UPPSALA
UNIVERSITET

Digital Comprehensive Summaries of Uppsala Dissertations from the Faculty of Medicine 1643

Surgical Treatment of Pelvic Ring Injuries and Acetabular Fractures

Aspects on Patient-reported Outcome

BJÖRN HERNEFALK

ACTA
UNIVERSITATIS
UPSALIENSIS
UPPSALA
2020

ISSN 1651-6206
ISBN 978-91-513-0887-6
urn:nbn:se:uu:diva-404264

Dissertation presented at Uppsala University to be publicly examined in H:son Holmdahlssalen, Akademiska sjukhuset, ing 100, 2 tr, Uppsala, Thursday, 23 April 2020 at 13:00 for the degree of Doctor of Philosophy (Faculty of Medicine). The examination will be conducted in Swedish. Faculty examiner: Docent Anna Tötterman (Karolinska Institutet).

Abstract

Hernefalk, B. 2020. Surgical Treatment of Pelvic Ring Injuries and Acetabular Fractures. Aspects on Patient-reported Outcome. *Digital Comprehensive Summaries of Uppsala Dissertations from the Faculty of Medicine* 1643. 53 pp. Uppsala: Acta Universitatis Upsaliensis. ISBN 978-91-513-0887-6.

The overall aim of the present thesis was to study the patient perspective on outcome following surgical treatment of pelvic ring injuries and acetabular fractures. All studies were based on patients treated for such injuries at the Department of Orthopaedics, Uppsala University Hospital, Sweden.

In Study I, a patient-reported outcome measure to provide condition-specific information regarding outcome after surgical treatment of pelvic ring injuries was developed. Seventy-three patients were asked to complete a questionnaire at three time points during follow-up. Evaluation of data resulted in the Pelvic Discomfort Index (PDI). This instrument is comprised of six questions regarding residual problems from the pelvic region with respect to pain, walking, hip motion, leg numbness, sexual life and the operation scar.

The influence of the time-point post-surgery at which patients with surgically treated pelvic ring injuries or acetabular fractures estimate their pre-traumatic state was examined in study II. Seventy-three patients assessed their pre-traumatic status at three time-points post-surgery. It was found that pre-traumatic quality of life was high and comparable to a reference population. Pre-existing discomfort from the pelvic region was uncommon. A tendency for patients to estimate a better pre-traumatic status when assessments were delayed was observed.

The objective of Study III was to compare outcome after surgical treatment of complex acetabular fractures in the elderly using either the combined hip procedure, consisting of open reduction and internal fixation (ORIF) in conjunction with an acute total hip arthroplasty, or ORIF alone with respect to mortality, need for secondary surgery and patient-reported outcome. Thirteen patients treated with the CHP were compared to 14 patients with similar fracture patterns treated with ORIF alone. The CHP conferred a markedly reduced need for secondary surgical procedures while no differences in perioperative mortality or patient-reported outcome could be demonstrated.

Patient-reported outcome at five years following surgical treatment of pelvic ring injury was evaluated in study IV. The consequences of these injuries were found to be substantial and long-standing. Females reported a worse outcome than males, while influence of variables age, injury type and presence of associated injuries was limited.

In Study V, patient experiences of life following treatment for pelvic ring injury was explored. Semi-structured interviews were conducted with ten patients at a median of 11 years after injury and analyzed using inductive content analysis. Patients described a heterogenous outcome, with residual impairment ranging from virtually none to severe disability. A need for adequate patient information and individual assessments of patients was noted.

Keywords: Pelvic ring injuries, acetabular fractures, patient.reported outcome, surgical treatment, PDI, SF-36

Björn Hernefalk, Department of Surgical Sciences, Orthopaedics, Akademiska sjukhuset, Uppsala University, SE-75185 Uppsala, Sweden.

ISSN 1651-6206
ISBN 978-91-513-0887-6
urn:nbn:se:uu:diva-404264 (http://urn.kb.se/resolve?urn=urn:nbn:se:uu:diva-404264)

List of Papers

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

I Borg T., Hernefalk B., Carlsson M., Larsson S. (2015) Development of a pelvic discomfort index to evaluate outcome following fixation for pelvic ring injury. *Journal of Orthopaedic Surgery*, 23(2):146–9

II Hernefalk B., Eriksson N., Borg T., Larsson S. (2016) Estimating pre-traumatic quality of life in patients with surgically treated acetabular fractures and pelvic ring injuries: Does timing Matter? *Injury,* 47(2):389-94

III Borg T., Hernefalk B., Hailer N P. (2019) 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;101-B:478-483*

IV Hernefalk B., Eriksson, N., Larsson S., Borg T. (2019) Patient-reported outcome in surgically treated pelvic ring injuries at five years post-surgery. *Scandinavian Journal of Surgery, Doi:10.1177/1457496919877583*

V Hernefalk B., Larsson S., Muntlin Å. The Long and Winding Road – Patient Experiences Following Surgical Treatment of Pelvic Ring Injuries. *Submitted manuscript*

Contents

Abbreviations

AO	Arbeitsgemeinschaft für Osteosynthesefragen/AO foundation
CI	Confidence Interval
COSMIN	COnsensus-based Standards for the Selection of Health Measurement INstruments
HHS	Harris Hip Score
ICU	Intensive Care Unit
KMO	Kaiser-Meyer-Olkin
MAP	Merle D'Aubigne-Postel
MVA	Motor Vehicle Accident
ORIF	Open Reduction Internal Fixation
OTA	Orthopaedic Trauma Association
PDI	Pelvic Discomfort Index
PRO	Patient-Reported Outcome
ROM	Range of Motion
SF-36	Short-Form 36
THA	Total Hip Arthroplasty

Introduction

In any traumatic injury, a reasonable goal of treatment is to restore function and minimize potential sequelae for the patient in the safest possible manner. In order to evaluate the safety and benefit of any given treatment, studies concerning outcome are necessary. However, outcome following trauma can be defined in many different ways. It may be as basic as describing mortality rates, which yields prognostic information but says nothing about the state of the patients who survive. Outcome could also be described in terms of objective findings derived from investigations of the patient, such as physical examination or radiographic evaluation. In orthopedic injuries, this could include factors such as presence of gait, muscular strength, range of motion (ROM), neurological status and radiographic evaluation of healing, malalignment or development of post-traumatic osteoarthritis. Although vital components in assessment of patients, they do not necessarily describe which impact the injury and subsequent treatment has had in the patient's life. For example, a decreased ROM of the hip joint may be perceived catastrophic by some patients while others may feel unimpaired, and radiological appearance doesn't necessarily correlate with the symptoms that patients experience. Furthermore, other important consequences of an injury, such as psychological and socioeconomic insults, may be overlooked.

Evaluation of patient-reported outcome (PRO), using generic and condition specific questionnaires to assess the self-reported health state of patients, has established itself as a standard in orthopaedic literature[1]. These instruments allow patients to report different aspects of their health status, providing further insight on outcome than objective outcome measures alone. They are beneficial in evaluating the effects of a given treatment and when comparing the outcome of different treatment modalities. However, owing to several factors, interpretation of PRO data is not unproblematic. Given their subjective nature, they are susceptible to information biases, such as recall bias and responder bias. Patients also have individual internal standards, values and conceptualizations of what constitutes quality of life, making comparisons of assessments between patients and groups difficult and susceptible to bias. Furthermore, these individual variables may change for patients over the course of time, a phenomenon referred to as response-shift[2], even making comparison of assessments from a single individual at different time-points potentially problematic.

Patient-reported outcome measures

A patient-reported outcome can be defined as any measurement of any aspect of the patient´s health status that comes directly from the patient[3]. In order to provide reliable information and allow effective evaluation of patients, the development of patient-reported outcome instruments needs to entail testing of their validity, reliability and responsiveness[4]. The taxonomy and terminology of these measurement properties have been established and defined in a study by the COSMIN initiative as follows[5]:

Validity

Validity is the degree to which a PRO measures what it claims to measure, and can further be categorized into content validity and construct validity.

Content validity - the degree to which the content of an instrument is an adequate reflection of the construct to be measured, i.e. whether it assesses all fundamental aspects of the topic.

Construct validity – the degree to which the scores of an instrument are consistent with hypotheses (for example with regard to relationships to other instruments) based on the assumption that the PRO instrument validly measures the construct to be measured.

Reliability

The reliability of an instrument is defined as the degree to which the measurement is free from measurement error. There are three measurement properties relating to this domain:

Internal consistency – measures the degree of the interrelatedness among the items or subscales of an instrument. One of the most widely used methods to check for internal consistency is the Cronbach's Alpha.

Reliability – the proportion of the total variance in the measurements which is due to ´true´ differences between patients.

Measurement error – the part of a patient´s score that is not attributed to true changes in the measured construct.

Responsiveness

The responsiveness of an instrument refers to its ability to detect change over time.

Floor and ceiling effects are terms used to describe the effect when a large proportion of scores tend to be close to or at the bottom or top of the measure. They are considered to be present if more than 15% of patients achieve the lowest (floor) or highest (ceiling) score, respectively[6]. If present, they limit the reliability as well as the responsiveness of PRO instruments, thus threatening their clinical usefulness.

Surgical Treatment of Pelvic Injuries

Disruptions of the pelvic ring and acetabular fractures that require operative treatment are injuries that constitute a substantial challenge for the orthopaedic community. They are relatively uncommon and the anatomy of the pelvic region is complex, stipulating high demands on the orthopaedic surgeon. In addition to this, these injuries have a high frequency of associated injuries that need to be considered and treated simultaneously[7–12]. Because of these factors, treatment is often centralized to specialized referral centres with experience in managing these injuries. It is not uncommon for such centres to admit patients from vast geographical areas for definitive treatment after they have received initial care at a local institution. Reliable data on patient-reported outcome following these injuries is of importance to provide surgeons with a tool to compare treatment modalities and evaluate patients. However, such data is difficult to obtain given the relative scarcity of injuries. Furthermore, results are susceptible to be influenced by associated extrapelvic injuries, thus making interpretation difficult.

Pelvic Ring Injuries

Pelvic ring injuries are rare, with an incidence reported to 20-23 per 100.000[13,14]. They are estimated to account for approximately 1.5-3% of all skeletal injuries, the majority consisting of stable injury patterns that can normally be managed conservatively[15,16]. The less frequent, severe forms often necessitate surgical treatment and carry a significant morbidity and mortality. Associated injuries to other body regions such as the chest, head, abdomen and lower extremity are common and have been reported to between 3-20%[17–19]. The mechanism of injury is normally a high-energy trauma such as MVA or fall from great height, although they may also occur as a result of low-energy trauma in the frail patient[10,20,21].

Classification

In order to provide surgeons with a tool to determine the appropriate treatment of a pelvic ring injury, numerous efforts have been made to develop classification systems[22]. The two main systems that have evolved are the AO/OTA classification[23] and the Young and Burgess classification[24]. The latter classes injuries into four main types based on the injury mechanism: lateral compression, antero-posterior compression, vertical shear and combined. These force vectors were originally described by Pennal *et al*.[25].

The AO/OTA-classification is the most comprehensive classification system for pelvic fractures and was used in the studies of the present thesis. It divides pelvic fractures into three basic types according to stability based on

the integrity of the posterior sacroiliac complex, a concept originally introduced by Tile *et al*[26]. (Table 1).

Table 1. *The AO/OTA Classification of Pelvic Ring Fractures: Main fracture types*

A	The fracture does not involve the posterior sacroiliac complex. Stable injuries.
B	Partial disruption of the posterior sacroiliac complex. Injuries are rotationally unstable.
C	Complete disruption of the posterior sacroiliac complex. Injuries are rotationally and vertically unstable.

As A-type fractures do not compromise the posterior sacroiliac complex, the pelvic ring is stable, enabling conservative treatment. These injury patterns are not examined in the studies of the present thesis.

In B-type injuries, there is partial disruption of the posterior sacroiliac complex, rendering them rotationally unstable but vertically stable. They are further divided into subgroups B1-B3. B1 injuries, the "open book-injury", are caused by an anteroposterior force on the pelvis. The posterior lesion involves either the anterior part of the SI-joint or the sacral ala. The anterior injury is typically a disruption of the pubic symphysis. Fractures of the pubis or rami are less frequent. The B2 injuries are caused by a lateral compression force, rendering a posterior lesion of either a compression fracture of the anterior sacrum or a fracture subluxation of the SI-joint. The anterior arch injuries include variable forms of compression of the symphysis or rami. B3 injuries are bilaterally partially stable injuries, comprised of any two combinations of type-B1 and type-B2.

Patients with injuries of C-type have suffered a complete insult to the posterior sacroiliac complex and are thus both rotationally and vertically unstable. They can be further divided into 3 subgroups.

C1-type injuries are unilateral injuries with complete posterior disruptions. The posterior lesion is either a complete fracture through the posterior ilium (C1.1), a crescent fracture (transiliac dislocation) with complete SI-joint displacement or a pure SI-joint dislocation (C1.2), or a completely unstable vertical fracture of the sacrum (C1.3).

C2-type injuries are bilateral injuries where one side is either of three C1-types and the other side is of B-type. They can be further divided depending on the type of C1-lesion, which is a fracture of the posterior ilium in C2.1, through the SI-joint in C2.2 and through the sacrum in C2.3 type injuries.

C3-type injuries are bilateral fractures of C1-type, either extrasacral on both sides (C3.1), extrasacral on one side and sacral on the contralateral side (C3.2) or sacral bilaterally (C3.3).

Surgical treatment of pelvic ring injuries

Indication for surgical stabilization of pelvic ring disruption include displacement and instability, as conservative treatment has been shown to yield unsatisfactory results in these instances[27,28]. The evolution of surgical methods in which to address these injuries is ongoing[29]. Up until the middle part of the 20th century, the treatment protocols were generally conservative. With increased involvement of orthopaedic surgeons in early trauma care and resuscitation, the use of external fixators as means to control stability and blood loss was introduced and increasingly used in the acute treatment of these injuries[30]. They are still an option in the acute management of mechanically unstable disruptions with hemodynamic instability and as a temporary solution until definitive operative treatment can be provided. Continued development in the field saw orthopaedic surgeons advocate open reduction and internal fixation, in order to achieve a better reduction and allow early mobilization[11,27,28]. The subsequent introduction of percutaneous techniques has provided even further options for addressing these injuries[31–33].

At our institution, the majority of cases are treated with a combination of a percutaneous procedure to address the posterior lesion followed by open reduction and internal fixation (ORIF) for the anterior injury. Strictly percutaneous procedures are the second most common mode of treatment while open procedures for both the posterior and anterior lesion is the least used method, reserved for cases where adequate reduction and stabilization of the posterior aspect of the pelvic ring cannot be achieved with cannulated screws alone.

Patient-reported outcome after surgical treatment of pelvic ring injuries

In 2012, Lefaivre *et al.* published a systematic review on the literature concerning patient-reported outcome following surgical treatment of pelvic ring disruptions and fractures[34]. In total, 28 studies were included in the review. It was found that generic outcome instruments were used in 15 studies. The by far most commonly used instrument was the SF-36, described in detail below, which was used in 12 studies. The only other generic instrument used more than once was the Short Musculoskeletal Functional Assessment (SMFA)[35], which was used twice.

Evaluation using a condition specific instrument was observed in 19 studies. In total, six different instruments were used, the most common being the Majeed score[36], which was used in 10 studies, followed by the Iowa Pelvis Score[37], which was used in five studies.

The systematic review concluded that the usage of generic and specific instruments in the literature pertaining to patient-reported outcome in surgically treated pelvic ring injuries is heterogeneous, both in terms of instruments used and how results are presented. It further stated that the overall validity, reliability and responsiveness of the pelvic-specific instruments have not been

established and that existing literature is inadequate to provide meaningful information about the outcome following surgical treatment of these injuries.

The Majeed score

The Majeed score, as mentioned the most commonly used outcome instrument, was published in 1989 as an alternative to evaluate outcome following pelvic ring injury in a systematic manner[36]. The instrument is based on 60 patients following treatment for pelvic ring injury and yields a score ranging from 0 (worst) to 100 (best) and consists of items concerning pain (30 points), work ability (20 points), sitting (10 points), standing (36 points) and sexual intercourse (4 points). The rationale for items chosen and their relative weighting is not disclosed, and the appropriateness of the weighting has been questioned[34]. Furthermore, ceiling effects, a threat to the responsiveness of the instrument, have been demonstrated[38].

Acetabular Fractures

The incidence of acetabular fractures has been reported to around 3 in 100.000 per year[39]. A bimodal age distribution has been described with a first peak representing younger patients who sustain their fractures through high-energy trauma and a second peak representing older, frail patients who sustain their injuries from low-energy falls[40,41].

Classification

The most widely referenced classification system for acetabular fractures is the Judet-Letournel system[7]. The AO/OTA classification is based on this system, which divides the fractures in one elementary group and one associated group, with five types in each group. (Figure 1)

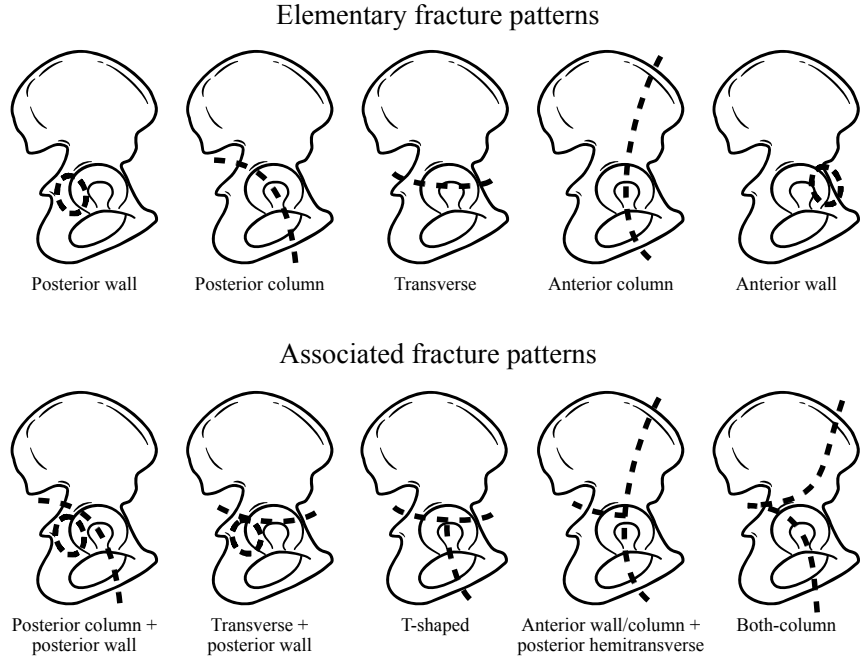

Figure 1. *The Judet-Letournel classification system for acetabular fractures. ©Robin Öberg*

Surgical treatment

There is little tolerance for displacement of acetabular fractures, as persisting incongruence yields a high incidence of secondary osteoarthritis and is associated with inferior outcome[42–44]. Thus, displaced fractures of the acetabulum are treated surgically with open reduction and internal fixation, unless contraindicated by patient factors that necessitate conservative treatment.

The surgical procedures at our department are carried out along established strategies for acetabular fractures[45]. The preferred method of choice to address posterior column injuries is a Kocher-Langenbeck approach, securing the posterior column using plate osteosynthesis. In cases of involvement of the anterior column, an ilioinguinal or a modified Stoppa approach is chosen for the ORIF.

The frequency of acetabular fractures in the elderly is increasing[46], and they may be complicated by severe acetabular impaction or concomitant femoral head injury, factors that are known to be associated with a poor outcome. Inferior outcome after ORIF alone has been reported and the results of delayed total hip arthroplasty (THA) are also discouraging[43,47]. Because of this, a Combined Hip Procedure (CHP), supplementing the ORIF with an acute THA in elderly patients with displaced acetabular fractures has been advocated[48].

Patient-reported outcome after surgical treatment of acetabular fractures

A systematic review by Dodd *et al.* on the reporting on functional outcomes following surgical treatment of acetabular fractures was published in 2016 and included 69 articles on the subject[49]. In total, eight different generic instruments, the most common being the SF-36, and five condition-specific instruments, the two most common being the Merle D'Aubigne-Postel (MAP) hip score followed by the Harris Hip Score (HHS), were utilised. The review concluded that the majority of studies employed outcome measures that were not validated for use in patients with acetabular fractures and that current literature does not provide reliable information to allow neither scientific comparison nor patient counselling.

Merle D'Aubigne-Postel hip score

The MAP hip score was originally published 1954 to evaluate functional results following hip arthroplasty and assesses three items: pain, walking ability and mobility[50]. It was modified by Matta *et al.* in 1986 to evaluate treatment following acetabular fractures[44] although the rationale for this modification was not presented. Both scores include physical examination of hip ROM and as such are physician-rated rather than patient-reported instruments. The rationale for selection of the items used and weighting applied is not presented. Although extensively used in the literature, their validity in evaluating patients suffering acetabular fractures is questioned. Inconsistent interpretations of scores have been reported as well as ceiling effects, limiting their clinical use[49,51].

Harris Hip Score

In 1969, Harris proposed a score to allow evaluation of hip function following hip surgery. The HHS is made up by 4 subscales; pain, function, absence of deformity and hip ROM. The resulting score ranges from 0-100 where higher scores indicate less dysfunction and better outcome. It is the most frequently used instrument for evaluation of patients undergoing THA, and although physician-rated in its original form, some evaluation of the appropriateness of using the score as a patient-reported measure has been undertaken[52]. Although empirically derived, it has undergone validity testing in the setting of THA[53]. However, ceiling effects have been demonstrated and thus the usefulness of the instrument has been questioned[54]. The instrument has not been validated for use in evaluation of patient-reported outcome following acetabular fractures[49].

Outcome instruments used in the present thesis

SF-36

The Short-Form 36 is the most widely used generic Quality of Life instrument in orthopedic outcome studies to date[55]. It was developed as part of the Medical Outcomes Study by Ware *et al.*[56] and consists of thirty-six questions. It generates eight scaled scores, or domains. These domains are:

Physical functioning (PF)
Physical role functioning (RP)
Bodily pain (BP)
General health (GH)
Vitality (VT)
Social role functioning (SF)
Emotional role functioning (RE)
Mental Health (MH).

The raw data obtained from the questionnaire is transformed to sub-scores for each domain ranging from 0 (worst) to 100 (best). These can be further transposed into two summary scores, a Physical Component Summary (PCS) and a Mental Component Summary (MCS)[55]. However, as the component scores were developed using an orthogonal model, domains concerning physical health have a negative weight in the MCS and correspondingly the domains concerning mental health have a negative weight in the PCS[55]. This means that a worsening in domains corresponding to the PCS leads to an increase of the MCS and vice versa. Hence, in orthopaedic outcome studies, where an insult to domains pertaining to physical function can be expected, the MCS could conversely be inflated. Furthermore, it can be argued that the interpretation of component scores is less intuitive compared with presenting data from the individual domains. For these reasons, component scores were not utilized in the studies included in the present thesis.

The SF-36 is the most frequently used instrument in studies reporting outcome in pelvic ring injuries as well as acetabular fractures[34,49], and it has been translated and tested for validity as well as reliability against an average Swedish population[57].

EQ5D

The EuroQoL5D (euroqol.org) is a widely used generic quality of life instrument. It is comprised of a description system containing five questions concerning the following dimensions; mobility, self-care, usual activities, pain/discomfort and anxiety/depression. The instrument also contains the EQ visual analogue scale (EQ VAS), which records the respondent's self-rated health and is graded between 0 (worst) and 100 (best)[58]. The instrument is brief and completion time is usually a few minutes.

There are two versions of the instrument available for use in an adult population. The original 3L version was introduced in 1990, where each of the five dimensions has three levels (no problems, some problems and extreme problems). A newer 5L version, where each dimension has five levels, was launched in 2009 in an effort to improve sensitivity and reduce ceiling effects.

EQ5D was used in study II and III. As the patients in these studies were followed according to the protocol of the local pelvic injury registry, established in 2003, the original 3L version was used in these studies.

Pelvic Discomfort Index

The development and validation of a patient-reported instrument, to allow evaluation of residual discomfort from the pelvic region after surgical treatment of pelvic ring injuries, were the aims of study I in the present thesis. The resulting instrument, the Pelvic Discomfort Index (PDI), consists of six questions regarding issues with pain, walking, hip motion, leg sensation, scar tissue from the pelvic region and sexual problems[59]. Each question is graded on a six-level scale, ranging from no discomfort to very severe discomfort. The development of this instrument was a continuation of previous work by the supervisors of this thesis, Borg and Larsson, concerning PRO following surgical treatment of acetabular fractures[60]. Using the same methodology, employing a questionnaire constructed by an expert group, for patients to complete at specific time-points during follow-up and subsequently reducing the number of items using factor analysis as well as evaluating the instruments for validity, reliability and responsiveness, the two instruments turned out identical to each other. Hence, the same instrument, the Pelvic Discomfort Index, seem to be useful in evaluation following surgical treatment of both pelvic ring injuries and acetabular fractures.

Upon completion of the six item-questionnaire, a pelvic discomfort index is calculated. This index ranges from 0% pelvic discomfort (best) to 100% pelvic discomfort (worst). The calculation is done by adding the score for each question (between 0 points for no discomfort up to 5 points for very severe

discomfort) into a total score. This is then divided by the maximum potential score, which is 30 if all questions are answered, yielding the index. Suggested categorization of discomfort is minimal (0–20%), moderate (21–40%), severe (41–60%), very severe (61–80%), and extremely severe (>80%).

How much discomfort do you presently have	None	Very little	Little	Moderate	Severe	Very severe
From pain in the pelvis?	☐	☐	☐	☐	☐	☐
From the pelvis when walking?	☐	☐	☐	☐	☐	☐
With decreased mobility of the hips?	☐	☐	☐	☐	☐	☐
From loss of sensation or numbness in the legs?	☐	☐	☐	☐	☐	☐
In your sexual life?	☐	☐	☐	☐	☐	☐
From operation scars?	☐	☐	☐	☐	☐	☐

Figure 2. *The Pelvic Discomfort Index (PDI).*

Aims

The aims of the present thesis were:

- To develop a condition-specific patient-reported outcome measure to allow evaluation of patients with surgically treated pelvic ring injuries (Paper I)

- To investigate the influence of the time-point post-injury at which patients with surgically treated pelvic ring injuries and acetabular fractures estimate their pre-traumatic status (Paper II)

- To compare the outcome of the Combined Hip Procedure with that of ORIF alone in elderly patients with displaced and impacted acetabular fractures, with respect to need for secondary surgical procedures, perioperative mortality and patient-reported outcome (Paper III)

- To evaluate the patient-reported outcome at five years following surgical treatment of pelvic ring injuries (Paper IV)

- To explore patients' experiences of life after surgically treated pelvic ring injuries (Paper V)

Patients and methods

Study populations

The pelvic injury register

All of the studies in the present thesis are based on patients surgically treated for pelvic ring injury or acetabular fracture at the Department of Orthopaedics, Uppsala University Hospital, Sweden. Since 2003, all patients that are Swedish citizens and aged 16 years or older who are referred to our department for treatment of such injuries are prospectively included into the local pelvic injury register. Informed consent is obtained from all patients before inclusion.

At inclusion, demographic data is collected. This includes patient age, gender, fracture type and specification of any comorbidities and associated injuries. Date of injury and surgery along with details on duration of the surgical procedure as well as estimated perioperative blood loss is also registered. The pre- and postoperative radiological examinations are examined and stored digitally.

Follow-up is comprised of radiographic evaluation, including frontal, inlet and outlet projections in patients with pelvic ring injury and frontal, axial and Judet projections in patients with acetabular fracture at two years post-surgery. In patients referred from other regions of the country, representing the majority of cases, this is organized by sending requests to the head of the orthopaedic department corresponding to the patient's domicile who then facilitates the investigations. Images are then transferred digitally and analysed at our institution.

Patient-reported outcome measures, consisting of the generic instruments SF-36 and EQ5D-3L and the condition-specific Pelvic Discomfort Index are collected and evaluated at one, two and five years post-surgery. The distribution of the questionnaires is completed via postal mail.

At two and five years post-surgery, patient charts, including charts from referring hospitals, are obtained and evaluated for complications such as thromboembolic events, infections and secondary surgical interventions. Personal identification numbers that are in nationwide use allows for collection of all patient charts and additionally provides accurate data on mortality as well as current information concerning patient addresses.

Paper I

The objective was to develop a condition-specific instrument to allow for evaluation of patient-reported outcome following surgical treatment of pelvic ring injuries.

Between September 2004 and June 2008, 73 consecutive patients (44 male, 29 female) with a mean age of 36 years underwent internal fixation for pelvic ring injury. According to the AO/OTA classification, there were 47 B-type and 26 C-type injuries (Table 2).

Table 2. *Injury types according to the AO/OTA classification*

B1	10	C1	18
B2	22	C2	5
B3	15	C3	3

At six, 12, and 24 months postoperatively, patients were asked to assess their discomfort from the pelvis using a 14-item questionnaire, which was developed by an expert group. Eleven questions were closed-ended and had six ordinal options ranging from 'no discomfort' (score=0) to 'extremely severe discomfort' (score=5). Three questions were open-ended, allowing patients to add dimensions that were not addressed in the closed-ended question. The responses to these questions were categorised by a single assessor.

The completed questionnaires were analysed using factor analysis to assess the content validity and relevance of the closed questions as well as reduce the number of items if appropriate. Factorability of the correlation matrix was measured via the Bartlett test of sphericity and the Kaiser-Meyer-Olkin measure of sampling adequacy. Factor loadings of >0.50 were considered acceptable for item representation.

Reliability in terms of internal consistency was expressed as Cronbach alpha coefficients.

A non-parametric rank-based method was used to evaluate paired assessments changing over time. The questionnaire was compared with the SF-36 to assess construct validity.

Paper II

The objective of this study was to evaluate pre-traumatic quality of life and level of pre-existing discomfort from the pelvis, as well as examining the influence of the time-point chosen post-operatively for obtaining patient-reported assessment of pre-traumatic status.

In total, 73 consecutive patients (62 male, 11 female), admitted to our department for surgical treatment of a pelvic ring injury or an acetabular fracture were asked to participate in the study. Patients <16 years of age and patients who were unable to complete the questionnaires, for example due to sedation during intensive care unit (ICU) treatment or cognitive disorders, were excluded.

Study participants received patient-reported outcome measures (SF-36, EQ5D-3L and PDI) for completion at three different time-points: a) perioperatively, b) at one month postoperatively, and c) at two months postoperatively. They were asked to assess their status a short period of time before suffering the traumatic event causing the pelvic ring injury or acetabular fracture.

The injury was an acetabular fracture in 50 cases and a pelvic ring disruption in 23 cases. Median age was 52 years (20–82). Trauma energy was considered as high in 56 cases. Median time from injury until surgery was five days (1–18).

Mixed-effects linear models, using all available observations, was used to investigate the influence of time-point chosen for self-assessment regarding the SF-36 data and to adjust this data for age, gender, energy and injury type. The mixed-effects models were set up using a repeated measures design assuming an unstructured covariance matrix with time of measurement entered as a factor variable. If a significant time effect was present for a certain test, the analysis was followed up by pairwise comparisons between time-points using least-square means to pinpoint between which time-points effects were present. Bowker´s test of symmetry was used to evaluate data from the EQ5D and PDI while a paired t-test was used to evaluate the EQ5D VAS scale, after determining that the distribution was appropriate for parametric testing. P-values<0.05 were considered significant.

Paper III

In order to compare the outcome of the CHP to that of ORIF alone, the 13 patients who were operated on with a CHP since the protocol was introduced in 2013 and had a minimum of two years of follow-up were included. Using the pelvic injury register, 14 patients with similar acetabular fractures (severe acetabular impaction with or without concomitant femoral head injury) which had been treated by ORIF alone were identified and used as a control group.

Outcomes were defined as perioperative mortality, need for secondary surgical procedures, patient-reported outcome, duration of surgical procedure and perioperative blood loss.

Patient and hip joint survival were estimated using Kaplan-Meier. Patient-reported outcome data (SF-36 and PDI) collected at six months, one year and two years post-surgery was compared using Mann-Whitney U-test while Students t-test was used to compare data on duration of surgical procedures and estimated perioperative blood-loss between groups.

At two years post-surgery, radiographs were obtained for CHP patients and the ORIF patients who had not been subject to secondary surgery. The radiographs were used to evaluate fracture union, heterotopic ossification and signs of implant complications.

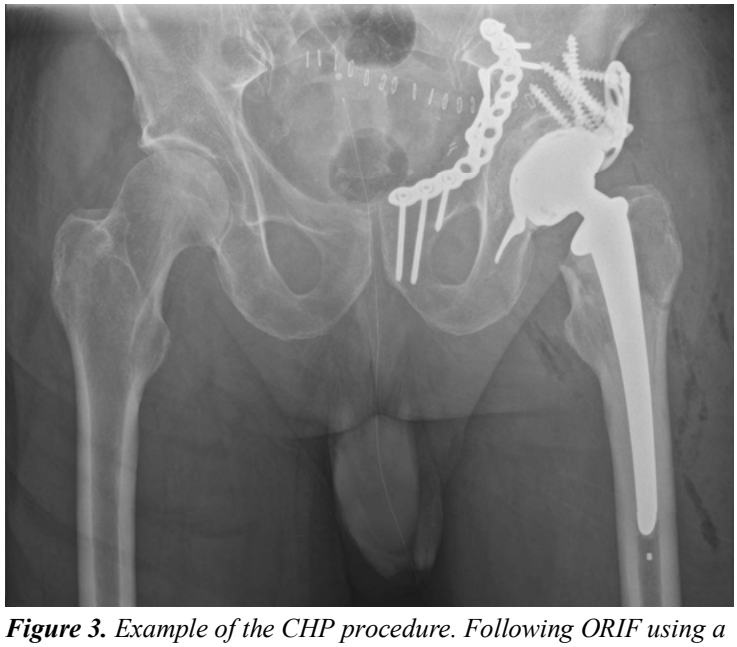

Figure 3. *Example of the CHP procedure. Following ORIF using a suprapectineal plate for stabilizing the anterior acetabular column, an acute THA is performed utilizing impact bone grafting and a Burch-Schneider type reinforcement ring in conjunction with a cemented bipolar cup and an anatomical, cemented stem.*

Paper IV

To evaluate patient-reported outcome in surgically treated pelvic ring injuries at five years post-surgery, patients admitted for surgical treatment of pelvic ring injury between years 2004 and 2009 were prospectively included using the pelvic injury registry.

Decision on surgical treatment was based on clinical and radiological evaluation, including plain radiographs and computed tomography of the pelvis, to assess pelvic instability. These evaluations were carried out by senior consultants in orthopedic trauma surgery with several years' experience in treating pelvic ring disruptions.

In total, 108 consecutive patients (68 male, 40 female), with a mean age of 38 years (ranging from 16 to 85 years) were included in the study.

The injuries were classified according to the AO/OTA classification. There were 68 B-type and 40 C-type injuries. The most common injury mechanisms were MVA (44 patients), followed by fall from height (29 patients) and crush injuries (15 patients).

Associated injuries were seen in 79 patients (73%). The most frequently injured body region was thorax (39 injuries), followed by spine (36 injuries), lower extremity (33 injuries), abdomen (28 injuries), upper extremity (22 injuries) and head (21 injuries). Out of the 108 patients, 47 (44%) had sustained a severe polytrauma indicated by an Injury Severity Score (ISS) of ≥16. Median time from trauma until definitive surgery was five days (range 1-22).

The surgical method of choice was open reduction and internal fixation in 22 patients, strictly percutaneous procedures with closed-reduction and fluoroscopy-guided screw placement in 35 and a combination of ORIF and percutaneous procedures in 51. One patient underwent early reoperation due to inadequate reduction.

The protocol for thromboprophylaxis was low molecular weight heparin (enoxaparin, 40 mg/day administered subcutaneously) for a minimum of ten days post-surgery. Intravenous cloxacillin (2g x 4) was used as perioperative antibiotic prophylaxis.

Medical records pertaining to the initial treatment and subsequent follow-up of the pelvic injury were retrieved at five years post index surgery and carefully examined for complications. As many patients were referred from other regions of the country, medical charts from the referring hospitals were also retrieved at five years post index surgery and scrutinized for complications, according to the routine of the pelvic injury registry.

Observed complications consisted of postoperative wound infections, which were reported in ten patients. Seven of these were superficial and resolved with antibiotic treatment alone. The remaining three were deep infections necessitating secondary debridement surgery. Non-surgical infections were reported in 17 patients, the most common manifestations being pneumonia (nine patients) and urinary tract infection (five patients). Concerning

thromboembolic complications, two pulmonary embolisms were diagnosed while no case of deep vein thrombosis was reported.

The patients were followed with patient-reported outcome measures at one, two and five years post-surgery. The instruments used were the generic quality of life-instrument SF-36 and the condition-specific PDI. These outcome instruments were distributed via postal mail. In case of no response they received one reminder.

Radiological exams of the pelvis were performed pre- and post-surgery and during the course of healing. A final radiological examination was conducted at two years post-surgery. The protocol consisted of plain radiographs including frontal, inlet and outlet views of the pelvis. Displacement of the posterior aspect of the pelvic ring was measured and categorized by two examiners as displacement of less than 5 mm or ≥5 mm or more according to the German pelvic study group[21]. In addition, implant integrity and position were evaluated.

Mixed-effects linear models, using all available observations, were used to analyze the SF-36 and PDI data to determine changes in health status over time. The models included variables gender (male/female), age (above/below median), fracture type (B/C) and presence or absence of associated injuries. The mixed- effects models were set up using a repeated measures design assuming an unstructured covariance matrix with time of measurement (one, two or five years post-surgery) entered as a factor variable. If a significant time, covariate, or interaction effect was present for a certain test, the analysis was followed up by pairwise comparisons using model-predicted least square means to pinpoint where differences were present.

Student's t test was used to compare SF-36 results to reference population data. Pearson's chi-square test was used to examine outcome with respect to residual posterior displacement of the pelvis.

Paper V

Aiming to explore patient experiences following surgical treatment of pelvic ring injury, potential study participants were identified through the local pelvic registry using the following criteria:

1) Swedish-speaking patients with B- or C-type pelvic ring injuries according to the AO/OTA classification.
2) Injuries sustained five years ago or more. This threshold was arbitrarily chosen based on the clinical experience of the time it usually takes for patients with these injuries to adapt to a new level of post-injury functioning.
3) Due to logistical reasons, only patients where the travel time between the hospital and their current address was less than three hours were included.

Using these criteria, 20 potential participants were identified. Patients received written information concerning the study via postal mail and accepted participation by returning a signed informed consent form. Ten patients accepted the invitation. No major differences between patients who accepted participation and those who declined were observed with respect to age, gender and injury type.

Examining the ten patients that formed the study group, mean age at the time of injury was 33 years (range 17-68 years). There were six males and four females. Median time from injury until interview was 11 years (7-12 years).

Semi-structured interviews using an interview guide were conducted, either at the hospital or at the patients' home or work, according to their preferences. The interviews were then transcribed and analysed using conventional content analysis.

Results

Paper I

The response rate of the 14-item questionnaire was 78%, at six months, 71% at 12 months, and 71% at 24 months post-surgery.

At six months post-surgery, the correlation between the 11 closed-ended questions was significant (r=0.24–0.90), and the number of questions was therefore reduced. Two items, assessing discomfort from voiding the bladder and bowels, were taken out of the questionnaire as the frequency of reported discomfort was deemed to be low. Factor analysis (scree test) of the remaining nine items revealed that four factors could explain 85% of the total variance. The Bartlett test of sphericity was significant ($p<0.01$) and the KMO test for sampling adequacy was 0.87, which indicated that data were appropriate for factor analysis.

Based on the factor analysis and responses to the open-ended questions, the number of questions was further reduced to six, including pain, walking, mobility of the hips, loss of sensation in the legs, sexual life and operation scar. Factor analysis (scree test) of the six-item questionnaire at 24 months revealed that the four factors could explain 96% of the total variance. The Bartlett test of sphericity was significant ($p<0.01$) and the KMO was 0.81, which indicated that data were appropriate for factor analysis. The first factor involved the first three items (pain, walking and hip motion) and addressed 'pelvis', whereas three factors involved the remaining items and each addressed peripheral neurology, sexual life, and operation scar.

Internal reliability (Cronbach alpha coefficient) was estimated to be $\alpha=0.89$ for the six items and $\alpha=0.91$ for the first factor 'pelvis'.

A Pelvic Discomfort Index was developed using these six items, based on the same methodology as used in the Oswestry Disability Index[61], which is the most common instrument for assessing low back pain. The PDI ranges from 0% (no discomfort) to 100% (extremely severe discomfort), which is calculated as the sum of scores of the six items out of the possible total score.

Correlation testing of the PDI and the SF-36 was performed to determine construct validity. The domains physical function, bodily pain, and general health were most relevant for the PDI, with r=0.50–0.77. Construct validity was deemed adequate based on the correlation between the domain 'bodily pain' in SF-36 and factor 'pain' in the PDI (r=0.69–0.78 at the three time

points). Reproducibility, in terms of intra-class coefficient, was 0.88 at six months, 0.89 at 12 months, and 0.91 at 24 months post-surgery.

Responsiveness of the instrument was demonstrated as patients with C-type injury improved over time in walking capacity. Patients with C-type injury also showed an improvement toward lesser pelvic discomfort between 12 and 24 months.

Analysing the responses to the three open-ended questions, some patients described problems with daily activities (sport and leisure activities, running, dancing, walking in the forest, lifting heavy loads, and sitting for a long time), and a few patients specifically reported sexual problems, psychological problems and problems with the scar. The responses to the open-ended questions supported the relevance of the closed-ended questions but did not provide any greater or additional dimension in assessing outcome. No ceiling effects were observed in the six closed-ended questions

Paper II

All 73 patients included in the study reported their pre-traumatic status perioperatively while admitted at our institution (time-point 0), 61 patients answered the questionnaires at one month and 53 patients provided answers at two months post-surgery. 50 patients provided answers at all three time-points.

SF-36

Results demonstrated that median values for all domains of the SF-36 were high and comparable to a sex- and age-matched population norm at all time-points. A trend was observed with gradually higher pre-traumatic estimates as well as consolidation of groups at one and two months post-surgery compared to perioperative measurements. Time-effects were investigated statistically with a mixed effects model based on all available observations. This was followed by subsequent pairwise comparisons where significant time-effects were observed**.** Overall, differences over time were observed for the domains bodily pain, general health, vitality and social role functioning. Pairwise comparisons revealed an increase in estimates at two months post-surgery compared with perioperative measurements for all four domains with general health also showing improvement at one month post-surgery. For the remaining domains (physical functioning, physical role functioning, emotional role functioning and mental health) no differences between time-points were found.

Using the mixed-effects model, the influence of variables injury type (acetabular fracture or pelvic ring injury), age (over or under median age of 52 years) and gender (male or female) on SF-36 data was examined. With respect to injury type, there was a difference between groups for the domain bodily pain, where patients with acetabular fractures reported a higher level of pre-traumatic pain than patients with pelvic ring injuries. Younger patients had a better pre-traumatic status concerning domains physical role functioning and general health. Males had better scores than females in domains vitality and social role functioning. No other effects of these three variables on SF-36 data could be determined.

EQ5D

Generally, EQ5D revealed a very high level of pre-traumatic quality of life overall with a median score of 0 for each question. A trend could be observed with patients gradually estimating a better pretraumatic status later on in follow-up, but no statistically nor clinically significant differences were observed between time-points in any of the five questions. For the EQ VAS, a

significant improvement was observed at one as well as two months post-surgery when compared to perioperative measurements.

Since reported levels of pre-existing problems were very low, no further stratification of results with respect to injury type, age or gender was performed.

PDI

Answers to each question were graded from 0 (no problems) to 5 (very severe problems). Results revealed a low level of pre-existing discomfort from the pelvic region, with a median score of 0 for each question. As was the case for the generic instruments, a trend was observed with lower mean scores, indicating less pre-traumatic pelvic discomfort, when evaluation was delayed.

Statistical analysis using Bowker's test revealed no significant differences between time-points. Since the levels of reported pre-existing pelvic discomfort were low overall, no subsequent investigation regarding the influence of variables age, gender and injury type on data was conducted.

Paper III

None of the 13 patients in the CHP group required further hip surgery, yielding a hip survival rate of 100% after three years. In the ORIF group, nine of 14 patients required revision surgery to THA within two years of the index procedure. An additional patient in the ORIF group developed femoral head necrosis and was treated with a Girdlestone procedure at 26 months post-injury. Thus, hip joint survival in the ORIF group at this stage, with 10 out of 14 patients subject to revision surgery, was 28.6% (95% CI 12.5 to 65.4; $p = 0.001$).

There were no dislocations observed in the CHP group. No superficial or deep infections requiring secondary surgery and no thromboembolic events were identified in either group, with the exception for one patient in the CHP group who preoperatively developed a pulmonary embolus.

Perioperative mortality was nil as no patient in either group died within the first year after index surgery. Three CHP patients died within three years of the index procedure yielding a patient survival of 72.5% (95% CI 49.5 to 100) in the CHP group and 100% ($p = 0.04$) in the ORIF group.

Concerning patient-reported outcome, all 10 available patients in the CHP group (two patients died, one had developed dementia) and 12 out of 14 available patients in the ORIF group answered the questionnaires (SF-36 and PDI) at two years post-surgery. No relevant differences between groups with respect to patient-reported outcome could be observed.

At two years post-surgery, radiological outcome was evaluated. In the CHP group, nine out of the 11 available patients underwent radiological examination. There were no signs of cage, acetabular component, stem, or hardware loosening in any patient. All fractures were considered healed and the bone graft was consolidated in all patients. In eight patients, heterotopic ossification was present. In the ORIF group, four out of the five patients that had not been subject to secondary surgery completed the radiological examination. All fractures were considered healed, and the implants remained intact in these cases. In one patient, osteonecrosis of the femoral head as well as hip joint dislocation was evident. Two patients demonstrated obvious signs of post-traumatic osteoarthritis, and heterotopic ossification was present in two cases.

Paper IV

Of the initial 108 patients, three patients died within a year after the surgical procedure, leaving 105 patients available for follow-up at one year post-surgery. Of these, 80 patients (76%) responded to the outcome measures. At two years post-surgery, an additional patient had died. Of the remaining 104 patients, 79 (76%) completed the questionnaires. Between two and five years post-surgery, three patients died, leaving 101 patients available for follow-up at five years post-surgery. Out of these, 78 patients (77%) responded.

Patient-reported outcome

SF-36

Results demonstrated that the impact on Quality of Life after surgical treatment for pelvic ring injury was substantial, with no domain of the SF-36 reaching the levels of an age- and sex-matched reference population at five years post-surgery. (Figure 4)

Improvement in physical functioning at five years compared to earlier assessments was observed. ($p<0.01$). Physical role functioning also improved at five years compared to results at one year post-surgery ($p<0.01$). For the remaining six domains, no statistically significant changes were found between time-points.

The influence of age (above/below median), gender (male/female), injury type (B/C) and presence of associated injuries on SF-36 results was investigated using the mixed-effects model.

Older patients scored lower than younger in the domain physical functioning, an effect estimated to a difference of 0.4 points per year, while no influence of age could be observed for remaining domains.

Examining the influence of gender, males improved in physical functioning between two and five years post-surgery, while females did not. Females demonstrated a worsening of bodily pain at five years compared to results at one year post-surgery, while males on the contrary demonstrated a recovery between these time-points. Concerning the domain general health, females estimated a worse outcome at five years post index surgery compared to males and had also deteriorated compared to earlier measurements, while males had not. For remaining domains, no significant influence of gender could be demonstrated, although a tendency for females to estimate lower scores than males was present in every SF-36 domain at five years post-surgery.

Patients with C-type injuries estimated lower general health overall compared to B-type injuries. No other influence of injury type on SF-36 results was found. The presence or absence of associated injuries was not found to affect outcome in any domain of the SF-36.

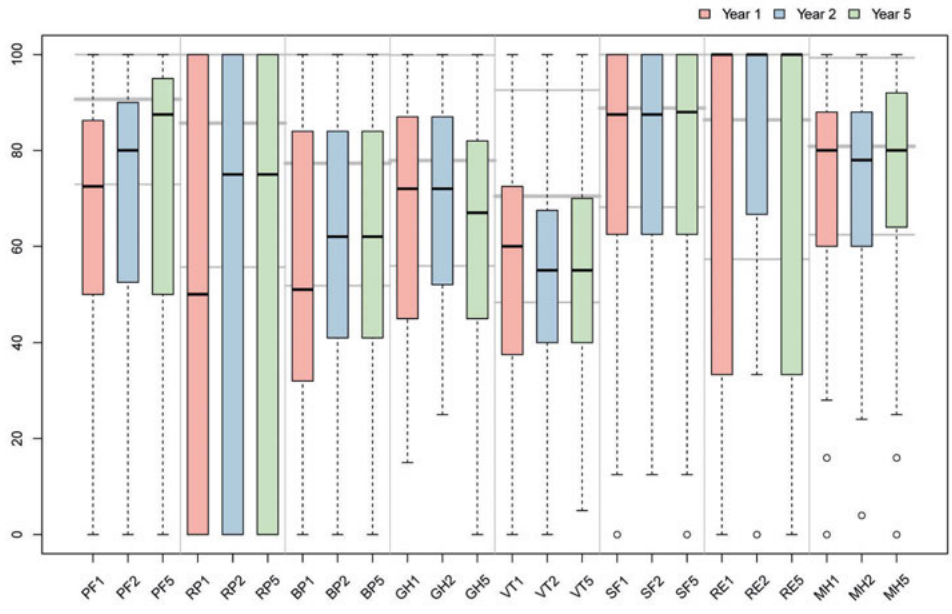

Figure 4 *SF-36 results at 1, 2 and 5 years post-surgery. PF=physcial functioning, RP=physical role functioning, BP=bodily pain, GH=general health, VT=vitality, SF=social role functioning, RE=emotional role functioning, MH=mental health. Grey lines in bakground indicate population norm mean (bold) +/- 1 SD (thin).*

PDI

Mean score at five years post-surgery was 27, indicating moderate residual pelvic discomfort overall. The PDI was largely stable between one, two and five years post index surgery when comparing results of the entire study population. No significant improvement or worsening in patient-reported pelvic discomfort was observed at five years post-surgery compared to earlier measurements.

Examining the influence of variables gender, age, fracture type, and presence of associated injuries, it was found that females reported a higher level of pelvic discomfort at five years post-surgery compared to males (p=0.03). Males recovered over time with less pelvic discomfort at five years compared to the results at two years (p=0.03). Females on the contrary reported an increase in pelvic discomfort at five years post-surgery, although this change was not found to be statistically significant.

None of the variables age, fracture type (B/C), or presence of associated injuries were found to have an influence on reported pelvic discomfort.

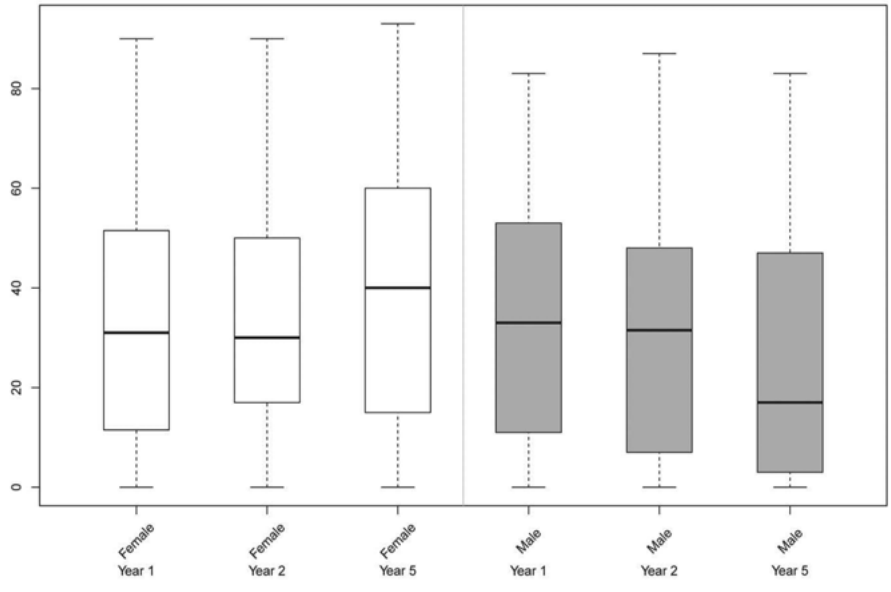

Figure 5. *PDI at 1,2 and 5 years post-surgery for females (white) and males (grey). PDI ranges from 0% pelvic discomfort (best) to 100% pelvic discomfort (worst).*

Paper V

The semi-structured interviews were conducted in Swedish using an interview guide. The interviews were set either at the hospital (n=5) or at the patient's home or place of work (n=5). All interviews were conducted by the first author and varied in length from 24 minutes to 57 min (median 45 minutes). The recorded interviews were transcribed and analysed using a process of conventional content analysis. Meaning units in the transcripts were identified and coded into what was considered to be their central parts. Codes were then further condensed and assigned to categories. From these categories, main categories emerged. The findings were discussed among the research team, and consensus was reached.

The two main categories that emerged from the content analysis were "Consequences of the injuries" and "Road to recovery".

As for consequences of the injuries, a wide range of sequelae was described. This included physical problems such as persisting pain from the pelvis, neurological deficits, dyspareunia, erectile dysfunction, inability to run or walk at a pre-injury pace and decreased range of motion in the hip joint. There were testimonies of psychological sequelae such as sleep disorders, depression and anxiety. Further consequences cited included change of career, need for adjusted work assignments or work environment, change of living conditions with avoidance of stairs, family strains including change in social status with separation, financial difficulties, and the need for specialized prenatal care.

Under the category Road to Recovery, patients described the rehabilitation process that ensued after suffering the pelvic trauma and their efforts to regain functions as well as accepting a new level of functioning post-injury. Further subcategorized to "Rehabilitation", "Adaptation", "Experiences from health care" and "The importance of the social network", this main category revolves around different aspects concerning the, sometimes, long and winding road to recovery after suffering major pelvic trauma.

Patients described how they gradually regained capabilities to perform ADL, having a functioning social life and to return to activities such as walking, horse-back riding, hiking, skiing and biking. Patients modified several different aspects of their life after the injury. This included physical activities, for example adjusting the pace when walking or abstaining from certain activities such as running and engaging in recreational sports. There were also examples of patients adapting their living situations, like getting an apartment on the ground floor in order to avoid stairs. Some patients altered their career choices or got adjusted work assignments. In general, patients had little recollection of their initial care, with fragmentary memories from the peritraumatic period and stay at the hospital. The impression of the care they had received was generally satisfactory, but there were accounts of difficulties with pain management and feelings of premature discharge from in-patient care. There

were few recollections of what information was provided concerning how the rehabilitation and follow-up was planned as well as what possible consequences may arise due to the injury. No patient could clearly recall receiving instructions regarding who to contact in case of problems during aftercare and rehabilitation.

The importance of the social network in the recovery process after severe trauma was expressed in the interviews. This included not only emotional support but also entailed practical aspects such as getting help with everyday chores and financial aid. In some cases, family members were also directly involved in providing health care to the patient, helping out with hygiene, wound management and physiotherapy. There was also evidence that the injuries sustained by patients placed strain on individuals within the patients' social networks, with consequences including separations and friends distancing themselves, as well as descriptions of distress and impaired psychological well-being in family members.

Discussion

The evaluation of patient-reported outcome following surgical treatment of pelvic ring injuries and acetabular fractures is complex and the current literature is limited, in part owing to the utilisation of non-validated outcome instruments[34,49]. Thus, the Pelvic Discomfort Index was developed in an effort to obtain valid, relevant and specific information following surgical treatment of pelvic ring injuries. The six-question instrument is brief, easy to use and no ceiling effects, something that has been demonstrated to limit the utilisation of other available instruments, were observed[38]. The items pertaining to affected mobility and sexual function have been cited as being among the most important consequences for patients following pelvic trauma in a previous study by Lefaivre *et al*.[38]. In a study by Tötterman *et al*. that examined outcome in 32 patients following surgical treatment of unstable sacral fractures, impaired motor and sensory function and sexual dysfunction was found to be common sequelae[12]. These items proved relevant in the PDI as well. It should be noted that in our study, the items pertaining to difficulties with voiding the bladder and bowels were removed pre-factor analysis due to a low level of reported discomfort, while Tötterman *et al*. on the contrary reported high frequencies of these problems[12]. Differences in injury patterns between the studies might partially explain this discrepancy but, although not a part of the PDI, the potential for urogenital and gastrointestinal issues should be considered in patients that has suffered severe pelvic trauma.

It should be noted that the PDI focuses on the physical consequences arising from pelvic ring injury. It does not investigate the psychological, social or economic consequences that may result from these injuries, factors that were evident to have an impact in the life of patients in study V and also previously have been cited by patients as being among the most important consequences of these injuries[38].

The Majeed score[36], currently the most used specific instrument for evaluation of pelvic ring injuries, contains sections regarding pain, sexual intercourse and walking/mobility, factors that proved relevant in the PDI as well. However, ceiling effects have been demonstrated and the weighting of the instrument has been questioned[34,38]. Therefore, it might not constitute the best alternative for evaluation of patient-reported outcome in pelvic injuries.

Although the use of validated outcome measures is of vital importance for future studies in the field, the diversity in instruments used and scores reported also constitutes a major limitation of the literature, as this make comparisons

between studies difficult. Furthermore, the value of an outcome instrument is severely limited if only scarcely used. Thus, a consensus concerning what outcome measures to utilize in evaluation of patients with surgically treated pelvic ring injuries, as well as acetabular fractures, is of importance.

A specific challenge in PROM-evaluation following traumatic injuries is that pretraumatic baseline measurements are missing. In study II, it was found that the pretraumatic Quality of Life in patients with surgically treated pelvic ring injuries and acetabular fractures generally is high and pretraumatic discomfort from the pelvic region, as measured by the PDI, is uncommon. A trend was observed in that patients estimated a better pretraumatic status when assessments were delayed as compared with perioperative measurements. Furthermore, a gradual consolidation of scores, with tighter distributions over time was observed. This might indicate that factors in the arguably turbulent period shortly after suffering traumatic injury might distort the patients´ ability to give an adequate estimation of their pre-traumatic status. Importantly, severely injured patients may be unable to answer the questionnaires at an early stage. The results of study II implicate that patients not only may be included at a later time-point, but also that the estimated baseline might be more accurate when doing so.

The main finding of study III was that the Combined Hip Procedure markedly reduced the need for secondary surgical procedures compared with ORIF alone in the surgical treatment of displaced acetabular fractures with impaction and/or concomitant femoral head injury in the elderly. Despite the more complex surgery of the CHP, in conjunction with patients in this group being older and sicker, perioperative mortality after this procedure was comparable to that after ORIF alone, with no patient dying in either group within the first year post-surgery. Although encouraging, this finding should be interpreted cautiously given the small size of the study.

The discouraging outcome for patients treated with ORIF alone, with ten patients requiring secondary hip surgery within three years and a further two hips demonstrating signs of osteoarthritis at evaluation after two years was not unexpected given the fracture patterns in our cohort. It is also in agreement with previous studies describing high failure rates after ORIF of acetabular fractures in elderly patients with injury to the femoral head and acetabular impaction[62,63]. There are studies that have described lower failure rates after ORIF but as the study populations are different, comparisons are difficult[64].

Patient-reported outcomes after delayed THA for failed ORIF of acetabular fracture, especially in the elderly, are less satisfactory when compared with patients treated with THA for osteoarthritis[65]. The finding of almost equal patient-reported outcomes between groups in our study is reassuring, although no comparison of CHP patients with patients who received THA for other

reasons was made. Our observations indicate that CHP can result in an improvement in patient-reported outcome over delayed THA after failed ORIF[66].

No differences in PRO were observed between groups. However, given the small cohorts with only 27 patients in total this finding is prone to type II-errors. Thus, the study should be considered as a safety, rather than an efficacy, study of a relatively novel treatment protocol.

The long-term negative impact on patient-reported outcome after surgical treatment of pelvic ring injuries is substantial and long-standing, as demonstrated by the findings in study IV, where patients failed to reach the values of a reference population in every domain of the SF-36 at five years post-surgery. This finding is consistent with the current literature[67–70]. Female gender was associated with a worse outcome, which is coherent with previous reports[71,72]. The influence of age, injury type and presence of associated injuries on patient-reported outcome was limited. Concerning injury type, previous studies have come to diverging conclusions, some suggesting that injury type has an influence on outcome[72,73], while others indicate that it has not[74]. The presence of associated injuries has previously been reported to correlate with a worse functional outcome[72,75]. However, discrepancies in study design, demographics, treatment modalities, and follow-up protocol make comparisons between studies difficult. Our study was underpowered to allow for acceptable subgroup analysis of outcome based on injury types as well as comparing the influence of different types of associated injuries. However, as the pelvic injury registry grows, such investigations could be a possibility in the future.

The results from study V support the notion that pelvic ring injuries requiring surgical treatment are serious, potentially life-changing events in which the road to recovery is long and demanding. However, outcomes are also heterogenous, ranging from virtually no remaining sequelae to major disability. This emphasises the need to conduct individual patient evaluations to determine what measures need to be undertaken in order to optimise outcomes.

Facilitation of the rehabilitation process by the health care system is of vital importance to make the journey easier for patients, and we believe that providing adequate information and support to patients and their families is key in this respect. There were testimonies from the patients in our study that the information provided was limited. This identifies a potential area of improvement, as patients would surely benefit from receiving standardised written as well as verbal information about their injury, including specifics on potential complications to the injury, allowed weightbearing, rehabilitation plan and contact information. Any centre managing these injuries should ensure that there is a sound, reliable infrastructure for transferring such information to patients and other health-care providers.

A wide range of negative consequences pertaining to the injuries was described, including physical impairment, residual pain, anxiety and depression,

negative economic consequences and family strains. These findings are coherent with what patients cited as the most important consequences of their injuries in the previously mentioned study by Lefaivre et al.[38]. Given the broad range of problems that may arise, a multimodal approach is necessary when managing pelvic ring injuries.

An important aspect to consider when evaluating the outcomes of traumatic injuries is that patients have individual demands and expectations on level of functioning. This was exemplified in our study by one patient, an elite-level skier, for whom a minor decrease in hip ROM caused a defect in his skiing technique, rendering him unable to progress with a skiing instructor career. Thus, the injury caused major consequences in his life, despite him making an almost complete recovery with no residual pain and a high level of physical functioning. Evaluating such a patient with our regular follow-up protocol, using radiological examinations and PROM-data, there is a significant risk for underestimating the consequences of the injury.

Strengths and limitations

A major strength of this thesis stem from the utilization of the local pelvic registry, which allows for consecutive and prospective collection of data on patient-reported outcome in patients with surgically treated pelvic ring injuries and acetabular fractures. As registration has been ongoing since 2003, this allowed a cohort size of 108 patients for study IV, which is to be considered large in the field of surgical treatment of pelvic ring injuries, especially with five years of follow-up. Furthermore, the thesis has aimed to address relatively novel topics in this field, including the development of a validated outcome instrument to assess patient-reported outcome, evaluating patient-reported pre-traumatic status and the influence of the time-point post-trauma chosen for these assessments as well as exploring the patient perspective after these injuries using qualitative methods.

There are several limitations to the studies in the present thesis. To a certain extent they all rely on subjective data obtained either from patient-reported outcome measures or interviews, which introduces the potential for different types of information bias, including recall bias, response bias and, for paper V, interviewer bias.

The Pelvic Discomfort Index was developed based on data from Swedish patients using a questionnaire in Swedish. Hence, the validity of the English version of the instrument is unproven and further studies will be necessary to evaluate the appropriateness of the PDI in this context.

A major concern regarding patient-reported outcome is that patients who are unable to complete the questionnaires are excluded. In the case of paper II, this includes the most severely injured patients, who required perioperative care with sedation at the ICU and thus were unable to estimate their pre-traumatic status. This selection bias is difficult, if not impossible, to avoid.

However, the results of the study imply that their assessments may be deferred and obtained within the first two months following their traumatic event.

Paper I and Paper III are limited by a small sample size. In study I, this introduces the potential for an insufficiently stable solution to the factor analysis, even though testing using Bartlett test of sphericity and Kaiser-Meyer Olkin indicated that the data was appropriate for factor analysis. Furthermore, small sample sizes make statistical analyses prone to type II errors. As mentioned, Study III should therefore be considered as a safety, rather than an efficacy, study of a relatively novel treatment option for displaced acetabular fractures in the elderly. Nevertheless, an obviously decreased need of secondary surgical procedures without a noticeable difference in perioperative mortality encourages further use and evaluation of the CHP procedure.

Conclusions

- The Pelvic Discomfort Index can be used to obtain valid and specific information pertaining to patient-reported outcome following surgical treatment of pelvic ring injuries.

- Pre-traumatic Quality of Life in patients with surgically treated pelvic ring injuries and acetabular fractures is generally high, and for SF-36 comparable to a reference population. Preexisting discomfort from the pelvic region, as reported through the PDI, is uncommon. Patients tend to estimate a higher level of pretraumatic function when assessments are carried out at one and two months post-injury as compared to measurements conducted in the direct perioperative period. The gradual consolidation of scores over time might indicate that patients more adequately estimate their pretraumatic status when assessments are carried out later than in the direct posttraumatic period.

- The Combined Hip Procedure confers a considerably reduced risk for secondary surgery when compared to ORIF alone in treatment of displaced acetabular fractures with acetabular impaction and/or femoral head injury in elderly patients, without an obvious increase in risk of perioperative mortality.

- Pelvic ring injuries that require surgical treatment are serious events which are associated with long-standing negative effects on patient-reported outcome. Males report a better outcome than females at five years post-surgery.

- The rehabilitation process after surgical treatment of pelvic ring injuries is long and challenging. Patient outcome is heterogenous both in terms of severity and spectrum of sequelae. The health care system serves an important role in providing information and support to the patients and their social networks. The use of qualitative methodology was purposeful in evaluation as it captured social, economic and psychological consequences of the injury that would have been overlooked using the regular follow-up protocol.

Future studies

There are several potential areas for future studies in the field of patient-reported outcome in surgically treated pelvic ring injuries and acetabular fractures.

Continuous use of the local pelvic registry will allow further evaluation of patient-reported outcome in patients with surgically treated pelvic ring injuries and acetabular fractures. With more patients included, there is a better possibility to conduct adequately powered studies to examine how different factors such as different injury types, age, gender, associated injuries, surgical approach and radiographic appearance influence outcome.

Further use and evaluation of the PDI in assessment of patient-reported outcome following surgical treatment of pelvic ring injuries and acetabular fractures will help determine whether it serves a purposeful role in providing relevant and clinically applicable information. The instruments translation to the English language and its external validity should also be evaluated.

The results from evaluating the CHP as a treatment option in displaced acetabular fractures in the elderly encourages larger studies, to allow evaluation of not only the safety but also the efficacy of the procedure.

Based on the patient experiences described in study V, further studies concerning how outcome following surgical treatment of pelvic ring injury is affected by information and support provided by the health-care system should be considered.

Acknowledgements

I would like to express my deepest gratitude to all those involved in the completion of this thesis, be it directly or indirectly. Special thanks to:

Sune Larsson My supervisor. Your calm and firm way of overseeing the work with this thesis has been truly exceptional. You´ve made me see possibilities instead of obstacles. I can´t remember how many times I´ve walked into a meeting full of concerns only to walk out feeling that everything is just on track. It has been a privilege.

Tomas Borg My co-supervisor. Your enthusiasm and passion for Orthopaedics is impressive and inspirational. I consider myself very lucky for getting to be a part of that.

Olle Nilsson A role model in every possible aspect of the word. I can´t describe how grateful I am for getting the opportunity to work with and learn from you. The standards you set are impossible to match, but I will spend my career trying.

Janne Milbrink For giving me the opportunity to work in the field of arthroplasty and, patiently, showing me how it´s done. I am forever thankful for everything you´ve taught me and I hope we have many surgeries still to come. Maybe one day I´ll even learn how to properly close a femoral canal.

Nils Hailer For getting me back on track with the work during this thesis. Your scientific and surgical knowledge is deeply impressive, as are your guitar skills. I hope the future holds a lot of research projects as well as jam sessions!

Former and current chiefs. Katarina Lönn, Karin Bernhoff, Stergios Lazarinis, Caroline Sköld For providing support and creating an environment allowing me to develop both as a clinician and a researcher.

Everybody at the section of Arthroplasty. For making every day at work exciting. I could not ask for better colleagues and I am so very proud to be a part of our team.

Åsa Muntlin Athlin For introducing me to qualitative research. Your guidance is highly appreciated!

Niclas Ericsson For patiently providing statistical expertise.

Anders and Mårten Words can´t describe how grateful I am for having you in my life. Getting to call you my friends is more than I could ever ask for. Also, I really appreciate how well you handle your joint custody over me. You´re the best!

To my family. Kajsa, Robin, Hanna, Anton, Emma, Sofia, Fredrik, Åke, Olle I am truly privileged to have you all in my life, and I look forward to our many upcoming adventures!

To my parents Ulla and Leif Thank you for the incredible love and support you´ve provided and keep providing. No matter the issue you´re always there. Without you, nothing would have been achieved. Am I finally getting that boat?

My children, Ebbe and Tage. You are my world. I love you.

Summary in Swedish

Det huvudsakliga målet med denna avhandling var att studera resultatet efter kirurgisk behandling av bäckenringskador och acetabularfrakturer utifrån ett patientperspektiv. Samtliga studier är baserade på patienter som opererats för sådana skador på Akademiska sjukhuset i Uppsala. Dessa patienter följs sedan 2003 via ett lokalt register som vid specifika tidpunkter inhämtar information kring patientrapporterat utfall, patientjournaler och radiologiska undersökningar.

Studie I syftade till att utveckla ett validerat instrument för inhämtning av patientrapporterat utfall efter kirurgisk behandling av bäckenringskador. 73 patienter besvarade ett formulär, bestående av elva slutna och tre öppna frågor, gällande besvär från bäckenregionen vid tre tillfällen: sex månader, ett år och två år efter skadan. Svaren som erhölls behandlades statistiskt, antalet frågor reducerades med hjälp av faktoranalys och egenskaper som reliabilitet, konstruktvaliditet och känslighet utvärderades. Det resulterande instrumentet, kallat Pelvic Discomfort Index (PDI), kan användas för att erhålla relevant och specifik information gällande patientrapporterat utfall efter kirurgisk behandling av bäckenringskador.

I Studie II undersöktes hur patienter som drabbats av bäckenringskador och acetabularfrakturer uppfattade sitt pretraumatiska status och betydelsen av vid vilken tidpunkt efter skadan denna uppskattning genomfördes. 73 patienter erhöll PROM-instrument (SF-36, EQ5D-3L och PDI) vid tre tidpunkter: perioperativt, en månad postoperativt och två månader postoperativt. De ombads att beskriva sitt status som det var en kort tid innan de drabbades av sin skada. Resultaten visade att den pretraumatiska livskvaliteten hos denna patientgrupp var hög och för SF-36 jämförbar med en referenspopulation. En låg nivå av preexisterande besvär från bäckenregionen rapporterades via PDI. En tendens för patienter att skatta ett bättre pretraumatiskt status vid en och två månader postoperativt jämfört med den perioperativa mätningen noterades.

Målsättningen med Studie III var att utvärdera resultatet efter kirurgisk behandling av dislocerade acetabularfrakturer med acetabulär impaktion och/eller skada på lårbenshuvudet hos äldre patienter med Combined Hip Procedure (CHP). Denna operation består av öppen reposition och fixation av acetabularfrakturen (ORIF) i kombination med en akut höftledsartroplastik. Patienter som erhållit en CHP (n=13) och hade minst två års uppföljning i det lokala bäckenregistret jämfördes med patienter med liknande frakturtyp som enbart erhållit ORIF (n=14). Grupperna jämfördes med avseende på perioperativ

mortalitet, behov av sekundär kirurgi och patientrapporterat utfall. Resultaten visade på en betydande minskning av behovet för sekundär kirurgi hos patienter som erhållit CHP, samtidigt som inga skillnader i perioperativ mortalitet eller patientrapporterat utfall kunde påvisas.

I studie IV utvärderades det patientrapporterade utfallet efter kirurgisk behandling av bäckenringskador. 108 patienter följdes med SF-36 och PDI vid ett, två och fem år efter det kirurgiska ingreppet. Resultaten pekar på att konsekvenserna av dessa skador är långvariga och omfattande, då patienterna skattade sin livskvalitet sämre än en referenspopulation i samtliga domäner av SF-36 fem år efter skadan. Kvinnor beskrev ett sämre utfall än män, medan inflytandet av variablerna ålder, skadetyp och förekomst av associerade skador var begränsat.

Syftet med studie V var att med kvalitativa metoder utforska patienters upplevelser av livet efter kirurgisk behandling av bäckenringskador. Semistrukturerade intervjuer genomfördes med 10 patienter, transkriberades och analyserades med konventionell innehållsanalys. Resultatet visade att patienternas upplevelser var heterogena och graden av kvarvarande besvär visade på stor variation. Ett flertal negativa konsekvenser av skadorna uppgavs, såväl fysiska, psykiska, sociala och ekonomiska. Beskrivningar av en lång och krävande rehabilitering framkom. Patientens sociala nätverk spelade en viktig roll i denna process. Ett behov av tydlig information till patienter och anhöriga om skadans art, dess potentiella konsekvenser och prognos identifierades.

References

1. Gagnier, J. J. Patient reported outcomes in orthopaedics. *J. Orthop. Res.* **35**, 2098–2108 (2017).
2. Integrating response shift into health-related quality of life research: a theoretical model. *Soc. Sci. Med.* **48**, 1507–1515 (1999).
3. U.S. Department of Health and Human Services FDA Center for Drug Evaluation and Research, U.S. Department of Health and Human Services FDA Center for Biologics Evaluation and Research & U.S. Department of Health and Human Services FDA Center for Devices and Radiological Health. Guidance for industry: patient-reported outcome measures: use in medical product development to support labeling claims: draft guidance. *Health Qual. Life Outcomes* **4**, 79 (2006).
4. Roach, K. E. Measurement of Health Outcomes: Reliability, Validity and Responsiveness. *JPO J. Prosthet. Orthot.* **18**, P8 (2006).
5. Mokkink, L. B. *et al.* The COSMIN study reached international consensus on taxonomy, terminology, and definitions of measurement properties for health-related patient-reported outcomes. *J. Clin. Epidemiol.* **63**, 737–745 (2010).
6. Terwee, C. B. *et al.* Quality criteria were proposed for measurement properties of health status questionnaires. *J. Clin. Epidemiol.* **60**, 34–42 (2007).
7. Letournel, E. Acetabulum fractures: classification and management. *Clin. Orthop.* 81–106 (1980).
8. Letournel, E. Pelvic fractures. *Injury* **10**, 145–148 (1978).
9. Tile, M. Fractures of the acetabulum. *Orthop. Clin. North Am.* **11**, 481–506 (1980).
10. Demetriades, D. *et al.* Pelvic fractures: epidemiology and predictors of associated abdominal injuries and outcomes. *J. Am. Coll. Surg.* **195**, 1–10 (2002).
11. Tile, M., Helfet, D. & Kellam, J. *Fractures of the Pelvis and Acetabulum*. (Lippincott Williams & Wilkins, 2003).
12. Tötterman, A., Glott, T., Madsen, J. E. & Røise, O. Unstable sacral fractures: associated injuries and morbidity at 1 year. *Spine* **31**, E628-635 (2006).
13. Ragnarsson, B. & Jacobsson, B. Epidemiology of pelvic fractures in a Swedish county. *Acta Orthop. Scand.* **63**, 297–300 (1992).
14. Balogh, Z. *et al.* The epidemiology of pelvic ring fractures: a population-based study. *J. Trauma* **63**, 1066–1073; discussion 1072-1073 (2007).
15. Hodgson, S. AO Principles of Fracture Management. *Ann. R. Coll. Surg. Engl.* **91**, 448–449 (2009).
16. Gänsslen, A., Pohlemann, T., Paul, Ch., Lobenhoffer, Ph. & Tscherne, H. Epidemiology of pelvic ring injuries. *Injury* **27**, 13–20 (1996).
17. Holstein, J. H., Culemann, U., Pohlemann, T. & Working Group Mortality in Pelvic Fracture Patients. What are predictors of mortality in patients with pelvic fractures? *Clin. Orthop.* **470**, 2090–2097 (2012).
18. Giannoudis, P. V. *et al.* Prevalence of pelvic fractures, associated injuries, and mortality: the United Kingdom perspective. *J. Trauma* **63**, 875–883 (2007).

19. Gustavo Parreira, J. *et al.* The role of associated injuries on outcome of blunt trauma patients sustaining pelvic fractures. *Injury* **31**, 677–682 (2000).
20. Mann, S. M. *et al.* High-energy trauma patients with pelvic fractures: Management trends in Ontario, Canada. *Injury* **49**, 1830–1840 (2018).
21. Pohlemann, T., Gänsslen, A., Schellwald, O., Culemann, U. & Tscherne, H. Outcome after pelvic ring injuries. *Injury* **27 Suppl 2**, B31-38 (1996).
22. Alton, T. B. & Gee, A. O. Classifications in Brief: Young and Burgess Classification of Pelvic Ring Injuries. *Clin. Orthop.* **472**, 2338–2342 (2014).
23. Meinberg, E. G., Agel, J., Roberts, C. S., Karam, M. D. & Kellam, J. F. Fracture and Dislocation Classification Compendium-2018. *J. Orthop. Trauma* **32 Suppl 1**, S1–S170 (2018).
24. Young, J. W., Burgess, A. R., Brumback, R. J. & Poka, A. Pelvic fractures: value of plain radiography in early assessment and management. *Radiology* **160**, 445–451 (1986).
25. Pennal, G. F., Tile, M., Waddell, J. P. & Garside, H. Pelvic disruption: assessment and classification. *Clin. Orthop.* 12–21 (1980).
26. Tile, M. Acute Pelvic Fractures: I. Causation and Classification. *J. Am. Acad. Orthop. Surg.* **4**, 143–151 (1996).
27. Matta, J. M. & Saucedo, T. Internal fixation of pelvic ring fractures. *Clin. Orthop.* 83–97 (1989).
28. Tile, M. Pelvic ring fractures: should they be fixed? *J. Bone Joint Surg. Br.* **70**, 1–12 (1988).
29. Stahel, P. F. & Hammerberg, E. M. History of pelvic fracture management: a review. *World J. Emerg. Surg.* **11**, 18 (2016).
30. Karaharju, E. O. & Slätis, P. External fixation of double vertical pelvic fractures with a trapezoid compression frame. *Injury* **10**, 142–145 (1978).
31. Keating, J. F. *et al.* Early fixation of the vertically unstable pelvis: the role of iliosacral screw fixation of the posterior lesion. *J. Orthop. Trauma* **13**, 107–113 (1999).
32. Routt, M. L., Kregor, P. J., Simonian, P. T. & Mayo, K. A. Early results of percutaneous iliosacral screws placed with the patient in the supine position. *J. Orthop. Trauma* **9**, 207–214 (1995).
33. Starr, A. J., Walter, J. C., Harris, R. W., Reinert, C. M. & Jones, A. L. Percutaneous screw fixation of fractures of the iliac wing and fracture-dislocations of the sacro-iliac joint (OTA Types 61-B2.2 and 61-B2.3, or Young-Burgess 'lateral compression type II' pelvic fractures). *J. Orthop. Trauma* **16**, 116–123 (2002).
34. Lefaivre, K. A., Slobogean, G. P., Valeriote, J., O'Brien, P. J. & Macadam, S. A. Reporting and interpretation of the functional outcomes after the surgical treatment of disruptions of the pelvic ring: a systematic review. *J. Bone Joint Surg. Br.* **94**, 549–555 (2012).
35. Swiontkowski, M. F., Engelberg, R., Martin, D. P. & Agel, J. Short musculoskeletal function assessment questionnaire: validity, reliability, and responsiveness. *J. Bone Joint Surg. Am.* **81**, 1245–1260 (1999).
36. Majeed, S. A. Grading the outcome of pelvic fractures. *J. Bone Joint Surg. Br.* **71**, 304–306 (1989).
37. Templeman, D., Goulet, J., Duwelius, P. J., Olson, S. & Davidson, M. Internal fixation of displaced fractures of the sacrum. *Clin. Orthop.* 180–185 (1996) doi:10.1097/00003086-199608000-00021.
38. Lefaivre, K. A., Slobogean, G. P., Ngai, J. T., Broekhuyse, H. M. & O'Brien, P. J. What outcomes are important for patients after pelvic trauma? Subjective responses and psychometric analysis of three published pelvic-specific outcome instruments. *J. Orthop. Trauma* **28**, 23–27 (2014).

39. Laird, A. & Keating, J. F. Acetabular fractures: a 16-year prospective epidemiological study. *J. Bone Joint Surg. Br.* **87**, 969–973 (2005).
40. Briffa, N., Pearce, R., Hill, A. M. & Bircher, M. Outcomes of acetabular fracture fixation with ten years' follow-up. *J. Bone Joint Surg. Br.* **93-B**, 229–236 (2011).
41. Ali, E. Acetabular Fractures - A Review of their Management. *J. Trauma Treat.* **4**, 1–5 (2015).
42. Tannast, M., Najibi, S. & Matta, J. M. Two to twenty-year survivorship of the hip in 810 patients with operatively treated acetabular fractures. *J. Bone Joint Surg. Am.* **94**, 1559–1567 (2012).
43. Matta, J. M. 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.* **78**, 1632–1645 (1996).
44. Matta, J. M., Mehne, D. K. & Roffi, R. Fractures of the acetabulum. Early results of a prospective study. *Clin. Orthop.* 241–250 (1986).
45. Tile, M., Helfet, D. L., Kellam, J. F., Vrahas, M. & Foundation, A. E. A. *Fractures of the Pelvis and Acetabulum (AO): Principles and Methods of Management*. (AO Publishing, Davos, 2015).
46. Ferguson, T. A., Patel, R., Bhandari, M. & Matta, J. M. Fractures of the acetabulum in patients aged 60 years and older: an epidemiological and radiological study. *J. Bone Joint Surg. Br.* **92**, 250–257 (2010).
47. Bellabarba, C. *et al.* Cementless acetabular reconstruction after acetabular fracture. *J. Bone Joint Surg. Am.* **83**, 868–876 (2001).
48. Herscovici, D., Lindvall, E., Bolhofner, B. & Scaduto, J. M. 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* **24**, 291–296 (2010).
49. Dodd, A., Osterhoff, G., Guy, P. & Lefaivre, K. A. Assessment of functional outcomes of surgically managed acetabular fractures: a systematic review. *Bone Jt. J.* **98-B**, 690–695 (2016).
50. D'aubigne, R. M. & Postel, M. Functional results of hip arthroplasty with acrylic prosthesis. *J. Bone Joint Surg. Am.* **36-A**, 451–475 (1954).
51. Øvre, S., Sandvik, L., Madsen, J. E. & Røise, O. Comparison of distribution, agreement and correlation between the original and modified Merle d'Aubigné-Postel Score and the Harris Hip Score after acetabular fracture treatment: moderate agreement, high ceiling effect and excellent correlation in 450 patients. *Acta Orthop.* **76**, 796–802 (2005).
52. Mahomed, N. N., Arndt, D. C., McGrory, B. J. & Harris, W. H. The Harris hip score: comparison of patient self-report with surgeon assessment. *J. Arthroplasty* **16**, 575–580 (2001).
53. Söderman, P. & Malchau, H. Is the Harris hip score system useful to study the outcome of total hip replacement? *Clin. Orthop.* 189–197 (2001) doi:10.1097/00003086-200103000-00022.
54. Wamper, K. E., Sierevelt, I. N., Poolman, R. W., Bhandari, M. & Haverkamp, D. The Harris hip score: Do ceiling effects limit its usefulness in orthopedics? *Acta Orthop.* **81**, 703–707 (2010).
55. Laucis, N. C., Hays, R. D. & Bhattacharyya, T. Scoring the SF-36 in Orthopaedics: A Brief Guide: *J. Bone Jt. Surg.-Am. Vol.* **97**, 1628–1634 (2015).
56. Ware, J. E. & Sherbourne, C. D. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. *Med. Care* **30**, 473–483 (1992).

57. Sullivan, M., Karlsson, J. & Ware, J. E. The Swedish SF-36 Health Survey--I. Evaluation of data quality, scaling assumptions, reliability and construct validity across general populations in Sweden. *Soc. Sci. Med. 1982* **41**, 1349–1358 (1995).
58. EuroQol--a new facility for the measurement of health-related quality of life. - PubMed - NCBI. https://www-ncbi-nlm-nih-gov.ezproxy.its.uu.se/pubmed/10109801.
59. Borg, T., Hernefalk, B., Carlsson, M. & Larsson, S. Development of a pelvic discomfort index to evaluate outcome following fixation for pelvic ring injury. *J. Orthop. Surg. Hong Kong* **23**, 146–149 (2015).
60. Borg, T., Carlsson, M. & Larsson, S. Questionnaire to assess treatment outcomes of acetabular fractures. *J. Orthop. Surg. Hong Kong* **20**, 55–60 (2012).
61. Fairbank, J. C. & Pynsent, P. B. The Oswestry Disability Index. *Spine* **25**, 2940–2952; discussion 2952 (2000).
62. Borg, T. & Hailer, N. P. Outcome 5 years after surgical treatment of acetabular fractures: a prospective clinical and radiographic follow-up of 101 patients. *Arch. Orthop. Trauma Surg.* **135**, 227–233 (2015).
63. Clarke-Jenssen, J., Røise, O., Storeggen, S. a. Ø. & Madsen, J. E. Long-term survival and risk factors for failure of the native hip joint after operatively treated displaced acetabular fractures. *Bone Jt. J.* **99-B**, 834–840 (2017).
64. Giannoudis, P. V., Grotz, M. R. W., Papakostidis, C. & Dinopoulos, H. Operative treatment of displaced fractures of the acetabulum: A META-ANALYSIS. *J. Bone Joint Surg. Br.* **87-B**, 2–9 (2005).
65. Scott, C. E. H. *et al.* Cemented total hip arthroplasty following acetabular fracture. *Bone Jt. J.* **99-B**, 1399–1408 (2017).
66. Frietman, B., Biert, J. & Edwards, M. J. R. Patient-reported outcome measures after surgery for an acetabular fracture. *Bone Jt. J.* **100-B**, 640–645 (2018).
67. Bott, A. *et al.* Long-Term Patient-Reported Functional Outcome of Polytraumatized Patients With Operatively Treated Pelvic Fractures. *J. Orthop. Trauma* **33**, 64–70 (2019).
68. Banierink, H. *et al.* Long-term physical functioning and quality of life after pelvic ring injuries. *Arch. Orthop. Trauma Surg.* **139**, 1225–1233 (2019).
69. Halawi, M. J. Pelvic ring injuries: Surgical management and long-term outcomes. *J. Clin. Orthop. Trauma* **7**, 1 (2016).
70. Neufeld, M. E., Broekhuyse, H. M., O'Brien, P. J., Guy, P. & Lefaivre, K. A. The Longitudinal Short-, Medium-, and Long-Term Functional Recovery After Unstable Pelvic Ring Injuries. *J. Orthop. Trauma* **33**, 608–613 (2019).
71. Holbrook, T. L., Hoyt, D. B. & Anderson, J. P. The importance of gender on outcome after major trauma: functional and psychologic outcomes in women versus men. *J. Trauma* **50**, 270–273 (2001).
72. Kokubo, Y. *et al.* Functional outcome of patients with unstable pelvic ring fracture: Comparison of short- and long-term prognostic factors. *J. Orthop. Surg.* **25**, 230949901668432 (2017).
73. Dienstknecht, T. *et al.* The long-term clinical outcome after pelvic ring injuries. *Bone Jt. J.* **95-B**, 548–553 (2013).
74. Gabbe, B. J. *et al.* Functional and return to work outcomes following major trauma involving severe pelvic ring fracture. *ANZ J. Surg.* **85**, 749–754 (2015).
75. Suzuki, T. *et al.* Long-term functional outcome after unstable pelvic ring fracture. *J. Trauma* **63**, 884–888 (2007).

Acta Universitatis Upsaliensis

Digital Comprehensive Summaries of Uppsala Dissertations from the Faculty of Medicine 1643

Editor: The Dean of the Faculty of Medicine

A doctoral dissertation from the Faculty of Medicine, Uppsala University, is usually a summary of a number of papers. A few copies of the complete dissertation are kept at major Swedish research libraries, while the summary alone is distributed internationally through the series Digital Comprehensive Summaries of Uppsala Dissertations from the Faculty of Medicine. (Prior to January, 2005, the series was published under the title "Comprehensive Summaries of Uppsala Dissertations from the Faculty of Medicine".)

Distribution: publications.uu.se
urn:nbn:se:uu:diva-404264

ACTA
UNIVERSITATIS
UPSALIENSIS
UPPSALA
2020