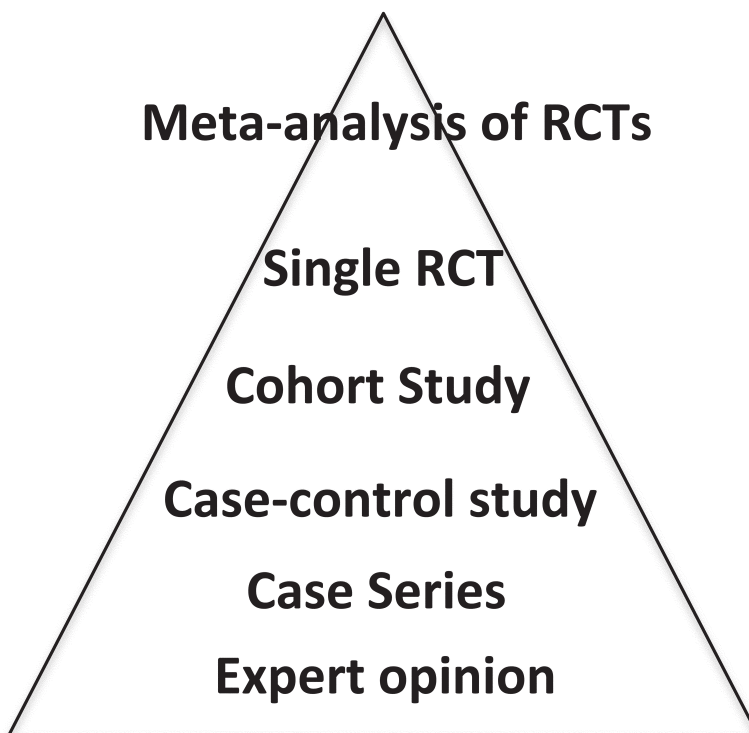
Since the inception of EBM, computerized access to information and scientific literature has become increasingly easy. However, the exponential increase in information and different databases only further underlines the need for individual clinicians to be able to screen relevant and valid information. To help clinicians coping in the avalanche of scientific information, support systems for decision-making have evolved. Cochrane reviews and meta-analyses pool and analyse the results of

studies on a single subject. Also, decision support systems such as UpToDate aim to answer specific clinical questions.(Sackett, 2000)

In terms of EBM, the literature can be divided into four subgroups, namely diagnostic studies, cohort (observational, prognostic) studies, randomized controlled studies and meta-analyses. There are several issues to take into account when reading the literature. When reviewing an article about diagnostic testing, certain things need to be considered. Firstly, the validity of a diagnostic test should be independently evaluated by comparing to a reference or more commonly to a “gold standard”. Secondly, the tested patient sample should be a good representation of the kind of population or patients to whom the diagnostic test will be applied in an actual clinical setting. Thirdly, the validity of a test should always be tested regardless of the result of the diagnostic test.(Sackett, 1991, Jaeschke et al., 1994b, Jaeschke et al., 1994a, Sackett, 2000) Studies on cohort samples should be evaluated by firstly assessing whether the studied patient sample was a representative sample of patients in a well-defined period of the ailment. Secondly, the length of follow-up is especially important in prognostic cohort studies. Thirdly, the outcome criteria should be well defined in advance and outcome assessors should be blinded. Lastly, adjustment for important prognostic factors needs to be analysed if groups that have different prognoses are found.(Sackett, 2000)

When therapeutic studies are considered, a certain hierarchy of evidence exists. (Sackett, 1991) Clinical experience and expert opinion lie at the bottom of the pyramid of evidence (Figure 1) and randomized clinical trials (RCTs) are at the top. When the outcomes of many RCTs are pooled and analysed, performing a meta-analysis can further increase the power of the original studies.(Sackett, 2000, Bhandari and Tornetta, 2004) In a randomized trial, patients are randomly allocated to alternative study groups randomly. By randomizing the groups that are eventually compared, trial conductors try to control known and unknown factors affecting the outcome. (Sackett, 1991) Blinding (patient) and double blinding (outcome assessor) are an important part of a high-quality comparative study and usually feasibly realizable in medical research.(Bhandari et al., 2002) It is obvious that in trials where the studied intervention includes invasive manoeuvres, such as internal fixation of a pertrochanteric hip fracture, the surgeon can not be blinded and blinding of a patient is at the very least difficult. In a study assessing the quality of 72 orthopaedic RCTs, Bhandari et al found that in at least 90% of trials both outcome assessors and data analysts could have been blinded.(Bhandari et al., 2002) They also suggested that in most trials (including surgical) the blinding of patients could have been feasible.

One aspect of RCTs is the analysis of results that should be done following the intention-to-treat principle, which means that all cases are analysed in the respective groups they were allocated to during randomization.(Sackett, 2000) This helps to avoid the skewing of results if there is a lot of crossover between the treatment groups during the trial.



**Figure 1.** Hierarchy of Evidence. Adapted from Bhandari and Tornetta, 2004.

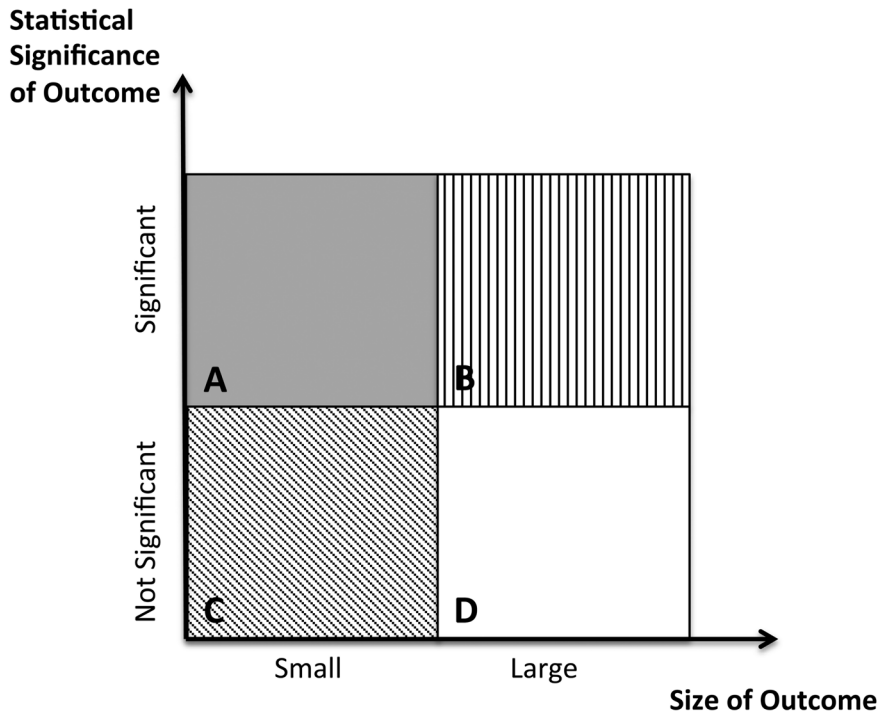
In orthopaedic literature the term evidence-based orthopaedics and the use of levels of evidence were introduced at the start of the millennium.(Bhandari and Sanders, 2003, Wright et al., 2003) Although RCTs are considered to lie on the top of the pyramid of evidence, observational studies such as cohort studies, case-control studies and case series can provide and add to the existing knowledge. Observational studies have been criticized for easily overestimating outcomes when patients are not allocated in study groups at random.(Bhandari et al., 2001, Bhandari et al., 2004) However, Concato and co-workers did not find evidence of cohort or case-control studies overestimating the outcomes when compared to RCTs.(Concato et al.,

2000) So it is probably not just a matter of RCTs when therapy or intervention is considered.(Hoppe et al., 2009) Additionally, high-quality evidence can arise from clearly defined case series prognostic studies such as arthroplasty or trauma register studies when patients are enrolled at the same point of their disease and there is a sufficient proportion of follow-up.(Hoppe et al., 2009, Trumm et al., 2012)

It is important to identify certain risks related to RCTs. A very common problem in orthopaedic literature has been that the studies have been underpowered.(Lochner et al., 2001) An underpowered study is not able to detect a difference (in other words, the results are not statistically significant) between the studied interventions when a difference actually exists, a problem also called a type II error.(Bhandari and Tornetta, 2004) A common way to try to avoid a type II error is to perform a sample size calculation when planning a trial. However, properly conducted sample size calculation only guarantees that an estimate of sufficient sample size has been assessed. If the difference in outcome measures used in sample size calculation has been poorly selected, a study can still be underpowered. But then, even if the results of a trial are statistically significant, it does not automatically mean that there is a clinically significant (relevant) difference between the studied groups.(Sackett, 1991) Figure 2. When planning a study, the outcomes measured need to be valid and the smallest clinically significant difference in outcome measures defined when doing sample size calculation. Usually patients in trials get better outcomes than regular patients since the patients regard themselves, and they are regarded by the physicians, nurses and physiotherapists treating them in a generally more positive way, a phenomenon also called the study effect. Results of sample-based studies always need to be considered carefully when trying to generalize for other populations. If, for instance, a plethora of patients were evaluated as candidates for a study but only a fraction were accepted, one needs to ask if the inclusion and exclusion criteria for the study were valid and representative. When reading a research paper, it should always be noted if the study has received outside funding or if a conflict of interest exists for any of the authors. Lastly, when evaluating the available literature, it is possible that only trials resulting in positive results (differences between studied interventions) get published, also called publication bias.(Sackett, 2000) For instance, the Cochrane collaboration has attempted to take publication and other types of reporting bias into account when conducting systematic reviews by including all studies independent of the original language of the report or medium of presentation.

Cohort studies can prove their significance when, for instance, studying a certain exposure would be unethical; an ethical review board would probably not





**Figure 2.** Statistical significance versus clinical significance. A= an outcome that is small but statistically significant. B= an outcome that is large and statistically significant. C= an outcome that is small and not statistically significant, D= an outcome that is large but not statistically significant.

approve an RCT study setting where patients referred to a university hospital with chest pain would either wait over 4 hours to see a consulting emergency room doctor or the consultation would be immediate. By assessing this setting with two cohorts (retrospectively), it would be possible to ascertain whether prolonged waiting time carries some risks. In addition, large nationwide cohort studies can show reliably whether treatment policies or costs of treatment have changed over time. A case-control study setting is especially useful if the studied outcome is rare. If, for instance, factors affecting post-operative infection rates were considered, a sample of patient cases with a certain outcome (infection) is identified from a data registry following arthroscopy, and the sample is then matched by control patients who underwent arthroscopy but did not develop an infection. By comparing these two groups, certain factors increasing the rates of postoperative infection could be assessed, although a risk of selection bias always exists. Case series are observational studies that are usually retrospective and not controlled. A successful case series is a

history of an individual or a group of patients where the value can be increased by standardizing the cases when prognostic factors can at least be hypothesized. (Bhandari et al., 2004, Bhandari and Tornetta, 2004, Hoppe et al., 2009, Uhari, 2012)

When assessing the evidence and, more importantly, the relevance of different studies, in the end it all comes down to the application and generalization of a study. Who were the patients and how were they chosen and when were they excluded? What was the studied intervention? Was there a control? What were the outcomes and how were they measured? And finally, what was the study type?

Commonly, a change in the clinical practice needs several high-quality studies and a marked difference in the outcomes measured. For instance, a Cochrane review and meta-analysis in 2004 concluded that conservative and operative treatment yield similar functional outcome in acute Achilles tendon rupture. (Khan et al., 2004) According to Khan and co-workers the rate of re-rupture was higher in conservatively treated patients. (Khan et al., 2004) As the conservative treatment of acute Achilles tendon rupture evolved by abandoning rigid cast treatment and a shift was made to early weight bearing with protected range of motion, new high-quality studies have emerged. (Suchak et al., 2008) According to these newer RCTs, conservative treatment with novel functional bracing produces similar functional outcomes as operative treatment with almost similar rate of re-rupture. (Metz et al., 2008, Nilsson-Helander et al., 2010, Willits et al., 2010, Wallace et al., 2011) A decrease in the rate of surgically treated acute Achilles tendon ruptures was seen in Finland since 2007, indicating that Finnish orthopaedic surgeons have adapted to the new evidence. (Mattila et al., 2013)

## 2.4 Finnish National Hospital Discharge Register

Initiated in 1956, the NHDR is one of the oldest hospital discharge registers in the world. (Sund, 2012) The first registered discharges were from tuberculosis sanatoriums and mental hospitals and since 1967 the register has had full nationwide collection of discharges from all hospitals. (Sund, 2012) The register data per discharge has included personal identification numbers since 1969 allowing the incorporation of register data against other data sources such as patient records. (Sund, 2012) The NHDR has been intensively used over the years in medical and epidemiological research. (Sund, 2012) Similar registers exist in other Scandinavian countries like Norway, Denmark and Sweden. At least in Sweden the register has been widely used in research and found to be of relatively good quality. (Ludvigsson et al., 2011)

The NHDR data includes records in rows that contain variables such as personal identification number, sex, domicile of the subject, duration and type of hospital stay, external cause of injury, primary, secondary and tertiary diagnoses and all procedures performed during the stay.(THL, 2012) In 2013, the data record includes up to 70 variables per one hospitalisation period. Data is collected and maintained by the National Institute for Health and Welfare, Helsinki, Finland. Some changes in the NHDR have happened in the course of its history. Diagnoses were recorded according to the ICD-8 (International Classification of Diseases) coding system between 1969 and 1986, ICD-9 between 1987 and 1996 and more recently ICD-10 since 1996.(Lääkintöhallitus, 1979, Lääkintöhallitus, 1986, Nienstedt, 1995) Similarly the procedural coding has changed; from 1986 to 1996 procedural coding was done according to guidelines set by the National League of Hospitals.(Sairaalaliitto, 1983) Starting in 1996 with national coverage from the beginning of 1997 procedural coding has been done according to directions by Nomesco (Nordic Medico-Statistical Committee) procedure classification.(Stakes, 1996) These changes in classification systems have to be taken into account when conducting research (for instance, trends over years) based on diagnoses or procedures.(Räisänen et al., 2013)

When conducting research based on administrative register data such as the NHDR, a high level of validity is needed. The NHDR undergoes routine internal validity checks that assess logical errors and missing data.(THL, 2012) When the data is reviewed, hospitals are asked to correct errors if needed. According to the internal validity checks, the reliability of the data is excellent.(Sund, 2012) Studies of the external validity of data from the NHDR have focused on inpatient discharges from hospitals. Studies of vascular disease, mental illnesses and injuries have been the most numerous and have focused on diagnosis: for instance, accuracy of diagnosis of stroke(Tolonen et al., 2007) or heart failure(Sund, 2012, Mähönen et al., 2013) In these studies the data from the administrative register (NHDR) is compared to a more clinically oriented, validated register, or the data is compared against medical records. According to a recent review by Sund, the positive predictive value (PPV) for common diagnoses in the NHDR was between 75 and 99%.(Sund, 2012) As far as injuries are concerned there is a limited number of studies assessing the validity of diagnoses and procedural coding. Keskimäki and Aro took a random sample of 2285 cases from the NHDR in 1986 and compared this data to the individual medical records. They found that the diagnosis was accurate in 95% of the cases but procedural coding was quite inaccurate (70 to 78%).(Keskimäki and Aro, 1991) In another study, Lüthje and co-workers analysed all patients hospitalized for pelvic fracture in 1988 and identified 1,212

primary cases. They conducted an analysis of validity on the accuracy of diagnosis by assessing the medical records of a number (n=114) of these cases randomly selected; the accuracy of diagnosis was 97%.(Lüthje et al., 1995) Mattila and co-workers aimed to assess the validity of the NHDR in relation to diagnosis of cruciate ligament injury. Coverage was assessed by comparing arthroscopic findings to the NHDR and accuracy by comparing NHDR data to findings on MRI and arthroscopy. They found both coverage (92%) and accuracy (89%) to be excellent.(Mattila et al., 2008) In contrast to analysing diagnoses, there are only few studies concentrating on evaluating the validity of procedural coding after the implementation of the Nomesco procedural classification system. Sund and co-workers found the completeness, accuracy and correctness of the National Hospital Discharge Register to be excellent in registering diagnosis and procedural coding.(Sund et al., 2007) Studies assessing the validity or use of external cause of injury are scarce.(Lunetta et al., 2008, Haikonen et al., 2013)

## 2.5 Clavicle fractures

Clavicle fracture (CF) is among the common injuries of the skeleton. In an analysis of all fractures treated in a single trauma unit, the incidence rate of CFs was 36.5 per 100,000 (n=195) person-years covering a 3.3% proportion of all fractures with a male to female ratio of 7:3 and an average age of 38 years at the time of the injury.(Court-Brown and Caesar, 2006) In another Scottish study, Robinson analysed retrospectively 1,000 consecutive CFs between 1988 and 1994.(Robinson, 1998) In Robinson's material, incidence of CF on over 13-year-old patients was 29 per 100,000 person-years with a mean age of 34 years. In an epidemiological study in Malmö General Hospital, 2,035 CFs were identified from one prospective and three retrospective cohorts and the results were pooled for analysis.(Nordqvist and Petersson, 1994) According to the Swedish study, CFs occurred mostly in men with an average age of 27 years at the time of the injury. In an Italian study, all fractures in the catchment area of a single hospital between 1990 and 2001 were analysed and 533 CFs were identified, encompassing 2.6% of all fractures with a male to female ratio of roughly 7:3.(Postacchini et al., 2002) Robinson found that sports injuries were more common in younger males and simple falls and falls from a standing height became more common in older age groups.(Robinson, 1998) In the Italian study, 48% of all fractures were traffic accident related with fall-related injuries following with a 33% proportion; traffic accident related CF was more common

in adults and fractures after falls were more common in children 0 to 10 years old; fractures occurring at birth were excluded from the study.(Postacchini et al., 2002) However, the Swedish study in Malmö identified simple falls as the leading cause of CFs.(Nordqvist and Petersson, 1994) In another Swedish study by Nowak and co-workers cycling was the leading cause of injury for both genders.(Nowak et al., 2000) Winter sports have also been reported to be associated with producing high numbers of CFs.(Matsumoto et al., 2002) While the epidemiological findings differ somewhat, simple falls either on an outstretched hand or onto the shoulder are traditionally thought to be the leading reasons for sustaining CF.(Allman, 1967, Stanley et al., 1988) According to an epidemiological study by van Staa and co-workers, and affirmed by the researchers at the Royal Infirmary of Edinburgh, CFs have in general a bimodal distribution with the first peak occurring in young males between the second and third decade of life and the second, smaller peak in patients predominantly female after the age of 75 years.(van Staa et al., 2001, Court-Brown and Caesar, 2006) When the incidence of CFs is stratified by fracture type, it seems that medial and lateral CFs have a bigger incidence rate in older age groups and midshaft fractures occur more often in younger age groups.(Nordqvist and Petersson, 1994, Robinson, 1998, Robinson et al., 2004)

As other fractures, CFs can be classified according to several different systems. Traditionally CFs have been classified according to Allman, who divided CFs into three subgroups: shaft, lateral and medial.(Allman, 1967) Although simple, the Allman classification does not take into account fracture splintering, shortening or displacement and therefore several other attempts at classification have been made afterwards. In his classification, Neer took into account soft tissue injuries and fracture displacement(Neer, 1960), while Rockwood later improved the classification by further subdividing lateral fractures.(Bucholz et al., 2006) In his already mentioned epidemiological study, Robinson, after analysing the fracturing pattern and healing, classified CFs into three groups: medial, shaft and lateral.(Robinson, 1998) Robinson also included prognostically valuable subgroups according to displacement, intra-articular involvement and comminution. Regardless of the classification system used, fractures of the shaft are the most common, covering over two thirds of CFs, with lateral fractures covering roughly one fourth; medial fractures are more uncommon with a proportion of under 3%.(Nordqvist and Petersson, 1994, Robinson, 1998)

CFs are common injuries that can be suspected just by clinical examination as the clavicle can be easily visualized and palpated. If fracture is suspected, radiological imaging is done, usually by taking just an anterior-posterior radiograph.

CFs are traditionally treated by immobilizing the upper extremity with a sling or a figure-of-eight –type bandaging and progressive mobilization after 2-3 weeks. Most CFs heal uneventfully and reach union in less than 12 weeks. Eskola and co-workers evaluated 83 patients with conservatively treated clavicle fractures with a 98% union-rate. In their study, 4.5% of the conservatively treated patients had an unsatisfactory clinical result.(Eskola et al., 1986b) In another Finnish study, both primary conservative and operative treatment after a non-union resulted in satisfactory outcomes.(Eskola, 1989) Fracture union is defined as a callus formation bridging the fracture gap evidenced on radiographs at 24 weeks.(Robinson et al., 2004) Formerly almost all CFs were treated with immobilization, but during recent years, after recognizing relatively poor results following conservative treatment in some displaced CFs, surgical treatment has gained popularity. Also, the introduction of new implants, such as locking plates and intramedullary nails and their aggressive marketing, may have played a role. However, there have been no large-scale population-based studies assessing solely the proportion of conservative and surgical treatment of CFs. Thus, we do not really know how CFs are currently treated.

In an older study by Neer, 2,235 patients with CFs of the shaft were treated conservatively and only 0.1% (n=3) developed a non-union.(Neer, 1960) Neer's study, however, also included children. In a Swedish study, 225 conservatively treated CFs were retrospectively analysed after more than 10 years after the initial injury.(Nordqvist et al., 1998) A majority, 68% of the patients had normal union, 29% had radiological malunion (defined as one or more bone widths of fracture displacement or over 30 degrees of angulation), and 3.8% had a non-union.(Nordqvist et al., 1998) Despite the high rate of malunion in the data, 82% of patients had a good clinical outcome.(Nordqvist et al., 1998) Of those patients who had a displaced CF, the proportion that was pain free and had normal function was 77%. (Nordqvist et al., 1998) Not all studies have been able to reproduce the good results, especially with displaced fractures. In their retrospective analysis of 52 displaced CFs of the shaft, Hill and co-workers observed a rate of non-union of 15%.(Hill et al., 1997) McKee and co-workers retrospectively assessed 30 patients from a total of 107 with a conservatively treated displaced CF of the shaft and found significant residual disability in function and strength of the shoulder.(McKee et al., 2006) In contrast, there were 607 displaced fractures in Robinson's study of 1,000 CFs and the rate of non-union among the displaced fractures was only 4.8%.(Robinson, 1998) In a recent meta-analysis, 2,144 CFs of the shaft were analysed, and the rate of non-union was 15% in the displaced fractures of the shaft that were treated con-

servatively.(Zlowodzki et al., 2005) In summary, according to the existing literature, non-displaced, minimally displaced and even some of the displaced middle-third CFs can be treated conservatively with good results, regardless of the fracture location. (Neer, 1960, Nordqvist and Petersson, 1994, Nordqvist et al., 1998, Robinson, 1998, Nowak et al., 2000, Robinson and Cairns, 2004) There are, however, occasions where surgical treatment should be considered. Common accepted absolute indications include open fractures, compromise of overlying skin, neural or vascular injury and floating shoulder.(Bucholz et al., 2006) Poor functional outcome after non-union of CF, especially in younger patients, may require surgical treatment. However, it has been estimated that with CFs of the lateral third and shaft, the risk of non-union is greatest in elderly female patients.(Eskola et al., 1986a, Robinson et al., 2004) In addition to female gender and advancing age, comminution and complete displacement were independently predictive of non-union.(Robinson et al., 2004)

There are several different surgical approaches described in the literature for treatment of CFs. The surgical approach is dependent on the fractured site.(Bucholz et al., 2006) Open reduction and plate fixation, nail fixation or the use of wires and screws have all been reported to yield sufficient results in the surgical treatment of CFs.(Jupiter and Leffert, 1987, Eskola et al., 1987, Ballmer and Gerber, 1991, Bradbury et al., 1996, Kao et al., 2001, Jubel et al., 2003) External fixation is a very rare procedure for CFs.(Bucholz et al., 2006) As CFs of the shaft encompass a proportion of over two thirds of all CFs, the literature on surgical treatment is focused on these fractures. A recent Cochrane review and meta-analysis included 555 patients from eight trials comparing conservative and surgical treatment of middle-third clavicle fractures. (Lenza et al., 2013) No clear evidence on the superiority of surgical over conservative treatment was found.(Lenza et al., 2013) Descriptions and results of RCTs on treatment of CFs are presented in Table 1(Kabak et al., 2004, COTS, 2007, Shen et al., 2008, Smekal et al., 2009, Ferran et al., 2010, Assobhi, 2011, Virtanen et al., 2012, Robinson et al., 2013) It seems that based on these level I studies, there is moderate evidence that some completely displaced CFs of the midshaft benefit from primary surgical fixation in terms of earlier return to work, etc.(COTS, 2007, Robinson et al., 2013) However, in the Finnish RCT by Virtanen and co-workers, clear evidence favouring surgical management over conservative treatment was not seen.(Virtanen et al., 2012) Based on these studies, though, the choice between different surgical approaches cannot yet be made. Additionally, there is need for studies comparing different treatment modalities for lateral and medial fractures of the clavicle.

**Table 1.** Randomised controlled trials on clavicle fractures. CF= clavicle fracture, SF-12 = short form 12; a twelve question patient related outcome measure of quality of life, DASH= disabilities of the arm, shoulder and hand; an outcome score for function, Constant score= an outcome score for function, ROM= range of motion, Oxford shoulder score= an outcome score for function. VAS= visual analog scale.

Study	Patients	Intervention	Primary outcome	Secondary outcomes	Results	Other
Kabak et al., 2004 Plating vs. plating	-33 consecutive adult patients with non-union (>24 weeks) of CFs of the shaft requiring surgical treatment -16 patients in dynamic plating and 17 in low-contact plating group -Mean age 41 years	-Dynamic compression plating -Low-contact dynamic compression plating -Identical rehabilitation program	-DASH	-Radiological parameters -Functional outcome -Complications	-DASH consistently better in low-contact plating group; difference in DASH scores > 10 at 3 and 6 months, difference 17.6 vs. 8.7 at 1 year -Time to union better with dynamic plating; 9.2 vs. 11.9 weeks	-Well conducted and reported -No sample size calculation -No difference in complications
COTS., 2007 Plating vs. conservative treatment	-132 patients 16 years or older with completely displaced CFs of the shaft -65 in conservative and 67 in surgical group -Mean age 34 years	-Immobilization in a sling for six weeks and progressive physiotherapy -Plating and sling immobilization for 7-10 days and progressive use according to physiotherapy regimen	-DASH	-Constant score -Union rate -Complications	-DASH superior at all time points, but > 10 only at six weeks -Constant score superior at all time points -No difference in ROM -Rate of complication smaller in surgical group; 37 vs. 63%	-Multicenter study -4 different plates used -Loss to follow-up greater in conservative group; -Patient satisfaction better in surgical group -Well conducted study with excellent presentation of results -Non-union defined as complication -No numeric values for functional scores given in the report
Shen et al., 2008 Plating vs. plating	-133 patients 18 years or older consecutive with completely displaced CFs of the shaft -67 in 3D plating and 66 in superior plating group -Mean age 44 years	-3D plating fixed on superior distal and anterior proximal surface of the clavicle -S-shaped plating fixed on the superior surface of the clavicle	-Not specified	-Radiological parameters -Union rate	-Healing rate (radiological) and union rate higher in 3D-plating group	-No functional outcomes measured -No sample size calculation



Study	Patients	Intervention	Primary outcome	Secondary outcomes	Results	Other
Smekal et al., 2009 Intramedullary nailing vs. conservative treatment	-68 patients 18 to 65 years old with completely displaced CFs of the shaft -30 in both groups	-Immobilization for 3 weeks and gradual mobilization according to sensations of pain -Titanium endomedullary nailing (TEN) and immediate mobilization according to sensation of pain	-Not specified	-DASH -Constant score -Radiological parameters -Complications	-DASH scores better during the entire 6 month period in surgical group, but difference diminished over time (results presented only in a graph) -Better Constant score at 2 years in surgical group; 97.9 vs. 93.7	-Only cases that completed the entire follow-up analyzed -DASH analyzed every week for 6 months, but not at the 12 and 24 month time points -More non-unions in conservative group at 24 weeks -No sample size calculation -Confusing presentation of results -More complication in conservative group, but not statistically significant
Ferran et al., 2010 Intramedullary pinning vs. plating	-32 patients with displaced CFs of the shaft -17 in pinning and 15 in plating group -Mean age 30 years	-Intramedullary pinning -Low-contact dynamic compression plating -Similar rehabilitation	-Constant score	-Oxford shoulder score -Union rate -Complications	-No difference in Constant or Oxford scores -No difference in union rates -Fixation material removal done for all pins, and counted as a complication	-If union was seen is pinning group, fixation material was removed -Sample size calculation done to differentiate 7,5 point difference in Constant score
Assobhi et al., 2011 Plating vs. intramedullary nailing	-38 patients with displaced CFs of the shaft -19 in both groups -Mean age 31 years	-Reconstruction plating -Titanium endomedullary nailing -Similar rehabilitation	-Constant score	-Union rate -Complications	-Constant score better in nailing group but statistically significant only at 6 weeks; 62.1 vs. 69.1 -No difference in union rate -More complications in plating group (3 vs. 0)	-No sample size calculation -Difference in Constant scores between groups under 5 points at all time points

Study	Patients	Intervention	Primary outcome	Secondary outcomes	Results	Other
Virtanen et al., 2012 Conservative treatment vs. plating	-60 patients 18 to 70 years with completely displaced CFs of the shaft -28 in conservative and 32 in surgical group -Mean age 37 years	-Immobilization with a sling for 3 weeks with gradual mobilization -Reconstruction plating and immobilization for three weeks -Similar rehabilitation	-DASH	-Constant score -Pain (VAS) -Complications	-No difference in DASH or Constant scores -Surgical group had less pain at 3 weeks (16 vs. 10), no differences after	-Well conducted and reported study -Sample size calculated -Younger patients in conservative group -Non-union associated with poorer DASH scores at 1 year, 3, 3 (n=19) vs. 19.1 (n=6) inside the conservative group
Robinson et al., 2013 Conservative treatment vs. plating	-200 patients 16 to 60 years with completely displaced CFs of the shaft -105 in conservative and 95 in surgical group -Mean age 32 years	-Immobilization with collar cuff for 3 weeks and then gradual guided rehabilitation -Surgery with locking plate within 2 weeks of injury and gradual similar rehabilitation as with conservative group	-Not specified	-Union rate -SF-12 -Constant DASH -Patient satisfaction	-DASH 6.1 vs. 3.4 favoring surgical group at 1 year -Constant 87.8 vs. 92.0 favoring surgical group at 1 year -Markedly lower non-union rate in surgical group (risk reduction 93%)	-No sample size calculation -Lost to follow-up n=22 (11%), but not different between groups -Cost of treatment evaluated, surgical over 4 times more expensive -Non-union predictive of poor functional outcome -Excellent study, well reported -Smoking associated with non-union

## 2.6 Proximal humeral fractures

Proximal humerus fracture (PHF) can be considered one of the most common fractures especially when only osteoporotic fractures are considered. (Seeley et al., 1991, Kannus et al., 2000, Court-Brown et al., 2001, Court-Brown and Caesar, 2006) PHF is heavily associated with osteoporosis as the majority of PHFs occur after low energy trauma, for instance falls from a standing height. (Kannus et al., 2000, Court-Brown et al., 2001) In a Scottish analysis of all fractures diagnosed over a period of one year, the incidence of PHF had an incidence of 63 per 100,000 person-years, representing 5.7% of all fractures. (Court-Brown and Caesar, 2006) The average age of a PHF patient has been shown to be 65 years and nearly 78% of all PHFs occur after the age of 50 with a male to female ratio of 3:7. (Court-Brown and Caesar, 2006) There is a clear rise in incidence at around 50 years of age with a female dominance. (Singer et al., 1998, Hagino et al., 1999) In Finns aged 60 or more the national age-adjusted incidence of PHFs has been rising steadily for the past decades. (Kannus et al., 2000, Palvanen et al., 2006) However, a recent analysis of octogenarians and older women showed a stabilizing trend in the age-adjusted incidence of PHFs (Kannus et al., 2009).

Codman classified PHFs according to the major fragments: minor and major tuberosities, articular surface and shaft. (Bucholz et al., 2006) Neer later developed the classification based on the number of fragments by adding the degree of displacement and angulation into the scheme. (Neer, 1970) According to Neer's classification, if fragments are less than 1cm apart or less than 45 degrees angulated, the fracture is considered minimally displaced. (Neer, 1970) Neer classifies PHFs into 16 different groups whereas AO (Arbeitsgemeinschaft für Osteosynthesefragen) -classification divides PHFs into A, B and C groups and further subgroups them based on fracture location, impaction, angulation, angulation or comminution of the surgical neck of the humerus and displacement. (Neer, 1970, Bucholz et al., 2006) Both Neer and AO-classifications are widely used in the diagnostics, treatment and research concerning PHFs. A point worth noting is that the classification systems have been shown to be associated with poor intra- and inter-observer agreement. (Brorson et al., 2002, Majed et al., 2011) In a unique epidemiological study conducted over a 5 year period in Scotland, 1,027 PHFs were reviewed and analysed retrospectively and fractures classified according to their morphology into Neer and AO-groups respectively. (Court-Brown et al., 2001) If classified by Neer classification, 49% of all analysed fractures were in the minimally displaced category, 37% were in the

two part surgical neck group, 10% were three-part greater tuberosity and surgical neck fractures and only 3% were four-part fractures.(Court-Brown et al., 2001) If AO-classification was used, 66% of the fractures were type A unifocal fractures involving either greater tuberosity or surgical neck.(Court-Brown et al., 2001) Type B fractures had a 27% proportion and type C fractures only 6% of all PHFs.(Court-Brown et al., 2001) There was a positive association between the number of more compound fractures and advancing age.(Court-Brown et al., 2001) Interestingly, when Brorson and co-workers evaluated the repeatability of treatment recommendations and fracture classification of PHFs, experienced shoulder surgeons were more likely to agree on treatment modalities than Neer classification.(Brorson et al., 2012)

In a retrospective study, Koval and co-workers analysed 128 conservatively treated minimally displaced PHFs (as described by Neer).(Koval et al., 1997) All fractures united. Functional assessment yielded good or excellent results for 77%, and 91% had mild pain at most.(Koval et al., 1997) In a Swedish study, 40 patients with three- or four-part displaced PHFs were randomized for either tension band surgery or conservative treatment; there were no differences in the functional results between the groups, but there were more complications in the surgically treated group.(Zyto et al., 1997) It seems that most PHFs can be maintained conservatively.(Neer, 1970, Rasmussen et al., 1992, Court-Brown et al., 2001) There is little information, though, on what proportion of all patients are actually treated conservatively. In a recent study in the United States, there was considerable variation between different regions in the proportion of patients with PHFs treated nonsurgically. The overall proportion of conservative treatment of PHFs in their cohort of 16,138 patients was 84%, but in some regions as much as 68% of patients with PHFs were operated on.(Bell et al., 2011)

Conservative treatment usually comprises of immobilization with a sling for up to 3 weeks with simultaneous mobilization of elbow and wrist.(Bucholz et al., 2006) After 2-3 weeks, mobilization with pendulum exercises and passive movements are initiated. However, Hodgson and co-workers found early physiotherapy to be related to less pain at 12 months after the injury when they compared immediate physiotherapy with delayed (2-3 weeks in a sling) physiotherapy.(Hodgson et al., 2003) Radiological evaluation is usually done after one week and again after six weeks following the injury.(Bucholz et al., 2006)

In some cases surgical treatment of PHFs is warranted. Absolute indications for surgery are thought to be three- or four-part fractures with dislocation, open fractures, compromise of neural or vascular tissue, pathological fractures and intra-articular

splitting.(Murray et al., 2011) Unfortunately, fracture classification cannot be used as a straightforward reference for surgical treatment, but other indications for surgical treatment should be considered as a whole, together with patient related factors, surgical factors and the fracture configuration or ‘fracture personality’, as dubbed by Murray and co-workers.(Murray et al., 2011) The choice between surgical and conservative treatment should be made bearing in mind that only those patients that benefit from surgical treatment should be operated on. A variety of different methods can be used for surgical treatment of PHFs, including minimally invasive techniques such as percutaneous fixation with pins, wires or screws, open reduction and plate fixation, intramedullary nailing and arthroplasty.(Bucholz et al., 2006, Mauro, 2011) Bell and co-workers reported of increased surgical activity with rising numbers of open reduction and internal fixation.(Bell et al., 2011) However, the report by Bell detailed only rates of open reduction and internal fixation and arthroplasty.(Bell et al., 2011) All interventions in the treatment of PHFs are associated with certain complications and have been identified with unique advantages. A Cochrane review and meta-analysis on the treatment of PHFs identified 6 trials with 270 patients focusing on conservative treatment versus surgical treatment, but it could not conclude whether conservative or operative treatment is superior to the other.(Handoll et al., 2012) Moreover, three trials comparing different surgical treatment modalities were analysed with no conclusion of superiority.(Handoll et al., 2012)

It is indisputably difficult to draw conclusions on the existing literature as the studies conducted on PHF treatment are generally of a low level of evidence and the study settings vary greatly.(Lanting et al., 2008, Handoll et al., 2012) Descriptions of RCTs comparing different methods of treatment of PHFs are listed in Table 2.(Zyto et al., 1997, Olerud et al., 2011b, Olerud et al., 2011a, Zhu et al., 2011, Boons et al., 2012, Fjalestad et al., 2012) Based on these five RCTs comparing surgical and nonsurgical treatment among persons over the age of 60, it seems that nonsurgical treatment yields corresponding results in terms of pain and function, but is associated with a lower rate of complications. However, an on-going international, multicentre RCT conducted in Finland and Sweden will probably add to our knowledge on the issue.(Launonen et al., 2012)

**Table 2.** Randomised controlled trials on proximal humeral fractures. PHF= Proximal humeral fracture, ROM= range of motion, Constant score= an outcome score for function, EQ-5D= an outcome score for quality of life, DASH= Disabilities of the Arm, Shoulder and Hand; an outcome score for function, ASES= an outcome score for daily activities, SST= simple shoulder test; an outcome score for function.

Study	Patients	Interventions	Primary outcome	Secondary outcomes	Results	Other
Zyto et al., 1997	-Consecutive patients with displaced three or four part PHF -40 patients. -Mean age 74 years. -Female 88%.	-Sling for 7-10 days, then start of physiotherapy. -Tension band surgery within 48 hours of admission	-Not specified	-Constant score -Pain -ROM -Power -Activity of daily living	-No difference between groups in primary or secondary outcomes	-Loss to follow-up: 5% at 12 months, 27% at 50 months -More complications in surgically treated -No sample size calculation
Olerud et al., 2011	-55 or older, mean age 74 years -Low energy trauma -Displaced (Neer criteria) three part PHF -60 patients, 30 vs. 30	-Immobilization for two weeks after which gradual physiotherapy (conservative) -Two experienced shoulder surgeons -Physiotherapy immediately after surgery, sling for four weeks	-Health related quality of life (EQ-5D)	-Constant score -DASH -Pain	-All outcome measurements favored surgery, but no statistically significant difference between groups -Differences in DASH between groups < 10	-Loss to follow-up 12% -Nine reoperations in the surgical group (31%) vs. 1 (3%) in conservative group -Difference in the start of physiotherapy may alter results -24 month follow-up -No sample size calculation
Olerud et al., 2011	-55 or older, mean age 77 years -Low energy trauma -Displaced (Neer criteria) four part PHF -55 patients, 27 in surgical group	-Immobilization for two weeks after which gradual physiotherapy (conservative) -Two experienced shoulder surgeons performed all procedures -Physiotherapy immediately after surgery	-Health related quality of life (EQ-5D)	-Constant score -DASH -Pain	-Health related quality of life better in surgically treated -No statistically significant differences between groups in secondary outcomes	-24 month follow-up -Difference in the start of physiotherapy may alter results -No sample size calculation

Fjalestad et al., 2012	-60 years or older patients with unstable three or four part PHF -Mean age 73 years -50 patients, 25 in both groups	-Immobilization with modified Velpeau bandage -Closed reduction if deemed necessary -Similar physiotherapy for both groups -Plate fixation and start of physiotherapy on the third post-operative day	-Constant score	-Activity scoring (ASES)	-Outcome measurements favored conservative treatment but no statistically significant difference	-Well described study -Radiological assessment didn't influence functional outcome -No sample size calculation
Boons et al., 2012	-65 years or older patients with four part displaced (Neer criteria) PHF -50 patients, 25 in both groups -Mean age 78 years	-Shoulder immobilizer for 6 weeks -Two experienced shoulder surgeons performed all procedures -Same progressive rehabilitation program for both groups	-Constant score	-SST -Abduction strength -Pain -Disability -ROM	-No difference between groups with Constant score or SST -Abduction strength better in conservative group at 3 and 12 months -Less pain in surgically treated at 3 months; 9 vs.11	-Clearly written -Well conducted -Small loss to follow-up 6% at 12 months -Sample size calculated properly
Conservative treatment vs. arthroplasty						
Study	Patients	Interventions	Primary outcome	Secondary outcomes	Results	Other
Zhu et al., 2011	-Skeletally mature patients with a two part PHF -57 patients, 28 in nail and 29 in plate group -Mean age 53 years	-Locking nail -Locking plate -Similar postoperative rehabilitation program -All procedures done by one surgeon	-ASES score	-Constant score -ROM -Pain -Supraspinatus strength	-ASES score better with nailing at 1 year; 83.6 vs. 90.8, but no difference at 3 years -Supraspinatus strength better in plating at 1 year; 64.3 vs. 77.4%, but no difference at 3 years -No difference in pain or ROM	-No infections -Five reoperations were done in plating group -Nailing had smaller overall complication rate (4% vs. 31%) -Sample size calculated -ASES difference of 6.4 was considered clinically significant
Intramedullary nailing vs. plate fixation						

## 2.7 Fractures of the humeral shaft

A fracture of the humerus occurring between the surgical neck of the proximal humerus and supracondylar ridge of the distal humerus are defined as fractures of the humeral shaft (HSF). (Bucholz et al., 2006, Browner, 2009) Fractures of the humeral diaphysis or shaft have not been studied as much as, for instance, DRFs. In fact, no large population-based studies on the epidemiology of HSFs exist. In a retrospective assessment of all fractures diagnosed in a single trauma unit in Scotland during a follow-up period of two years on patients between 15 and 94 years of age, the incidence of HSF was found to be between 16.9 and 185 per 100,000 person-years according to the age group. (Singer et al., 1998) Partly overlapping the previously mentioned study by Singer and co-workers in the same trauma unit, but evaluating only 249 consecutive HSFs between 1989 and 1992, the incidence of HSFs was estimated at between 30 and 100 per 100,000 person-years. (Tytherleigh-Strong et al., 1998) In their evaluation of patients over 12 years of age, with 5,953 fractures identified in a single trauma unit in Scotland in 2000, HSFs were estimated to have an incidence of 12.9 cases per 100,000 person-years, accounting for 1.2% of all fractures. (Court-Brown and Caesar, 2006) In the same study Court-Brown and colleagues found that the average age for patients presenting with HSF was 55 years, and 67% of all HSFs occurred to patients over 50 years of age. (Court-Brown et al., 2001) In a Swedish study of 401 consecutive HSFs in patients 16 years and older, the incidence of HSF was 14.5 per 100,000 person-years, ranging from 10 to 100 per 100,000 person-years depending on age and gender. (Ekholm et al., 2006a) The overall fracture distribution pattern for HSFs is bimodal for both genders with the first peak occurring between the second and third decades of life and the latter peak after 50 years of age. (Court-Brown and Caesar, 2006)

Reasons for sustaining an HSF vary in different age groups and are also gender dependent. Younger male patients typically sustain a higher energy trauma, for instance in motor vehicle accidents, whereas older female cases occur after simple falls. (Tytherleigh-Strong et al., 1998) Diagnosis is based on radiological imaging, typically taken in two different planes at 90 degrees to each other. Fracture classification is based on radiological imaging. AO-classification is commonly used with HSFs. (Cole and Wijdicks, 2007) According to AO-classification, type A fractures have a proximal and a distal fragment that are in contact, type B fractures have two or more fragments which have some contact and type C fractures are complex fractures where the fragments are not in contact. (Bucholz et al., 2006, Browner, 2009)



As with other fractures, the goal in the treatment of HSF is a functionally working pain free arm. It has been suggested that most HSFs can be treated without surgical intervention.(Sarmiento et al., 2000) Interestingly, no high-quality studies with modern methodology comparing conservative and surgical treatment exist. Functional bracing, as first described by Sarmiento(Sarmiento et al., 1977), has become the gold standard in the conservative treatment of HSFs. Functional bracing allows for shoulder and elbow motion, is light in construction and well tolerated. (Sarmiento et al., 1977, Sarmiento et al., 2000) Zagorski and colleagues treated 233 patients with an HSF with a functional brace, resulting in a non-union rate of 1.8% with 98% of patients having good or excellent functional outcome.(Zagorski et al., 1988) In their analysis of 922 patients, Sarmiento described a union rate of 97%, when HSFs were treated with a functional brace.(Sarmiento et al., 2000) The results of the two studies are persuasive as the fracture types included were comprehensive, especially in the latter, but there was a significant loss to follow-up and the patient selection and follow-up were insufficiently described diminishing the value of the studies.(Zagorski et al., 1988, Sarmiento et al., 2000) Not all studies on conservative treatment of HSFs have been able to replicate the high rates of union shown by Sarmiento. Koch and co-workers had a union rate of 87%(Koch et al., 2002), and in a Finnish study there was a union rate of 77%, although the average time for bracing in the nonunited patients was only about 7 weeks(Toivanen et al., 2005). The lack of prospective studies on conservative treatment is evident, and the existing literature is plagued by small sample sizes.(Papasoulis et al., 2010)

It is thought that there are some occasions when surgical treatment needs to be considered as the first treatment modality, such as simultaneous vascular- or nerve tissue damage, open or compound fractures, multiple fractures of the same upper extremity or bilateral HSFs.(Bucholz et al., 2006, Browner, 2009, Cole and Wijdicks, 2007) Sometimes secondary surgical treatment is opted for after the failure of primary conservative treatment. Some have suggested that radiological parameters indicating surgical treatment of HSFs after failure to obtain or maintain closed reduction could be: shortening of more than 3 cm, rotation of more than 30 degrees or angulation of more than 20 degrees.(Bucholz et al., 2006, Browner, 2009) Options for surgical treatment include intramedullary nailing, plating, external fixation and the use of screws or pins.(Cole and Wijdicks, 2007) Over the years plating and intramedullary nailing have gained popularity over other surgical techniques and recent literature is focused on comparing these two surgical methods. In a Cochrane review and meta-analysis comparing intramedullary nailing and plate fixation of

HSFs, the results of 5 studies with 260 participants were pooled for analysis. There was no conclusive evidence favouring either method of surgical treatment. (Kurup et al., 2011) In general there are few RCTs conducted on the surgical treatment of HSFs. Descriptions of recent trials and their results are in Table 3. (Chapman et al., 2000, McCormack et al., 2000, Changulani et al., 2007, Putti et al., 2009, Singiseti and Ambedkar, 2010)

Scientific literature does not provide enough evidence on the best treatment method for HSFs and different methods of treatment may vary considerably between countries and trauma units. As the epidemiology of the fracture and its implemented treatment modalities are poorly known, it is difficult to design clinical studies.

## 2.8 Distal radius fractures

Distal radius fracture (DRF) is among the most common fractures in adults. (Court-Brown and Caesar, 2006) In general the incidence of DRFs peaks in children between 8 to 13 years and in adults after the age of 50. (Court-Brown and Caesar, 2006) The overall fracture distribution curve for DRF in adults is unimodal for young men and older women. (van Staa et al., 2001, Court-Brown and Caesar, 2006) In different populations and geographically defined regions, DRFs in adults have been described to have an incidence rate between 100-300 per 100,000 person-years. (Hagino et al., 1999, van Staa et al., 2001, Thompson et al., 2004, Court-Brown and Caesar, 2006, Brogren et al., 2007, Lofthus et al., 2008, Flinkkilä et al., 2011, Sigurdardottir et al., 2011, Wilcke et al., 2013) In a study of 5953 fractures diagnosed in a single Scottish trauma unit, it was estimated that DRFs encompass 17.5% of all adult fractures. In an epidemiological study by Kaukonen and co-workers that was conducted in Southern Finland, the annual incidence of distal forearm fractures was 365 per 100,000 person-years in residents of the city of Helsinki 15 years or older. (Kaukonen, 1985, Kaukonen, 1989) In a more recent epidemiological study in Northern Finland, Flinkkilä et al found DRFs to have an incidence rate of 258 per 100,000 person-years in residents of the city of Oulu aged 16 or older. (Flinkkilä et al., 2011) Slippery winter days were found to be associated with a higher risk of sustaining a DRF. (Flinkkilä et al., 2011)

DRFs are fractures of the forearm that occur within 3cm of the proximal from the radiocarpal joint. The diagnosis of DRF is based on radiological findings and, since the implementation of radiological imaging a multitude of classification sys-

**Table 3.** Randomised controlled trials on humeral shaft fractures. HSF= humeral shaft fracture, ROM= range of motion, ASES= an outcome score for daily activities.

Study	Patients	Interventions	Primary outcome	Secondary outcomes	Results	Other
Chapman et al., 2000 Intramedullary nailing vs. plating	-Skeletally mature patients with acute HSF requiring surgical treatment -89 patients, 38 in nailing and 46 in plating -Mean age 33 years	-Intramedullary nailing with either dynamic or static nail locking -Dynamic compression plating -No immobilization	-Not specified	-Radiological assessment -ROM -Pain -Complications	-No statistically significant differences between the two surgical methods -Similar amount of complications	-5 patients lost after wrong fixation material used -No functional assessment -Results and time points poorly presented -No sample size calculation
McCormack et al., 2000 Intramedullary nailing vs. plating	-44 patients with surgical stabilization requiring HSFs -21 patients in nailing and 23 in plating group -Mean age 45 years	-Intramedullary nailing (anterior and posterior approach) -Dynamic compression plating	-ASES shoulder score -Pain	-Complications -Need of reoperation	-No difference in functional assessment or pain between groups -Need for reoperations higher in nailing group; 1 vs. 7 patients	-Protocol changed during trial (plate approach changed from anterior to posterior) -Complications and reoperations with antegrade nailing -No sample size calculation
Changulani et al., 2007 Intramedullary nailing vs. plating	-Skeletally mature 47 consecutive patients with HSFs requiring surgical stabilization -23 patients in nailing and 24 in plating group -Mean age 37 years	-Intramedullary nailing (anterior approach) -Dynamic compression plating (anterior and posterior approach) -Similar rehabilitation	-Not specified	-ASES shoulder score -Ability to return to work within 6 months -Union rate -Complications	-No statistically significant differences in ASES -Similar amount between groups returned to work -No difference in nonunion rates	-More infections with plating -More restriction of shoulder movement with nailing -No sample size calculation

Putti et al., 2009 Intramedullary nailing vs. plating	-Adult patients with HSFs -34 patients, 16 in nailing and 18 in plating group	-Intramedullary nailing (anterior approach) -Dynamic compression plating (anterior or posterior approach) -Similar rehabilitation programs between groups	-Not specified	-ASES score -Union rate -Complications	-No differences in ASES score -More complications in nailing group -No difference in nonunion rate	-No loss to follow-up at 24 months -Small sample size with no sample size calculation
Singsetti et al., 2010 Intramedullary nailing vs. plating	-45 consecutive adult patients with HSFs requiring surgical stabilization -25 in nailing and 20 in plating group	-Intramedullary nailing (anterior approach) -Dynamic compression plating (anterior or posterior approach) -Similar rehabilitation between groups	-Not specified	-Functional score Rodriguez-Merchan -Complications -Time to union	-More complication with nailing -Time to union higher with nailing -Higher functional scores with plating	-Loss to follow-up 20% -Unclear if randomization done prospectively -Results analyzed, described and presented poorly -High >50% total complication rate -No statistical methods used -No sample size calculation

tems for DRFs have been created: Gartland and Werley, Melone, Frykman, AO- and Mayo classification.(Bucholz et al., 2006, Browner, 2009) Frykman divided distal radius fractures into 7 subtypes: extra-articular fracture, extra articular fracture with a fracture of ulnar styloid, with radiocarpal articular involvement, radiocarpal involvement with ulnar styloid fracture, radioulnar involvement, radioulnar involvement with ulnar styloid fracture, radioulnar and radiocarpal involvement, radioulnar and radiocarpal involvement with ulnar styloid fracture.(Bucholz et al., 2006) AO-classification is probably the most used system and is based on the fracture line location, displacement of the distal fragment, articular involvement and the presence of ulnar styloid fracture.(Bucholz et al., 2006) In clinical practice, DRFs are also classified using eponyms such as Colles', Smith's, Chauffeur's and Barton's fractures.(Bucholz et al., 2006, Browner, 2009) In a study by Kaukonen and colleagues, Colles' fracture had a proportion of 91.5%, Smiths' fracture followed with 3%, combination fractures of distal radius and ulna with 5%, and there were only 0.5% of Barton's fractures and no Chauffeur's fractures.(Kaukonen, 1985, Kaukonen, 1989) A problem of the multitude of classification systems is that they do not predict instability of an individual fracture and thus are seldom used in the clinical setting.

The goal for treatment of DRF is to gain a functionally working wrist with pain-free motion. To succeed in this, most DRFs undergo closed reduction with or without manipulation and immobilization.(Bucholz et al., 2006) However, in a Cochrane review and meta-analysis of 37 trials with over 4,000 patients included, different conservative treatment modalities were compared but no conclusive evidence on superiority could be found, for instance, whether or not to apply manipulation to gain fracture reduction, use immobilisation or position and immobilise the fractured forearm in a specific way.(Handoll and Madhok, 2003a) In fact, most DRFs can and are still managed by primary conservative treatment, but during recent years reports of increased surgical activity in the treatment of DRFs have been published. (Koval et al., 2008, Wilcke et al., 2013)

Over the years a multitude of different surgical approaches have been developed in order to gain a sufficient fracture reduction in cases where conservative treatment has not succeeded or is thought to yield unsatisfactory results. The principally used surgical approaches are percutaneous pinning, external fixation, internal fixation and bone grafting or a combination of these techniques.(Bucholz et al., 2006, Browner, 2009) Pinning and external fixation are closed techniques whereas the latter two require an open surgical approach. Various different materials and surgical approaches inside these main categories exist.

Orthopaedic surgeons have long debated which DRFs should undergo surgical treatment. The classification systems have been developed in order to find a specific fracture needing specific treatment. Just as the fracture classifications, the indications for surgical treatment are based on radiological imaging. Radiocarpal articular continuity has been seen as an important parameter for both a functionally working wrist and degenerative changes occurring later.(Knirk and Jupiter, 1986) Usually, a step of <2mm on the face of the radiocarpal articulation is accepted.(Bucholz et al., 2006, Browner, 2009) The loss of palmar tilt or dorsal tilt should not exceed 10 degrees. Radial loss of length in relation to ulna should not exceed 2mm. A loss of more than 5 degrees of radial inclination is not accepted. However, there is ambiguity on how the radiological findings correlate with a functionally working and pain free wrist. In a Finnish trial, 652 patients with DRFs were analysed 5 years after the injury and neither AO nor Frykman classification could predict the clinical outcome after the fracture.(Flinkkilä et al., 1998)

No universal consensus has been reached on the indications of surgical treatment. Taking into account how common an injury DRF is, there is a surprisingly small number of RCTs comparing conservative and operative treatment. A Cochrane review identified 6 trials including 420 patients in which nonsurgical treatment was compared to percutaneous pinning in the treatment of DRFs and a pooled analysis was made.(Handoll et al., 2007b) The conclusions of the meta-analysis are very limited as the trials were heterogeneous in patient demographics, included fracture types, care after intervention and outcomes measured. Another Cochrane review, aimed at assessing whether external fixation is superior to nonsurgical treatment of DRFs, pooled and analysed the results of 15 trials including 1022 patients.(Handoll et al., 2007a) In light of the meta-analysis, anatomical results in the externally fixated DRFs were superior to the conservatively treated.(Handoll et al., 2007a) There is also evidence that the functional results are better with external fixation, but the functional assessment and outcomes of the included trials were diffuse. Secondary displacement of the fractures was more frequent in the conservatively treated patients. All in all, drawing overall conclusions is hindered by the varying inclusion criteria, insufficient study populations and heterogenic outcomes.(Handoll and Madhok, 2003b, Handoll et al., 2007a, Handoll et al., 2007b, Handoll et al., 2008)

When surgical treatment is opted for as the appropriate procedure, it is unclear in light of scientific evidence which surgical technique should be chosen and when. Before the introduction of open surgical techniques, surgeons mostly relied on closed techniques, first pinning and then external fixation later on. During the last

two decades, the open surgical approach has gained popularity as new materials for osteosynthesis, especially plates, have been developed. During the 1990s dorsally applied plates became popular, but were plagued by complications such as tendon irritation and patient dissatisfaction. (Ring et al., 1997, Rozental et al., 2003) More recently the volar approach of plate fixation has gained popularity and seems to have stormed the field at the expense of traditional closed techniques. (Koval et al., 2008, Chung et al., 2009, Wilcke et al., 2013)

As open reduction by volar plate fixation has gained popularity at the expense of external fixation during the last decade, studies comparing these two methods have emerged. The outlines of 8 RCTs comparing external fixation to plate fixation have been described in Table 4. (Grewal et al., 2005, Kreder et al., 2005, Egol et al., 2008, Leung et al., 2008, Wei et al., 2009, Wilcke et al., 2011, Jeudy et al., 2012, Williksen et al., 2013) As with the two previously mentioned Cochrane meta-analyses, it is difficult to pool results for studies that present such a large variety of interventions and outcomes used. According to the recent RCTs presented in Table 4 there might be some evidence that volar plating allows faster functional recovery, but the differences in measured outcomes between those treated with external fixation diminish over time. These results do not seem to warrant the change in the surgical treatment of DRFs. Overall there is a clear need for studies that utilize similar interventions and measure the same outcomes in addition to the other requirements of well-conducted RCTs.

**Table 4.** Randomised controlled trials on distal radius fractures. DRF= distal radius fracture, MFA= musculoskeletal assessment form; an outcome score for function, SF-36 = short form 36; a 36-question patient-related outcome measure of quality of life, Jebsen test= an outcome score for function, ROM= range of motion, CI= confidence interval, DASH= disabilities of the arm, shoulder and hand; an outcome score for function, AO= Arbeitsgemeinschaft für Osteosynthesefragen; fracture classification system, Gartland and Werley score= an outcome score for function, Green and O'Brien= an outcome score for function, VAS= visual analog scale, PRWE= patient-rated wrist evaluation; an outcome score for function, Mayo wrist score= an outcome score for function.

Study	Patients	Interventions	Primary outcome	Secondary outcomes	Results	Other
Kreder et al., 2005	-Skeletally mature aged 16-75 with 2mm step-off or gap on radiocarpal articulation after initial closed reduction	-Manipulation of fragments, then fixation with K-wire, screws or external fixation. Fixation material removed after 6-8 weeks.	-MFA	-SF-36 score -Jebsen test -ROM -Radiological analysis	-MFA difference favouring open group; 6.2 (99.95% CI -20.1 to 7.7) -No difference in pain -Better grip strength in indirect until 6 months -No difference in Jebsen score	-Intervention in the open group in surgeons discretion -Not intended to compare different implants -Loss to follow up large, group proportions remained -118 (66%) in the final 2 year evaluation -No difference in residual radiological findings -Sample size calculated
Grewal et al., 2005	-Patients under 70 years of age with intra-articular fracture having 2mm or more step on articulation prior or after primary reduction -62 patients included, 33 for external fixation and 29 for plating	-External fixation with K-wire fixation -Dorsal plate fixation (Pi plate)	-DASH	-SF-36 -Grip strength -ROM -Radiological assessment -Complications	-No difference in DASH -More complications with plating; 23 vs. 57% -Better grip strength with external fixation; 97 vs. 86%	-Loss to follow-up 13% at 12 months -Outcomes not broken down in follow-up time points -No sample size calculation



Leung et al., 2008	-16-60 aged with AO C1, C2 or C3 fractures fulfilling radiological criteria after initial closed reduction	-K-wires for reduction of fragments, radiocarpal bridging for external fixation. Fixation removed after 5-6 weeks	-Garland and Werley scoring	-Arthritis scoring 12 and 24 months	-Plating scored better functional results according to Gartland and Werley but no difference in Green and O'Brien score at 24 months	-Arthritis scoring done by two authors unblinded -Arthritis more common with external fixation -No breakdown of results according to plate fixation material -Not specified primary or secondary outcomes
External fixation versus open reduction with plate fixation	-144 entered, 74 in external fixation vs. 70 in plate fixation group -Mean age 42 years (17-60)	-Volar, dorsal or combined approach and plating. Casting for 2-3 weeks. Dorsal plates removed after 6 months.	-Green and O'Brien scoring			
Egol et al., 2008	-Consecutive patients who were eligible if loss of reduction after initial closed reduction according to radiological criteria	-Radiocarpal bridging with pins, K-wires to hold reduction and K-wires for fragment reduction if needed. External fixation removed at 6 weeks	-Not specified	-DASH -Pain (VAS) -Grip strength -Radiological assessment -ROM	-No difference is DASH at any measured time point -Earlier improvement in ROM in volar plating but no difference at 12 months -Grip strength, pain similar	-Not specified primary or secondary outcomes -Proportion of AO class C patients larger in external fixation group -No sample size calculation
External fixation versus open reduction with volar plate fixation	-Mean age 50 (18 to 87) -88 patients (44 in both groups)	-Volar plating -Follow up at 2 and 6 weeks and 3,6 and 12 months -Volar plaster for all for 1 week				

Study	Patients	Interventions	Primary outcome	Secondary outcomes	Results	Other
Wei et al., 2009 External fixation versus plate fixation	-18 years and older patients with unstable fractures after initial closed treatment according to specified radiological criteria -46 patients, 22 for external fixation and 24 for plating -Mean age 57 years	-Radiocarpal bridging with pin or fracture pinning and K-wire stabilization. External fixation removed at 5-6 weeks. -Volar or radial column plating -Follow-up at 1 and 6 weeks and 3, 6 and 12 months	-DASH	-ROM -Grip strength -Radiological assessment	-DASH scores better with plate fixation at 6 weeks and 3 months but no difference at 6 and 12 months -No difference in grip strength -At 6 weeks ROM better with plates, no difference after	-Two different plates used -Radial column plate consistent with less loss of radial length -Sample size calculated
Wlicke et al., 2011 External fixation versus volar plating	-20-70 year old patients with dorsally displaced fracture -63 patients included, 30 for external fixation and 33 for plating -Mean age 56 years	-Radiocarpal bridging with closed reduction, K-wires not routinely used. Material removed at 5 weeks -Volar plating, dorsal plaster for 10-12 days	-DASH	-PRWE -Grip strength -ROM -Radiological assessment	-Functional scores better at 3 and 6 months, no difference after -Minimal difference in ROM at 12 months	-Minimal loss to follow-up (2%) -Less radial shortening and dorsal angulation with plate fixation -Sample size calculated
Jeuzy et al., 2012 External fixation versus volar plating	-40-80 year old patients with intra-articular fractures -75 patients included, 39 for external fixation and 36 for plating	-Radiocarpal bridging with percutaneous pinning to control posterior tilt if needed. External fixation removed after 6 weeks. -Volar plating and splint for 6 weeks	-Ulnar variance	-Green and O'Brien score -PRWE -ROM	-Difference in ulnar variance in favor of volar plating at 6 months, but not statistically significant -No differences in functional scores	-Sample size calculation done using ulnar variance -Methodological problems in reporting results, difficult to identify means that have been compared -Short follow-up (6 months)
Williksen et al., 2013 External fixation versus volar plating	-18 years and older patients with AO A or C fracture with radiological criteria after 1 attempt of closed reduction -114 patients included, 60 for external fixation and 54 to plating -Mean age 54 years (20-84)	-Radiocarpal bridging, pins used to obtain reduction. Fixation material removed after 6 weeks -Volar plating followed by dorsal plaster orthosis for 2 weeks	-DASH	-Pain (VAS) -Radiological assessment -Mayo wrist score -Grip strength	-No difference in DASH or pain -Mayo wrist score better at 12 months with plating -Better grip strength with plating at 6 months but no difference at 12 months	-Minimal loss to follow-up (94% at 12 months) -Assessment not blinded -More C1 class fractures in the external fixation group -Ulnar variance better in plating -Better supination at 12 months with plating -Sample size calculated

### 3. AIMS OF THE STUDY

The aim of this thesis study was to assess the trends and incidence rates of surgical treatment of common upper limb fractures in Finland in recent years. Another aim was to evaluate the reliability of the Finnish National Hospital Discharge Register. The detailed objectives of the study were to investigate:

1. Validity of the Finnish National Hospital Discharge Register in respect to diagnosis, external cause of injury and procedural coding
2. Trends in the rate of surgical treatment of clavicle fractures
3. Trends in the rate of surgical treatment of proximal humeral fractures
4. Trends in the rate of surgical treatment of humeral shaft fractures
5. Trends in the rate of surgical treatment of distal radius fractures

## 4. MATERIALS AND METHODS

### 4.1 Validity of the Finnish National Hospital Discharge Register (I)

For the purpose of this study, a sample was collected from three hospitals in Finland: Tampere University Hospital, Hatanpää City Hospital of Tampere and the Central Hospital of Kanta-Häme located in Hämeenlinna. All patients 18 years or older admitted alive to any of the three study hospitals between January 1<sup>st</sup> 2008 and December 31<sup>st</sup> 2010 with a diagnosis of pertrochanteric hip fracture (including both intertrochanteric and trochanteric fractures) were included. All re-hospitalisations due to either rehabilitation, medical or surgical complications were excluded based on the original medical records, and thus only primary hospitalisations after the initial injury were included in the study. Patients were selected from the NHDR registry by using ICD-10 code S72.1 (pertrochanteric fracture of the femur). Pertrochanteric hip fracture was selected because practically all cases undergo surgery and therefore result in hospitalisations with procedure coding registered in the NHDR. Furthermore, according to the recommendations of the use of the ICD-10, whenever injury coding (S00-T98) is used, it is obligatory to use external causes of morbidity and mortality (V01-Y98) to try and classify the environmental events and circumstances leading to the injury.(WHO, 2010)

By comparing the NHDR data to the original medical records and x-rays of individual patients, we were able to assess whether diagnostic codes and procedural codes were accurate.

After the sample was collected, all selected cases were re-evaluated by going through the patient chart and x-rays taken both pre- and post-operatively.

We assessed the accuracy of diagnosis by examining pre-operative x-rays and determining the type of the hip fracture (fracture of the femoral neck, pertrochanteric, or subtrochanteric fracture) and then comparing the result to the type of fracture (pertrochanteric hip fracture) recorded in the NHDR.

The coverage of the procedural coding was quantified by reading through the medical records and radiographs to find all patients who had undergone surgery. This number was then compared to the number of patients that were recorded into the NHDR with a surgical procedure code.

The accuracy of the procedural coding was assessed by examining the post-operative x-rays and determining the type of fixation used, and then comparing to the type of osteosynthesis (procedural code) recorded in the NHDR.

The coverage of the external cause of injury was examined by comparing the number of patients who had been injured (had a diagnosis of a pertrochanteric fracture recorded in the NHDR) to the number of patients whom had an external cause of injury recorded in the NHDR. The accuracy of the external cause of injury was assessed by going through the medical records and determining the mechanism of injury (for example, a fall) and then comparing it to the external cause of injury recorded in the NHDR.

All of the results were expressed as a percentage with a 95% confidence interval (CI).

## 4.2 Clavicle fractures (II)

To study the changes in the surgical treatment of clavicle fractures in ICD-9 and ICD-10 time, patient data from the NHDR was collected between January 1<sup>st</sup> 1987 and December 31<sup>st</sup> 2010. All patients 18 years or older who had been hospitalized with a primary or secondary diagnosis code indicating a fracture of the clavicle were included in the study. All clavicle fracture types were included.

During the 24-year study period both diagnosis coding and procedural coding changed. From 1987 to 1995, all diagnoses recorded into the NHDR were according to the ICD-9 classification. (Lääkintöhallitus, 1986) Starting in 1996, diagnosis coding has been recorded according to the ICD-10 classification. (Nienstedt, 1995) The ICD-9 diagnosis codes used were 8100A, 8101A and 9052A between 1987 and 1995. ICD-10 code S42.0 was used from 1996.

Between 1986 and 1996 the procedural coding was recorded according to the Finnish Hospital League manual. (Sairaalaliitto, 1983) Starting in about mid 1996, procedural coding was recorded according to a Finnish version of Nomesko procedure classification. (Stakes, 1996) The procedural code used between 1987 and 1996 in this study was 9128 (open reduction and osteosynthesis). Starting 1997, codes NBJ53 (open reduction of clavicle fracture) and NBJ92 (other fracture surgery of clavicle) were used.

For the purpose of analysing the trend of all surgically treated clavicle fractures between 1987 and 2010 procedures NBJ53 and NBJ92 were pooled.

The main outcome variable was the number of patients undergoing surgical treatment of a clavicle fracture. To calculate the incidence rates of surgically treated clavicle fractures, the annual mid-population was obtained from the Official Statistics of Finland, an electronic register of the Finnish population. An analysis based on the type of hospital stay was also carried out. The type of operation was classified as either in- or outpatient surgery: this information has been recorded in the NHDR, starting 1997. For this analysis hospitals were also categorized as either public or private.

### **4.3 Proximal humeral fractures (III)**

To study the changes in the surgical treatment of proximal fractures of the humerus in ICD-9 and ICD-10 time, patient data from the NHDR was collected between January 1<sup>st</sup> 1987 and December 31<sup>st</sup> 2009. All patients 20 years or older who had been hospitalized with a primary or secondary diagnosis code indicating a fracture of the proximal part of humerus were included in the study.

During the 23-year study period, both diagnosis coding and procedural coding changed. From 1987 to 1995, all diagnoses recorded into the NHDR were according to the ICD-9 classification. (Lääkintöhallitus, 1986) Starting in 1996, diagnosis coding has been recorded according to the ICD-10 classification. (Nienstedt, 1995) The ICD-9 diagnosis codes used were 81200 and 81210 between 1987 and 1995. ICD-10 code S42.2 was used starting in 1996.

Between 1986 and 1996 the procedural coding was recorded according to the Finnish Hospital League manual. (Sairaalaliitto, 1983) Starting in about mid 1996, procedural coding was recorded according to a Finnish version of Nomesko procedure classification. (Stakes, 1996) The procedural codes used between 1987 and 1997 in

this study were 9126 (closed reduction and osteosynthesis), 9128 (open reduction and osteosynthesis), 9130 (external fixation) and 9132 (endoprosthesis). Starting 1998, codes NBJ60 (open reduction and osteosynthesis by nailing), NBJ62 (open reduction and osteosynthesis by plate fixation), NBJ64 (fracture reduction and screw, percutaneous pinning or absorbable screw fixation), NBJ70 (external fixation) and NBB10-30 (arthroplasty) were used.

For the purpose of analysing trends of the different surgical procedures in the treatment of proximal humeral fractures between 1987 and 2009, the procedural codes according to the two different coding systems were pooled to form four groups: closed reduction and osteosynthesis (9126 and NBJ64), open reduction and osteosynthesis (9128, NBJ60 and NBJ62), external fixation (9130 and NBJ70) and arthroplasty (9132 and NBB10-20).

Starting 1998, a second analysis was made to further investigate the rates of different procedures. Between 1998 and 2009 the numbers and incidences of procedures NBJ60, NBJ62, NBJ64 and NBJ70 were analysed.

The main outcome variable was the number of patients undergoing first surgical treatment of a proximal humerus fracture. The mean length of hospital stay is also reported. To calculate the incidence rates of surgically treated proximal humeral fractures, the annual mid-population was obtained from the Official Statistics of Finland.

#### **4.4 Humeral shaft fractures (IV)**

To study the changes in the surgical treatment of humeral shaft fractures in ICD-9 and ICD-10 time, patient data from the NHDR was collected between January 1<sup>st</sup> 1987 and December 31<sup>st</sup> 2009. All patients 18 years or older who had been hospitalized with a primary or secondary diagnosis code of humeral shaft fracture were included in the study.

During the 23-year study period, both diagnosis coding and procedural coding changed. From 1987 to 1995, all diagnoses recorded into the NHDR were according to the ICD-9 classification. (Lääkintöhallitus, 1986) Starting in 1996, diagnosis coding has been recorded according to the ICD-10 classification. (Nienstedt, 1995) The ICD-9 diagnosis codes used were 8122A and 8123A between 1987 and 1995. ICD-10 code S42.3 was used starting in 1996.

Between 1986 and 1996 the procedural coding was recorded according to the Finnish Hospital League manual.(Sairaaliitto, 1983) Starting in about mid 1996, procedural coding was recorded according to a Finnish version of Nomesko procedure classification.(Stakes, 1996) The procedural codes used between 1987 and 1997 were 9126 (closed reduction and osteosynthesis), 9128 (open reduction and osteosynthesis) and 9130 (external fixation). Starting 1997, procedural codes NBJ60 (fracture reduction and osteosynthesis by nailing), NBJ62 (open reduction and osteosynthesis by plate fixation), NBJ64 (open reduction and screw, percutaneous pinning or absorbable screw fixation) and NBJ70 (external fixation) were used.

For the purpose of analysing trends of the different surgical procedures in the treatment of humeral shaft fractures between 1987 and 2009, the procedural codes according to the two different coding systems were pooled to form three groups: closed reduction and osteosynthesis (9126 and NBJ60), open reduction and osteosynthesis (9128, NBJ62 and NBJ64) and external fixation (9130 and NBJ70).

Starting 1997, a second analysis was made to further investigate the rates of different procedures. Between 1997 and 2009 the numbers and incidences of procedures NBJ60, NBJ62, NBJ64 and NBJ70 were analysed.

The main outcome variable was the number of patients undergoing the surgical treatment of a humeral shaft fracture. Only hospitalisations with the first surgical procedure were analysed. Mean length of hospital stay is also reported. To calculate the incidence rates of surgically treated humeral shaft fractures, the annual mid-population was obtained from the Official Statistics of Finland.

## 4.5 Distal radius fractures (V)

To study the changes in the surgical treatment of distal radius fractures the adult population of Finland between January 1<sup>st</sup> 1998 and December 31<sup>st</sup> 2008 was studied. The DRF data was obtained from the electronic data registry, the NHDR. All patients who were aged 20 years and older and who had been hospitalized with a main or secondary diagnosis of distal radius (ICD-10 code S52.5) or distal radius and ulnar fracture (ICD-10 code S52.6) and undergone a surgical procedure for the treatment of the fracture, were selected. The NHDR is mandatory for all hospitals including public, private and other institutions providing an excellent coverage for the data.(Sund, 2012) In addition, all surgical procedures are recorded regardless of the type of hospital stay, meaning both in- and outpatient surgery is recorded.



For the purpose of analysing different surgical approaches, the surgical procedures were categorized into three groups according to the Nomesco classification: plate fixation (procedural codes NCJ62 and NDJ62), percutaneous pinning (procedural codes NCJ64 and NDJ64) and external fixation (NCJ70 and NDJ70). Between 1998 and 2001 only the main procedural code was allowed. Thus we were unable to assess the second and third procedural codes during this time period. Combination surgery was therefore categorized according to the main procedure code. Only patients undergoing the first surgical procedure were analysed.

The main outcome variable was the number of patients undergoing a surgical procedure to treat a distal radius fracture. To calculate the incidence rates of surgically treated distal radius fractures, the annual mid-population was obtained from the Official Statistics of Finland.

## 5. RESULTS

### 5.1 Validity of the Finnish National Hospital Discharge Register (I)

To evaluate the reliability of the NHDR, a sample of 1,112 hospitalisations was collected. Each hospitalisation had a primary or secondary diagnosis of pertrochanteric hip fracture (ICD-10 code S72.1). Only primary hospitalisations were included and all secondary admissions were excluded, as described in the methods. The resulting study sample consisted of 741 cases: 509 women (69%) and 232 men. The mean age of the patients was 81 years. Men were younger (mean age 76 years) than their female counterparts (mean age 83 years).

Most (n=729, 98 %) of the 741 patients with a pertrochanteric hip fracture were treated operatively. Of the nonsurgically treated patients (n=12, 2%), two refused surgery and 10 died prior to surgery.

A pertrochanteric hip fracture was coded as the diagnosis in all of the 741 (100%) patients as it was an inclusion criterion in the study sample. According to the radiological assessment, the diagnosis in the NHDR was accurate for 709 of the 741 patients, giving an accuracy of diagnosis of 96% (95% CI: 94 to 97%). The remaining 32 fractures were falsely registered: 24 were actually fractures of the neck of femur, 5 were subtrochanteric hip fractures and 3 were fractures of the diaphysis of the femur.

A procedural code was found in the NHDR on 711 of the 729 cases whom had undergone a surgical procedure. The coverage of the procedural coding was therefore 98% (95% CI: 96 to 98%). The reasons for not registering a surgical procedure in the NHDR were not uniform and difficult to assess reliably afterwards. Therefore we did not categorize these 18 cases. A common reason for not registering a surgical procedure was that the patient had been transferred to another ward because of a medical reason (for instance, after suffering heart failure or infection) prior to surgery and the operation was later performed while the patient was staying on a nonsurgical ward.

Of the 711 patients who had a procedure recorded on the NHDR, 10 died before post-operative radiological assessment was made. Therefore it was not possible to validate these cases. Of the remaining 701 patients, 616 had a correctly placed procedural code. The accuracy of the procedural coding was therefore 88% (95% CI: 85 to 90%). The remaining 85 procedures were erroneously registered in the NHDR. Internal fixation of fracture of proximal femur with trochanteric nail (NFJ50) was wrongly used in one case. Internal fixation of fracture of proximal femur with sliding hip screw (NFJ52) was wrongly used in 24 cases. Internal fixation of fracture of proximal femur with trochanteric nail (NFJ54) was wrongly used in 57 cases. Internal fixation of fracture of other parts of femur (NFJ62) was wrongly used in three cases. The most common errors were in mixing up procedures NFJ52 and NFJ54.

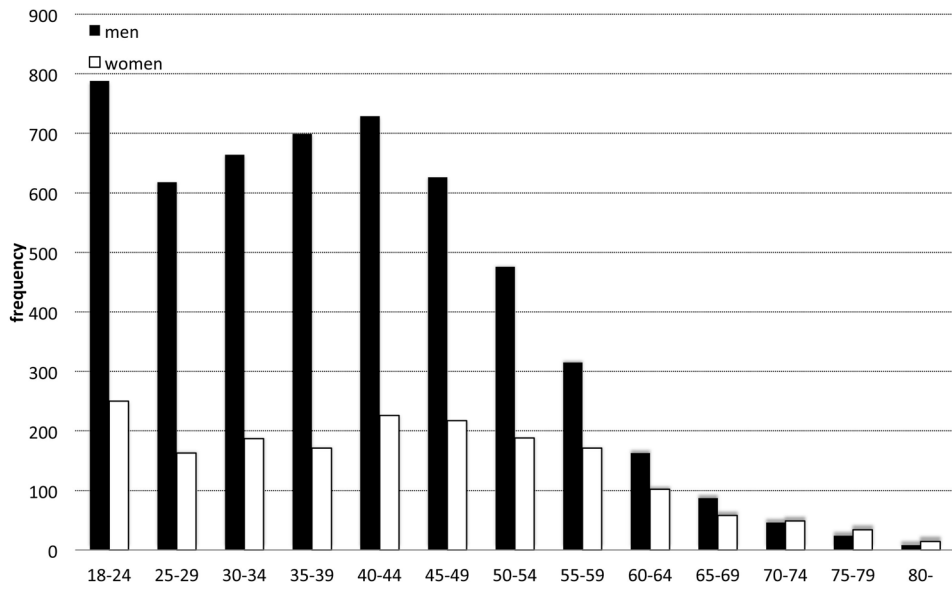
An external cause of injury was registered on 707 of the 741 patients resulting in coverage of 95% (95% CI: 94 to 97%). Of these 707 patients with an external cause of injury, 635 had a correct code registered in the NHDR resulting in an accuracy of 90% (95% CI: 87 to 92%).

## 5.2 Surgically treated clavicle fractures in Finland (II)

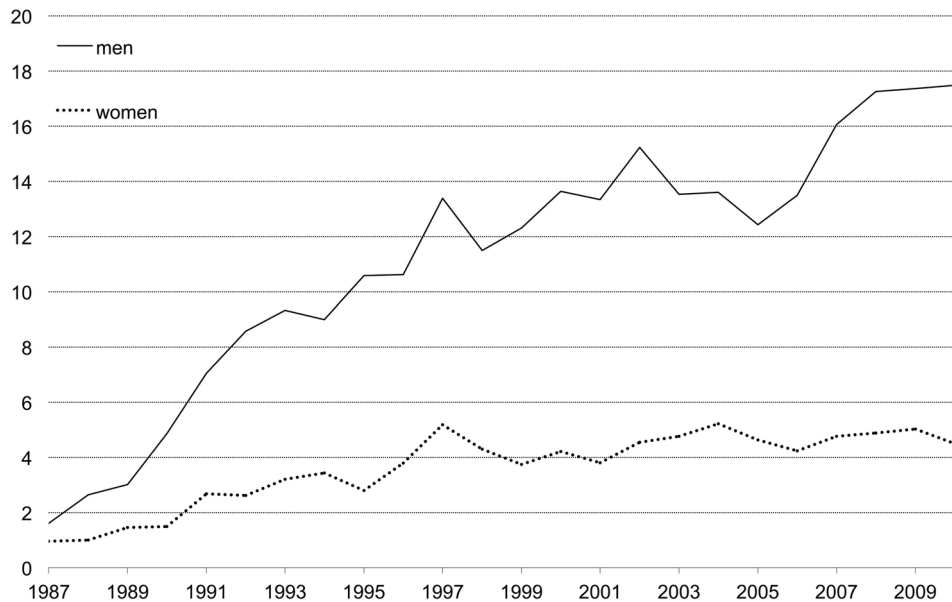
A total of 20,486 hospitalisations with primary or secondary diagnosis of clavicle fractures were registered in the NHDR during the 24-year study period. The number of hospitalised patients was 325 in 1987 and 1,163 in 2010. The rate of hospitalisation following clavicle fracture increased from 8.6 per 100,000 person-years in 1987 to 27.2 per 100,000 person-years in 2010. The rate of hospitalisation in men was 10.2 in 1987 and 38.5 in 2010, both per 100,000 person-years. The corresponding figures in women were 7.0 in 1987 and 16.5 in 2010.

Altogether 7,073 surgically treated clavicle fractures were registered in the NHDR. The annual number of surgically treated clavicle fractures increased from 48 in 1987 to 462 on 2010. The total number of surgically treated clavicle fractures was 5,243 (74%) for men and 1,830 (26%) for women. The mean age for the surgically treated men was 39.0 (SD 13) years while the mean age for surgically treated women was 42.9 (SD 15) years. The age distribution curve of the surgically treated patients is shown in Figure 3.

The rate of surgical treatment of clavicle fractures was 1.3 (n=48) per 100,000 person-years in 1987 and 10.8 (n=462) per 100,000 person-years in 2010. In men the rate of surgical treatment increased from 1.6 (n=29) in 1987 to 17.5 (n=363)

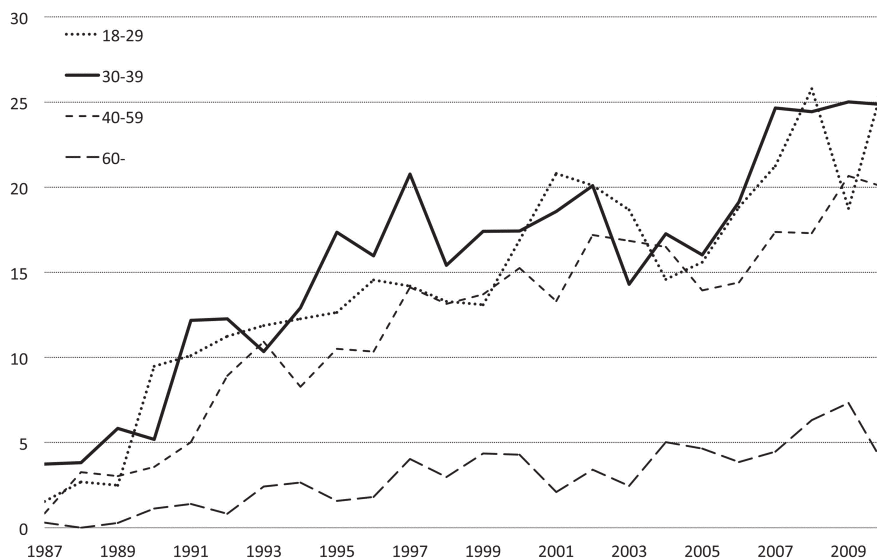


**Figure 3.** Age distribution of the surgically treated men and women with clavicle fracture.

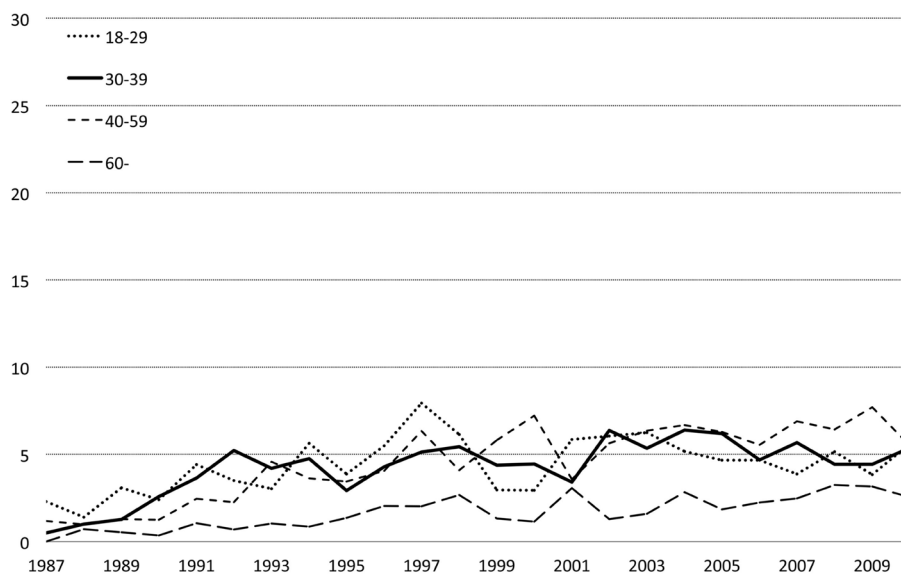


**Figure 4.** Rate of surgically treated adult clavicle fractures per 100,000 person years between 1987 and 2010.

in 2010. The corresponding figures for women were 1.0 (n=19) in 1987 and 4.5 (n=99) in 2010. Figure 4. Thus, the steepest rises in rate of surgical treatment were seen in men; the increase was notable in all age groups under 60 years of age. Figure 5. In women the overall and age-specific changes in the rate of surgical treatment were more moderate. Figure 6.



**Figure 5.** Rate of surgically treated clavicle fractures in Finnish male adults per 100,000 person years between 1987 and 2010.



**Figure 6.** Rate of surgically treated clavicle fractures in Finnish female adults per 100,000 person years between 1987 and 2010.

In a secondary analysis we assessed the type of hospital (public, private) and the surgical procedure between 1997 and 2010. Altogether 5,359 procedures were included in this analysis.

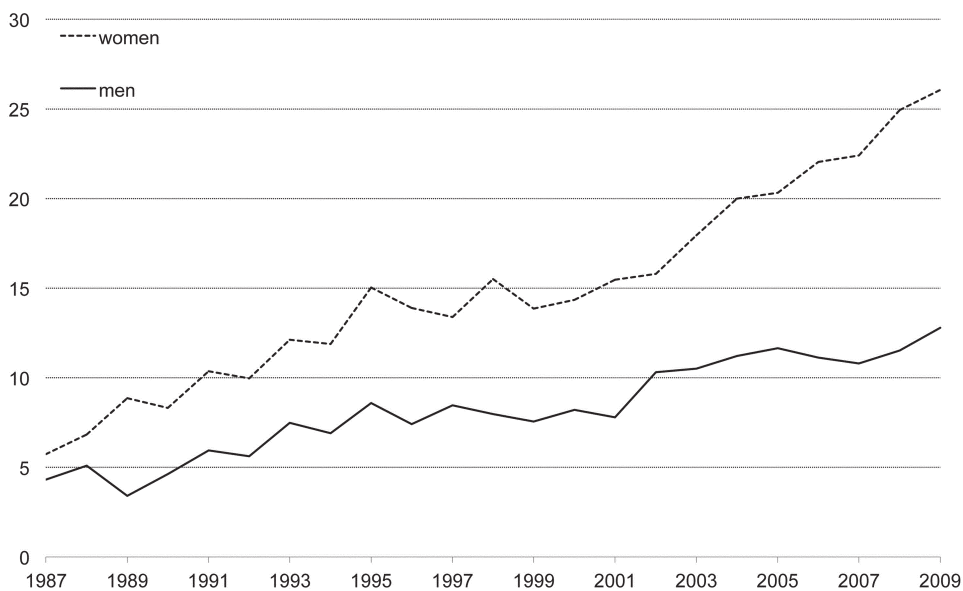
Most of the surgical procedures (n=4,760, 89%) were carried out in public hospitals and the remaining (n=599, 11%) in private hospitals. A clear majority of the procedures were performed on an inpatient basis (n=4,843, 90%) and 516 (10%) were performed on an outpatient basis. The mean age for the surgically treated men in public hospitals was 40 years and 39 in private hospitals. The corresponding figures for women were 44 years in public and 43 years in private hospitals.

A difference was seen in surgical treatment between public and private hospitals. In public hospitals 3,417 (96%) men were treated as inpatients and 127 (4%) as outpatients. In private hospitals, the corresponding figures were 181 (40%) as inpatients vs. 276 (60%) as outpatients. Concerning women in public hospitals, 1,174 (97%) were treated as inpatients and 42 (3%) as outpatients. In private hospitals the corresponding figures were 71 (50%) as inpatients vs. 71 (50%) as outpatients.

### **5.3 Surgically treated proximal humerus fractures in Finland (III)**

Between 1987 and 2009 a total of 47,960 hospitalisations with primary or secondary diagnosis of proximal humeral fracture were identified. During the 23-year period, 10,560 surgical procedures were registered in the NHDR. The number of surgical procedures in women was roughly twice that in men (n=7,008, 66% in women and n=3,552, 34% in men).

The rate of surgical treatment of proximal humerus fractures increased from 1987 to 2009. The rate was 5.1 (n=185) per 100,000 person-years in 1987 and 19.6 (n=808) per 100,000 person-years in 2009. The increase was especially strong in women as the rate rose from 5.7 (n=110) per 100,000 person-years in 1987 to 26.1 (n=553) per 100,000 person-years in 2009. In men the corresponding figures were 4.3 (n=75) per 100,000 person-years in 1987 and 12.8 (n=255) per 100,000 person-years in 2009. Figure 7.

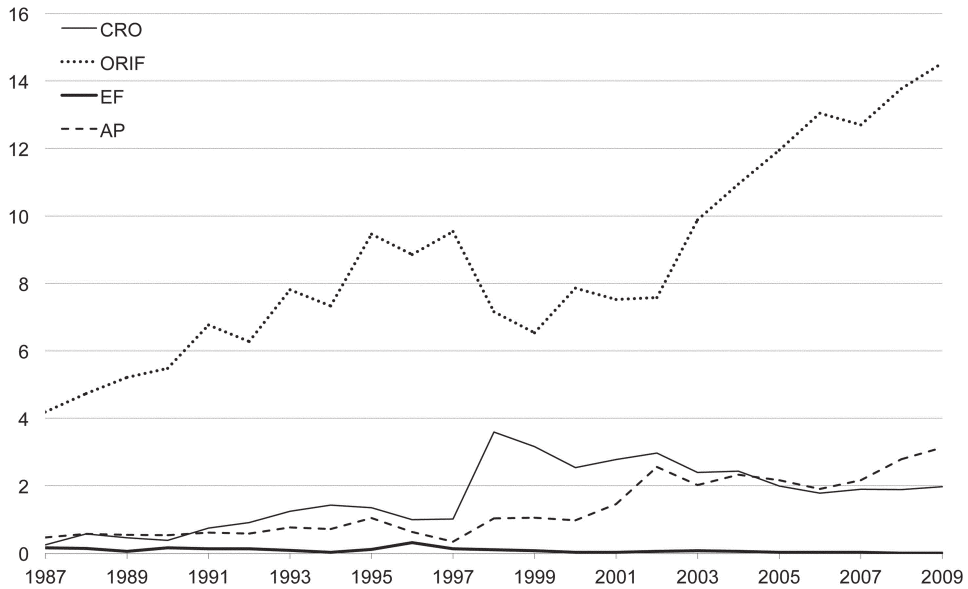


**Figure 7.** Rate of surgically treated adult proximal humeral fractures per 100,000 person years between 1987 and 2009.

Open reduction and osteosynthesis was the most common procedure between 1987 and 2009 ( $n=7,774$ , 74%), followed by closed reduction and osteosynthesis ( $n=1,515$ , 14%), arthroplasty ( $n=1,198$ , 11%) and external fixation ( $n=73$ , 1%).

The changes in the rates of different surgical approaches between 1987 and 2009 are shown in Figure 8 and Table 5. The rate of open reduction and osteosynthesis was 4.2 ( $n=153$ ) per 100,000 person-years in 1987 and 14.5 ( $n=598$ ) per 100,000 person-years in 2009. The steepest rise in incidence rate was observed in open reduction and osteosynthesis in women with an increase from 4.4 ( $n=84$ ) per 100,000 person-years in 1987 to 19.1 ( $n=405$ ) per 100,000 person-years in 2009. The incidence of closed reduction and osteosynthesis was 0.25 ( $n=9$ ) per 100,000 person-years in 1987 and 2.0 ( $n=81$ ) per 100,000 person-years in 2009. The corresponding values for arthroplasty were 0.5 ( $n=17$ ) and 3.1 ( $n=129$ ).

Between 1998 and 2009 a second analysis was made, resulting from the fact that NomESCO classification allowed for a more specific procedural coding. During the period, 7,075 surgical procedures were performed. Open reduction and osteosynthesis by plate fixation (NBJ62) was the most common procedure ( $n=4,395$ , 62%), followed by fracture reduction and screw, percutaneous pinning or absorbable screw fixation (NBJ64,  $n=1,166$ , 16%), arthroplasty (NBB10-20,  $n=945$ , 13%),



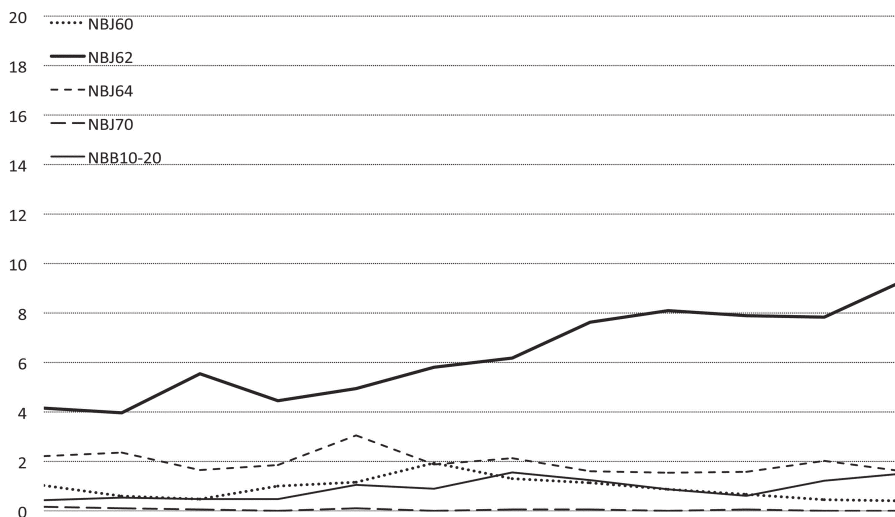
**Figure 8.** Changes in the rate of surgically treated proximal humeral fractures in Finnish adults per 100,000 person years between 1987 and 2009. CRO=closed reduction and osteosynthesis, ORIF=open reduction and osteosynthesis, EF=external fixation, AP=arthroplasty.

**Table 5.** Rate of surgically treated proximal humeral fractures. CRO= closed reduction and osteosynthesis, ORO= open reduction and osteosynthesis, EF= external fixation, AP= arthroplasty, ALL= all surgical procedures combined.

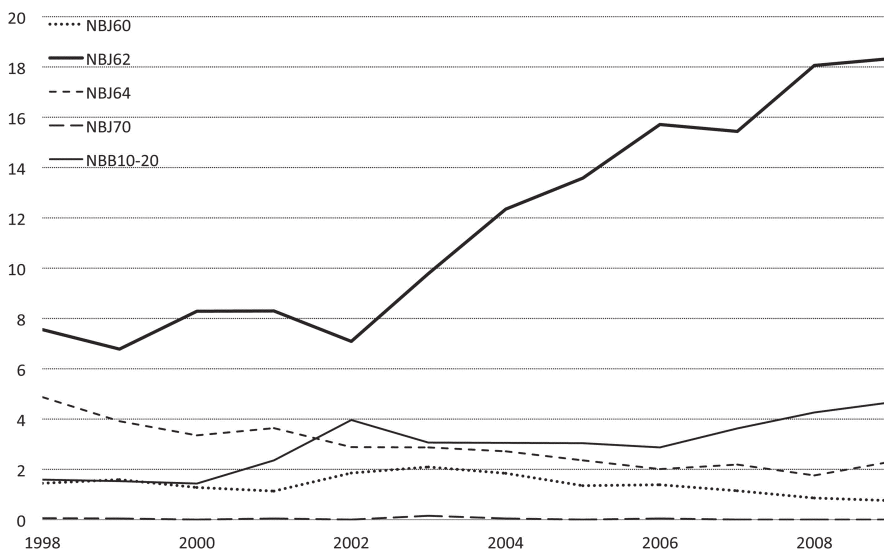
	1987	2009
CRO		
men	0.2 (n=3)	1.6 (n=32)
women	0.3 (n=6)	2.3 (n=49)
all	0.2 (n=9)	2.0 (n=81)
ORO		
men	4.0 (n=69)	9.7 (n=193)
women	4.4 (n=84)	19.1 (n=405)
all	4.2 (n=153)	14.5 (n=598)
EF		
men	0.1 (n=1)	0 (n=0)
women	0.3 (n=5)	0 (n=0)
all	0.2 (n=6)	0 (n=0)
AP		
men	0.1 (n=2)	1.5 (n=30)
women	0.8 (n=15)	4.7 (n=99)
all	0.5 (n=17)	3.1 (n=129)
ALL		
men	4.3 (n=75)	12.8 (n=255)
women	5.7 (n=110)	26.1 (n=553)
all	5.1 (n=185)	19.6 (n=808)



open reduction and osteosynthesis by nailing (NBJ60, n=555, 8%) and external fixation (NBJ70, n=19, 0.3%). Changes in the rate and proportions of different surgical approaches between 1998 and 2009 stratified by sex are shown in Figure 9 and Figures 10 and in Table 6.



**Figure 9.** Rate of surgically treated proximal humeral fractures in Finnish male adults per 100,000 person years between 1998 and 2009. NBJ60=nail, NBJ62=plate, NBJ64=screw, NBJ70=external fixation, NBB10-20=arthroplasty.

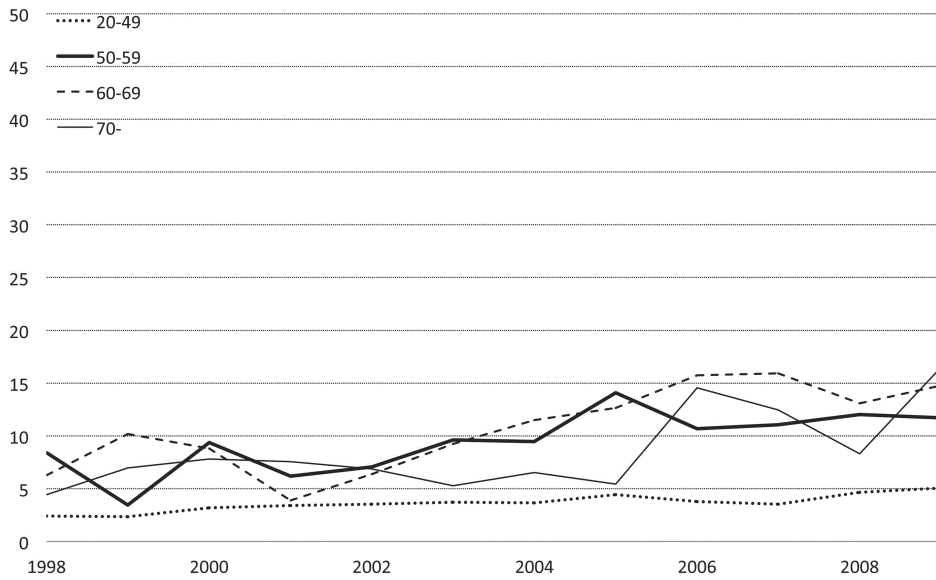


**Figure 10.** Rate of surgically treated proximal humeral fractures in Finnish female adults per 100,000 person years between 1998 and 2009. NBJ60=nail, NBJ62=plate, NBJ64=screw, NBJ70=external fixation, NBB10-20=arthroplasty.

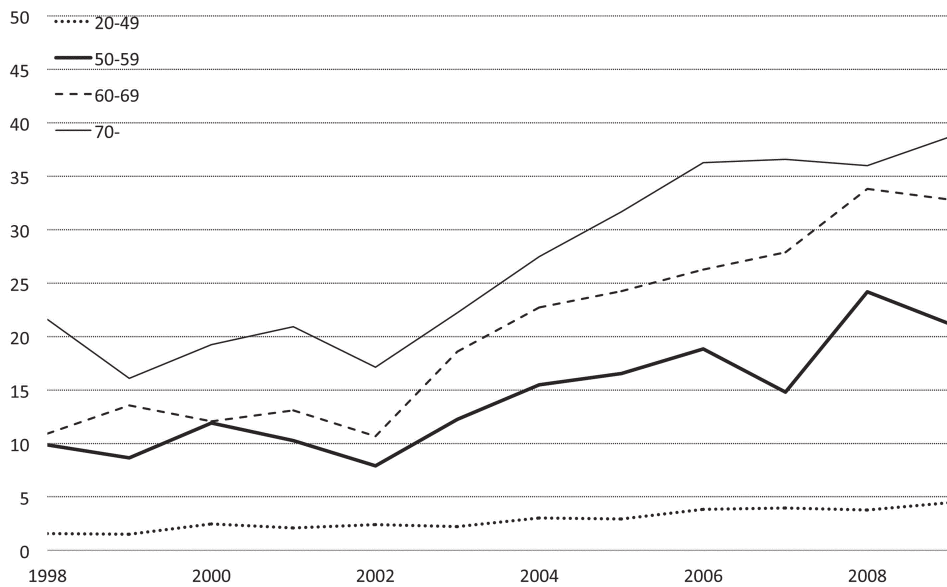
**Table 6.** Rate of surgically treated proximal humeral fractures. NBJ60= nail, NBJ62=plate, NBJ64=screw, NBJ70=external fixation, NBB10-20=arthroplasty, ALL=all procedures combined.

	<b>1998</b>	<b>2009</b>
<hr/>		
NBJ60		
men	1.0 (n=19)	0.4 (n=8)
women	1.4 (n=29)	0.8 (n=16)
all	1.2 (n=48)	0.6 (n=24)
<hr/>		
NBJ62		
men	4.1 (n=77)	9.3 (n=185)
women	7.6 (n=152)	18.3 (n=389)
all	5.9 (n=229)	13.9 (n=574)
<hr/>		
NBJ64		
men	2.2 (n=41)	1.6 (n=32)
women	4.9 (n=98)	2.3 (n=49)
all	3.6 (n=139)	2.0 (n=81)
<hr/>		
NBJ70		
men	0.2 (n=3)	0 (n=0)
women	0.05 (n=1)	0 (n=0)
all	0.1 (n=4)	0 (n=0)
<hr/>		
NBB10-20		
men	0.4 (n=8)	1.5 (n=30)
women	1.6 (n=32)	4.7 (n=99)
all	1.0 (n=40)	3.1 (n=129)
<hr/>		
ALL		
men	8.0 (n=148)	12.8 (n=255)
women	15.5 (n=312)	26.1 (n=553)
all	11.9 (n=460)	19.6 (n=808)

The rate of plate fixation was 5.9 (n=229) per 100,000 person-years in 1998 and it increased to 13.9 (n=574) per 100,000 person-years in 2009. The rise was especially clear in women; the rate was 7.6 (n=152) per 100,000 person-years in 1998 and 18.3 (n=389) per 100,000 person-years in 2009. Changes in the rates of plating between 1998 and 2009 stratified by sex and age are shown in Figures 11 and 12.



**Figure 11.** Rate of plating in proximal humerus fractures in Finnish male adults per 100,000 person years between 1998 and 2009.



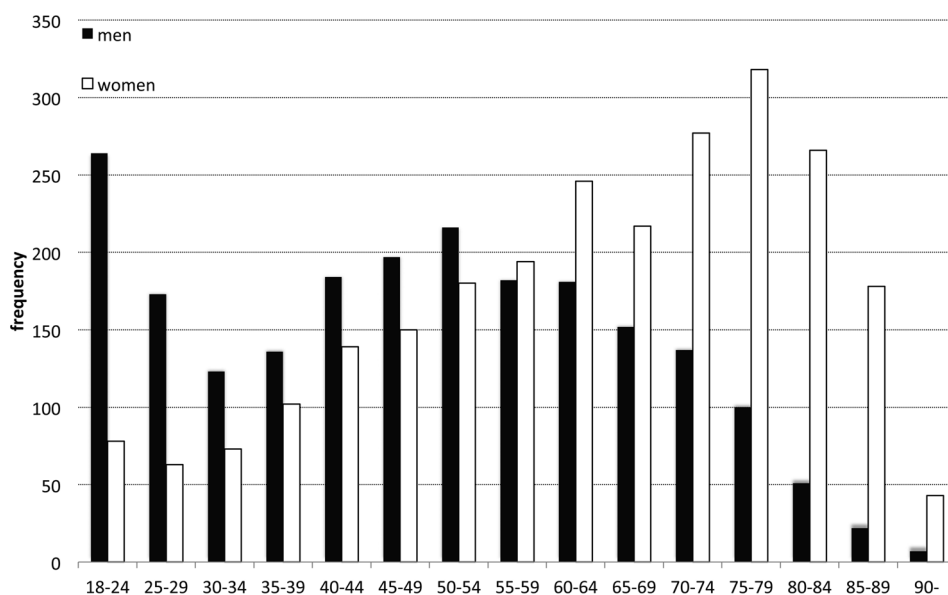
**Figure 12.** Rate of plating in proximal humerus fractures in Finnish female adults per 100,000 person years between 1998 and 2009.

As the rates of nailing, external fixation and screw, pin or absorbable screw decreased from 1998 to 2009, the rates of arthroplasty increased from 1.0 (n=40) per 100,000 person-years in 1998 to 3.1 (n=129) per 100,000 person-years in 2009.

The mean age at the time of surgery varied: 65 years (SD 15) for nailing, 62 years (SD 15) for plating, 59 years (SD 16) for screw pin or absorbable screw, and 70 (SD 11) for arthroplasty.

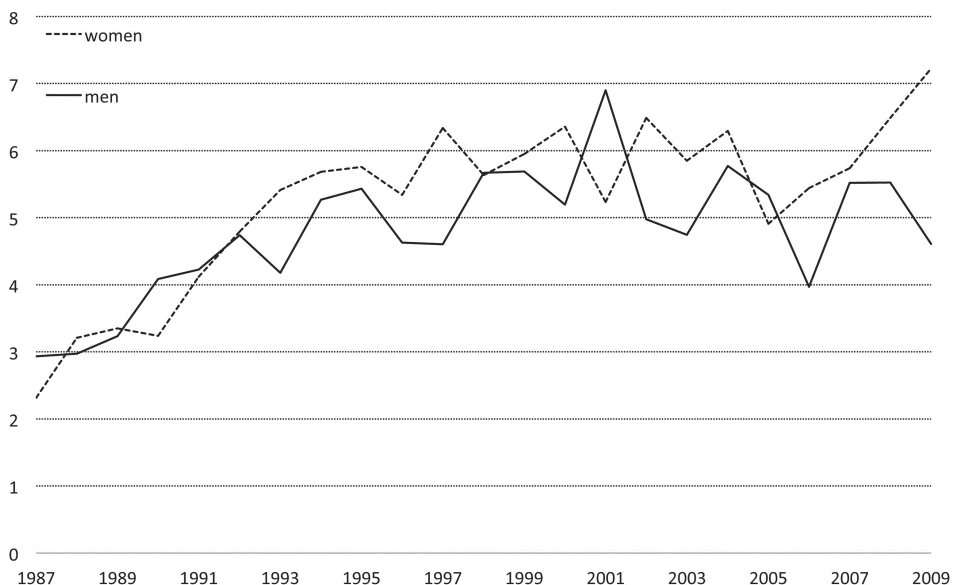
## 5.4 Surgically treated fractures of the humeral shaft in Finland (IV)

Between January 1<sup>st</sup> 1987 and December 31<sup>st</sup> of 2009 15,096 hospitalisations with primary or secondary diagnosis of a fracture of the humeral shaft were recorded in the NHDR. During these 15,096 hospitalisations due to humeral shaft fractures, 4,518 surgical procedures were performed and registered in the NHDR. Surgical treatment of humeral shaft fractures was more common in women (n=2,462, 54%) than in men (n=2,056, 46%). Surgically treated women were older (mean 63 years, SD 18) than men (mean 49 years, SD 18). The mean age of the surgically treated men increased from 43 years in 1987 to 52 years in 2009. There was a corresponding increase in the mean age of the surgically treated women from 57 years in 1987 to 64 years in 2009. The age distribution curve of the surgically treated population is shown in Figure 13.



**Figure 13.** Age distribution of the surgically treated men and women with humeral shaft fracture.

The rate of surgical treatment of humeral shaft fracture rose steadily from 2.6 (n=98) per 100,000 person-years in 1987 to 5.7 (n=253) per 100,000 person-years in 2009. The rate was 2.3 (n=46) per 100,000 person-years in 1987 and 6.9 (n=151) per 100,000 person-years in 2009 in women and 2.9 (n=52) per 100,000 person-years in 1987 and 4.4 (n=91) per 100,000 person-years in 2009 in men. Figure 14.

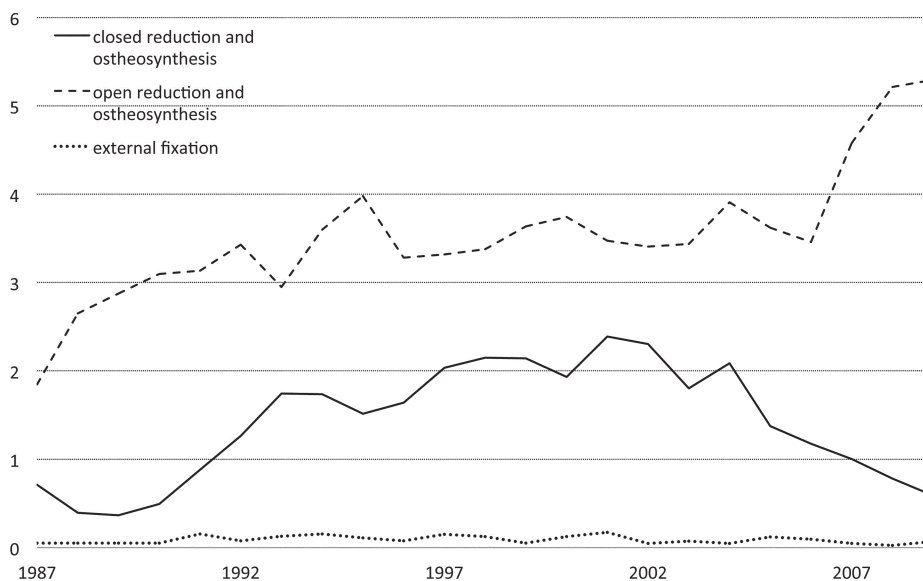


**Figure 14.** Rate of surgically treated humeral shaft fractures in Finnish adults per 100,000 person years between 1987 and 2009.

During the study period, open reduction and osteosynthesis was the most common surgical procedure in the treatment of humeral shaft fracture (n=3,179, 70%). Closed reduction and osteosynthesis (n=1,268, 28%) and external fixation (n=71, 2%) followed. The changes in the rates of different surgical procedures are shown in Figure 15.

The rate of open reduction and osteosynthesis was 1.8 (n=69) per 100,000 person-years in 1987 and 5.1 (n=218) per 100,000 person-years in 2009. The rate of closed reduction and osteosynthesis was 0.7 (n=27) per 100,000 person-years in 1987 and 0.5 (n=22) per 100,000 person-years in 2009. The corresponding rates for external fixation were 0.1 (n=2) per 100,000 person-years in 1987 and 0.05 (n=2) per 100,000 person-years in 2009. The strongest change occurred in the open reduc-

tion and osteosynthesis group in women where the rate was 1.7 (n=34) per 100,000 person-years in 1987 and 6.3 (n=137) per 100,000 person-years in 2009. Table 7.



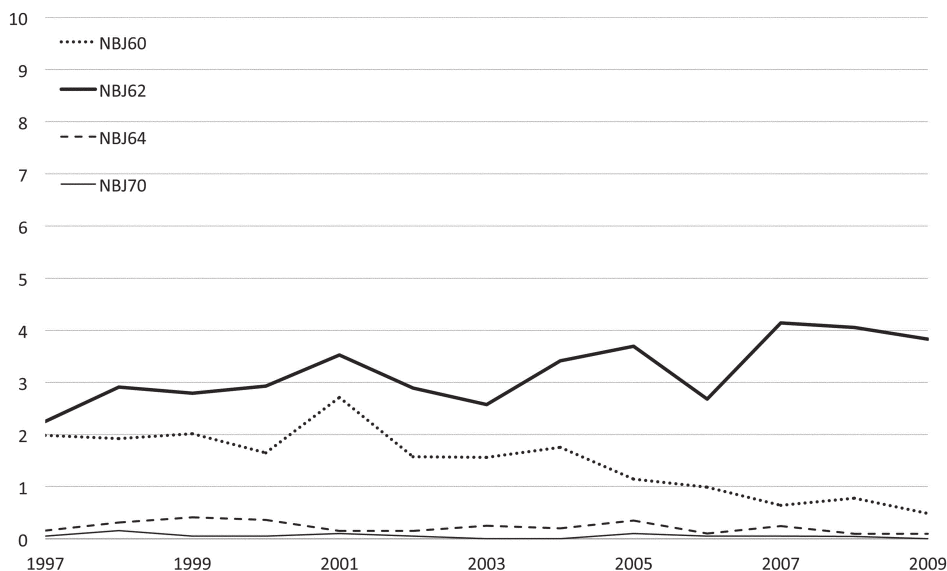
**Figure 15.** Changes in the rate of surgically treated humeral shaft fractures in Finnish adults per 100,000 person years between 1987 and 2009.

**Table 7.** Rate of surgically treated humeral shaft fractures. CRO= closed reduction and osteosynthesis, ORO= open reduction and osteosynthesis, EF= external fixation, ALL= all surgical procedures combined.

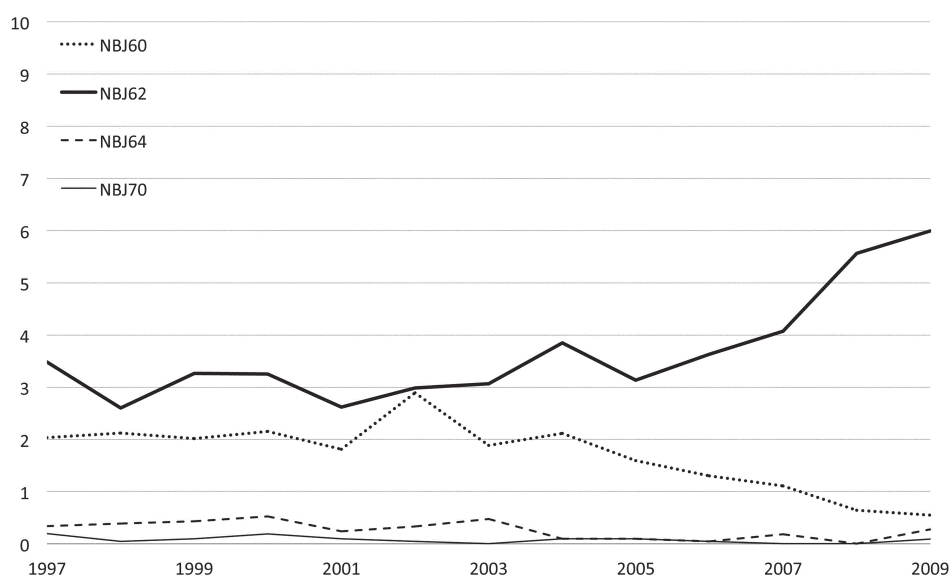
	1987	2009
<b>CRO</b>		
men	0.8 (n=15)	0.5 (n=10)
women	0.6 (n=12)	0.6 (n=12)
all	0.7 (n=27)	0.5 (n=22)
<b>ORO</b>		
men	1.9 (n=35)	3.9 (n=81)
women	1.7 (n=34)	6.3 (n=137)
all	1.8 (n=69)	5.1 (n=218)
<b>EF</b>		
men	0.1 (n=2)	0 (n=0)
women	0 (n=0)	0.1 (n=2)
all	0.1 (n=2)	0.05 (n=2)
<b>ALL</b>		
men	2.9 (n=52)	4.4 (n=91)
women	2.3 (n=46)	6.9 (n=151)
all	2.6 (n=98)	5.7 (n=242)

ICD-10 allowed for a second analysis between 1997 and 2009 to further break down the distribution of different surgical procedures. A total of 2,852 surgical procedures were included in the second analysis. Open reduction and osteosynthesis with plate fixation (NBJ62) was the most common procedure (n=1,841, 65%) followed by fracture reduction and osteosynthesis by nailing (NBJ60, n=847, 30%), open reduction and screw, percutaneous pinning or absorbable screw fixation (NBJ64, n=129, 5%) and external fixation (NBJ70, n=35, 1%).

A clear increase was seen with plating as the rate rose from 2.9 (n=115) per 100,000 person-years in 1997 to 4.9 (n=210) per 100,000 person-years in 2009. The increase was especially clear in women where the rate was 3.5 (n=72) per 100,000 person-years in 1997 and 6.0 (n=131) per 100,000 person-years in 2009. The increase in plating coincided with the declining rate of nailing, with 2.0 (n=80) per 100,000 person-years in 1997 and 0.5 (n=22) per 100,000 person-years in 2009. According to present results, screw, pin and absorbable pin fixation and external fixation were relatively uncommon procedures in the treatment of humeral shaft fractures. Changes in the rates and proportions of different surgical approaches between 1997 and 2009 stratified by sex are shown in Table 8 and Figures 16 and 17.



**Figure 16.** Rate of surgically treated humeral shaft fractures in Finnish male adults per 100,000 person years between 1997 and 2009. NBJ60=nail, NBJ62=plate, NBJ64=screw, NBJ70=external fixation.



**Figure 17.** Rate of surgically treated humeral shaft fractures in Finnish female adults per 100,000 person years between 1997 and 2009. NBJ60=nail, NBJ62=plate, NBJ64=screw, NBJ70=external fixation.

**Table 6.** Rate of surgically treated humeral shaft fractures. NBJ60= nail, NBJ62=plate, NBJ64=screw, NBJ70=external fixation, ALL=all procedures combined.

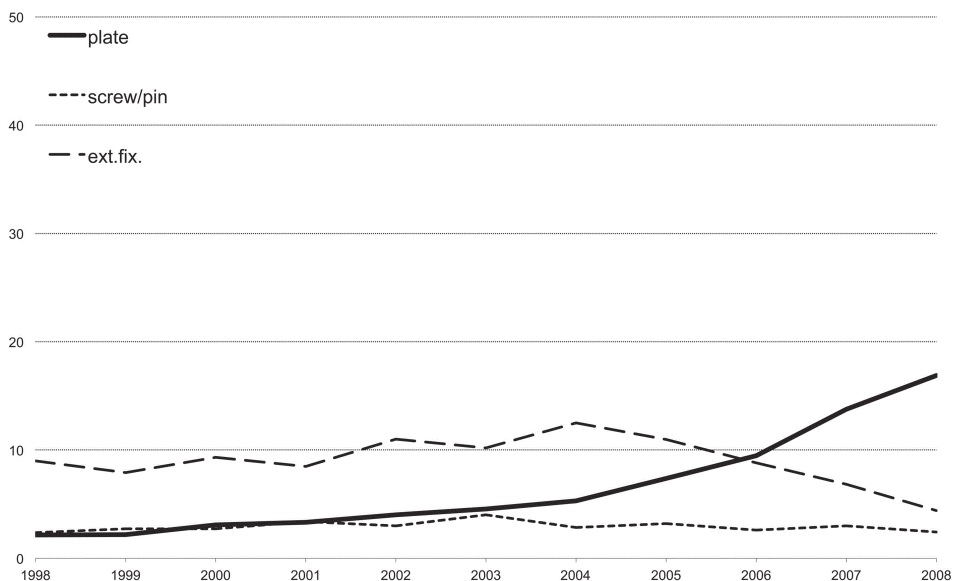
	1997	2009
<hr/>		
NBJ60		
men	2.0 (n=38)	0.5 (n=10)
women	2.0 (n=42)	0.5 (n=12)
all	2.0 (n=80)	0.5 (n=22)
<hr/>		
NBJ62		
men	2.2 (n=43)	3.8 (n=79)
women	3.5 (n=72)	6.0 (n=131)
all	2.9 (n=115)	4.9 (n=210)
<hr/>		
NBJ64		
men	0.2 (n=3)	0.1 (n=2)
women	0.3 (n=7)	0.3 (n=6)
all	0.3 (n=10)	0.2 (n=8)
<hr/>		
NBJ70		
men	0.1 (n=1)	0 (n=0)
women	0.2 (n=4)	0.1 (n=2)
all	0.1 (n=5)	0.05 (n=2)
<hr/>		
ALL		
men	4.4 (n=85)	4.4 (n=91)
women	6.0 (n=125)	6.9 (n=151)
all	5.3 (n=210)	5.7 (n=242)



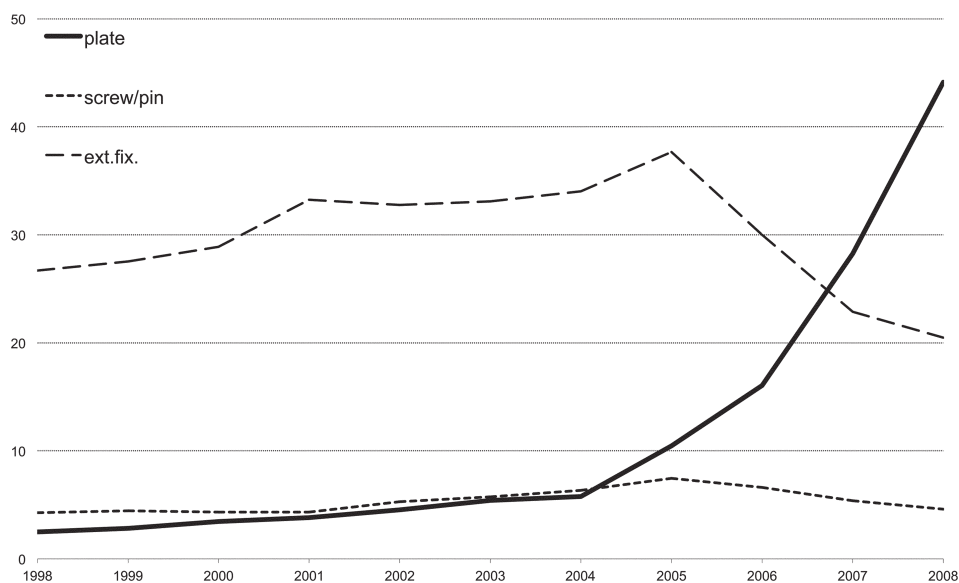
The mean length of hospital stay decreased from 10.7 days in 1987 to 4.2 days in 2009. Mean hospital stay by surgery type was 6.3 days for closed reduction and osteosynthesis, 6.0 days for open reduction and osteosynthesis and 14.7 days for external fixation.

## 5.5 Surgically treated distal radius fractures in Finland (V)

There were 14,514 surgical procedures to treat DRFs in adults recorded in the NHDR between 1998 and 2008. Surgical treatment was more common in women (n=10,595, 73%) than in men (n=3,919, 27%). The overall rate of the surgical treatment of distal radius fractures increased from 23.9 per 100,000 person-years (n=924) in 1998 to 47.2 per 100,000 person-years (n=1,929) in 2008. The rates of surgical procedures for men were 13.5 per 100,000 person-years (n=251) in 1998 and 23.7 per 100,000 person-years (n=469) in 2008, while the corresponding rates for women were 33.4 per 100,000 person-years (n=673) in 1998 and 69.2 per 100,000 person-years (n=1,460) in 2008.



**Figure 18.** Rate of surgically treated distal radius fractures in Finnish male adults per 100,000 person years between 1998 and 2008.



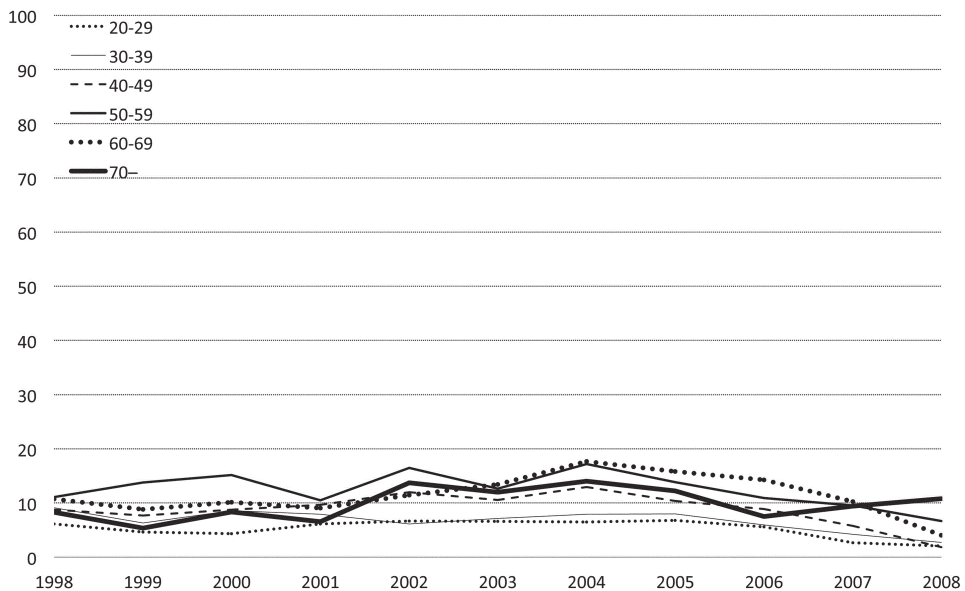
**Figure 19.** Rate of surgically treated distal radius fractures in Finnish female adults per 100,000 person years between 1998 and 2008.

The most common surgical procedure during the study period between 1998 and 2008 was external fixation ( $n=8,630$ , 59%), followed by open reduction and fixation by plating ( $n=4,053$ , 28%) and percutaneous pinning ( $n=1,831$ , 13%).

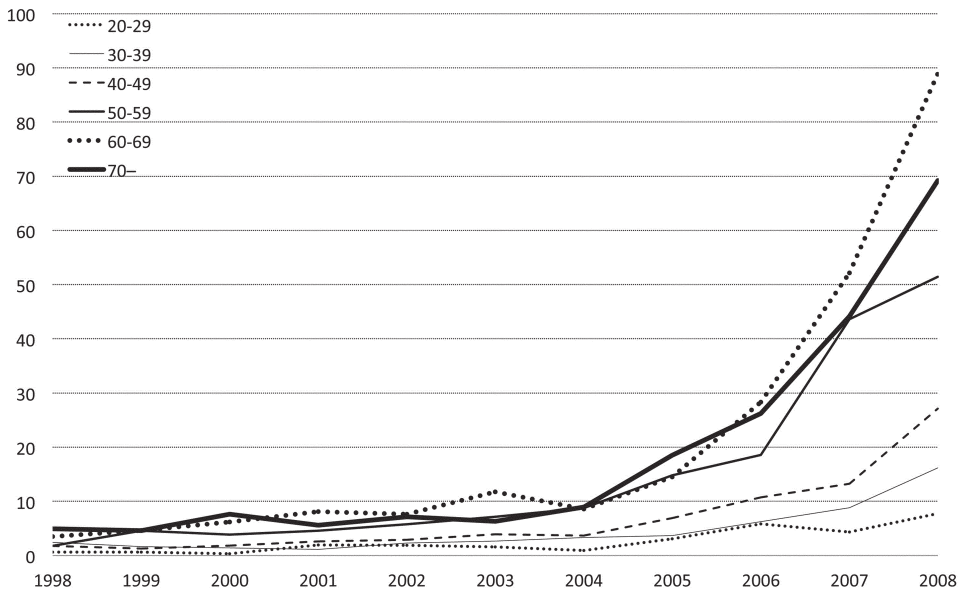
A clear change occurred during the 11-year study period. The rate of external fixation was 18.2 per 100,000 person-years ( $n=704$ ) in 1998 and 12.7 per 100,000 person-years ( $n=519$ ) in 2008. The rate of external fixation in men was 9.0 per 100,000 person-years ( $n=167$ ) in 1998 and 4.4 per 100,000 person-years ( $n=87$ ) in 2008. Figure 18. The corresponding rates per 100,000 person-years for women were 26.7 ( $n=537$ ) in 1998 and 20.5 ( $n=432$ ) in 2008. Figure 19. The change in the rate of the external fixation was strong in women aged 50 years and more: however, there was not a marked change in men. Figures 20 and 21.



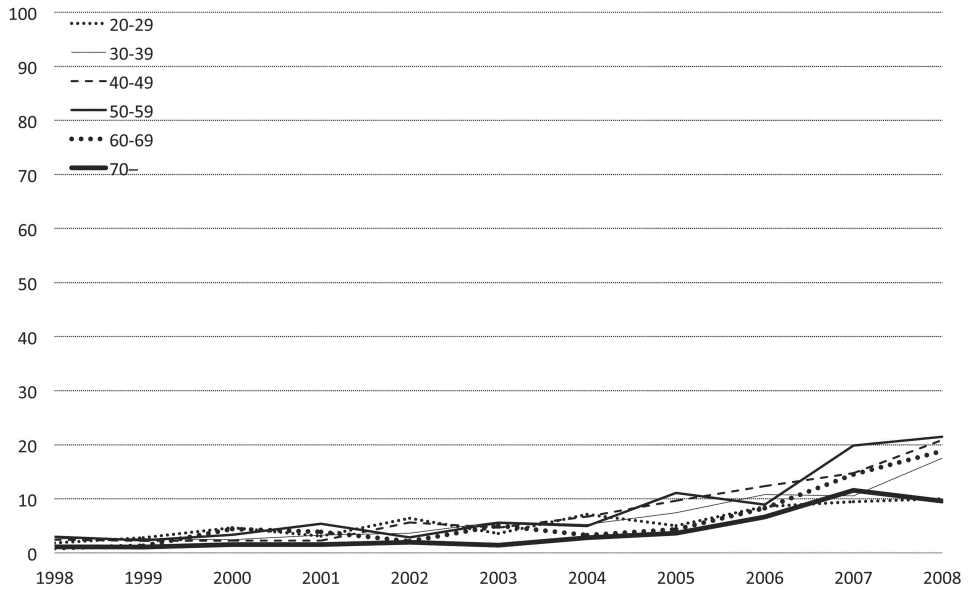
**Figure 20.** Rate of external fixation in distal radius fractures in Finnish female adults per 100,000 person years between 1998 and 2008.



**Figure 21.** Rate of external fixation in distal radius fractures in Finnish male adults per 100,000 person years between 1998 and 2008.



**Figure 22.** Rate of plating in distal radius fractures in Finnish female adults per 100,000 person years between 1998 and 2008.



**Figure 23.** Rate of plating in distal radius fractures in Finnish male adults per 100,000 person years between 1998 and 2008.

For open reduction and plate fixation, the rate was 2.3 (n=90) per 100,000 person-years in 1998 and 30.9 (n=1,265) per 100,000 person-years in 2008. For men, the rate in open reduction and plate fixation was 2.2 (n=40) per 100,000 person-years in 1998 and 16.9 (n=334) per 100,000 person-years in 2008. Figure 18. The corresponding figures per 100,000 person-years for women were 2.5 (n=50) in 1998 and 44.1 (n=93) in 2008. Figure 19. As with external fixation, the clearest change for plating occurred in women 50 years and older. Figure 22. The changes in men were not as strong as in women. Figure 23.

The rates of percutaneous pinning were 3.4 (n=130) per 100,000 person-years in 1998 and 3.5 (n=145) per 100,000 person-years in 2008. The rate of percutaneous pinning in men was 2.4 (n=44) per 100,000 person-years in 1998 and 2.4 (n=48) per 100,000 person-years in 2008. Figure 18. In women, the rates were 4.3 (n=86) per 100,000 person-years in 1998 and 4.6 (n=97) per 100,000 person-years in 2008. Figure 19.

The mean length of hospital stay was 2.8 days in 1998 and 2.3 days in 2008. Mean duration of hospital stay by surgery type was 2.7 days in the external fixation group, 2.9 days in the open reduction and plate fixation group and 2.7 days in the percutaneous pinning group.

## 6. DISCUSSION

### 6.1 Reliability and validity of the Finnish National Hospital Discharge Register in pertrochanteric hip fractures

The NHDR is a statutory, computer-based register in Finland with an almost six decade-long history.(Sund, 2012) The data is collected and maintained by the National Institute for Health and Welfare, and the registry is therefore government funded. It undergoes routine internal validity checks to spot logical errors and missing data. If needed, corrections are requested from individual hospitals.(THL, 2012) External validation and reliability assessment has focused on the accuracy of diagnosis, while many other variables, such as procedural coding and external cause of injury, have been less evaluated. According to a recent review of studies assessing the quality of the NHDR, the PPV for common diagnoses was between 75 and 99%.(Sund, 2012) Most studies evaluating the reliability of the NHDR have focused on mental illnesses and vascular diseases and to a lesser extent on other diseases or injuries. (Sund, 2012) In general, the reliability of injury-related diagnoses has been found to have a better PPV, possibly because diagnosing fractures is more clear-cut than, for instance, bipolar disorder.

Validity of the NHDR is important as the National Institute of Health and Welfare and also individual hospital districts routinely use the data on the register in assessing the need for various treatments. What is more, a part of the billing of Finnish public hospitals is based on the NHDR data. The data in the NHDR has also been used in research, which places a high demand of validity on the data. Errors in the register can occur on many levels of data generation. It is common in Finland that treating physicians describe the course of medical care, including

procedures, by dictaphone, and a clinic secretary later types out the dictations on the actual medical records. When an individual patient is discharged, the hospitalisation record is closed and the data stored by the hospital administration until collectively sent to the NHDR. Errors in the NHDR data can occur in different levels. First, the physician can make an incorrect diagnosis. Secondly, it is also possible that the clinician assigns the right diagnosis but uses the wrong diagnosis code when dictating. Thirdly, it is later possible that the secretary makes a typo or misunderstands the physician's dictation.

In previous studies on injuries, Keskimäki and Aro found that accuracy of diagnosis was excellent (95%), but procedural coding was less accurate (70-78%). (Keskimäki and Aro, 1991) In two separate studies Lühje, Sund, and co-workers found the accuracy of diagnosis to be excellent. (Lühje et al., 1995, Sund et al., 2007) Mattila et al assessed both accuracy and coverage and found that both were excellent (92 and 89%). (Mattila et al., 2008) The present study the accuracy of diagnosis and both accuracy and coverage of external reason for injury and procedural coding was evaluated.

In the present study, the accuracy of diagnosis of trochanteric hip fracture was 96% (95% CI: 94 to 97%). The coverage of external cause of injury was 95% (95% CI: 94 to 97%) and accuracy was 90% (95% CI: 87 to 92%). The coverage of procedural coding was 98% (95% CI: 96 to 98%) and accuracy was 88% (95% CI: 85 to 90%).

Our results on the accuracy of diagnosis are well in line with the findings of Keskimäki, Lühje, Sund and Mattila. (Keskimäki and Aro, 1991, Lühje et al., 1995, Sund et al., 2007, Mattila et al., 2008) In the present study, the coverage of diagnosis was not assessed due to the study setting. The assessment of the coverage of diagnosis would have required an evaluation of all pelvic radiographs during the study period in all of the studied hospitals, which was not deemed feasible. In addition, diagnostic reliability has been assessed in numerous previous studies. (Sund, 2012) In their study, Sund and co-workers assessed the accuracy of hip fracture diagnosis in all hip fractures treated in a single hospital in Finland, and found that there was some variation in the accuracy of diagnosis between different types of hip fractures. (Sund et al., 2007) Additionally, Sund and co-workers studied the completeness, accuracy and correctness of procedural coding and external reason of injury. (Sund et al., 2007) In contrast to the findings of Keskimäki and Aro, our results on the accuracy of procedural coding are better, and similar to those reported by Sund and co-workers. (Keskimäki and Aro, 1991, Sund et al., 2007) However, the studies

differ; Keskimäki and Aro used a random sample taken from all hospitalisations in 1986.(Keskimäki and Aro, 1991) The present study evaluated a pooled sample taken from three individual hospitals including only patients with a primary or secondary diagnosis of trochanteric hip fracture. Sund and co-workers evaluated all hip fractures treated in a single hospital in a little over a year's time.(Sund et al., 2007) Keskimäki and Aro's sample contains a variety of different hospitalisations and, consequently, procedure types that might increase the inaccuracy.(Keskimäki and Aro, 1991) Their study was carried out in 1986, when procedural coding was done according to the Hospital League and diagnosis was according to ICD-8.(Lääkintöhallitus, 1979, Sairaalaliitto, 1983) To date, the study by Sund and co-workers is the only other study evaluating the reliability of both external cause of injury and procedural coding that has been published since the implementation of ICD-10 in Finland.(Sund et al., 2007) The development of the NHDR, introduction of the ICD-10 coding system and better schooling in their uses are also likely to explain a part of the difference between the studies.

The strength of the present study on the validity of the NHDR is a sufficient sample size (n=741). Simple dichotomies (yes/no) on the studied variables were created that were assessed by reading through the original medical records of the entire hospitalisation. Original radiographs were also evaluated. The information was then compared to the data on the NHDR.

Hospital discharge registers that have national coverage are rare and seem to be a Scandinavian phenomenon. For instance, in the United States studies assessing trends in the surgical treatment of certain injuries are based on samples from smaller populations, which are then generalized.(Koval et al., 2008, Bell et al., 2011) This is due to the fact that health care is insurance-based and all citizens are not entitled to free health care unlike in the Scandinavian countries.

Other Scandinavian discharge registers have been assessed for validity. In a Norwegian study, Lofthus and co-workers found that there were major discrepancies in registering diagnosis in different Norwegian hospital discharge registers and questioned their reliability.(Lofthus et al., 2005) In contrast, Ludwigsson et al found that the Swedish National Inpatient Register had excellent reliability for diagnosis coding, especially in injury-related hospitalisations with a high reporting rate for external cause of injury.(Ludvigsson et al., 2011) The Swedish findings are similar to those of a recent review assessing the reliability of the Finnish NHDR.(Sund, 2012) The Danish National Patient Register in Denmark was established in 1977, and is less thoroughly validated than it's Swedish and Finnish counterparts.(Lynge et al., 2011)



## 6.2 Surgical treatment of clavicle fractures

Based on our nationwide analysis between 1987 and 2010, a marked increase in the rate of surgically treated CFs was observed; the overall rate of surgical treatment increased over ninefold. The increase in surgical treatment in men was swift for the first third of the study period, after which the incidence remained stable for some years and started another increase in the mid 2000s. In women the changes have been more moderate.

When the results were stratified by age and sex, it was clear that the strongest increase in surgical activity has happened in men less than 60 years of age. In women, the increase in incidence of surgical treatment has remained quite constant in all age groups.

The reasons for the increase in surgical treatment rates of CFs are unknown. According to the present results, the surgically treated patients with CFs are mostly young or middle-aged and therefore an aging population cannot explain the increase in surgical treatment. It is possible that Finnish middle-aged people are nowadays more active and therefore more injury-prone during their leisure time. However, there is no scientific evidence supporting this assumption.

It is most likely that an increasing proportion of CFs are treated operatively: however, the claim cannot be verified by this study due to the study setting. A clear limitation of the present study is that, based solely on the data in NHDR, the overall incidence rate of CFs cannot be assessed as most conservatively treated CFs are treated in emergency rooms, or outside hospitals in health care centres or private clinics on an outpatient basis, thus falling outside the NHDR. The scientific literature seems to be quite uniform that different types (e.g. lateral, middle-third and medial) of CFs should be handled as separate entities. Therefore it is surprising that the International Classification of Diseases recognizes only one diagnosis code for CF. (Lääkintöhallitus, 1986, Nienstedt, 1995) This leads to an obvious limitation of the present study: it is not possible to differentiate the anatomical sites or fracture patterns of the CFs included in this study.

There are no large population based studies assessing the distribution of conservative and operative treatment of CFs. Even though the more recent studies have not been able to replicate the near perfect fracture union rates of Neer and Rowe, it is possible to conclude that nearly all clavicle fracture types can be treated without a surgical intervention. (Neer, 1968, Rowe, 1968, Nordqvist et al., 1993, Nordqvist et al., 1998, Robinson, 1998, Nowak et al., 2000) Therefore, a clear in-

crease in surgical activity over conservative treatment would require strong evidence. Completely displaced CFs of the shaft have been identified as resulting in a greater rate of non-union.(Zlowodzki et al., 2005) One aspect in being able to evaluate interventions in orthopaedic research is the use of standardised functional scores. DASH (Disabilities of Arm, Shoulder and Hand) is an example of a standardised and validated measure of functional outcome. DASH is scored from 0 to 100. (Hudak et al., 1996) A higher score indicates greater disability. When Constant Shoulder Score is used, the functional measures of the injured side are compared to the unaffected side.(Constant and Murley, 1987) Greater difference between the affected and unaffected side indicates greater disability.

As seen on Table 1, there were serious methodological issues in a trial by Smekal et al (2009) but the three other studies (COTS 2007, Virtanen 2012 and Robinson 2013) comparing plating to conservative treatment are of high quality. In a multicentre randomized controlled trial by the Canadian Orthopaedic Trauma Society, DASH scores were better in all time points but the difference was about 10 at one year.(COTS, 2007) Virtanen and co-workers found that at one year DASH scores were better (<5) than those treated without surgery, but the difference was not statistically significant.(Virtanen et al., 2012) Robinson et al reported similar findings; surgical treatment yielded better DASH scores (<5) at one year and the results were statistically significant.(Robinson et al., 2013) All three trials included only completely displaced CFs with mean age of patients from 32 to 37 years. Based on the results of these trials, it seems that there is some evidence that surgical treatment by plate fixation produces better results than conservative treatment in the treatment of completely displaced CFs, but the differences are still minor as the functional scores are not drastically different. A recent Cochrane review and meta-analysis found no clear evidence supporting neither operative nor conservative treatment of fractures of the middle third of the clavicle.(Lenza et al., 2013) Also, from an economical perspective, we need to consider if the difference is enough to justify an operative intervention that Robinson and colleagues found to be four times more expensive.(Robinson et al., 2013) Further studies of similar settings and a pooled meta-analysis of these studies will probably result in a better understanding. (Handoll and Lenza, 2013)

The change in the rate of surgical treatment of CFs observed in this study is marked and most probably cannot be explained by change in overall incidence of CFs. It may be that the new hardware, especially locking plates which allow better grip in comminuted bone, have encouraged surgeons to undertake increased surgical

activity. It may also be hypothesized that rigorous marketing of the new hardware has played a role. Finally, as the anatomically different CFs are considered as individual entities, it would be preferable that in future versions of ICD these different fractures (lateral, medial and shaft) be recognized as separate entities.

### 6.3 Surgical treatment of proximal humeral fractures

The rate of surgical treatment of PHFs nearly quadrupled in Finland between 1987 and 2009. At the same time the incidence of hospitalisation due to PHF only doubled. The change is important, as PHF is one of the most common osteoporotic fractures. Two separate analyses were made, between 1987 and 2009 and 1998 and 2009 respectively. The 10,560 surgically treated patients were predominantly women (n=7,008, 66%) and the increase in surgical treatment was steeper in women. Between 1987 and 2009 open reduction and osteosynthesis was the most common surgical procedure.

Between 1998 and 2009 a second analysis was made to further evaluate the distribution of different surgical procedures (n=7,075). Open reduction and osteosynthesis by plate fixation was the most common procedure with an increasing rate throughout the period. The change was especially marked in women in the older age groups. The increase of surgical treatment by plating in women over 70 years was somewhat unexpected, as the rates of PHFs in Finland in older women have remained steady since the 1990s.(Kannus et al., 2009) The increased rates of surgical treatment may be a result of a decreased rate of conservative treatment, as reported by Bell et al in the United States.(Bell et al., 2011) The trend towards an increased amount of surgical treatment is surprising as there is a clear lack of evidence on the superiority of surgical treatment over nonsurgical treatment of PHFs.(Handoll et al., 2012) As fracture patterns are not recorded on the NHDR, it is not possible to report, according to the present study, whether the surgically treated PHFs have had a certain morphology, for instance if the rate of displaced fractures has increased thus explaining the increase in surgical activity. It is possible and even plausible that as osteoporotic fractures are more complex, they have been the targets of increased surgical activity, especially plating.

Surprisingly little research has been done comparing different surgical approaches in a high-quality setting. A recent Cochrane meta-analysis identified only three trials comparing different surgical procedures in the treatment of PHFs.(Handoll et al.,

2012) Obviously it is impossible to draw conclusions on the basis of three trials that compared different interventions.

In two separate studies by Olerud et al, conservative treatment was compared with plate fixation and arthroplasty, respectively.(Olerud et al., 2011a, Olerud et al., 2011b) Although many relevant and validated outcome measures were used, they defined no actual primary outcome measures in their two studies.(Olerud et al., 2011a, Olerud et al., 2011b) After a two-year follow-up there was a difference between conservatively treated and plate fixated groups favouring surgical treatment, but the difference in DASH-score between the groups was under 10, which is commonly considered a limit for clinical significance.(Olerud et al., 2011a) Also, in the other study by Olerud and co-workers, surgically treated (hemiarthroplasty) patients had slightly better (<10) DASH-scores than those that were treated conservatively.(Olerud et al., 2011b) Both studies lacked sample size calculations, and were found to be underpowered, probably partly explaining why differences between interventions were not statistically significant. Fjalestad and colleagues compared conservative treatment to plate fixation, and found Constant scores after 12 months of follow-up to be equal between the groups.(Fjalestad et al., 2012) After extending the follow-up to two years, Fjalestad and co-workers still found no differences between the operative and conservative groups.(Fjalestad and Hole, 2014) Boons et al compared conservative treatment to hemiarthroplasty and found no differences between the groups when Constant score was used to assess function. (Boons et al., 2012)

All of the above-mentioned four studies were done on patients older than 55 years of age, with either three- or four-part displaced PHFs. Table 2.

In light of the scarce evidence, the marked increase in plating that occurred after the beginning of the 2000s is noteworthy. The rate of plating more than doubled without any clear evidence of superiority compared to other surgical interventions or even conservative treatment. The finding may imply that other factors have affected decisions in the treatment choices of PHFs. Orthopaedic surgeons may adopt new fixation systems without conclusive evidence or knowledge of whether these fractures need to be treated surgically at all. It may be that thanks to the new hardware, especially locking plates which allow better grip in comminuted bone, surgeons have spurred into increased surgical activity. It may also be hypothesized that rigorous marketing of the new hardware has played a role. Especially in the older women, we would have expected to see a stronger rise in the incidence rate of arthroplasty but the increase has been upstaged by plating. Unfortunately, based

on the present study, it is not possible to assess whether the increase in the rate of surgery is a result of increased tendency to treat PHFs operatively as a part of patients with PHFs are treated outside hospitals and therefore outside the catchment of the NHDR. Based on the present study, it is not possible to assess the true incidence of PHFs. However, a recent study in Finland assessing the incidence of PHFs in patients 50 years and older reported of a stabilising incidence of PHFs.(Kannus et al., 2009) As the present study witnessed a steady increase in the rate of surgical activity in patients over 50 years of age, this might suggest an increase in the overall surgical activity in the treatment of PHFs.

There seems to be a trend towards of increased surgical activity in the treatment of PHFs in Finland with plating and to a lesser degree arthroplasty being the only approaches gaining popularity. Based on the available evidence, most PHFs can still be treated without surgery. More high-quality intervention studies are needed to indicate the superiority of plating over other surgical procedures in the treatment of PHFs, especially in the older age groups.

## 6.4 Surgical treatment of humeral shaft fractures

Two analyses were made to assess the change in the rate and trends in the surgical treatment of HSFs between 1987 and 2009, and 1997 and 2009 respectively. The present study shows that between 1987 and 2009 there was a steady rise in the rate of surgical treatment of HSFs. More than two-thirds (n=3,179, 70%) of the surgically treated patients received open surgery, closed treatment followed (n=1,268, 28%) and external fixation was quite rare (n=71, 2%). The mean age of patients who received surgical treatment increased between 1987 and 2009.

The steepest rise in the rate of surgical treatment of HSFs was seen during the first half of the study period: from the late 1990s, the overall rate of surgical treatment has remained steady. The reason for the increased surgical activity is unknown. Unfortunately, the overall rate of HSFs cannot be assessed using the NHDR data alone, as a part of the humeral shaft fractures are treated as outpatient cases, for instance in health care centres. Therefore it is not possible to draw conclusions, whether there has been a similar increase in the overall incidence of HSFs. Moreover, as fracture patterns are not recorded on the NHDR, it is not possible to report, according to the present study, whether the surgically treated HSFs have had a certain morphology, for instance if the rate of high-energy and complex fractures has increased thus

explaining the increase in surgical activity. Large-scale epidemiological studies on the overall fracture incidences for HSFs do not exist, but incidences of PHFs and distal humeral fractures have been studied in Finland: their incidence rates in older age groups have risen steadily during the last decades until about the mid 1990s, after which the incidence rates have remained quite steady.(Kannus et al., 2009, Palvanen et al., 2010) These studies have similar limitations as the present study, with a part of the fractures falling outside the NHDR as they are treated in health care centres. Assuming that the incidence rate of HSFs resembles those of PHFs and distal humeral fractures, we could therefore speculate, whether the greatest increase in surgical activity has coincided with an increase in the overall incidence rates. It is possible that after the increase in surgical treatment rates, the proportion of conservative treatment has diminished. However, there are no studies evaluating the distribution of conservative and operative treatment on a population basis. High-quality intervention studies comparing conservative and operative treatment of HSFs are non-existent, but based on case-series, it is evident that HSFs can be treated without surgical interventions resulting in a good clinical outcome.(Sarmiento et al., 1977, Zagorski et al., 1988, Sarmiento et al., 2000, Koch et al., 2002) Some fracture types may result in worse outcomes, but this is a statement needing further research.(Toivanen et al., 2005, Ekholm et al., 2006b) Certainly there are factors affecting the choice of treatment that are independent of scientific evidence: the experience and education of an individual orthopaedic surgeon, patient beliefs, expectations and compliance. It is also possible that nowadays, older people are more active and physically demanding than before, leading to increased numbers of surgically treated HSFs.

Between 1997 and 2009 the rate of plate fixation increased most in women and in the older age groups (60 years and older). At the same time the rate of intramedullary nailing decreased to one-fourth. External fixation and fracture fixation with pins or absorbable or non-absorbable screws were rare in the surgical treatment of HSFs. Heineman et al published a meta-analysis including 203 patients but did not find differences in functional results between plating and nailing of HSFs.(Heineman et al., 2010) In another systematic review and meta-analysis published a year later by Kurup and co-workers, including 260 patients and comparing intramedullary nailing and plating, no clear differences in the functional results between the two interventions were observed.(Kurup et al., 2011) According to the latter meta-analysis there was a statistically significant difference in shoulder impingement and restriction of movement favouring plating over nailing. However, as described in

Table 3, many of the studies have methodological issues that diminish their use in a meta-analysis. Furthermore, it is disturbing that patients included in the Cochrane meta-analysis were mainly males under 50 years of age, when according to our results most surgically treated patients in Finland were women with a mean age of over 50.

According to the results of the present study, the role of pinning, screw fixation and external fixation is small and has been decreasing steadily. External fixation probably has a role in the treatment of some comminuted fractures especially if associated with extensive soft tissue damage, bacterial infection, or both. (Cole and Wijdicks, 2007)

Based on the NHDR data, it is not possible to separate the operations that have been done for primary treatment of the fracture from those done as a secondary treatment (for instance failure of closed treatment). This is due to the fact that based on our experience, non-union is quite commonly diagnosed with the initial injury diagnosis code instead of the actual code for non-union. Therefore, no straightforward conclusions can be made regarding the choice of primary treatment options (operative vs. conservative) based on the present results.

There are no previous studies evaluating trends in the surgical treatment of HSFs. The available scientific evidence does not warrant the changes in the surgical treatment of HSFs observed in the present study. Further studies are needed to firstly identify fracture types and patterns benefiting from surgical treatment. Secondly, high-quality intervention studies are needed to compare different interventions in the treatment of HSFs. It would also be very interesting to know, on a national level, how many non-unions due to primary conservative treatment need secondary surgical stabilization. There are two published study protocols that will probably add to our knowledge on the choice between conservative and operative treatment of HSFs. (Matsunaga et al., 2013, Mahabier et al., 2014) Mahabier and co-workers describe an observational multicentre trial that will assess differences between conservative and operative treatment. (Mahabier et al., 2014) Interestingly, according to the study protocol, the intervention will be completely left to the treating surgeons discretion. (Mahabier et al., 2014) In a Brazilian RCT protocol, conservative treatment with a functional brace will be compared to plate osteosynthesis. (Matsunaga et al., 2013) Both study protocols are well described, but it will be interesting to see what the eventual study demographics will be as both protocols include all patients 18 years and older, and not focusing on the older age groups. (Matsunaga et al., 2013, Mahabier et al., 2014)

## 6.5 Surgical treatment of distal radius fractures

Between 1998 and 2008 the rate of surgically treated DRFs in Finland more than doubled. Over two-thirds of the surgically treated patients were women and the increase in surgical treatment was more pronounced in women. The total incidence of DRFs cannot be assessed using solely the NHDR data since a portion of DRFs are treated outside hospitals as outpatient cases for instance in health care centres. Additionally, a recent study by Koski and co-workers that compared manually collected fracture data to register data concluded that register data underestimates incidence rates for DRFs. (Koski et al., 2014) It is therefore difficult to estimate how much of the change in the incidence of surgical treatment in Finland is explained by the increase in the incidence of DRFs. There are no recent studies on the trend in the incidence rate of DRF in Finland but in a recently published study in Sweden, the incidence of DRF has decreased in children and in patients older than 65 years. (Wilcke et al., 2013)

In the United States, Chung et al found that closed treatment has decreased mostly at the expense of a rise in open reduction and internal fixation of DRFs. (Chung et al., 2009) In the same study and later affirmed by Koval and co-workers, it was noted that the rate of percutaneous pinning has decreased at the same time as the rates of open reduction and fracture fixation with plates have increased. (Koval et al., 2008, Chung et al., 2009) In a recent study in the Netherlands, Putter and co-workers observed a decrease in the incidence of wrist fractures with a simultaneous increase in the rate of operative treatment in women. (de Putter et al., 2013) In the Dutch study, there was an evident trend in all age groups towards plate fixation in the operative treatment of DRFs. (de Putter et al., 2013) In the present study the shift in the choice of surgical approach was significant; the rate of percutaneous pinning remained quite constant, but the rate of external fixation decreased and the rate of plating increased. A Swedish study recently confirmed the present results: Wilcke and co-workers observed a marked increase in plating at the expense of external fixation and percutaneous pinning. (Wilcke et al., 2013)

Interestingly the increase in surgical treatment of DRFs and plating in Finland was especially visible among women over the age of 60 years. It is possible that as these DRFs are osteoporotic they may be more complex, and thus encouraged an increased surgical activity, such as volar locked plating. It may be that the increased rates of surgical treatment in the older age groups prove to be controversial: Arora and co-workers first published a retrospective analysis to evaluate whether con-



servative and operative treatment yield different results in patients over 70 years of age and found that there was no difference in the functional results: there were no differences in functional scores or pain.(Arora et al., 2009) After the initial findings, the same group designed an RCT with a similar setting to obtain better evidence on the difference between surgical and nonsurgical treatment in the older age groups. In the RCT there were initial differences between surgical treatment (volar plate fixation) and nonoperative treatment groups favouring surgical intervention, but after 12 weeks the difference diminished and after 12 months the DASH-scores were similar; 5.7 vs. 8.0.(Arora et al., 2011)

When generalizing the results of a study, it is important to acknowledge both the inclusion and exclusion criteria of the study. A point worth noting is that in many of the trials listed in Table 4, the included patients are under 50 years of age. It is essential that major changes in policies for treatment of such a common injury as a DRF should be based on the principles of EBM. To justify the change we have observed, at least some RCTs conducted with patients in the older age groups favouring surgical over nonsurgical treatment should exist. Results from studies conducted among under 50-year-old patients should not be generalised to patients older than 65, as it can be argued that bone properties and functional needs differ in different age groups.(Sackett, 1991, Sackett, 2000)

As previously described, if surgical treatment is opted for, the literature concerning surgical treatment of DRFs is all but unanimous on the best choice of surgical approach.(Handoll et al., 2007a, Handoll et al., 2007b, Handoll et al., 2008) During recent years, external fixation has been compared with different types of plate fixation. It seems that, compared to external fixation, volar plating allows for a more swift initial recovery of function than external fixation, but the differences diminish over time.(Egol et al., 2008, Wei et al., 2009, Wilcke et al., 2011) Furthermore, as the follow-up times of recent high-quality studies are limited, the need for fixation material removal has been inadequately assessed.

Certainly, there is no evidence that any of the existing methods of surgical treatment would be universally better than the others in the treatment of DRFs. It would be desirable that when drastic changes in the chosen treatment for a certain injury or illness occur, the changes would be based on the best evidence available. When two or more surgical interventions are compared, the study setting should be RCT.(Sackett, 1991, Guyatt et al., 1993, Sackett, 2000) It is surprising that a fracture that encompasses almost 20% of all adult fractures has been so scarcely studied, at least on a high-quality basis. The economic impact of DRFs should be

reflected as a corresponding input in high-quality trauma research, as DRFs pose a considerable strain on health-care systems globally.(de Putter et al., 2012) Based on the available literature, the observed change in the present study has happened without proper scientific justification. It may be that the new hardware, especially volar locking plates, has encouraged surgeons to favour operative treatment. It may also be hypothesized that rigorous marketing of the new hardware has played a role.

## 7. SUMMARY AND CONCLUSIONS

In the first original article of this thesis, the reliability of the NHDR was evaluated comparing data on the NHDR to the original medical records and radiographs in patient samples from three individual hospitals. In the following four original articles, trends and rates of surgical treatment of common upper limb fractures were assessed. The articles were based on data obtained from the Finnish National Hospital Discharge Register (NHDR). The four studies on surgical treatment of upper limb fracture rates were purely descriptive.

The first article, which assessed the reliability of the NHDR, consisted of a sample from three Finnish hospitals with all pertrochanteric hip fractures that were hospitalised in three study hospitals between 2008 and 2010. The accuracy of diagnosis, and both accuracy and coverage of external cause of injury and procedural coding was evaluated. The data on surgical treatment of different upper limb fractures was evaluated between 1987 and 2010 (clavicle fractures), 1987 and 2009 (proximal and diaphyseal humerus fractures), and 1998 and 2008 (distal radius fractures). The data on surgical treatment of distal radius and proximal humeral fractures encompassed all surgically treated patients aged 20 years and older. The data on humeral shaft and clavicle fracture surgery consisted of all patients aged 18 and older. The number of surgically treated individual fractures was assessed from the NHDR, after which the actual population based rates were calculated using the mid-population rates obtained from the Official Statistics of Finland.

According to the reliability assessment of the NHDR, this study concludes that it can be used with confidence in epidemiological research, as the accuracy of diagnosis was excellent, 96% (95% CI: 94 to 97%). The procedural coding was

also extensively placed with coverage of 98% (95% CI: 96 to 98%) and accuracy of 88% (95% CI: 85 to 90%). External cause of injury had an excellent coverage, 95% (95% CI: 94 to 97%) and an accuracy of 90% (95% CI: 87 to 92%).

Between 1987 and 2010 the incidence rate of clavicle fracture surgery increased ninefold. The increase has a magnitude warranting the assumption that the proportion of patients treated surgically has increased without high quality of evidence. As conservative and surgical treatment yield similar functional results, the observed change may prove to be controversial. Between 1987 and 2009 the incidence rate of proximal humeral surgery nearly quadrupled and there was an especially steep rise in the incidence rates in women 60 years and older. The increase of plating over other surgical approaches in the older age groups in women was also noteworthy and is without sound scientific base. There was a clear rise in the incidence rate of surgically treated humeral shaft fractures between 1987 and 2009 with a concurrent increase in plating over intramedullary nailing. The rate of surgical treatment of distal radius fractures increased markedly between 1998 and 2008 and there was a significant shift from external fixation to plating. The scientific evidence does not support the changes that have occurred.

Concluding the results of this thesis, the NHDR was found to be a reliable tool in assessing trends in surgical treatment of different upper limb fractures. Surgical activity of common upper limb fractures has increased significantly over recent years. Severe discrepancies between scientific evidence and observed trends in the surgical treatment of these upper limb fractures were found. A marked change in the choice of surgical approach has emerged as plate fixation has increased diminishing the proportion of other procedures. Especially with proximal humeral fractures and distal radius fractures, the rate of older age groups receiving surgical treatment has increased considerably. There is no evidence supporting the increasing rate of surgical treatment of these fractures in the older age groups as similar functional results can be attained with conservative treatment. In the future, it is imperative that changes in treatment policies for common injuries are based on high-quality research.

Recalling the five earlier mentioned aims of the present study, the conclusions of this thesis study are as follows:

- 1) The Finnish National Hospital Discharge Register was found to be a reliable source of information in pertrochanteric hip fractures in respect to the validity of diagnosis, external cause of injury and procedural coding.

- 2) The rate of operatively treated clavicle fractures in Finnish adults between 1987 and 2010 increased over ninefold. The strongest changes have occurred in men under 60 years of age. The increase was moderate in women. There is a clear lack of evidence on the choice of treatment for clavicle fractures.
- 3) The rate of operatively treated proximal humeral fractures in Finnish adults nearly quadrupled in Finland between 1987 and 2009. The change was most profound in the older female age groups of 60 years and older. Plate fixation has gained popularity over other surgical techniques during recent years diminishing the role of other surgical techniques. There is no sound scientific evidence supporting the change observed in the present study.
- 4) The rate of operatively treated humeral shaft fractures in Finnish adults increased between 1987 and 2009. The fastest rate of increase occurred in the 1990s. A shift towards plate fixation in the operative treatment of humeral shaft fractures has occurred in recent years with the proportion of nail fixation continuously decreasing.
- 5) The rate of operatively treated distal radius fractures over doubled in Finnish adults between 1998 and 2008. The change was especially strong in female patients 60 years of age or older. Plate fixation has gained popularity without clear evidence on superiority over other surgical techniques.

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## LIST OF ORIGINAL PUBLICATIONS

# **Pertrochanteric fracture of the femur in the Finnish National Hospital Discharge Register: validity of procedural coding, external cause for injury and diagnosis**

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## **Abstract**

### **Background**

Hospital discharge data is routinely collected in Finland and it is an invaluable source of information when assessing injury epidemiology as well as treatment. The database can be used when planning injury prevention and redirecting resources of the health care system. Most recently our hospital discharge register has been used to assess the incidence of surgical treatment of common fractures. This study was aimed to evaluate the coverage and accuracy of the Finnish National Hospital Discharge Register (NHDR) focusing on hip fractures. In other words, patients hospitalized for a pertrochanteric hip fracture were used to assess the validity of the NHDR.

### **Methods**

The validity of the NHDR was assessed by comparing the data in hospital discharge register with the original patient records and radiographs in three separate hospitals; Tampere University Hospital, Hatanpää City Hospital of Tampere, and the Central Hospital of Kanta-Häme. The study analysis included 741 patients hospitalized due to pertrochanteric hip fracture between 1<sup>st</sup> January 2008 and 31<sup>st</sup> December 2010.

### **Results**

The diagnosis was correctly placed on 96% (95% CI: 94 to 97%) of the 741 patients when radiographs were used as golden standard. The procedural coding had coverage of 98% (95% CI: 96 to 98%) and an accuracy of 88% (95% CI: 85 to 90%). The coverage of the external cause for injury was found to be 95% (95% CI: 94 to 97%) with an accuracy of 90% (95% CI: 87 to 92%).

### **Conclusions**

Our results show that the validity of the Finnish NHDR is excellent as determined by accuracy of diagnosis and both accuracy and coverage of procedural coding and external cause for injury. The database can be used to assess injury epidemiology and changes in surgical treatment protocols.

## **Background**

The National Hospital Discharge Register (NHDR) is statutory, computer-based register in Finland including all hospitalization data in the country since 1967. Currently it contains data on almost 70 variables including a personal identification number, age, sex and domicile of the subject, place and cause of injury, duration of hospital stay, diagnoses, and procedures performed during the hospital stay.

The Finnish NHDR has been valuable and widely used in epidemiological studies on sports and other injuries, and more recently when describing incidence of surgical treatment [1-5]. A few studies have investigated the validity, i.e. coverage and accuracy of the register with

regard to diagnosis [6-9]. In a recent review, Sund compiled all studies concerning the quality of the Finnish NHDR and found it to be a valid source of information [10].

We previously investigated the coverage and accuracy of diagnosis in the Finnish NHDR and found that concerning the diagnosis of the cruciate ligament injury of the knee the NHDR had coverage of 92% and an accuracy of 89% [8]. Other previous studies observed that the accuracy of pelvic and hip fracture diagnoses ranged from 95% to 98% [6,7].

As noted above, in addition to the diagnoses placed during the hospitalization, the Finnish NHDR contains information on procedural coding, external cause for injury and type of injury or accident. However, when conducting register-based epidemiological studies on injuries it is of utmost importance that coverage and accuracy of these variables are well assessed.

Currently, studies on the validity of procedural coding and external cause for injury are scarce[6], and to our knowledge no previous study has focused on assessing the validity of procedural coding after implementation of the Nomesco (Nordic Medico-Statistical Committee) procedure classification in 1996.

In this study we assessed the validity of the Finnish NHDR in relation to the diagnosis, procedural coding and external cause for one specific injury (perthrochanteric hip fracture) by determining the coverage and accuracy of these parameters in three Finnish hospitals. Pertochochanteric hip fracture was considered suitable for our purposes because it is a common, surgically treated injury.

## Methods

The study sample included three level one to three trauma hospitals in Finland: Tampere University Hospital (level I), Hatanpää City Hospital of Tampere (level III), and the Central Hospital of Kanta-Häme (level II). Patients 18 years or older were included. In Finland, register-based studies do not require the approval of ethics committee by legislation. However, all register studies that utilize any confidential medical information such as patient charts and radiographs, require an approval of the corresponding institution or hospital. These permissions were obtained from all hospitals that participated our study.

The sample was obtained by selecting from the NHDR all patients with a diagnosis of perthrochanteric hip fracture admitted alive to any of the three study hospitals between 1<sup>st</sup> of January 2008 and 31<sup>st</sup> of December 2010. All re-hospitalizations due to either rehabilitation, medical or surgical complications were excluded based on the original medical records and thus only primary hospitalizations after the initial injury were included into the study. We used the International Classification of Diseases 10<sup>th</sup> edition (ICD-10) code S72.1 [11]. After 1996 all procedural coding in Finland has been done according to a Finnish version of Nomesco procedure classification and so Nomesco procedural coding was used in this study. The main outcome variable in the study was assessed by comparison of data from the NHDR to the original patient charts and x-ray archives.

As noted above, the Finnish NHDR is a mandatory national register for all of our hospitals encompassing private, public, and other institutions. The NHDR is collected and maintained by the National Institute for Health and Welfare, Helsinki, Finland.

After the sample was collected, all selected cases were evaluated by going through the patient chart, and x-rays taken both pre- and post-operatively. Accuracy of the diagnosis was assessed by examining pre-operative x-rays and determining the type of the hip fracture (fracture of the femoral neck, pertrochanteric fracture or subtrochanteric fracture) and then comparing the result to the type of the fracture (diagnosis) recorded in the hospital register. Coverage of the procedure coding was determined by reading through the medical records and radiographs to find the patients who had undergone surgery. It was then determined how many of these procedures were recorded into the NHDR. Accuracy (dichotomy right/wrong) of the procedural coding was assessed by examining the post-operative x-rays and determining the type of fixation used and then comparing to the type of fixation (procedure code) in the NHDR.

Coverage of the external cause for injury was examined by comparing the number of patients who were injured (and had a diagnosis of a pertrochanteric fracture) to the number of patients who had an external cause for injury recorded on the hospital discharge register. Accuracy of the external cause for injury was assessed by going through the medical records and determining the mechanism of injury (for example a fall) and then comparing it to the external cause for injury recorded on the hospital register.

All of the results were expressed as a percentage with 95% confidence interval (CI).

Two experienced physicians (T.T.H. and V.M.M.) examined the patient charts and radiological findings separately. In case of a disagreement, consensus was reached. If there was an unresolved radiological finding, the result was resolved by the expert opinion of the radiologist who had originally evaluated the radiological images.

## Results

According to the sample taken from the above noted three individual hospitals a total of 1,112 hospitalizations with a primary or secondary diagnosis of pertrochanteric hip fracture were identified during the study period. As only the primary hospitalizations were included into the study sample comprised 741 cases. Majority of patients were female (n = 509, 69%) The mean age of patients was 81 years. Men were younger (mean age 76 years) than their female counterparts (mean age 83 years).

Most (n = 729, 98%) of the 741 patients with a pertrochanteric hip fracture were operated on. Of the non-surgically treated patients (n = 12, 2%), two refused surgical treatment and 10 died prior surgery.

A pertrochanteric hip fracture was coded as diagnosis in all of the 741 (100%) patients (inclusion criterion). According to the radiological assessment, the NHDR diagnosis was accurate on 709 of the 741 patients resulting in an accuracy of the diagnosis of 96% (95% CI: 94 to 97%). The remaining 32 fractures were falsely registered: 24 (75%) of these were actually fractures of the neck of the femur, 5 (16%) were subtrochanteric hip fractures and 3 (9%) were fractures of the shaft of femur.

A procedural code was found on 711 of the 729 patients of who had undergone a surgical procedure. The coverage of the procedural coding was therefore 98% (95% CI: 96 to 98%). The reasons for not registering a surgical procedure into the NHDR were not uniform and

therefore we were unable to further categorize these 18 cases. Most commonly the reason was that the patient was transferred from the surgical ward into another ward because of a medical reason (for instance after suffering heart failure or infection) and the surgical procedure was later performed while being on a non-surgical ward.

Of the 711 patients with a procedural code recorded on the NHDR, 10 died soon after the surgery and did not have x-rays taken after the operation. Therefore it was not possible to validate these cases. Of the remaining 701 patients 616 had a correct code. The accuracy of the procedural coding was therefore 88% (95% CI: 85 to 90%). The remaining 85 procedures were erroneously registered into the NHDR. Internal fixation of fracture of neck of femur with nail or screw (NFJ50) was wrongly used in 1 case. Internal fixation of fracture of upper part of femur with sliding hip screw (NFJ52) was wrongly used in 24 cases. Internal fixation of fracture of upper part of femur with trochanteric nail (NFJ54) was wrongly used in 57 cases. Internal fixation of fracture of other parts of femur (NFJ62) was wrongly used in 3 cases. The most common errors were to mix procedures NFJ52 and NFJ54.

An external cause for injury was registered on 707 of the 741 patients resulting in coverage of 95% (95% CI: 94 to 97%). Of these 707 patients with an external reason for injury 635 had a correct code registered on the NHDR resulting in an accuracy of 90% (95% CI: 87 to 92%).

## Discussion

Data collection in Finnish hospitals is statutory and therefore performed routinely for all hospital admissions. The collected data should be readily usable for epidemiological research and in fact numerous reports have been published utilizing this data. However, no previous research has been made in attempt to validate the coverage and accuracy of the procedural coding in the NHDR, although in general the coverage and accuracy of diagnosis in the Finnish NHDR have been found to be good [10].

In this study we assessed the validity of diagnosis, procedural coding and external cause for injury in hospitalizations after a pertrochanteric fracture of the femur. Accuracy of diagnosis and both coverage and accuracy of procedural coding and external cause for injury were found to be excellent.

Petrochanteric hip fracture was selected because practically all cases undergo surgery and therefore result in hospitalizations with procedure coding registered into the NHDR. Furthermore, according to the recommendations of use of the ICD-10, whenever injury coding (S00-T98) is used it is obligatory to use the external causes for morbidity and mortality (V01-Y98) to try and classify the environmental events and circumstances leading to the injury [11]. Thus, in our study during one hospitalization period it was possible to assess information of the use of these three individual variables.

Petrochanteric hip fracture is an injury that requires swift treatment [12]. It is common practice in Finland that surgeons dictate the course of procedures including procedural coding after the operation. It is possible that work done during uncomfortable hours increases the inaccuracy of procedural coding. There are no studies comparing the validity of procedural coding in the NHDR between elective and acute surgical procedures. Petrochanteric hip fracture can be surgically treated by using various surgical approaches, which also increases

the risk for inaccuracy. In this regard our results of 88% accuracy of procedural coding can be considered excellent.

In our previous study on validity of anterior cruciate ligament injury diagnosis, we found the diagnosis coding to have both good coverage (92%) and accuracy (89%) [8]. In addition, Luthje and coworkers took a sample from the NHDR in 1988 by selecting all patients (n = 1,212) hospitalized due to pelvic fracture [7]. They then validated the diagnosis by selecting every tenth case randomly and reviewing the case medical records against the data on the NHDR. Accuracy of diagnosis was found to be very high, 97%.

Our current result on accuracy of diagnosis of 96% is well in line with our own previous results with anterior cruciate ligament injury (92%) and with the findings of Luthje and coworkers (97%). The true coverage of the diagnosis could not be assessed in our present study, as the diagnosis code S72.1 was a selection criterion for the study population. Assessment of coverage of diagnosis would have required a different study setting and therefore our principal aim was to assess the coverage and accuracy of procedural coding.

We are not aware of any recent study trying to assess accuracy of diagnosis and both accuracy and coverage of procedural coding and external cause for injury in the Finnish or any other NHDR. In a Norwegian study, Loftus and coworkers found that there were major variations in registering diagnosis in different hospital discharge registers and questioned their reliability [13]. In a recent review, Ludvigsson et al. found that the Swedish National Inpatient Register had excellent injury diagnosis coding with a high reporting rate for external cause for injury [14]. In Finland Keskimäki and Aro took a random sample of 2,285 cases from the Finnish NHDR including all different reasons for hospitalizations in the year 1986 and compared this data to the individual medical records. The diagnosis was found to be accurate in 95% of cases but procedural coding was quite inaccurate (70-78%). Coding for external cause for injury was also poorly placed (64%). It has to be remembered, however, that the study was done in 1986 and the register used the ICD-8. The development of the NHDR, introduction of the ICD-10 coding system and better schooling in their use are likely to explain the major differences to our current results.

Although orthopedic surgeons may concentrate more on outcomes of surgical procedures, the validity of the NHDR could be increased further by personal feedback and education in using the NHDR. Thus, we suggest that more resources should be put into education and proper use of procedural coding including surgeons in training. This will help in assessing the future trends in common musculoskeletal injuries and their treatment.

## **Conclusions**

We found that the accuracy of diagnosis and both accuracy and coverage of procedural coding and external cause for injury in the Finnish National Hospital Discharge Register are excellent. The register can be used as a reliable source of information especially in epidemiological studies of injuries.

## **Competing interests**

The authors declare that they have no competing interests.



## Authors' contributions

TH and VM contributed in all stages of the study. PK and HP contributed in study design, data interpretation and writing the final manuscript. All authors read and approved the final manuscript.

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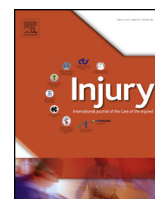
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## Surgical treatment of clavicular fractures in Finland – A register based study between 1987 and 2010



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### ABSTRACT

**Background:** Clavicle fractures are among the most common upper extremity injuries. Traditionally most clavicle fractures have been treated non-surgically, but during recent decades the surgical treatment of clavicle fractures has increased. The purpose of this study was to assess the numbers and trends of surgically treated clavicle fractures in Finland between 1987 and 2010.

**Methods:** The study covered the entire adult (>18 years) population of Finland over the study period. Data on surgically treated clavicle fractures was collected from the Finnish National Hospital Discharge Register. We assessed the number and incidence of surgically treated clavicle fractures annually.

**Results:** A total of 7073 surgically treated clavicle fractures were identified in the register over the study period. Three-fourths of the surgically treated patients were men and one-fourth was women. The incidence of surgical treatment increased nearly ninefold from 1.3 per 100,000 person years in 1987 to 10.8 per 100,000 person years in 2010. The increase in the rate of surgical treatment was especially notable in men.

**Conclusions:** A striking increase in incidence of surgically treated clavicle fractures was seen from 1987 to 2010. Although the actual incidence of clavicle fractures is not known, we assume that the proportion of patients receiving surgical treatment has increased markedly without high-quality evidence. Since recent reports have suggested similar functional results between operative and conservative treatment critical evaluation of the treatment policy of clavicle fractures is warranted.

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### Introduction

Fractures of the clavicle are common injuries and typically fall-related. Previous epidemiological studies have estimated that clavicle fractures encompass up to 4% of all fractures [1,2]. However, these estimates are based on small study samples, and the authors are not aware of any national population-based studies on the true incidence of clavicle fractures.

Clavicle fractures are common in young male individuals, but the incidence of the injury increases in both genders with age [3]. Traditionally clavicle fractures are divided into three groups

according to the anatomy of the clavicle [4]. The majority of clavicle fractures are type I fractures in the middle third of the bone. Group II fractures are in the lateral or distal third and group III fractures in the medial or proximal third of the bone.

Most clavicle fractures regardless of the fracture site are treated non-surgically, usually by primary immobilization with a sling or figure-of-eight – type of bandage and progressive mobilization. According to a recent review indications for primary surgical treatment of clavicle fractures include open fracture, damage to neural or vascular tissues, fractures that threaten the skin, multiple trauma and floating shoulder. Relative indications for primary surgical treatment may include the treatment of a young, active patient with considerable shortening of the fractured bone and displacement of the fracture. A number of different surgical approaches have been described including fixation with screws, pins, wires or plates and external fixation.

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Bone grafting has also been used, especially in fractures with non-union [5].

Traditionally most of the middle-shaft clavicle fractures have been treated non-surgically and the literature describes that conservative treatment gives good results [6,7]. More recent studies have, however identified types of fractures that are at risk for an increased non-union rate and maybe benefit from primary surgical treatment [8–10]. In a multicentre trial, Canadian Orthopaedic society had 132 patients with displaced mid-shaft fractures randomized to either non-surgical treatment or primary plate fixation. Surgical treatment was found to be significantly superior to non-surgical treatment according to the functional tests used and the rate of mal-union was significantly lower on the surgically treated group. The difference between the groups as assessed by Constant and DASH scores was approximately 10 points [10]. Thus, these findings have made the choice between surgical and non-surgical treatment has become difficult and partly controversial. Displaced group II (lateral-end) fractures have been described to have an even higher rate of non-union compared to the more common group I (mid-shaft) fractures [11,12]. Although this assumption is not well documented in the literature, it is likely that most orthopaedic surgeons agree with it.

In general, it seems that surgical treatment of clavicle fractures has gained increasing popularity. However, the literature is scarce concerning prospective, randomized clinical trials on treatment of clavicle fractures and thus strong treatment recommendations are difficult to give [13,14].

To the best of our knowledge, no population-based studies on the incidence of the surgical treatment of clavicle fractures have been made. In our previous studies of other upper limb fractures, we found that after the introduction of locking plates in Finland, surgical treatment of these injuries gained popularity [15–17]. We thus hypothesized that surgical treatment of clavicle fractures has also increased during the last two decades. For this purpose we analyzed all surgically treated clavicle fractures in Finland between 1987 and 2010. We also report the demographics of the patients and the type (inpatient vs. outpatient) and duration of hospital stay.

## Materials and methods

Patient data was collected from the Finnish National Hospital Discharge Register (NHDR) between 1st of January 1987 and 31st of December 2010. Only adults 18-years-old or older were

included in the study. The Finnish NHDR was founded in 1967 and provides a reliable database for epidemiologic studies of injuries with excellent coverage and accuracy [18–20]. The database includes information on all hospitalizations, and it includes variables such as age, sex, domicile of the subject, duration of hospital stay, diagnoses and procedures performed during the hospitalization. The data collected for the NHDR is mandatory for all health care institutions in Finland including private, public and military hospitals.

The main outcome variable for this study was the number of patients undergoing surgical treatment of clavicle fracture. Patients were included in the study if either primary or secondary diagnosis was clavicle fracture (ICD-9 codes 8100A, 8101A or 9052A in 1987–1995, and ICD-10 code S42.0 in 1996–2010). Procedures were also registered according to ICD-9-coding between 1987 and 1997 and ICD-10 coding from 1998 to 2010. The procedural code during the ICD-9 coding was 9128 (open reduction and osteosynthesis) and during the ICD-10 coding NBJ53 (open reduction of clavicle fracture) and NBJ92 (other fracture surgery of clavicle).

For the purpose of analysing the trend of all surgically treated clavicle fractures from 1987 to 2010, ICD-10 procedures NBJ53 and NBJ92 were pooled for the analysis.

To calculate the incidence ratios of surgically treated clavicle fractures, the annual mid-population of Finland was obtained from the Official Statistics of Finland, a statutory electronic population register of the country. The rates of surgically treated clavicle fractures (per 100,000 persons) were based on the entire adult (18-year-old and older) population of Finland rather than sample or cohort -based estimates and thus, in full agreement with our previous studies [15–17], 95% confidence intervals were not calculated. Statistical analysis was performed using PASW 19.0<sup>®</sup>.

## Results

A total of 20,486 hospitalizations with a diagnosis of clavicle fracture were registered in the Finnish NHDR during the 24-year study period. The number of hospitalized patients was 325 in 1987 and 1163 in 2010. The incidence of hospitalization following clavicle fracture increased from 8.6 per 100,000 person-years in 1987 to 27.2 per 100,000 person-years in 2010. The incidence of hospitalization in men was 10.2 in 1987 and 38.5 in 2010, both per 100,000 person-years. The corresponding figures in women were 7.0 in 1987 and 16.5 in 2010.

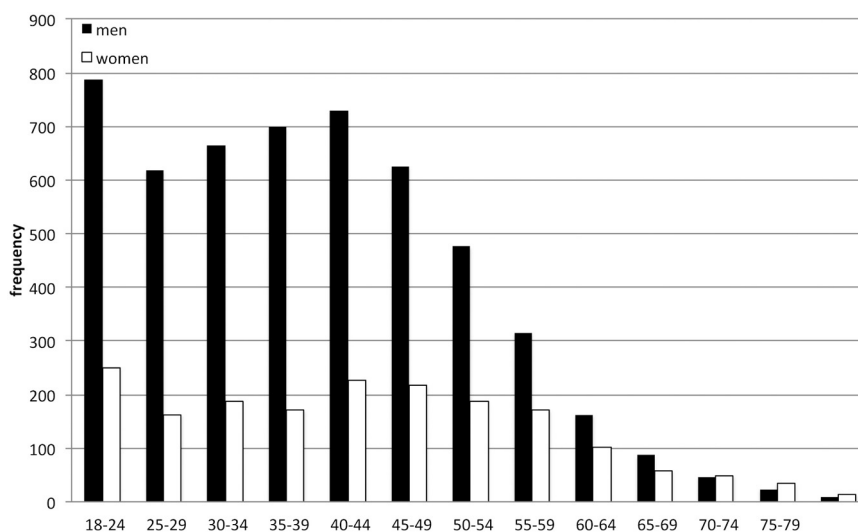


Fig. 1. Age distribution of the surgically treated men and women with clavicle fracture.

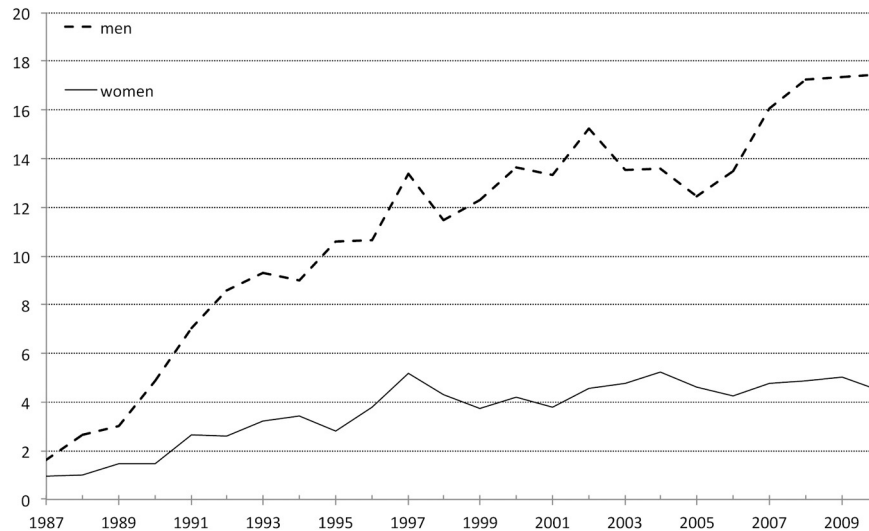


Fig. 2. Incidence of surgically treated clavicle fractures in Finnish adults per 100,000 person-years between 1987 and 2010.

During the study period, altogether 7073 clavicle fractures were operated and registered into the NHDR. The number of surgically treated clavicle fractures increased from 48 in 1987 to 462 on 2010. The total number of surgically treated clavicle fractures was 5243 (74%) for men and 1830 (26%) for women. The mean age for the surgically treated men was 39.0 (SD 13) years while the mean age for surgically treated women was 42.9 (SD 15) years. The age distribution curve of the surgically treated patients is shown in Fig. 1.

The incidence for surgical treatment of clavicle fractures was 1.3 per 100,000 person years ( $n = 48$ ) in 1987 and 10.8 ( $n = 462$ ) in 2010. In men the incidence of surgical treatment increased from 1.6 ( $n = 29$ ) in 1987 to 17.5 ( $n = 363$ ) in 2010. The corresponding figures for women were 1.0 ( $n = 19$ ) in 1987 and 4.5 ( $n = 99$ ) in 2010 (Fig. 2). Thus, the steepest rises in incidence of surgical treatment were seen in men; the increase was notable in all age groups under 60 years of age (Fig. 3). In women the overall and age-specific changes in the incidence of surgical treatment were more moderate (Fig. 4).

As the recording of all surgical procedures in the NHDR is mandatory in Finland, an analysis based on the operating unit and type of hospital stay was also made. Hospital stay type was

categorized either as inpatient or outpatient. The hospitals were categorized as public or private, and the analysis was possible from 1997 (type of hospital stay was not recorded before 1997). 5,359 surgical procedures were included in the analysis.

Most of the surgical procedures ( $n = 4760$ , 89%) were made in public and the remaining ( $n = 599$ , 11%) in private hospitals. Majority of the operations were made on an inpatient basis ( $n = 4843$ , 90%) and 516 (10%) as outpatients. The mean age for surgically treated men in public hospitals was 39.8 years and 38.8 in private hospitals. Corresponding figures for women were 44.4 years in public and 42.7 years in private hospitals.

A difference was seen in surgical treatment between public and private hospitals. In public hospitals 3417 (96%) men were treated as inpatients and 127 (4%) as outpatients. In private hospitals, the corresponding figures were 181 (40%) as inpatients vs. 276 (60%) as outpatients. Concerning women in public hospitals 1174 (97%) patients were treated as inpatients and 42 (3%) as outpatients. In private hospitals the corresponding figures were 71 (50%) as inpatients vs. 71 (50%) as outpatients.

The mean hospital stay for men was 2.0 days in public vs. 1.1 in private hospitals. Corresponding figures for women were 2.1 vs. 1.1 days.

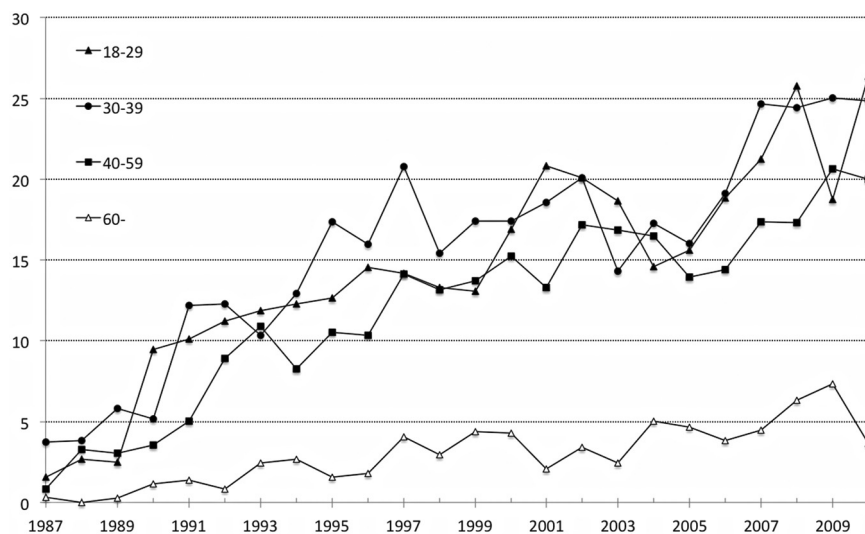


Fig. 3. Age-specific changes in the incidence of surgically treated clavicle fractures in Finnish adult men per 100,000 person-years between 1987 and 2010.

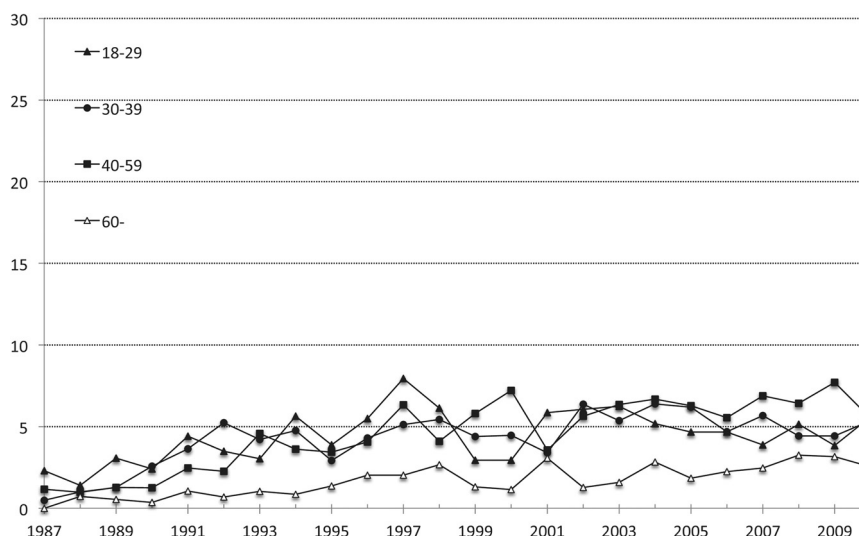


Fig. 4. Age-specific changes in the incidence of surgically treated clavicle fractures in Finnish adult women per 100,000 person-years between 1987 and 2010.

## Discussion

Our nationwide study allowed us to analyze the incidence and trends of surgically treated clavicle fractures in the entire adult Finnish population. Over the 24-year study period we noticed a significant increase in the number and incidence of surgical treatment of clavicle fractures. The magnitude of the finding is somewhat surprising even though we hypothesized that a clear increase would be found.

The overall incidence of surgical treatment of clavicle fractures increased ninefold but the increase was notably steep in men where the incidence of surgical treatment increased nearly elevenfold. Among men the increase was clear in all other age groups except for men over 60 years of age. The increase in the incidence of surgical treatment was swift for men till the late 1990s after which the incidence stayed quite constant until a new rise in the middle 2000s. In women, a more moderate rise in the incidence of surgical treatment was seen till the late 1990s, but unlike in men, since then the incidence has remained quite constant.

The reasons for the increased surgical activity are unknown. Clavicle fractures are typically fall-induced and therefore unintentional. Unfortunately the NHDR is unable to give exact information on the type of the incident and therefore it cannot shed light on the true reasons of the underlying fracture. According to our results the surgically treated adult patients are mostly young or middle-aged and therefore the increase in the surgical incidence cannot be explained via population ageing. It is possible that Finnish middle-aged people are nowadays more active and therefore more injury-prone during their leisure time. However, the authors are not aware of any scientific evidence supporting this assumption.

It may also be that the new hardware, especially locking plates, which allows better grip to comminuted bone, have encouraged surgeons to operate. The rigorous marketing of new fixation materials may also play a role. This is of interest because no radical changes on the national treatment recommendations of clavicle fractures (changes that would have favoured surgical treatment over conservative treatment) have been made.

A limitation of our as well as any previous register-based study is that the overall incidence of clavicle fractures can not be assessed using the data on NHDR, because conservatively treated clavicle fractures are often treated in emergency rooms only, or outside hospitals in community health care centres and private

outpatient clinics thus falling outside the NHDR. However, a ninefold increase in the rate of surgical treatment cannot be based solely to an increase in the actual incidence of clavicle fractures, but is due to an increase in surgical treatment.

It seems that the literature is rather uniform in stating that different types of fractures (e.g. lateral vs. diaphysis vs. medial) should be handled and treated as separate entities. Therefore it is surprising that the version 10 of the International Classification of Diseases (ICD-10) recognizes only one diagnosis, S42.0 for the fracture of the clavicle. ICD-9 recognizes complicated (8101A) and non-complicated (8100A) fractures and additionally fracture consequences (9052A). This leads to an obvious limitation of our study: we were unable to differentiate the anatomical sites of the clavicle fractures included in this study.

During the 24-year study the increase in surgically treated men is puzzling. The steepest rise in the incidence of surgical treatment for men was seen up till the end of the 1990s, which probably reflects the literature and common practice over that period. In their work Hill and co-workers found a high rate of non-union (15%) in conservatively treated mid-shaft clavicle fractures. Even though the combined rate of mal- and non-union was high (27%) in their work, Nordqvist and co-workers reported a low rate of patient discontent.

Although the demand for better functional outcome is clear with younger men, the rise in incidence was nearly similar in the age groups 40–59 years old. Robinson and cowriters found advancing age, female gender, displacement of the fracture and fracture comminution as risk factors for non-union [21]. As the risk of non-union also increases the risk for surgical treatment it would be understandable why these factors might explain the change in the older age groups (especially female), but not in the younger males. According to our results, the majority of increase in the incidence of surgical treatment comes from men under 60 years of age. This begs to ask whether these patients had been seen as good candidates for undisturbed healing. It is also possible that people in general are nowadays more active and expectations on (surgical) treatment and results are high.

A recent review suggests that conservative treatment is still the first treatment option for primary clavicle fractures regardless of the site of fracture [5]. On the other hand, conservative treatment on mid-shaft clavicle fractures has been proved to yield unsatisfactory results with a high rate of non-union and high rate

of patient dissatisfaction [8,9,14,21–23]. Some studies have showed that displaced middle-shaft fractures benefit from internal fixation when compared to conservative treatment [10,24]. In the study performed by the Canadian Orthopaedic society, a statistically significant difference regarding function between surgically and nonsurgically treated groups was found although the clinical relevance of the difference could be questioned as the DASH score differences at the end of the follow-up between the groups were approximately 10. In their recent high-quality randomized controlled trial, Virtanen et al. reported significantly lower non-union rate in the surgically treated patients, but there was no significant group difference in Constant or DASH scores regarding function and disability between these nonsurgically and surgically treated groups [25]. Additionally, they observed no difference in function between the united and non-united fracture cases when assessed with Constant score, and patients with non-unions declined corrective surgery.

Strength of our study is the excellent national coverage of surgically treated clavicle fractures, because all public and private hospitals must register their procedures into the NHDR [18–20]. Therefore all surgically treated clavicle fractures in Finland between 1987 and 2010 were recorded in this study.

In conclusion, we found a marked increase in the number and incidence of surgically treated clavicle fractures over the 24-year study period in Finland. The change has mainly occurred in men less than 60 years of age. Although the true incidence and trend of all clavicle fractures are not known, we conclude that the increase of surgical treatment has been remarkable. However, there is no high-quality evidence supporting this type of radical change in the treatment recommendation of clavicle fractures. High-quality research is needed to see whether a similar change has occurred in other countries. Additionally we feel that as the different types of clavicle fractures are separate entities, they deserve to be recognized with separate codes in the future versions of the International Classification of Diseases.

### Conflict of interest statement

All authors of this reported paper declare no conflict of interest.

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RESEARCH ARTICLE

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# Trends in the surgical treatment of proximal humeral fractures – a nationwide 23-year study in Finland

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## Abstract

**Background:** Proximal humeral fractures are common osteoporotic fractures. Most proximal humeral fractures are treated non-surgically, although surgical treatment has gained popularity. The purpose of this study was to determine changes in the surgical treatment of proximal humeral fractures in Finland between 1987 and 2009.

**Methods:** The study covered the entire adult (>19 y) population in Finland over the 23-year period from 1st of January 1987 to 31st of December 2009. We assessed the number and incidence of surgically treated proximal humeral fractures in each year of observation and recorded the type of surgery used. The cohort study was based on data from Finnish National Hospital Discharge Register.

**Results:** During the 23-year study period, a total of 10,560 surgical operations for proximal humeral fractures were performed in Finland. The overall incidence of these operations nearly quadrupled between 1987 and 2009. After the year 2002, the number of patients treated with plating increased.

**Conclusion:** An increase in the incidence of the surgical treatment of proximal humeral fractures was seen in Finland in 1987–2009. Fracture plating became increasingly popular since 2002. As optimal indications for each surgical treatment modality in the treatment of proximal humeral fractures are not known, critical evaluation of each individual treatment method is needed.

## Background

Proximal humeral fractures are common and they are the third most common osteoporotic fracture after hip and distal radius fractures [1-3]. The rate of proximal humeral fractures typically increases in women after age 50 and in men after age 70 [4]. Based on recent literature, the age- and sex-specific incidence rate of proximal humeral fractures varies from 10 to 300 per 100,000 person-years in different populations [1,2,4,5].

Proximal humeral fractures typically occur due to a low-energy trauma, most commonly by falling from standing height [6]. The incidence of proximal humeral fractures has clearly increased over the past few decades [5,7]. Despite the high prevalence of these injuries, surprisingly little

is known which proximal humeral fractures should be treated surgically [8].

Most proximal humeral fractures are treated nonsurgically [1,9,10]. A variety of different methods can be used for surgical treatment of proximal humeral fractures, including percutaneous fixation, open reduction and internal fixation (ORIF), and arthroplasty. While there are a few clinical case series of surgical treatment few high-quality randomized controlled trials have been performed [11].

Fjalestad and coworkers found no evidence of a difference between surgical and conservative treatment, whereas Olerud and coworkers reported that arthroplasty is associated with a better quality of life. In another study Olerud et al. compared plating to conservative treatment but found no statistical difference for quality of life in elderly patients [11-14].

New treatment options, such as locking plates, were introduced to clinical practice during the recent decade,

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but their superiority over other treatment options has not yet been demonstrated [8,11].

The aim of the current study was to assess the incidence and trends in the surgical treatment of fractures of the proximal humerus. We were especially interested to see how the number and incidence of different surgical treatment methods have evolved at this site.

## Methods

The Institutional Review Board approved the study.

Patient data were obtained from the Finnish National Hospital Discharge Register (NHDR) between 1987 and 2009. All patients 20 years of age or older admitted to hospitals alive were included. The Finnish NHDR, founded in 1967, provides data on age, sex, domicile of the subject, hospital stay duration, primary and secondary diagnosis, and operations performed during the hospital stay. The data collected by the NHDR is mandatory for all hospitals, including private, public, and other institutions. The validity of the NHDR is excellent regarding both coverage and accuracy of the database [15-17]. On the other hand, the NHDR is a *hospital discharge register* and it does not provide conclusive data on co-morbidities and other risk factors for fractures.

Patients were selected in the study if they had either primary or secondary diagnosis of a proximal humeral fracture. As the ICD-coding changed during the study period, ICD-9 codes 81200 and 81210 were used to select patients in the study between 1987 and 1995. ICD-10 code S42.2 was used to select patients in the study between 1996 and 2009. The main outcome variable for the study was the number of patients undergoing surgical treatment of a proximal humeral fracture. The procedural codes also changed during the study period. The ICD-9 was used in Finland from 1987 to 1997. During this period, we included ICD-9 surgical treatment codes 9126 (closed reduction and osteosynthesis), 9128 (open reduction and osteosynthesis), 9130 (external fixation), and 9132 (endoprosthesis). In 1998, the more specific ICD-10 procedural coding system was introduced. The ICD-10 surgical treatment codes for the proximal humeral fractures included NBJ60 (open reduction and osteosynthesis by nailing), NBJ62 (open reduction and plating), NBJ64 (fracture reduction and screw, percutaneous pinning or absorbable screw fixation), NBJ70 (external fixation), and NBB10-20 (arthroplasty). For analysis of the data for the whole study period from 1987 to 2009, the codes of the ICD-9 system were pooled with those of the ICD-10 system, and surgical treatment was categorized into four groups; closed reduction and osteosynthesis (codes 9126 and NBJ64), open reduction and osteosynthesis (codes 9128, NBJ60, and NBJ62), fracture reduction and external fixation (codes 9130 and NBJ70), and arthroplasty (codes 9132 and NBB10-20).

Implementation of the ICD-10 in 1998 allowed us to further dissect the proximal humeral procedures, and therefore a more specific analysis was performed for the years 1998 to 2009 to specify the proportions of individual surgical procedures. For this period, from 1998 to 2009, the numbers and incidences of procedures NBJ60, NBJ62, NBJ64, NBJ70, and NBB10-20 were analysed individually.

## Statistical analysis

To compute the incidence ratios of proximal humerus fractures requiring surgical intervention and thus leading to hospitalization, the annual mid-population was obtained from the Official Statistics of Finland, an electronic national population register [18]. The rates of surgically treated proximal humerus fractures (per 100,000 persons) were based on the entire adult population of Finland rather than cohort-based estimates and thus 95% confidence intervals were not calculated. Statistical analysis was performed using PASW19.0®.

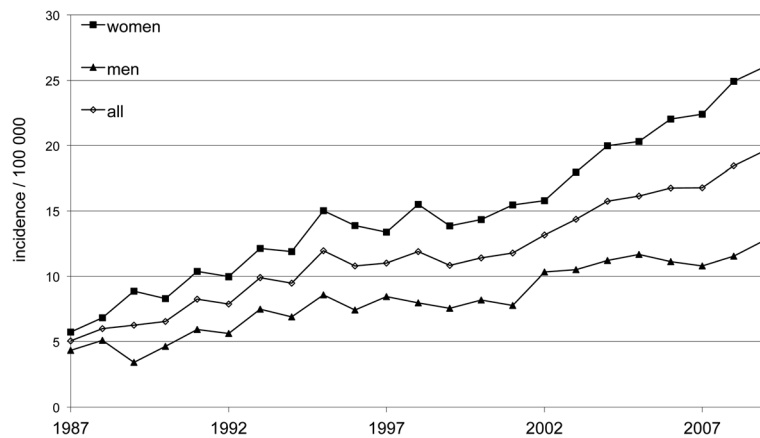
## Results

A total of 47,960 hospitalizations with a diagnosis of proximal humeral fracture were registered in the NHDR during the 23-year study period. The number of patients was 1136 in 1987 and 2944 in 2009. The incidence of hospitalization following proximal humeral fracture increased from 31.1 per 100,000 person years in 1987 to 71.5 per 100,000 person years in 2009.

During the 23-year period, 10,560 surgical operations of these fractures were registered in the NHDR. The number of surgically treated proximal humerus fractures increased from 1987 to 2009. The number of surgical procedures in women was roughly twice that in men ( $n = 7008$ ; 66% in women and  $n = 3552$ ; 34% in men). The total incidence of surgical procedures was 5.1 per 100,000 person years ( $n = 185$ ) in 1987 and 19.6 per 100,000 person years ( $n = 808$ ) in 2009. In women, the incidence increased from 5.7 per 100,000 person years ( $n = 110$ ) in 1987 to 26.1 per 100,000 person years ( $n = 553$ ) in 2009. In men, the incidence increased from 4.3 per 100,000 person years ( $n = 75$ ) in 1987 to 12.8 per 100,000 person years ( $n = 255$ ) in 2009 (Figure 1).

During the entire 23-year study period, ORIF was the most common surgical procedure performed ( $n = 7774$ , 73.6%), followed by closed reduction and osteosynthesis ( $n = 1515$ , 14.3%), arthroplasty ( $n = 1198$ , 11.3%), and external fixation ( $n = 73$ , 0.7%). As the number and incidence of external fixations were so low during the entire study period, they were excluded from further analysis.

The number and incidence of different surgical procedures changed markedly (Figure 2). The incidence for ORIF was 4.2 per 100,000 person years ( $n = 153$ ) in 1987 and 14.5 per 100,000 person years ( $n = 598$ ) in 2009. The steepest rise in the number and incidence of the ORIF was observed



**Figure 1** Incidence of surgically treated proximal humeral fractures in Finnish men and women per 100,000 person-years between 1987 and 2009.

among women: from 4.4 per 100,000 person years ( $n = 84$ ) in 1987 to 19.1 per 100,000 person years ( $n = 405$ ) in 2009. The incidence of closed reduction and osteosynthesis was 0.25 per 100,000 person years ( $n = 9$ ) in 1987 and 2.0 per 100,000 person years ( $n = 81$ ) in 2009. The corresponding values for arthroplasty were 0.5 ( $n = 17$ ) and 3.1 ( $n = 129$ ).

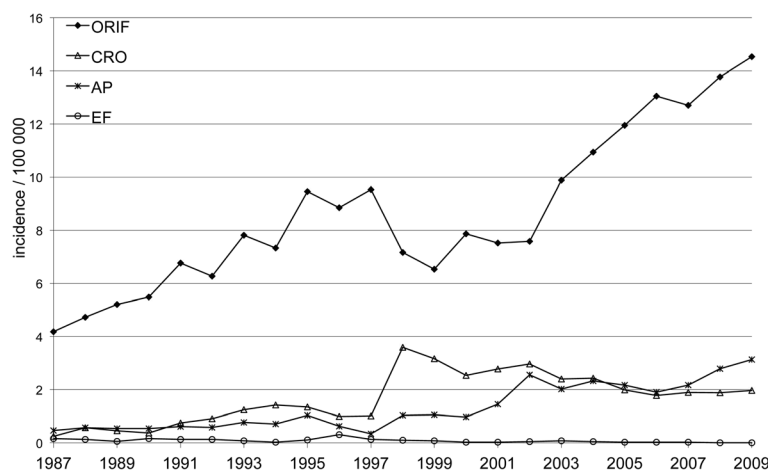
Between 1998 and 2009, when the more specific ICD-10 codes were available, the incidence in plating (NBJ62) increased from 5.9 per 100,000 person years ( $n = 229$ ) in 1998 to 13.9 per 100,000 person years ( $n = 574$ ) in 2009 (Figure 3). The increase in plating was greater in women as the incidence rose from 7.6 per 100,000 person years ( $n = 152$ ) in 1998 to 18.3 per 100,000 person years ( $n = 389$ ) in 2009 (Figure 4). The plating incidence nearly doubled in every age group between 1998 and 2009 (Figure 5).

The incidence of nailing (NBJ60) decreased over time, from 1.2 per 100,000 person years ( $n = 48$ ) in 1998 to 0.6

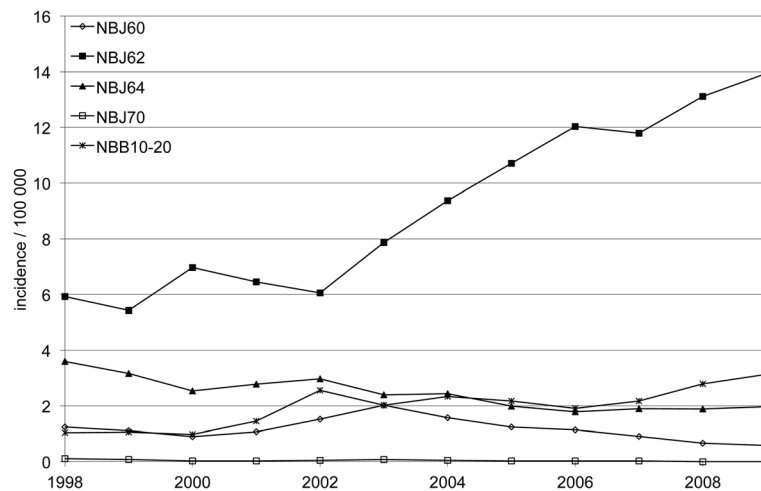
per 100,000 person years ( $n = 24$ ) in 2009 (Figure 3). The corresponding values for fracture reduction with screw, and percutaneous pinning or absorbable screw fixation (NBJ64) were 3.6 ( $n = 139$ ) and 2.0 ( $n = 81$ ). The incidence of arthroplasty (NBB10-20) increased from 1.0 ( $n = 40$ ) in 1998 to 3.1 per 100,000 person-years ( $n = 129$ ) in 2009 (Figure 3). The mean age by surgery type varied: 65.0 yrs. (SD 15) for nailing, 61.7 yrs. (SD 15) for plating, 59.3 yrs. (SD 16) for screw, pin or absorbable screw, 68.1 (SD 12) for external fixation and 69.5 (SD 11) for arthroplasty.

### Discussion

In this cohort study based on a nationwide register, we analysed the trends for surgical treatment of proximal humeral fractures in the entire adult Finnish population. The main finding was that the incidence of surgical treatment of proximal humeral fractures nearly quadrupled between



**Figure 2** Changes in the incidence of surgically treated proximal humeral fractures in Finnish adults per 100,000 person-years from 1987 to 2009. ORIF = open reduction and internal fixation, CRO = closed reduction and osteosynthesis, AP = arthroplasty, EF = external fixation.

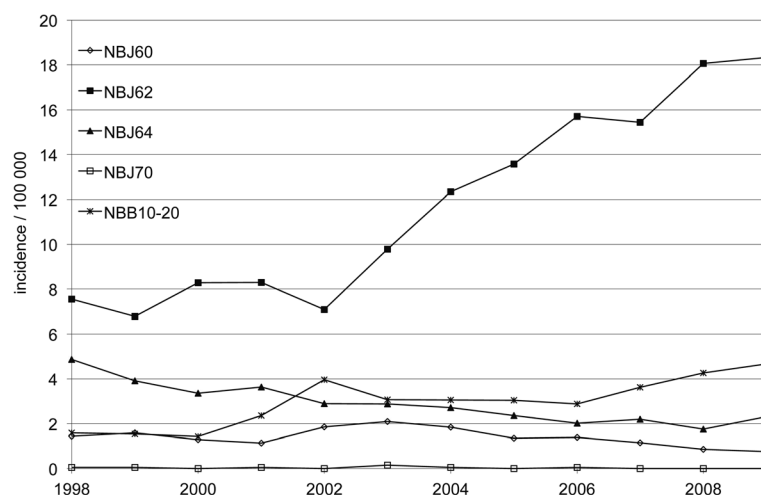


**Figure 3 Incidence of plating for proximal humeral fractures in Finnish adults per 100,000 person-years between 1998 and 2009.** NBJ60 = nail, NBJ62 = plate, NBJ64 = screw, NBJ70 = external fixation, NBB10-20 = arthroplasty.

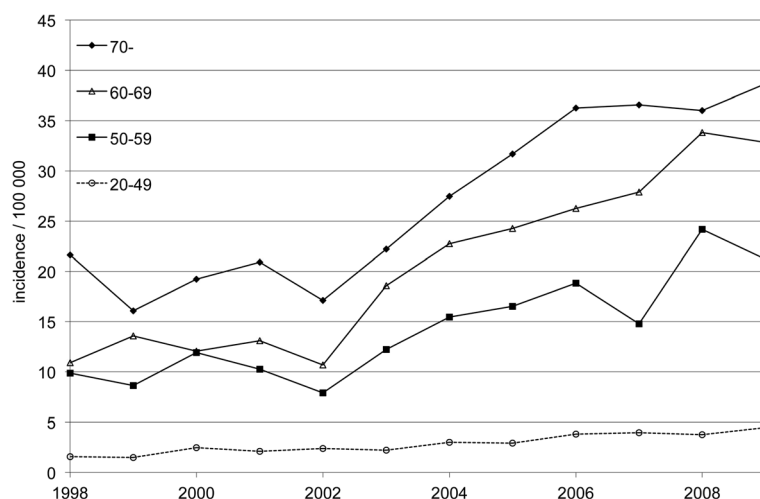
1987 and 2009. This is of interest as proximal humeral fracture is the third most common osteoporotic fracture type and as such poses considerable strain on our healthcare system. At the same time the incidence of hospitalization due to proximal humeral fractures only doubled, and more specifically, in the oldest age groups the age-adjusted incidence of these fractures has stayed quite constant since the late 1990s [5].

A majority of proximal humeral fractures occur in women with incidence increasing almost exponentially with aging [19,20]. According to our study the incidence for surgical treatment rose for both men and women but it is unclear why the rise in incidence is steeper with women. Aging women have shown to have a greater risk than men for an osteoporotic fracture such as proximal humeral fractures [21,22].

Surprisingly little is known regarding whether two, three, or four part humeral fractures in elderly patients should be treated operatively or conservatively [8,11]. There are few randomized controlled trials comparing nonsurgical versus surgical treatment with adequate scoring in follow-up reports [12-14]. In light of the scarce evidence, the significant increase in plating that occurred after the introduction of locking plates in Finland in 2002 is noteworthy. The number and incidences of ORIF with plating more than doubled between 1998 and 2009. These findings may imply that orthopaedic surgeons adopt new fixation systems without conclusive evidence or knowledge whether these fractures should be treated surgically at all. In a previous independent study we observed a significant increase in the surgical treatment of humeral shaft fractures [23]. The change in the rate of surgical treatment was



**Figure 4 Incidence of surgically treated proximal humerus fractures in Finnish female adults per 100,000 person-years between 1998 and 2009.** NBJ60 = nail, NBJ62 = plate, NBJ64 = screw, NBJ70 = external fixation, NBB10-20 = arthroplasty.



**Figure 5** Age-specific incidence of platings for proximal humeral fractures in Finnish female adults per 100,000 person-years between 1998 and 2009.

not as drastic as in the current study on proximal humeral fractures.

The small number of arthroplasty in the surgical treatment of proximal humeral fractures was surprising as based on the literature, joint replacement is usually suggested especially in age groups of 70 years and older [24]. The incidence of arthroplasty was quite steady from the late 80's until the late 90's. The incidence has since risen (Figure 4) but not as sharply as plating. At the same time fracture plating in women over 70 has gained popularity (Figure 5).

In Finland, medical treatment is equally available to everyone and the study population comprised the entire Finnish adult population; therefore, we consider our study reliable. In addition, previous studies reported the coverage and accuracy of the NHDR injury codes to be over 90% [17]. A strength of our study is the excellent national coverage of surgically treated proximal humeral fractures; all surgically treated proximal humeral fractures between 1987 and 2009 are included in this study, whether treated as outpatients or inpatients.

A weakness of this study is that the precise incidence of all proximal humeral fractures cannot be assessed using the NHDR data alone because an unknown number of the fractures were treated conservatively on an outpatient basis. Thus we are not able to deduct whether a part of the increase in the incidence of operative treatment of proximal humeral fractures is due to growing numbers of proximal humeral fractures or a growing tendency towards surgical treatment. The available scientific literature suggests that the majority of proximal humeral fractures are still treated nonsurgically [10,25]. Another limitation of our 23-year study is the change in the ICD procedure-coding system in 1998. Due to the less specific procedural codes in the ICD-

9 system, specific data about the implants (i.e., pinning, plates) used could not be evaluated during 1987–1997. Because of this, the main finding of this study between 1987 and 1997 is the increase in the incidence of surgical treatment of proximal humeral fractures. The implementation of locking plates in Finland occurred at the beginning of the 2000s when the more specific ICD-10 coding system was already in use.

In Finland the use of procedural coding of humeral fracture surgery is exercised as explained in Methods but the practical use of procedural coding between different countries may vary. For instance plating of humeral fracture in Finland is NBJ62 but NBJ61 in Norway. The possible differences in procedural coding have to therefore be taken into account when comparing results between different countries.

According to Bell and co-workers, the incidence of surgical treatment for proximal humeral fractures has increased in North America [10]. With the lack of consensus on the treatment of choice for proximal humeral fractures, this increased incidence of surgical treatment seems controversial, especially for the older age groups. The lack of evidence makes it difficult to determine whether ORIF with plating is the best surgical treatment option. According to our data, with the exception of plating and arthroplasty, the incidence of all other surgical treatment options has decreased with time, consistent with the findings of Bell et al. [10].

## Conclusions

Given the scarce amount of evidence concerning surgical versus nonsurgical treatment of proximal humeral fractures, the marked increase in plating procedures performed after the introduction of locking plates in 2002 is

noteworthy. In clinical practice good functional outcome and patient satisfaction in shoulder-specific questionnaires, and minimal rate of complications and reoperations should be characteristic for surgical treatment of the proximal humeral fractures. To assess whether (or which) surgical treatment provides this we need more high-quality prospective randomised clinical studies with adequate follow-up.

#### Competing interests

The authors declare no competing interests.

#### Authors' contributions

TH and VM were in charge and contributed in all stages of the study. AL contributed in data interpretation and writing the final manuscript. PK and HP contributed in study design, data collection, data interpretation and writing the final manuscript. All authors read and approved the final manuscript.

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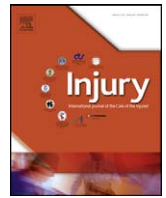
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## Surgical treatment of humeral-shaft fractures: A register-based study in Finland between 1987 and 2009

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### SUMMARY

**Introduction:** Humeral-shaft fractures are not uncommon osteoporotic fractures. While most of the humeral-shaft fractures can be treated conservatively, some need surgical treatment. The purpose of this study was to assess the trends of the surgical treatment of humeral-shaft fractures. The study determined whether surgical treatment of humeral-shaft fractures has changed in Finland between 1987 and 2009. We assessed the number and incidence of surgically treated humeral-shaft fractures in each year and recorded the type of surgery used.

**Patients and methods:** The study covered the entire adult (>18 years) population in Finland over the 23-year period from 1 January 1987 to 31 December 2009. Data on surgically treated humeral-shaft fractures were obtained from the nationwide National Hospital Discharge Registry.

**Results:** During the 23-year study period, a total of 4469 surgical operations of the humeral shaft were performed in Finland. The male patients were markedly younger (49 years) than their female counterparts (63 years). The incidence of surgical treatment nearly doubled in men and over tripled in women. Between 1987 and 2009, there occurred a clear shift towards plating in the surgical treatment of humeral-shaft fractures.

**Conclusions:** A marked increase in the surgical treatment of humeral-shaft fractures was seen in Finland in 1987–2009. Fracture plating increased during the first decade of the millennium. Since high-quality evidence for treatment of humeral-shaft fractures is absent, critical evaluation of the chosen treatment options is needed.

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### Introduction

As with many other adult fracture types, scientific literature provides no fresh population-based studies on the epidemiology of humeral-shaft fractures. Some smaller epidemiological studies estimate that fractures of the humeral shaft account for up to 3% of all adult fractures.<sup>1</sup> Humeral-shaft fractures seem to be related to falls and osteoporosis as the majority of patients are over the age of 50 years.<sup>1–3</sup>

Non-surgical treatment options of humeral-shaft fractures include casting, functional bracing, or a sling<sup>4</sup> and it has been suggested that most of these fractures can be treated non-surgically.<sup>5</sup> Non-surgical treatment, especially functional bracing, seems to give good results.<sup>5–9</sup> However, there are some occasions,

in which surgical treatment needs to be considered including vascular- or nerve-tissue damage, open or pathological fractures, multiple fractures of the same upper extremity and bilateral humeral-shaft fractures. Inadequate closed reduction may also result in consideration of surgical treatment.<sup>10</sup> Surgical-treatment options include mainly intramedullary nailing and compression plating, rarely external fixation or the use of screws or pins.<sup>11</sup>

Both surgical and non-surgical treatment options have unique profiles for complications. With functional bracing, the rate of non-union varies between 2% and 23%.<sup>5–7,9,12,13</sup> Complications associated with surgical treatment include non-union, fracture of the fixation material, infection, soft tissue irritation including radial nerve injury and the need for fixation material removal.<sup>14–19</sup>

In the clinical setting, the use of nailing and plating seems to have risen above the other surgical treatment options. Recent studies have focussed on comparing intramedullary nailing to compression plating.<sup>14,16–18</sup> Plating and intramedullary nailing are both widely used, but scientific literature provides no clear answer, which is the best surgical treatment option for humeral-shaft

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fractures, especially regarding functional outcome.<sup>20,21</sup> The choice between different surgical treatment options may vary considerably in different countries, but the authors feel that at least in Finland the trend has clearly been towards plating over the other treatment options.

To our knowledge, there are no population-based epidemiologic studies analysing the surgical trends in fractures of the humeral shaft. Therefore, the purpose of this nationwide study was to analyse all surgically treated humeral-shaft fractures in Finland between 1987 and 2009.

## Materials and methods

Patient data were collected from the Finnish National Hospital Discharge Register (NHDR) between 1 January 1987 and 31 December 2009. All patients 18 years or older were included in the study. The Finnish NHDR was founded in 1967 and provides an excellent database for epidemiologic studies. The data stored in the database include variables such as sex, domicile of the subject, duration of hospital stay, primary and secondary diagnosis and procedures performed during the hospital stay. The data collected by the NHDR are mandatory for all hospitals encompassing private, public and other institutions. The validity of the NHDR is excellent regarding both coverage and accuracy of the database.<sup>22–24</sup>

The main outcome variable for this study was the number of patients undergoing surgical treatment of a humeral-shaft fracture. The patient had the fracture as a main or secondary diagnosis (International Classification of Diseases Ninth Revision (ICD-9) codes 8122A and 8123A in 1987–1995 and ICD-10 code S42.3 in 1996–2009). During the study, the procedural codes also changed. Procedural codes were in the ICD-9 form between 1987 and 1997 and the ICD-10 form between 1998 and 2009. The used ICD-9 codes were 9126 (closed reduction and osteosynthesis), 9128 (open reduction and osteosynthesis) and 9130 (external fixation). The ICD-10 codes were NBJ60 (open reduction and osteosynthesis by nailing), NBJ62 (open reduction and osteosynthesis by plating), NBJ64 (fracture reduction and screw, percutaneous pinning or absorbable screw fixation) and NBJ70 (external fixation).

For the purpose of analysing trends during the entire study period from 1987 to 2009, the ICD-9 procedural codes were pooled with ICD-10 codes and surgical treatment were categorised into three groups: closed reduction and osteosynthesis (9126 and NBJ60), open reduction and osteosynthesis (9128, NBJ62 and NBJ64) and external fixation (9130 and NBJ70). From 1998

onwards and further the ICD-10 procedural coding enabled more elaborate dissection of the different procedures, as the coding system is more specific. Thus, a second analysis between 1998 and 2009 was performed. For this period, the numbers and incidences of procedures NBJ60, NBJ62, NBJ64 and NBJ70 were analysed.

To calculate the incidence ratios of surgically treated humeral-shaft fractures, the annual mid-population was obtained from the Official Statistics of Finland, a statutory electronic register of the population. The rates of surgically treated humeral-shaft fractures (per 100,000 persons) were based on the entire adult population ( $\geq 18$  years of age) of Finland rather than sample or cohort-based estimates and thus, in full agreement with our previous study,<sup>25</sup> 95% confidence intervals were not calculated. Statistical analysis was performed using PASW 19.0®.

## Results

A total of 15,906 hospitalisations with a diagnosis of humeral-shaft fracture were registered in the Finnish NHDR during the 23-year study period. The number of patients was 358 in 1987 and 819 in 2009. The incidence of hospitalisation following humeral-shaft fracture increased from 9.4 per 100,000 person-years in 1987 to 19.3 per 100,000 person-years in 2009. The incidence of hospitalisation for men was 8.3 in 1987 and 12.6 in 2009. The corresponding figures for women were 10.5 in 1987 and 25.6 in 2009.

During the 23-year period, 4649 surgical operations of the humeral shaft were registered into the NHDR. The number of surgically treated fractures increased from 1987 to 2009, from 99 to 253. The total number of surgically treated humeral-shaft fractures was 2524 (54%) for women and 2125 (46%) for men. The surgically treated men were significantly younger than the surgically treated women (mean age 49 years (SD 18) for men, while it was 63 years (SD 18) for women). The mean age for the surgically treated men increased from 43 years in 1987 to 52 years in 2009. A similar increase was seen in women (from 57 years in 1987 to 64 years in 2009). The age distribution curve of the entire female and male study population is shown in Fig. 1.

The overall incidence of surgical procedures was 2.6 per 100,000 person-years ( $n = 99$ ) in 1987 and 6.0 per 100,000 person-years ( $n = 253$ ) in 2009. In women, the incidence of surgical procedures increased from 2.3 per 100,000 person-years ( $n = 46$ ) in 1987 to 7.2 per 100,000 person-years ( $n = 158$ ) in 2009. In men, the incidence increased from 2.9 per 100,000 person-years ( $n = 53$ ) in 1987 to 4.6 per 100,000 person-years ( $n = 95$ ) in 2009 (Fig. 2).

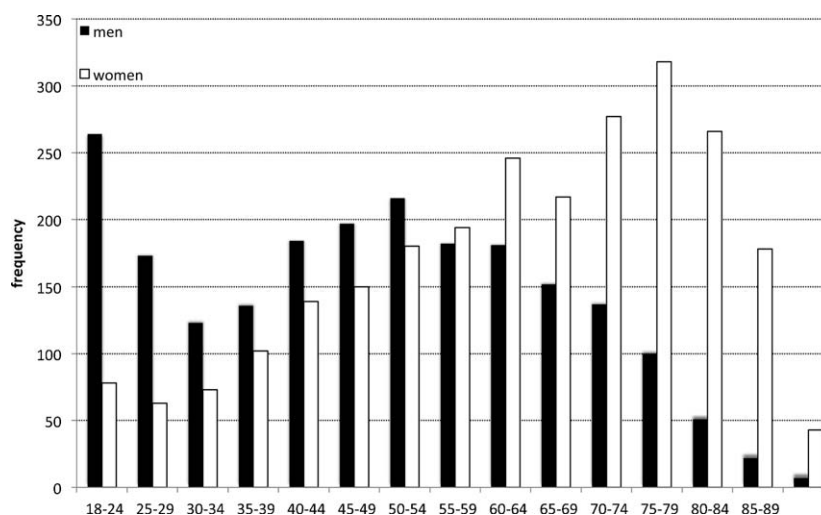


Fig. 1. Age distribution of the surgically treated men and women with humeral-shaft fracture.

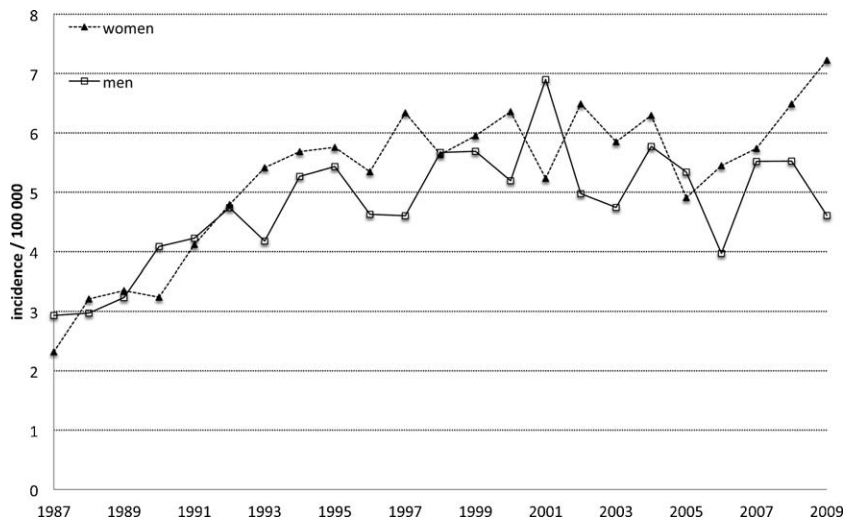


Fig. 2. Incidence of surgically treated humeral-shaft fractures in Finnish adults per 100,000 person-years between 1987 and 2009.

During the entire 23-year period, open reduction and osteosynthesis was the most common surgical procedure for humeral-shaft fracture ( $n = 3264$ , 70.2%) followed by closed reduction and osteosynthesis ( $n = 1303$ , 28%) and external fixation ( $n = 82$ , 1.8%). The numbers and incidences of different surgical techniques changed over time (Fig. 3). The incidence of open reduction and osteosynthesis was 1.8 per 100,000 person-years ( $n = 70$ ) and 5.3 per 100,000 person-years ( $n = 225$ ) in 2009. The incidence for closed reduction and osteosynthesis was 0.7 per 100,000 person-years ( $n = 27$ ) in 1987 and 0.6 per 100,000 person-years ( $n = 25$ ) in 2009. The corresponding figures for external fixation were 0.05 ( $n = 2$ ) in 1987 and 0.07 ( $n = 3$ ) in 2009. The clearest change occurred in the open reduction and osteosynthesis group in women; the incidence was 1.7 per 100,000 person-years ( $n = 34$ ) in 1987 and 6.5 per 100,000 person-years ( $n = 142$ ) in 2009. At the same time, the corresponding incidences for men were 2.0 per 100,000 person-years ( $n = 36$ ) in 1987 and 4.0 per 100,000 person-years ( $n = 83$ ) in 2009.

Between 1998 and 2009, the more specific ICD-10 procedure codes were used in Finland and thus the data allowed a more specific analysis between the surgical procedures. A clear increase in the incidence of plating was observed starting in 2004 while the incidence of other techniques decreased (Fig. 4). The incidence of

nauling (NBJ60) was 2.1 per 100,000 person-years ( $n = 83$ ) in 1998 and 0.5 per 100,000 person-years ( $n = 22$ ) in 2009. For plating (NBJ62), the incidence was 2.9 per 100,000 person-years ( $n = 115$ ) in 1998 and 4.9 per 100,000 person-years ( $n = 210$ ) in 2009.

The steepest rise in plating was seen with women and in the older age group as the incidences for the procedure over doubled in age groups over 60 between 1998 and 2009 (Fig. 5). The fixation with screw, pin or screw (NBJ64) was an uncommon technique between 1998 and 2009 as the incidence was 0.4 per 100,000 person-years ( $n = 14$ ) and 0.2 per 100,000 person-years ( $n = 8$ ) in 2009. The incidence of external fixation was even lower as the corresponding figures were 0.1 in 1998 and 0.05 in 2009.

The mean length of hospital stay for the surgically treated patients with humeral-shaft fracture decreased from 10.7 days in 1987 to 4.2 days in 2009. Mean hospital stay was 6.3 days for closed reduction and osteosynthesis, 6.0 days for open reduction and osteosynthesis and 14.7 days for external fixation.

## Discussion

In this nationwide study, we analysed the incidence and trends of the surgical treatment of humeral-shaft fractures in the entire

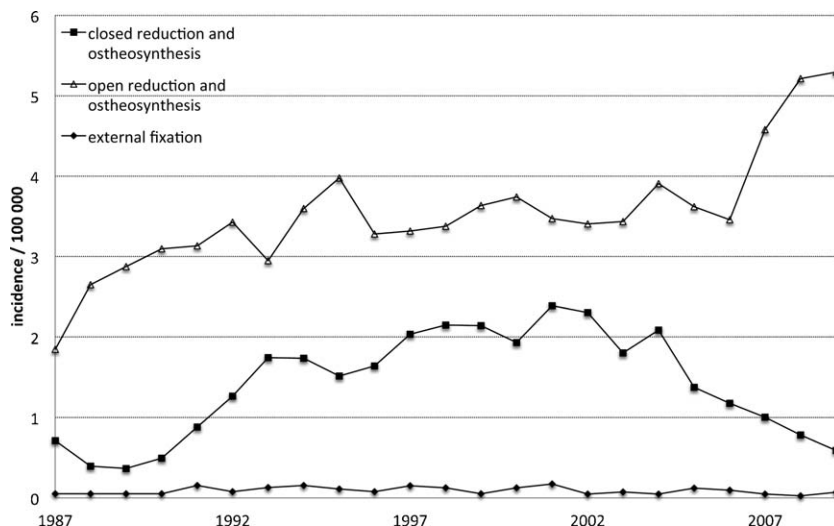
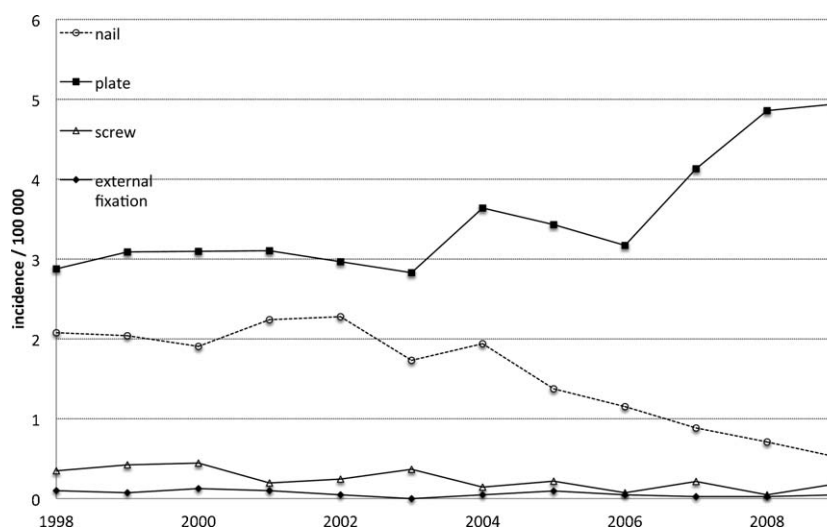


Fig. 3. Changes in the incidence of surgically treated humeral-shaft fractures in Finnish adults per 100,000 person-years from 1987 to 2009. 9126 = closed reduction and osteosynthesis, 9128 = open reduction and osteosynthesis, 9130 = external fixation.





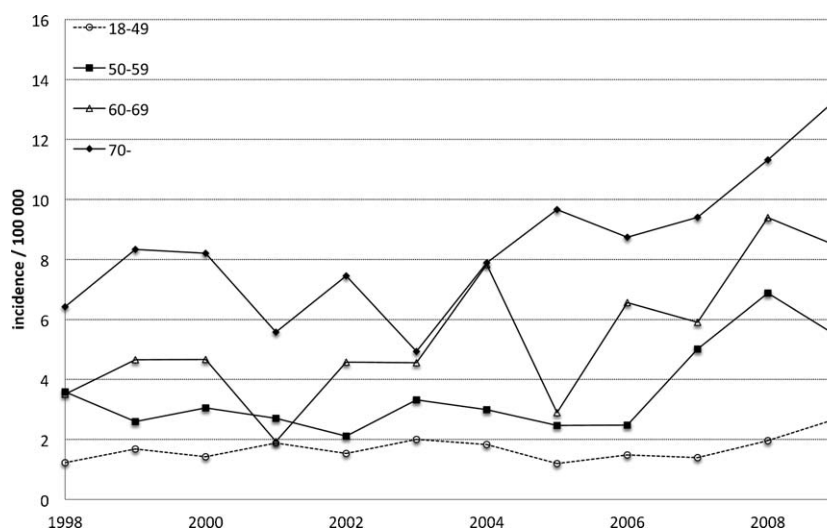
**Fig. 4.** Incidence of surgically treated humeral-shaft fractures in Finnish adults per 100,000 person-years between 1998 and 2009. NBJ60 = nail, NBJ62 = plate, NBJ64 = screw, NBJ70 = external fixation.

adult Finnish population. An important finding was also that the incidence of plating increased markedly; in the older age groups, the incidence more than doubled between 1998 and 2009. At the same time, the incidence of nailing decreased to one-fourth. This is in accordance with our clinical observations and our hypothesis that plating has risen in popularity over nailing in Finland.

The overall incidence of surgical treatment of humeral-shaft fractures increased markedly in Finland between 1998 and 2009, more so with women and in the older age groups. The steepest rise in the overall surgical activity was seen in the first half of the study period: from the late 1990s, the overall incidence of surgical treatment has been quite steady. The reason for the increased surgical activity is unknown. Factors affecting the choice of treatment include the experience and education of an individual orthopaedic surgeon, available scientific evidence and patients' beliefs, expectations and compliance. One could speculate that elderly people are nowadays more active and physically more demanding than before. Surgical treatment may allow earlier mobilisation and better function in the early phases of the treatment.<sup>26</sup> This may have led to increased activity of surgical treatment amongst the elderly. On the other hand, during the last

10 years some studies have paid attention to increased number of non-unions with regard to certain fracture types of the humeral shaft.<sup>6,7,12</sup> This may also have influenced the choice of treatment option. Unfortunately, we cannot reliably separate the operations that have been done for primary treatment of the fracture from those done as a secondary treatment. A minor part of the plate fixations has probably been done as this kind of secondary treatment; hence, no straightforward conclusions can be made regarding the choice of primary treatment options (surgical vs. non-surgical) based on these figures.

During the 23-year study period, the mean age of patients with surgical treatment for humeral-shaft fractures increased in both sexes. The increasing surgical treatment of humeral-shaft fractures in the older age groups is puzzling as there is no evidence that humeral-shaft fractures of elderly people should be treated surgically. Further, studies included in a recent Cochrane review consisted of patients with mean age firmly below the age of 50 years and over 50% of the patients were male.<sup>20</sup> This is interesting as we discovered that most of the patients with surgically treated humeral-shaft fractures are women and clearly older than 50 years. In previous studies, the incidence of humeral-shaft fractures



**Fig. 5.** Age-specific incidence of platings for humeral-shaft fractures in Finnish female adults per 100,000 person-years between 1998 and 2009.

has been described as having two peaks: the first peak between the second and third decades of life and the second peak between the fifth and sixth decades of life.<sup>1,3</sup>

The best treatment of humeral-shaft fractures has been under debate for decades. A large proportion of these fractures can be treated non-surgically with good results.<sup>5–7</sup> Interestingly, there are no prospective randomised studies comparing surgical versus non-surgical treatment. Regarding different surgical methods, a recent Cochrane review identified some 260 patients in five separate prospective randomised trials comparing intramedullary nailing and plating. According to this analysis of Kurup and co-workers, there was a statistically significant increase in shoulder impingement and the need for fixation material removal with intramedullary nailing. Regarding functional outcome and other complications rates, both surgical procedures gave similar results.<sup>20</sup> In their meta-analysis Heineman and co-workers did not find differences between intramedullary nailing or plate fixation regarding functional outcome.<sup>21</sup> After the publication of this meta-analysis, Putti and study group and Singiseti and co-workers have showed similar results in trials.<sup>17,18</sup>

According to our data, the role of pinning and screw fixation is minor and has been steadily decreasing. Similarly, it seems that currently the use of external fixation in the treatment of humeral-shaft fractures is very uncommon, although the role of external fixation still remains in the treatment of some comminuted fractures especially if associated with extensive soft tissue damage, bacterial infection, or both.<sup>11</sup>

A strength of our study is the excellent national coverage of surgically treated humeral-shaft fractures; all surgically treated humeral-shaft fractures between 1987 and 2009 are included in this study. A limitation in the NHDR is that the precise incidence of all humeral-shaft fractures in Finland cannot be assessed using the NHDR data alone as many of the non-surgically treated humeral-shaft fractures are treated in an outpatient setting in primary care and thus not covered by the NHDR. In addition, NHDR is a hospital discharge register and it does not provide conclusive data on comorbidities and other risk factors for fractures, which is an obvious limitation associated with all register-based studies. The change of ICD coding from ICD-9 to ICD-10 also produced some limitations. Due to the less specific procedural codes of the ICD-9, specific information about the fixation material used (i.e., nailing and plates) cannot be retrieved from the NHDR register data for the period 1987–1997. Because of this, the main finding between 1987 and 1997 is the change (increase) in the incidence of surgical treatment of the humeral-shaft fractures. An additional limitation of our study was that secondary procedures of the humeral-shaft fractures could not be analysed. It is possible that a shift towards surgical treatment of the acute fractures has decreased the need for secondary operations, but this needs to be addressed in further research. Finally, this study is a register-based study reporting on the trends of surgical treatment of humeral-shaft fractures and therefore no treatment recommendations can be given on the basis of this study.

## Conclusions

The marked increase in the surgical treatment of humeral-shaft fractures in Finland is of great interest as there is no evidence regarding the superiority of surgical over non-surgical treatment. It is also noteworthy that the clear shift towards plating in the surgical treatment of humeral-shaft fractures has occurred after the implementation of locking plates and without a solid scientific base. Thus, a need for high-quality, randomised clinical studies, comparing surgical treatment with the non-surgical approach and various surgical treatment options with each other, is evident. It should also be researched whether the increase in primary surgical treatment for humeral-shaft fractures has decreased the rate of

non-union fractures. In the mean time, every orthopaedic surgeon should critically evaluate his or her treatment protocol on humeral-shaft fractures.

## Conflict of interest statement

All authors of this reported paper declare no conflict of interest.

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# Significant Change in the Surgical Treatment of Distal Radius Fractures: A Nationwide Study Between 1998 and 2008 in Finland

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**Background:** Studies from the United States report a large increase in the surgical treatment of distal radius fractures with open reduction and internal fixation using locked plates. The aim of the present study was to determine whether the same trend has occurred in a Scandinavian country by assessing the number, incidence, and surgical methods of all surgically treated distal radius fractures in Finland over a recent 11-year period.

**Methods:** The study covered the whole adult population (aged >19 years) in Finland during the 11-year period from January 1, 1998, to December 31, 2008. Data on surgically treated distal radius fractures were obtained from the nationwide National Hospital Discharge Registry.

**Results:** During the 11-year study period, a total of 14,514 surgical operations (external fixation, percutaneous pinning, or plating) for adult distal radius fractures were performed in Finland. There was a dramatic shift toward internal fixation with plating; the incidence and number of platings more than doubled between 2006 and 2008. The incidence and number of external fixations decreased correspondingly. Percutaneous pinning was used in 13% of the surgical procedures during the study period.

**Conclusions:** A striking shift from external fixation to plating in the treatment of distal radius fractures has occurred in Finland over the past few years, despite the fact that the scientific literature does not support plating over external fixation. In addition, the incidence and number of surgeries for distal radius fractures doubled between 1998 and 2008. The reasons for these changes are not known.

**Key Words:** Distal radius, Bone fracture, Epidemiology, Surgery.

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Distal radius fractures are very common injuries, and high prevalence rates are reported worldwide.<sup>1–3</sup> Distal radius fractures account for ~20% of all fractures and are the second most common fracture requiring hospital stay, next to

hip fractures.<sup>4</sup> Distal radius fractures occur at two age peaks: children aged 8 years to 13 years and among persons older than 60 years.<sup>1–3</sup> Women have a two- to three-fold greater risk for fractures than men.<sup>2,5</sup> The overall incidence of distal radius fractures varies between 100 and 350 per 100,000 persons-years.<sup>1,3,5</sup> Recent reports describe an increasing trend toward surgical treatment for distal radius fractures, concomitant with a significant increase in the incidence of these fractures over the past two decades.<sup>2,6</sup>

There is no uniform treatment for distal radius fractures. Most distal radius fractures can be treated nonsurgically with a cast. During the past few decades, however, the interest in surgical treatment has increased. Surgical options include external fixation, percutaneous pinning, and open reduction with internal fixation (ORIF) using volar or dorsal plates.<sup>7</sup> Based on recent studies from the United States, there have been striking changes in the selection of surgical techniques; the rate of using internal fixation with volar locked plating has increased from 3% to 16%,<sup>8</sup> whereas the proportion of percutaneous fixations has decreased from 58% to 19%,<sup>9</sup> despite the lack of clear evidence supporting the superiority of either internal or external fixation in the treatment of distal radius fractures.<sup>7,10–17</sup> In addition, Cochrane reviews report significant flaws in the studies of surgical treatment for these fractures.<sup>14–17</sup>

To assess whether countries other than the United States show the same trend toward ORIF using volar plates, we designed a nationwide study to assess the number and incidence of distal radius fractures requiring surgical treatment in Finland. The second aim of the study was to assess the secular trend toward surgical treatment of these fractures and possible trend changes between percutaneous pinning, external fixation, and internal fixation.

## MATERIALS AND METHODS

This study covered the whole adult population (aged >19 years) in Finland during an 11-year period, from January 1, 1998, to December 31, 2008. The total number of Finnish inhabitants aged 20 years or older was 3.9 million in 1998 and 4.1 million in 2008.<sup>18</sup> The distal radius fracture data were obtained from the statutory, computer-based National Hospital Discharge Register of Finland (NHDR), which included information on all patients admitted alive to any Finnish hospital as a patient for the operative treatment of a distal

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radius fracture. The NHDR covers all operatively treated fractures, treated either as an inpatient or outpatient setting. This register is the oldest nationwide discharge register, and its coverage and accuracy are excellent.<sup>19–21</sup> Medical treatment including surgery is equally available to everyone in Finland because of the nationwide public health insurance legislated by the Finnish Ministry of Social Affairs and Health, ensuring that the hospitalization database we used has comprehensive coverage.

The NHDR contains data on the age, sex, domicile of the subject, length of hospital stay, primary and secondary diagnosis, and operations performed during the hospital stay. The information is collected equally from all hospital categories (private, public, and other). The diagnosis in the NHDR had been coded since 1996 using the 10th revision of the International Classification of Diseases (ICD).<sup>22</sup>

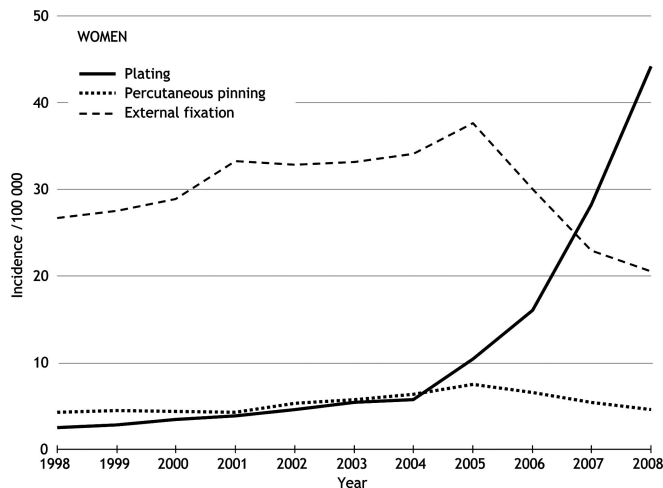
The main outcome variable for this study was the number of patients hospitalized as an inpatient with a main or secondary diagnosis of (1) distal radius fracture (ICD-10 code S52.5) and (2) distal radius and ulnar fracture (ICD-10 code S52.6) for operative treatment. In Finland, all surgical interventions concerning distal radius fractures are coded to NHDR. When describing the number and incidence of surgeries for distal radius fractures, we categorized the surgical treatment into three groups. The groups and corresponding ICD-10 codes were NCJ62 and NDJ62 for distal radius plating, NCJ64 and NDJ64 for percutaneous pinning, and NCJ70 and NDJ70 for external fixation. The main and secondary operation codes were allowed during the whole study period, with the exception years from 1998 to 2001, when only the main operative code was allowed. Therefore, we were unable to assess the second and third operation code between 1998 and 2001. Therefore, a combination surgery (e.g., external fixation and percutaneous pinning) was categorized according to the main operation code. Approval of the Institutional Review Board is not required for hospital register studies in Finland.

**Statistical Analysis**

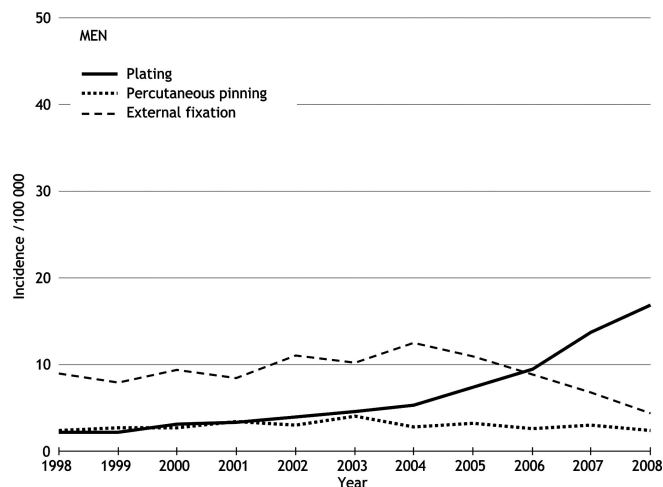
To compute the incidence ratios of distal radius fractures requiring surgical intervention and thus leading to hospitalization even for a day, the annual mid-population was obtained from the Official Statistics of Finland, a computer-based national population register.<sup>18</sup> The rates of surgically treated distal radius fractures were thus the true results concerning the entire adult population in Finland during the study period rather than cohort-based estimates, and thus 95% confidence intervals were not calculated. Incidence rates were calculated with the Open Epi Program.

**RESULTS**

During the 11-year study period, a total of 14,514 surgical operations (external fixation, percutaneous pinning, or plating) for adult distal radius fractures were performed in Finland. The number of operations performed in women was markedly greater than that performed in men (n = 10,595; 73% in women and n = 3,919; 27% in men). The rate of surgical treatment for distal radius fractures increased from 1998 to 2008. The incidence and number of surgical opera-



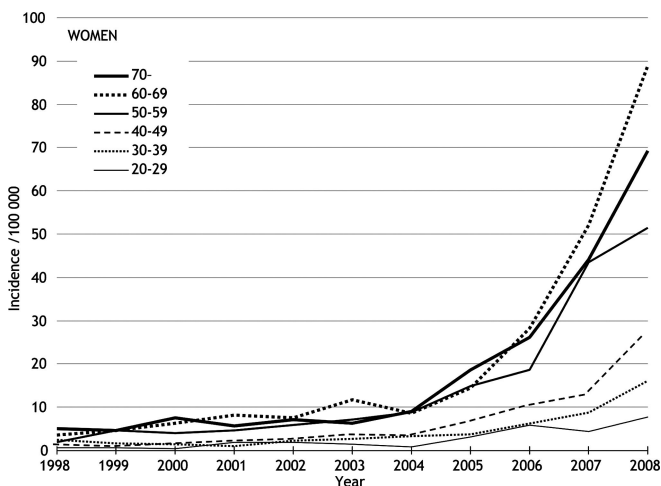
**Figure 1.** The incidence of surgically treated distal radius fractures in Finnish male adults per 100,000 person-years between 1998 and 2008.



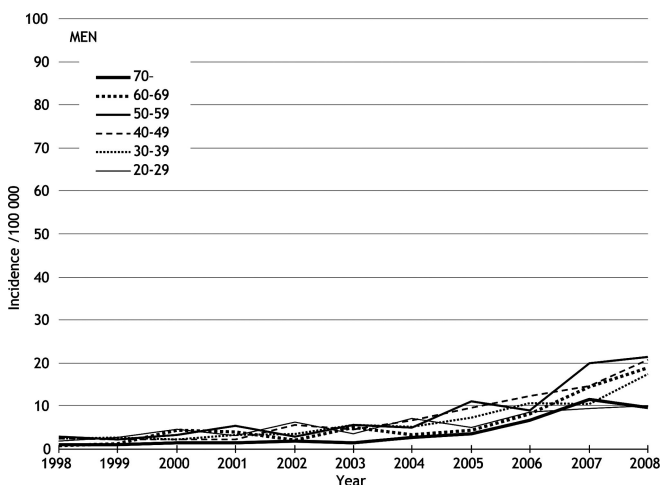
**Figure 2.** The incidence of surgically treated distal radius fractures in Finnish male adults per 100,000 person-years between 1998 and 2008.

tions was 23.9 per 100,000 persons-years (n = 924) in 1998 and 47.2 per 100,000 person-years (n = 1929) in 2008. The sex-specific figures in 1998 were 13.5 per 100,000 person-years (n = 251) in men and 33.4 per 100,000 person-years (n = 673) in women. In 2008, the corresponding figures were 23.7 (n = 469) in men and 69.2 (n = 1460) in women.

External fixation was the most common operation during the entire study period (n = 8,630, 59%), followed by open reduction/ORIF with plating (4,053, 28%) and then by percutaneous pinning (n = 1,831, 13%). However, a steep change in the type of surgical intervention occurred during the study period. The incidence and number of platings increased from 2.3 (n = 90) to 30.9 (n = 1265) per 100,000 person-years between 1998 and 2008. This change was most dramatic from 2006 to 2008, during which the incidence and number of platings more than doubled (Figs. 1 and 2). While plating became more popular, the incidence and number of



**Figure 3.** The incidence of platings in distal radius fractures in Finnish female adults per 100,000 person-years between 1998 and 2008.



**Figure 4.** The incidence of platings in distal radius fractures in Finnish male adults per 100,000 person-years between 1998 and 2008.

external fixations correspondingly decreased (Figs. 1 and 2). Percutaneous pinning was a relatively uncommon surgical procedure during the study period, and the incidence and number of percutaneous pinnings did not change markedly (Figs. 1 and 2).

When the change in surgical intervention due to distal radius fractures was stratified by sex, the shift from external fixation to plating was especially clear in women in the elder age groups. Among women, the incidence and number of platings increased from 2.5 per 100,000 person-years ( $n = 50$ ) in 1998 to 44.1 ( $n = 931$ ) in 2008 (Fig. 3). In men, the corresponding values were 2.2 per 100,000 person-years ( $n = 40$ ) in 1998 and 16.9 per 100,000 person-years ( $n = 334$ ) in 2008 (Fig. 4).

The mean duration of hospitalization was 2.8 days in 1998 and 2.3 days in 2008. The length of stay did not differ with the type of the surgery. Mean duration of hospital stay

was 2.9 days in the plating group, 2.7 days in the percutaneous pinning group, and 2.7 days in the external fixation group.

## DISCUSSION

The principal finding of this study was that the incidence and number of surgical treatments for distal radius fractures doubled in Finland between 1998 and 2008. In the past few years, there has been a striking change in the treatment for distal radius fractures from external fixation to ORIF with plating. The increase in plating was especially dramatic in women older than 60 years. Thus, the same phenomenon that was reported in the United States seems to have also occurred in Finland, that is, this nationwide study confirmed a similar dramatic increase in ORIF with plating in the treatment of distal radius fractures.

The increased incidence and number of platings for distal radius fractures is interesting, especially because the evidence supporting plating over external fixation is not convincing.<sup>7,10-13</sup> The intense marketing of plating, especially with the locking screw method, over the past few years may play a role in this change, although the true reasons for this change in practice are not known.

Medical treatment, including surgery, is equally available in Finland, and the study population comprised the whole adult population of Finland. Therefore, we consider the results of this study very accurate, especially as the information in the Finnish NHDR is collected equally from public, private, and military hospitals. Previous studies demonstrated that the accuracy and completeness of the NHDR database are excellent.<sup>20,21</sup> The weakness of our study, however, was that we had no means to identify the number of nonsurgically treated distal radius fractures in Finland, because the majority of these were treated on an outpatient basis and no outpatient database is available.

The literature indicates that the number and incidence of surgical treatment for distal radius fractures has increased, as observed in this study. Chung et al.<sup>8</sup> from the United States reported an increasing number and incidence of internal fixations with volar locked plating in elderly people, which corresponds with our results. The striking change in the older age groups may prove to be controversial, as Arora et al presented a study showing that in elderly people, there was no difference between the functional and subjective outcomes for the surgical and nonsurgical treatments.<sup>23</sup> In addition, in accordance with the findings of Koval's study group, we detected a decrease in the proportion of percutaneous fixations.<sup>9</sup> As noted above, however, there is no clear evidence to indicate that either internal or external fixation for the treatment of distal radius fractures provides a better clinical outcome.<sup>10-13</sup> The increase in the use of plating corresponds with the commercial initiation of volar plating with the locking screw method. In Finland, the first volar plates with locking screws became widely available in 2004. It is thus possible that surgeons are attracted to modern technologies, such as distal radius plating with locking screws. The increase in ORIF with volar plating might also be due to better

availability and marketing of the technology than to clinical evidence from published studies.

The advantages of internal fixation with plating are suggested to be better visualization and therefore more accurate maintenance of normal anatomy. Internal fixation may allow earlier mobilization and has decreased incidence of malunions requiring surgical intervention.<sup>9,24</sup> The problems with internal fixations include operation site-related complications, such as soft tissue irritation.<sup>10,11,13,24</sup> External fixation in turn has the advantage of percutaneous fixation and therefore less soft-tissue dissection. On the other hand, external fixation techniques are associated with a greater number of pin-track infections.<sup>14–17</sup> Evidence also suggests that a loss of reduction may occur for a period up to 6 months after external fixation surgery,<sup>25</sup> although there is also contradictory evidence that the radiographic parameters do not differ between external and internal fixation at 1 year postoperatively.<sup>11</sup> The immobilization period following internal fixation is shorter than that following external fixation or cast immobilization (0–2 weeks vs. 5–6 weeks).

To summarize, despite the fact that scientific literature does not support plating over external fixation, there has been a striking shift from external fixation to plating as a treatment for distal radius fractures in Finland over the past few years. In addition, the incidence and number of surgeries for distal radius fractures has doubled in this country between 1998 and 2008. The reasons for these changes are not known, however. For this reason, each orthopedic surgeon and hand surgeon should carefully evaluate his/her surgical protocol when treating distal radius fractures. More research-based knowledge is needed regarding the benefits and adverse effects of this change in the treatment protocol.

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## EDITORIAL COMMENT

The authors report on surgical treatment of distal radius fractures between 1998 and 2008 in Finland. The National Hospital Discharge Register of Finland was used, which includes all patients surgically treated even if they were discharged on the same day. The Registry represents a great resource. The authors could not comment on whether there was an increase in the incidence of distal radius fractures. The purpose of article was to report the type of fixation used, and some interesting results were noted. However, those results were not unexpected regarding the fact that volar locked plates have increased in popularity the past several years. In light of the recent literature, it would have been interesting to evaluate the breakdown per age group versus treatment methods used.<sup>1,2</sup>

Interestingly, the patient's length of stay contrasted to what would be expected after a distal radius fracture. The authors stated ~95% of operatively treated distal radius

fractures have at least a one night stay in the hospital. The average length of stay for patients in this study was 2.3 days. The authors commented in a response to my review that “Free health care in Finland is provided by the government and a third party like an insurance company cannot influence the treatment of an individual patient in Finland.” I question why would the patients really need a 2.3-day stay? It is not cost-effective and I cannot understand which intervention they are receiving while in the hospital that cannot be completed at home or on an outpatient basis.

A weakness of this study includes that they really cannot comment on the overall incidence of distal radius fractures. So we do not know whether there is an increase in osteoporotic distal radius fractures. However, they found a 100% rise in the surgical treatment between 1998 and 2008, and they feel it is because of the rise in surgery cases rather than a number of total fractures. The authors state volar locking plates became popular in Finland in 2004. Plating more than doubled between 2006 and 2008, which indicates this trend has definitely caught on in the country. As plating rose in Finland, external fixation decreased. But external fixation was the most common operation accounting for 59% of the cases in the study. Percutaneous pinning was consistent in 13% of procedures throughout the study and really did not vary.

There was a marked gender difference in the number of surgeries performed: 73% of women and 27% of men. The number of platings was especially noted to increase in women over 60 years. The Register covered the entire Finnish pop-

ulation age greater than 18 years old. So it is difficult to draw conclusions regarding whether the use of the plates was just in the older patient. There is no information provided on the surgeon population and age distribution of the surgeon or years in practice as the senior surgeons might not use the plate regularly.

Overall, this study does contribute to the literature by demonstrating the trends in distal radius fixation. Because we do not know the true incidence of fractures, questions still remain as to why there are more surgeries being performed. These may be unnecessary in light of results recently reported that nonoperative treatment of distal radius fractures in the elderly can lead to similar results as operative fixation.<sup>1</sup> It seems the authors are confirming the popularity of the volar locked plate for distal radius fractures. Would the number of surgeries increase for other fractures as more novel technology becomes popularized?

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