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INTEGRATED STUDY MASTER'S THESIS

Management of Complex Pelvic Fractures

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1. Summary

This systematic literature review focuses on the management of complex pelvic fractures. Complex pelvic fractures are severe injuries that are often seen in polytrauma patients. They frequently present with severe or life-threatening complications. Therefore, the management still remains a challenge, that often needs a multidisciplinary team approach.

A literature search was done to identify and evaluate the various diagnostic techniques, surgical and non-surgical treatment options and outcomes associated with the management of complex pelvic fractures. Databanks were searched with defined search criteria, as well as inclusion and exclusion criteria.

The literature research has shown that the following approaches are beneficial and should be considered in the management of complex pelvic fractures. Pelvic binder application is of great advantage for stabilising pelvic fractures during early management. Additionally, pre-hospital assessment tools or precise classifications play an important role in the initial management as well. Surgical management can have many different approaches, based on specific patient factors and fracture patterns. The focus is on minimally invasive surgery techniques, as well as on overall surgical advancements for specific injury patterns.

Specific patient groups, such as geriatric patients, need to be considered, as well as unique cases that may require specific treatment approaches.

2. Keywords

Complex Pelvic Fracture, Management of Complex Pelvic Fracture, Severe Pelvic Injury, Surgery

3. Introduction

With an increasing number of high-rise traumas, the frequency of pelvic ring fractures has also risen in recent decades. This is one of the reasons why an interest in these fractures is increasing. Whereas a few decades ago the main aim of treatment was the mere survival of the patient, today the focus is more on the complete functional recovery and social reintegration of the patient. Although pelvic fractures are relatively less common compared to all fractures, with a prevalence of three to eight percent, they have a high mortality rate and are the main cause of death in patients with high-energy trauma. (1)

As the pelvic ring itself is very stable, a pelvic fracture usually requires a high-energy trauma, most commonly motor vehicle accidents or falls from height. (1)

In high-energy traumas, the surrounding soft tissues, nerves, and vessels are often also injured, which is specific to complex pelvic fractures. Complex pelvic fractures therefore frequently occur

in polytrauma patients and continue to remain a challenge in trauma and orthopedic surgery that requires a multidisciplinary approach. (2)

The most common cause of death in patients with complex pelvic fractures is hemorrhagic shock, with 80 to 90%, caused for example by pelvic mass hemorrhages from the fracture surfaces, venous plexus, and arteries. (1)

Pelvic fractures can occur during low-impact trauma as well, although less common. They typically occur in adolescents or the elderly. In adolescents, athletic injuries are usually the reason for low-impact trauma and in the elderly falls while ambulating can result in low-impact trauma.

As complex pelvic fractures can lead to life-threatening hemorrhage, visceral injury, neurovascular compromise and long-term disability, prompt and effective management is important. Primarily, the management should focus on controlling the bleeding, restoration of hemodynamics, early diagnosis and the treatment of associated injuries, as well as early stabilization of the pelvic ring.

A key component of successful treatment and a good recovery is the rapid implementation of preclinical and clinical emergency care measures and adequate therapy. Moreover, the requirements for avoiding late complications have increased in line with progress made in the indication and surgical measures. (1)

3.1. Anatomy

3.1.1 Osseous Pelvic Ring

The bony pelvic ring is made up of the two Ossea coxae and the Os sacrum. The two ligament-guided sacroliliac joints join the sacral bone to the pelvic ring. It is elastically closed at the front via the symphysis pubica. (2)

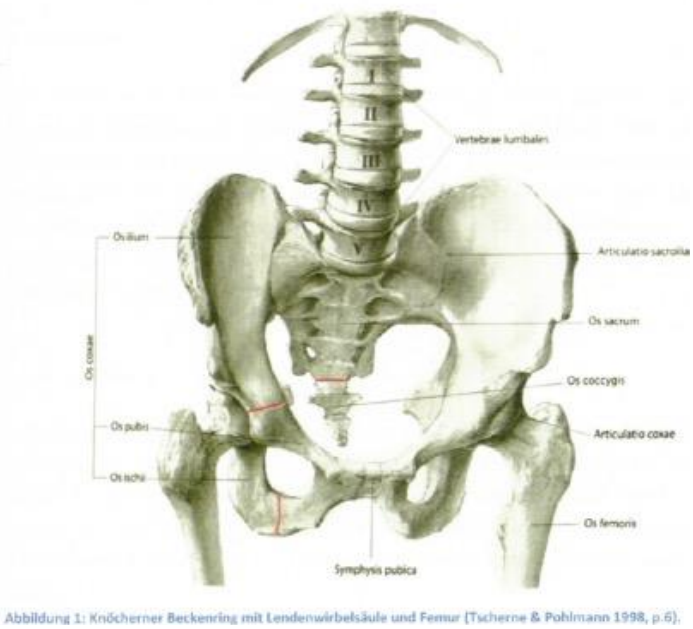


Abbildung 1: Knöcherner Beckenring mit Lendenwirbelsäule und Femur (Tscherne & Pohlmann 1998, p.6).

Figure 1: "Bony pelvic ring with lumbar spine and femur", "Ergebnis nach operative Behandlung von Beckenfrakturen", 2018, Ruppel D, p.3, Copyright by Ruppel (1)

3.1.1.1 Os coxae

The Os coxae originally consists of three bony structures that fuse together during development between the ages of 14 and 16. (2)

3.1.1.2 Os ilium

Two main structures are distinguished in the anatomical literature. On the one hand, the corpus ossis ilii forms the roof of the acetabulum. On the other hand, the alae ossis ilii (iliac crests) are the load-transmitting structures to the sacral bone and serve as the origin of important muscle groups (abductors, gluteus maximus, iliacus muscle). The iliac bone is therefore of great static importance and also plays a key role in the transfer of force from the lower extremities. (1)

3.1.1.3 Os ischii

The corpus ossis ischii, including the acetabular fossa, comprises about 2/5 of the acetabular surface and can no longer be differentiated individually once bone development is complete. The ramus ossis ischii borders the formaen obturatum dorsocaudally. The tuber ischiadicum continues caudally, which is of major importance for load application when sitting. As an attachment point for the ischiocrural muscles (hip extensors) and the adductor magnus muscle, it performs additional dynamic stabilisation functions in the hip joint. (1)

3.1.1.4 Os pubis

The os pubis, together with the r. ossis ischii, forms the anterior pelvic ring and surrounds the foramen obturatum. The ventral part of the acetabulum is formed by the corpus ossis pubis. At the medial junction of the two pubic bone branches, the symphysial facies forms the transition to the symphysis pubica. The pubic tubercle forms a slightly protruding notch, the ventral surface of which represents the attachment surface of the rectus abdominis muscle. (2)

3.1.1.5 Symphysis pubica

The interpubic disc is located between the symphysial pars of both pubic branches and consists mainly of fibrocartilage. According to recent studies, it has all the characteristics of a synovial joint. The perichondrium is additionally reinforced by periosteum, tendon attachments and smaller ligament connections. However, no muscle bridges the symphysis. (1)

3.1.1.6 Os sacrum

The os sacrum emerges from the fusion of five vertebrae and constitutes the connecting structure between the spine and the pelvic ring. Additionally, it is an important stabilising part of the pelvic ring. (2)

The base of the triangular sacral bone points cranioventrally, while it tapers dorsocaudally. In the sacral curvature, in the region of the third sacral vertebra, the orientation changes from dorsal caudal to ventral caudal. The sacrum ends caudally with the apex ossis sacri.

The Os coccygis joins distally and consists of three to four vertebral rudiments.

The arched bulge described by Waldeyer is an arch-shaped protrusion in the iliac articular surface, which is supported in the corresponding depression in the sacral articular surface. A bony wedging of the sacrum into the pelvic ring, according to the keystone theory, does not occur, however, according to more recent views. It is more likely that the sacrum would fall out of the pelvic ring when standing upright after all the ligaments have been severed. (1)

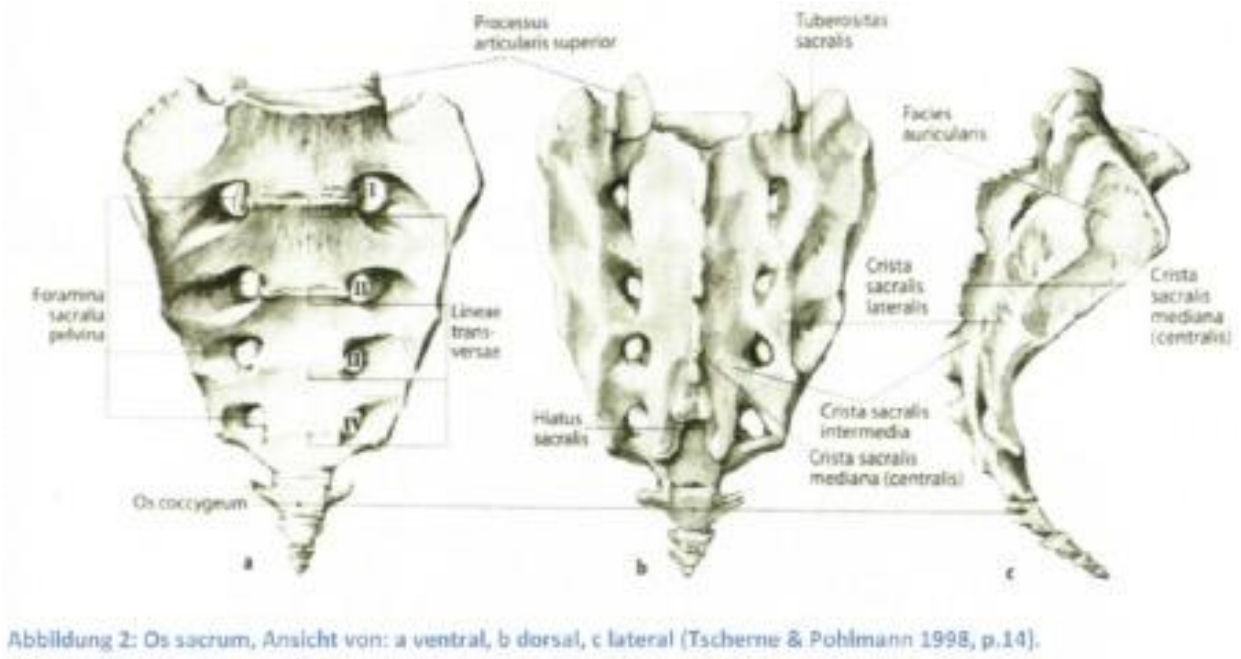


Abbildung 2: Os sacrum, Ansicht von: a ventral, b dorsal, c lateral (Tscherne & Pohlmann 1998, p.14).

Figure 2: "Os sacrum: view from: a ventral, b dorsal, c lateral" "Ergebnis nach operative Behandlung von Beckenfrakturen", 2018, Ruppel D, p.5, Copyright by Ruppel (1)

3.1.2 Ligamentous Connections

The relatively weakly developed anterior sacroiliac ligament, the interosseous sacroiliac ligament and the posterior sacroiliac ligament are formed by the joint capsule of the sacroiliac joint. Between the right and left pubic symphysis on the anterior part of pelvic ring, the symphyseal ligaments are present. Resistance of external rotation through the sacroiliac joints posteriorly. (3)

Stability to the pelvic ring is provided through the posterior sacroiliac complex and the ligaments of the pelvic floor posteriorly. The anterior structures, the sacrospinous ligaments and sacrotuberous ligaments, of the pelvic floor are in relation to the sacroiliac joint and resist shear and external rotation through the sacroiliac joint. The most important structure for the stability of the pelvic ring is the posterior sacroiliac complex, which is the posterior most-ligamentous structure. (3)

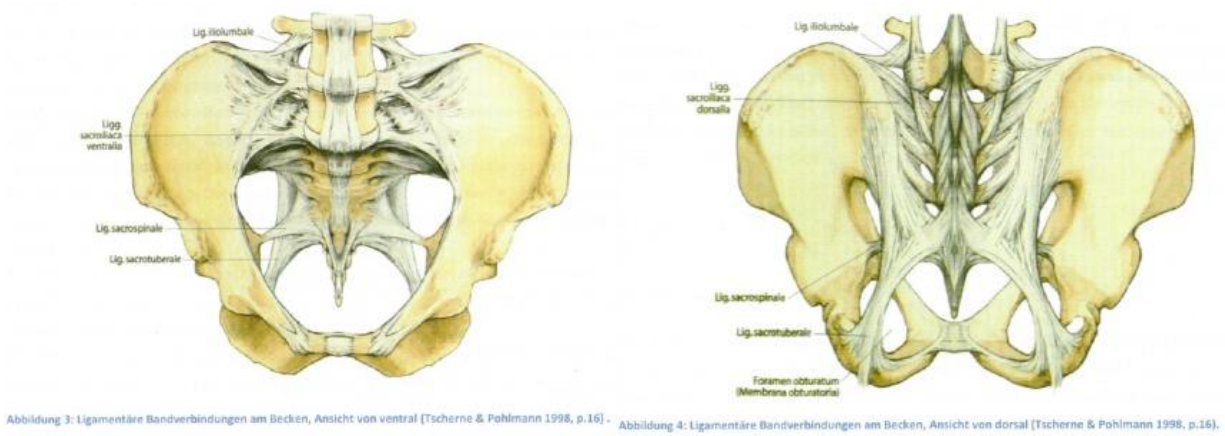


Figure 3: "Ligamentous Connections of the pelvis, ventral view and dorsal view", "Ergebnis nach operativer Behandlung von Beckenfrakturen", 2018, Ruppel D, p.6, Copyright by Ruppel (1)

3.1.3 Musculature

The pelvic ring is the origin or starting point of several muscle groups. These include the back, abdominal and hip muscles. The back surface of the sacral bone is attached to the muscles of M. errector spinae (M. multifidus and M. longissimus dorsi), as parts of the autochthonous back musculature.

The group of abdominal wall muscles includes the external abdominal oblique muscle, the internal abdominal oblique muscle, the transverse abdominal muscle, the rectus abdominis muscle and the pyramidal muscle. (1)

The hip muscles, most of which originate from the pelvic ring, are categorised according to their function into flexors, extensors, abductors, adductors and rotators. The hip flexors include the iliopsoas muscle, consisting of the psoas major and iliacus muscles, and the tensor fasciae latae muscle. The only hip extensor that originates from the pelvic ring is the gluteus maximus muscle, which has additional functions as an adductor, adductor and external rotator.

The abductors include the gluteus medius and gluteus minimus muscles, whereas the adductor muscles include the pectineus muscle, the adductor longus muscle, the gracilis muscle, the adductor brevis muscle, and the adductor magnus muscle. (1)

The piriformis muscle, the internal obturator muscle, the superior and inferior gemelli muscles, the quadratus femoris muscle and the external obturator muscle, which has additional adducting functions, act as external rotators.
The pelvic ring is closed off caudally by the muscles of the pelvic floor. (2)
These have an important function in maintaining continence and can be subdivided into a pelvic diaphragm (levator ani muscle with puborectalis, pubococcygeus and iliococcygeus muscles) and a urogenital diaphragm (transversus perinei profundus and superficialis muscles and sphincter muscles of the urethra). The fasciae of these muscle systems create connective tissue spaces that can be of clinical significance following injury. (1)

3.1.4 Topography of pathways

3.1.4.1 Arteries

The entire lower extremity is supplied by the common iliac artery as the main vessel. Before the sacroiliac joint, it divides into the internal iliac artery and the external iliac artery, which leaves the pelvic cavity as the femoral artery after passing through the lacuna vasorum.
With the exception of the testicles, the internal iliac artery supplies all pelvic organs.
At the level of the linea terminalis, it divides into a posterior and an anterior main trunk.
The posterior main trunk gives off the iliolumbar artery, the lateral sacral artery and the superior gluteal artery, thus supplying the muscles of the trunk wall. The anterior main trunk supplies the bladder, rectum and genital organs by giving off the inferior gluteal artery, the internal pudendal artery and the obturator artery. (1)

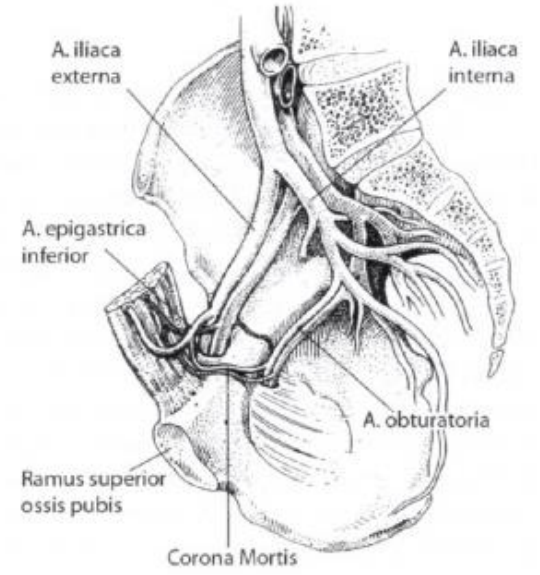


Figure 4: "arterial supply of the pelvis" From: "Ergebnis nach operativer Behandlung von Beckenfrakturen", 2018, Ruppel D, p.8, Copyright by Ruppel (1)

The term 'corona mortis' is generally used to describe anastomoses between the obturator vessels and the external system of iliac vessels. It is often formed by the obturator ramus of the inferior epigastric artery and the pubic ramus of the obturator artery.
Venous variants are also described. The incidence of arterial anastomoses is between 14.8 and 36 per cent. Injury to the corona mortis harbours a high risk of massive bleeding. As it runs along the upper branch of the pubic bone, it is a relevant vascular connection, particularly for anterior pelvic ring fractures. (2)

3.1.4.2 Veins

The venous plexus system in the pelvis drains primarily into the internal iliac vein. However, there are also additional portocaval anastomoses via the rectal veins. The plexuses include the vesical venous plexus, the rectal venous plexus, the presacral venous plexus and, in women, the uterine venous plexus. (2)

3.1.4.3 Lymphatic system

The Nodi lymphatici inguinales superficiales et profundi serve as the main collection point for lymphatic drainage from the pelvic floor and the lower extremities. The sacral lymphatic nodes collect the lymphatic drainage from the bones, muscles, and joints of the posterior pelvic ring. (2)

3.1.4.4 Nerves

The lumbar plexus, the sacral plexus and the coccygeal plexus are important for neurological concomitant injuries in pelvic ring and sacral fractures.

The lumbar plexus originates from the ventral nerve roots from Th12 to L4. It gives rise to the lateral femoral cutaneous nerve (L2 - L3, provides sensory supply to the lateral thigh), the obturator nerve (L2 - L4, motor supply to the adductor muscles and sensory supply to the skin on the distal, medial thigh) and the femoral nerve (L2 - L4, innervation of the extensors of the thigh). (1)

The sacral plexus is divided into the sciatic plexus and the pudendal plexus. The sciatic plexus is made up of the L4 to S3 nerve roots and supplies both the pelvic girdle and the lower limb. It is further subdivided into the sciatic nerve, the lumbosacral trunk, the superior gluteal nerve, and the inferior gluteal nerve. The pudendal plexus carries fibres from roots S2 to S4, but also has sympathetic and parasympathetic parts. The main branch is the pudendal nerve, which innervates the skin and muscles of the pelvic floor, perineum, and external genitalia.

The coccygeal plexus originates from the roots S3 to S5. It is involved in the innervation of the levator ani muscle and the coccygeus muscle. It also sensitively supplies the skin over the os coccygis and the anus. (1)

3.1.4.5 Biomechanics of the pelvis

The posterior pelvic ring plays the key role in transferring the load from the hip joints to the trunk. This is illustrated by clinical observations in patients who are missing the entire anterior osteoligamentous pelvic region due to tumour operations, for example. The posterior pelvic ring is sufficiently stabilising for load transfer in order to function without restrictions.

When standing upright, it becomes apparent that there is no mechanical shape congruence between the Os sacrum and the Ossae illi in the sense of a “keystone”. Rather, the os sacrum corresponds to

an inverted keystone that would fall out without ligamentous support structures. Bony jamming due to wedge shape of the os sacrum can only be assumed in the sitting position. (1)

The sacroillac joint plays a special role in dynamic force transmission, The approximate axis of rotation, which is located at the transition from the first to the second sacral body, changes its position during movement. Under load, the sacral os rotates and translocates, whereby the cranial sacral parts move ventrally and caudally. This movement initially leads to compression of the sacroililac joint surfaces by tensing the sacroiliac dorsal ligaments. The rotational movement is slowed down by the sacrospinous and sacrotuberous ligaments, which explains the shock absorbing function of the pelvis during movement. (1)

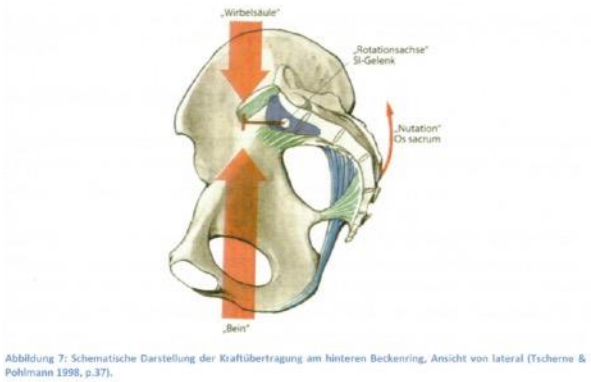


Abbildung 7: Schematische Darstellung der Kraftübertragung am hinteren Beckenring, Ansicht von lateral (Tscherne & Pohlmann 1998, p.37).

Figure 5: "Biomechanics of the anterior pelvic ring", From: "Ergebnis nach operativer Behandlung von Beckenfrakturen", 2018, Ruppel D, p.11, Copyright by Ruppel (1)

3.2. Classification of pelvic fracture

There are different ways of categorising fractures of the bony pelvic ring. Firstly, a distinction is made between fractures of the acetabulum and fractures of the pelvis.

Acetabular fractures are often found in combination with pelvic ring injuries due to their spatial and functional proximity. Simple pelvic fractures can be divided into uncomplicated and complex fractures. Uncomplicated fractures are purely osteoligamentous injuries without significant soft tissue damage. Complex fractures, on the other hand, are defined as fractures associated with peripelvic soft tissue damage or injury to pelvic organs, nerves, vessels, or the urinary tract. They are associated with a mortality rate of up to 50.0%. (2)

The remaining stability of the pelvis after the fracture is particularly important for the classification of pelvic fractures. Both this and any existing dislocations are decisive for treatment.

Fractures in the dorsal region lead to a serious biomechanical weakening of the ring system, resulting in an unstable pelvic ring. In contrast, fractures in the anterior pelvic region do not result in any significant mechanical weakening of the ring, so that a biomechanically stable pelvic ring remains.

A distinction is therefore made between fractures that do not cause any instability, fractures that cause partial instability of the pelvic ring and injuries that lead to a complete separation of one or both halves of the pelvis from its origin. (2)

The 'Comprehensive Classification of Fractures' by Tile was first published in 1988 and later accepted after modification by the Osteosynthesis Working Group.

The classification is divided into 3 main groups, each with 3 subgroups. (2)

Type A	**Intact posterior pelvic ring; Intact pelvic floor; stable fracture**
A1	Avulsion fracture: - Spina iliaca anterior superior - Spina iliaca anterior inferior - Tuber ossis ischii
A2	Iliac fracture: - With or without dislocation of the pelvic ring
A3	Transverse sacral fracture: - With or without pelvic ring involvement - Fractures of the coccyx
Type B	**Incompletely interrupted posterior pelvic ring, resulting in vertical rotational instability; partially unstable fracture**
B1	"Open book" – External rotation: - Anterior sacroiliac injury - Sacrum fracture
B2	Lateral compression – Internal rotation: - Ventral impression fracture of the sacrum - Partial sacroiliac joint dislocation - Incomplete posterior ilium fracture
B3	Bilateral B-Fractures: - Bilateral B1-Injury - B1- and B2- Injury - Bilateral B2-Injury
Type C	**Completely interrupted posterior pelvic ring, resulting in transitory and rotatory instability**
C1	Unilateral: - Injury of the ilium - Injury of the sacroiliac joint - Sacrum fracture
C2	Ipsilateral complete, contralateral incomplete fracture: - Completely through the ilium - Completely through the sacroiliac joint - Completely through the sacrum
C3	Bilateral complete fracture: - Bilateral extrasacral injury - Sacral and extrasacral injury - Bilateral sacral injury

Table 1: Tile Classification; From: "Beckenfrakturen – Ursache, Diagnostik und Behandlung", 2015, Overmeyer S, p.11 (2)

3.3. Aim of Paper and Research Question

The aim of this final thesis is to conduct a systematic literature review which comprehensively analyses and synthesises the existing and relevant literature on the management of complex pelvic fractures. This review aims to identify and evaluate the various diagnostic techniques, surgical and non-surgical treatment options and outcomes associated with the management of complex pelvic fractures.

The research question is: what are the new trends and controversies in current management of the most severe pelvic injuries?

By doing so, it aims to provide information for clinicians to improve patient care, identify gaps in current knowledge, and suggest areas for future research in the field of complex pelvic fracture management.

4. Research Methods

This chapter illustrates the methodological approach of this systematic review, which includes a detailed description of the literature search, the inclusion and exclusion criteria used, as well as the critical evaluation of the studies and the data analysis.

A suitable search strategy was developed, and specific databases were selected to answer the research question.

4.1.Strategy used to search for sources

4.1.1 Search Terminology

A Medical Subject Heading (MeSH) analysis was conducted in the MeSH database to find suitable MeSH headings and subheadings. The MeSH Tree was analysed. Based on the research aim and focus the following MeSH terms were defined: “pelvic bones / surgery” and “pelvic bones / injuries”. Furthermore, the following keywords were chosen: “severe”, “pelvis injuries” and “pelvic fracture”. Boolean operators (“AND/OR”) and truncations (*) were used as appropriate. For details see attached annex.

4.1.2 Search Strategy

The databases PubMed and Cochrane Library were used to conduct a literature search. Since this research focuses on the latest trends, the filter for the publication date as of 2014 was used.

4.2 Criteria used to include and exclude articles

4.2.1 Inclusion Criteria

Articles reporting on the management of complex pelvic fractures were included, provided they reported on the intervention of complex pelvic fractures, as well as their outcome. After applying the exclusion criteria, all relevant abstracts were assessed, and the full text of the selected publications was obtained.

4.2.2 Exclusion Criteria

Articles that reported on the management of complex pelvic fractures in cadaver studies, in children and in animals, as well as articles with a publication date of over 10 years ago were omitted. Other exclusion criteria were military-related studies, studies focussing on management in areas with limited resources available, and studies focussing on the outcomes of mental health, as well as psychological outcomes of patients with pelvic fractures. Research that did not provide a specific statement on the management of complex pelvic fractures or injuries were rejected. Articles in languages other than English and German were excluded, except one French article. Duplicates were removed.

4.3 Strategy used to select articles

The strategy for selecting the articles was based on title and abstract screening with regard to the inclusion and exclusion criteria. Furthermore, duplicates were removed. If the title and abstract were a match, the full text was used. In case of doubt, the full text was always used.
After screening the full texts, these were evaluated, and data extracted where necessary. In Chapter 5 a detailed description of the critical evaluation of the studies is provided.

5. Research Results

5.1. Characteristics of selected research

5.1.1 Instrument for the critical appraisal of selected research

For the critical appraisal of the selected research a table was used and can be found in Appendix 1. This evaluation sheet contains all relevant criteria that could influence the methodological quality and thus the credibility of a systematic review.

5.2 Research Results and Discussion

5.2.1 Research Results

This chapter describes the results of the literature search, as well as the study characteristics of the included studies, the methodological quality, and the effectiveness of the individual management approaches with regard to complicated pelvic fractures.

5.2.1.2 Results of the systematic literature research

The systematic literature search resulted in a total of 219 hits in the databases. 56 full texts of the identified systematic reviews were examined in more detail and assessed for their methodological quality in accordance with the predefined inclusion and exclusion criteria.

5.2.2 Effectiveness of different management approaches for complex pelvic fractures

There are different ways of approaching the management of complex pelvic fractures. The approaches may vary depending on the individual clinical case, or different aspects may need to be considered depending on the specific case, such as the importance of the timing of treatment and the effectiveness of early management. To illustrate and present these different aspects, they are sorted in the following chapters.

5.2.2.1 Managing complex pelvic fractures in patients with unique injury patterns

In complex pelvic fractures that are accompanied by other severe fractures or injuries, management can be quite challenging. It has to be specific to a unique and complex type of injury, and there is no standardised diagnostic or classification criteria, nor is there a standardised surgical procedure. (4)
Three studies have focused on unique injury patterns.
In the study by Li, Renjie et al. (2023) the authors focused on patients that sustained unstable pelvic fractures, as well as acetabular fractures. 24 patients, more specifically 15 male patients and 9 female patients, with a mean age of 44.8 years, met the inclusion criteria. On admission, supracondylar femoral traction was given to all patients and X-rays of the pelvis in multiple angles were done. Then, the pelvic ring injuries were classified with the Young-Burgess classification and the Tile classification, with 15 cases being Tile Classification Type B and nine cases being Tile Classification Type C. (4)
The Letournel-Judet typing was used for the acetabular fractures, and identified eight cases of transverse acetabular fractures, six cases of both-column fractures, four cases of transverse and posterior wall fractures, three cases of anterior and posterior hemitransverse fractures, two cases of

T-shaped fractures and one case of anterior column fractures. Both fractures, the unstable pelvic fractures and the acetabular fractures, were treated surgically. The choice of surgical approach, as well as the order of reduction, was individualised to each unique case, meaning in some cases the pararectus approach was chosen, for other patients an anterior approach via the paramedian approach or a modified Stoppa approach and posterior Kocher-Langenbeck approach seemed more appropriate. (4)

For a statistical analysis, the Matta and Tornetta scale was used to evaluate the pelvic fractures. To assess functional outcome according to pain, sitting and standing, gait and walking distance or sexual ability, the Majeed functional scale was applied. Lastly, the Matta criteria and the Modified Merle D'Aubigne and Postel scale were applied. They analysed the post-operative repositioning of actebular fractures within one week after the operation, and for clinical outcome of treatment of acetabular fractures at the final follow-up. Hip function was assessed in terms of walking, pain and range of motion. The functional outcomes in this study achieved excellent rates with 87.5% for pelvic fractures and 83.3% for hip function. Lastly, the authors highlight the importance of taking into account case-specific aspects that are essential when treating such a complex injury pattern, such as the degree of displacement and patient's physiological status. (4)

Another unique pelvic injury case is the case report by Gillespie, Matthew John et al. (2021), where a case of an unusual and isolated ischial fracture is presented. This case is rare, since the authors claim that no similar cases were found during a literature review and none of the current classification systems, such as the Young-Burgess or Tile, are able to classify this specific injury. Type A fractures of the Tile Classification also include ischial fractures, but these are not comparable to such a major injury, as they are usually only minor avulsions. To cause such an injury, high energy is needed, since muscle and fat protect the ischial tuberosity. (5)

The patient in this case is a 36-year-old male who fell from his dirt bike and sustained a direct impact to his right side, more specifically to the ischial tuberosity. A displaced ischial body fracture was seen on radiographical examination, and a CT-scan confirmed the integrity of the pelvic ring. The patient was active and young and required fixation. Because he sustained a displacement of more than 15-20mm, surgical fixation was decided on. The displaced fragment could compromise the sciatic nerve, as well as leading to a potential malunion or high risk of non-union. This could cause severe functional impairment in the future. (5)

Figure 6: "preoperative anteroposterior radiograph illustrating right ischial fracture", From: "The 'nightstick' ischial fracture: a unique oddity of the pelvic injury family.", 2021, Gillespie, M J et al., Fig.2, Copyright by Gillespie, Makaram, White, Molyneux (5)

Figure 7: "anteroposterior radiograph of the right hemipelvis illustrating satisfactorily maintained reduction and evidence of union", From: "The 'nightstick' ischial fracture: a unique oddity of the pelvic injury family.", 2021, Gillespie, M J et al., Fig.2, Copyright by Gillespie, Makaram, White, Molyneux (5)

The patient underwent open reduction and internal fixation, without any perioperative complications. At the 5-month follow-up, he was discharged from the clinic and allowed to fully weight-bear, since the clinical examination was satisfactory. The authors conclude that the surgery was the right decision in this specific case, since it protected the sciatic nerve, as well as reducing the otherwise high risk of a limited activity level or chronic pain and weakness. (5)

The case report by Hernandez, J., Rosenthal, AA (2022), illustrates that some cases may require hemipelvectomy. A pedestrian, a 25-year-old male, was struck by a train and sustained extensive complex pelvic fractures, right external iliac artery and vein laceration, as well as right femur and tibia fractures. During the damage control surgery, a revascularisation of the right lower extremity was attempted. Since the extremity became ischemic, it was decided that a knee amputation, followed by a hip disarticulation, as well as a hemipelvectomy was required. To gradually close the pelvic wounds, negative pressure wound therapy was used. (6)

The authors conclude that the hemipelvectomy improved the patient's outcome immensely. They emphasise that, in their opinion, in cases like this, where the patient sustains such severe pelvic injuries caused by high energy trauma, a hemipelvectomy may be necessary and the preferable choice for a more favourable outcome. (6)

5.2.2.2 Managing complex pelvic fractures in patients with urological injuries

Four studies were found during the systematic literature review that focus on the management strategies of pelvic fractures with associated urological injuries. One of the studies was a literature review by Tischler Eric H et al. (2023), that reviewed management of associated genitourinary injuries in open pelvic fractures. The study is set in a trauma care setting, with a multidisciplinary team available. (7)

The main focus is on the genitourinary injury rates, infection, vaginal laceration, and mortality. Overall, 343 patients were included with an average age of 35.1 years and a mean Injury Severity Score of 26.5. The inclusion criteria are patients sustaining open pelvic fractures and associated genitourinary injuries. Management included systemic and local antibiotic therapy, surgical stabilisation and multidisciplinary approached to address the associated injuries. High-energy blunt trauma was the prevalent cause for the trauma, with 95.5%, including motorcycle accidents or motor vehicle collisions. Vaginal lacerations in females and genitourinary injuries were listed as the main complications. An infection rate of 18.7% and a mortality rate of 31.2% was calculated. (7)
The literature review shows that outcomes are improved by stabilising the injuries early, for example with pelvic binders or external fixation. For infection control, antibiotic coverage is critical, including administration locally and systemically. The authors conclude that in order to manage the associated injuries, a multidisciplinary care team is essential. (7)
The retrospective study by Rehné Jensen, Lasse et al. (2023) focuses on lower urinary tract trauma in pelvic fracture patients. The study highlights that even in highly experienced centres, management and follow-up of these patients is not sufficient. Long-term complications are still a major problem and the management approaches for urethral injuries vary vastly. The study discovered that severe short- and long-term complications were associated with complete urethral ruptures. Lastly, the author emphasises that there is a lack of evidence to support recommendations for treatment approaches and stresses that multicentre studies should be conducted. (8)
The fourth and last study by Velazquez, N et al. (2020) investigates not only genitourinary injuries in pelvic fracture patients, but also lower gastrointestinal injuries. It assesses their morbidity and mortality. Patients that were included in the study sustained pelvic fractures due to blunt trauma. Exclusion criteria included incomplete records or penetrating injuries. (9)
The main management approaches included rectal repair, which was done in 81% of patients, followed by urinary repair with 62%, faecal diversion, performed in 46% of patients, and urinary diversion in 29% of patients. Figure 8 illustrates the management of pelvic fractures that are associated with lower genitourinary injuries and gastrointestinal injuries.

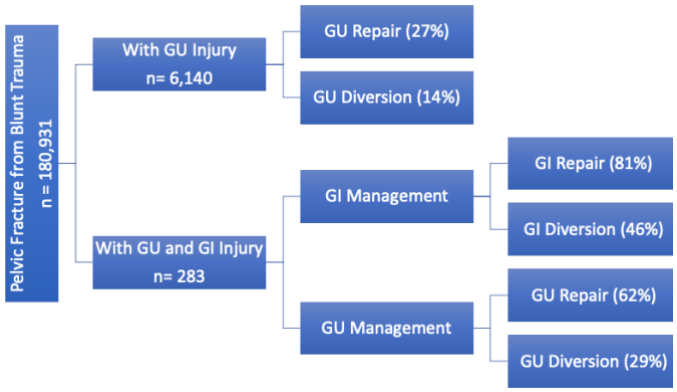


Figure 8, From: "Blunt trauma pelvic fracture-associated genitourinary and concomitant lower gastrointestinal injury: incidence, morbidity, and mortality.", 2020, Velazquez, Nermarie et al., Fig.2, Copyright by Velaquez, Fantus, Fantus, Kingsley, Bjurlin (9)

The study found that not only sustaining associated genitourinary injuries in pelvic fractures, but also lower gastrointestinal injuries, increased the hospital length of stay (26.8 vs. 14.5 days), as well as leading to higher injury severity scores and higher mortality rates (11.3% vs. 4%). (9)

5.2.2.3 Managing complex pelvic fractures with pelvic binders

Pelvic binders are used in pelvic fracture patients to compress the pelvis, as well as decrease the volume within the pelvis, in order to decrease bleeding. The correct application of the binder is of great importance, as it will not have any effect otherwise. It should be positioned around the greater trochanter and pubic symphysis in order to achieve leg adduction, as well as correctly decreasing the pelvic volume. A pelvic binder could increase bleeding if it is placed in a lateral fracture. (3)
Furthermore, it should not be overlooked that a pelvic binder could also cause complications if it is used in a patient for more than 24 hours. It could moreover cause pressure ulcers or skin necrosis, as rapidly as two to three hours after placement. A high risk of deep venous thrombosis also applies here, which is further increased by bone fractures and restricted mobility. (3)
Regarding pelvic binders in the management of complex pelvic fractures, the studies by Hsu, Sheng-Der et al. (2017), Reiter, Alonja et al. (2024), Berger-Groch, Josephine et al. (2022) and Schweigkofler, U et al. (2016) were included. In all three studies, no statistically significant reduction in the survival rate could be determined through the use of pelvic binders.
The first study mentioned, by Hsu, Sheng-Der et al. (2017), is a retrospective cohort study. The study group included 56 patients with traumatic injuries and pelvic fractures confirmed by radiological imaging. They received pelvic binder application early. The control group included 148 patients, who also suffered traumatic injuries and pelvic fractures confirmed by radiological imaging. The control group, however, only received the pelvic binder thereafter. In this study, no significant differences, such as the revised trauma score or the abbreviated injury score, were measured between the study group and the control group. (10)
Furthermore, the study stated, that the initial placement of the pelvic binder in the study group achieved a significantly improved survival, as well as shorter lengths of hospital and/or Intensive Care Units (16.11 ± 12.54 vs. 19.55 ± 26.14 days and 5.33 ± 5.42 vs. 8.36 ± 11.52 days), compared to the control group, but these tendencies were not able to reach statistical significance. (10)
This retrospective cohort study shows that there are differences between patients that were initially stabilised with a pelvic binder, compared to the control group, but none of these differences reached statistical significance. These differences are illustrated in Table 2 below. (10)

The authors conclude that pelvic binders are a non-invasive tool that is easy to apply at a relatively low cost and benefits the pelvic stability, with a low risk for complication. Therefore, they would advocate an early application of pelvic binders in patients where a pelvic injury is suspected, before the definitive radiological imaging is available. (10)

This is also supported by the retrospective cohort study by Reiter, Alonja et al. (2024). 66 unstable pelvic ring fracture patients were analysed. First, the ideal position for the pelvic binder was established. Thereafter, three subgroups were created, consisting of ideal position, outside optimal range or not at all. 60.3% of patients suffered a moderate to severe injury with a mean injury severity score or 21.9. The study concludes the use of pelvic binders had no significant impact on patient outcomes. Nevertheless, the use of pelvic binders is recommended as they can improve stabilisation and management of blood loss, which is consistent with the results of the previously mentioned study. (11)

Baseline patient characteristics.

Variable	Before Study Group (n = 148)	Study Group (n = 56)	*p*-Value
	Mean (Standard Deviation)	Mean (Standard Deviation)	
Age	45.14 (20.96)	46.36 (21.07)	0.711
Gender (M/F)	1.11 (78/70)	0.86 (26/30)	0.520
Hospital_LOS	19.55 (26.14)	16.11 (12.54)	0.346
ICU_LOS	8.36 (11.52)	5.33 (5.42)	0.252
RTS	7.26 (1.89)	7.12 (1.62)	0.609
ISS	15.80 (12.02)	16.91 (13.77)	0.571
Hypotension (systolic blood pressure ≤ 90), n (%)	12 (8.1%)	10 (17.6%)	0.09
respiration	18.26 (3.66)	19.63 (2.32)	0.043
GCS	13.86 (3.30)	13.66 (3.20)	0.704
Blood transfusion (mL)	4385 (3326)	2462 (2215)	0.009
Abbreviated injury score, n (%)			0.365
≤3	114 (77.0%)	39 (69.6%)	
>3	34 (23.0%)	17 (30.4%)	
Associated injury, n (%)			0.732
Yes	42 (28.38%)	18 (32.14%)	
No	106 (71.62%)	38 (67.86%)	
Angiography for TAE [a], n (%)			0.878
Yes	2 (1.35%)	1 (1.79%)	
No	146 (98.65%)	55 (98.21%)	
Outcome, n (%)			0.785
Survive	131 (88.51%)	51 (91.07%)	
Mortality	17 (11.49%)	5 (8.93%)	
Fracture classification [b], n (%)			
L	124 (83.8%)	45 (80.4%)	0.710
A	21 (14.2%)	9 (16.1%)	0.907
V	3 (2.0%)	2 (3.6%)	0.617
Complication related to use pelvic binder (skin necrosis, soft tissue damage or ischemic change)	2 (1.35%)	1 (1.79%)	0.731

Values are presented as means and SD unless otherwise indicated. [a] transcatheter arterial embolization (TAE) was specific to the hemostasis of pelvic fracture-related retroperitoneal hemorrhage. [b] fracture classification: L (Lateral compression), A (Anterior posterior compression), V (Vertical shear). Abbreviations: LOS (length of stay), ICU (intensive care unit), RTS (revised trauma score), ISS (injury severity scale), GCS (Glasgow coma score).

Table 2: "Baseline patient characteristics", From: "Effect of Early Pelvic Binder Use in the Emergency Management of Suspected Pelvic Trauma: A Retrospective Cohort Study.", 2017, Hsu, S et al., Table 1, Copyright by Hsu, Chen, Chou, Wang, Chan (10)

Another study comes to similar conclusions. The retrospective analysis by Berger-Groch, Josephine et al. (2022) studied the effect of Pelvic Circular Compression Devices in patients sustaining severe injuries. It draws a similar conclusion to the ones of the two previously mentioned studies. In severe pelvic trauma patients, the Pelvic Circular Compression Device was applied more often. These patients presented with a higher injury severity score. However, the application of the device had no significant effect on mortality, nor did it decrease the need for blood transfusion. (12)

There is also the question of how and when to open an already placed pelvic binder again. This particular question was discussed in the article by Schweigkofler, U et al. (2016) and resulted in a "clear the pelvis algorithm". (13)

The algorithm is intended to describe a structure for the approach according to which criteria and under which circumstances pelvic binders can be safely opened in a severely injured patient. (13)

As a result, the following points were raised: 1) the clinical situation needs to be assessed, including the trauma kinematics. 2) Assessing the hemodynamic status of the patient. 3) Before all diagnostic tests are completed, the need to open the pelvic binder for therapeutic and/or diagnostic methods should be checked. 4) Radiology diagnostic testing should be assessed, and the pelvic region can be released. The article concludes and advises that the pelvis should not be released before CT scans or X-rays with an open pelvic binder are available if the patient's ability to be assessed is limited. (13)

5.2.2.4 Managing complex pelvic fractures in patients with polytrauma

The management of polytrauma can be challenging and if it involves complex pelvic fractures, it can significantly increase the challenge in management of these patients. They are frequently associated with life-threatening complications, such as multisystem trauma or massive haemorrhage. Patients are at risk of rapidly deteriorating physiologically since the pelvis plays a key role in structural support and vascular anatomy. Timely and appropriate management is of great importance in these patients.

The observational study by Caillot, M. et al. (2016) investigates the efficacy of a predefined decision-tree protocol for managing severe pelvic trauma and evaluates the correlation between pelvic fracture types and mortality. Patients that were included in this study had an Injury Severity Score of more than 15. The setting of this study was a single-centre Level 1 trauma facility in France. The Tile classification was used to compare mortality in different types of fractures. Figure 9 shows the failure estimates according to the Tile grade. (14)

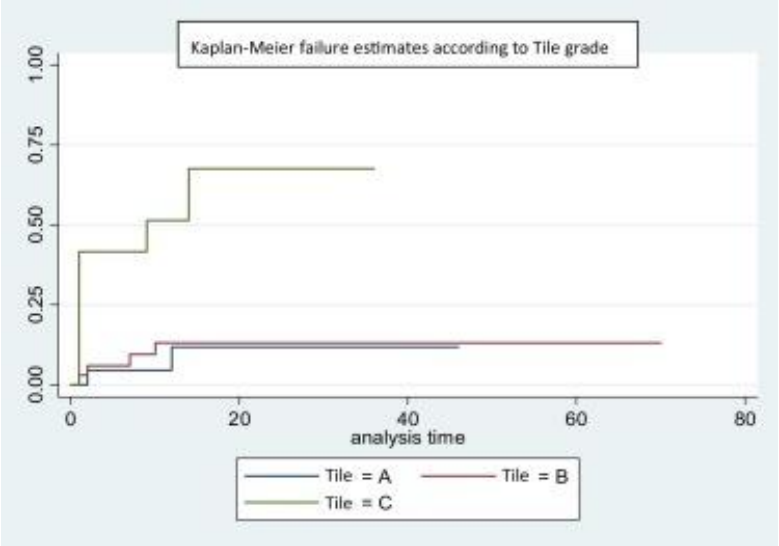


Figure 9: "Kaplan-Meier failure estimates according to Tile grade", From: "Pelvic fracture in multiple trauma: a 67-case series", 2016, Caillot, M et al., Fig. 2, Copyright by Caillot, Hammad, Baron, Villes, Leone, Flecher (14)

The mortality rate was significantly higher in patients with Tile C fractures, with 58%, compared to a mortality rate of 12.1% and 9.1% in Tile B and Tile A fractures, respectively. Additionally, Tile C fracture patients presented with higher injury severity scores and required more blood transfusions. Increased mortality was also associated with patients with lower haemoglobin and elevated lactatemia. Overall, a mortality rate of 19% was reported, and a mortality rate of 42% in haemorrhagic shock patients. (14)

The predefined decision-tree, as shown in Figure 10, included the application of a pelvic binder, if not already done, or in case of haemorrhagic shock, defined as a systolic blood pressure of ≤ 90mmHg despite receiving two litres of crystalloid substitution. (14)

On admission a focused assessment with sonography in trauma (FAST) and radiological assessment was done. Afterwards, the predefined decision-tree protocol differentiates between stabilised and non-stabilised patients. A full body CT scan is performed for stable patients, whereas non-stabilised patients are brought to the operating theatre. (14)

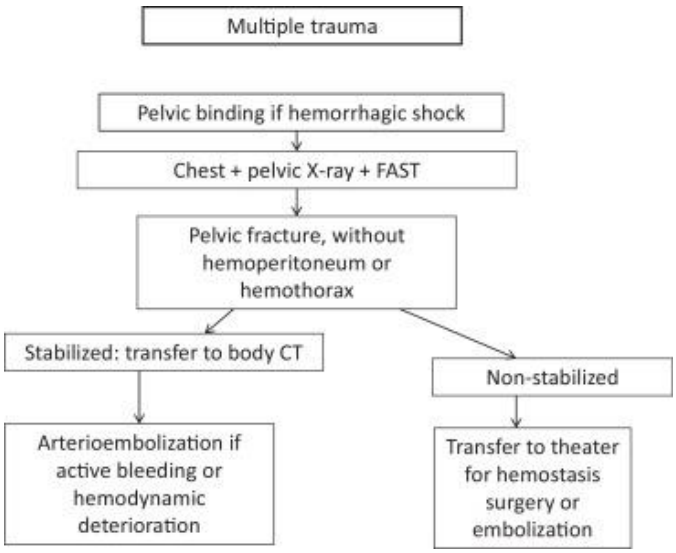


Figure 10: "Pre-defined decision-tree", From: ""Pelvic fracture in multiple trauma: a 67-case series", 2016, Caillot, M et al., Fig. 2, Copyright by Caillot, Hammad, Baron, Villes, Leone, Flecher (14)

The observational study by Caillot, M. et al. (2016) concludes that the predefined decision-tree protocol can be helpful in reducing early complications, as well as effectively managing haemorrhagic shock, especially through the application of pelvic binders. (14)

The study by Brioschi, Marco et al. (2022) focuses on the floating hip injury in polytraumatised patients. 45 patients with floating hip injuries were included in the study. (15) The Mueller

classification was used to classify floating hip fractures and the AO/OTA system for the other fractures. Surgical strategies are summarised in Table 3 and compares Mueller Type A fractures with Mueller Type B fractures. In the majority of patients (80%) the Damage control orthopaedics (DCO) was performed, especially in Type B (95.8% vs. 56.3%, $p = 0.004$). In Type A (75% vs. 33.3%, $p = 0.011$) a combined definite internal fixation (IF) of both fractures was often performed.

Surgery	Mueller A Patients *n* (%)	Mueller B Patients *n* (%)	*p*
DCO			
Pelvis	N/A	22/24 (91.7%)	N/A
Femur	9/16 (56.3%)	21/24 (87.5%)	0.032
Bridge Ex-Fix	2/16 (12.5%)	11/24 (45.8%)	0.029
Total	9/16 (56.3%)	23/24 (95.8%)	0.004
Internal fixation			
Pelvis/acetabulum	13/16 (81.3%)	10/24 (41.7%)	0.014
Femur	15/16 (93.8%)	17/24 (70.8%)	0.082
Stages			
Combined IF	12/16 (75%)	8/24 (33.3%)	0.011
1 stage	2/12 (16.7%)	3/8 (37.5%)	0.296
2 stages	10/12 (83.3%)	5/8 (62.5%)	0.296
Femur first	7/12 (58.3%)	5/8 (62.5%)	0.612
Revision surgery	8/16 (50%)	3/24 (12.5%)	0.013

Table 3: From: "Floating hip in polytraumatized patients: complications, mechanism of injury, and surgical strategy.", 2022, Brioschi, Marco et al., p. 365, Copyright by Brioschi, Randelli, Capitani, Capitani (15)

Surgical fixation of floating hip injuries still remains a challenge, since these are rare and complex injuries. The authors stress the necessity of prospective observational studies based on surgical protocols are necessary in future. (15)

Furthermore, the monocentric study by Bachmann, Robert et al. (2020) explored whether additional abdominal injury in pelvic fracture patients affects the quality of the surgical treatment. (16)

To measure the quality of fracture reduction, the Matta scoring system was used. Data on duration of mechanical ventilation, the mortality and revision surgery rate, the length of hospital- and ICU-stay, as well as the overall Injury Severity Score (ISS) was collected. (16)

Regarding overall mortality, revision surgery rates and the quality of fracture reduction, no significant difference was found between patients with or without abdominal injuries. It concluded that the presence of abdominal injury did not compromise the quality of pelvic fracture fixation. (16)

5.2.2.5 Managing complex pelvic fractures with surgical approaches

The surgical management of complex pelvic fractures not only includes the surgery alone, but it also encompasses surgical indications, preoperative planning, as well as intraoperative imaging techniques and navigational advancements for better surgical outcomes.

The narrative review by Godolias, Periklis et al. (2024) investigates the trends of recent years regarding surgical treatment of spinopelvic dissociation. To classify sacral fractures the AO Spine Sacral Injury Classification System can be used, which takes into account earlier classification systems in order to improve reliability, as well as treatment planning. (17)

The narrative review focuses on different fixation techniques, including the transsacral-transiliac screw fixation, lumbopelvic fixation, triangular fixation and posterior tension band plating. The transsacral-transiliac screw fixation is a minimally invasive percutaneous technique that is used to treat U-shaped sacral fractures. It is considered the gold-standard for these fractures when feasible, since placement can be technically challenging. In summary, for specific fracture types, such as U-shaped sacral fractures, transsacral-transiliac screw fixation can be used. In more complex cases, triangular fixation or lumbopelvic fixation may be required. (17)

The article states that minimally invasive techniques can reduce complication rates and improve treatment outcomes in cases that achieved satisfactory closed fracture reduction and do not require decompression. (17)

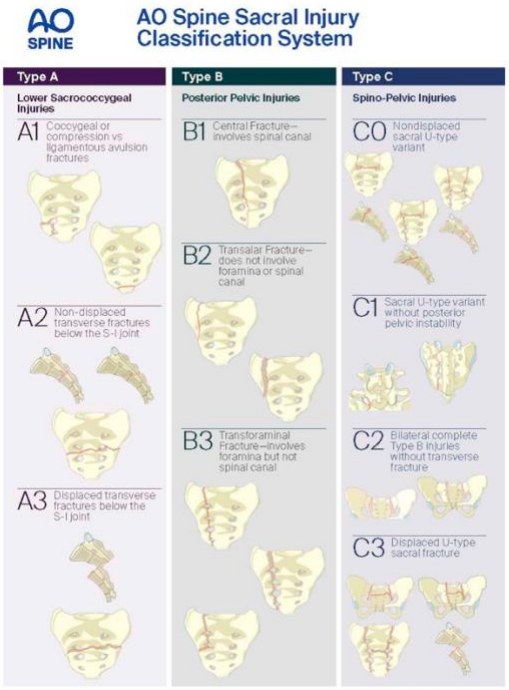


Figure 11: "AO Spine Sacral Injury Classification System", From: "Posterior pelvic ring injuries, lumbosacral junction instabilities and stabilization techniques for spinopelvic dissociation: a narrative review.", 2024, Godolias, P et al., p.1630 Copyright: Godolias, Plümer, Cibura, Dudda, Schildhauer, Chapman (17)

Another study analysed the indications and surgical approach for stabilising pelvic injuries with symphyseal plating, as well as their outcome. (18)

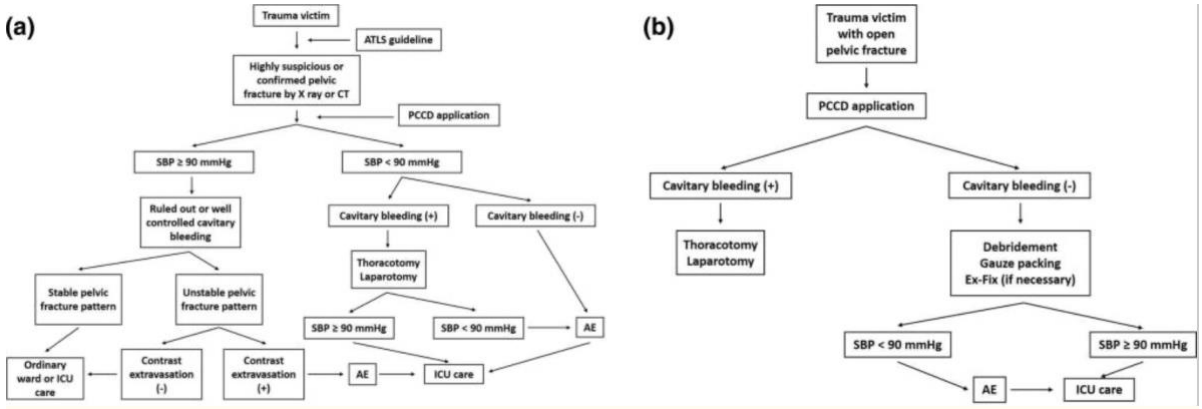
The study by Jordan, Martin C. et al. (2020), included 64 patients with a mean age of 44 years. The main cause of pelvic injuries were traffic accident injuries. The mean inpatient stay was 29 days, and the mean Injury Severity Score was 32. (18)

For the surgical intervention, a Pfannenstiel incision was made, followed by exposure of the rectus sheath and a longitudinal incision of the linea alba. After retrosymphysial dissection and fluoroscopic guidance for reduction, the symphysis was stabilised with either four-hole or six-hole repositioning plates. After the surgery post-operative imaging with either X-ray or CT scan was done, as well as another X-ray six weeks post-operatively. Implant loosening occurred in 52 (81.3%) patients, but only in 14 patients' severe complications that required further treatment, were observed. (18)

The study concludes that although radiological signs of implant loosening are frequently observed, they are rarely the reason for revision surgery. Since complete implant failures mainly occur within the first postoperative weeks and require early revision, additional X-ray imaging should be carried out in cases that raise suspicion of complete implant failure to clarify the matter in good time. (18)

The retrospective review by Yu, Yi-Hsun et al. (2023) focuses on open pelvic fracture management. Management in these cases can be challenging, especially because it can lead to a high mortality rate. (19)

Depending on the type of pelvic fracture, such as closed, or open pelvic fracture, two groups were formed for the resuscitation protocol. The resuscitation protocol is illustrated in Figure 12. (19)



Resuscitation protocol of patients with pelvic fracture. **a** Closed pelvic fracture. **b** Open pelvic fracture

Figure 12: "Resuscitation protocol", From: "Three-year functional outcome after open pelvic fracture treatment: a retrospective case series from a level I trauma center.", 2023, Yu, Yi-Hsun et al., Fig.1, Copyright by: Yu, Hsu, Chou, Liu, Tseng, Chen

Overall, an open pelvic fracture was diagnosed 37 patients (4.9%), who were primarily resuscitated or transferred to the emergency department. The mortality rate was 21.6%. (19)

Depending on the injury pattern, treatment methods differed between patients. For anterior pelvic ring injury, the most common approach was conservative, with 52.6%. For posterior pelvic ring injury, open reduction and internal fixation was the most common surgical procedure with 47.4%. Table 4 shows the different approaches to achieve osteosynthesis. (19)

Summary of approaches for osteosynthesis and related implants

	Patient number, *N* (%)								
		CRIF	ORIF						
	Conservative treatment	Percutaneous (IS, TITS, Ex-Fix)	Lateral window	Dorsal approach	Pfannenstiel	Ilioinguinal	Iliofemoral	Kocher-Langenbeck	Spinopelvic osteosynthesis
Anterior pelvic ring	10 (52.6)	7 (36.8)	0	0	2 (10.5)	0	0	NA	NA
Posterior pelvic ring	2 (10.5)	8 (42.1)	2 (10.5)	2 (10.5)	NA	1 (5)	1 (5)	1 (5)	2 (10.5)
Loss of fixation	NA	3 (15.8)	0	0	0	0	0	0	0

CRIF closed reduction and internal fixation; *Ex-Fix* external fixator; *IS* iliosacral screw; *NA* not available; *ORIF* open reduction and internal fixation; *TITS* trans-iliac-trans-sacral screw

Table 4: "Summary of approaches for osteosynthesis and related implants", From: "Three-year functional outcome after open pelvic fracture treatment: a retrospective case series from a level I trauma center.", 2023, Yu, Yi-Hsun et al., Table 4, Copyright by: Yu, Hsu, Chou, Liu, Tseng, Chen

Overall, patients that survived the initial resuscitation had a favourable likelihood of completing the full course of treatment. Management approach of fracture should be individualised for each patient and should take all patient-specific factors into account. Recovery in function may be expected over time, even if the functional scores earlier on were low. The authors stress that further research needs to evaluate the long-term functional progress of these patients. (19)

The article by Keil, Holger et al. (2019) emphasises the advantages of intraoperative imaging, as it enables better and more precise surgical work. The article concludes that compared to intraoperative 3D imaging, intraoperative CT offers a larger field of view, as well as better correction of artefacts. The standard is 2D imaging, but this entails limitations, such as superimposition of structures or anatomy. (20)

The propensity-matched cohort study by Ohmori, T et al. (2018) analyses the effectiveness of external fixation on mortality. To exclude the possibility of blood loss due to other injuries, isolated unstable pelvic ring fractures were identified in a database. An isolated pelvic ring fracture was defined by an Abbreviated Injury Score (AIS) for other injuries of < 3. An unstable pelvic ring fracture was defined as having an AIS ≥ 4. (21)

In total, 1163 patients were identified, who had been treated for an isolated unstable pelvic ring fracture, with 386 patients being treated with external fixation and 777 patients without external fixation. A subgroup analysis was carried out for patients suffering massive blood loss and those requiring blood transfusion within 24 hours of arrival in the Emergency Department. Propensity-score matching was performed, using the completed data and 346 patients were matched. After adjusting the propensity-score, patients treated with external fixation were associated with a significantly lower risk of death ($p = 0.047$). For the subgroup analysis, external fixation was associated with a significantly lower risk of mortality in patients who needed blood transfusion within 24 hours ($p = 0.014$) and in those with massive blood loss ($p = 0.016$). (21)

The study concludes that treating unstable pelvic ring fractures with external fixation, especially severe fractures, results in a significantly lower mortality risk. (21)

The article by Peng, Ye et al. (2019) illustrates a new approach to the management of complex pelvic fractures that are accompanied by sacral nerve injuries. (22)

In order to accomplish precise fracture reduction, a combination of the Starr Frame and the Da Vinci robotic surgery system are used. It describes the case of a woman that was injured during a traffic accident. She sustained multiple injuries, including a pelvic fracture. The pelvic fracture was classified as a type C3 according to the Tile classification. On the right side a Denis II sacral fracture was diagnosed, as well as bilateral pubic rami and ischial ramus fractures, and a sacroiliac joint dislocation on the left side. The motor function was normal, but in the posterolateral region of the right thigh and lateral aspect of the right foot, the patient reported numbness. (22)

Before the Starr Frame surgery at three days after admission, a pelvic binder was applied, and blood transfusion were used to stabilise the patient. During the surgery, an arc stick was added to reduce the “open book” injury. The pelvic ring underwent closed reduction and was fixed with a percutaneous transsacral-transiliac screw. The patient’s condition directly after the surgery, as well as during the next few weeks after the surgery, was good. (22)

At the three-month follow-up however, the patient complained of neurological numbness and pain in the right foot, more specifically the plantar and lateral regions. Mecobalamin and Neurotrophin were used for an effective consecutive treatment. At the two-year follow-up the motor function still was not affected, however the numbness and pain in the right foot had worsened and started to affect the patients sleep. A multiplanar CT reconstruction nerve scan was done, after the pelvic CT scan showed good positioning of the transsacral-transiliac screw. The multiplanar CT reconstruction nerve scan, showed a large amount of scar tissue in front of the S1 sacral foramen, so it was considered that the scar tissue must have compressed the S1 nerve. (22)

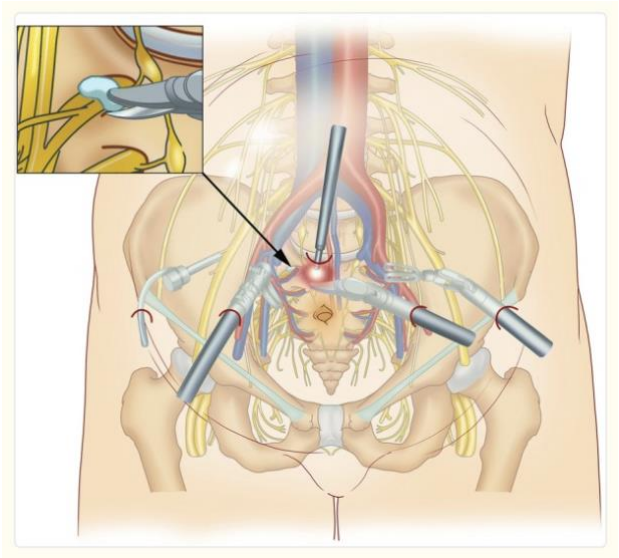


Figure 13: "DaVinci surgical approach", From: "Using the Starr Frame and Da Vinci surgery system for pelvic fracture and sacral nerve injury.", 2019, Peng, Ye et al., Fig. 9, Copyright by Peng, Zhang, Zhang, Wang, Zhang, Ma, Tang, Zhang

After six months of conservative treatment, during which the symptoms continued to worsen, it was decided to perform sacral nerve exploration and neurolysis using the Da Vinci surgery system. The Da Vinci surgical approach is illustrated in Figure 13. (22)

This helped to alleviate the patient of the numbness and at all follow-ups the patient reported no pain or numbness. The authors highlight that a combination of the Starr Frame and Da Vinci Surgery system has advantages and could be an alternative for sacral nerve injury and pelvic fracture. (22)

Unstable pelvic fractures can be treated with posterior screw fixation. The prospective case series by O'Hara, Nathan N et al. (2022) analysis the patient-reported function and pain of a pelvic fracture, that was treated with posterior screw fixation within 24-months. (23)

The Brief Pain Inventory (BPI) was used to measure the average pain. To measure function from six to twenty-four months after injury, the Majeed Pelvic Outcome Score was used. 88 adult patients were included and underwent pelvic fracture treatment with transiliac or sacroiliac screws. On the 10-point BPI scale the mean pain was 2.22, regarding six to twenty-four months after injury (95% Cl, 0.64-3.81) The mean pelvic function measured with the 100-point Majeed scale was 71 within twenty-four months of injury (95% Cl, 60-82). (23)

Factors that were significantly associated with increased pain included an initial fracture displacement of ≥ 5mm (0.99; 95% Cl, 0.23-1.69; P = 0,01), a history of chronic pain (1.31; 95%

CI, 0.26-2.37; P = 0.02) and socioeconomic deprivation (0.28; 95% CI, 0.11-0.44; P < 0.01). (23) Overall, posterior screw fixation in unstable pelvic ring fracture patients achieved good to excellent pelvic function, as well as minimal to no pelvic pain during six to twenty-four months after injury. (23)

The study by König, M A et al. (2018) describes the combination of iliosacral screw fixation with in-screw cement augmentation (ISFICA). This particular approach may be very promising for patients with weak or insufficient bone stock, as seen in elderly patients. (24)

The study includes 20 patients, eleven female patients and nine male patients, with a mean age of 74.4 years. All patients included in the study were treated with iliosacral screw fixation with in-screw cement augmentation (ISFICA). Osteoporosis was diagnosed in nine patients prior to admission, two patients obtained osteoporosis after undergoing prednisone therapy after a solid organ transplantation. (24)

A preoperative CT scan of the pelvis was done for all patients, in order to evaluate the bone stock of the posterior pelvic ring. In total, 26 screws were implanted during the study. The surgery included a K wire insertion under inlet-outlet view to guide the fully threaded screw, which was then placed in adequate position. Through a bone filler device, the cement was applied. Intraoperative CT scan was used to control the distribution of the cement, as well as potential leakage and the accurate screw placement. (24)

Post-operatively no neurological deficits or cement leakage were discovered, and all patients were able to be mobilised. Due to severe osteoporosis, one case of breach of the iliac cortical bone was reported, as well as one screw migration one year postoperatively. In two cases, the screws had to be removed due to iliosacral joint arthropathy. (24)

The authors conclude that this approach is very promising, as it proves to be reliable and minimally invasive. The average length of hospital stay was 13 ± 5 days and postoperatively, all patients were able to fully weight-bear and mobilise. It aligns with prior studies, although the authors note that the long-term outcomes, such as screw loosening despite cement augmentation or lasting mechanical stability, needs to be studied with larger patient numbers in further studies. (24)

The article by Beucler, Nathan (2024) describes a surgical approach to manage Tile C pelvic ring injuries and unstable U-shaped sacral fractures, via open trans-muscular iliac screw placement using a fluoroscopy-guided teardrop view. (25)

The case of a 40-year-old male patient who suffered a highspeed bike accident is presented. He had a Glasgow-Coma-Score of 15 and a proximal function pain-related motor deficit of the lower limbs of 2/5 on the modified Medical Research Council Scale. (25)

A CT scan revealed anterior pelvic disruption, comminute right iliac fracture with active bleeding, fractures in both forearms, as well as an unstable AO Spine B3 fracture at T12-L1 without spinal

cord compression and an unstable Tile C vertical shear pelvic ring injury with spinopelvic instability. Haemostatic fixation of the right iliac crest, as well as surgical fixation of the right forearm and casting of the left forearm were performed during emergency management. (25)
For the Fluoroscopy setup, it needs to be ensured that bilateral iliac oblique outlet views are possible for the teardrop alignment. Lower lumbar fixation is done with posterior pedicle screws that are placed at L4-L5, possibly at L3 or S1 as well if needed. The posterior superior iliac spine and iliac crest are identified and exposed. The pedicle probe is guided to the centre of the teardrop and the screw is inserted under continuous fluoroscopy. It must be ensured that the screw head is recessed within the bone cubicle, to prevent complications. The same approach is done for the contralateral screw insertion. Iliac connectors are linked to iliac screws, the curved rods span from lumbar to iliac hardware. (25)
For the reduction manoeuvres, a distraction between the iliac connector and lumbar screw for correction of vertical displacement is done, as well as a contraction between the iliac connector and iliac screw for correction of horizontal displacement. Using intraoperative Matta criteria, the reduction is confirmed. To achieve additional horizontal stability, transverse connectors are placed between the lumbar rods. (25)

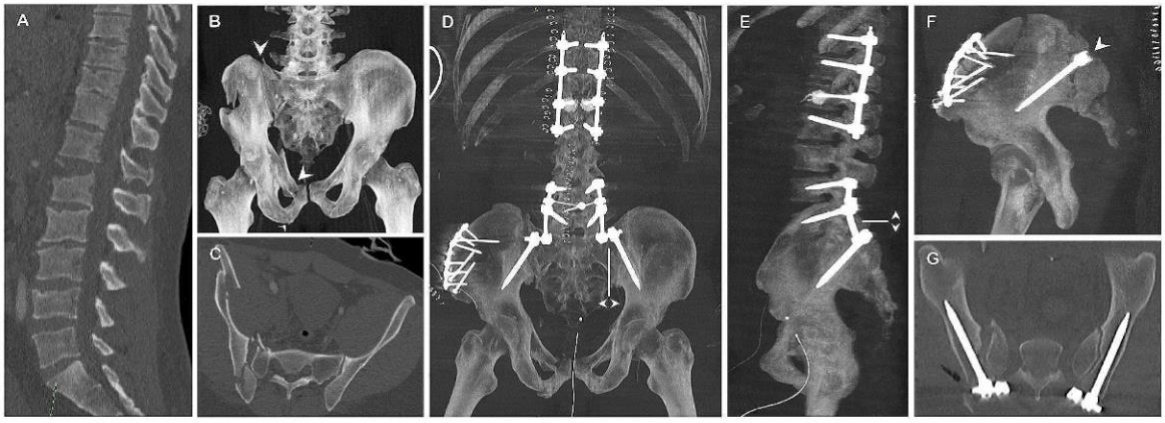


Fig. 1 (a to c) Preoperative and **(d to g)** postoperative computed tomography scan. **(a)** T12-L1 AO Spine B3 thoracolumbar trauma on sagittal view. **(b, c)** Right-sided Tile C vertical shear pelvic ring disruption with (b, upper white arrowhead, and c) posterior spinopelvic instability, (b, lower white arrowheads) anterior pelvic ring disruption. **(d, e)** Postoperative computed tomography scan, maximum intensity projection reconstruction, displays modified triangular spinopelvic construct on **(d)** coronal and **(e)** sagittal view. (f, white arrowhead, and g) Note that the head of the iliac screws have been hided in a bone cubicle at Schildhauer's iliac tubercle entry point in order to avoid long-term screw prominence under the skin

Figure 14, From: "Fluoroscopy guided teardrop technique for open trans-muscular iliac screw placement and open reduction maneuvers during modified triangular spinopelvic fixation for unstable U-shaped sacral and tile C pelvic traumas: technical note.", 2024, Beucler, N, Fig.1, Copyright by Beucler

The article stresses that over time, the issue of iliac screw heads may become more prominent. It is a frequent indication of hardware removal since it might cause skin tension and eventually skin ulcers. Schildhauer describes recessing a sufficiently large bone cubicle at the iliac tubercle to hide the iliac screw head below the level of the iliac crest. Furthermore, displaced bone fragments pointing towards the skin might cause the same problems. Improper reduction of the bone arches of the pelvis might jeopardise biomechanical efficiency of the spinopelvic junction and could cause

long-term orthopaedic disability during standing position and walking. However, the author mentions that the triangular spinopelvic construct is getting popular for the surgical management of unstable traumas and supports performing this procedure whenever it is deemed necessary. (25)
The article by Borg, Tomas et al. (2015) focused on evaluating the outcome after pelvic ring injuries managed with fixation, created a pelvic discomfort index. (26)
Patients included were 29 female patients and 44 male patients, with a mean age of 36 years. They all underwent internal fixation, and each individual pelvic ring injury was classified according to the AO/OTA classification. (26)
At six months, 12 months, and 24 months post-operatively, the patients' discomfort was assessed through a 14-item questionnaire. The questionnaire included three open-ended questions and eleven closed-ended questions. Afterwards, the 14-items were reduced to six items, which encompassed pain, hip mobility, walking, leg sensation loss, operation scar and sexual life. (26)

5.2.2.6 Managing complex pelvic fractures in geriatric patients

Management of complex pelvic fractures may also differ depending on age group of patients. The studies mentioned during this chapter focused on the management of complex pelvic fractures in geriatric patients, meaning the patient's age is more than or equal to 65 years old. The retrospective study by Lee, Se-Won et al. (2017) focuses on posterior locked lateral compression injury (PLLCI), which is defined by locking between the medially displaced fractured ilium and the anterior border of the sacrum, regardless of whether the fractured ilium involves the sacroiliac joint. (27)
Such an injury is usually caused by high-energy trauma, but this study highlights that it can also result from low-energy trauma as a consequence of a fragility fracture of the pelvis. All patients in this study sustained their injuries due to falling onto the ground from a standing position. (27)
Patients either received conservative treatment or surgical treatment, more specifically anterior external fixation, or pelvic brim plating with anterior external fixation. Koval walking ability scores were used to evaluate their walking ability. This score underlined that patients who were treated surgically with pelvic brim plating with anterior external fixation, were more likely to regain their pre-injury walking ability than patients who only underwent anterior external fixation or conservative treatment. (27)
The study by Borg, T et al. (2019) and the retrospective analysis by Panteli, Michalis et al. (2023) focus on acetabular fractures. The latter agrees with the study by Lee, Se-Won et al. (2017) according to which the typical cause of injury in the elderly is not necessarily high-energy trauma, but rather low-energy trauma. However, it is pointed out that high energy injuries may also occur as a result of road traffic collisions. (28)

The retrospective analysis by Panteli, Michalis et al. (2023) examines the outcomes of open reduction and internal fixation (ORIF) in elderly patients that sustained acetabular fractures. In total 62 patients with a mean age of 71.5 years fit the inclusion criteria. (28)

The study by Borg, T et al. (2019) mentions the combined hip procedure (CHP) which is a combination of open reduction and internal fixation (ORIF) and acute total hip arthroplasty (THA). It compares the outcomes after ORIF alone with those of the combined hip procedure. (29)

Overall, the authors conclude that the combined hip procedure did show a reduction in needing further surgery when compared to ORIF alone in elderly patients that sustained complex acetabular fractures. (29)

Another important aspect of managing complex pelvic fractures in geriatric patients is to ensure that conventional surgical approaches, such as plate osteosynthesis, are also valid options in patients with osteoporotic bone. (30)

The study by Herteleer, Michiel et al. (2022) compared single-plate osteosynthesis (SPO) with double plate osteosynthesis (DPO) and evaluated the extent of implanted-related problems, as well as their risk factors.

Based on the findings of the study, the authors would recommend double-plate osteosynthesis over single-plate osteosynthesis to fixate anterior pelvic ring fractures. (30)

One of the major implant-related problems is screw loosening. In the double-plate osteosynthesis group of patients no cases of screw loosening in the anterior plate were observed. Factors such as presence of bone defects, restrictions of post-operative weight bearing, unilateral or bilateral anterior pelvic ring fractures, posterior pelvic ring osteosynthesis or the presence of infra- or supra-acetabular screws had no significant influence regarding screw loosening in either group. (30)

Furthermore, the double-plate osteosynthesis group had a reduced need for revision surgery compared to the single-plate osteosynthesis group, in which six patients had to undergo revision osteosynthesis. The complications between the single and double plate osteosynthesis are compared in Table 5 (30)

Comparison of the complications between single and double plate osteosynthesis

	Total	Single	Double	Significance
Screw loosening superior plate				
No	26	18	8	$p = 0.16$
Yes	22	19	3	
Time of screw loosening				
Within first week	9	3	0	$p = 0.19$
Between 1st week and 1st month	3	3	0	
After 1st month	10	7	3	
Localisation of screw loosening				
Nakatani I	10	8	2	$p = 0.843$
Nakatani I + II	7	6	1	
Nakatani I + III	2	2	0	
Nakatani II	1	1	0	
Nakatani III	1	1	0	
Nakatani I + II + III	1	1	0	
Degree of screw loosening				
No	24	18	8	$p = 0.361$
Minimal	8	6	2	
Moderate	8	7	1	
Severe	6	6	0	
No-minimal	34	24	10	$p = 0.14$
Moderate-severe	14	13	1	
Plate breakage superior plate				
Yes	4	3	1	$p = 1$
No	44	34	10	
Revision osteosynthesis				
Yes	6	6	0	$p = 0.31$
No	42	31	11	

Table 5, From: "Plate fixation of the anterior pelvic ring in patients with fragility fractures of the pelvis.", 2022, Herteleer, Michiel et al., Table 2, Copyright by Herteleer, Boudissa, Hofmann, Wagner, Rommens

The case report by Yano, Sei et al. (2017) reports the case of an 81-year-old polytrauma patient. The woman suffered from multiple traumatic injuries including an unstable pelvic ring fracture after a traffic accident. (31)

Bilateral external fixation was performed as initial emergency stabilisation. Less invasive posterior fixation technique with iliac screws, rods, lumbopelvic fixation with percutaneous pedicle screws was performed as surgical stabilisation. During the procedure, two iliac screws were inserted on each side following an 8cm midline posterior incision from the S1 to S3 spinous process, with the subcutaneous detached from the fascia or the paraspinal muscles. The S2 spinous process was removed, and two rods were connected to the bilateral iliac screws to stabilise the bilateral ilium in a switchback fashion. To connect the two rods at the base of the S2 spinous process, a crosslink device was applied. Percutaneous pedicle screws are inserted into the L4 and L5 vertebral bodies on both sides and connected to the cranial rod connecting the bilateral iliac screws to complete the lumbopelvic fixation. (31)

No postoperative complications were reported, and the 10-month follow-up showed a successful bone union at the superior ramus of the pubis. The patient is pain free and was able to return to her preinjury activity level. (31)

This case report shows that this particular posterior fixation technique, which is also less invasive, provided sufficient stabilisation for an unstable pelvic ring fracture, as the patient was able to make a full recovery without complications. (31)

5.2.2.7 The role of angiographic embolization in the management of complex pelvic fracture patients

Pelvic fractures, especially complex cases, can lead to massive bleeding that may require control with angioembolisation.

The study by Lustenberger, Thomas et al. (2015) evaluates the institutional management of severe pelvic fracture patients, as well as their outcomes, as a variety of strategies have been proposed in recent years for the treatment of haemodynamically unstable patients with pelvic ring fractures. (32) Only in hemodynamically stable patients or in patients responding to fluid resuscitation with the finding of an arterial blush in a CT scan, was angiographic embolization used as a first line treatment. Pre-peritoneal pelvic packing in combination with mechanical pelvic stabilisation was immediately carried out in haemodynamically unstable patients. Angio-embolisation was only carried out post-operatively if the signs of persistent bleeding remained present. In this retrospective review that included a total of 173 patients with pelvic ring fractures, angioembolisation was performed in only 16 patients (19%). (32)

The retrospective cohort study by Agri, Fabio et al. (2017) analysed the correlation between the use of pelvic binders and arterial angio-embolisation and the mortality of patients with pelvic fractures. It included a total of 288 patients, with a median age of 43.5 years. Patients with isolated acetabular fractures were excluded. (33)

5.2.2.8 Effectiveness of pre-hospital measures and instruments in the management of complex pelvic fracture patients

The study by Lustenberger, Thomas et al. (2016) investigated the frequency of overlooked pelvic injuries in a pre-hospital setting. From the 11.062 patients that were included, 7201 patients (65.1%) had a pelvic fracture, that was diagnosed on hospital admission. In 44.1% of patients, with no pre-clinically suspected pelvic fracture, it was later on confirmed. (34)

An AIS head ≥ 3, a Glasgow-Coma Scale of ≤ 8 and an age of over 60 years were independent risk factors for overlooking a pelvic injury in the prehospital setting. The risk of overlooking a pelvic injury was reduced by the presence of hypotension (SBP ≤ 90 mmHg) and high overall severity of injury (ISS ≥ 25). (34)

The study highlights that in the pre-hospital setting, a significant proportion of severe Type B and Type C pelvic fractures were not suspected. Consequently, consideration should be given to performing mechanical pelvic stabilisation already in the prehospital setting for severely injured patients with blunt trauma, regardless of the results of the pelvic physical examination. (34)

Another study that evaluated pre-hospital diagnostic accuracy is the study by Yong, E et al. (2016). This study focused on the pre-hospital diagnostic accuracy of pelvic girdle injuries, however it still found similar results. (35)

Misdiagnoses still happen, even though the threshold for applying pelvic binders is low. Usually, it included patients that presented with distracting injuries, varying Glasgow-Coma-Scores, and normal systolic blood pressure. Pre-hospital predictors of pelvic girdle injuries were identified. No statistically significant association between age, Glasgow-Coma-Score, trauma mechanism, on scene suspicion of intoxication and pre-hospital intubation with pelvic girdle injury incidence was found. However, there was a statistically significant association found between presence of circulatory shock, with a $p < 0.000002$, gender ($p < 0.01$) and multiple injuries ($p < 0.00001$) with pelvic fracture. (35)

2×2 table.

		Actual	
		Pelvic girdle injury	No pelvic girdle injury
Predicted	Pelvic binder	18	27
	No pelvic binder	8	116

Table 6: From: "Pre-hospital pelvic girdle injury: Improving diagnostic accuracy in a physician-led trauma service.", 2016, Yong, E et al., Table 2, Copyright by: Yong, Vasireddy, Pavitt, Davies, Lockey

A 2 x 2 contingency table, seen in T (), was created in order to display the study's main results. Table 7 shows the false negatives versus true positives and table 8 the pre-hospital predictors of pelvic girdle injury. (35)

False negatives (missed fractures) versus true positives.

Variable	*p* value
Sex	NS
Age	NS
Trauma mechanism	NS
Glasgow Coma Score	NS
Circulatory shock	<0.04
Intoxication	NS
Multiple injuries	NS
Pre-hospital Intubation	NS

NS: p value > 0.05.

Table 7: From: "Pre-hospital pelvic girdle injury: Improving diagnostic accuracy in a physician-led trauma service.", 2016, Yong, E et al., Table 4, Copyright by: Yong, Vasireddy, Pavitt, Davies, Lockey

Prehospital predictors of pelvic girdle injury.

Variable	Fracture – 26	No fracture – 143	*p* value
	n (%)	*n* (%)	
Sex			<0.01
Male	15 (57.7)	117 (81.8)	
Female	11 (42.3)	26 (18.2)	
Age			NS
<18	1 (3.8)	14 (9.8)	
≥18	25 (96.2)	129 (90.2)	
Trauma mechanism			NS
Fall	8 (30.8)	49 (34.3)	
RTC – driver	2 (7.7)	9 (6.3)	
RTC – passenger			
RTC – motorcyclist	14 (53.8)	66 (46.2)	
RTC – pedal cyclist			
RTC – pedestrian			
Crush injury	2 (7.7)	3 (2.1)	
Struck by object	0 (0)	16 (11.2)	
Assault			
Other			
Glasgow Coma Score			NS
≥13	12 (48.0)	92 (64.8)	
9–12	3 (12.0)	23 (16.2)	
≤8	10 (40.0)	27 (19.0)	
Unknown	1	1	
Circulatory shock			<0.000002
Yes	12 (46.2)	9 (6.3)	
No	14 (53.8)	134 (93.7)	
Intoxication			NS
Yes	2 (7.7)	31 (21.7)	
No	24 (92.3)	107 (74.8)	
Maybe	0 (0)	5 (3.5)	
Multiple injuries			<0.00001
Yes	24 (92.3)	77 (53.8)	
No	2 (7.7)	66 (46.2)	
Pre-hospital intubation			NS
Yes	16 (61.5)	69 (48.3)	
No	10 (38.5)	74 (51.7)	

NS: p value > 0.05.

Table 8: From: "Pre-hospital pelvic girdle injury: Improving diagnostic accuracy in a physician-led trauma service.", 2016, Yong, E et al., Table 1, Copyright by: Yong, Vasireddy, Pavitt, Davies, Lockey

To calculate the diagnostic accuracy, sensitivity and specificity were established. The sensitivity was 0 .69 (95% CI 0.50–0.85) and the specificity was 0.81 (95% CI 0.74–0.87). The likelihood ratio for a positive result was 3.67 (95% CI 2.40–5.61) and the likelihood ratio for a negative result was 0.38 (95% CI 0.21–0.68). Lastly, the study recommends stabilising the pelvis in pre-hospital settings, as diagnostic accuracy cannot be blindly relied upon. (35) The third study in this chapter is by Spering, Christopher et al. (2024) and aims to identify predictive factors for pelvic fracture patients with per-pelvic vascular injury. These factors are being incorporated into a pelvic vascular injury score (P-VIS), in order to detect severe bleeding during pre-hospital management. (36)

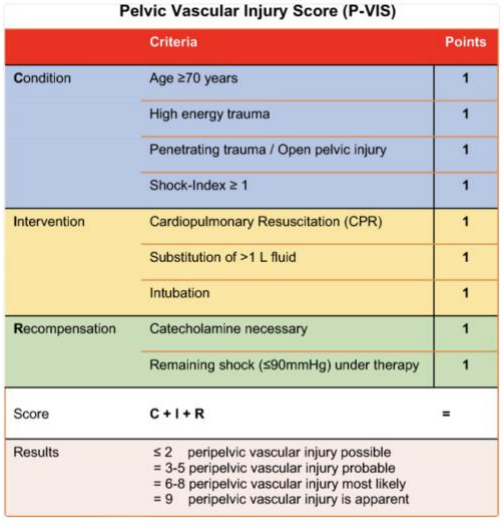


Figure 15: "The pelvic vascular injury score (P-VIS): a prehospital instrument to detect significant vascular injury in pelvic fractures.", 2024, Spering,C et al., Fig 3, Copyright by Spering, Lehmann, Möller, Bieler, Schweigkofler, Hackenberg, Sehmisch, Lefering

Inclusion criteria included pelvic fracture patients with an AIS of ≥ 3 and an ISS score of ≥ 16. 9227 patients in the Trauma registry met the inclusion criteria, from which 2090 patients sustained a significant peripelvic vascular injury and 7137 patients were included in the control group. (36) Identification and scoring of predictive factors for significant peripelvic vascular injuries. Patients charts and digital recordings are analysed, as well as radiographical diagnostics, vascular bleeding source and mechanism and pattern of injury. (36)

Nine predictive parameters for peripelvic vascular injury comprise the peripelvic vascular injury score as illustrated in Table 16. They include the following: Age ≥ 70 years, high energy trauma, penetrating trauma/open pelvic injury, shock index ≥ 1, cardio-pulmonary-resuscitation, substitution of > 11 fluid, intubation, necessity of catecholamine substitution, remaining shock (≤ 90 mmHg) under therapy. The peripelvic vascular injury score scoring is divided into probable vascular injury (≥ 3 points), most likely (≥ 6 points) and apparent injury (9 points). (36)

The nine predictive factors for peripelvic vascular injury, defining the P-VIS

Condition of the patient	Intervention	Recompensation
Age ≥ 70 years	Cardio-pulmonary-resuscitation (CPR)	Necessity of catecholamine substitution
High-energy trauma	Substitution of > 1 l fluid	Remaining shock (RRsys ≤ 90 mmHg) under therapy
Penetrating trauma/open pelvic injury	Intubation	
Shock Index ≥ 1		

Table 16: "The pelvic vascular injury score (P-VIS): a prehospital instrument to detect significant vascular injury in pelvic fractures.", 2024, Spering,C et al., Table 5, Copyright by Spering, Lehmann, Möller, Bieler, Schweigkofler, Hackenberg, Sehmisch, Lefering

One of the limitations of this study is that no data were collected on long-term outcomes to show that an immediate transfer to a Level I Trauma Centre and the pelvic binder application is the principal life-saving procedure. Furthermore, a prospective multi-centre study design is needed. (36)

The authors conclude that the peripelvic vascular injury score (P-VIS) can be beneficial as an initial risk assessment tool to consider the presence of a vascular injury in unstable pelvic injury patients. (36)

5.2.2.9 Effectiveness of the WSES classification system for complex pelvic fractures

The World Society of Emergency Surgery (WSES) created guidelines and classification systems for pelvic injuries. The study by Wang, Szu-Han et al. (2021) investigates the effectiveness of the WSES classification for pelvic injuries and assesses the roles that associated vascular injury and open fracture in this system play. (37)

Blunt pelvic fracture patients were included, however penetrating trauma patients, severe head injuries or patients with burns, other or unknown trauma mechanisms were excluded. Data including age, sex, injury severity score, as well as systolic blood pressure, pulse, respiratory rate, and oxygen saturation in the emergency department, were collected and evaluated. (37)
The retrospective case-cohort study by Wu, Yu-Tung et al. (2020) assesses the correlation of fracture pattern and vascular injury with the clinical outcome of pelvic fracture trauma patients. (38) 155 patients were included, from which 84 patients (54.2%) were females and 71 patients (45.8%) were males, since they were diagnosed with a pelvic fracture, were over the age of 18, had no abbreviated injury scale score of higher than 2 in any body region other than the pelvis. The mean age of patients was 44.7 ± 21 years, and the mean injury severity score (ISS) was 14 ± 4.9. The mean length of ICU stay and total length of hospital stay was 1.4 ± 3.9 and 11.8 ± 9.8 days, respectively. (38)
All patients were treated according to the standardised protocol for initial resuscitation and management in accordance with the ATLS recommendation and guidelines for the treatment of pelvic trauma. (38)
The study concludes that even in patients with relatively isolated pelvic injuries, the severity of the vascular injury is more closely correlated with outcome than the type of anatomical fracture. Therefore, a more balanced classification of pelvic injuries that takes into account both fracture pattern and haemodynamic status, such as the WSES classification appears to be of greater benefit to clinical practice. (38)

5.2.2.10 Developing learning algorithms for better diagnosis and preoperative planning of complex pelvic fracture management

Different studies aimed to develop new methods to make preoperative planning more efficient and accurate. One of these studies is by Zeng, Bolun et al. (2024). By simulating fractures and restoring structures, a new bidirectional framework for automatic pelvic fracture surgical planning is being developed. (39)
Datasets from clinical CT scans were derived and simulated fracture models for the surgical planning of pelvic fracture patients. Figure () shows an overview of the method. Three components make up the bidirectional fracture simulation-restoration framework: Fracture simulation data generation, Fracture structure restoration and Reduction surgery planning. During the first step, structural characteristics, random factors, and information on bone density are incorporated into a novel map of the segmented pelvis image. The normal pelvic structure is partitioned into realistic regions, which are then generated to create simulated fracture fragments through random rigid transformations. Afterwards, paired datasets pre- and post-fracture are produced for training by

applying the transformations to the consequent CT images. During step two, a structural restoration network (SRN) is able to learn deformation from fracture images to healthy ones using large-scale simulation images from healthy cases. Trained with simulated data, fine-tuned with real unilateral fractures via self-supervised learning using pelvic symmetry. Lastly, the Structural Restoration Network predicts the restored pelvic anatomy for the Reduction surgery planning. (39)

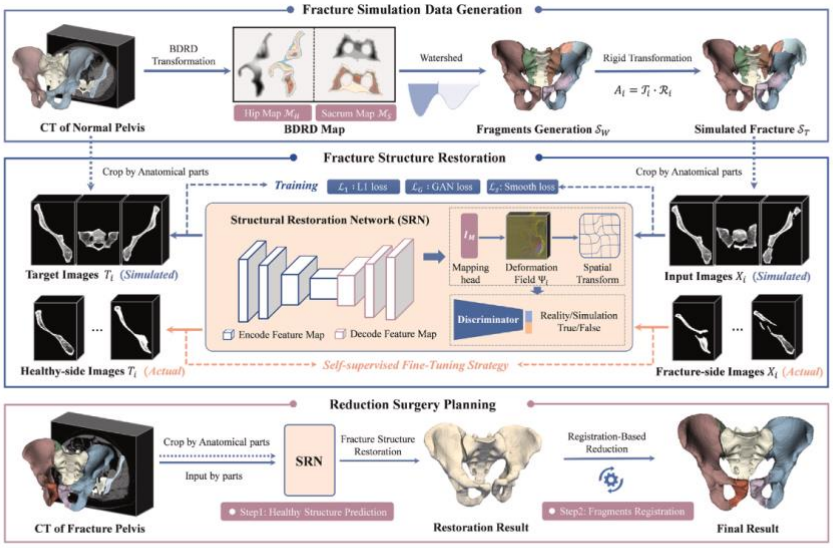


Fig. 1. Overview of the proposed method. In the first component (top box), maps incorporating the structure, density, and fracture random characteristics are constructed from normal pelvic images, which are used to generate simulated fracture images through the watershed and rigid transformations. In the second component (middle box), a Structural Restoration Network (SRN) is employed to learn deformation mapping from these fracture images, with a self-supervised strategy based on symmetric anatomical priors to fine-tune the SRN for enhanced performance. In the third component (bottom box), integrating the FPFH registration method the results for reduction planning are obtained.

Figure 16; From: "A bidirectional framework for fracture simulation and deformation-based restoration prediction in pelvic fracture surgical planning.", 2024, Zeng, Bolun et al., p. 3, Copyright by Zeng, Wang, Tao, Shi, Joskowicz, Chen

The study showed high accuracy, with a mean SSIM of 90.7% for structure restoration and translational errors of 2.88mm with rotational errors of 3.18°. Furthermore, regarding reduction planning accuracy and fracture structure restoration, it outperformed deep learning-based methods, such as UNet or GN-SPAK. It also was able to maintain high accuracy in CT scans that included metal implants. Additionally, the study showed that this method significantly enhanced the surgical planning process, since the conventional workflow requires 122min, whereas the novel framework completes the process in 52.9 seconds. (39)

5.2.2.11 The importance of initial and early management in complex pelvic fractures

The study by Incagnoli, Pascal et al. (2019) aims to establish guidelines and provide clear guidelines on how to treat haemorrhagic shock in severe pelvic trauma patients. (41)
Inclusion criteria were severe pelvic fracture patients, as well as patients with high trauma severity scores, haemodynamic instability, and associated injuries to other organ systems, such as the abdomen, head, or chest. Intervention included pelvic binders, angiographic embolisation, external fixation and pre-peritoneal pelvic packing as strategies for early management. Literature and

publications from the last 20 years were analysed. As a result, 22 recommendations were proposed, from which eleven were based on high-level evidence and eleven on low-level evidence. (41)
In the systematic literature review by Vardon, F. (2014) a decision-making algorithm is proposed, regarding the treatment of pelvic fractures in trauma patients. Massive and uncontrollable haemorrhage may be caused by pelvic injuries that are associated with multiple injuries. Severe pelvic haemorrhage makes up 8-10% of mortality after pelvic trauma. (42)
Inclusion criteria were patients diagnosed with severe pelvic ring injuries, especially cases with haemodynamic instability or haemorrhagic shock, often seen in polytrauma patients. To determine the role of pelvic injury in haemorrhage, an initial trauma assessment is performed in order to define the therapeutic strategy of pelvic trauma care. (42)
The approach of pelvic trauma care includes arterial embolization and pelvic ring stabilisation. The study shows results of reduced mortality rates, as well as a reduction of complications, for example organ failure or sepsis. The study concludes that early pelvic stabilisation, for example with binders, external fixators, or clamps, should be used in order to reduce bleeding. Arterial embolization may be done for arterial bleeding control. It has a success rate of over 90% if done early. In case embolization is not immediately possible, preperitoneal pelvic packing (PPP) can be effective for venous bleeding. Once the bleeding is controlled, thromboprophylaxis can be performed. Overall, mortality can be significantly reduced by multidisciplinary care and trauma networks. (42)

5.2.3 Discussion of results

The results of the literature reviewed during this systematic literature review show that the management of complex pelvic fracture still remains a challenge. These types of injuries are predominantly caused by high-energy trauma and often bring associated injuries, that are in a lot of cases life-threatening.
In regard to that, a clear and predefined treatment strategy needs to be present. As highlighted by some of the studies, early and timely management is of great importance in complex pelvic fracture, especially in cases with life-threatening complications or associated injuries.
Early application of pelvic binders helps to stabilise the pelvis and may reduce bleeding. Not in all studies a statistically significant difference was found between applying the pelvic binder early compared to the control group. However, most studies pointed out that since the application of pelvic binders does not have a high risk of causing complications and is low cost, it could be recommended to apply a pelvic binder, in order to stabilise the pelvis early. Furthermore, it was stated that the application of a pelvic binder improves the survival rate and shortens the length of stay in the hospital or intensive care unit significantly, but it does not reach statistical significance.
Another point that was raised during the review was the question of how and when an already

placed pelvic binder should be opened again. A “clear the pelvis” algorithm was proposed, in order to approach the pelvic binder opening more safely. The algorithm concludes that in patients with a limited ability to be assessed, the pelvic binder should only be released after X-rays or CT scans are available with an open pelvic binder.

Other studies highlighted the importance of initial and early management in complex pelvic fractures. It was found that if a multidisciplinary team and the possibility of early management is available, the mortality rate can be reduced. Since complex pelvic fractures are often seen in polytraumatised patients, that may sustain other life-threatening injuries, such massive bleeding, this is especially of importance. Studies showed that in order to reduce bleeding, early pelvic stabilisation can be achieved through the use clamps, pelvic binders or external fixators. Arterial embolization showed a high success rate for arterial bleeding control. Additionally, if no immediate embolization was possible, venous bleeding could be reduced with preperitoneal pelvic packing. Thromboprophylaxis can be performed once the bleeding is controlled.

Polytrauma patients have a high risk of a rapidly deteriorating physiologically, meaning predefined decision-tree protocols for managing severe pelvic trauma is of great importance. It can helpful regarding effectively managing haemorrhagic shock and reducing early complications.

Complex pelvic fractures can sometimes present with unique types of injuries. Different studies highlighted different unique injury types and emphasised that these types of injuries may need specific management. One of the cases reported the choice of performing a hemipelvectomy in a 25-year-old male that was struck by a train as a pedestrian. His pelvic injuries were extensive and accompanied by multiple injuries. During the damage control surgery, the attempt of a right lower extremity revascularisation failed and a hemipelvectomy was required. In this specific case the hemipelvectomy turned out to be the preferable choice, since it leads to an immensely improved outcome.

Guidelines and classification systems for pelvic injuries are created to alleviate and improve the management of complex pelvic fractures. The World Society of Emergency Surgery (WSES) includes not only the fracture pattern, but also the hemodynamic status into their classification of pelvic injuries. This leads to a greater clinical utility, since studies show that vascular injury patterns have a stronger correlation with the outcomes of management, compared to fracture pattern alone.

Pre-hospital measures may be helpful to reduce the risk of overlooking pelvic injuries. The threshold for pelvic binder application is low, however, misdiagnoses still happen. Studies recommend that applying mechanical pelvic stabilisation in a pre-hospital setting should be considered in blunt trauma patients, that are severely injured, regardless of the physical examination results. A peripelvic vascular injury score (P-VIS) was created for severe bleeding detection during

pre-hospital management. It contains nine predictive parameters and proofed to be beneficial in the study as an initial risk assessment tool, although the authors stress few limitations.
Surgical management of complex pelvic fractures can have many different approaches, depending on the specific type of pelvic fracture, as well as severity and patient specific factors. Pre-operative planning and precise classification are of great importance, as well as intraoperative imaging which has made quite a few advancements during the past years. Surgical techniques themselves also improve quickly and lead to better patient outcomes. Minimal invasive techniques are advancing, while exhibiting reduced complications. Robotic-assisted surgeries are developed and demonstrate enhanced surgical accuracy, such as the Starr Frame and Da Vinci robotic surgery system. Implant-related complications, such as the loosening of implants or hardware failure still remain a challenge, however, the overall mortality and outcomes have improved.
In pelvic fractures that are accompanied by genitourinary injuries, a multidisciplinary approach is essential, in order to manage the associated injuries.
Managing complex pelvic fractures in geriatric patients entails a few differences and distinctive features. One would be that the major cause of injury in geriatric patients is caused by low energy trauma, such as falls from standing, contrasting the high-energy trauma that is the primary reason for complex pelvic fractures in younger people. Surgical techniques that showed promising results, were double plate osteosynthesis, as well as open reduction with internal fixation in combination with total hip arthroplasty and pelvic brim plating with external fixation. The studies showed that these management approaches in geriatric patients usually lead to satisfactory outcomes, as well as good functional recovery.

6. Conclusion

This systematic literature review shows that the management of complex pelvic fractures entails many different approaches and often needs to be tailored to patient specific factors. A precise evaluation, as well as a correct classification of these injuries, is of great importance to improve the treatment approach and subsequently the outcome.
This review shows the benefits of initial risk assessment tools, such as the peripelvic vascular injury score (P-VIS), which greatly impact reducing misdiagnoses or overlooking of injuries in the pre-hospital setting. The World Society of Emergency Surgery (WSES) also includes the hemodynamic status into their classification of pelvic injuries, instead of only the fracture pattern. This leads to a greater clinical utility.
Pelvic binders also proofed to be a helpful tool in order to stabilise the pelvis and reduce bleeding. The application of pelvic binders showed significant improvement of survival rate, as well as

shortened lengths of stay in the hospital or intensive care unit, however, it does not reach statistical significance. Nevertheless, most studies stressed that the application is easy, low cost and has a low risk of complications, which leads to the recommendation of applying a pelvic binder for early pelvic stabilisation. Algorithms such as the “clear the pelvis” algorithm have been developed to ensure safe opening and removal of pelvic binders.

The management of complex pelvic fracture can be even further complicated in patients sustaining polytrauma, which in some cases might be associated with life-threatening injuries. Pre-defined decision-tree protocols have proven to be helpful. They can reduce early complications and effectively manage haemorrhagic shock.

Specific cases, such as pelvic fractures associated with genitourinary injuries, are also reviewed during this systematic literature review. These cases underline the importance of a multidisciplinary team approach.

In case of surgical treatment, many different approaches can be beneficial in different types of injury and fracture patterns. This systematic literature review shows the advancements that are not only seen regarding minimal invasive surgical approaches, but also in intraoperative imaging. Minimal invasive surgery techniques are still continuously improved, since the placement of transsacral-transiliac screws can be technically challenging but demonstrate reduced complications and improved treatment outcomes. Furthermore, approaches like the Starr Frame and Da Vinci surgery, showed that robotic-assisted approaches enhance surgical accuracy. This leads to satisfactory results and improved outcomes, as well as reduced mortality.

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8. Annex

Annex 1: Data Extraction

Source: Early management of severe pelvic injury (first 24 hours)
Aim of study
Establishing guidelines concerning haemorrhagic shock in management of patients with severe pelvic trauma to provide clear strategies; Including pre-hospital use of pelvic binders, appropriate imaging strategy and appropriate use of surgical or interventional radiological control of bleeding
Inclusion Criteria
People: Patients with severe pelvic fractures, including patients with hemodynamic instability, high trauma severity scores, associated injuries to other organ systems (e.g. head, chest, abdomen)
Intervention: early management strategies such as pelvic binders, external fixation, angiographic embolization, and pre-peritoneal pelvic packing
Control Intervention: no specific control interventions outlined; focus on establishing best practices for early care based on existing literature and expert consensus
Outcomes: Recommendation to apply external pelvic compression (suggestion to use pelvic binders) as soon as possible in all pts with suspected pelvic trauma; recommendation to transport patients to a trauma centre and suggest a pelvic x-ray for hemodynamically unstable patients and/or require urgent intervention(s) to stabilise vital signs; recommendation to perform thoraco-abdomino-pelvic CT-scan with contrast before angiographic embolization in pts with severe pelvic trauma when allowed by pts hemodynamic status
Setting: pre-hospital and hospital trauma care systems, including advanced trauma centers with multidisciplinary teams
Method
Databank: Literature from the last 20-25 years analysed using GRADE (Grading of Recommendations, Assessment, Development, Evaulation) methodology
Research Period: Publications from the past 20 years were prioritised, with some data extending to 25 years if evidence was scarce
Meta-Analysis:
Results
Proposed 22 recommendations, with 11 based on high-level evidence and 11 on low-level evidence Key outcomes include strong recommendations for rapid hemorrhage control, using pelvic binders and angiographic embolisation, and prioritising transfer to trauma centers; emphasis on multidisciplinary care and adherence to structured management protocols

Annex 1: Data Extraction

Source: Pelvic Trauma (Book)
Aim of study
To review the evaluation and management of traumatic pelvic injuries, as well as the importance of an interprofessional team approach to pts with pelvic fractures
Inclusion Criteria
People: Patients with pelvic fractures
Intervention:
Control Intervention:
Outcomes:
Setting: Hospitals, Trauma centre, …
Method
Databank:
Research Period:
Meta-Analysis:
Results

Annex 1: Data Extraction

Source: Intraoperative Imaging in Pelvic Surgery
Aim of study
To examine surgical management of pelvic ring and acetabular fractures, focusing on indications for surgery, preoperative planning with CT imaging, intraoperative imaging techniques and advancements in navigation and 3D imaging for improved surgical outcomes
Inclusion Criteria
People: Patients with pelvic ring injuries or acetabular fractures, requiring surgical evaluation and treatment
Intervention: Surgical treatment (of pelvic ring and acetabular fractures), including open reduction, osteosynthesis, minimally invasive procedures, as well as the use of advanced imaging techniques (e.g. 2D standard views, intraoperative 3D imaging, CT imaging, and navigation systems)
Control Intervention: non-operative or conventional surgical techniques without advanced imaging or navigation aids
Outcomes: Effective fracture reduction, proper implant placement, improved imaging during surgery, patient-specific treatment based on fracture characteristics and general condition
Setting: Hospital and surgical settings equipped with advanced imaging tools (such as C-arms and intraoperative CT systems)
Method
Databank:
Research Period: focus on advancements in the past decade with references to the increasing use of intraoperative 3D imaging and navigation systems
Meta-Analysis: no meta-analysis is explicitly stated
Results
- Surgical indications are based on fracture type, dislocation and patient-specific factors - Preoperative CT imaging is essential for surgical planning - 2D imaging, including anteroposterior, inlet/outlet, and iliac oblique views, remains standard, but can be limited by anatomy and superimposing structures - Intraoperative 3D imaging and advanced C-arms improve visualisation but may suffer from artefacts caused by implants - Intraoperative CT offers better artefact correction and a larger field of view - Radiation-free navigation facilitates precise implant placement in minimally invasive procedures, enhancing surgical outcomes and safety

Annex 1: Data Extraction

Source: Fractures of the pelvic ring (Wong; Bucknill)
Aim of literature review:
Analyse and present management and outcomes of pelvic ring fractures, emphasizing their classification, initial treatment, surgical interventions and advancements in techniques. It highlights the evolution of treatment approaches, the importance of controlling life-threatening hemorrhage and the role of operative fixation in improving long-term functional outcomes and reducing complications associated with non-operative management.
Inclusion Criteria
People: patients with pelvic ring fractures (ranging from low-energy stable fractures to high-energy life-threatening injuries); specific cases (pts with hemodynamic instability, urological injuries, other complications secondary to pelvic fractures)
Intervention: - **Nonoperative management:** o Traditionally employed for stable or minimally displaced fractures - **Operative Management:** o Anterior and posterior pelvic fixation: utilising internal + external fixation techniques o Pelvic binders, pelvic angiography, embolization, external fixation for hemorrhage control o Surgical Procedures: open reduction and internal fixation for unstable or severely displaced fractures o Minimally invasive methods: percutaneous screw fixation + navigated surgical techniques
Control Intervention: non-operative management/conservative care, as opposed to surgical interventions
Outcomes: - **Primary outcomes:** o Pt survival rates, particularly after severe fractures o Reduction in hemorrhage-related mortality o Correction of deformity + restoration of pelvic function - **Secondary outcomes:** o Complications rates associated with surgical and non-surgical interventions (e.g. infections, malunion) o Long-term functional outcomes, such as pain, gait disturbances and quality of life
Setting: Trauma centers + hospitals with advanced care facilities
Method
Databank: -
Research Period: -
Meta-Analysis: -
Results
- **Priorities of initial management**: identification and treatment of life-threatening injuries and hemorrhage

- **Aims of definitive fixation**: to correct deformity, restore function and reduce complications
- More pts with unstable injuries survive, poor results associated with nonoperative management and increasing pt expectations of outcome will make surgical management of these fractures increasingly common

Annex 1: Data Extraction

Source: A review of open pelvic fractures with concurrent genitourinary injuries
Aim of Literature Review
Literature Review on open pelvic fractures with associated genitourinary injuries, focusing on the rates of genitourinary injury, vaginal laceration, infection and mortality, as well as discussing their management
Inclusion Criteria
People: Patients with open pelvic fractures and associated genitourinary injuries
Intervention: Management strategies for open pelvic fractures, including surgical stabilisation, antibiotic therapy (systemic and local) and multidisciplinary approaches to address associated injuries
Control Intervention:
Outcomes: Rates of infection, mortality, and successful stabilisation and healing of fractures and associated injuries
Setting: Trauma care settings, including hospitals with multidisciplinary teams capable of managing complex pelvic and genitourinary injuries
Method
Databank: PubMed database
Research Period: Studies published from 1980 to 2018
Meta-Analysis:
Results
- 343 patients in total; average age 35.1 years, with a mean Injury Severity Score (ISS) of 26.5 - Predominantly high-energy blunt trauma (95.5%), including motor vehicle collisions, motorcycle accidents and pedestrian strikes - Complications: Genitourinary injuries, vaginal lacerations (in females) - Mortality rate: 31.2%; Infection rate: 18.7% - Early stabilisation (pelvic binders, external fixation) improves outcomes - Antibiotic coverage is critical for infection control, including systemic and local administration - Multidisciplinary care is essential for managing associated injuries

Annex 1: Data Extraction

Source: Combined pelvic and acetabular injuries: clinical features and treatment strategies of a unique injury pattern
Aim of study
- **Focus of study:** on pts with unstable pelvic fractures combined with acetabular fratures - **Main objective of study:** To assess clinical characteristics of pts with unstable pelvic fractures combined with acetabular fractures; to discuss treatment strategies for such pts to help guide treatment
Inclusion Criteria
People: Pts with unstable pelvic fractures (Tile B or C classification) combined with acetabular fractures**;** recorded + assessed pts' age, sex, cause of injury, systolic blood pressure on admission, injury severity score (ISS), Glasgow Coma Score (GCS), blood transfusion within 24h of injury, fracture typing, time from admission to surgery, sequence of reduction, quality of reduction, postoperative complications + prognosis -> 15 male patients, 9 female patients; mean age of 44.8 years (17 to 72 years)
Intervention: Surgical treatment of both unstable pelvic and acetabular fractures - **On admission:** supracondylar femoral traction on admission, multi-angle x-rays of the pelvis (pelvic front view, inlet view, outlet views, iliac oblique view, and obturator oblique view) and thin-section CT -> to determine type of fracture; pelvic fractures were classified according to Tile classification + Young-Burgess classification; acetabular fractures classified according to Letournel-Judet classification - **Surgical Treatment:** o Choice of surgical approach + sequence of reduction was individualised o Pararectus approach: Pts with significantly displaced acetabular fracture that could not be fixed percutaneously and who had significantly displaced ipsilateral sacroiliac joint o Closed reduction percutaneous hollow screw fixation of acetabular fracture before treating pelvic ring injury, for pts with less displaced acetabular fracture that is feasible for closed reduction o Single pararectus approach (for anatomical reduction in acetabular fractures first, combined with small iliac fossa incision if necessary): pts with posterior pelvic ring injuries where closed reduction percutaneous hollow screw fixation is feasible o Anterior approach via the paramedian approach or a modified Stoppa approach and posterior Kocher-Langenbeck approach: adopting a combined anterior-posterior approach, in case of combined posterior acetabular wall or posterior column fractures o Treatment carried out separately depending on severity of injury: in case of unclear mechanism of injury, no intrinsic link between the pelvic and acetabular injuries (such as when posterior pelvic ring is not on same side as acetabular fracture) o Fixation of anterior pelvic ring injuries: often considered last - **Postoperative management:** o Postoperative deep wound drains: placed for 2-4 days o Routine anticoagulants: to prevent thrombosis o Multiangle radiographs (pelvic front view, inlet view, outlet view, iliac oblique view, and obturator oblique view) and thin section CT: within 1 week after surgery o Regular follow-up visits: assess pts recovery + guide functional exercises o 8 weeks post-op: walk using crutches

- 12 weeks post-op: attempt to walk without crutches depending on healing of fracture

- **Statistical analysis:**
  - Routine photographic evaluation (performed at 1, 3, 6, 12 + 24 months post-op)
  - Matta and Tornetta scale: to evaluate pelvic fractures
  - Quality of reduction was evaluated according to maximum distance of fracture displacement on pelvic radiographs in 3 positions (pelvic front view, inlet view, outlet views) -> within one week after surgery (≤4mm excellent; 5-10mm good; 10-20mm moderate; >20mm poor)
  - Majeed functional scale: assess functional outcome according to pain, sitting + standing, ability to work, sexual ability, assisted walking, gait + walking distance
  - Matta criteria: assess quality of post-op repositioning of acetabular fractures within one week post-op
  - Modifiied Merle D'Aubigne and Postel scale: assess clinical outcome of treatment of acetabular fractures at final follow-up => evaluates hip function according to pain, walking and range of motion

Control Intervention:

Outcomes: Healing time, quality of fracture reduction, post-op complications and functional outcomes based on Majeed and modified Merle D'Aubigné scales

Setting: Department of Traumatology and Orthopedics, First Affiliated Hospital of Bengbu Medical College

Method

Databank: Retrospective analysis of pts admitted to specified hospital

Research Period: June 2018 – June 2022

Meta-Analysis:

Results

All surgeries were completed successfully, no deaths
Mean pelvic fracture healing time: 14.8 weeks
Mean acetabular fracture healing time: 15.9 weeks
Functional outcomes: excellent rates of 87.5% (pelvic fractures) and 83.3% (hip function)
Post-operative complications included deep vein thrombosis, sciatic nerve injury and incision related issues
Discussion:

- Treatment of pts with combined pelvic and acetabular injuries requires planning based on pts physiological status + other concomitant injuries
- In general, 4-7days after injury is a good time to operate or as early as possible if closed internal fixation of posterior pelvic ring is feasible
- No clear consensus on order of reduction for combined pelvic and acetabular injuries (few comparisons, maybe read over? P.7) -> in this study they took an individual approach to treatment, carefully assessing pts on preoperative x-ray + CT and referred the following principles for selection of order of reduction:
  I. In general, displacement of posterior pelvic ring of less than 1cm is acceptable, whereas displacement of weight-bearing area at top of acetabulum should be less than 2mm -> more anatomical reduction in acetabulum during treatment
  II. According to previous studies in literature, posterior pelvic ring provides main stability of pelvis (60-70%) and anterior pelvic ring provides 30-40% of stability of pelvis; tend to treat anterior pelvic ring last
  III. Complex acetabular fractures, such as both-column fractures, when combined with

significant displacement of ipsilateral posterior pelvic ring -> reest. + fix posterior pelvic ring under direct vision via pararectus approach or iliac-inguinal approach preferred

Conclusion:

- Complex type of injury – therefore no uniform diagnostic + classification criteria, nor uniform surgical procedure
- Due to complexity of mechanism of injury, case-by-case analysis is needed (taking into account pts physiological status, fracture classification and degree of displacement to achieve best prognosis)

Annex 1: Data Extraction

Source: Management and outcomes of severe pelvic fractures in level I and II ACS verified trauma centers
Aim of study
Evaluate the management strategies and outcomes of severe isolated pelvic fractures in Level I and II ACS-verified trauma centers, focusing on differences in blood product utilisation, VTE prophylaxis, complications and mortality rates
Inclusion Criteria
People: Patients (≤ 18 years old) with severe isolated pelvic fractures (pelvic AIS 3 or higher)
Intervention: Non-operative management (NOM) or interventions such as angiography or pharmacological VTE prophylaxis
Control Intervention: Comparisons between Level I and Level II trauma centers in terms of care protocols and patient outcomes?
Outcomes: Mortality, complications (e.g. ARDS, infection), ICU and hospital length of stay and failure rates of NOM
Setting: Level I and II ACS-verified trauma centers in the United States
Method
Databank: American College of Surgeons Trauma Quality Improvement Program (ACS TQIP)
Research Period: January 2013 to December 2016
Meta-Analysis:
Results
- 3.906 patients (2.629 in Level I centers and 1.277 in Level II centers) - Median age: 46 years in Level I centers, 50 years in Level II centers) - VTE prophylaxis using LMWH was higher in Level I centers (74.8% vs 66.5% in Level II) - Use of blood products within 24hours was higher in Level II centers (8.1% vs. 6.3%) - ICU length of stay was longer in Level II centers (2.0 vs. 1.4 days, $p < 0.001$) - Overall complication rates were higher in Level II centers (6.2% vs. 4.7%, $p = 0.049$), including a higher incidence of ARDS (0.8% vs. 0.2%, $p = 0.011$) - No significant difference in mortality rates between Level I and Level II centers

Annex 1: Data Extraction

Source: Posterior pelvic ring injuries, lumbosacral junction instabilities and stabilization techniques for spinopelvic dissociation: a narrative review
Aim of Literature Review
Examines literature of recent years regarding surgical treatment options and trends in spinopelvic dissociation (SPD), outlining risks and benefits of each treatment option and addressing biomechanical aspects of sacral injuries and common classification systems
Inclusion Criteria
People: Patients with unstable sacral fractures and SPD, mostly resulting from high-energy trauma, such as "suicidal jumper's fractures"
Intervention: Surgical stabilisation techniques, including minimally invasive (MIS) and traditional approaches like transsacral-transiliac screw fixation, lumbopelvic fixation, triangular fixation and posterior band plating.
Control Intervention: Older, conventional fixation methods and non-operative management approaches for sacral fractures
Outcomes: Biomechanical stability, reduction in complications, shorter operative time, reduced blood loss, and better clinical outcomes
Setting: Surgical and clinical environments where unstable sacral fractures and SPD are treated
Method
Databank: Relevant online databases (Ovid MEDLINE, Ovid EMBASE, PubMed, Cochrane Register of Controlled Trials, and Web of Science); Historical publications (older than 10 years) were included to illustrate basic principles (such as fracture classifications or presentation of historical surgical techniques, but excluded to describe current surgical techniques)
Research Period: Studies from the last decade; Historical publications older than ten years were referenced for foundational principles
Meta-Analysis:
Results
Study highlighted that minimally invasive techniques are increasingly preferred due to reduced complication rates and improved patient outcomes. Stand-alone transsacral-transiliac screws are effective for specific fracture types (e.g. U- and H-type fractures without anterior pelvic pathology). More complex cases require lumbopelvic fixation or triangular fixation, with MIS approaches offering significant advantages when feasible. Advances in fracture classification systems have also improved treatment planning and reliability

Annex 1: Data Extraction

Source: Blunt trauma pelvic fracture-associated genitourinary and concomitant lower gastrointestinal injury: incidence, morbidity, and mortality
Aim of study
To determine the incidence, characteristics, predictors and early management strategies for pelvic fractures with associated genitourinary (GU) and lower gastrointestinal (GI) injuries, and to assess their morbidity and mortality
Inclusion Criteria
People: Patients with pelvic fractures caused by blunt trauma, excluding those with penetrating injuries or incomplete records
Intervention: Management of pelvic fractures with GU and/or GI injuries, including surgical interventions such as urinary and fecal diversion or repair
Control Intervention: Pelvic fractures without GU or GI injuries or treated conservatively
Outcomes: Incidence of injuries, independent predictors, hospital resource utilisation, morbidity, and mortality rates
Setting: Data from trauma centers contributing to the National Trauma Data Bank (NTDB) from 2010-2014
Method
Databank: National Trauma Data Bank (NTDB) research datasets
Research Period: 2010-2014
Meta-Analysis: Retrospective cohort analysis with multivariable logistic regression to identify independent risk factors and predictors
Results
Among 180,931 pelvic fractures, 3.3% were associated with GU injuries, and 0.15% had both GU and GI injuries. Combined injuries were associated with higher injury severity scores (ISS), increased hospital length of stay (26.8 vs. 14.5 days) and higher mortality rates (11.3% vs. 4%) Disruption of the pelvic circle, male gender, pubic fracture, innominate fracture and systolic blood pressure <90mmHg were identified as the strongest independent predictors of combined injuries Management strategies included urinary repair (62%), urinary diversion (29%), rectal repair (81%), and fecal diversion (46%)

Annex 1: Data Extraction

Source: Pelvic trauma mortality reduced by integrated trauma care
Aim of study
Retrospective cohort study To evaluate the effect of a multidisciplinary, multi-faceted trauma care system implemented over a 12-year period on mortality outcomes in patients with serious pelvic injuries
Inclusion Criteria
People: 1213 patients sustaining serious pelvic injuries Abbreviated Injury Scale ≥ 3
Intervention: Comprehensive trauma care protocol implementation that includes: - Improved triage - Early pelvic binder application - Early administration of blood/products - Algorithm-based management - Focused sonography (FAST) - Early contrast CT angiography - Angio-embolisation - Early specialist surgical intervention
Control Intervention: Standard trauma care practices used in 2002, before implementation of new trauma protocol
Outcomes: Primary outcome: mortality at hospital discharge
Setting: Trauma care system
Method
Databank: Hospital/Trauma registry records
Research Period: 2002 - 2013
Meta-Analysis:
Results
Serious pelvic injury cases increased: 2002 – 51 cases; 2013 – 156 cases Mortality significantly dropped: 2002 – 20%; 2013 – 7.7% (p = 0.02) Significantly lower risk even after adjusting for confounders is indicated by the adjusted odds ratio for mortality in 2013 versus 2002 was 0.10 (95% Cl: 0.02-0.60)

Annex 1: Data Extraction

Source: Pelvic fracture in multiple trauma: A 67-case series
Aim of study
To evaluate the relationship between pelvic fracture types and mortality and assess the efficacy of a predefined decision-tree protocol for managing severe pelvic trauma in a Level I trauma center
Inclusion Criteria
People: Patients with severe trauma (Injury Severity Score >15) admitted between July 2011 and July 2013, including 67 cases with pelvic fractures
Intervention: Use of a pelvic binder and subsequent management per the decision-tree, including arteriography, embolization, or surgery based on the presence of hemorrhagic shock and active bleeding
Control Intervention: Conservative management without the predefined decision-tree protocol
Outcomes: Mortality rates, blood transfusion requirements, hospital stay duration, and rates of hemorrhagic shock
Setting: Single-center Level 1 trauma facility in France
Method
Databank: Continuous prospective observational study data collected from the trauma center
Research Period: July 2011 to July 2013
Meta-Analysis: not applicable
Results
Mortality rate was 19% overall and 42% in pts presenting with hemorrhagic shock Tile C fractures (vertical shear) had significantly higher mortality (58%) compared to Tile A (9.1%) and Tile B (12.1%) Patients with Tile C fractures required more blood transfusions and had higher injury severity scores Elevated lactatemia, lower hemoglobin, and higher blood transfusion needs were associated with increased mortality The decision-tree protocol, including early pelvic binding, effectively managed hemorrhagic shock and reduced early complications

Annex 1: Data Extraction

Source: Floating hip in polytraumatized patients: complications, mechanism of injury, and surgical strategy
Aim of study
To analyse the complications, injury mechanisms, and surgical strategies associated with floating hip injuries in polytraumatised patients
Inclusion Criteria
People: 45 polytraumatised patients with combined pelvic or acetabular and ipsilateral femoral fractures admitted between 2004 and 2019
Intervention: Surgical management strategies, including damage control orthopedics (DCO), external fixation, and staged internal fixation (IF), with a "femur first" approach for definitive treatment; statistical analysis of complication rates and injury patterns using logistic regression and Fisher's exact test
Control Intervention: Conservative or alternative surgical approaches not involving the specified DCO or staged IF strategies
Outcomes: Complication rates, mortality, correlation between injury patterns and fracture types, and the effectiveness of surgical strategies
Setting: Single-center retrospective study at a trauma facility in Milan, Italy
Method
Databank: Retrospective review of medical records, imaging studies, and surgical outcomes
Research Period: January 2004 to December 2019
Meta-Analysis:
Results
86.7% of patients experienced high-energy trauma, such as motorcycle crashes or falls from height Müller types A and B were the most common injuries (35.6% and 53.3% respectively) Complications occurred in 51.1% of patients, with heterotopic ossification (22.2%) and sciatic nerve palsy (15.6%) being the most frequent Type 61-C pelvic fractures and type 62-B acetabular fractures had the highest complication rates (73.3% and 88.8%, respectively) A "femur first" two-stage approach was the most common surgical strategy, particularly for Müller type A injuries, which had the highest need for revision surgery (50%) Damage control orthopedics was used in 80% of cases, especially for type B injuries

Annex 1: Data Extraction

Source: The 'nightstick' ischial fracture: a unique oddity of the pelvic injury family
Aim of study
Case Report Unusual (isolated) ischial fracture - Rare case: ischial tuberosity is protected by muscle and fat and a large and strong bone; strong osseoligamentous pelvic structure usually resists deforming forces; high energy is required to cause fractures - Current classification systems (e.g. Tile, Young-Burgess) do not cover cases like this; Tile's A-type fractures include ischial fractures, but usually minor avulsions, not comparable to this severe case - No similar cases found during literature review, no consensus on how to manage similar injuries Discusses mechanism; describes appropriate investigations and surgical management of this fracture
Inclusion Criteria
People: 36-year-old male; sustained direct blow to his right buttock (ischial tuberosity) following a fall from a dirt bike; no associated pelvic instability Examination: firm hematoma, with severe pain on any stretch involving the posterior compartment of the thigh Radiography: revealed displaced fracture of the ischial body; CT: confirmed integrity of pelvic ring Patient underwent open reduction and internal fixation with a partially threaded cannulated screw via a "modified longitudinal" posterior approach to the ischium
Intervention: Initial resuscitation followed Advanced Trauma Life Support (ATLS) guidelines Pelvic binder application, IV access, IV crystalloids (normal saline), vital monitoring Binder was removed after initial and repeat radiographs showed an intact pelvic ring Risks if surgery is not done are identified: - High risk of non-union and potential malunion because of fracture displacement (34mm), which could lead to severe pain with sitting and impaired quality of life (severe functional impairment) - Sciatic nerve might be compromised from displaced fragment Surgical fixation: open reduction and internal fixation - S-shaped incision over gluteal fold, dissection between gluteus maximus and hamstrings - Fracture reduced; K-wire for temporarily holding fixation under fluoroscopic guidance with a cancellous screw
Control Intervention:
Outcomes: No perioperative complications: post-op analgesic requirements were greatly reduced Partially weight-bearing for 6 weeks; 6-month follow-up confirmed satisfactory clinical and radiographic outcomes 5-month follow-up: fracture remained well reduced, clinical examination was satisfactory; patient is allowed to fully weight-bear and was discharged from the clinic
Setting:

Method
Databank:
Research Period:
Meta-Analysis:
Results
Rare case, no similar cases found during literature review Surgery was decided on because of a displacement of more than 15-20mm, requiring fixation; patient was young (36-year-old) and active; sciatic nerve was protected; without surgery there would have been high risk of chronic pain, weakness and activity limitations

Annex 1: Data Extraction

Source: A bidirectional framework for fracture simulation and deformation-based restoration prediction
Aim of study
Describing a novel bidirectional framework for automated fracture surgical planning, integrating fracture surgical planning, integrating fracture simulation and deformation-based restoration prediction to improve accuracy and efficiency in preoperative planning
Inclusion Criteria
People: Patients with pelvic fractures requiring surgical planning, with datasets derived from clinical CT scans and simulated fracture models
Intervention: Deep learning-based framework incorporating fracture simulation, structure restoration, and reduction planning to optimise pelvic fracture management
Control Intervention: Conventional manual or semi-automatic surgical planning methods relying on surgeon expertise and time-intensive preoperative imaging analysis
Outcomes: Accuracy of fracture restoration and reduction planning, computational efficiency, and improvement over traditional clinical workflows
Setting: Multi-center study utilising the publicly available CTPelvic1K dataset for validation, including both simulated and real pelvic fracture CT scans
Method
Databank: CTPelvic1K dataset (which includes 1006 healthy pelvic CT scans, 103 fractures pelvic CT scans, and 13 fractures CT scans with imaging artifacts)
Research Period: not mentioned
Meta-Analysis: not applicable (performance was evaluated through comparative experiments, statistical analysis, and a phantom study)
Results
- Framework achieved a mean SSIM of 90.7% for structure restoration and translational errors of 2.88mm with rotational errors of 3.18°, demonstrating high accuracy - The method significantly accelerated the surgical planning process, completing it in 52.9s compared to the 122min required by conventional workflows - It outperformed existing deep learning-based methods (UNet, Swin-UNETR, and GN-SPAK) in fracture structure restoration and reduction planning accuracy - Model remained robust even with imaging artifacts, maintaining high accuracy in CT scans with metal implants - Phantom experiments confirmed clinical feasibility, with postoperative reduction errors of 2.81mm and 1.10°, demonstrating potential for real-world application

Annex 1: Data Extraction

Source: Evaluation of Pelvic Circular Compression Devices in Severely Injured Trauma Patients with Pelvic Fractures
Aim of study
Retrospective analysis To evaluate the effect of pelvic circumferential compression devices (PCCDs) on mortality and bleeding in severely injured trauma patients PCCDs temporarily stabilise the pelvic ring, reduce its volume and to tamponade bleeding
Inclusion Criteria
People: 9.910 patients included (from which 1.103 patients suffered a relevant pelvic trauma; AIS = 3-5) Age 16 or older; complete status documentation on PCCD and mortality Injury severity score (ISS) of 9 or higher; Abbreviated Injury Scale AIS of 3-5
Intervention: Cohort analysis: patients suffering from relevant pelvic fractures Data collection of mortality and requirements for blood transfusion Expected outcome derived from Version II of the Revised Injury Severity Classification (RISC II) was compared to the observed outcome and accordingly adjusted Calculation of Standardised Mortality Ratio (SMR)
Control Intervention:
Outcomes: 1.103 patients PCCD: 454 cases (41%) -> no significant effect on mortality and did not decrease the need for blood transfusion in the multivariate regression analysis Application of PCCD is a general indicator for a critical patient with increased mortality (12.0% no PCCD applied vs. 23.2% PCCD applied prehospital vs. 27.1% PCCD applied in the emergency department) ISS was higher in patients with PCCD (34.12 ± 16.4 vs. 27.9 ± 13.8; $p < 0.001$)
Setting:
Method
Databank: Trauma Register DGU, Germany
Research Period: 2015 - 2016
Meta-Analysis:
Results
Severe pelvic trauma patients (according to ISS, AIS and deterioration in circulatory status) had PCCD more applied -> no reduction in need for blood transfusion or mortality

Annex 1: Data Extraction

Source: Does a prehospital applied pelvic binder improve patient survival?
Aim of study
Retrospective cohort study To evaluate the effectiveness of prehospitally applied pelvic binders in improving outcomes for pts with pelvic fractures Analysis of impact of early pelvic stabilisation on mortality, hospital length of stay, and blood transfusions Evaluation of pelvic binder administration frequency, number of patients who required one due to the presence of an unstable fracture, and the proportion of patients who received a properly applied pelvic binder
Inclusion Criteria
People: 66 patients with unstable pelvic ring fracture classified as AO61B or 61C
Intervention: Ideal position for pelvic binder was determined and patients were divided into three sub-groups based on whether they received a pelvic binder in the ideal position, outside optimal range or not at all; the primary outcome measure was the survival rate of patients Shapiro-Wilk test was performed on all continuous variable to determine if they were normally distributed and determine whether parametric or non-parametric test are appropriate ->ANOVA with Bonferroni, Kruskal-Wallis test?
Control Intervention:
Outcomes: Mean ISS score was 21.9, with 60.3% of patients having a moderate to severe injury (ISS > 16 points); no significant difference with pelvic binder usage with an ISS < or ≥ 16 points
Setting: Level I hospital in the emergency room
Method
Databank:
Research Period: January 2014 – December 2018
Meta-Analysis:
Results
No significant impact regarding patient outcomes with prehospital pelvic binders for unstable pelvic fractures, with the strongest predictor of survival being the injury severity score (ISS). Injury severity assessment and blood loss management plays a crucial role for these patients. Even through there was no significant impact found regarding pelvic binders, they still play a role in stabilising pelvic fractures, as well as managing blood loss.

Annex 1: Data Extraction

Source: Hemipelvectomy as a Salvage Procedure in Massive Pelvic Trauma
Aim of study
Case report; severe case “Pedestrian struck by train” – one of the highest magnitude blunt force traumas Case highlights interventions that helped a young man struck by a train to survive; hemipelvectomy improved his outcome significantly, indicating that severe pelvic injuries caused by high energy trauma may demand hemipelvectomy
Inclusion Criteria
People: 25-year-old male; struck by train as a pedestrian Injuries sustained: extensive complex pelvic fractures, right external iliac artery and vein laceration, right femur, and tibia fracture
Intervention: Damage control surgery, attempted revascularisation of right lower extremity (extremity became ischemic -> required knee amputation followed by hip disarticulation, as well as hemipelvectomy) Negative pressure wound therapy to gradually close pelvic wounds
Control Intervention:
Outcomes: Discharged; continued recovery in rehab facility
Setting:
Method
Databank:
Research Period:
Meta-Analysis:
Results
Significant improvement after hemipelvectomy -> case highlights that those severe pelvic injuries caused by high energy trauma may demand hemipelvectomy

Annex 1: Data Extraction

Source: [The initial management in intensive care of pelvic ring injury patients]
Aim of study
Systematic literature review Proposal of a decision-making algorithm for the treatment of trauma pelvic fracture patients Describes pathophysiology of pelvic fractures, as well as efficacy and safety of haemostatic procedures and with their respective indications Background: - Pelvic injuries are frequently associated with multiple injuries -> may lead to dramatic and uncontrollable haemorrhage - 8-10% of mortality after pelvic trauma, is mainly related to severe pelvic haemorrhage, as well as extrapelvic injuries (thoracic, abdominal or brain injuries
Inclusion Criteria
People: Patients with severe pelvic ring injuries, especially presenting with haemodynamic instability or haemorrhagic shock, often polytrauma patients
Intervention: Initial trauma assessment aims to determine the role of the pelvic injury in haemorrhage to define the therapeutic strategy of pelvic trauma care (arterial embolization/pelvic ring stabilisation)
Control Intervention:
Outcomes: Improved haemorrhage control, stabilisation of pelvic fractures, reduction in mortality, reduction in complications, i.e., organ failure or sepsis
Setting: Specialised trauma units
Method
Databank: systematic literature search via PubMed
Research Period:
Meta-Analysis:
Results
Mortality of 8-10% in pelvic fractures -> with haemodynamic instability or open fractures 25-40% Major cause of death: haemorrhage Early pelvic stabilisation (e.g., binders, clamps, external fixators) to reduce bleeding Arterial bleeding control: arterial embolization (>90% success if done early) Preperitoneal pelvic packing (PPP): effective for venous bleeding, especially when embolization is not immediately possible Thromboprophylaxis (LMWH or mechanical): once bleeding is controlled Multidisciplinary care and trauma networks: significantly reduce mortality

Annex 1: Data Extraction

Source: Perioperative impact of ultrasound-guided ilioinguinal and iliohypogastric nerve blocks in patients undergoing pelvic fracture surgery
Aim of study (Retrospective analysis)
Comparison of ultrasound-guided ilioinguinal (IIN) and iliohypogastric nerve (IHN) blocks with conventional general anesthesia (GA) in pelvic fracture patients undergoing internal fixation surgery.
Inclusion Criteria
People: 100 patients
Intervention: Patients underwent internal fixation surgery for pelvic fractures; Monitoring of hemodynamics, intropeative anesthesia drug usage, postoperative pain levels, and incidence of adverse reactions between the two groups
Control Intervention: control group underwent conventional GA with induction and maintenance drugs, administration method and dosage consistent with those of the ultrasound group
Outcomes:
Setting: Patients were divided into 2 groups: ultrasound-guided group (n = 50) and control group (n = 50)
Method
Databank:
Research Period: January 2019 to December 2022
Meta-Analysis:
Results
Ultrasound-guided group: 23 females, 27 males; average age 58.32 ± 2.14 Control group: 22 females, 28 males; average age 58.51 ± 2.04

Annex 1: Data Extraction

Source: [Outcome after plate stabilization of symphyseal diastasis]
Aim of study
Symphyseal plating can stabilise a separation of the pubic symphysis with corresponding diastasis; this is a retrospective evaluation of 64 patients who underwent symphyseal plating with a follow-up period of 24 months
Inclusion Criteria
People: 64 patients (56 male patients, 8 female patients); average age of 44 years; traffic injuries were the main cause of the pelvic injuries mean injury severity score (ISS) was 32; mean inpatient stay was 29 days
Intervention: Surgical technique: - Access via Pfannenstiel incision; exposure of rectus sheath; longitudinal incision of linea alba - Retrosymphysial dissection; Fluoroscopic guidance for reduction - Symphisis is stabilised with repositioning plates (either 4-hole or 6-hole) or a 3.5 pelvic implant Post-operative imaging (x-ray or CT) Post-op x-ray after 6 weeks
Control Intervention:
Outcomes: implant loosening occurred in 52 (81.3%) patients; severe complications that required treatment in 14 patients; Implant failure was the leading reason for revision surgery
Setting: Emergency Department in a trauma centre
Method
Databank:
Research Period: 2006 - 2016
Meta-Analysis:
Results
Radiological signs of implant loosening are commonly observed but rarely are the reason for revision surgery. Complete implant failures require early revision and occur mainly within the first postoperative weeks, therefore additional x-ray imaging should be carried out if this is suspected for a timely clarification.

Annex 1: Data Extraction

Source: The Reliability of the Pre-hospital Physical Examination of the Pelvis: A Retrospective, Multicenter Study
Aim of study
To assess the incidence of missed pelvic injuries in pre-hospital setting
Inclusion Criteria
People: 11,062 patients included, from which 7201 patients (65.1%) had a pelvic fracture diagnosed on hospital admission Pre-clinically no pelvic injury was suspected in 44.1% of patients with a confirmed pelvic fracture
Intervention:
Control Intervention:
Outcomes: Independent risk factors for missing a pelvic injury in the pre-hospital setting were an AIS head ≥3, a GCS ≤ 8 and age above 60 years. The presence of hypotension (SBP ≤ 90mmHg) as well as a high overall injury severity (ISS ≥ 25) decreased the risk of missing a pelvic injury.
Setting:
Method
Databank: TraumaRegister DGU of the German Trauma Society DGU
Research Period: 2002-2011
Meta-Analysis:
Results
In pre-hospital setting a significant proportion of severe pelvic fractures type B and C were not suspected -> reason why a mechanical pelvic stabilisation should be considered in the pre-hospital environment in severely injured blunt trauma patients, irrespective of the findings of the physical examination of the pelvis.

Annex 1: Data Extraction

Source: Association of pelvic fracture patterns, pelvic binder use and arterial angio-embolization with transfusion requirements and mortality rates; a 7-year retrospective cohort study
Aim of study
Assess the association of the pelvic fracture pattern according to the Tile classification system with transfusion requirements and mortality rates, and to evaluate the correlation between the use of pelvic binders and arterial angio-embolisation and the mortality of patients with pelvic fractures
Inclusion Criteria
People: 288 patients; median patient age was 43.5 years; 68.9% were male; Patients with a final diagnosis of pelvic fractures were included; exclusion of patients with isolated acetabular fractures
Intervention:
Control Intervention:
Outcomes: Tile C pelvic fractures are associated with higher transfusion requirements and a higher mortality rate than Tile A or B fractures; furthermore in these patients with pelvic fractures no association between the use of pelvic binders or arterial angio-embolisation and survival was observed (!!)
Setting: Trauma registry of Lausanne University Hospital Switzerland
Method
Databank: Trauma registry of Lausanne University Hospital Switzerland
Research Period: (Patients with a final diagnosis of pelvic fractures from) January 2008 to June 2015
Meta-Analysis:
Results

Annex 1: Data Extraction

Source: Posterior iliac crescent fracture-dislocation: is it only rotationally unstable?
Aim of study
Investigates if in posterior iliac crescent fracture-dislocation vertical instability can occur and analyses clinical features of vertically unstable iliac crescent fracture-dislocation and treatment strategies
Inclusion Criteria
People: Four patients: vertically unstable fracture dislocation, accounting for 12.9% of iliac crescent fracture-dislocation; all four patients were hemodynamically unstable on admission and had complications of associated injuries with a higher injury severity score -> in 3 of the 4 pts, iliac crescent fracture-dislocations were reduced via posterior approach at initial stage + underwent fixation with a plate – the remaining pts were given transcondylar traction because of severe complications + underwent open reduction and internal fixation via posterior approach at later stage
Intervention: study analyses clinical features (including incidence, hemodynamic state, associated injuries, injury severity score, treatment methods for vertically unstable iliac crescent fracture-dislocation)
Control Intervention:
Outcomes:
Setting:
Method
Databank: authors department? (State Key Laboratory of Trauma, Burn and Combined Injury, Department of Trauma Surgery, Daping Hospital, Third Military Medical University, ChongQing, China)
Research Period: June 2009 to June 2012
Meta-Analysis:
Results

Annex 1: Data Extraction

Source: Accuracy of the WSES classification system for pelvic ring disruptions: an international validation study
Aim of study (retrospective)
Validating the effectiveness of the classification for pelvic injuries by the World Society of Emergency Surgery (WSES), as well as evaluating the roles of associated vascular injury and open fracture in this system
Inclusion Criteria
People: Inclusion criteria were patients with blunt pelvic fractures; exclusion criteria were patients with penetrating trauma, burns, other or unknown trauma mechanisms or severe head injuries
Intervention: Collection and evaluation of data recorded in the NTDB (age, sex, systolic blood pressure (SBP) in the emergency department, pulse in ED, respiratory rate in ED, oxygen saturation in ED, Glasgow Coma Scale in ED and injury severity score (ISS)) - All original files from the NTDB were merged and analysed; nominal data are presented as numbers and percentages + were compared using chi-square tests, numerical data are presented as the means with standard deviation and were compared using Student's t test
Control Intervention:
Outcomes: WSES guidelines are accurate and reproducible classification of pelvic fractures; Recommendation that open/closed fractures and associated vascular injuries should be evaluated as supplements of the WSES classification
Setting:
Method
Databank: National Trauma Data Bank
Research Period: 12-month study period in 2015
Meta-Analysis:
Results

Annex 1: Data Extraction

Source: Plate fixation of the anterior pelvic ring in patients with fragility fractures of the pelvis
Aim of study
To find out if conventional plate osteosynthesis is a valid option in pts with osteoporotic bone/to evaluate plate osteosynthesis of the anterior pelvic ring in patients with FFP by assessing the amount of implant-related problems and their risk factors The secondary aim is comparing single-plate osteosynthesis (SPO) with double plate osteosynthesis (DPO) ➔ Background: in fragility fractures of the pelvic (FFP), fractures of the posterior pelvic ring are nearly always combined with fractures of the anterior pelvic ring -> when the posterior pelvis is surgically stabilised, it is recommended to stabilise the anterior pelvis as well
Inclusion Criteria
People: Fragility fracture patients, who underwent plate osteosynthesis of the anterior pelvic ring
Intervention: 48 patients were reviewed; mean age of 76.8 years Comparison between single plate osteosynthesis (SPO; 37 cases) at the pelvic brim and double plate osteosynthesis (DPO; 11 cases) with plates at the pelvic brim and anteriorly
Control Intervention:
Outcomes: Screw loosening (SL) in the superior plate (45% of patients): - SPO group: 51% (19 of 37 patients) - DPO group: 27% (3 of 11 patients) Screw loosening: predominantly located near the pubic symphysis; none observed in anterior plate of DPO group Revision osteosynthesis: required in 6 patients (SPO group) No significant influence on screw loosening in either group by the following: presence of bone defects, unilateral or bilateral anterior pelvic ring fractures, postoperative weight-bearing restrictions, osteosynthesis of posterior pelvic ring, presence of infra- or supra-acetabular screws
Setting: Department of Orthopedics and Traumatology, University Medical Center Mainz, Germany
Method
Databank: University Medical Center Mainz, Germany
Research Period: 2009 - 2019
Meta-Analysis:
Results
Lower rate and severity of screw loosening, reduced need for revision surgery in DPO group For fixation of anterior pelvic ring fractures, recommendation of DPO over SPO (particularly near pubic symphysis)

Annex 1: Data Extraction

Source: Lower urinary tract injuries in patients with pelvic fractures at a level 1 trauma center - an 11-year experience
Aim of study
Retrospective study To describe incidence, diagnosis, treatment, as well as morbidity following lower urinary tract injuries in pelvic fractures Background: Pelvic fracture patients may suffer from urological injuries -> Treatment recommendation is often pragmatical and lack solid evidence -> short- and long-term complications following lower urinary tract trauma needs to be continuously demonstrated
Inclusion Criteria
People: Pelvic fracture patients (including acetabular) Total of 39 (5%) pelvic fracture patients had concomitant urethral and/or bladder injuries; one acetabular fracture patient had bladder injury
Intervention: Immense variation concerning management of urethral injuries
Control Intervention:
Outcomes: Complete urethral ruptures: associated with sever short- and long-term complications One bladder injury patient experienced severe long-term complications
Setting: Level I Trauma Center
Method
Databank:
Research Period: 2009 - 2020
Meta-Analysis:
Results
Major challenge to manage lower urinary tract injuries in severe pelvic fracture patients ➔ Focus should be on urethral injuries – study highlights even in highly experienced centres treatment and follow-up can be quite unsystematic (also attributed to complicated multidisciplinary patient trajectories) ➔ Multicenter studies are needed to address the continuous need to reduce long-term complications after urethral trauma

Annex 1: Data Extraction

Source: Pelvic injury prognosis is more closely related to vascular injury severity than anatomical fracture complexity: the WSES classification for pelvic trauma makes sense
Aim of study
Retrospective case-cohort study To investigate correlation of vascular injury and fracture pattern with the clinical outcome of trauma patients whose principle injury was pelvic fracture
Inclusion Criteria
People: 8111 patients out of which 425 patients sustained a pelvic fracture Included patients (155 patients): - Diagnosis of pelvic fracture - > 18 years of age - No abbreviated injury scale (AIS) score higher than 2 in any body region other than the pelvis 71 (45.8%) males, 84 (54.2%) females; mean age of 44.7 ± 21 years Mean ISS was 14 ± 4.9; mean length of ICU stay and total length of hospital stay was 1.4 ± 3.9 and 11.8 ± 9.8 days, respectively
Intervention: Standardised protocol for initial resuscitation and management according to ATLS recommendations and pelvic trauma treatment guidelines (for all patients)
Control Intervention:
Outcomes: Even in pts with relatively isolated pelvic injuries, vascular injury severity is more closely correlated to the outcome than the type of anatomical fracture. Therefore, a more balanced classification of pelvic injury that takes both the fracture pattern and hemodynamic status into consideration, such as WSES classification, seems to have better utility for clinical practice (!)
Setting: Retrospective case-cohort study approved by the Institutional Review Board of Chang Gung Memorial Hospital
Method
Databank: Chang Gung Memorial Hospital trauma registry
Research Period: January 2016 – December 2017
Meta-Analysis:
Results

Annex 1: Data Extraction

Source: Fragment distance-guided dual-stream learning for automatic pelvic fracture segmentation
Aim of study
Developing a method that is able to identify pelvic fracture fragments in various quantities and locations using a dual-branch architecture that leverages distance learning from bone fragments
Inclusion Criteria
People:
Intervention: extensive experiments on three pelvic fracture datasets from different medical centers demonstrated the accuracy and generalisability of the proposed method.
Control Intervention:
Outcomes: mean dice coefficient and mean sensitivity of 0.935±0.068 and 0.929±0.058 in the dataset FracCLINIC, and 0.955±0.072 and 0.912±0.125 in the dataset FracSegData; method optimises the process of pelvic freacture segmentation, potentially serving as an effective tool for preoperative planning in the clinical management of pelvic fractures
Setting:
Method
Databank:
Research Period:
Meta-Analysis:
Results

Annex 1: Data Extraction

Source: The role of angio-embolization in the acute treatment concept of severe pelvic ring injuries
Aim of study
Retrospective review Evaluation of institutional management of patients with severe pelvic fractures and analyses their outcomes
Inclusion Criteria
People: 173 patients with pelvic ring fractures (46% type A fracture, 25% type B fracture, 29% type C pelvic ring fracture)
Intervention: Surgical treatment required in 21% of pts (pelvic C-clamp; supra-acetabular external fixator; pelvic packing; definitive plate osteosynthesis of pubic symphysis); Angio-embolisation in 16 patients (only specific treatment for pelvic injury in 8 patients on day 0, and in 8 pts it was performed immediately post-operatively)
Control Intervention:
Outcomes: overall mortality rate 12.7%
Setting: Level I trauma centre
Method
Databank: Patient records were documented prospectively in a trauma database + evaluation was performed by SPSS
Research Period: 2007 - 2012
Meta-Analysis:
Results
Angiographic embolization as a first-line treatment: only performed in hemodynamically stable patients or in patients responding to fluid resuscitation with finding of an arterial blush in CT scan Pre-peritoneal pelvic packing in combination with mechanical pelvic stabilisation (immediately carried out), followed by angio-embolisation post-operatively if signs of persistent bleeding remained present: in hemodynamically unstable patients

Annex 1: Data Extraction

Source: Pre-hospital pelvic girdle injury: Improving diagnostic accuracy in a physician-led trauma service
Aim of study
Evaluation of pre-hospital diagnostic accuracy of pelvic girdle injuries and how this would be affected by implementing the pelvic injury treatment guidelines recently published by the Faculty of Pre-Hospital Care
Inclusion Criteria
People: - mean age of patients: 38.6 years (range 2-91) - age, sex, mechanism of injury and baseline GCS were recorded - Application (or not) of pre-hospital pelvic circumferential compression device (pelvic binder) was also recorded
Intervention:
Control Intervention:

Outcomes:
- Table 2 (p.4)
- Diagnostic accuracy calculated:
  o Sensitivity: 0.69 (95% Cl 0.50-0.85)
  o Specificity: 0.81 (95% Cl 0.74-0.87)
  o Likelihood ratio for positive result was 3.67 (95% Cl 2.40-5.61)
  o Likelihood ratio for a negative result was 0.38 (95% Cl 0.21-0.68)
- Pelvic girdle injuries were then categorised:
  o "severe" (those requiring internal fixation)
  o "less severe" (those necessitating non-operating treatment) …? (p.4-5 pdf)
- Missed fracture group (e.g. those not fitted with a binder but were found to have a fracture)
  o However, most had distracting injuries
- ….

Setting: Physician-based trauma service set at an urban Major Trauma Center (doctor-paramedic team are primarily dispatched to major trauma missions and respond by helicopter or fast response car)
Method
Databank: specialist pre-hospital trauma service
Research Period: August and December 2011 (5 month period)
Meta-Analysis:
Results
Study included patients of all ages, GCS grades and injury severity, a sensitivity of 0.69 (95% Cl 0.50-0.85) and a specificity of 0.81 (95% Cl 0.74-0.87) was established for pelvic fracture diagnosis. Despite a low threshold for placement of pelvic binders, there was a group of patients, usually with distracting injuries, normal systolic blood pressure and varying GCS scores, who were still misdiagnosed. Presence of distracting injuries can hamper the clinical during the examination, diagnosis and treatment of a patient usually with multiple injuries in the pre-hospital setting. The use of FPHC guidelines combined with ongoing training and perhaps moulage simulation, could provide the most appropriate means for improving clinical accuracy

Annex 1: Data Extraction

Source: The pelvic vascular injury score (P-VIS): a prehospital instrument to detect significant vascular injury in pelvic fractures
Aim of study
To identify predictive factors for peri-pelvic vascular injury in patients with pelvic fractures and to incorporate these factors into a pelvic vascular injury score (P-VIS) to detect severe bleeding during the prehospital management
Inclusion Criteria
People: Pelvic fracture patients; AISpelvis ≥ 3 ISS ≥ 16 (subgroup) N = 9227 patients (Trauma-DGU registry) -> met inclusion criteria ➔ 2090 patients: significant peripelvic vascular injury ➔ 7137 patients: control group
Intervention: Predictive factors for significant peri pelvic vascular injury are identified and scored Analysis of patient's charts and digital recordings, radiographical diagnostics, mechanism and pattern of injury, vascular bleeding source Statistical analysis: inference statistical calculation 10-year time period (Trauma Register DGU): - Combination of pelvic fracture with significant bleeding (> 20% of blood volume) and injury of the iliac or femoral artery or blood transfusion of ≥ 6 units (pRBC) prior to ICU admission as definition for relevant peri-pelvic bleeding in patients with AISpelvis ≥ 3 (N = 9227) Multivariate analysis: nine items that constitute pelvic vascular injury score (P-VIS)
Control Intervention: Control group: comparison with patients without significant vascular injury
Outcomes: Validation and development of P-VIS Detection of significant bleeding risk Statistical correlation with actual injuries P-VIS: initial risk assessment for presence of a vascular injury in unstable pelvic injury patients ➔ Management can be positively influenced at very early stage, prehospital resuscitation performed safely targeted and further resources can be activated in final treating Trauma Centre
Setting: Level I Trauma Centre
Method
Databank: Trauma Register DGU, national register Germany
Research Period: 2012 - 2021
Meta-Analysis:
Results
Significant vascular injury: 24 of 467 blunt pelvic trauma patients (PVI, N = 24; control (C, N = 443)

Pelvic fracture patients with vascular injury: higher ISS, lower haemoglobin at admission, lower blood pression; higher mortality rate (PVI: 17.4%, C: 10.3%)

Peripelvic vascular injury score (P-VIS) composed of nine predictive parameters for peripelvic vascular injury:

- Age ≥ 70 years
- High energy trauma
- Penetrating trauma/open pelvic injury
- Shock index ≥ 1
- Cardio-pulmonary- resuscitation
- Substitution of > 1l fluid
- Intubation
- Necessity of catecholamine substitution
- Remaining shock (≤ 90mmHg) under therapy

P-VIS scoring:
≥ 3 points = probable vascular injury
≥ 6 points = most likely
9 points = apparent injury

Annex 1: Data Extraction

Source: Three-year functional outcome after open pelvic fracture treatment: a retrospective case series from a level I trauma center
Aim of study
Retrospective review
Inclusion Criteria
People: 772 patients with pelvic fractures, that were resuscitated -> of which 37 (4.9%) were diagnosed with open pelvic fracture; 8 patients failed to respond to resuscitation and died in ED due to multiple injuries
Intervention: analysation of resuscitation protocol, osteosynthesis strategy, reduction quality of the pelvic ring and functional outcomes Best surgical strategy to perform osteosynthesis for pelvic fractures remains controversial
Control Intervention:
Outcomes: Overall mortality rate for patients with pelvic fractures was 21.6%
Setting:
Method
Databank: Retrospectively collected data and images of patients from the registration database of the institute
Research Period: January 2014 – June 2018
Meta-Analysis:
Results
Mortality rate in this study was considerable, but patients had a good chance of receiving complete treatment course if they survived resuscitation Approaches for treatment of fractures should be individualised according to fracture pattern, location of open wound in pelvis and concomitant injuries Despite the poor initial functional scores, functional improvements may be anticipated Additionally, anatomical restoration of pelvic ring suggested better functional performance at least a 36-month follow up A further study should be conducted to follow these patients in order to obtain long-term functional outcomes

Annex 1: Data Extraction

Source: Prospective Characterization of Pain and Function in Patients With Unstable Pelvic Fractures Treated With Posterior Screw Fixation
Aim of study
Describe patient-reported pain and function within 24 months of a pelvic fracture treated with posterior screw fixation and identify factors associated with increased pain (?)
Inclusion Criteria
People: 88 adult patients sustaining a pelvic fracture treated with sacroiliac or transiliac screws
Intervention: - Brief Pain Inventory (BPI) to measure average pain; - Majeed Pelvic Outcome Score from 6 to 24 months postinjury to measure function
Control Intervention:
Outcomes: - Mean pain from 6-24 months postinjury: 2.22 on 10-point BPI scale (95% Cl, 0.64-3.81) - 69 patients (78.4%) reported mild to no pain at 6 months; 12 patients (13.6%) had severe pain - Two years after injury, 71 patients (80.6%) exhibited mild to no pain - Within 24 months of injury, mean pelvic function was 71 on Majeed scale (95% Cl, 60-82) - Good to excellent pelvis function by 6 months postinjury for half of the sample (n=44); 55 patients (62.5%) attained this level of function by 24 months - Factors that are significantly associated with increased pain: history of chronic pain (1.31; 95% Cl, 0.26-2.37; P = 0.02), initial fracture displacement (≥5mm) (0.99; 95% Cl, 0.23-1.69; P = 0.01) and socioeconomic deprivation (0.28; 95% Cl, 0.11-0.44; P < 0.01)
Setting: Academic trauma center
Method
Databank: Therapeutic Level IV
Research Period:
Meta-Analysis:
Results
Study findings suggest that most patients with unstable pelvic ring fractures treated with posterior screw fixation achieve minimal to no pelvis pain and good to excellent pelvic function 6-24 months after injury

Annex 1: Data Extraction

Source: Design and evaluation of an intelligent reduction robot system for the minimally invasive reduction in pelvic fractures
Aim of study
Study presents a self-developed robot reduction system for pelvic fractures and realises intraoperative real-time 3D image navigation A special holding system was designed to control the healthy hemipelvis, as well as a reduction manipulator arm to reduce the fracture fragments; the fracture fragment was then successfully reduced with the robot reduction system according to the planned path
Inclusion Criteria
People: 3D printed models based on patient CT scans

Intervention:
- 3 parts:
  o Preparation of 20 pelvic fracture models
  o Automatic reduction algorithm of our robotic reduction system (including intraoperative real-time 3D navigation, reduction path planning, control and fixation and robotic-assisted fracture reduction
  o Image registration accuracy and fracture reduction accuracy were calculated and analysed
- Laboratory performed
- Data is obtained from normal pelvic CT scans of 20 anonymous patients (age range: 25-72 years; 12 males, 8 females)
- According to Tile classification: 6 cases of type B1; 8 cases of type B2; 6 cases of type C1
➔ Osteotomy was performed on 20 pelvic 3D printing models, based on the fracture morphology of these 20 clinical pelvic fracture cases, in order to simulate these 20 cases
- Algorithm of RAFR system (4 main parts):
  o Pelvic fracture reduction software (including reduction path planning software, intraoperative navigation, registration software),
  o Photoelectric tracking device (NDI Polaris Vega and trackers)
  o Pelvic holding equipment
  o Reduction robot (UR16e)

Control Intervention:
Outcomes: - All 20 pelvic fracture bone models were reduced by the RAFR system - Mean registration error E1: 1.29 ± 0.57mm (table 1) - Mean reduction error E2: 2.72 ± 0.82mm - Global error analysis of registration and reduction results showed that higher errors are mainly located at the edge of the pelvis (e.g. iliac wing)
Setting: Laboratory performed study
Method
Databank: pelvic CT scans from patients of Beijing Jishuitan Hospital
Research Period:
Meta-Analysis:
Results

Demonstrated precision and effectiveness of RAFR system, as well as its applicability and usability in clinical practice, therefore paving the way toward robot minimally invasive pelvic fracture surgeries

Annex 1: Data Extraction

Source: Use of N-butyl cyanoacrylate in the successful transcatheter arterial embolization of an arteriovenous fistula caused by blunt pelvic fracture: A case report and review of literature
Aim of study
Detection of traumatic arteriovenous fistulas (AVFs) of the pelvis may be difficult, since they are uncommon and usually present with a variety of clinical manifestations Usually the first choice of treatment is an endovascular approach, because surgical intervention is complicated due to the location of the lesions Case: 68 year old man, admitted with severe pelvic pain following a fall ➔ Diagnosis: pelvic bone fracture (Young and Burgess Classification, lateral compression type II) was revealed on pelvic computed tomography (CT), while a pelvic sidewall hematoma, unaccompanied by any vascular injury was detected on multidetector CT (?)
Inclusion Criteria
People: 68-year-old man was admitted after a fall with severe pelvic pain
Intervention: AVF between internal iliac artery and vein revealed during pelvic angiography, was undetected by MDCT -> AVF was successfully treated using transcatheter arterial emoblisation (TAE) with n-butyl cyanoacrylate (NBCA)
Control Intervention:
Outcomes: Patient recovered well, was discharged 4 weeks later; no complications noted at 8-month follow-up
Setting:
Method
Databank:
Research Period:
Meta-Analysis:
Results
AVF may occur as a complication of blunt pelvic bone fracture High index of angiography, as well as prompt diagnosis resulted in successful management of our patient who presented with risk factors. TAE using NBCA enables minimally invasive and effective treatment of traumatic pelvic AVF.

Annex 1: Data Extraction

Source: The application of the WSES classification system for open pelvic fractures-validation and supplement from a nationwide data bank
Aim of study
To validate the WSES classification system for pelvic injuries in open pelvic fractures, which are quite different from closed fractures
Inclusion Criteria
People: total of 830 open pelvic fracture patients
Intervention:
Control Intervention:
Outcomes:
Setting:
Method
Databank: National Trauma Data Bank (NTDB)
Research Period: NTDB 2015 dataset
Meta-Analysis:
Results
WSES guidelines can be applied to evaluate patients with open pelvic fracture with accurate evaluation of outcomes; the presence of sepsis is recommended as a supplement to WSES classification for open pelvic fractures

Annex 1: Data Extraction

Source: Surgical technique of percutaneous iliosacral screw fixation in S3 level in unstable pelvic fracture with closed degloving injury and morrell lavallee lesion: Two case reports
Aim of study
To show life threatening and very severe cases with polytrauma, that rarely survive with a good outcome, as well as describing the technique of percutaneous iliosacral screw insertion at the level of S3
Inclusion Criteria

People:
- 1st case:
  o 11-year-old boy
  o Marvin-Tile (MT) C1 pelvic fracture with sacroiliac (SI) joint disruption, skin avulsion and Morel-Lavallée lesion
- 2nd case:
  o 30-year-old male
  o Open pelvic fracture MTB2 and vertical sacral fracture Denis zone I with Morel-Lavallée lesion, intraperitoneal bladder rupture, infected laparotomy wound dehiscence

Intervention: percutaneous screws insertion on both pubic rami and IS screw on S1 and S3 to both cases; Majeed and Hannover pelvic score used to evaluate functional outcome
Control Intervention:
Outcomes: - Both patients survived and had good reduction with no residual displament on SI joint - First case presented with excellent outcome (100/100) by Majeed score and very good outcome (4/4) by Hannover score at 21-month follow up - Second case presented with good outcome (85/100) Majeed score and fair outcome (2/4) Hannover score at 18-month
Setting: Emergency Room/Emergency Operating Theater
Method
Databank: Dr. Cipto Mangunkusumo Emergency Room
Research Period:
Meta-Analysis:
Results
Percutaneous screw fixation at the level of S3 is feasible and can be inserted in S3 level by sacroiliac type and sacral type with minimal soft tissue intervention and good functional outcome

Annex 1: Data Extraction

Source: Automated Association for Osteosynthesis Foundation and Orthopedic Trauma Association classification of pelvic fractures on pelvic radiographs using deep learning
Aim of study
To develop and evaluate a deep learning algorithm to classify pelvic fractures on radiographs per the AO/OTA system Background: - Pelvic ring injuries can be caused by high-energy impacts (e.g. vehicle crashes or falls) - Pelvic radiography struggles to diagnose bleeding, but can promptly assess fracture location and extent - AO/OTA classification system grades pelvic instability, but its use in emergency settings is limited due to its complexity
Inclusion Criteria
People:
Intervention: - Retrospective analysis (at a single center) of pelvic radiographs of 773 patients with pelvic fractures and 167 patients without pelvic fractures - Categorisation of pelvic fractures by orthopedic surgeons according to the AO/OTA classification system
Control Intervention:
Outcomes:
Setting:
Method
Databank:
Research Period:
Meta-Analysis:
Results

Annex 1: Data Extraction

Source: Posterior locked lateral compression injury of the pelvis in geriatric patients: an infrequent and specific variant of the fragility fracture of pelvis
Aim of study
To describe the characteristics of posterior locked lateral compression injury (PLLCI) of the pelvic ring in geriatric patients, an infrequent fragility fracture variant and to assess the incidence and outcomes of this injury
Inclusion Criteria
People: Geriatric patients (≥ 65 years) with pelvic ring injuries
Intervention: Surgical management including pelvic brim plating with anterior external fixation
Control Intervention: Conservative treatment or anterior external fixation alone
Outcomes: Walking ability (Koval score), pain (visual analogue scale) and radiographic healing
Setting: Retrospective analysis of patients at Daejeon St Mary's Hospital, South Korea
Method
Databank: Medical records, radiographs, and CT scans of 312 patients
Research Period: January 2008 – April 2015
Meta-Analysis:
Results
- Seven patients (median age 81, 6 females, 1 male) with PLLCI were identified - All injuries resulted from low-energy trauma (fall from a standing position) - Superior rami fractures were minimally displaced; inferior rami fractures were overlapped - Five patients underwent surgery and two were treated conservatively - Patients who had pelvic brim plating with anterior external fixation showed better recovery in walking ability and pain scores - No cases of neurologic injury or other organ injuries were reported

Annex 1: Data Extraction

Source: [Recommendations for Releasing the Pelvic Binder After a Non-Invasive Pelvic Stabilisation Procedure Under Emergency Room Conditions]
Aim of study
To describe procedures for handling pelvic binders, particularly as to how to deal with an already applied pelvic binder and how to "clear the pelvic region" while reducing the risk of hemodynamic instability Systematic (?) literature review and Delphi-like discussion; One of the main causes of death in pts with major trauma is heavy bleeding, which can be caused by unstable pelvic ring fractures (what's the C problem). This is usually due to hemorrhagic shock caused by the loss of large volumes of blood from the presacral venous plexus, iliac vessels and fracture surfaces. Unstable pelvic ring injuries in the preclinical setting are usually underestimated as shown by many clinical studies. Therefore, it is recommended to apply a non-invasive external pelvic ring stabilisation (pelvic binder) if a pelvic fracture is possible. As shown in clinical and biomechanical studies, in unstable fractures there is a favourable hemodynamic effect due to rapid closure of the pelvic ring. Thus, unstable pelvic ring fractures may be radiologically and clinically overlooked, especially in unconscious patients. Additionally, in the diagnostic evaluation, the real severity of the injury may be underestimated. Unconsidered opening of the pelvic binder can thus provoke renewed deterioration of the circulatory situation, especially if the injury was adequately treated by the binder and the C problem was controlled. Following points were raised: - Assessment of the clinical situation, including trauma kinematics - Assessment of hemodynamic status - Check of the need to open the pelvic binder for diagnostic/therapeutic measures before completing all diagnostic tests - Assessment of radiology diagnostic testing and release of the pelvic region ➔ Result is a "clear the pelvis algorithm": describes structured approach according to specific criteria and which specifies the circumstances under which the pelvic binder can be opened
Inclusion Criteria
People:
Intervention:
Control Intervention:
Outcomes:
Setting: Emergency Room
Method
Databank:
Research Period: 2016
Meta-Analysis:
Results
Result is a "clear the pelvis algorithm": describes structured approach according to specific criteria and which specifies the circumstances under which the pelvic binder can be opened; Literature review advises to not "clear the pelvis if no x-rays or CT scans of the pelvis have been carried out without (or with an opened) pelvic binder

Annex 1: Data Extraction

Source: Effect of early restrictive fluid resuscitation on inflammatory and immune factors in patients with severe pelvic fracture
Aim of study
To describe procedures for handling pelvic binders, particularly as to how to deal with an already applied pelvic binder and how to "clear the pelvic region" while reducing the risk of hemodynamic instability Detailed analysis of the literature and Delphi-like discussion among several experts were performed
Inclusion Criteria
People:
Intervention:
Control Intervention:
Outcomes:
Setting:
Method
Databank:
Research Period:
Meta-Analysis:
Results
"Clear the pelvic algorithm" - Describes structured approach according to specific criteria and which specifies the circumstances under which the pelvic binder can be opened - Additional studies are needed

Annex 1: Data Extraction

Source: Optimal sequence of surgical procedures for hemodynamically unstable patients with pelvic fracture: A network meta-analysis
Aim of study
To determine the optimal sequence of surgical procedures for haemorrhage control in hemodynamically unstable patients with pelvic fractures by evaluating the safety and efficacy of different interventions using a network meta-analysis
Inclusion Criteria
People: adult patients with hemodynamically unstable pelvic fractures
Intervention: various surgical procedures, including angio-embolisation (AE), external fixation (EXFIX), and preperitoneal pelvic packing (PPP), either alone or in combination
Control Intervention: Comparison between different surgical interventions for haemorrhage control
Outcomes: - Primary safety outcome: in-hospital mortality - Primary efficacy outcome: blood transfusion volume within the first 24hrs after hospital admission
Setting: Analysis of clinical trials from multiple databases, focusing on surgical treatment of hemodynamically unstable pelvic fractures
Method
Databank: Medline (1950-January 2017); Cochrane Central Register of Controlled Trials, Embase (1974-January 2017), ClinicalTrials.gov.
Research Period: January 2000-2016 (covering trials from 2000 to 2016
Meta-Analysis: a network meta-analysis was conducted using a frequentist framework to compare the safety and efficacy of multiple interventions
Results
13 clinical trials with 24,396 participants were included Pelvic packing was found to be safest intervention, while external fixation was the most effective in controlling haemorrhage Recommended treatment sequence: 1. Initial application of external fixation 2. If hemodynamic instbalibilty persists, proceed with pelvic packing 3. Angio-embolisation is used as a complementary but not a primary alternative for hemorrhage control

Annex 1: Data Extraction

Source: Development of a pelvic discomfort index to evaluate outcome following fixation for pelvic ring injury
Aim of study
To develop a pelvic discomfort index (PDI) to evaluate outcome following fixation for pelvic ring injury
Inclusion Criteria
People: 29 female and 44 male consecutive patients; mean age: 36 years
Intervention: Internal fixation for type B1 (n=10), B2 (n=22), B3 (n=15), C1 (n=18), C2 (n=5), C3 (n=3) pelvic ring injury based on AO/OTA classification. 14-item questionnaire to assess patients discomfort in the pelvis at 6-, 12- and 24-months post-op (3 open-ended questions, responses categorised by a single assessor; remaining 11 questions were closed-ended and had 6 ordinal options from "no discomfort" (score=0) to "extremely severe discomfort" (score=5); content validity and relevance of 11 close-ended questions was determined
Control Intervention: 14-item questionnaire was compared with 36-item Short Form Health Survey (SF-36)
Outcomes: respectively at 6-, 12-, and 24-months post-op, 78%, 71% and 71% of pts completed the 14-item questionnaire The 14-items were reduced to 6 final items, including pain, walking, hip mobility, leg sensation loss, sexual life and operation scar 96% of the total variance could be explained by four factors, whereby the first factor includes the first three items (pain, walking, hip motion) all related to pelvis, whereas 3 factors involve the remaining items and address peripheral neurology, sexual life and operation scar. Using these 6 items a PDI was developed; it has high internal reliability (α=0.89), adequate content and criterion validity, and moderate correlation with the SF-36 total score or scores of physical function, bodily pain and general health (r=0.50-0.77)
Setting:
Method
Databank: Uppsala University Sweden
Research Period: September 2004 - June 2008
Meta-Analysis:
Results
During the study, 3 (pain, walking and sexual life) of the 5 items of the Majeed score proved to be relevant, however weighting system for the Majeed score remains controversial The Iowa Pelvic Score lacks a sexual life category, but pain, walking and cosmesis (operation scar) were relevant Scoring issues that were found are that the Iowa score uses arbitrary weighting and the Hannover and Orlando scores include radiographic findings but are untested The PDI that was developed during this study provides valid, specific and relevant information to assess treatment outcome following internal fixation for pelvic ring injury: - It has a high response rate, well-balanced number of items - It is easy to calculate (0-100% scale) - No weighting needed – each factor is represented by one item - Discomfort levels:

- Minimal (0-20%)
- Moderate (21-40%)
- Severe (41-60%)
- Very severe (61-80%)
- Extremely severe (>80%)

Annex 1: Data Extraction

Source: CT-guided sacroiliac percutaneous screw placement in unstable posterior pelvic ring injuries: accuracy of screw position, injury reduction and complications in 71 patients with 136 screws
Aim of study
To analyse the effectivity of computer-tomography-guided (CTG)-SPSP including accuracy of screw-placement, quality of injury-reduction and documentation of perioperative-complications Furthermore, procedure-dependent radiation-dose and outcome should be analysed Background: Sacroiliac-percutaneous-screw-placement (SPSP) for unstable-posterior-pelvic-ring-injuries (UPPRI) might be associated with severe neurovascular complications because of screw-malposition
Inclusion Criteria
People: 71 patients with UPPRI were operated by CTG-SPSP
Intervention: 136 sacroiliac screws were inserted to S1 and S2; All screws were visualised three-dimensionally post-operatively, by the use of a computerised-radiologic-work-station
Control Intervention:
Outcomes:
Setting: Trauma level 1 hospital
Method
Databank:
Research Period:
Meta-Analysis:
Results

Annex 1: Data Extraction

Source: Open pelvic fracture with bilateral common iliac arteriovenous injury successfully treated with hemicorporectomy following damage control interventional radiology in a hybrid emergency room
Aim of study
Case report To the best of the authors knowledge, this is the first case of severe open pelvic fractures with blood vessel damage, successfully treated by initial hemostasis using the helicopter emergency medical service, hybrid emergency room system, and following hemicorporectomy as a definitive care (definitive ?)
Inclusion Criteria
People: 47-year-old man with severe pelvic trauma due to a crush injury to his lower body from a wood processing machine in a furniture-manufacturing plant
Intervention: Helicopter emergency medical survive provided early intervention, including rapid transarterial embolization as damage control interventional radiology (in the hybrid emergency room), and hemicorporectomy as a multidisciplinary approach.
Control Intervention:
Outcomes: this series of treatments was lifesaving, and he was discharged home
Setting: Helicopter emergency medical service (HEMS) in Japan, Hybrid emergency room system
Method
Databank:
Research Period:
Meta-Analysis:
Results

Annex 1: Data Extraction

Source: Operative management of acetabular fractures in the elderly: a case series
Aim of study
Retrospective analysis; evaluated the medium- to long-term clinical outcomes of ORIF for the treatment of acetabular fractures in the elderly To report on patient demographics, fracture characteristics, prevalence of post-traumatic osteoarthritis and incidence of mortality in elderly patients (> 60 years of age) presenting with an acetabular fracture to a single Major Trauma Centre, managed with an open reduction and internal fixation (ORIF) (?), as well as their outcomes, primarily the risk for need for further surgery in the form of a total hip arthroplasty (THA) and factors associated with it. Furthermore, additional outcomes such as infection, avascular necrosis (AVN) of the femoral head and heterotopic ossification (HO) were also examined
Inclusion Criteria
People: total of 62 patients; age of 71.5 ± 8.04 years (14 female; follow-up 54.2 months, range 1-195 months); patients that are included are also frail with multiple co-morbidities
Intervention: Inclusion criteria: elderly patients (> 60 years) presenting with acetabular fracture requiring operative management (ORIF) Exclusion criteria: if initial management involved conservative treatment which either resulted in failure or complications necessitating surgical management, or if their care was transferred to other institutions; Patients that received simultaneous ORIF and THA (at the same treatment episode) Initial treatment: All of the patients were initially managed by the Emergency Department team, the trauma multidisciplinary team (MDT) managed high energy injuries in accordance with the ATLS principles; following initial resuscitation, imaging of the pelvis was obtained, including plain radiographs and a computed tomography (CT) scan Definitive treatment: Managed by MDT under set protocol. Patients were positioned on a radiolucent table (OSI) (supine in case of ilioinguinal or Stoppa approach, prone with traction in case of Kocher-Langenbeck approach, two stages in case of dual approach, with 5-14 days between each stage, depending on physiological state of each patient). Fixation type was the decision of the operating surgeon. Patients followed a strict physiotherapy regime postoperatively. Follow-up at 2 and 6 weeks, 3, 6, 12 months and yearly thereafter until resolution of symptoms or conversion to THA
Control Intervention:
Outcomes: In the elderly, acetabular fractures ORIF is a safe and reliable option. The relatively incidence of development of severe post-operative arthritis was 45.2%. Conversion to THA was 25.8%, with 8.1% having the arthroplasty procedure within a year of the original trauma surgery secondary to loss of reduction and early AVN. Even through HO was the most commonly observed complication (n = 9; 14.5%), only one patient required re-operation to address this. Most common mechanism of injury was road traffic accident, although in 69.4% of the cases (n = 43), the energy involved was described as low. Overall length of hospital stay (LOS) was 31.4 days (SD 22.5 days), with 39 patients (62.9%) required transfer to a higher dependency unit (HDU) or Intensive Care Unit (ICU), pre- or post-operatively or both (5.0 ± 4.9 days). Time of injury to definitive operation (ORIF) was 12.7 days (SD 31.0 days); the mean follow-up period was 54.2 months (SD 45.7 months) Regarding fracture classification, 20 patients presented with an elementary type fracture pattern, compared to 44 patients displaying an associated fracture pattern; most common combination of

associated type fractures was anterior/posterior column fractures (n = 17; 27.4%), followed by transverse type fractures (n = 7; 11.3%)
Table 4: fracture fixation combinations; most common plate combination used was one consisting of an anterior column plate, a quadrilateral plate fixation plate and cannulated screws to augment the fixation, usually in the anterior to posterior column direction
Surgical approach Table 5: single surgical approach was used in most of the cases (most common: ilioinguinal approach (n=33, 53.2%)); Kocher-Langenbeck approach used in 33% of cases (n = 21); dual approach used in 6.5% of cases; isolated percutaneous approach (cannulated screws) used in 8.1%; mean operative length of time was 203.8min (SD 101min)
Concomitant injuries, Table 6: frequent, most common were limb fractures (n = 30; 48.4%), followed by thoracic wall injuries (n = 11; 17.7%)
Postoperative complications, Table 7: Heterotopic ossification most observed complication (n = 9; 14.5%)
Table 8, Independent analysis of potential factors associated with an increasing probability of requiring a THA at a secondary stage: no statistical significance was found -> further examined into a multivariable logistic regression analysis model to adjust for confounders between the independent factors, which did not reveal any statistically significant associations either; additional factors were independently examined to investigate their association with development of HO as a significant pot-operative complication, with the use of ilioinguinal was the only factor associated with a statistically significant increased risk of developing HO (p = 0.010; OR 32.06; 95% CI 2.27-468.79)
Kaplan-Meier survival analysis: effect of fracture pattern (Associated vs Elementary) and mechanism of injury energy (High vs Low energy) on the cumulative probability of requiring a THR
Median time to a THR in patients with an elementary fracture pattern was 80.3 months (95% CI 51.9-108.6) compared to 105 months (95% CI 68.q-141.9) in those with an associated fracture pattern; there was no statistically significant difference in the cumulative survival probability in requiring a THA in future [Log-rank test (Mantel-Cox): p = 0.104]; Mechanism of injury (high versus low energy) also demonstrated no association [Log-rank test (Mantel-Cox): p = 0.104]
Median post-operative survival following an acetabular fracture treated with ORIF: 90.1 months (95% CI 72.9-107.2)

Setting: Level I Trauma Centre

Method

Databank: University of Leeds / Leeds General Infirmary
Data used included patient demographics and comorbidities, mechanism of injury, time to theatre, operation details, complications (local and systemic), outcomes, length of hospital stay (LOS) and mortality
Fractures were classified according to Letournel classification

Research Period: January 2003 – February 2016

Meta-Analysis:

Results

Rate of conversion to THA following acetabular ORIF was 25.8% (n = 16), which is comparable to the re-operation rates from studies by Khoshbin et al. and Navarre et al.
Additional post-operative complication rates: 9 patients developed HO, 2 patients developed early AVN, 3 patients reported surgical site infection, loss of reduction in 3 patients, post-operative nerve palsy (all involved lateral cutaneous nerve of the thigh, following an ilioinguinal approach)
Study by Weaver et al. identified a trend for higher reoperation rates in the ORIF group in terms of a secondary THA, however, it did point out a higher complication rate in terms of infection/dislocation when compared to THAs performed for osteoarthritic changes (although SSI

was noted in this study's patient cohort, only one patient required a re-operation as a result)

All 16 patients undergoing THR received cemented components, with only one patient having a constrained cup because of compliance issues and high risk of dislocation;
Complication rate of this THA group is comparable with that of the literature (one patient undergoing revision because of deep infection, one patient having chronic dislocation (secondary to aseptic cup loosening, which was managed conservatively as not fit for revision surgery); one patient sustaining a minimally displaced Vancouver B2 periprosthetic fracture (managed conservatively)

Multivariate analysis model: did not identify any factors associated with progression to THA following acetabular ORIF, which contradicts the findings from a study by Rollman et al. which suggested that increasing by one year, fracture displacement by 1mm, involvement of the posterior wall, or contusion/impact of the femoral head were all independently associated with increased risk of need for a subsequent THA procedure (above study did not have any age restrictions; therefore not necessarily applicable to the elderly population); only association noted was increased risk of development of HO following ilioinguinal approach

Study demonstrates that neither fracture pattern nor complexity, nor mechanism of injury had any effect on the risk for need for a THA as a delayed procedure

Literature review: to evaluate latest outcomes of treatment, identified six studies published between 2018 and 2022 relevant for acetabular fracture treatment outcomes

This study provides a detailed long-term post operative record for acetabular fractures in elderly patients; ORIF is a safe and viable option in selected elderly patients, with comparable outcomes to simultaneous THA

Limitations: absence of PROMs; small sample size -> might mask certain effects

To compare conservative treatment, ORIF, and ORIF + THA with clinical and patient-reported outcomes, a well-designed multicentre RCT is needed

Annex 1: Data Extraction

Source: Using the Starr Frame and Da Vinci surgery system for pelvic fracture and sacral nerve injury
Aim of study
To provide a new method for fracture reduction and percutaneous fixation as well as use of Da Vinci surgery system for late-onset sacral nerve neurolysis To establish a method of approach and neurolysis for this complex disease; alternative strategy for use in trauma patients
Inclusion Criteria
People: Woman with multiple injuries caused by traffic accident; on admission diagnosed with pelvic fracture, bilateral pulmonary contusions, dislocation of right shoulder, dislocation of left elbow; Tile classification: Type C3 pelvic fracture; including Denis II sacral fracture on the right side, sacroiliac joint dislocation on the left side, bilateral pubic rami and ischial ramus fractures; Fracture fragment compression in S1 sacral foramen; Numbness in posterolateral region of right thigh and lateral aspect of right foot; normal motor function
Intervention: Stabilised by blood transfusion and use of pelvic binder 3 days after admission: operation, Starr Frame (modified; additional arc stick to reduce "open-book" injury, in which the arc center coincides with sacrum center; reduction along arc to avoid over-reduction or insufficient reduction of sacroiliac joint; pelvic ring underwent closed reduction and was fixed with placement of percutaneous transsacral-transiliac screw under general anesthesia)
Control Intervention:
Outcomes: Post-op: good condition; numbness had been relieved in posterolateral right thigh and lateral right foot; neurotrophic agents and detumescent and analgesic drugs were used for patients symptoms 7 days post-op: discharged; free to sit and turn over 4 weeks: post-op: weight bearing as tolerated; started rehabilitation exercises 3 month follow up: neurological numbness and pain in plantar and lateral regions of right foot; consecutive treatment (effective): Mecobalamin and neurotrophin 2 year follow-up: numbness and pain in plantar and lateral regions of right foot had worsened, affected patients sleep; motor function was not affected
Setting:
Method
Databank:
Research Period:
Meta-Analysis:
Results
Reduction strategy: - Pelvic fracture: reduced posterior ring (with Starr Frame in coronal plane, sagittal plane, transverse plane) and then anterior ring (LC-II Schanz pin) o Modified Starr Frame: adding arc bar in the front, which the center was in middle of sacrum -> in this way, rotation reduction can be manipulated by moving LC-II Schanz pin along with the arc bar and will not cause anterior or posterior

displacement
    - In this case there was no superior or inferior displacement -> only reduction of sagittal and transverse planes were needed
    - Forward traction by implanting a 4mm LC-II Schanz pin in left side to reduce sagittal plane displacement and rotation under the inlet view
    - Then, lateral traction (to reduce out-shift of the right side sacral fragment in front of the S1 sacral foramen)
    - Anterior reduction using LC-II Schanz pin
- Starr Frame is very helpful for closed reduction percutaneous fixation in complex pelvic fracture, but rarely works in sacral fracture segment reduction

Fixation strategy:
- Rigid fixations required in Tile C type fracture with sacroiliac joint dislocation on one side and sacral fracture on the other side
- Computer- and robot-assisted system (2D navigation and optical tracking system) used to implant percutaneous transsacral-transiliac screw (hollow screw 7.3mm, S1 screw length 155mm, S2 screw length 140mm) without compression
    - Control part, optical tracking part, robot arm part
    - Only inlet and outlet views of pelvis were needed with assisted system; transferred for surgical planning
    - Optical tracking system can guide the robot arm to right position through marker on the pelvis and inlet and outlet views with marker
    - Surgeon made a percutaneous screw fixation plan on the computer; the robot arm will move guider to correct position for percutaneous transsacral-transiliac screw without fluoroscopy
    - Surgeon only needs to drill into the guide wire and implant screw
    - Second, the anterior pelvic ring underwent closed reduction and internal fixation with INFIX (anterior subcutaneous pelvic fixator)
    - Surgery: 2h, 200ml of blood loss

Physical examination and image of CT scan
- Patient complained of numbness and aggressive pain of right foot
- Motor function normal, sensory function impaired
- Electromyography examination: abnormal nerve conduction velocity
- Pelvic CT scan:
    - Good positioning of the transsacral-transiliac screw and a proper tunnel for S1 nerve on injury side
    - However, large amount of scar tissue was present in front of S1 sacral foramen with multiplanar CT reconstruction nerve scan

Neurolysis strategy:
- Conclusion: scar tissue around nerve had compressed S1 nerve and aggravated the patients symptoms
- Conservative treatment (6 months) for incomplete sacral nerve injury:
    - Symptoms are getting worse and affect sleep of patient
- Da Vinci surgery system: sacral nerve exploration and neurolysis
    - Explored S1 nerve and found large amount of scar tissue in front of S1 sacral foramen -> adhesions were removed and sacral nerve was relieved
    - 3h surgery, 50ml blood loss
    - Day after surgery: patient reported numbness and pain had been relieved
    - 3 days post-op: patient was discharged, returned to work
    - 1- and 3-month follow-ups: numbness and pain had not recurred, patient reported

good function and sensation

Starr Frame is effective for closed reduction and percutaneous fixation but has limitations in anterior ring reduction;
Modification of Starr Frame with arc stick improves anterior ring reduction and prevents over- or under-reduction of sacroiliac joint fractures
TINAVI robot-assisted surgery was used to implant transsacral-transiliac screws, reducing surgery and fluoroscopy times with precise screw placement
Sacral fracture and nerve injury treatment remains controversial:

- Conservative treatment (6-8 weeks) often ineffective
- Early decompression is recommended for crush injuries
- Multiplanar CT and clinical exams are crucial for diagnosis
- Conservative treatment (3 months) is advised if nerve is not fully ruptured, but delayed neurolysis becomes more difficult

Da Vinci robotic system:

- Well-suited for sacral nerve decompression and sacral fracture reduction, because of minimal blood loss, reduced operative trauma, shorter surgery time and clearer surgical view

Study limitations:

- Limited case numbers for Da Vinci surgery neurolysis, this being the first reported case
- Long learning curve and technically demanding
- For better outcome evidence more comparative studies between laparoscopic and Da Vinci surgery are needed

⇨ Computer- and robot-assisted surgery with Starr Frame is very helpful for closed reduction percutaneous fixation
⇨ Da Vinci surgery system has great advantages for minimally invasive neurolysis of sacral nerve and electrocoagulation for hemostasis in pre-sacral space
⇨ Combination of those methods could be an alternative for pelvic fracture and sacral nerve injury; authors believe it will become more beneficial for orthopedic surgeons in the near future

Annex 1: Data Extraction

Source: In-screw cement augmentation for iliosacral screw fixation in posterior ring pathologies with insufficient bone stock
Aim of study
To report in detail a new technique combining iliosacral screw fixation with in-screw cement augmentation (ISFICA); report outlines easy technique for cement augmentation using regular screws and bone cement without the need of special implants like bars or fenestrated screws; Describing a promising technique for treating pelvic ring fractures in patients with weak bone stock, combining cement augmentation and minimally invasive screw placement Background: Minimal invasive screw fixation is common for treating posterior pelvic ring pathologies, but lack of bone quality may cause anchorage problems Insufficiency fractures in elderly people sometimes require percutaneous posterior ring fixation -> screw migration is a common problem in this patient population (multiple reasons: steel screws do not really incorporate in bone and are prone to dislocation; osteoporotic bone offers only little resistance to screw pullout forces; patients are often not able to partially bear weight, which further enables screw dislocation before healing of fracture can occur)
Inclusion Criteria
People: 20 consecutive patients (11 female, 9 male) treated with ISFICA; mean age was 74.4 years (range 48-98) Young classification In four cases, an S1 osteolytic metastasis with impending fractures and three patients with sacral insufficiency fractures due to osteoporosis were included In nine patients, osteoporosis was diagnosed prior to admission (two had acquired osteoporosis due to prednisone therapy after solid organ transplantation) All patients received preoperative CT scan of pelvis (for evaluation of bone stock of posterior pelvic ring) Pain evaluation: VAS score pre-op, post-op and after 6 weeks Intraoperative complications were noted Mobility of patients and duration of in-hospital stay, as well as newly appeared neurological dysfunctions, were additional outcome parameters; if available, late complications were noted in outpatient clinic
Intervention: To guide the fully threaded screw, a K wire was inserted under inlet-outlet view Screw placement in adequate position Cement applied through bone filler device, inserted at the screwdriver Intraoperative CT scan for immediate control of cement distribution, accurate screw placement and potential leakage Clinical evaluation of post-op neurological deficits, pain reduction and immediate post-op mobilisation
Control Intervention:
Outcomes: Implantation of 26 screws All patients were post-op instantly mobilised with reduced pain No neurologic deficits apparent; no cement leakage One case of breach of iliac cortical bone due to severe osteoporosis; One screw migration (after 1 year) and two patients showed iliosacral joint arthropathy, which led to screw removal

Setting:

Method

Databank: data collected prospectively and analysed retrospectively

Research Period: December 2013 and December 2014

Meta-Analysis:

Results

ISFICA is a very promising technique in terms of safety, precision and initial postoperative outome
Long-term outcomes (e.g. lasting mechanical stability or pain reduction and screw loosening despite cement augmentation) needs to be investigated in further studies with larger patient numbers
26 screws were implanted according to above mentioned surgical protocol; mean surgery time was 45.25min (range 30-100min)
Four patients initially received conservative treatment for an average of 4 ± 2 days before undergoing surgery
One case of screw intrusion into iliac bone occurred due to severe osteoporosis, but surgery proceeded as planned
No cement leakage or screw mispositioning was observed
All patients were mobilised postoperatively with reduced pain and full weight-bearing under physiotherapy supervision
Five patients used crutches for better gait balance
Average hospital stay: 13 ± 5 days
No new neurological deficits were observed post-op
Two patients required screw removal due to iliosacral arthropathy (after 6 and 8 months)
One case of screw migration occurred after 1 year due to severe osteoporosis

- ⇨ Using transiliosacral bars or longer screws engaging the sacrum improves fixation in osteoporotic bone
- ⇨ Combining cement augmentation with osteosynthesis enhances screw fixation, as shown in biomechanical studies
- ⇨ Cement-Augmented Iliosacral Screws: Technique described by Wähnert et al. allows cement discharge via perforations after screw placement; other approaches inject cement before final screw placement via Jamshidi needles or cannulated screws – Results: immediate pain relief, mobilisation, and no perioperative complications in studies using 3D navigation
- ⇨ Study aligns with prior results, confirming reliable screw placement and accurate cement deposition
- ⇨ Risk: screw intrusion through cortical bone highlights the need for careful reinsertion in weak bone stock
- ⇨ Proposed improvement: cement application after final screw placement to reduce weakening of screw purchase
- ⇨ Visualisation Methods: study used C-arm fluoroscopy, proving effective but debated against 3D navigation or CT guidance
- ⇨ Expert opinion suggests experienced surgeons can safely use C-arm fluoroscopy for screw placement
- ⇨ Advantages: short surgery time, minimal ventilation risks, and immediate pain relief with mobilisation
- ⇨ Limitations: need for long-term research on screw pull-out rates and lasting pain reduction
- ⇨ ISFICA is fast, reliable, minimally invasive for pelvic ring fractures in osteoporotic patients

Annex 1: Data Extraction

Source: Fluoroscopy guided teardrop technique for open trans-muscular iliac screw placement and open reduction maneuvers during modified triangular spinopelvic fixation for unstable U-shaped sacral and tile C pelvic traumas: technical note
Aim of study
Technical note, specific surgical technique for complex pelvic trauma is being described; open trans-muscular iliac screw placement using a fluoroscopy-guided teardrop view; treating unstable U-shaped sacral fractures and Tile C pelvic ring injuries
Inclusion Criteria
People: 40-year-old male patient; highspeed bike accident Admission: GCS of 15, proximal function pain-related motor deficit of lower limbs 2/5 on modified Medical Research Council scale CT scan: - Anterior pelvic ring disruption - Comminute right iliac fracture with active bleeding - Fractures in both forearms - Unstable AO Spine B3 fracture at T12-L1 without spinal cord compression - Unstable Tile C vertical shear pelvic ring injury with spinopelvic instability Emergency orthopedic management: Hemostatic fixation of right iliac crest, as well as surgical fixation of right forearm and casting of left forearm
Intervention: Fluoroscopy setup: ensure bilateral iliac oblique outlet views possible (30° cranial, 40° lateral tilt) for teardrop alignment Lower lumbar fixation with posterior pedicle screws placed at L4-L5 (possibly L3 or S1 as well if needed) Posterior superior iliac spine and iliac crest are identified and exposed Pedicle probe is guided to center of teardrop and screw is inserted under continuous fluoroscopy; it must be ensured that the screw head is recessed within bone cubicle Same approach to contralateral screw insertion Iliac connectors are linked to iliac screws; curved rods span from lumbar to iliac hardware Reduction maneuvers: Distraction between iliac connector and lumbar screw for correction of vertical displacement; Contraction between iliac connector and iliac screw for correction of horizontal displacement; using intraoperative Matta criteria, reduction is confirmed Supplementary stabilisation: For additional horizontal stability, transverse connectors are placed between lumbar rods
Control Intervention:
Outcomes: Issue of iliac screw heads may become prominent over time (due to weight loss for example): might cause skin tension and eventually skin ulcer over time -> frequent indication of hardware removal ➔ Schildhauer describes recessing a sufficiently large bone cubicle at iliac tubercle to hide the iliac screw head below the level of iliac crest Biomechanical efficiency of the spinopelvic junction might be jeopardised by improper reduction

of the bone arches of the pelvis -> could cause long-term orthopaedic disability during standing position and walking Displaced bone fragments pointing toward the skin (e.g. posteriorly displaced U-shaped sacral fractures -> might cause skin tension and then skin ulceration
Setting:
Method
Databank:
Research Period: 2023
Meta-Analysis:
Results
Such heavy and technical procedure still is rarely encountered in daily clinical practice, but for surgical management of unstable traumas of the spinopelvic junction, the triangular spinopelvic construct is getting popular Choice between open and percutaneous spinopelvic construct should be left at discretion of operating surgeon

Annex 1: Data Extraction

Source: Effect of Early Pelvic Binder Use in the Emergency Management of Suspected Pelvic Trauma: A Retrospective Cohort Study
Aim of study
Retrospective cohort study; To evaluate the effectiveness of early pelvic binder use in the emergency management of suspected pelvic trauma/suspected high risk of pelvic bleeding from blunt force pelvic fractures, compared with the conventional stepwise approach
Inclusion Criteria
People: Total of 204 patients with high-energy multiple trauma Patients with trauma injury/any type of pelvic fractures confirmed by radiological imaging (e.g. pelvic X-ray, CT scan) in accordance with new protocol (Figure 1) emphasising early use of pelvic binder performed by ED physicians for trauma patients with suspected pelvic injury were included Study group: patients admitted to the ED with traumatic injury requiring activation of the trauma team and one of the following risk factors: - Loss of consciousness or Glasgow coma score (GCS) of <13 points - Systolic blood pressure (BP) of <90mmHg - Injury due to falling from a height of 6m (second floor) - Injury to multiple vital organs and/or - Suspected pelvic injury
Intervention: Pelvic binders: used to stabilise pelvic fractures in patients with trauma injury in accordance with ATLS guidelines from ACS Committee on Trauma; use of SAM Pelvic Sling -> commercially available, circumferential pelvic binder (made of tightly woven cloth in a ratcheting belt design); to achieve uniform, high-pressure, circumferential compression ➔ Applied immediately after patients arrival in ED and was removed after possibility of pelvic fracture was excluded by radiological imaging or until a definitive pelvic fracture fixation by an orthopedic surgeon <u>Multivariate logistic regression analysis:</u> To assess independent impact of pelvic binder use on treatment outcome (adjusted for age, gender, GCS, initial vital signs (blood pressure, respiratory rate, pulse rate), RTS, ISS, angiography for transcatheter arterial embolization (TAE), AIS, pelvic fracture types ➔ Results were presented as mean with standard deviation (SD), proportions, odds ratio (OR); probability (p) value < 0.05 considered statistically significant
Control Intervention: Control group: patients between January 2011 and July 2013; pelvic binders applied after clinical or radiological confirmation of pelvic fracture Routinely recorded: demographic characteristics, initial vital signs in ED (blood pressure, respiratory rate, pulse rate), revised trauma score (RTS), injury severity scale (ISS) score, volume of transfused blood in first 24h, ICU length of stay, percentage of patients in each group with abbreviated injury score (AIS) of ≤ 3 and hospital length of stay Comparison to study group: complications related to pelvic binder use, ho long to find out about any complications, duration a patient wore a pelvic binder, time taken to receive an external fixation, number of patients receiving pelvic surgery, time taken to receive an open reduction and internal fixation (ORIF)

Outcomes:
Recommendation: prompt pelvic binder use for suspected pelvic injury before definitive imaging is available, as a cervical spine collar is used to protect the cervical spine from further injury prior to definitive identification and characterisation of an injury

Setting: Level I trauma center in North Taiwan

Method

Databank:

Research Period: August 2013 – July 2014

Meta-Analysis:

Results

Study group: 56 patients (with trauma injury and pelvic fractures confirmed by radiological imaging who had received early use of pelvic binder)
Control group: 148 patients (suffered from trauma injury and pelvic fractures confirmed by radiological imaging and then received use of a pelvic binder)

- ➔ No significant differences in patient age, gender, hospital length of stay, ICU length of stay, RTS, ISS score, percentage of systolic blood pressure < 90mmHg, GCS, percentage of AIS ≤ 3, angiography for TAE, type of pelvic fracture, treatment outcome between groups
- ➔ Patients with suspected pelvic fractures with initial placement of a pelvic binder achieved significantly improved survival than those for whom a pelvic binder was not initially used - but this tendency did not reach statistical significance
- ➔ No statistically significant differences between these two groups, trauma patients with suspected pelvic fractures that were initially stabilised with a pelvic binder had shorter hospital and ICU stays (16.11 ± 12.54 vs. 19.55 ± 26.14 days and 5.33 ± 5.42 vs. 8.36 ± 11.52 days)
- ➔ AIS, hypotension, fracture classification: more severe in those patients for whom suspected pelvic fractures were initially stabilized with a pelvic binder
- ➔ Average volume of transfused blood in the first 24 h was significantly lower for patients who were initially stabilized with a pelvic binder (2462 ± 2215 mL vs. 4385 ± 3326 mL, respectively; $p < 0.01$) (Table 1)
- ➔ Complications of using pelvic binder: no statistically significant differences between these two groups, but trauma patients with initially stabilised with a pelvic binder had a longer time to find complication (42 ± 8 vs. 57 h; $p = 0.08$) (Table 2)
- ➔ Multivariate logistic regression: after adjustment for potential confounders, incl. percentage of systolic blood pressure < 90mmHg in the ED, respiration rate at arrival, volume of transfused blood in the first 24h, because they reached or were near statistical significance, a univariate analysis showed a tendency of shorter ICU LOS for group with s uspected pelvic fractures that were initially stabilized with a pelvic binder, but this tendency did not reach statistical significance (OR, 0.95; $p = 0.269$). After adjustment for the influence of confounders, the group with suspected pelvic fractures initially stabilized with a pelvic binder achieved significantly lower mortality in multivariate analysis (OR, 0.00326; $p = 0.039$) (Table 3)

Pelvic fractures account for ~3% of skeletal fractures but can have high mortality (10-50%) when associated with other injuries
Pelvic instability should only be tested once to avoid dislodging blood clots and worsening hemorrhage
Pelvic binders are recommended for early, noninvasive stabilization to reduce bleeding and pelvic volume
Primary hemorrhage source: venous bleeding (arterial bleeding is less common but more severe)

Pelvic binders:
Compression and tamponade reduce venous bleeding
Do not effectively stop arterial bleeding deep in pelvic tissues
Are useful for early resuscitation and pre-hospital care
Should only be used short term to avoid skin/tissue damage
CT scans: helpful to determine the need for angioembolization; might delay critical interventions
Angioembolisation guided by intravenous contrast extravasation (ICE) on CT; targets arterial bleeding, but only useful in 3-10% of pelvic fractures

Pelvic binders compared to external fixation show no statistical significant difference in this study, but trend suggest benefit, since transfusion requirements, hospital stay and mortality are reduced with binders

Limitations:
Few potential limitations -> single-center experience, may reflect local patient characteristics
More studies might be needed to support conclusions of this study, since retrospective studies, unmeasured or unknown variables may be responsible for effects seen and subsequent conclusions formulated

Conclusion:
Recommendation for early pelvic binder use if pelvic injury is suspected before definitive imaging is available -> because of ease of application, noninvasive tool, relatively inexpensive cost, low potential for complications, and benefit to pelvic stability

Annex 1: Data Extraction

Source: Machine learning model based on radiomics features for AO/OTA classification of pelvic fractures on pelvic radiographs
Aim of study
To develop a radiomics-based machine learning algorithm to quickly diagnose fractures on pelvic x-ray and classify their instability
Inclusion Criteria
People: 990 adults aged 18 or older, diagnosed with pelvic fracture and 200 patients without pelvic fracture each received a pelvic radiography before and after imaging (anteroposterior pelvic radiograph AP x-ray)
Intervention:
Control Intervention:
Outcomes:
Setting: Gachon University Gil Hospital
Method
Databank:
Research Period: January 2015 – December 2020
Meta-Analysis:
Results
Limitations: - Retrospective study - Analysis was performed using pelvic x-ray images, cases where fracture site was not clearly indicated because of bowel gas located in pelvis or other organs in the pelvis -> therefore, posterior surface of pelvic ring (sacral fracture or sacroiliac joint widening) may not have been clearly analysed - AO/OTA classification classifies fracture patterns based on location of fracture and vertical and rotational instability of pelvic ring -> radiomics-based machine learning analysis has limitations in reflecting three-dimensional information such as vertical and rotational instability - Elderly patients may have developed osteoporosis -> texture of fracture in x-ray may differ - Analysis was performed regardless of age, care must be taken when interpreting/generalising results Unlike with existing classification methods, this study was able to classify normal pelvis and pelvic fractures of types A, B, and C, as suggested by AO/OTA classification, through feature selection and machine learning algorithms Ten features that contributed to this classification were identified Study to classify and extract features of each bone by dividing each bone constituting the pelvic ring in more detail is needed If performance is improved through additional research it will be of great help in developing a pelvic fracture diagnostic aid system

Annex 1: Data Extraction

Source: The impact of external fixation on mortality in patients with an unstable pelvic ring fracture: a propensity-matched cohort study
Aim of study
Databank used to identify isolated unstable pelvic ring fractures to exclude the possibility of blood loss from other injuries, and analysed the effectiveness of EF on mortality in this group of patients Background: no adequate evidence to establish whether external fixation (EF) of pelvic fractures leads to a reduced mortality
Inclusion Criteria
People: 1163 patients who had been treated for an isolated unstable pelvic ring fracture with (386 patients) or without (777 patients) EF Isolated pelvic ring: defined by an Abbreviated Injury Score (AIS) for other injuries of < 3 Unstable pelvic ring fracture: AIS ≥ 4
Intervention: Primary outcome: mortality Subgroup analysis: carried out for patients who required blood transfusion within 24h of arrival in ED and those who had massive blood loss Propensity-score matching: to identify cohort like EF and non-EF groups
Control Intervention:
Outcomes: 346 patients were matched with the use of propensity-score matching using the completed data When the propensity-score matching was adjusted, EF was associated with a significantly lower risk of death ($p = 0.047$) Subgroup analysis: EF associated with a significantly lower risk of death in patients who needed blood transfusion within 24h ($p = 0.014$) and in those with massive blood loss ($p = 0.016$)
Setting:
Method
Databank: Japan Trauma Data Bank database
Research Period: 2018
Meta-Analysis:
Results
Use of EF to treat unstable pelvic ring fractures was associated with a significantly lower risk of death, especially in patients with severe fractures

Annex 1: Data Extraction

Source: Less invasive lumbopelvic fixation technique using a percutaneous pedicle screw system for unstable pelvic ring fracture in a patient with severe multiple traumas
Aim of study
Case report To report a successful case of treating an unstable ring fracture using a less invasive posterior fixation technique in a polytrauma patient
Inclusion Criteria
People: 81-year-old woman; sustaining multiple traumatic injuries including an unstable pelvic ring fracture (fractures of bilateral sacrum with right sacroiliac disruption, right superior and inferior pubic rami, left superior pubic ramus, and ischium) in a traffic accident

Intervention:
Bilateral external fixation as initial emergency stabilisation
Less invasive posterior fixation technique with iliac screws, rods, lumbopelvic fixation with percutaneous pedicle screws as surgical stabilisation
- Emergency surgery: bilateral external fixation applied to iliac crest -> to stabilise pelvic ring
- 2nd and 3rd surgeries 11 and 18 days after first surgery to treat multiple fractures
  o 3rd surgery: less invasive posterior fixation technique to stabilise pelvic ring fracture surgically
  ▪ 2 iliac screws inserted on each side following an 8cm midline posterior incision from the S1 to S3 spinous process, with subcutaneous tissue detached from the fascia of paraspinal muscles
  ▪ S2 spinous process was removed, 2 rods were connected to bilateral iliac screws to stabilise bilateral ilium in switchback fashion
  ▪ To connect 2 rods at base of S2 spinous process a crosslink device was applied
  ▪ Percutaneous pedicle screws inserted into L4 and L5 vertebral bodies on both sides and connected to the cranial rod connecting the bilateral iliac screws -> completing lumbopelvic fixation

Control Intervention:
Outcomes: Post-op complications: none 10-month follow up: bone union achieved at superior ramus of pubis Pain-free, returned to preinjury daily activity level
Setting:
Method
Databank: single case report
Research Period: not specified; 10-months follow-up post-op
Meta-Analysis:
Results
Less invasive posterior fixation technique provided sufficient stabilisation for unstable pelvic ring fracture -> full recovery without complications

Annex 1: Data Extraction

Source: 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
Aim of study
To compare the outcome after CHP or ORIF alone Background: In the elderly, displaced, comminuted acetabular fractures are increasingly common, but there is no consensus on whether they should be treated non-surgically, surgically with open reduction and internal fixation (ORIF), or with acute total hip arthroplasty (THA) "Combined hip procedure" (CHP): combination of ORIF and acute THA
Inclusion Criteria
People: Total of 27 patients with similar acetabular fractures (severe acetabular impaction with or without concomitant femoral head injury) Mean age of 72.2 years (50 to 89); followed for a minimum of 2 years
Intervention: 14 were treated with ORIF alone; 13 were treated with CHP Estimation of hip joint and patient survival Assessment of operating times, blood loss, radiological outcomes and patient-reported outcomes
Control Intervention:
Outcomes: CHP group: - No patient required further hip surgery; THA: survival rate of 100% (95% confidence interval (CI) 100 to 100) after three years - No dislocation or deep infections ORIF group: - 28.6% hip joint survival (85% Cl 12.5 to 65.4; p = 0.001) Patient-reported outcomes: no relevant differences Within the first year after index surgery no patient died, but lower patient survival in the CHP group after three years
Setting:
Method
Databank:
Research Period:
Meta-Analysis:
Results
Further use of, as well as larger prospective studies on, the CHP, are encouraged based on the findings of this study - CHP confers considerably reduced need of further surgery when compared with ORIF alone in elderly patients with complex acetabular fractures

Annex 1: Data Extraction

Source: [Quality of operative treatment of pelvic fractures is not influenced by an additional abdominal injury: A monocentric registry study]
Aim of study
Monocentric study To investigate whether quality of operative treatment for pelvic fractures is affected by the presence of an additional abdominal injury
Inclusion Criteria
People: 185 patients, among which 48 had additional abdominal injuries Surgically treated Tile type B or C pelvic fractures
Intervention: Open or closed reduction and internal fixation as surgical treatment of pelvic fractures
Control Intervention: Comparison between patients with pelvic fractures with versus without additional abdominal injuries
Outcomes: Matta scoring system was used to measure fracture reduction quality Duration of mechanical ventilation Length of hospital and ICU stay Overall injury severity (ISS) Mortality and revision surgery rate
Setting: Single Level-I trauma center
Method
Databank: Institutional pelvic fracture database, Germany
Research Period: 2003 - 2019
Meta-Analysis:
Results
Patients with abdominal injuries: longer ventilation times and longer ICU stays No significant difference (between patients with or without abdominal injuries): - Quality of fracture reduction - Overall mortality and revision surgery rates Presence of abdominal injury did not compromise quality of pelvic fracture fixation

Annex 1: Data Extraction

Source: [Hip arthroscopy after luxatio obturatoria. With contralateral unstable pelvic ring fracture]
Aim of study
Case Report To evaluate feasibility and outcomes of this approach of hip arthroscopy after obturator hip dislocation (luxatio obturatoria) with contralateral unstable pelvic ring fracture
Inclusion Criteria
People: 39-year-old male patient; motorcycle accident
Intervention: Hip arthroscopy (right hip): - Assess cartilage damage - Remove intraarticular fragment Open reduction and internal fixation of contralateral pelvic ring fracture
Control Intervention:
Outcomes: Intraarticular fragment was successfully removed Harris Hip Score: 94 -> 1 year post-op MRI: mild post-traumatic changes, slight cartilage wear, no major complications or AVN
Setting: Hospital in Germany
Method
Databank:
Research Period: Case treated in 2020; one year post injury follow-up period
Meta-Analysis:
Results
Even in complex trauma situations as reported in this case, hip arthroscopy can be safely performed -> permitting effective treatment of intraarticular pathology and achieving good clinical outcomes

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37277572	Early experience with resuscitative endovascular balloon occlusion of the aorta for unstable pelvic fractures in the Republic of Korea: a multi-institutional study	Kim DH, Moon J, Chang SW, Kang BH.	Eur J Trauma Emerg Surg. 2023 Dec;49(6):2495-2503. doi: 10.1007/s00068-023-02293-x. Epub 2023 Jun 5.	Kim DH	Eur J Trauma Emerg Surg	2023	6/5/2023			10.1007/s00068-023-02293-x
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26508436	Retroperitoneal packing or angioembolization for haemorrhage control of pelvic fractures--Quasi-randomized clinical trial of 56 haemodynamically unstable patients with Injury Severity Score ≥33	Li Q, Dong J, Yang Y, Wang G, Wang Y, Liu P, Robinson Y, Zhou D.	Injury. 2016 Feb;47(2):395-401. doi: 10.1016/j.injury.2015.10.008. Epub 2015 Oct 22.	Li Q	Injury	2016	10/29/2015			10.1016/j.injury.2015.10.008
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30443777	Clinical and radiological short-term outcomes of pubic symphysis diastasis treated with modified pedicle screw-rod fixation	Wang J, Cao L, Wu J, Wang Q, Bi C.	Eur J Trauma Emerg Surg. 2020 Aug;46(4):865-871. doi: 10.1007/s00068-018-1050-4. Epub 2018 Nov 15.	Wang J	Eur J Trauma Emerg Surg	2020	11/17/2018			10.1007/s00068-018-1050-4
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38404697	Operative management of sacroiliac joint dislocation in children with unstable pelvic fractures - A STROBE-compliant investigation	Wang Y, DU X, Tomaszewski R, Journeau P, Mayr J.	J Orthop. 2024 Feb 14;52:6-11. doi: 10.1016/j.jor.2024.02.004. eCollection 2024 Jun.	Wang Y	J Orthop	2024	2/26/2024	PMC10881409		10.1016/j.jor.2024.02.004

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