ON THE CLASSIFICATION, EPIDEMIOLOGY, AND OUTCOME OF ACETABULAR FRACTURES

Madelene Albrektsson

Department of Orthopaedics

Institute of Clinical Sciences

Sahlgrenska Academy, University of Gothenburg

Gothenburg, Sweden

UNIVERSITY OF GOTHENBURG

2025

Cover photo:
Madelene Albrektsson, Louise Alm, and Andreas Albrektsson

Layout:
Guðni Ólafsson / GO Grafik
gudni@gografik.se

Illustrations:
Pontus Andersson / Pontus Art Production

On the classification, epidemiology, and outcome of acetabular fractures

madelene.albrektsson@vgregion.se

ISBN 978-91-8115-016-2 (PRINT)
ISBN 978-91-8115-017-9 (PDF)
http://hdl.handle.net/2077/84440

Printed in Borås, Sweden 2025
Printed by Stema Specialtryck AB

Trycksak
3041 0234

"We may not be able to get certainty, but we can get probability, and half a loaf is better than no bread."

C.S. LEWIS

ABSTRACT

Acetabular fractures were traditionally managed non-surgically, largely due to the absence of effective surgical methods. Since the 1960's, the field of acetabular fracture surgery has undergone rapid advancements. The Judet/Letournel classification system and analysis of these fractures have been widely disseminated and embraced by acetabular surgeons worldwide. Advancements in surgical techniques, radiographic imaging, and implant technology have broadened the spectrum of treatment options. An ageing, more active population has increased the demand for treating complex fractures in osteoporotic bone, placing a greater burden on the treating surgeon. Recent advancements and evolving treatment methodologies warrant continued investigation of this patient cohort. This thesis aims to contribute to understanding the classification, epidemiology, and treatment outcomes of acetabular fractures using data from the Swedish Fracture Register (SFR). The SFR contains a large cohort of acetabular fracture patients that have yet to be studied and presented.

Study I in this thesis is a validation study to assess the accuracy of the fracture classification in the SFR and concurrently evaluate its practical utility. The findings of this study demonstrate a moderate level of concordance with the established gold standard, a level deemed acceptable for scientific reporting. However, cautious interpretation is advised for specific fracture types. Study II is an epidemiological study providing one of the largest cohorts of acetabular fractures (n=2,132) and includes non-surgically and surgically treated patients. This study shows that the typical patient sustaining an acetabular fracture is >70 years of age, male, and has experienced a low-energy trauma event. The mortality after an acetabular fracture is comparable to the well-known high mortality following hip fractures. Studies III and IV focus on the outcome after the trauma event. Study III reports clinical results on patient-reported outcome measures (PROMs) and confirms the presence of functional impairment in all patient groups 1-year post-injury. Study IV presents findings related to therapeutic failure and subsequent surgical intervention requirements. Following a five-year period, 17% of patients treated with open reduction and internal fixation (ORIF) for acetabular fractures required a secondary arthroplasty procedure.

SAMMANFATTNING PÅ SVENSKA

Acetabulumfrakturer har traditionellt behandlats icke-kirurgiskt, främst på grund av bristen på bra kirurgiska metoder. Sedan 1960-talet har dock fältet för kirurgi av frakturer i acetabulum utvecklats snabbt. Systemet för frakturklassificering utvecklat av Judet/Letournel samt deras sätt att analysera dessa frakturer har spridits och anammats av acetabulumkirurger världen över. Utvecklingen av kirurgiska metoder, radiologisk avbildning och förbättrade implantat har ökat de möjliga behandlingsalternativen. En åldrande och mer aktiv befolkning har ökat behovet av att operera komplexa frakturer även i osteoporotiskt ben vilket ställer högre krav på den behandlande kirurgen. Till följd av denna utveckling och förändringar i behandlingsmetoder finns det ett behov av att studera denna patientgrupp närmare. Denna avhandling syftar till att bidra med mer information och förståelse kring klassifikation, epidemiologi och behandlingsresultat för patienter med acetabulumfrakturer med hjälp av data från det Svenska Frakturregistret (SFR). SFR innehåller en stor kohort av patienter med acetabulumfrakturer som ännu inte har studerats och presenterats.

Studie I i denna avhandling är en valideringsstudie med syfte att bedöma noggrannheten och tillförlitligheten av frakturklassificeringen i SFR och samtidigt utvärdera dess användbarhet. Resultatet av denna studie visar en måttlig överensstämmelse med den framtagna ”Gold standard”, en nivå som anses acceptabel för vetenskaplig rapportering. Viss försiktighet vid tolkning av data för enskilda frakturtyper rekommenderas dock. Studie II är en epidemiologisk studie som tillhandahåller en av de största kohorterna av acetabulumfrakturer (n=2132) och inkluderar både icke-kirurgiskt och kirurgiskt behandlade patienter. Studien visar att den typiska patienten som drabbas av en acetabulumfraktur är >70 år, man och har varit med om ett lågenergitrauma. Dödligheten efter en acetabulumfraktur är jämförbar med den välkänt höga dödligheten efter höftfrakturer. Studie III och IV fokuserar på utfallet efter skadan. Studie III rapporterar kliniska resultat i form av patientrapporterade utfallsmått (PROMs) och bekräftar funktionsnedsättning i alla patientgrupper ett år efter skadan. Studie IV beskriver resultat i form av misslyckad behandling och behov av ytterligare kirurgi. Efter fem år har 17% av de patienter som behandlats med öppen reposition och intern fixation (ORIF) för acetabulumfraktur genomgått sekundär behandling i form av en höftprotes.

MADELENE ALBREKTSSON

ACETABULAR FRACTURES

LIST OF PAPERS

The thesis is based on the following papers, referred to in the text by their Roman numerals.

I. Albrektsson M, Wolf O, Enocson A, Sundfeldt M.

Validation of the classification of surgically treated acetabular fractures in the Swedish Fracture Register

Injury 2022;53:2145-2149.

II. Albrektsson M, Möller M, Wolf O, Wennergren D, Sundfeldt M.

Acetabular fractures: Epidemiology and mortality based on 2,132 fractures from the Swedish Fracture Register

Bone Jt Open 2023;4:652-658.

III. Albrektsson M, Möller M, Sundfeldt M, Wennergren D, Wolf O, Bergdahl C.

Patient-reported outcome following an acetabular fracture: an observational study of 385 patients from the Swedish Fracture Register

Acta Orthopaedica 2024;*95*:695–700.

IV. Albrektsson M, Möller M, Sundfeldt M, Wennergren D, Wolf O.

Secondary surgery and mortality following primary treatment for acetabular fractures – an observational study from Swedish national quality registers

Submitted

TABLE OF CONTENTS

ABBREVIATIONS

FRACTURE TYPES

PW	Posterior Wall
PC	Posterior Column
AW	Anterior Wall
AC	Anterior Column
TRANS	Pure Transverse
T	T-shaped
PC+PW	Posterior Column and Posterior Wall
TRANS+PW	Transverse and Posterior Wall
A+PHT	Anterior and Posterior HemiTransverse
ABC	Associated Both Column

OTHER ABBREVIATIONS

AO	Arbeitsgemeinschaft für Osteosynthesefragen
AIP	Anterior IntraPelvic approach
ASIS	Anterior Superior Iliac Spine
CHP	Combined Hip Procedure
CI	Confidence Interval
CT	Computed Tomography

EIF	Extended Iliofemoral approach
EQ-5D	EuroQol 5 Dimension
EQ-VAS	EuroQol Visual Analogue Scale
GS	Gold Standard
HHS	Harris Hip Score
HR	Hazard Ratio
IQR	Interquartile Range
MIC	Minimal Important Change
MID	Minimal Important Difference
NPR	National Patient Register
NQR	National Quality Register
ORIF	Open Reduction Internal Fixation
OTA	Orthopaedic Trauma Association
PROM	Patient Reported Outcome Measure
PSIS	Posterior Superior Iliac Spine
SAR	Swedish Arthroplasty Register
SF-36	36-Item Short Form Health Survey
SFR	Swedish Fracture Register
SI-joint	Sacroiliac joint
SMFA	Short Musculoskeletal Function Assessment
THA	Total Hip Arthroplasty
TKA	Total Knee Arthroplasty

DEFINITIONS IN SHORT

Accuracy	The degree to which an assessment correctly reflects the reality/true value.
Bias	A systematic error or deviation from the truth in data collection, analysis, or interpretation that may lead to inaccurate conclusions.
Cohen's kappa	A statistical measure that assesses the level of agreement between two raters or observers, beyond what would be expected by chance.
Confidence interval	A range of values used to estimate the true value of a population parameter, indicating the degree of uncertainty or precision in a sample estimate. For example, a 95% confidence interval means that if the study were repeated multiple times, the true value would fall within this range 95% of the time.
Completeness	The extent to which all possible cases in a population is included in a database or register.
Coverage	The extent to which a database represents the entire target population. In this thesis, the proportion of orthopaedic departments enrolled in the SFR.
Gold standard	A best practice against which other measurements are compared for accuracy, reliability, and validity.
Hazard ratio	The rate at which an event occurs in one group relative to another over time.

Intrarater reliability	The consistency or stability of measurements or assessments made by the same rater or observer when the process is repeated under similar conditions.
Interrater reliability	The degree of agreement or consistency between two or more raters or observers when they assess the same phenomenon or subject.
Kaplan-Meier	A statistical technique used to estimate and visualise the probability of survival or the time to an event (in this thesis secondary surgery or death) over time.
Mortality	The incidence or rate of death within a specific population or group, often within a defined period.
Validity	The extent to which a test, measurement, or assessment accurately measures what it is intended to measure.

01.

MADELENE ALBREKTSSON

ACETABULAR FRACTURES

INTRODUCTION

The management of acetabular fractures has undergone substantial evolution, driven by advancements in comprehending the fracture, technological innovations, and surgical techniques [1-3]. In the early stages of medical history, acetabular fractures were poorly understood and managed non-surgically, often resulting in long-term disabilities and severe complications. The analysis and treatment of these fractures underwent a revolutionary transformation in the 1960s, spearheaded by Professor Robert Judet and his resident and successor, Emile Letournel. Following their lead, others have further developed treatment and surgical methods to improve patient outcomes. Advancements in imaging techniques, including the widespread availability of computed tomography (CT) scans, have allowed a more detailed understanding of fracture patterns and the complex anatomy of the acetabulum. This advancement in imaging methods has also aided surgeons in preoperative planning and choosing the most suitable approach for each specific fracture. Moreover, the development of better surgical tools and implants has improved the outcomes of acetabular fracture management [4-7].

The ongoing change and development in acetabular fracture treatment along with an ageing and more active population, also require evaluation of the current treatment concepts to continue improving the outcome for these patients. The use of national quality registers (NQRs) provides larger cohorts of patients and allows us to study the epidemiology and results for these patients on a larger scale.

ANATOMY OF THE PELVIS AND ACETABULUM

The innominate bone, or the hemipelvis, is formed by the fusion of three bones: the ileum, ischium, and pubis [8]. These three bones meet in the acetabulum and form three acetabular socket parts. The ilium is the larger of the three bones, forming the ala (iliac wing), iliac crest, and the body of the ilium, which forms the superior part of the acetabulum (the acetabular roof). The body of the ischium forms the posterior part of the acetabulum. The ramus of the ischium forms the posterior part of the obturator foramen. The pubis forms the anterior part of the acetabulum along with the superior ramus. The inferior ramus of the pubis forms the anterior part of the obturator foramen. Figures 1 and 2 illustrate the different parts of the bony pelvis.

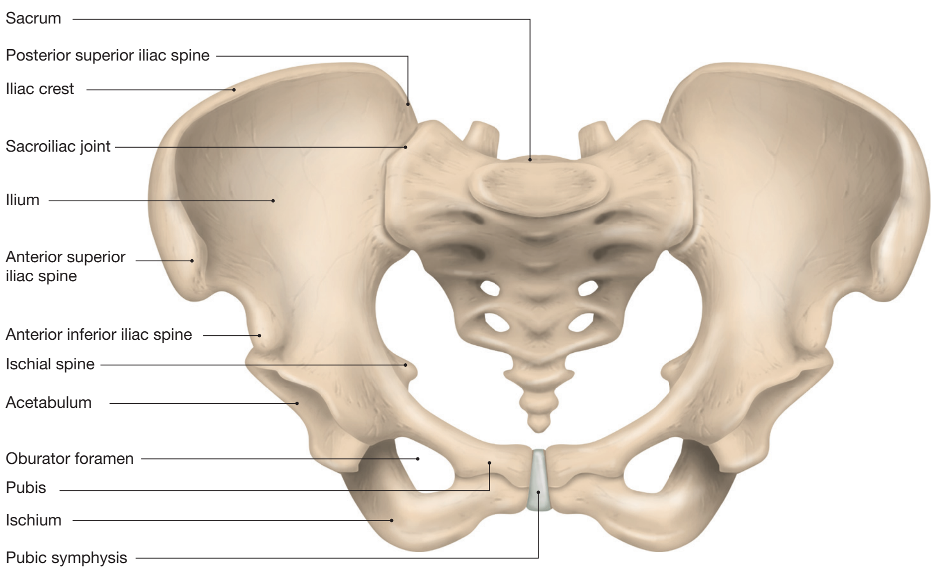


Figure 1. Anatomy of the bony pelvis.

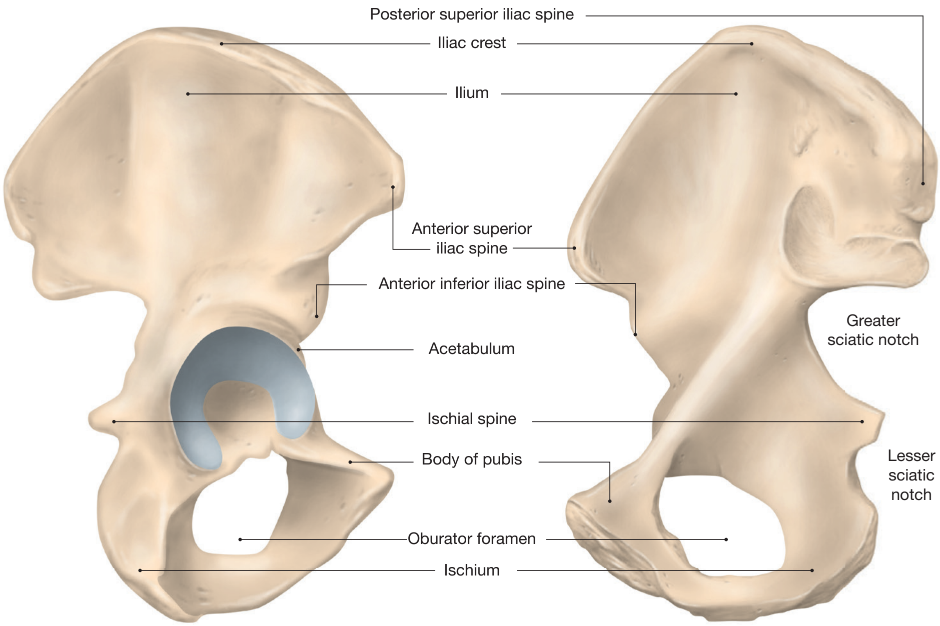


Figure 2. Lateral and medial view of the acetabulum and hemipelvis.

HISTORY AND CLASSIFICATION OF ACETABULAR FRACTURES

Until the 1950s, non-surgical treatment was the treatment of choice almost universally for acetabular fractures, mainly because good surgical methods were unavailable. The literature describes very infrequent attempts of operative treatment, mostly in cases with central dislocation of the femoral head. It was in this context that Professor Robert Judet started treating more patients surgically due to disappointing results following non-surgical treatment [(9)].

The field has grown and developed rapidly since Judet and Letournel's early publications. Imaging techniques have improved, and computed tomographies with 3D reconstructions are now standard in many countries to examine acetabular fractures preoperatively. New surgical techniques and instruments have been developed to facilitate treatment.

Early studies focused mainly on the operative treatment of younger patients with acetabular fractures after high-energy trauma. The evolution of better surgical techniques, combined with an ageing population with higher functional demands, has also led to the operative treatment being offered to elderly patients. This has opened a new field and led to concerns about how to treat acetabular fractures in patients with osteopenic bone. The orthogeriatric patient is often a main topic of discussion when fracture surgeons meet today.

THE TWO-COLUMN CONCEPT

Judet and Letournel developed the "two column concept" to better understand the architecture of the innominate bone. This concept was presented in their classical article in 1964 [10], which was further developed and presented in 1966 [11]. This concept remains the foundation for understanding acetabular fractures and the basis for the Letournel classification system described below.

The acetabulum is described as positioned under an inverted Y. The Y consists of two columns: one posterior and one anterior. The posterior, ilio-ischial column supports the posterior part of the acetabular articular surface, includes the greater and lesser sciatic notches, and extends down to the ischial tuberosity. The anterior, ilio-pubic column extends from the anterior part of the iliac crest to the pubic symphysis. The posterior column meets the anterior column at an angle of about 60° just above the anterior column midlevel (Figure 3) [9].

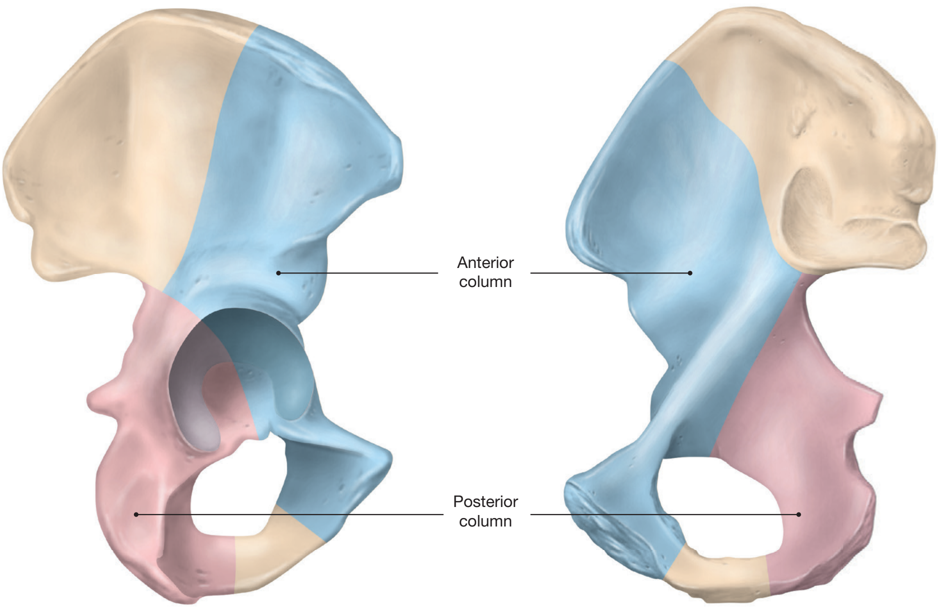


Figure 3. Judet and Letournel description of the posterior and anterior columns.

THE LETOURNEL CLASSIFICATION SYSTEM

Judet and Letournel developed the classification system that is still the most used classification for acetabular fractures worldwide. This system interprets the fracture patterns and aids the treating surgeon in choosing the appropriate approach for each fracture. Although acknowledging the number of fracture patterns that can occur when forces are applied to the femoral head at different angles is infinite and impossible to divide into strict categories, they identified 10 main fracture groups.

The Letournel classification system comprises five elementary fracture patterns and five associated patterns (Figure 4). The elementary fractures detach the entire or part of only one column, either the posterior or anterior. The exception is the pure transverse fracture, which is also included in the elementary fracture patterns because of its purity.

The five elementary fracture patterns:

- Posterior wall fracture (PW)
- Posterior column fracture (PC)
- Anterior wall fracture (AW)
- Anterior column fracture (AC)
- Pure transverse fracture (TRANS)

The associated fractures are combinations of at least two elementary fracture patterns.

The five associated fracture patterns:

- T-shaped fracture (T)
- Posterior column and posterior wall fracture (PC+PW)
- Transverse and posterior wall fracture (TRANS+PW)
- Anterior (column or wall) and posterior hemitransverse fracture (A+PHT)
- Both-column fracture (ABC)

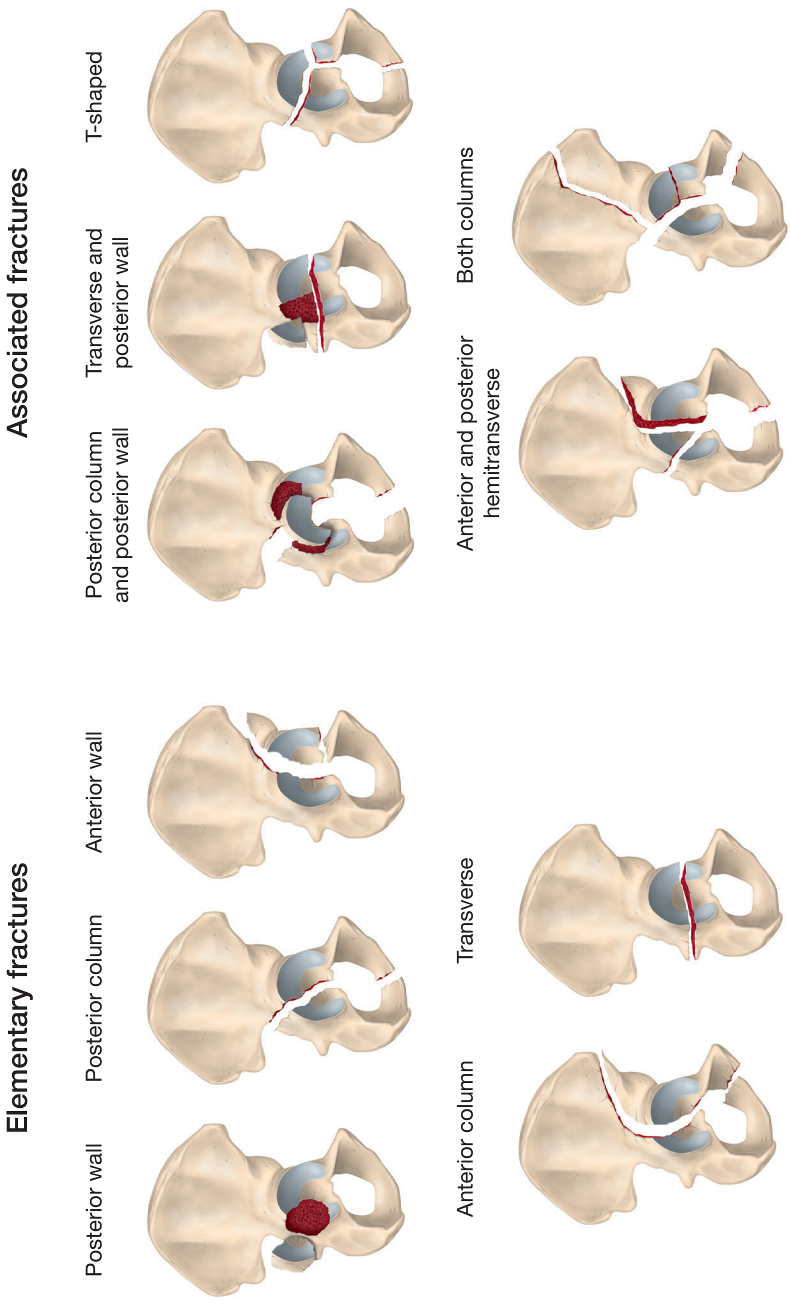
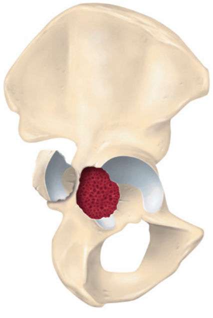


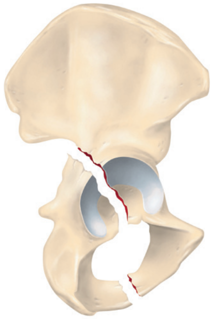
Figure 4. The 10 fracture classes according to Letournel. Showing right hemipelvis lateral view.

A review of the ten fractures reveals that three are absent when considering a symmetrical representation of fractures in the two columns. These would be the posterior column and anterior hemitransverse fracture (PC+AHT) and the anterior wall and anterior column fracture (AW+AC). In addition, the A+PHT should be two classes instead of one, namely the anterior column and posterior hemitransverse (AC+PHT) and the anterior wall and posterior hemitransverse (AW+PHT). However, the AC+PHT and AW+PHT fractures have been grouped because they both require the same approach and adding a fracture line through the ischio-pubic ramus is of little importance and is never fixed operatively. Furthermore, the T-shaped fracture is difficult to distinguish from the PC+AHT fracture on plain radiographs, which was the available imaging at the time of the development of the classification system. However, even after CT scanning with 3D imaging became available, these two fracture types remained in the same group (T-shaped fractures) as they required the same approach. The AW+AC fractures are included in the AW group because, in this case, adding a fracture through the ischio-pubic ramus is clinically insignificant. Another combination that one might deem to be missing is the combination of a posterior wall fracture with an anterior hemitransverse. However, this combination is not feasible, as a fracture involving the greater sciatic notch would necessitate classification within the transverse category [9].



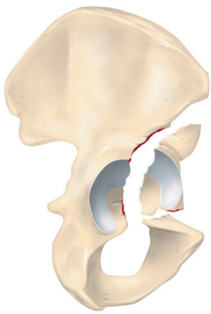
POSTERIOR WALL FRACTURE

The PW fracture separates a part of the posterior articular surface of the acetabulum. It is often associated with a posterior dislocation of the femoral head. The detached part of the posterior wall may be composed of one or more fragments, potentially involving the posterior articular surface but excluding the posterior horn and roof [9].



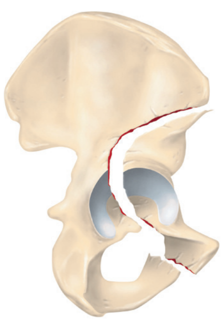
POSTERIOR COLUMN FRACTURE

The typical PC fracture detaches the whole posterior column in one fragment. The fracture line starts at the greater sciatic notch, descends through the retro-acetabular and quadrilateral surfaces and usually fractures the ischio-pubic ramus at a variable point [9].



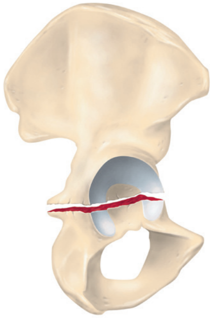
ANTERIOR WALL FRACTURE

The AW fracture separates a part of the anterior articular surface of the acetabulum. The fracture line starts anteriorly a little below the anterior inferior iliac spine, descends through the cotyloid fossa, crosses the ilio-pectineal line, and exits the bone through the superior pubic ramus at the level of the ischio-pubic notch. As mentioned above, a combination of anterior wall fracture with the addition of a fracture line through the ischiopubic ramus (anterior column) is also included in this group [9].



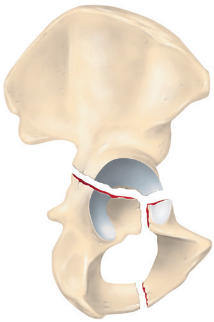
ANTERIOR COLUMN FRACTURE

The AC fracture extends from the middle of the ischio-pubic ramus to any point above as far backwards as the mid-point of the iliac crest. As a result, the size of the detached segment exhibits significant variation. The AC fractures are divided into four categories depending on which level the fracture line exits the bone: very low (anterior horn of the articular surface), low (psoas gutter), intermediate (anterior interspinous notch) and high (iliac crest) [9].



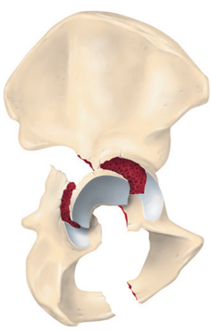
PURE TRANSVERSE FRACTURE

The TRANS fracture cuts transversely through the acetabulum, dividing both the anterior and posterior columns. The plane and direction of the fracture line may vary. Three subgroups are described depending on the fracture level: Infra-tectal (inferior part of the acetabular walls, horizontal split of the cotyloid fossa), juxta-tectal (through the highest point of the cotyloid fossa) and trans-tectal (at roof level) [9].



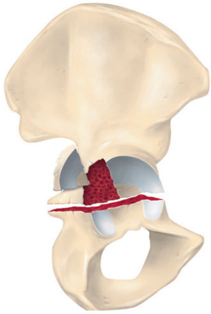
T-SHAPED FRACTURE

The T fracture is transverse, combined with an oblique or vertical split through the ischio-pubic segment. The stem of the T is described to take three directions: Vertical (through the middle of the ischio-pubic ramus), anterior (anterior part of the ischio-pubic notch to the body of the pubis) and posterior (body of the ischium) [9].



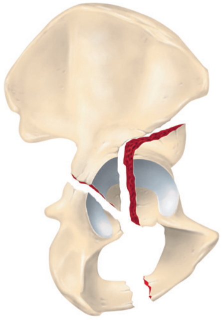
POSTERIOR COLUMN AND POSTERIOR WALL FRACTURE

The PC+PW fracture includes any PW fracture combined with a fracture of the posterior column. The fracture line of the posterior column component starts in the cavity created by the posterior wall fracture and extends to the greater sciatic notch. Distally, it usually reaches the ischio-pubic notch, but it never cuts the ilio-pectineal line. The ischio-pubic ramus may or may not be broken [9].



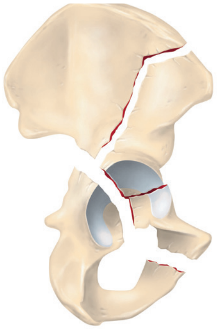
TRANSVERSE AND POSTERIOR WALL FRACTURE

As its name suggests, the TRANS+PW fracture is a composite injury combining elements of both transverse and posterior wall fracture patterns. It is often accompanied by a posterior and sometimes central dislocation of the femoral head [9].



ANTERIOR AND POSTERIOR HEMITRANSVERSE FRACTURE

The A+PHT fracture combines a fracture of the anterior part of the acetabulum (wall or column) and a fracture of the posterior column, the same as the posterior half of a pure transverse fracture. The fracture pattern includes all the variations of the AC fracture and the posterior half of the TRANS fracture [9].



BOTH-COLUMN FRACTURE

The ABC fracture separates the anterior and posterior columns from each other, together with their respective segments of the articular surface. No part of the articular surface is in contact with the only stable fragment of the iliac wing connected to the sacrum and axial skeleton. These fractures often become more complex because secondary fractures split the main fragments [9].

The Letournel classification system is known to be difficult to fully understand. It has been criticised for being too complex, oversimplified, and incomplete [12–15]. Some authors suggest alternative classification systems [14–16], but the Letournel classification has stood the test of time and is still the most used system worldwide. The Swedish fracture register (SFR) uses the Letournel classification, adapted to the AO/OTA system for fracture classification [17].

EPIDEMIOLOGY

The incidence of acetabular fractures is increasing primarily among the elderly population while decreasing in the younger population [3, 18–22]. Previous studies have shown that 3 to 11 out of 100,000 individuals sustain an acetabular fracture each year [18, 20–22]. For unknown reasons, there is a male predominance among these patients [18, 19, 21–23]. A change in fracture patterns and injury mechanisms has been noticed over time, exhibiting a contemporary spectrum notably different from that delineated by Judet and Letournel in the 1960s [2, 10].

Two main patient groups can be identified: older adults suffering low-energy trauma, and younger patients with fractures following high-energy trauma mechanisms. The early studies by Letournel almost exclusively described the latter group of patients, and surgery on any patient >60 years of age was dissuaded [10]. The combination of an ageing population with increasing functional needs and advancements in surgical techniques has led to a greater frequency of surgical interventions among older patients. The change in the patient spectrum is most likely also the cause of the change in fracture patterns. Fragility fractures are becoming increasingly prevalent and may pose challenges in classification using the Letournel system. Fractures involving the acetabulum's anterior column and anterior wall are much more frequent today than presented in early studies [2, 19, 24]. Osteopenic bone structure and low-energy trauma in the form of direct force to the greater trochanter may explain this increase.

TREATMENT

The goal of treatment is to restore the anatomy of the acetabulum, provide stability to the hip joint, and promote early mobilisation to prevent cardiopulmonary complications. To meet the needs of the ageing but still very active population suffering acetabular fractures, surgical approaches have been improved and have enabled the reduction and stable fixation of more fracture types. Open reduction with screw and plate fixation are still the most common method of surgery for these fractures. Yet, newer techniques (e.g. computed navigation) have enabled more percutaneous fixation methods. Primary total hip arthroplasty (THA) or a combination of THA and plate fixation (combined hip procedure, CHP) have also become a more frequent option for surgical management of these fractures [2, 25, 26]. While surgical procedures have evolved considerably, the majority of patients with acetabular fractures are treated non-surgically. The surgery indications depend on factors such as patient age, level of function, comorbidities, fracture type, and degree of fracture displacement.

NON-SURGICAL TREATMENT

Historically, acetabular fractures were typically managed non-surgically due to a limited understanding of the injury and a lack of effective surgical methods. Traditional treatment methods usually encompassed bed rest, traction, and immobilisation. However, the importance of early mobilisation has been recognised and non-surgical treatment is reserved for minimally displaced and stable fracture patterns. This treatment option remains the most common treatment choice, demonstrating favourable outcomes when patient selection is carefully considered [27, 28].

Non-surgical treatment usually involves partial weight bearing for a specified period (i.e. 6-12 weeks) and patients should be provided with dedicated physiotherapy. However, many older patients cannot comply with partial weight bearing and should be allowed to weight bear as tolerated [29]. Nonetheless, the importance of professionally supervised early ambulation cannot be overemphasised to avoid further falls. Additionally, pain management and thromboprophylaxis are crucial. Both clinical assessment of symptomatic improvement and radiographic controls of fracture displacement are warranted although intervals can be adjusted according to the fracture pattern.

OPEN REDUCTION INTERNAL FIXATION (ORIF)

Among the operatively treated patients, open reduction and internal fixation (ORIF) is usually the treatment of choice to restore anatomy and preserve the native hip joint, especially in younger patients [9, 30].

Surgical approaches to the acetabulum have evolved significantly. Some large extensile approaches used in the early days of acetabular fracture surgery has now largely given way to less invasive and smaller approaches [31]. One example is the extended iliofemoral (EIF) approach, used in the original series by Letournel [32]. Extensile approaches, including the EIF and the triradiate approach, have declined in popularity due to a high incidence of complications such as avascular necrosis, infections, and thrombosis and are now infrequently employed [31, 33, 34].

The fracture classification guides the surgeon in the choice of surgical approach. The Kocher-Langenbeck approach is often used to reach the acetabulum's posterior parts. The anterior column and medial aspects of the acetabulum and parts of the iliac wing can be addressed through the ilioinguinal, anterior intrapelvic or pararectus approaches. These are the current workhorses of acetabular fracture surgery, briefly described below. For the anterior surgical approaches, in cases where there is a medialisation of the femoral head, traction from a Schantz pin in the greater trochanter may facilitate fracture reduction.

KOCHER-LANGENBECK APPROACH

The Kocher-Langenbeck approach provides posterior access to the acetabulum, allowing for the reduction and fixation of fractures involving the posterior wall, posterior column, and associated fractures [35, 36]. The retro-acetabular surface is exposed from the ischial tuberosity to the lower region of the iliac wing. The quadrilateral plate can be palpated, and clamps can be positioned through the greater sciatic notch.

The patient can be positioned either in a lateral position on the unaffected side or in the prone position. During the procedure, keeping the knee flexed and the hip extended is important to avoid tension on the sciatic nerve. A prone position may facilitate this way of relieving sciatic nerve tension (35). However, prone position has been associated with more frequent post-surgical sciatic palsies (37).

The skin incision starts a few centimetres distal and lateral to the posterior superior iliac spine (PSIS). The incision continues anteriorly over the greater trochanter, where it is curved distally to align with the lateral aspect of the femoral shaft. The incision ends at the mid-third of the thigh. The gluteus maximus is split in line with its fibres up to the first neurovascular bundle, keeping one-third of the muscle anteriorly and two-thirds posteriorly. Distally, the iliotibial tract is incised to the mid-third of the thigh. The insertion of the gluteus maximus muscle at the gluteal tuberosity of the femur can be completely or partially detached to allow less tension and easier mobilisation. The piriformis muscle is identified, tagged with a suture, and dissected. The sciatic nerve is identified, and the underlying triceps coxae (gemellus superior, obturator internus, and gemellus inferior) are marked and dissected in the same manner as the piriformis. The triceps coxae are reflected to cover the sciatic nerve. Retractors are placed in the greater and lesser sciatic notch.

This incision can be further developed using a trochanteric osteotomy to provide additional cranial and anterior exposure. Ganz's safe surgical hip dislocation technique can be employed using this incision, which also includes a trochanteric osteotomy (38).

To close the incision, all tendons are reinserted. The iliotibial tract is sutured, and the gluteus maximus split is closed with adaptation sutures.

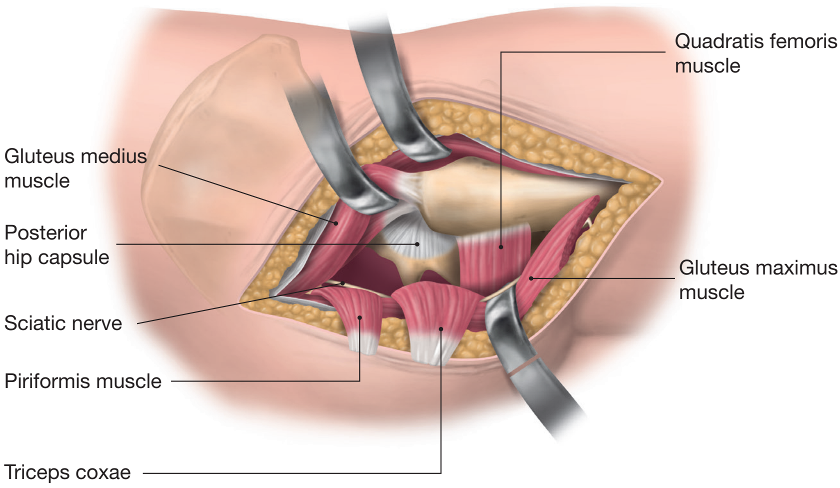


Figure 5. The Kocher Langenbeck approach to the posterior acetabulum.

ILIOINGUINAL APPROACH

The ilioinguinal approach, developed by Professor Letournel, allows access to the anterior column and medial aspect of the acetabulum (9, 32, 35, 39, 40). The inner aspect of the pelvis, from the sacroiliac (SI) joint to the pubic symphysis, can be visualised. Fractures managed through this approach include the anterior wall, anterior column, and associated anterior and posterior hemitransverse fractures. The ilioinguinal approach can also manage certain T-shaped, pure transverse, and both column fractures.

The patient is placed supine on a radiolucent table. A skin incision starts about 2 cm above the pubic symphysis, curving laterally toward the anterior superior iliac spine (ASIS) and continuing along the iliac crest posteriorly. The deep dissection is performed through three windows. The first (lateral) window is developed by incising the abdominal muscle fascia along the iliac crest and lifting the iliacus muscle by subperiosteal dissection. This window allows access to the inner aspects of the ilium from the SI joint to the lateral border of the iliopsoas muscle. The second (middle) window is located between the iliopsoas muscle with the femoral nerve laterally and the external iliac vessels medially, providing access to the pelvic brim and the quadrilateral plate from the SI joint to the lateral third of the superior pubic ramus. The fascia of the external abdominal oblique muscle is incised from the ASIS to the pubic tubercle, and the inguinal ligament is split longitudinally at the proximal third. Care should be taken not to injure the lateral femoral cutaneous nerve running laterally. The third (medial) window is situated medial to the external iliac vessels and lateral to the spermatic cord or round ligament, which are mobilised. This area can be exposed by either retracting the rectus abdominis muscle or releasing its insertion. This window grants access to the inner surface of the quadrilateral plate and the anterior pelvic ring from the pubic symphysis to the external iliac vessels.

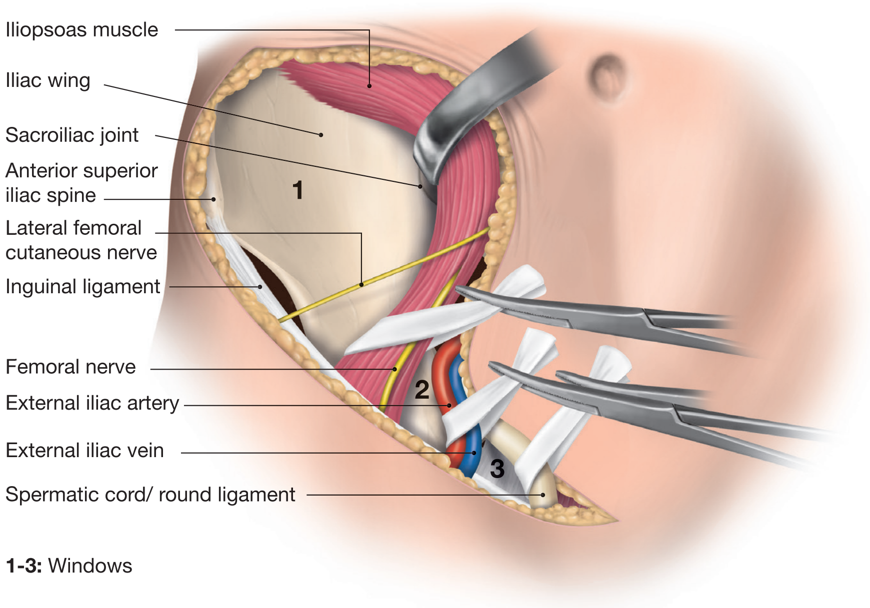


Figure 6. The three windows of the ilioinguinal approach. The first window lies beneath the iliopsoas muscle. The second window is located between the iliopsoas and the external iliac vessels. The third window lies medial to the external iliac vessels and lateral to the spermatic cord/round ligament.

The approach's closure includes reconstructing the inguinal ligament, suturing of the abdominal fascia, and reintroducing the abdominal wall origin to the iliac crest.

MODIFIED STOPPA / ANTERIOR INTRAPELVIC APPROACH (AIP)

At numerous facilities, the ilioinguinal approach has been superseded by the modified Stoppa, also known as the anterior intrapelvic approach (AIP). This approach is less invasive, with fewer complications, less blood loss, and shorter operating time [41, 42]. The Stoppa approach was first described for the treatment of inguinal hernias [43]. Cole and Bolhofner introduced the modified Stoppa approach for acetabular fracture fixation in a publication in 1994 [44]. Access is allowed to the superior rami, the pelvic brim, and the quadrilateral plate and extends proximally to the sacroiliac joint [45]. Depending on the area needing access, this approach can be used alone or in combination with the first window of the ilioinguinal approach. The indications for the AIP approach are the same as for the ilioinguinal approach.

With the patient in the supine position, the AIP approach uses the Pfannenstiel or a midline incision. The surgeon is positioned on the opposite side of the fractured acetabulum for the best view. The rectus abdominis muscles are separated through the linea alba and the underlying bladder and peritoneum are protected. The rectus insertion on the injured side is released to allow access to the superior ramus. It is not uncommon that the rectus has already been released at the time of the trauma. The dissection continues posteriorly along the pelvic brim to the sacroiliac joint. To release tension and facilitate the exposure, knee support is advised for flexion of the hip. The corona mortis is identified and ligated. The external iliac vessels, femoral nerve, and psoas muscle are elevated and retracted laterally. The obturator nerve is identified and protected during the procedure. The greater sciatic notch is not visible through this approach, but a retractor is usually placed in the notch and a clamp can be positioned to aid fracture reduction.

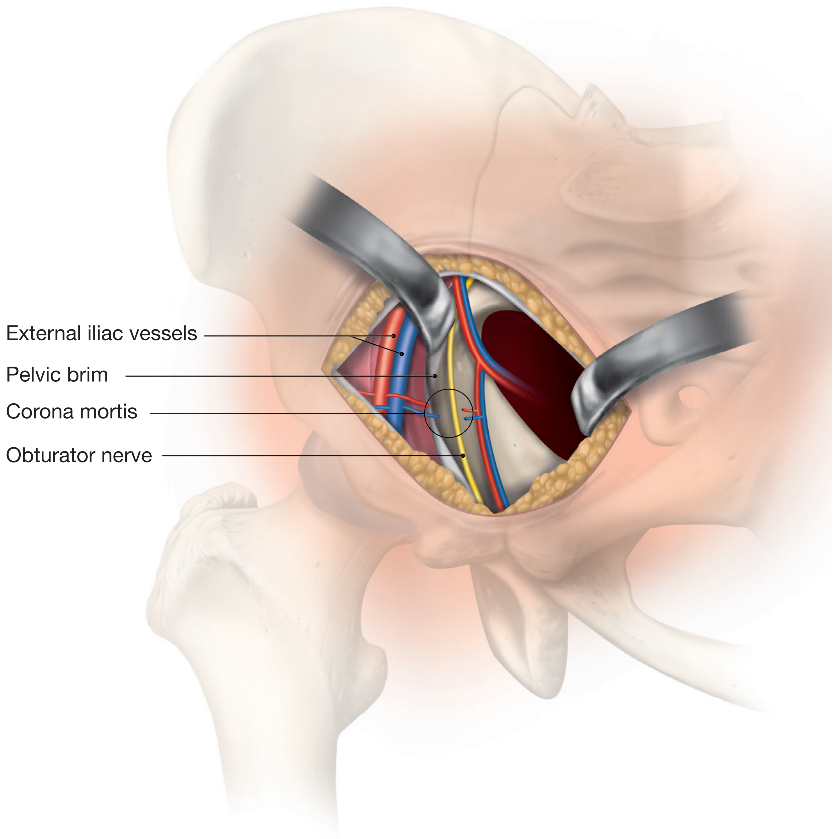


Figure 7. The modified Stoppa/ anterior intrapelvic approach to the acetabulum.

PARARECTUS APPROACH

Marius J.B. Keel et al. described the pararectus approach in 2012 as an alternative to the AIP and the ilioinguinal approach [46,47]. Like the AIP, this approach allows access to the quadrilateral plate but in a different angle that, in some cases, may facilitate fracture reduction. Additionally, the pararectus approach provides better access to the iliac wing.

The patient is placed supine on a surgical table, and the skin incision is made along the lateral border of the rectus abdominis. Three landmarks – the pubic symphysis, the ASIS, and the umbilicus – are used to determine the correct position of the skin incision. These three landmarks form a triangle, and the incision is slightly curved starting at the lateral third of the umbilicus-ASIS line and reaching the medial third of the ASIS-symphysis line (Figure 8).

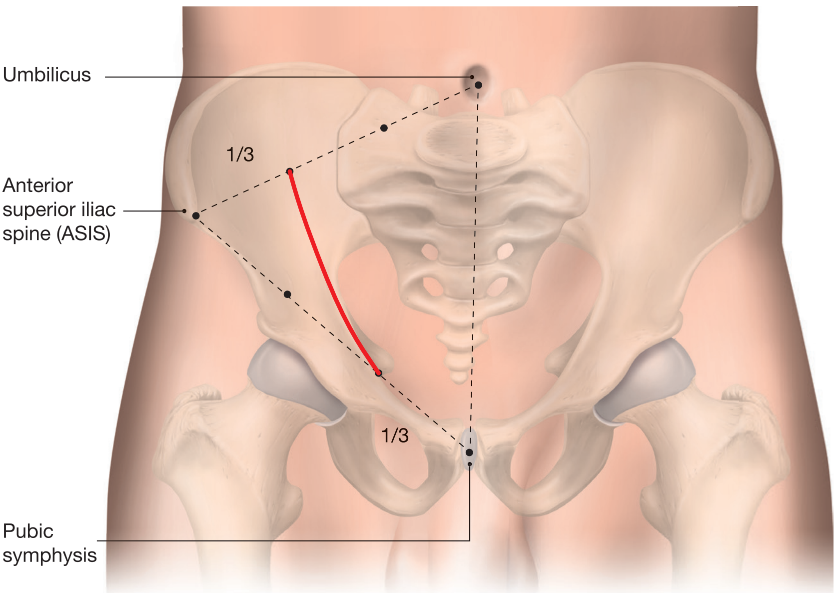


Figure 8. Landmarks and skin incision for the pararectus approach.

The fascia of the abdominal wall and the rectus sheath are incised. The underlying transversalis fascia is incised carefully so as not to perforate the peritoneum or the inferior epigastric vessels. The external iliac vessels are identified and mobilised. Further dissection can be adjusted according to fracture pattern and depends on which areas must be exposed. The pararectus approach describes five windows that reach different regions of the acetabulum:

- *First window*: Between the iliac crest and the iliopsoas muscle.
- *Second window*: Between the iliopsoas muscle and the external iliac vessels.
- *Third and fifth window*: Between the external iliac vessels and the spermatic cord or round ligament. The third window lies above the pelvic brim, and the fifth is below.
- *Fourth window*: Medial to the spermatic cord or round ligament.

Similar to the AIP approach, ligation of the corona mortis is necessary, while the obturator nerve requires identification and preservation.

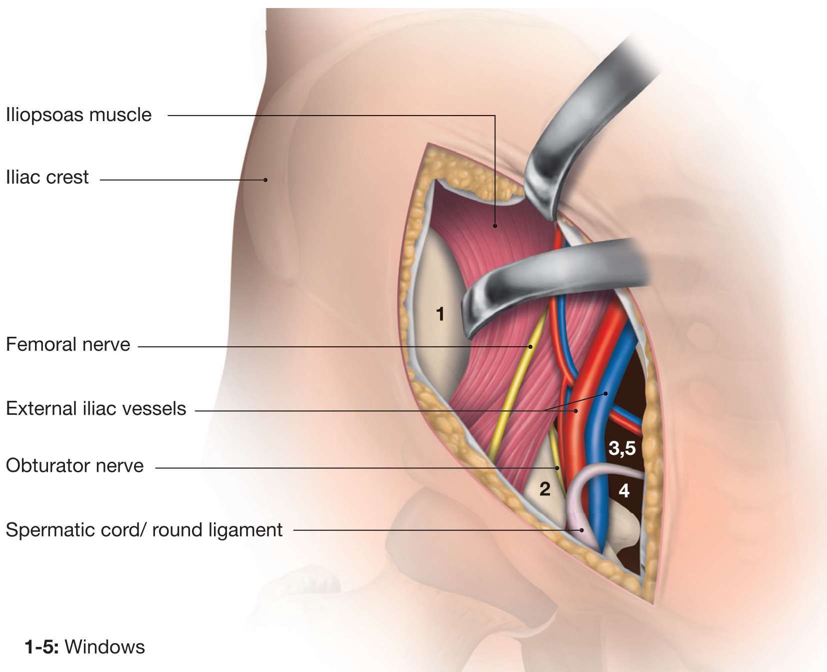


Figure 9. The five windows of the pararectus approach.

MINIMALLY INVASIVE SURGERY USING COMPUTED NAVIGATION

Apart from the surgical approaches described above, there has been a development in technical instruments to aid the treating surgeon to improve accuracy in implant placement and allow minimal invasive methods to stabilise fractures [(48)]. However, percutaneous fracture reduction may be challenging, thus rendering minimally invasive techniques most suitable for unstable fractures with minimal displacement. Additionally, patients medically unfit for more extensive surgery or patients with compromised soft tissues preventing open operative treatment may benefit from a minimally invasive procedure [(36)].

Computed navigation allows precise placement of periacetabular screws to both the anterior and posterior columns. The procedure is performed by placing bone anchored reference markers on the patient, and an intraoperative CT scan is performed. The obtained CT images are transferred to the navigation system, and the markers on the patient, along with markers on the instruments, guide the surgeon to place the screws accurately, allowing the surgeon to see the screws' planned trajectory on the CT images before screw placement.

This technique is time-consuming but due to more accurate screw placement and minimal wound exposures, complications are less frequent.

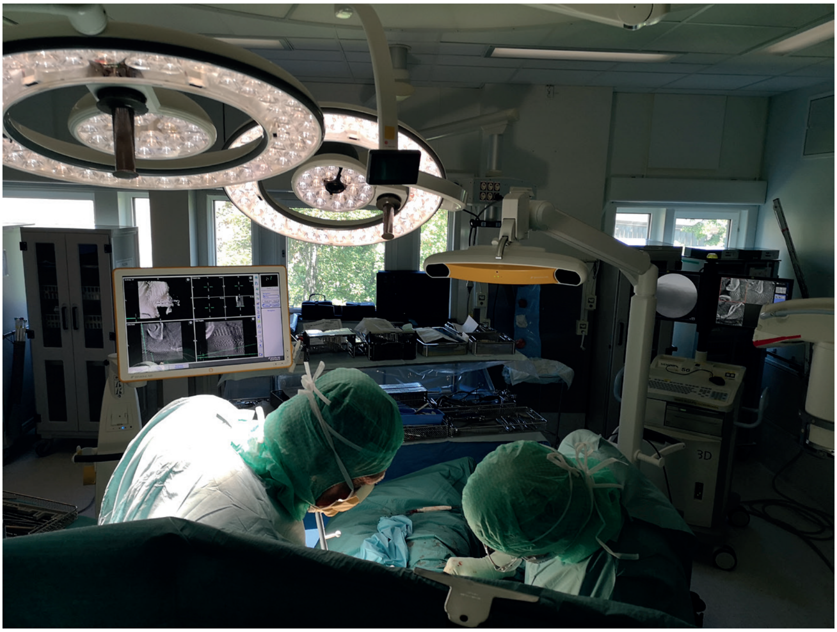


Figure 10. Intraoperative photo of pelvic fracture surgery using computed navigation. (Photo by Madelene Albrektsson)

ACUTE TOTAL HIP ARTHROPLASTY (THA) AND COMBINED HIP PROCEDURE (CHP)

In older patients with complex acetabular fracture patterns due to osteopenic bone, the native joint may not be salvageable. This is often the case when the joint surface has a large impaction, or comminution is great. Achieving joint congruency in such instances may prove highly challenging, making hip replacement the most suitable treatment option (25, 26, 49, 50).

As a primary treatment, total hip arthroplasty (THA) for acetabular fracture patients can be performed with or without additional stabilisation with ORIF. Combining an ORIF and a THA procedure is referred to as a combined hip procedure (CHP). Although the procedure may be more extensive compared to other treatment options, acute hip replacement allows immediate full weight bearing and reduces the risk of secondary surgery. Early weight-bearing reduces the patients' risk of thromboembolic events, pulmonary complications, and developing pressure ulcers. Acute THA performed due to acetabular fracture incurs more complications than elective THA performed due to osteoarthritis. Nevertheless, delayed THA following acetabular fracture surgery demonstrates inferior outcomes, exhibiting higher revision rates and poorer functional scores when compared to acute THA for these patients [49, 51].

The CHP presents several challenges for the treating surgeon. Experience in both acetabular fracture fixation techniques and revision arthroplasty is required. In many orthopedic departments today, where sub-specialisation is becoming more pronounced, this procedure warrants for collaboration between trauma and arthroplasty surgeons. The reduction in a CHP does not need to be anatomic, but the shape of the acetabulum needs to be restored, and the columns stabilised. The incisions depend on the fracture pattern and which parts require stabilisation. The Kocher-Langenbeck approach for posterior stabilisation allows for both ORIF and THA to be performed using the same incision. For ORIF of the anterior column, a double incision may be used. The acetabular component of the THA is often a cementless multi-hole porous metal cup, but the surgeon needs to be familiar with multiple implant options or additional implants that may be required [52]. Possibilities of cup fixation vary between patients, and bone defects, fracture comminution, and osteoporosis must be considered.

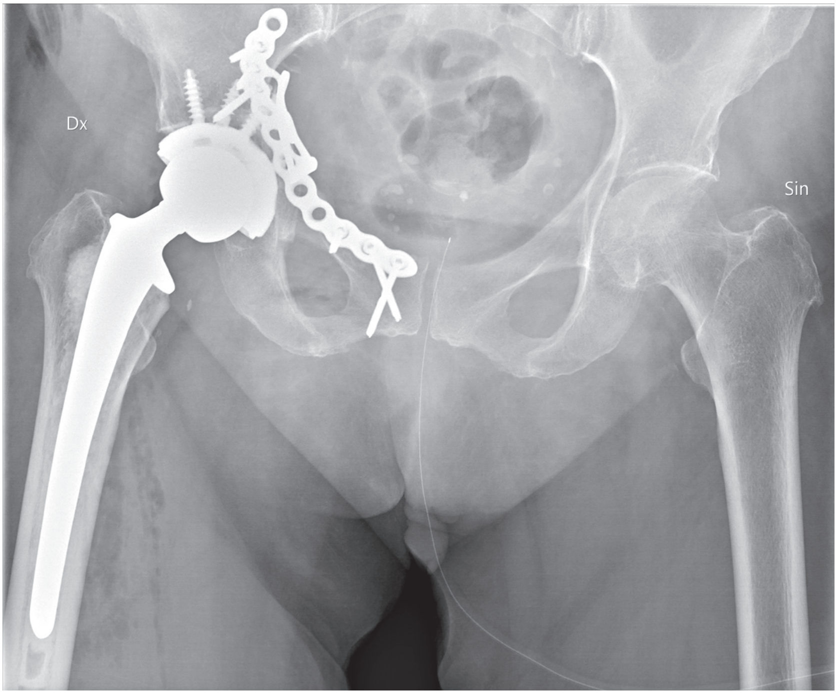


Figure 11. Postoperative radiograph of a combined hip procedure with a suprapectineal plate placed through the anterior intrapelvic approach and a total hip arthroplasty with an uncemented multihole porous coated cup.

NATIONAL QUALITY REGISTERS

This thesis uses two NQRs: the Swedish Fracture Register (SFR), which is the basis for all the register studies conducted in this thesis, and the Swedish Arthroplasty Register (SAR), which has been used to improve the completeness of data in study IV.

NQRs provide valuable information and follow-up on large cohorts that would be impossible to include in other types of research. The amount of data is increasing continuously, and the registers enable long-term follow-up on a larger scale. NQRs with a high coverage rate carry the strength of patient inclusion from various regions and socioeconomic areas.

SWEDISH FRACTURE REGISTER (SFR)

The SFR was established in 2011 and has rapidly grown to include all extremities, pelvis, and spine fractures. The registered information in the SFR includes patient age and sex, injury mechanism, fracture classification, given treatment, reoperations, patient-reported outcome measures (PROMs), and mortality. The PROMs in the SFR include the EQ-5D, EQ-VAS, and SMFA.

All orthopaedic departments in Sweden treating acute fractures are now participating in the SFR registration process. The physician treating the patient registers the patient in three steps. The first step accounts for the injury date and trauma mechanism chosen from a detailed list of options. The registrant also determines whether the trauma mechanism was a high- or low-energy injury. The second step describes the fracture. The fractured bone segment and side are chosen, and the fracture is classified according to the AO/OTA classification system for most body areas. Whether the fracture is open or closed is registered and if open, it is classified according to Gustilo-Anderson. The third step concerns the treatment. The first treatment choice is registered as surgical or non-surgical, and subcategories are selected to define the given treatment further. The date for initiated treatment is registered. For each fracture, subsequent treatments can be registered as planned secondary surgeries or as a consequence of various complications or sequelae. All patients presenting with a fracture sustained in Sweden receive a PROM questionnaire and are asked to report their health status as it was a week before the injury (recall technique), and this forms the baseline value (PROM 0). After the baseline questionnaires, a follow-up questionnaire is distributed to each patient 1-year post-injury to assess their current health status, establishing a 1-year follow-up for all responding patients (PROM 1). Mortality information from the Swedish Tax Agency is added daily to the SFR. The latest addition to the SFR is the registration of implants for individual patient surgery. Assisting operating theatre nurses perform the registration during surgery using bar code or data matrix scanners. Implementation on a national scale started in 2023, and registrations are currently being done in only a few departments.

The introduction and implementation of the SFR has been described in detail [53-56]. There has been a stepwise introduction of departments since the beginning in Gothenburg in 2011. In 2020, the SFR achieved nationwide coverage, indicating that all orthopaedic departments treating acute fractures actively participate in the register. However, as in all registers, achieving and maintaining a high degree of completeness is challenging. The SFR deals with this through cross-referencing diagnosis codes in the medical records at each department with the SFR, which enables late registrations to increase the degree of completeness. For research purposes, cross-reference is often made with other registers using the Swedish personal identification number system. Completeness analyses are performed regularly, in which the SFR registrations are compared to the National Patient Register (NPR).

All patients are informed about the SFR and their inclusion in it. Patients can choose to be removed from the register (opt-out) if they do not wish to participate.

SWEDISH ARTHROPLASTY REGISTER (SAR)

The Swedish knee arthroplasty register started in 1975, and the Swedish hip arthroplasty register in 1979. The two registers have had a great impact internationally, and in 2021, they were joined into one register, the Swedish Arthroplasty register (SAR). The SAR includes information on patients, the performed surgery, reoperations, and PROMs [57].

All acute and elective THAs and hemiarthroplasties of the hip are registered in the SAR. Total knee arthroplasties (TKAs) and unicompartmental knee arthroplasties are registered, and since 2013, knee osteotomies have also been included in the register. Patient factors in the SAR include age, sex, BMI, ASA class, presence of dementia, and indication for surgery. Detailed information about the surgery and implants, as well as the incision, thromboprophylaxis, antibiotics, and the duration of the operation, is registered.

PROMs are collected before and after surgery. For hip arthroplasties, only patients operated with THA receive follow-up PROMs at 1-, 6-, and 10-years post-surgery. Following TKA, follow-up PROMs are collected at 1-year post-surgery.

The SAR has a coverage of 100% and enjoys high completeness for both hip and knee operations. In 2022, the completeness of primary THA and TKA procedures was 98% (58). In 2021, the pre- and 1-year postoperative PROM response rates of patients included in the follow-up routine were 63% for elective THA and 53% for elective TKA.

PATIENT-REPORTED OUTCOME MEASURES (PROMS)

Many different PROMs are used to quantify how patients perceive their health status or their change in health following a certain event, such as an accident, illness, or treatment method. Some PROMs are validated and widely used, while others are used locally. Many are developed to measure a specific function or target particular body parts. As mentioned, the SFR uses the EQ-VAS, EQ-5D, and the SMFA. Because the SFR includes injuries to all parts of the skeleton, it must contain questions and measurement tools relevant to all kinds of skeletal injuries. The simultaneous pursuit of breadth and specificity presents a significant challenge.

SHORT MUSCULOSKELETAL FUNCTION ASSESSMENT QUESTIONNAIRE (SMFA)

This thesis uses the SMFA to measure patients' health status and function changes. The SMFA is a questionnaire containing 46 items originating from the longer musculoskeletal function assessment (MFA) (59). This assessment tool was translated into Swedish and tested for validity, reliability, and responsiveness in 2003 (60). The SMFA consists of two main parts: The dysfunction index derived from 34 questions, and the bother index derived from the remaining 12 questions. The dysfunction index, in turn, is divided into four categories: daily activities, emotional status, function of the arm and hand, and mobility. Twenty-five of the 34 dysfunction questions focus on the difficulty the respondent has performing a certain task. The other nine questions stress on how often the respondent perceive these difficulties. The bother index, of 12 items, describes how much the respondent is bothered by problems in different areas of daily life. Each question is answered using a five-point response scale, with one point representing good function or not at all bothered and five points signifying poor function or extremely bothered.

The SMFA scores for dysfunction and bother indices are calculated by summing the responses to each question and then transforming the scores to range from 0 to 100. The higher the score, the poorer the function.

The SMFA can be used either as a total score, divided in the different categories, or as individual questions [59].

OUTCOMES FOLLOWING ACETABULAR FRACTURES

PROM

Functional results reported by the patients following an acetabular fracture have been described using different scoring systems. The scoring system most frequently employed in the literature concerning acetabular fractures is that described by Merle d'Aubigné [2, 61]. The SF-36 (36-Item Short Form Health Survey) and the Harris hip score (HHS) are also commonly employed [62, 63]. In 2012, Borg et al. developed a questionnaire specifically designed to assess functional outcomes following an acetabular fracture [64].

According to the systematic review by Kelly et al., a little over 75% of patients surgically treated for an acetabular fracture reported excellent or good results using the Merle d'Aubigné or the HHS scoring systems, although the time point for the assessment varied between studies [(2)]. Thus, almost 25% only had a fair or poor result. Matta reported excellent or good clinical results in 76% of the cases using a modification of the Merle d'Aubigné system, and similar results using the HHS were found by Mears et al. [(30, 65)]. A more recent study from the Netherlands showed better SF-36 scores for patients with a preserved hip joint compared to patients with posttraumatic osteoarthritis or late conversion to THA [(66)].

All patients included in these studies were treated surgically, and studies on patient-reported functional outcomes for the non-surgically treated patients are lacking. Some reports on older populations include non-surgical treatment in which most acetabular fracture patients were unable to return to their previous level of mobility and independence [(67, 68)].

SECONDARY SURGERY

Patients with operatively treated acetabular fractures are reported to undergo secondary surgery at a later stage in 13% of the cases [(2)]. Most of these procedures are total hip replacements. While the rationale for revision is not consistently articulated, when it is, post-traumatic arthritis is the most prevalent cause of delayed THA.

The number of studies with long-term follow-up is limited. However, in one long-term investigation, Tannast et al. followed a series of 816 patients and showed a cumulative 20-year survival of the native hip joint after acetabular fracture surgery of 79% [(50)]. The median time to failure was 1.5 years. Some of the factors identified to have a negative effect on the survival of the native hip joint were patient age over 40 years, fractures involving the posterior wall, marginal impaction, femoral head lesions, initial displacement of the articular surface of 20 mm or more, anterior hip dislocation, and a remaining postoperative incongruence of the acetabular roof. Other authors have confirmed similar risk factors for failure or conversion to THA [(69, 70)].

There is an ongoing trend towards primary THA, either alone or in combination with osteosynthesis, for certain acetabular fractures in specific patient groups to minimise later conversion to THA and lower postoperative pain for these patients [26, 71-73]. The combined hip procedure or acute THA has been shown to have lower reoperation rates compared to ORIF alone [25, 74].

Despite the advances in surgical treatment of acetabular fractures, most patients are still treated non-surgically, especially in older populations. These patients' outcomes can be difficult to summarise because of the great variety in fracture patterns and degree of displacement. The fractures may range from completely non-displaced and insignificant for patient mobilisation to a both-column fracture with secondary congruency. The decision to treat an acetabular fracture surgically or non-surgically also depends on the individual patients' needs and comorbidities [28]. Ryan et al. described surprisingly good results in patients >60 years following non-surgical treatment of acetabular fractures that, in a younger population, would have met the criteria for surgery [75]. Conversion to operative treatment occurred in 15% of the cases.

02.

MADELENE ALBREKTSSON

ACETABULAR FRACTURES

AIMS

The main objective of this thesis is to expand knowledge on acetabular fractures using NQRs. The focus is to investigate fracture classification, epidemiology, treatment methods, mortality, and outcomes following treatment.

The specific aims of the thesis are to:

- Assess the classification accuracy of surgically treated acetabular fractures in the SFR and evaluate the intra- and interrater consistency of the Judet-Letournel and AO/OTA classification systems. **(Study I)**
- Outline the epidemiology of acetabular fractures in Sweden, including patient demographics, causes of injury, fracture types, treatment approaches, and mortality rates. **(Study II)**
- Evaluate the patient's self-reported health changes 1 year after experiencing an acetabular fracture. Secondary objectives include analysing variations in patient-reported outcomes based on sex, age groups, injury causes, fracture type, and treatment methods. **(Study III)**
- Evaluate the frequency of secondary treatments in patients with acetabular fractures managed non-surgically or surgically. A secondary objective is to examine mortality rates among acetabular fracture patients. **(Study IV)**

03.

MADELENE ALBREKTSSON

ACETABULAR FRACTURES

PATIENTS AND METHODS

STUDY I

STUDY POPULATION

After power estimation using the distribution of fracture types in the SFR and with a 10% margin for eventual missing or unavailable imaging material, 132 surgically treated acetabular fractures sustained by patients aged ≥16 years were randomly selected from the SFR.

METHODS

A letter was sent to the 24 treating hospitals requesting the preoperative computed tomographies for the selected patients. Ethical approval for the study was available to all departments, and additional applications were filled out when local guidelines so required. Most radiology departments answered the initial letter, and all imaging material could be obtained after a single reminder to some departments. Of 132 acetabular fractures, 4 were excluded because of lacking or deficient imaging, and another 4 because of injuries requiring a different classification system (i.e., periprosthetic fractures and one penetrating injury).

During 3 online meetings, 3 experienced acetabular fracture surgeons classified the remaining 124 acetabular fractures. The surgeons classified all fractures independently on the first two occasions, without discussion. These two sessions were held five weeks apart. When raters agreed at least five of the six times each fracture was classified, this was considered the gold standard (GS) for that fracture. Fractures for which the raters agreed on four or fewer classifications were presented at the third meeting when discussion was allowed to achieve consensus regarding the appropriate classification.

To analyse the accuracy between GS and what had been registered in the SFR, Cohen´s kappa was used and the interpretation of agreement strength was performed according to Landis and Koch [76]. Inter- and intraobserver agreements were analysed in the same manner.

The AO/OTA classification was used, which contains the same fracture groups as the Letournel classification described above. In this study, the fracture groups were also merged into their AO types (A, B, or C).

STUDY II

STUDY POPULATION

Acetabular fractures (ICD-10 S32.4) in the adult skeleton and a native joint (no periprosthetic fractures) were included in the study. Data were extracted from the SFR for registrations from 1 January 2014 until 23 October 2020. After excluding patients with bilateral fractures or an additional contralateral acetabular fracture during the study period, 2,132 patients were included in the data analysis.

METHODS

Study variables retrieved from the register included patient age, sex, injury date, injury mechanism, fracture classification, treatment and if applicable, date of death. Injury mechanisms were divided into the same six categories used in previous studies [77, 78]. These categories were a simple fall, fall from height, unspecified fall, transport accident, miscellaneous, and non-traumatic. The miscellaneous group includes abuse, self-inflicted injuries, and unspecified injuries. A seventh group, in which the injury mechanism was unknown, was also described in the study. Injury mechanisms were also presented as high- or low-energy injuries. The treatment choice was divided into surgical or non-surgical. Surgical treatment was subcategorised as ORIF, CHP, THA, and other surgical treatments.

The study was purely descriptive, and no comparisons between subgroups were made. Nominal variables were presented as numbers, proportions of all registered fractures, and median with interquartile range (IQR).

STUDY III

STUDY POPULATION

All patients aged ≥16 years with an acetabular fracture (ICD-10 S32.4) registered in the SFR between 1 January 2014 and 1 January 2022 were selected for data extraction. Patients with additional fractures, concomitant or within 18 months of the acetabular fracture, were excluded. Periprosthetic and paediatric fractures were also excluded. Only patients who responded to both PROM 0 and PROM 1 questionnaires were analysed. A total of 385 patients were included in the study. Non-responders were only included to compare demographic data with the responding study population.

METHODS

Variables collected from the SFR included the patient´s age, sex, fracture classification, injury energy level, treatment type, and PROM scores. Patients were divided into two age groups: ≤70 years and >70 years.

As described above, the PROM score used in this study was the SMFA, analysing the bother, dysfunction, and mobility sub-indices. The difference between preinjury and 1-year postinjury scores was calculated for each study participant (ΔSMFA), and the mean change was calculated for the group.

$$\Delta SMFA = PROM\ 1 - PROM\ 0$$

- * The higher the score, the poorer the function.
- * Positive ΔSMFA = Decrease in function between measurements
- * Negative ΔSMFA = Improvement in function between measurements

Mean ΔSMFA were presented with 95% confidence intervals (CIs). Demographic data were compared between responders and non-responders. Differences in proportions were presented as percentage points with 95% CIs. Differences in median age were given in years with 95% CI.

STUDY IV

STUDY POPULATION

Patients >18 years old with an acetabular fracture (ICD-10 S32.4) registered between 1 January 2014 and 18 October 2023 were retrieved from the SFR and cross-referenced with the SAR. Patients with one of three primary treatment methods were included: non-surgical treatment, ORIF, and THA/CHP. Periprosthetic, paediatric, stress, and pathological fractures were excluded. Some patients had an arthroplasty due to a femoral neck fracture and were therefore excluded. Only one fracture was included for patients with bilateral fractures. Only the first was included for patients with a subsequent acetabular fracture during the study period. After exclusions, the final sample included 3,318 patients.

METHODS

Variables collected from the SFR included the patient´s age, sex, injury mechanism and date, fracture classification, treatment, and mortality.

The individuals' personal identification numbers were cross-referenced with the SAR to identify secondary treatment with conversion to THA or THA revision surgery.

The primary outcome was secondary treatment. For non-surgically and ORIF-treated patients, secondary treatment signified conversion to late THA. For patients primarily treated with THA/CHP, secondary treatment was any revision surgery.

The secondary outcome was mortality in the three treatment groups.

Kaplan-Meier survival estimates with 95% CIs were calculated for the primary and secondary outcomes stratified by the three treatment groups. A Cox regression model, adjusted for age and sex, was used to analyse the association between primary treatment and outcome.

ETHICAL CONSIDERATIONS

The Swedish Ethical Review Authority (registration numbers 2020-03775 and 2023-01499-02) granted ethical approval for the studies included in this thesis. The study designs ensure that no patient information presented or published can be traced to any individual.

Swedish legislation does not require signed consent from patients registered in the SFR and other Swedish NQRs. However, all patients must be informed that registration takes place and allowed to withdraw their participation at any time. This opt-out system is crucial for NQRs to receive as accurate and complete information on the entire population as possible.

04.

MADELENE ALBREKTSSON

ACETABULAR FRACTURES

RESULTS / SUMMARY OF PAPERS

STUDY I

Of the 124 fractures classified by the expert group, 51% were correctly classified in the SFR (Table 1). The Cohens' kappa coefficient of 0.43 corresponds to moderate agreement according to the interpretation by Landis and Koch.

Table 1. Accuracy of the SFR vs the gold standard.

	PA (Per cent agreement)	Kappa (95% CI)
AO/OTA group	51%	0.43 (0.34-0.52)
AO/OTA type	69%	0.5 (0.37-0.62)

The degree of agreement differed between fracture types. The highest per cent agreement (PA) was found for the anterior wall fractures, but since there was only one in the study cohort this may not be accurate. Posterior wall fractures had a PA of 91% (Table 2). The posterior column and posterior wall fracture, the pure transverse fracture, and the anterior and posterior hemitransverse fracture had the lowest per cent agreement.

Table 2. Accuracy of the SFR vs the gold standard (GS) for each fracture group.

Fracture group	Number of correctly classified fractures in the SFR (total number according to GS)	PA (per cent agreement)
A1 (PW)	21 (23)	91%
A2.1/2 (PC)	1 (2)	50%
A2.3 (PC+PW)	1 (7)	14%
A3.1 (AW)	1 (1)	100%
A3.2/3 (AC)	10 (26)	38%
B1.1/2 (TRANS)	1 (7)	14%
B1.3 (TRANS+PW)	4 (7)	57%
B2 (T)	2 (9)	22%
B3 (A+PHT)	1 (7)	14%
C (ABC)	20 (32)	63%
Not able to classify	1 (3)	33%

The intrarater agreement was substantial to almost perfect and the mean intrarater kappa value was 0.74 (Table 3). The mean kappa value for interrater agreement was 0.59, corresponding to moderate agreement (Table 4).

Table 3. Intrarater agreement. Percent agreement (PA) and Kappa values comparing the classification of each rater between two seminars.

	Rater 1		Rater 2		Rater 3	
	PA	Kappa (95% CI)	PA	Kappa (95% CI)	PA	Kappa (95% CI)
AO /OTA group	74%	0.7 (0.61-0.78)	86%	0.84 (0.77-0.91)	73%	0.67 (0.58-0.76)
AO/OTA type (A/B/C)	89%	0.82 (0.74-0.91)	94%	0.9 (0.83-0.97)	81%	0.72 (0.62-0.82)

Table 4. Interrater Kappa values with 95% CI, comparing raters with each other at two seminars.

	Rater 1 vs Rater 2		Rater 1 vs Rater 3		Rater 2 vs Rater 3	
	Seminar 1	**Seminar 2**	**Seminar 1**	**Seminar 2**	**Seminar 1**	**Seminar 2**
AO /OTA group	0.6 (0.5-0.69)	0.6 (0.5-0.69)	0.63 (0.54-0.72)	0.68 (0.6-0.77)	0.5 (0.4-0.59)	0.54 (0.45-0.63)
AO/OTA type (A/B/C)	0.75 (0.65-0.85)	0.72 (0.61-0.82)	0.69 (0.59-0.8)	0.77 (0.68-0.87)	0.6 (0.48-0.71)	0.66 (0.55-0.77)

STUDY II

There was a male predominance among patients suffering an acetabular fracture (62%). The median age at the time of injury was 73 years for men and 82 years for women. A simple fall was the most common injury mechanism, and low-energy injuries was the cause of 63% of the fractures. The age distribution, sex, and injury energy level are shown in figure 12.

Fractures of the anterior wall were the most common fracture type overall. The most common fracture type for the less common high-energy injuries was the posterior wall type. Figure 13 illustrates the distribution of fracture classes and the associated energy levels that caused them.

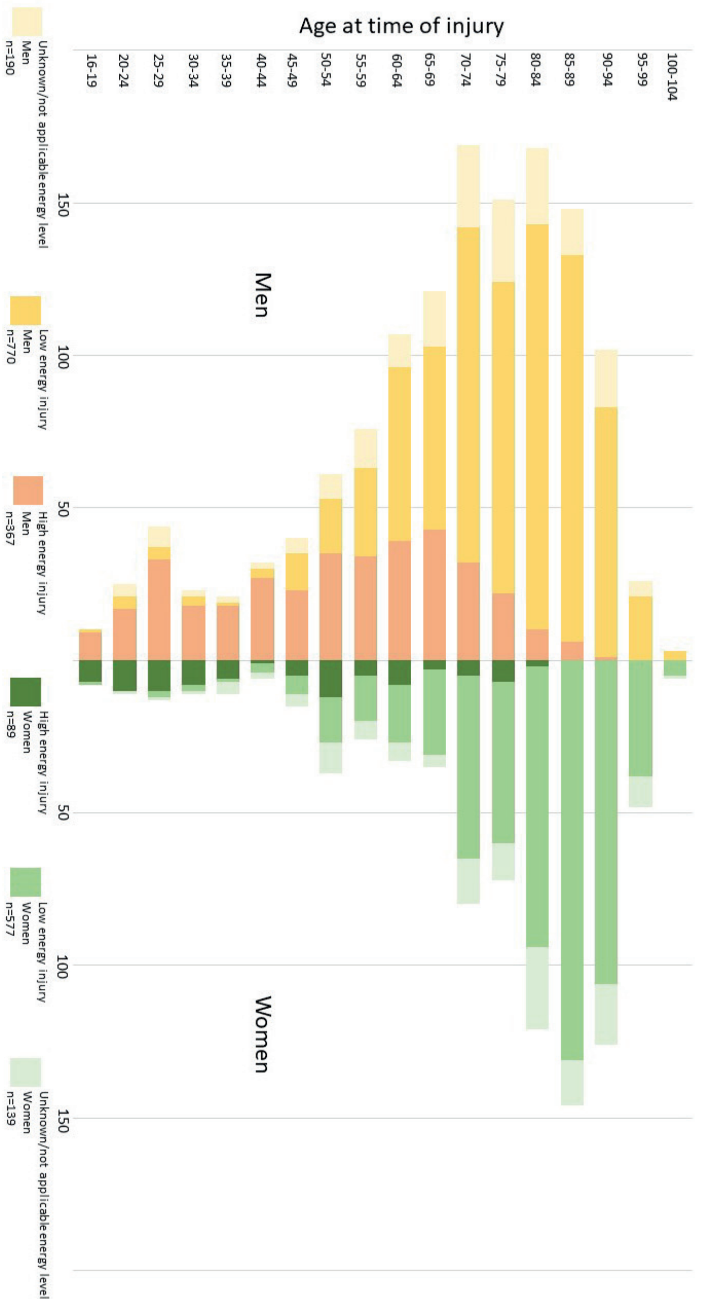


Figure 12. Distribution of age, sex, and injury energy level in 2,132 acetabular fracture patients.

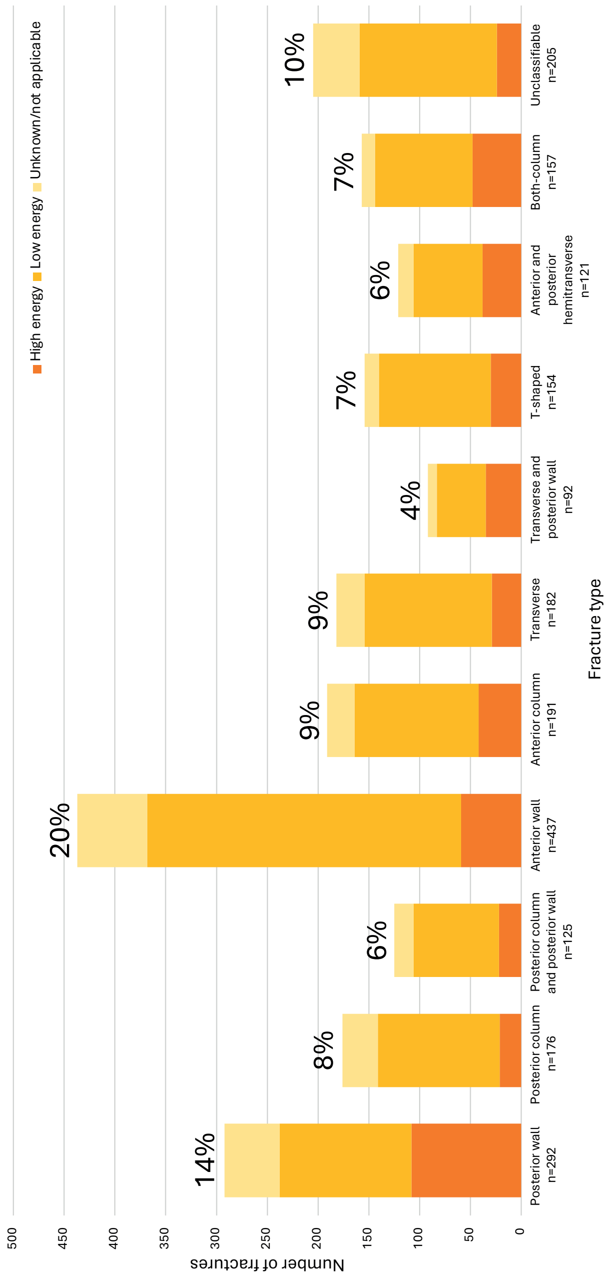


Figure 13. Distribution of fracture classes and injury energy level in 2,132 acetabular fracture patients.

Three of four fractures were treated non-surgically. ORIF was performed in 73% of the cases among the surgically treated patients. A CHP or THA was the chosen treatment in 22% of the cases. The associated fracture patterns, A-PHT and ABC, were more often treated surgically.

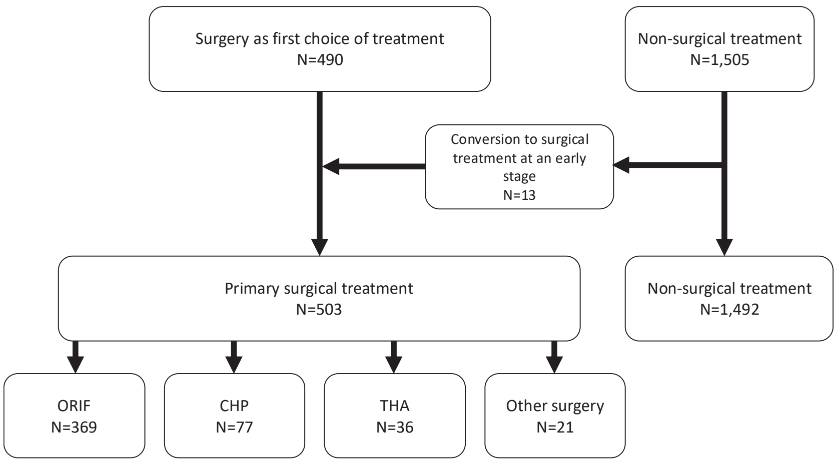


Figure 14. Primary treatment flowchart in 1,995 acetabular fractures with registered treatment. (ORIF – open reduction internal fixation).

In patients >70 years, the 30-day mortality after an acetabular fracture was 8%; for patients ≤70 years, it was 0.2% (Table 5). Mortality at one year after fracture was 24% in patients over 70 and 2% for the younger age group.

Table 5. Mortality at 30 days and 1 year in age groups >70 and ≤70 years. Data presented by age group and sex for 2,131 acetabular fracture patients. (One patient was excluded because of obvious false data, i.e., negative survival value.)

Age group, years	30 days, n (%)	1 year, n (%)
≤ 70 (n=813)	2 (0.2)	17 (2)
> 70 (n=1,318)	100 (8)	317 (24)
Male ≤ 70 (n=596)	2 (0.3)	11 (2)
Male > 70 (n=730)	70 (10)	184 (25)
Female ≤ 70 (n=217)	0 (0)	6 (3)
Female > 70 (n=588)	30 (5)	133 (23)

STUDY III

The 385 patients who responded to both PROM 0 and PROM 1 did not differ significantly from the non-responding patients on sex or fracture type. However, the responding group was younger and had more often suffered high-energy injuries and had a higher rate of primary surgical treatment (Table 6).

Table 6. Demographics of responders and non-responders.

Characteristic	Responders (N=385)	Non-responders (N=1,559)	Difference responders vs non-responders * (95% CI)
Sex			
Male	256 (66)	991 (64)	2.9 (-2.4-8.1)
Female	129 (34)	568 (36)	
Median age (IQR)			
All	71 (60-79)	79 (66-87)	7 (6-9)
Male	70.5 (60-77)	76 (63-85)	
Female	74 (58-84)	84 (74-90)	
Type of energy			
High energy	87 (23)	201 (13)	11 (5.6-15)
Low energy	229 (59)	1,069 (69)	12 (6.3-17)

*The difference between responders and non-responders are accounted for in percentage points, except median age which is in years.

The mean ΔSMFA values showed a decrease in function for all analysed subgroups, i.e., positive ΔSMFA (Table 7-9). The mobility index displayed the largest numerical impairment among the analysed SMFA indices. No statistically significant differences between subgroups could be observed in this cohort, except for surgically versus non-surgically treated patients. However, because of selection bias, these two groups should not be compared to each other. Although statistical significance could not be established, there were numerical differences between groups.

The ΔSMFA scores were similar among male and female patients, but larger difference was reported between the two age groups (Table 7). Patients in the group aged ≤70 years reported greater numerical impairment compared to patients >70 years. When considering only patients who underwent surgery, the age-related discrepancy was more pronounced (Table 8). Among non-surgically treated patients, the scores of each age group were more similar.

High-energy injuries resulted in worse scores compared to low-energy injuries (Table 9).

Table 7. Differences in patient-reported function categorised by sex and age group, 1 year after an acetabular fracture compared with 1 week prior to the injury. Data are presented as mean values of individual ΔPROMs with 95% confidence intervals.

Patient group	ΔSMFA index					
	Bother		Dysfunction		Mobility	
	Mean	*95% CI*	*Mean*	*95% CI*	*Mean*	*95% CI*
All	11.3 (n=347)	9.1-13.5	10.2 (n=382)	8.5-11.9	13.7 (n=382)	11.7-15.7
Male	11.8 (n=237)	9.2-14.4	9.9 (n=253)	7.9-12.0	13.2 (n=253)	10.8-15.5
Female	10.1 (n=110)	5.9-14.4	10.8 (n=129)	7.8-13.8	14.7 (n=129)	11.1-18.3
≤70 years	13.8 (n=172)	10.4-17.1	11.4 (n=182)	9.0-13.9	15.5 (n=182)	12.5-18.4
>70 years	8.8 (n=175)	5.9-11.7	9.1 (n=200)	6.8-11.5	12.0 (n=200)	9.3-14.8

Table 8. Differences in patient-reported function categorised by treatment and age group, 1 year after an acetabular fracture compared with 1 week prior to the injury. Data are presented as mean values of individual ΔPROMs with 95% confidence intervals

Primary treatment	Age group	ΔSMFA index					
		Bother		Dysfunction		Mobility	
		Mean	*95% CI*	*Mean*	*95% CI*	*Mean*	*95% CI*
Surgical	All	18.3 (n=108)	14.0-22.6	15.8 (n=120)	12.7-18.9	21.6 (n=120)	17.9-25.2
	≤70 years	20.5 (n=72)	14.6-26.3	17.9 (n=78)	13.8-22.1	24.1 (n=78)	19.4-28.9
	>70 years	13.9 (=36)	8.3-19.6	11.8 (n=42)	7.4-16.2	16.8 (n=42)	11.4-22.2
Non-surgical	All	7.2 (n=218)	4.7-9.8	7.0 (n=239)	5.0-9.0	9.2 (n=239)	6.9-11.5
	≤70 years	6.7 (n=91)	3.2-10.2	5.0 (n=95)	2.6-7.4	6.9 (n=95)	4.1-9.8
	>70 years	7.6 (n=127)	4.1-11.2	8.4 (n=144)	5.4-11.3	10.7 (n=144)	7.4-14.1

Table 9. Differences in patient-reported function categorised by injury energy level, 1 year after an acetabular fracture compared with 1 week prior to the injury. Data are presented as mean values of individual ΔPROMs with 95% confidence intervals.

Injury type	ΔSMFA index					
	Bother		Dysfunction		Mobility	
	Mean	*95% CI*	*Mean*	*95% CI*	*Mean*	*95% CI*
High-energy	13.7 (n=84)	8.3-19.1	13.3 (n=86)	9.7-16.9	17.8 (n=86)	13.5-22.0
Low-energy	10.6 (n=200)	8.1-13.1	9.8 (n=228)	7.7-12.0	12.5 (n=228)	10.0-15.1

When analysing the 10 fracture types, the ΔSMFA scores tended to increase with the fracture's complexity (Figure 15). Diverging from this trend, posterior wall fractures, which is considered a simple fracture type, also displayed higher scores.

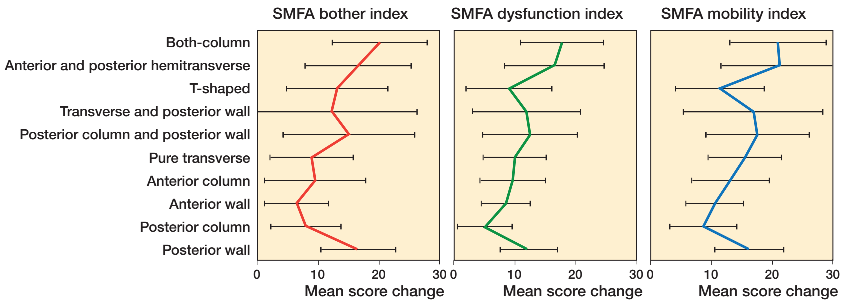


Figure 15. Differences in patient-reported function categorised by fracture, 1 year after an acetabular fracture compared to 1 week prior to the injury. Data are presented as mean values of individual ΔPROMs.

STUDY IV

Most of the 3,318 patients in the study cohort were treated non-surgically (74%). Eighteen per cent were treated with ORIF and 8% with THA/CHP (Table 1 in Paper IV). The median age was 76 years and male patients accounted for 64%.

Secondary treatment at five years post-fracture was 4.4% for non-surgically, 17.3% for ORIF, and 11.8% for THA/CHP-treated patients (Table 2 in Paper IV). At one year, 1.7% of the non-surgically treated patients and 6.2% of the ORIF-treated patients had undergone late THA surgery. For patients primarily treated with THA/CHP, the 1-year revision rate was 7.5%.

Secondary treatment after primary THA/CHP was most common during the first year post-fracture (Figure 2 in Paper IV). After one year, the ORIF-treated patients received secondary treatment to a greater extent. However, long-term differences between the ORIF and the THA/CHP groups were not statistically significant. Non-surgically treated patients had a significantly lower rate of secondary treatment at most time points and had a lower hazard ratio (HR) compared to the other treatment groups (Table 10). For the THA/CHP group, most revision surgery was performed during the first year and most late THA after primary ORIF was performed during the first two years.

The highest rates of late THA after non-surgical treatment were seen for the PC+PW fractures, followed by the A-PHT and T-shaped fractures (Table 3 in Paper IV). Secondary THAs after ORIF were most common for the PC+PW, T, and PW fractures. The rate of revision surgery after primary THA/CHP was the highest for TRANS and TRANS+PW fractures.

In non-surgically treated patients, 30-day mortality was 5.7%, and 1-year mortality was 18.8% (Figure 3 and Table 4 in Paper IV). For the ORIF treatment group, 30-day mortality was 1.5%, and 1-year mortality was 4.4%. When primarily treated with THA/CHP, 30-day mortality was 2.6%, and 1-year mortality 14.4%. The HR for death was reduced for both primary surgical treatment groups compared to those who did not undergo surgery (Table 10).

Table 10. Hazard ratios (HRs) with 95% Confidence intervals (CIs) for secondary treatment and mortality in the three primary treatment groups (non-surgical, ORIF, and THA/CHP).

	Non-surgical	ORIF	THA/CHP
Secondary treatment HR (95% CI)	1	4.4 (3.1-6.3)	3.3 (2.0-5.3)
Mortality HR (95% CI)	1	0.6 (0.5-0.8)	0.7 (0.6-0.9)

05.

MADELENE ALBREKTSSON

ACETABULAR FRACTURES

DISCUSSION

SWEDISH FRACTURE REGISTER

Following the creation of the SFR, many new opportunities have emerged. National-scale studies involving larger populations are now feasible. Prospective data collection on fracture patients creates a continuously growing database, and real-time registrations have also enabled register-based RCTs to be conducted. The SFR is unique in that it includes all orthopaedic departments in the country. Moreover, encompassing all treatment modalities, not solely those surgically addressed, enhances the informational value and offers a more comprehensive representation of reality.

Although the SFR poses many advantages and new possibilities, some challenges remain. Even if complete coverage has been achieved, the register's completeness and accuracy may still present challenges. These challenges are subject to ongoing evaluation, with a constant endeavour to maintain the highest possible standard of registration. In 2023, the completeness of fractures in the SFR, relative to the NPR, was 58%. However, significant variability exists across different orthopaedic departments [(79)]. Nevertheless, the reported number of fractures in the NPR overestimates the actual count, a point to consider when interpreting these numbers [(54)].

The differences between departments raise the question of whether the registered patients represent the entire Swedish population. Variations in the prevalence of injuries may exist across geographical regions, with socioeconomic factors, lifestyle, and occupation impacting injury mechanisms and outcomes. The SFR's inception in 2011 saw registrations from Gothenburg and its surrounding areas in western Sweden. Over a decade, the registry experienced gradual growth until all departments were incorporated. An overview of completeness figures from the SFR website for 2023 reveals no discernible trend suggesting a specific type of region with lower completeness rates (Figure 16). Various city areas and more rural regions appear to be represented.

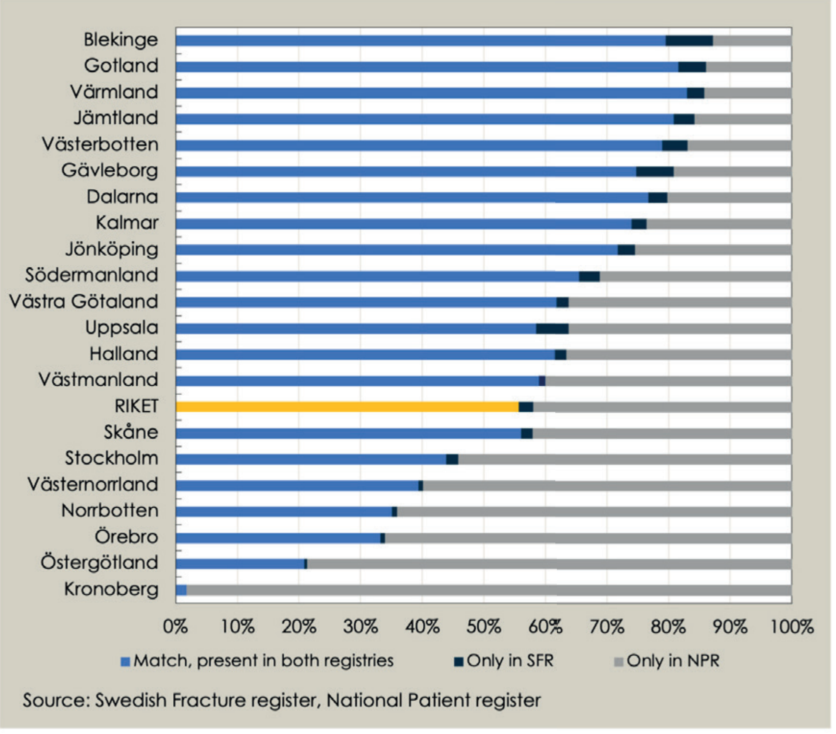


Figure 16. Completeness (%) in the SFR and NPR for the different regions in Sweden showing patients with certain fractures compared to the NPR in 2023. (Figure provided by the Swedish Board of Health and Welfare)

Obtaining high completeness for reoperations has proven to be particularly difficult, and two studies have shown completeness for reoperations of 62% for humeral and 63% for tibial fractures [80, 81]. To improve completeness of data on fractures around the hip, the SFR and

SAR are linked, with patient information about hip arthroplasty being exchanged daily between the two registries. In **Study IV**, a complete cross-reference between the two registers was conducted to ensure an as complete dataset as possible. The completeness for hip revision surgery in the SAR was between 93 and 96% in 2013-2022 [58].

The validity of fracture classifications is another crucial factor determining the SFR's utility. Several validation studies have been performed, one of which is included in this thesis (Study I) [82-87]. The validation of acetabular fracture classification is further discussed below.

FRACTURE CLASSIFICATION

Fracture classification instruments facilitate objective evaluation and effective communication among treating physicians and researchers. A good classification system can also guide in choosing the proper treatment, anticipating complications, and implying something about the prognosis. A main challenge in developing effective classification systems is the inherent contradiction between simplicity and comprehensiveness. Precise details and thorough descriptions must be provided. Still, a classification system needs to be reproducible, user-friendly, and easy to learn, or it will not be used, especially if employed daily in a register setting.

Despite its widespread use, the Letournel classification system for acetabular fractures presents certain limitations. No regard is given to the degree of displacement when classifying fractures according to Letournel. This limits the classification's ability to guide treatment and prognosis. The classification, however, is designed to guide the surgeon in choosing a surgical incision. Several research groups have studied the reliability of the Judet-Letournel classification. Beaulé et al. describe interobserver kappa values from 0.51 for less experienced raters to 0.74 for more experienced raters when using plain radiographs and CT. Intraobserver reliability in the same study ranged from 0.69 to

0.83 [12]. Though focused on the choice of imaging technique, O'Toole et al. showed an interobserver reliability of 0.64 (Cohen's kappa) using three-dimensional CT reconstructions [88]. Zhang et al. demonstrated a mean kappa value of 0.591 for interobserver and 0.735 for intraobserver reliability [16]. The results in **Study I,** with interrater kappa values of 0.5 to 0.68 and intrarater values of 0.67 to 0.9, are consistent with previous findings. Merging the classification groups into types A, B, and C, resulted in a somewhat higher kappa value. The merger attempted to investigate whether most misclassifications were due to closely related fracture patterns. However, the classification of acetabular fractures is more complex. For instance, an anterior column fracture, A3.2/3, is more similar to a B3 or a C fracture than it is to A1, a posterior wall fracture. Wennergren et al. addressed this problem by classifying humerus fractures with a series of Boolean questions to determine which fracture groups are the most closely related [83]. We attempted a comparable approach using the questions of a diagnostic algorithm proposed by Riouallon et al. to aid in classifying acetabular fractures [89]. However, the Judet-Letournel classification system relies on a single fracture line to differentiate many groups, resulting in this attempt to fuse related fractures into larger groups to be indiscriminate.

The moderate agreement between classifications made in the SFR and the established GS in **Study I** was not unexpected. The level of agreement varied between fracture types, revealing that certain fracture classifications presented more challenges than others. There is a learning curve to this classification system, but even among experienced pelvic surgeons, there are disagreements and misunderstandings. During the third session of **Study I**, the discussion among the three raters focused less on the classification itself, as there appeared to be consensus among them. Instead, the discussion was about specific fracture lines distinguishing one group from the other. Some undisplaced and discrete lines that everyone had not seen on previous occasions made the difference in which group to place each fracture. Such a fracture may not even be visible on a plane radiograph. This raises the question of the relevance of these lines. For example, a completely undisplaced line through the posterior column might not be viewed as a posterior column injury in a functional sense and, therefore, be classified as a posterior wall fracture if that was considered the main issue for the patient.

The reliability of the SFR classifications with a kappa value of 0.43 may be subject to debate. One limitation of **Study I** was the number of fractures in each fracture group. Despite the pre-study power analysis, there were very few fractures in some groups, resulting in large effects on accuracy in both positive and negative directions. Until a more comprehensive validation has been made, caution is advised when interpreting data on specific fracture types. However, acetabular fracture patients registered in the SFR can be analysed as one cohort, and some fracture types with higher accuracy may be used for subgroup-analysis.

Another limitation was that the validation was only performed for surgically treated patients. In this first part of validating acetabular fracture classifications, focus was placed on displaced fractures requiring surgical care. Including all fractures at this stage may have clouded the cohort and emphasised simple, undisplaced fractures of little or no consequence to the patient. The non-surgically treated fractures can also be validated, but preferably in a separate study.

EPIDEMIOLOGY

The results of **Study II** displayed a classic bimodal distribution of fractures. The older patient groups sustained an acetabular fracture mainly due to low-energy injury mechanisms, and the younger, often male, patients suffered high-energy injuries. It was evident that the older patients far outnumbered the younger patients. Previous studies have shown an increase in the incidence of acetabular fractures among older adults [20-22,90]. As mentioned earlier in this thesis, the field of acetabular fracture surgery has been forced to adapt to this shift in patient demography.

Study II presents a relatively large cohort of patients compared to most publications, and including non-surgically treated patients is also less frequent in previous studies. The study showed that 75% of acetabular fracture patients are treated non-surgically, greatly impacting the results. One of the main differences compared to the existing literature was the high prevalence of anterior wall fractures. This observation may partly be due to misclassifications. For example, lateral fractures of the superior pubic ramus may often be interpreted as anterior wall fractures. Furthermore, registrants may experience difficulty in appropriately categorising fractures involving the anterior wall and anterior column. According to the Letournel classification, the combination of AW and AC fractures is included in the AW group, but these may be misclassified as AC fractures. AW fractures are generally treated non-surgically and may explain their high prevalence in this cohort compared to the existing literature. Both column fractures and anterior and posterior hemitransverse fractures are described to be the most common acetabular fractures in the senior population [91, 92]. These fracture types were underrepresented in **Study II** compared to previous research. However, as most studies report on surgically treated patients or originate from trauma referral centres, the previously described fracture-type distribution may also be skewed.

When isolating high-energy trauma mechanisms, posterior wall fractures were the most common, and 80% of the patients in this group were male. The rate of PW fractures in **Study II** is consistent with previous studies reporting mainly on surgically treated patients [32, 93]. As discussed above and as seen in **Study I**, these fractures are also easier to classify correctly, facilitating comparisons to other studies. The large proportion of male patients suffering high-energy trauma is also in line with previous research [94, 95]. Male individuals tend to more often engage in high-risk activities and are more often involved in traffic accidents [96, 97]. A PW fracture frequently occurs in motor vehicle accidents when axial forces are exerted upon the flexed hip joint.

However, high-energy trauma mechanisms were only responsible for 21% of the fractures in **Study II**. Low-energy trauma mechanisms in older adults were observed more frequently, corroborating previous reports indicating an increasing incidence of acetabular fractures within this age group [20-23]. Increased age is associated with a higher rate of fracture types involving the anterior column and quadrilateral plate [24, 98]. Additionally, acetabular roof impaction and medialisation of the femoral head are more common in this patient group. In **Study II**, ORIF was the predominant surgical technique employed among patients undergoing surgical treatment. However, research indicates that THA/ CHP is increasingly favoured within this patient cohort [25, 26, 72, 99].

As discussed above, male patients account for most high-energy trauma mechanisms. Nevertheless, patients in the low-energy trauma group was also predominately male, which is somewhat surprising given that females are more susceptible to most other fragility fractures [100]. The male/female ratio aligns with previous investigations [18, 21-23]. The underlying reasons are yet to be determined, but part of the explanation may be differences in behaviour and activities also in later years. Another explanation could relate to anatomical differences in the pelvis. Differences between the sexes in anteversion and inclination of the acetabulum, as well as hip stability, may influence the likelihood of fracture and dislocation [101, 102].

Although it was not the focus of **Study II**, reflections on treatment modalities in different geographic areas can be subject to discussion, and questions may be raised about equality of care. Sweden is divided into 21 regions responsible for health care in the respective geographical areas. The university hospitals performing acetabular fracture surgery are mainly located in the country's southern regions. Non-surgical treatments may be favoured in areas with restricted access to acetabular fracture surgery. These patients may, instead, be more prone to delayed arthroplasty as a consequence of posttraumatic arthritis.

MORTALITY

Study II confirms that the mortality after acetabular fractures in the geriatric population mimics the mortality of hip fracture patients [103,104]. Unlike hip fractures, where surgical intervention is typically preferred to enable early ambulation, the management of acetabular fractures in geriatric patients is less aggressive, frequently involving immobilisation and protected weight bearing. Such an approach is recognised to have adverse consequences on the ageing physiology [105,106]. This does not imply that all acetabular fractures should be treated surgically. However, the ability to ambulate and weight bear must be considered when treating these patients. The comparable mortality rates observed in patients with hip and acetabular fractures are likely attributable to the similar characteristics of the patient cohort experiencing these kinds of fractures. Comorbidities, age, and preinjury functions are likely comparative for these two groups and the type of fracture they sustained after a simple fall is secondary to mortality outcomes. Therefore, adopting similar care protocols for acetabular fractures as those employed for patients with hip fractures may prove beneficial. Research has indicated that multidisciplinary orthogeriatric care may diminish mortality rates among hip fracture patients [107,108]. Implementation of this care model has begun also for patients with acetabular fractures [109].

Khoshbin et al. reported a 30-day mortality of 6.6% in surgically treated acetabular fracture patients >60 years [110]. In a study by Bible et al., the 1-year mortality rate was 8.1% after an isolated acetabular fracture [111]. In their cohort, 64% were treated surgically. Patients who underwent surgical treatment exhibited lower mortality rates in comparison to those who did not receive surgical intervention. This disparity may be attributed to selection bias, as patients deemed appropriate for surgical procedures likely presented with fewer comorbidities. This was also illustrated in **Study IV**, where patients treated with THA/CHP had a lower 30-day mortality compared to non-surgically treated patients. However, a relatively elevated 1-year mortality was observed in this group. The patients in the THA/CHP group were older than those in the ORIF group and had a median age approximating that of the non-surgically treated group. However, they were deemed healthy enough to undergo extensive surgery, which could explain the differences in 30-day mortality. Although the ORIF group was younger, the 30-day mortality was not significantly higher for the THA/CHP group.

Study II divided patients into two age groups (≤70 or >70 years). In the older patient group, male patients displayed a higher 30-day mortality compared to female patients. The reasons for this disparity are yet to be clarified. Kannegaard et al. demonstrated a similar excessive early mortality for male patients following hip fractures [112]. Although the male patients were younger at the time of injury, the difference in mortality between the sexes endured after adjustment for comorbidities. In the general population, male individuals have a higher overall mortality risk, but even when this is taken into consideration, an increased mortality after hip fracture persists among male patients [113, 114].

PROM

PROM has become an increasingly popular tool for measuring how patients perceive the outcome of a certain event or treatment. Nevertheless, in contemporary society, individuals are inundated with questionnaires and evaluation forms, resulting in a probable decrease in response rates attributable to questionnaire fatigue. Additionally, obtaining PROM responses from trauma patients can be challenging due to the unexpected nature of their injuries, which have disrupted their prior functioning. Patients who have undergone elective surgery often have a history of long-standing disability, and the planned procedure typically results in improved functionality. Hence, gratitude and improvement may make these patients more inclined to answer questionnaires about their health.

The response rate for the PROM questionnaires in **Study III** approximated 20%. This rate raises the question of who answers the PROM forms and how they differ from those who do not. The average age of individuals with acetabular fractures is relatively high, and the presence of comorbidities such as dementia may impede their ability to respond. Others might choose to ignore the inquiry. An attempt to answer the question of the differences between responders and non-responders in the SFR was performed by Juto et al., who included patients with fractures of the humerus, radius, or ulna [(115)]. These authors concluded that although patients responding to PROM 0 and/or PROM 1 were slightly older and more often female than non-responders, these differences disappeared after case-control matching. No significant differences in PROM scores were found between responders and non-responders, except for the dysfunction index at the 1-year follow up, where responders reported worse function compared to non-responders. This difference also disappeared after case-control matching. In **Study III**, no significant differences between the sexes were noted, but responders were younger and had more serious injuries, i.e., high-energy trauma, and more often required surgical treatment. **Study III** did not analyse differences in PROM scores between responders and non-responders. However, SMFA scores were higher for surgically treated patients, those suffering high-energy injuries, and the younger patient group. Given the higher response rate observed in these patient groups, it could be argued that responders might experience poorer outcomes.

Another consideration when interpreting PROM responses is the effect that other injuries or illnesses may have on the patient's health, making it difficult to isolate what impression one specific injury had on the patient's function. This suggestion was why patients with additional fractures were excluded from **Study III**. Regrettably, this approach may have excluded some multitrauma patients whose pelvic injury outcome would be valuable. Nonetheless, this decision was made and driven by the study's objective of isolating the effects of an acetabular fracture. Including these patients could have obscured the intended analytical focus.

The Swedish version of the SMFA has been assessed for reliability and responsiveness, demonstrating it to be a valid instrument for measuring musculoskeletal function [60,116]. However, the difference in SMFA scores between two time points considered clinically important for the patient is still unclear. This change in score is termed the minimally important change (MIC) [117]. MIC is the smallest change in an SMFA score that an individual patient perceives as important. MIC is not to be confused with a minimal important difference (MID), which refers to how much the score needs to differ to be considered of clinical importance when comparing different patient groups. Neither MIC nor MID has been established for the Swedish SMFA. The lack of defined MIC and MID values complicates the interpretation of findings in **Study III**. Statistical significance between groups was calculated, but the impact that the patient experiences cannot be fully clarified.

The main result of **Study III** was the decline in function reported by all analysed subgroups, as demonstrated by the overall positive values of the mean ΔSMFA. The spread of individual ΔSMFA scores was wide, and even if most patients reported a decline in function, there were some that reported an improved function 1-year post-injury. This data distribution may be attributable to difficulties in understanding the questionnaire. For instance, the reliance on recall techniques in PROM 0's inquiries regarding pre-injury function may lead to misinterpretations, as some patients may inadvertently describe their current functional status, potentially influenced by their recent fracture. However, other patients may well experience an improvement in function after their injury. For example, for a patient with disabling arthrosis pre-injury treated with THA/CHP, the post-injury function at 1 year may be a marked improvement to pre-injury function. Nonetheless, the overall patient-reported outcome of impaired function confirms previous reports on mobility and disabilities following fractures of the acetabulum [67,68].

Few statistically significant differences between subgroups were found in **Study III**. However, indications and numerical differences were demonstrated. Younger patients, high-energy trauma mechanisms, and surgically treated patients seemed to have worse outcomes. Surgical treatment was the only variable that displayed significantly higher scores, which can be explained by selection bias. Other differences, especially between different fracture patterns, could not be determined in **Study III**; however, research and clinical experience suggest the probable existence of differences, although this cohort was too small to reveal them [(50, 118–120)]. An indication in line with previous studies was the worse outcome scores for posterior wall fractures and more complex (associated) fracture types.

SECONDARY TREATMENT

Study IV presented secondary treatment rates for acetabular fracture patients divided into three treatment groups: non-surgical, ORIF, and THA/CHP-treated patients. Treatment choice is based on several factors, including fracture pattern and displacement, as well as patient characteristics, such as age, activity level, and comorbidities. The threshold for being classified as an older adult has risen due to the increased lifespan and greater health and activity levels of the elderly. Expected survival and functional demands must be considered when choosing the proper treatment method.

Three of four patients were treated non-surgically, and this group also had the lowest rate of secondary treatment. These findings confirm that non-surgical treatment is advisable in most cases. Most fractures in this group likely had minimal displacement. However, this is a limitation of the Letournel classification that the degree of displacement is not considered. Similar to the findings in **Study IV**, Clarke-Jensen et al., who studied minimally displaced acetabular fractures treated non-surgically, reported a 10-year survival of the native hip of 94% [(121)]. An intraarticular step of ≥2 mm was associated with a higher risk of late THA.

In **Study IV**, almost one in five ORIF patients were converted to THA five years post-injury. This result aligns with previous findings on this patient group [69,93,122,123]. O'Toole et al. reported a slightly higher conversion rate, but the patients in that study cohort were older, which may contribute to their finding [124]. In Clarke-Jenssen et al.'s study, the population was younger, and a lower conversion rate was reported. Predictors of joint failure included injuries to the femoral head, acetabular impaction, patient age, body mass index, and fracture type [93,123]. In a German pelvic trauma registry study, the risk of late THA after ORIF increased by 6% per age year and for every millimetre of subluxation (i.e., asymmetrical femoral head position), the risk increased by 21% [125].

According to **Study IV**, the fracture types associated with the highest conversion rates from ORIF to THA were the PC+PW, T, and PW fractures. Both Cichos et al. and Preston et al. reported high risks for conversion to THA for T-shaped fractures [69, 93]. Multiple authors have described involvement of the posterior wall as an indication of poor prognosis [50, 125, 126]. However, as discussed above, the determination of treatment selection cannot be solely based on fracture type. These fracture types with higher conversion rates to late THA need to be assessed in combination with other radiological factors and patient characteristics. With this in mind, some patients treated primarily with ORIF may derive greater benefit from primary treatment with THA/CHP instead.

Although statistical significance could not be obtained, primary treatment with THA/CHP indicated lower rates of secondary surgery compared to ORIF in **Study IV**. In a review by Liang et al., THA/CHP in the acute setting showed higher revision rates than elective THA due to osteoarthritis but lower revision rates than late THA after failed ORIF [49]. In addition to minimising the risk of further surgery, patients treated with THA/CHP primarily benefit from the ability to bear full weight immediately after surgery. The choice of THA/CHP over ORIF in specific patient groups is further justified by the absence of a significant difference in 30-day mortality between these two treatment groups.

06.

MADELENE ALBREKTSSON

ACETABULAR FRACTURES

CONCLUSIONS

The accuracy of acetabular fracture classifications within the SFR was moderate and aligned with previous SFR validation studies on other fracture types. Given that accuracy levels vary across different fracture groups, it is important to exercise caution when interpreting SFR data specific to certain acetabular fracture groups. The consistency of ratings by the same individual (intrarater agreement) ranged from substantial to nearly perfect, while the agreement between different raters (interrater agreement) was moderate to substantial. **(Study I)**

Most patients sustaining acetabular fractures are >70 years old, predominantly male, and typically sustain the fracture following a simple, low-energy fall. Non-surgical treatment is generally favoured for the management of acetabular fractures. The 1-year mortality rate for older patients with acetabular fractures is comparable to that of hip fracture patients, suggesting that a similar multidisciplinary approach to care should be considered for these individuals. **(Study II)**

Most patients with acetabular fractures show reduced functional abilities 1-year post-injury compared to pre-injury. Younger patients with high-energy trauma and complex fracture configurations, frequently requiring surgical intervention, tend to have the least favourable outcomes. In contrast, the larger group of patients treated non-surgically reported only minor functional changes, which may be attributed to selection bias. **(Study III)**

A 17% conversion rate to arthroplasty was observed within five years among patients treated with ORIF for an acetabular fracture, compared to a 4% rate among patients initially managed non-surgically. The current approach to treatment selection for acetabular fracture patients in Sweden appears appropriate. However, patient selection within the ORIF group may benefit from further refinement. To reduce the likelihood of additional surgeries, primary THA/CHP is recommended as a more comprehensive treatment option for older adults with complex acetabular fractures. **(Study IV)**

07.

MADELENE ALBREKTSSON

ACETABULAR FRACTURES

FUTURE PERSPECTIVES

The SFR provides a unique source of nationwide population-based data encompassing all fracture types at a national level and enables different kinds of studies to be performed on large patient cohorts. Research based on the SFR has grown rapidly, but much information still needs to be analysed and reported. As an ever-growing database, the research on the SFR also needs to be updated as more patients are included and clinical practise develops. Specific to acetabular fractures, the fracture classification of non-surgically treated patients remains to be validated to guarantee data accuracy.

PROMs offer a valuable means of assessing treatment outcomes, but their low response rate and diverge range of responses pose challenges to interpretation. For practical reasons, the same questionnaires were used for all patients when introducing PROMs into the register. Such questionnaires need to be quite general in assessing disabilities and health. The instrument's sensitivity may be insufficient to measure the desired functional change following a specific injury accurately. Because the PROMs have now been digitalised, using PROMs more specific to the sustained injury could be considered to improve the quality of patient-reported outcomes. Additionally, efforts to improve response rates and analysis of missing data would be beneficial. A questionnaire aimed at the specific injury could possibly make patients more inclined to answer. Future study designs would benefit from incorporating additional methods to elicit patient perspectives.

The lack of MIC and MID for the PROMs used is a major limitation. Determining these values would significantly benefit all researchers using these instruments.

The growing population of both active and frail older adults has been frequently documented. This patient group will most likely continue to grow and drive the development of implants and surgical methods. Researchers must keep up with that development and evaluate the benefits and complications of new techniques. The recent trend of early THA/CHP treatment for older patients with acetabular fractures has shown promising results, but comprehensive long-term follow-up of these patients is warranted.

08.

MADELENE ALBREKTSSON

ACETABULAR FRACTURES

ACKNOWLEDGEMENTS

First, I would like to thank the University of Gothenburg for the opportunity to conduct research. It has been a great learning experience. I am still confused, but on a higher level.

I would also like to express my sincere gratitude to all orthopaedic departments and colleagues in Sweden for taking the time to enter data into the SFR. You are the ones enabling the studies in this thesis and many other research projects aimed at improving the care for all fracture patients.

Michael Möller, my supervisor and friend. I was so happy when you suggested that we do this PhD project together. A wise man once told me that the most important thing when writing a thesis is that you surround yourself with the right people, and you are most definitely the right "people". Thank you for your always so calm and wise guidance and for your generosity both professionally and in welcoming me into your multiple homes.

Mikael Sundfeldt, my co-supervisor and partner in crime. Thank you for your never-ending support, encouragement, and wonderful and annoyingly accurate analyses. Thank you for pushing me out of my comfort zone to ensure progress and development and being my safety net and source of wisdom when things get difficult. Thank you for backing me up no matter what. But above all, thank you for your friendship.

Olof Wolf, my co-supervisor and research machine. Thank you for all the fun discussions; I believe we are almost equally stubborn. Thank you for all your detailed comments and thorough reviews of all the manuscripts. You have made me rewrite more than anyone, but I must admit, you were usually right and I´ve learned a lot from you.

David Wennergren, my co-supervisor and role model. Your thesis and dissertation have been my source of inspiration and model of how a PhD project should be carried out. It has been a privilege to have you on-board. Thank you for all the pedagogic sessions, in which you always managed to turn what seemed to be a huge problem into one obvious solution, leaving me thinking, “Why didn´t I think of that?”.

Jón Karlsson, thank you for your generous back-up support, especially during the initial stages of this project. Thank you for your always so considerate queries, offers to help, and willingness to share your vast experience.

Anders Enocson, my co-author and idol, it was a joy to work with you during the first study of this PhD project. Thank you for being so thorough and providing such great suggestions in the most pedagogic and thoughtful way. I would love to work more with you.

Carl Bergdahl, my co-author and deeply admired colleague. You are a true inspiration in both scientific work and clinical practice. So much knowledge and wisdom fit into that head of yours. Thank you for your great advice and for providing patience when I lost mine.

Jan Ekelund, thank you for your positivity and always being generous with your extensive knowledge. Your guidance, brilliant explanations, and help navigating the complex world of statistics have been invaluable.

Nektarios Solidakis, the friendly radiologist who taught me how to create a decent demonstration of computed tomographies for Study I. Thank you.

Karin Svensson Malchau, thank you for going above and beyond in reviewing my first two manuscripts. You did not stop at improving the language, you also contributed great ideas and new perspectives on the subject at hand. Your lovely personality infuses the best energy boost to any room.

Leslie Shaps, thank you for your thorough language review of manuscripts three and four and this thesis. You not only provided corrections and improvements to the text but also educated and improved my language skills for the future.

Pontus Andersson, your exceptional illustrations for this thesis are greatly appreciated. Your patience and perseverance in navigating the more intricate designs deserve particular commendation.

Guðni Ólafsson, thank you for your exceptional work on the layout of this thesis.

Anna Orosz, thank you for guiding and helping me through the administrative brushwood of the university.

Anna Nilsdotter, Head of the Department of Orthopaedics at Sahlgrenska University Hospital, thank you for your dedication to promoting and fostering research within our department.

Anna Rubenson, Head of the Trauma Section at the Department of Orthopaedics, Sahlgrenska University Hospital. I am deeply grateful for your continued support and for affording me the opportunity to take time away from my clinical practice to complete this doctoral project.

To all my colleagues in the **Trauma Section** and throughout the **Orthopaedic Department** at Sahlgrenska University Hospital. Thank you for being such superb colleagues and for covering for me when I was away conducting research and writing this thesis. A special thank you to my fellow pelvic and acetabular fracture surgeons: **Mikael Sundfeldt**, **Janos Solyom**, **Andreas Runge**, and **David Hengst.**

To my friends and colleagues in the **Moomin Valley** and on the slopes of the golf course, thank you for your support, advice, and patience and for making everyday life a little bit more fun. **Camilla Bergh**, **Alicja Bojan**, **Sophia Halldin Lindorsson**, **Anna Rubenson**, and **Christina Berger**.

Caroline Stigevall and **Emilia Möller Rydberg**, "What if I told you SPSS stands for Substantial PhD Student Suffering?"* Suddenly, it all makes sense. Thank you for your friendship and support and for your help in not losing my sanity during this journey.

* *(modified quote from all-about-psychology.com)*

Matthias Fassbender, my friend, mentor, and role model who lit that spark of trauma interest and kept feeding the fire in the best way imaginable. Without you, I would not be where I am today *(and most likely would never have met any of the wonderful people mentioned above)*. Thank you.

Louise Alm, the very best part that I took from medical school, my survival partner. You know me better than I know myself, and still, you want to spend time with me. That is awesome! Thank you for being in my life. Family isn't always blood.

Catharina and **Bengt-Arne Albrektsson**, my dear parents who taught me to always do my best and, more importantly, that my best will always be good enough. Thank you for your unconditional love and support. I love you.

Maria and **Andreas Albrektsson**, **Therese** and **David Johansson**, my brothers and sisters (some in-law and some not). Thank you for all the fun moments and adventures we get to share and for always being there for all the ups and downs of life.

Oscar Johansson, **Amanda Albrektsson**, and **Elsa Johansson**, my nephew and nieces, the best an aunt could ever wish for. Thank you for bringing so much joy and craziness into my life.

To **all** my **family and friends**, I consider myself very lucky to have you in my life, and what a privilege it is to be a part of yours.

This thesis was made possible with
the financial support of the

Guldbyxan Foundation

and the

Hjalmar Svensson Foundation

Thank you

09.

MADELENE ALBREKTSSON

ACETABULAR FRACTURES

REFERENCES

1. Giannoudis PV, Grotz MR, Papakostidis C, Dinopoulos H. Operative treatment of displaced fractures of the acetabulum. A meta-analysis. The Journal of bone and joint surgery British volume. 2005;87(1):2-9.
2. Kelly J, Ladurner A, Rickman M. Surgical management of acetabular fractures - A contemporary literature review. Injury. 2020;51(10):2267-77.
3. Ochs BG, Marintschev I, Hoyer H, Rolauffs B, Culemann U, Pohlemann T, et al. Changes in the treatment of acetabular fractures over 15 years: Analysis of 1266 cases treated by the German Pelvic Multicentre Study Group (DAO/DGU). Injury. 2010;41(8):839-51.
4. Ciolli G, De Mauro D, Rovere G, Smakaj A, Marino S, Are L, et al. Anterior intrapelvic approach and suprapectineal quadrilateral surface plate for acetabular fractures with anterior involvement: a retrospective study of 34 patients. BMC Musculoskelet Disord. 2021;22(Suppl 2):1060.
5. Kwak DK, Jang JE, Kim WH, Lee SJ, Lee Y, Yoo JH. Is an Anatomical Suprapectineal Quadrilateral Surface Plate Superior to Previous Fixation Methods for Anterior Column-Posterior Hemitransverse Acetabular Fractures Typical in the Elderly?: A Biomechanical Study. Clin Orthop Surg. 2023;15(2):182-91.
6. Gras F, Marintschev I, Grossterlinden L, Rossmann M, Graul I, Hofmann GO, et al. The Anterior Intrapelvic Approach for Acetabular Fractures Using Approach-Specific Instruments and an Anatomical-Preshaped 3-Dimensional Suprapectineal Plate. J Orthop Trauma. 2017;31(7):e210-e6.
7. Nicol G, Sanders E, Liew A, Wilkin G, Gofton WT, Papp S, et al. Does use of a quadrilateral surface plate improve outcome in elderly acetabular fractures? J Clin Orthop Trauma. 2020;11(6):1045-52.
8. Moore KL, Dalley AF. Clinically oriented anatomy. Fourth edition ed. Philadelphia: Lippincott Williams & Wilkins; 1999.
9. Letournel EJ, R. Fractures of the Acetabulum. Second Edition ed. Berlin Heidelberg: Springer-Verlag; 1993.
10. Judet R, Judet J, Letournel E. FRACTURES OF THE ACETABULUM: CLASSIFICATION AND SURGICAL APPROACHES FOR OPEN REDUCTION. PRELIMINARY REPORT. J Bone Joint Surg Am. 1964;46:1615-46.
11. Judet R, Judet J. [Fractures of the acetabulum]. Acta Orthop Belg. 1966;32(3):469-76.
12. Beaulé PE, Dorey FJ, Matta JM. Letournel classification for acetabular fractures. Assessment of interobserver and intraobserver reliability. J Bone Joint Surg Am. 2003;85(9):1704-9.
13. Harris JH, Jr., Lee JS, Coupe KJ, Trotscher T. Acetabular fractures revisited: part 1, redefinition of the Letournel anterior column. AJR American journal of roentgenology. 2004;182(6):1363-6.
14. Harris JH, Jr., Coupe KJ, Lee JS, Trotscher T. Acetabular fractures revisited: part 2, a new CT-based classification. AJR American journal of roentgenology. 2004;182(6):1367-75.
15. Herman A, Tenenbaum S, Ougortsin V, Shazar N. There Is No Column: A New Classification for Acetabular Fractures. J Bone Joint Surg Am. 2018;100(2):e8.
16. Zhang R, Yin Y, Li A, Wang Z, Hou Z, Zhuang Y, et al. Three-Column Classification for Acetabular Fractures: Introduction and Reproducibility Assessment. J Bone Joint Surg Am. 2019;101(22):2015-25.

17. Fracture and dislocation compendium. Orthopaedic Trauma Association Committee for Coding and Classification. J Orthop Trauma. 1996;10 Suppl 1:v-ix, 1-154.

18. Laird A, Keating JF. Acetabular fractures: a 16-year prospective epidemiological study. The Journal of bone and joint surgery British volume. 2005;87(7):969-73.

19. Ferguson TA, Patel R, Bhandari M, Matta JM. Fractures of the acetabulum in patients aged 60 years and older: an epidemiological and radiological study. The Journal of bone and joint surgery British volume. 2010;92(2):250-7.

20. Rinne PP, Laitinen MK, Huttunen T, Kannus P, Mattila VM. The incidence and trauma mechanisms of acetabular fractures: A nationwide study in Finland between 1997 and 2014. Injury. 2017;48(10):2157-61.

21. Lundin N, Huttunen TT, Berg HE, Marcano A, Felländer-Tsai L, Enocson A. Increasing incidence of pelvic and acetabular fractures. A nationwide study of 87,308 fractures over a 16-year period in Sweden. Injury. 2021;52(6):1410-7.

22. Melhem E, Riouallon G, Habboubi K, Gabbas M, Jouffroy P. Epidemiology of pelvic and acetabular fractures in France. Orthopaedics & traumatology, surgery & research : OTSR. 2020;106(5):831-9.

23. Herath SC, Pott H, Rollmann MFR, Braun BJ, Holstein JH, Höch A, et al. Geriatric Acetabular Surgery: Letournel's Contraindications Then and Now-Data From the German Pelvic Registry. J Orthop Trauma. 2019;33 Suppl 2:S8-s13.

24. Butterwick D, Papp S, Gofton W, Liew A, Beaule PE. Acetabular fractures in the elderly: evaluation and management. J Bone Joint Surg Am. 2015;97(9):758-68.

25. Borg T, Hernefalk B, Hailer NP. Acute total hip arthroplasty combined with internal fixation for displaced acetabular fractures in the elderly: a short-term comparison with internal fixation alone after a minimum of two years. The bone & joint journal. 2019;101-b(4):478-83.

26. Herscovici D, Jr., Lindvall E, Bolhofner B, Scaduto JM. The combined hip procedure: open reduction internal fixation combined with total hip arthroplasty for the management of acetabular fractures in the elderly. J Orthop Trauma. 2010;24(5):291-6.

27. Cacciola G, Aprato A, Branca Vergano L, Sallam A, Massé A. Is non-operative management of acetabular fracture a viable option for older patients? A systematic review of the literature for indication, treatments, complications and outcome. Acta Biomed. 2022;92(S3):e2021555.

28. Mohan K, Broderick JM, Raza H, O'Daly B, Leonard M. Acetabular fractures in the elderly: modern challenges and the role of conservative management. Ir J Med Sci. 2022;191(3):1223-8.

29. Shah N, Gill IP, Hosahalli Kempanna VK, Iqbal MR. Management of acetabular fractures in elderly patients. J Clin Orthop Trauma. 2020;11(6):1061-71.

30. Matta JM. Fractures of the acetabulum: accuracy of reduction and clinical results in patients managed operatively within three weeks after the injury. J Bone Joint Surg Am. 1996;78(11):1632-45.

31. Rickman M, Varghese VD. Contemporary acetabular fracture surgery: treading water or swimming upstream? The bone & joint journal. 2017;99-b(9):1125-31.

32. Letournel E. Acetabulum fractures: classification and management. Clin Orthop Relat Res. 1980(151):81-106.

33. Stannard JP, Alonso JE. Controversies in acetabular fractures. Clin Orthop Relat Res. 1998(353):74-80.

34. Alonso JE, Davila R, Bradley E. Extended iliofemoral versus triradiate approaches in management of associated acetabular fractures. Clin Orthop Relat Res. 1994(305):81-7.

35. Cutrera NJ, Pinkas D, Toro JB. Surgical Approaches to the Acetabulum and Modifications in Technique. The Journal of the American Academy of Orthopaedic Surgeons. 2015;23(10):592-603.

36. Browner BJ, J.; Krettek, C.; Andersson, P. Skeletal trauma: Basic science, management, and reconstruction, fifth edition: Elsevier Saunders; 2015.

37. Chen JY, Sharma I, Sabbagh RS, Narendran N, Everhart JS, Slaven JE, et al. Risk of Postoperative Sciatic Nerve Palsy After Posterior Acetabular Fracture Fixation: Does Patient Position Matter? J Orthop Trauma. 2023;37(2):64-9.

38. Ganz R, Gill TJ, Gautier E, Ganz K, Krügel N, Berlemann U. Surgical dislocation of the adult hip a technique with full access to the femoral head and acetabulum without the risk of avascular necrosis. The Journal of bone and joint surgery British volume. 2001;83(8):1119-24.

39. Büchler L, Anwander H. Ilio-Inguinal Approach. 2019. p. 43-52.

40. Matta JM. Operative treatment of acetabular fractures through the ilioinguinal approach. A 10-year perspective. Clin Orthop Relat Res. 1994(305):10-9.

41. Scrivano M, Vadalà A, Fedeli G, Di Niccolo R, Topa D, Porcino S, et al. A comparison between ilioinguinal and modified Stoppa approach in anterior column acetabular fractures. Injury. 2024;55(2):111166.

42. Ma K, Luan F, Wang X, Ao Y, Liang Y, Fang Y, et al. Randomized, controlled trial of the modified Stoppa versus the ilioinguinal approach for acetabular fractures. Orthopedics. 2013;36(10):e1307-15.

43. Stoppa RE, Rives JL, Warlaumont CR, Palot JP, Verhaeghe PJ, Delattre JF. The use of Dacron in the repair of hernias of the groin. Surg Clin North Am. 1984;64(2):269-85.

44. Cole JD, Bolhofner BR. Acetabular fracture fixation via a modified Stoppa limited intrapelvic approach. Description of operative technique and preliminary treatment results. Clin Orthop Relat Res. 1994(305):112-23.

45. Archdeacon MT, Kazemi N, Guy P, Sagi HC. The modified Stoppa approach for acetabular fracture. The Journal of the American Academy of Orthopaedic Surgeons. 2011;19(3):170-5.

46. Keel MJ, Ecker TM, Cullmann JL, Bergmann M, Bonel HM, Büchler L, et al. The Pararectus approach for anterior intrapelvic management of acetabular fractures: an anatomical study and clinical evaluation. The Journal of bone and joint surgery British volume. 2012;94(3):405-11.

47. Keel MJB, Siebenrock KA, Tannast M, Bastian JD. The Pararectus Approach: A New Concept. JBJS Essent Surg Tech. 2018;8(3):e21.

48. Ochs BG, Gonser C, Shiozawa T, Badke A, Weise K, Rolauffs B, et al. Computer-assisted periacetabular screw placement: Comparison of different fluoroscopy-based navigation procedures with conventional technique. Injury. 2010;41(12):1297-305.

49. Liang K, Gani MH, Griffin X, Culpan P, Mukabeta T, Bates P. Acute versus delayed total hip arthroplasty after acetabular fracture fixation: a systematic review and meta-analysis. European journal of orthopaedic surgery & traumatology : orthopedie traumatologie. 2023;33(7):2683-93.

50. Tannast M, Najibi S, Matta JM. Two to twenty-year survivorship of the hip in 810 patients with operatively treated acetabular fractures. J Bone Joint Surg Am. 2012;94(17):1559-67.

51. Nicol GM, Sanders EB, Kim PR, Beaulé PE, Gofton WT, Grammatopoulos G. Outcomes of Total Hip Arthroplasty After Acetabular Open Reduction and Internal Fixation in the Elderly-Acute vs Delayed Total Hip Arthroplasty. The Journal of arthroplasty. 2021;36(2):605-11.

52. Malhotra R, Gautam D. Acute total hip arthroplasty in acetabular fractures using modern porous metal cup. Journal of orthopaedic surgery (Hong Kong). 2019;27(2):2309499019855438.

53. Möller M, Wolf O, Bergdahl C, Mukka S, Rydberg EM, Hailer NP, et al. The Swedish Fracture Register - ten years of experience and 600,000 fractures collected in a National Quality Register. BMC Musculoskelet Disord. 2022;23(1):141.

54. Bergdahl C, Nilsson F, Wennergren D, Ekholm C, Möller M. Completeness in the Swedish Fracture Register and the Swedish National Patient Register: An Assessment of Humeral Fracture Registrations. Clinical epidemiology. 2021;13:325-33.

55. Wennergren D, Ekholm C, Sandelin A, Möller M. The Swedish fracture register: 103,000 fractures registered. BMC Musculoskelet Disord. 2015;16:338.

56. Wennergren D, Möller M. Implementation of the Swedish Fracture Register. Der Unfallchirurg. 2018;121(12):949-55.

57. sar.registercentrum.se.

58. W-Dahl AK, J; Rogmark, C; Nåtman, J; Bülow, E; Ighani Arani, P; Mohaddes, M; Rolfson, O. Annual report 2023, The Swedish Arthroplasty Register. 2023. Report No.: 1654-5982.

59. Swiontkowski MF, Engelberg R, Martin DP, Agel J. Short musculoskeletal function assessment questionnaire: validity, reliability, and responsiveness. J Bone Joint Surg Am. 1999;81(9):1245-60.

60. Ponzer S, Skoog A, Bergström G. The Short Musculoskeletal Function Assessment Questionnaire (SMFA): cross-cultural adaptation, validity, reliability and responsiveness of the Swedish SMFA (SMFA-Swe). Acta orthopaedica Scandinavica. 2003;74(6):756-63.

61. d'Aubigné RM, Postel M. The classic: functional results of hip arthroplasty with acrylic prosthesis. 1954. Clin Orthop Relat Res. 2009;467(1):7-27.

62. Ware JE, Jr., Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. Med Care. 1992;30(6):473-83.

63. Harris WH. Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty. An end-result study using a new method of result evaluation. J Bone Joint Surg Am. 1969;51(4):737-55.

64. Borg T, Carlsson M, Larsson S. Questionnaire to assess treatment outcomes of acetabular fractures. Journal of orthopaedic surgery (Hong Kong). 2012;20(1):55-60.

65. Mears DC, Velyvis JH, Chang CP. Displaced acetabular fractures managed operatively: indicators of outcome. Clin Orthop Relat Res. 2003(407):173-86.

66. Frietman B, Biert J, Edwards MJR. Patient-reported outcome measures after surgery for an acetabular fracture. The bone & joint journal. 2018;100-b(5):640-5.

67. Walley KC, Appleton PT, Rodriguez EK. Comparison of outcomes of operative versus non-operative treatment of acetabular fractures in the elderly and severely comorbid patient. European journal of orthopaedic surgery & traumatology : orthopedie traumatologie. 2017;27(5):689-94.

68. Baker G, McMahon SE, Warnock M, Johnston A, Cusick LA. Outcomes of conservatively managed complex acetabular fractures in the frail and elderly one year post injury. Injury. 2020;51(2):347-51.

69. Cichos KH, Spitler CA, Quade JH, McGwin G, Jr., Ghanem ES. Fracture and Patient Characteristics Associated With Early Conversion Total Hip Arthroplasty After Acetabular Fracture Fixation. J Orthop Trauma. 2021;35(11):599-605.

70. Anglen JO, Burd TA, Hendricks KJ, Harrison P. The "Gull Sign": a harbinger of failure for internal fixation of geriatric acetabular fractures. J Orthop Trauma. 2003;17(9):625-34.

71. Mears DC, Velyvis JH. Acute total hip arthroplasty for selected displaced acetabular fractures: two to twelve-year results. J Bone Joint Surg Am. 2002;84(1):1-9.

72. Weaver MJ, Smith RM, Lhowe DW, Vrahas MS. Does Total Hip Arthroplasty Reduce the Risk of Secondary Surgery Following the Treatment of Displaced Acetabular Fractures in the Elderly Compared to Open Reduction Internal Fixation? A Pilot Study. J Orthop Trauma. 2018;32 Suppl 1:S40-s5.

73. Boraiah S, Ragsdale M, Achor T, Zelicof S, Asprinio DE. Open reduction internal fixation and primary total hip arthroplasty of selected acetabular fractures. J Orthop Trauma. 2009;23(4):243-8.

74. Jauregui JJ, Weir TB, Chen JF, Johnson AJ, Sardesai NR, Maheshwari AV, et al. Acute total hip arthroplasty for older patients with acetabular fractures: A meta-analysis. J Clin Orthop Trauma. 2020;11(6):976-82.

75. Ryan SP, Manson TT, Sciadini MF, Nascone JW, LeBrun CT, Castillo RC, et al. Functional Outcomes of Elderly Patients With Nonoperatively Treated Acetabular Fractures That Meet Operative Criteria. J Orthop Trauma. 2017;31(12):644-9.

76. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics. 1977;33(1):159-74.

77. Bergdahl C, Ekholm C, Wennergren D, Nilsson F, Möller M. Epidemiology and patho-anatomical pattern of 2,011 humeral fractures: data from the Swedish Fracture Register. BMC Musculoskelet Disord. 2016;17:159.

78. Wennergren D, Bergdahl C, Ekelund J, Juto H, Sundfeldt M, Möller M. Epidemiology and incidence of tibia fractures in the Swedish Fracture Register. Injury. 2018;49(11):2068-74.

79. sfr.registercentrum.se.

80. Bergdahl C, Wennergren D, Swensson-Backelin E, Ekelund J, Möller M. No change in reoperation rates despite shifting treatment trends: a population-based study of 4,070 proximal humeral fractures. Acta orthopaedica. 2021;92(6):651-7.

81. Wennergren D, Bergdahl C, Selse A, Ekelund J, Sundfeldt M, Möller M. Treatment and re-operation rates in one thousand and three hundred tibial fractures from the Swedish Fracture Register. European journal of orthopaedic surgery & traumatology : orthopedie traumatologie. 2021;31(1):143-54.

82. Wennergren D, Ekholm C, Sundfeldt M, Karlsson J, Bhandari M, Möller M. High reliability in classification of tibia fractures in the Swedish Fracture Register. Injury. 2016;47(2):478-82.

83. Wennergren D, Stjernstrom S, Moller M, Sundfeldt M, Ekholm C. Validity of humerus fracture classification in the Swedish fracture register. BMC Musculoskelet Disord. 2017;18(1):251.

84. Juto H, Möller M, Wennergren D, Edin K, Apelqvist I, Morberg P. Substantial accuracy of fracture classification in the Swedish Fracture Register: Evaluation of AO/OTA-classification in 152 ankle fractures. Injury. 2016;47(11):2579-83.

85. Knutsson SB, Wennergren D, Bojan A, Ekelund J, Moller M. Femoral fracture classification in the Swedish Fracture Register - a validity study. BMC Musculoskelet Disord. 2019;20(1):197.

86. Bergvall M, Bergdahl C, Ekholm C, Wennergren D. Validity of classification of distal radial fractures in the Swedish fracture register. BMC Musculoskelet Disord. 2021;22(1):587.

87. Blixt S, Burmeister F, Mukka S, Bobinski L, Försth P, Westin O, et al. Reliability of thoracolumbar burst fracture classification in the Swedish Fracture Register. BMC Musculoskelet Disord. 2024;25(1):281.

88. O'Toole RV, Cox G, Shanmuganathan K, Castillo RC, Turen CH, Sciadini MF, et al. Evaluation of computed tomography for determining the diagnosis of acetabular fractures. J Orthop Trauma. 2010;24(5):284-90.

89. Riouallon G, Sebaaly A, Upex P, Zaraa M, Jouffroy P. A New, Easy, Fast, and Reliable Method to Correctly Classify Acetabular Fractures According to the Letournel System. JB & JS open access. 2018;3(1):e0032.

90. Herteleer M, Dejaeger M, Nijs S, Hoekstra H, Laurent MR. Epidemiology and secular trends of pelvic fractures in Belgium: A retrospective, population-based, nationwide observational study. Bone. 2021;153:116141.

91. Daurka JS, Pastides PS, Lewis A, Rickman M, Bircher MD. Acetabular fractures in patients aged > 55 years: a systematic review of the literature. The bone & joint journal. 2014;96-b(2):157-63.

92. Firoozabadi R, Cross WW, Krieg JC, Routt MLC. Acetabular Fractures in the Senior Population- Epidemiology, Mortality and Treatments. The archives of bone and joint surgery. 2017;5(2):96-102.

93. Preston G, Heimke IM, Heindel K, Scarcella NR, Furdock R, Vallier HA. Survivorship of the Hip Joint After Acetabulum Fracture. The Journal of the American Academy of Orthopaedic Surgeons. 2021;29(18):781-8.

94. Ansorge A, de Foy M, Gayet-Ageron A, Andereggen E, Gamulin A. Epidemiology of high-energy blunt pelvic ring injuries: A three-year retrospective case series in a level-I trauma center. Orthopaedics & traumatology, surgery & research : OTSR. 2023;109(2):103446.

95. Bakhshayesh P, Weidenhielm L, Enocson A. Factors affecting mortality and reoperations in high-energy pelvic fractures. European journal of orthopaedic surgery & traumatology : orthopedie traumatologie. 2018;28(7):1273-82.

96. Turner C, McClure R. Age and gender differences in risk-taking behaviour as an explanation for high incidence of motor vehicle crashes as a driver in young males. Inj Control Saf Promot. 2003;10(3):123-30.

97. Aldred R, Johnson R, Jackson C, Woodcock J. How does mode of travel affect risks posed to other road users? An analysis of English road fatality data, incorporating gender and road type. Inj Prev. 2021;27(1):71-6.

98. Antell NB, Switzer JA, Schmidt AH. Management of Acetabular Fractures in the Elderly. The Journal of the American Academy of Orthopaedic Surgeons. 2017;25(8):577-85.

99. Ortega-Briones A, Smith S, Rickman M. Acetabular Fractures in the Elderly: Midterm Outcomes of Column Stabilisation and Primary Arthroplasty. BioMed research international. 2017;2017:4651518.

100. Bergh C, Wennergren D, Möller M, Brisby H. Fracture incidence in adults in relation to age and gender: A study of 27,169 fractures in the Swedish Fracture Register in a well-defined catchment area. PloS one. 2020;15(12):e0244291.

101. Miyasaka D, Sakai Y, Ibuchi S, Suzuki H, Imai N, Endo N. Sex- and age-specific differences in femoral head coverage and acetabular morphology among healthy subjects-derivation of normal ranges and thresholds for abnormality. Skeletal radiology. 2017;46(4):523-31.

102. Wang SC, Brede C, Lange D, Poster CS, Lange AW, Kohoyda-Inglis C, et al. Gender differences in hip anatomy: possible implications for injury tolerance in frontal collisions. Annual proceedings Association for the Advancement of Automotive Medicine. 2004;48:287-301.

103. Bergh C, Möller M, Ekelund J, Brisby H. 30-day and 1-year mortality after skeletal fractures: a register study of 295,713 fractures at different locations. Acta orthopaedica. 2021;92(6):739-45.

104. Bergh C, Möller M, Ekelund J, Brisby H. Mortality after Sustaining Skeletal Fractures in Relation to Age. Journal of clinical medicine. 2022;11(9).

105. Dittmer DK, Teasell R. Complications of immobilization and bed rest. Part 1: Musculoskeletal and cardiovascular complications. Can Fam Physician. 1993;39:1428-32, 35-7.

106. Teasell R, Dittmer DK. Complications of immobilization and bed rest. Part 2: Other complications. Can Fam Physician. 1993;39:1440-2, 5-6.

107. Van Heghe A, Mordant G, Dupont J, Dejaeger M, Laurent MR, Gielen E. Effects of Orthogeriatric Care Models on Outcomes of Hip Fracture Patients: A Systematic Review and Meta-Analysis. Calcif Tissue Int. 2022;110(2):162-84.

108. Grigoryan KV, Javedan H, Rudolph JL. Orthogeriatric care models and outcomes in hip fracture patients: a systematic review and meta-analysis. J Orthop Trauma. 2014;28(3):e49-55.

109. Keppler AM, Gosch M, Kammerlander C. Orthogeriatric co-management in pelvic and acetabular fractures. Arch Orthop Trauma Surg. 2024.

110. Khoshbin A, Atrey A, Chaudhry H, Nowak L, Melo LT, Stavrakis A, et al. Mortality Rate of Geriatric Acetabular Fractures Is High Compared With Hip Fractures. A Matched Cohort Study. J Orthop Trauma. 2020;34(8):424-8.

111. Bible JE, Wegner A, McClure DJ, Kadakia RJ, Richards JE, Bauer JM, et al. One-year mortality after acetabular fractures in elderly patients presenting to a level-1 trauma center. J Orthop Trauma. 2014;28(3):154-9.

112. Kannegaard PN, van der Mark S, Eiken P, Abrahamsen B. Excess mortality in men compared with women following a hip fracture. National analysis of comedications, comorbidity and survival. Age and ageing. 2010;39(2):203-9.

113. Kanis JA, Oden A, Johnell O, De Laet C, Jonsson B, Oglesby AK. The components of excess mortality after hip fracture. Bone. 2003;32(5):468-73.

114. Vestergaard P, Rejnmark L, Mosekilde L. Increased mortality in patients with a hip fracture-effect of pre-morbid conditions and post-fracture complications. Osteoporosis international : a journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA. 2007;18(12):1583-93.

115. Juto H, Gärtner Nilsson M, Möller M, Wennergren D, Morberg P. Evaluating non-responders of a survey in the Swedish fracture register: no indication of different functional result. BMC Musculoskelet Disord. 2017;18(1):278.

116. Hedbeck CJ, Tidermark J, Ponzer S, Blomfeldt R, Bergström G. Responsiveness of the Short Musculoskeletal Function Assessment (SMFA) in patients with femoral neck fractures. Quality of life research : an international journal of quality of life aspects of treatment, care and rehabilitation. 2011;20(4):513-21.

117. Terwee CB, Peipert JD, Chapman R, Lai JS, Terluin B, Cella D, et al. Minimal important change (MIC): a conceptual clarification and systematic review of MIC estimates of PROMIS measures. Quality of life research : an international journal of quality of life aspects of treatment, care and rehabilitation. 2021;30(10):2729-54.

118. Murphy D, Kaliszer M, Rice J, McElwain JP. Outcome after acetabular fracture. Prognostic factors and their inter-relationships. Injury. 2003;34(7):512-7.

119. Ziran N, Soles GLS, Matta JM. Outcomes after surgical treatment of acetabular fractures: a review. Patient Saf Surg. 2019;13:16.

120. Gänsslen A, Lindahl J, Staresinic M, Krappinger D. Outcomes of acetabular fractures. Arch Orthop Trauma Surg. 2024.

121. Clarke-Jenssen J, Wikerøy AK, Røise O, Øvre SA, Madsen JE. Long-Term Survival of the Native Hip After a Minimally Displaced, Nonoperatively Treated Acetabular Fracture. J Bone Joint Surg Am. 2016;98(16):1392-9.

122. Manson TT, Slobogean GP, Nascone JW, Sciadini MF, LeBrun CT, Boulton CL, et al. Open reduction and internal fixation alone versus open reduction and internal fixation plus total hip arthroplasty for displaced acetabular fractures in patients older than 60 years: A prospective clinical trial. Injury. 2022;53(2):523-8.

123. Clarke-Jenssen J, Røise O, Storeggen S, Madsen JE. Long-term survival and risk factors for failure of the native hip joint after operatively treated displaced acetabular fractures. The bone & joint journal. 2017;99-b(6):834-40.

124. Khoshbin A, Hoit G, Henry PDG, Paterson JM, Huang A, Atrey A, et al. Risk of Total Hip Arthroplasty After Acetabular Fracture Fixation: The Importance of Age. The Journal of arthroplasty. 2021.

125. Rollmann MF, Holstein JH, Pohlemann T, Herath SC, Histing T, Braun BJ, et al. Predictors for secondary hip osteoarthritis after acetabular fractures-a pelvic registry study. Int Orthop. 2019;43(9):2167-73.

126. Zha GC, Sun JY, Dong SJ. Predictors of clinical outcomes after surgical treatment of displaced acetabular fractures in the elderly. J Orthop Res. 2013;31(4):588-95.