

**Thesis**

**Lumbopelvic Fixation And Its Limitations After  
Unstable Pelvic Ring Injury**

Submitted by

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*Hart bei Graz, am 24.01.2022*

*Florian Trummer eh.*

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# Table of contents

<b>Acknowledgements</b> .....	<b>I</b>
<b>List of figures</b> .....	<b>IV</b>
<b>Zusammenfassung</b> .....	<b>V</b>
<b>Abstract</b> .....	<b>VII</b>
<b>1 Introduction – Theoretical Background</b> .....	<b>1</b>
<b>1.1 Anatomy of the pelvis</b> .....	<b>1</b>
1.1.1 Os Coxae .....	2
1.1.2 Ilium .....	2
1.1.3 Ischium .....	3
1.1.4 Pubis .....	3
1.1.5 Sacrum .....	3
1.1.6 Coccygis .....	4
<b>1.2 Important ligaments and joints in the pelvic region</b> .....	<b>5</b>
1.2.1 Pubic symphysis.....	5
1.2.2 Sacroiliac joint .....	5
1.2.3 Lumbosacral joint .....	6
<b>1.3 Sacrococcygeal articulation</b> .....	<b>7</b>
<b>1.4 Mechanical properties of the pelvis</b> .....	<b>8</b>
1.4.1 Mechanical properties of the pelvis, when standing.....	9
1.4.2 Mechanical properties of the pelvis, when sitting .....	10
1.4.3 Mechanical properties of the pelvis, when walking .....	10
<b>1.5 The muscles of the pelvis</b> .....	<b>11</b>
1.5.1 Muscles of the back.....	11
1.5.2 Abdominal muscles.....	11
1.5.3 Muscles of the hip .....	12
1.5.4 Muscles of the thigh .....	13
1.5.5 The pelvic floor .....	14
<b>1.6 The vascular system in the pelvic region</b> .....	<b>15</b>
1.6.1 Arteries .....	15
1.6.2 Veins .....	16
1.6.3 Lymphatic vessels .....	16

1.7	The nervous system in the pelvic region.....	17
1.8	Different types of pelvic ring injuries according to the “AO/OTA Fracture and Dislocation Classification” .....	20
1.9	Acute treatment of pelvic ring injuries .....	21
1.10	Treatment of different types of pelvic ring injuries according to the “AO/OTA Fracture and Dislocation Classification” .....	23
1.11	Epidemiology of pelvic ring fractures .....	26
<b>2</b>	<b>Material and methods .....</b>	<b>28</b>
2.1	Patients .....	28
2.2	Surgical Procedure .....	30
<b>3</b>	<b>Results.....</b>	<b>32</b>
3.1.1	Sex and age distribution .....	32
3.1.2	Causes of injury .....	32
3.1.3	Length of time between trauma and lumbopelvic fixation .....	33
3.1.4	Length of time between lumbopelvic fixation and discharge .....	33
3.1.5	Lumbopelvic fixation instrumentation removal .....	33
3.1.6	Bony consolidation .....	34
3.1.7	Disturbance by osteosynthesis material.....	35
3.1.8	Disturbance, bony consolidation and hardware removal in context.....	36
3.2	<b>Complications .....</b>	<b>38</b>
3.2.1	Early complications.....	38
3.2.2	Late complications.....	39
3.2.3	BMI and complications .....	40
<b>4</b>	<b>Discussion.....</b>	<b>40</b>
<b>5</b>	<b>Conclusion .....</b>	<b>42</b>
<b>6</b>	<b>Bibliography .....</b>	<b>43</b>

## List of figures

All figures were drawn by the author with “*Inkscape*” a free and open source software based on pictures and figures of the sources that are marked bellow. Charts and diagrams were made with “*Microsoft Word or Excel*”.

<b>FIGURE 1;</b> THE PELVIS OF A MALE BASED ON (2) .....	1
<b>FIGURE 2;</b> ILIUM (RED), PUBIS (YELLOW), ISCHIUM (GREEN), GROWTH PLATE (BLUE) BASED ON (2) .....	2
<b>FIGURE 3;</b> SACRUM FROM THE BACK BASED ON (2) .....	4
<b>FIGURE 4;</b> PUBIC SYMPHYSIS BASED ON (2).....	5
<b>FIGURE 5;</b> PELVIS FROM THE BACK WITH LIGAMENTS BASED ON (2) .....	7
<b>FIGURE 6;</b> STRESS ON THE SYMPHYSIS WHEN STANDING ON TWO FEET. THE WEIGHT OF THE BODY (YELLOW ARROW) CAN BE DIVIDED INTO TWO PARTIAL LOADS (BLUE ARROW) THAT GO THROUGH THE ILIOSACRAL JOINTS INTO THE HIP JOINTS. THE RESULT IS A FORCE (GREEN) THAT STRESSES THE FEMORAL HEAD, WHILE THE SYMPHYSIS IS TORN APART (LIGHT BLUE ARROW). BASED ON (4) .....	9
<b>FIGURE 7;</b> STRESS ON THE SYMPHYSIS WHEN SITTING; THE PARTIAL LOADS (BLUE) ARE DIRECTED TOWARDS THE ISCHIAL TUBEROSITIES. A VERTICAL FORCE (GREEN) RESULTS AND SINCE THE ISCHIAL TUBEROSITIES LIE MEDIAL TO THE ILIOSACRAL JOINTS A SMALL TRANSVERSAL DIRECTED FORCE COMPRESSES THE SYMPHYSIS. BASED ON (4) .....	10
<b>FIGURE 8;</b> THE PELVIC REGION VISUALIZED WITH IMPORTANT STRUCTURES BASED ON (6).....	19
<b>FIGURE 9;</b> 61A2.1 FRACTURE BASED ON (11) .....	21
<b>FIGURE 10;</b> B-TYPE FRACTURE BASED ON (11) .....	25
<b>FIGURE 11;</b> C-TYPE FRACTURE BASED ON (11).....	26
<b>FIGURE 12;</b> STUDY PATIENT FLOW CHART .....	29
<b>FIGURE 13;</b> LUMBOPELVIC FIXATION INSTRUMENTATION SEEN FROM THE BACK BASED ON (38) .....	31
<b>FIGURE 14;</b> AGE/SEX DISTRIBUTION.....	32
<b>FIGURE 15;</b> CAUSES OF INJURY .....	33
<b>FIGURE 16;</b> BONY CONSOLIDATION OVER TIME IN DAYS.....	34
<b>FIGURE 17;</b> LENGTH OF TIME UNTIL DISTURBANCE IN DAYS .....	35
<b>FIGURE 18;</b> DISTURBANCE, BONY CONSOLIDATION AND HARDWARE REMOVAL IN CONTEXT ....	37
<b>FIGURE 19;</b> NUMBER OF PATIENTS FACING COMPLICATIONS.....	39

## **Zusammenfassung**

**Hintergrund:** Instabile Beckenringfrakturen haben eine geringe Inzidenz und sind in der Literatur selten berichtet, insbesondere die relativ neue Methode der lumbopelvinen Abstützung. Nach einer Darstellung der Anatomie der Region und den gängigsten Klassifikationen und Therapien der Beckenverletzung zielt, die in dieser Diplomarbeit geschilderte retrospektive Studie darauf ab, das Ergebnis der lumbopelvinen Abstützung mit einer größeren Studiengruppe und Nachbeobachtungszeit von mindestens 12 Monaten zu bewerten.

**Methode:** Alle Patientinnen und Patienten, die von Jänner 2013 bis Oktober 2019 an der Universitätsklinik für Orthopädie und Traumatologie der Medizinischen Universität Graz aufgrund einer traumatisch bedingten instabilen Beckenringfraktur eine lumbopelvine Abstützung erhielten, wurden retrospektiv untersucht. Die Patientinnen und Patienten mussten mindestens 18 Jahre alt sein und die Fraktur nach der AO/OTA-Klassifikation als C-Typ-Fraktur klassifiziert werden. 53 Personen erfüllten die Einschlusskriterien. Der Autor dieser Diplomarbeit hat alle Krankenakten und Original-Röntgendaten retrospektiv und unverblindet verarbeitet.

**Ergebnisse:** Bei 39 von 53 Patientinnen und Patienten konnte eine „Störung“ festgestellt werden. Eine „Störung“ wurde definiert als: Schmerzen im Bereich des Instrumentariums, Bewegungsmangel oder Komplikationen, die zur Entfernung der Implantate führten. Die mediane Dauer bis zur Störung betrug 236 Tage. Insgesamt erreichten 81 % der Patientinnen und Patienten innerhalb einer medianen Zeit von 267 Tagen eine knöchernen Konsolidierung. Bei etwa 70 % der Patientinnen und Patienten wurde die Entfernung der Implantate aufgrund von Störungen oder Komplikationen veranlasst. Insgesamt hatten 18 Personen postoperative Komplikationen, von denen 4 eine Infektion entwickelten und 6 mit einer Lockerung oder einem Bruch des Implantats konfrontiert waren. Die Gruppe „Keine Implantat-Entfernung“ war älter (Mittelwert=57), als die Gruppe mit „Implantat-Entfernung“ (=Mittelwert 41). Darüber hinaus waren 12 der 14 Patientinnen und Patienten ohne Störung durch die Implantate Übergewichtig und/oder älter als 50 Jahre.

**Schlussfolgerung:** Eine CT-Untersuchung und eine Operation zur Entfernung der Implantate könnten 12 Monate nach der primären Operation im Voraus

geplant werden, da die meisten Patientinnen und Patienten bis zu diesem Zeitpunkt eine vollständige knöchernen Konsolidierung erreicht und eine Störung aufweisen werden. Diese Strategie sollte insbesondere für junge und normalgewichtige Patientinnen und Patienten gelten.

## **Abstract**

**Background:** Unstable pelvic ring fractures have a low incidence and are therefore rarely reported in the literature, especially regarding the relatively new method of lumbopelvic fixation. After presenting the anatomy of the region and the most common classifications and therapies for pelvic ring injuries, the aim of the retrospective study described in this thesis is to evaluate the outcome of this surgical treatment within a larger study group and prolonged follow-up of at least 12 months.

**Methods:** All patients that received lumbopelvic fixation at the Department of Orthopaedics and Trauma, Medical University Graz from January 2013 until October 2019, due to unstable pelvic ring fractures caused by trauma were retrospectively included. Patients had to be at least 18 years old and the fracture had to be classified as C-type fracture according to the AO/OTA classification. Fifty-three patients met the inclusion criteria. The author of this diploma thesis reviewed all medical records and original radiographic data retrospectively in a nonblinded fashion.

**Results:** Thirty-nine out of 53 patients noted a disturbance. A disturbance was defined as: Pain in the region of the instrumentation, lack in range of motion or complications that led to hardware removal. Median length until disturbance was 236 days. In total, 81% of patients reached bony consolidation, within a median time of 267 days. Around 70% of patients requested hardware removal, due to disturbances or complications. In total, 18 patients had postoperative complications with 4 of them developing infection and 6 implant loosening or breakage. The group "No hardware removal" was older (mean=57), than the group with hardware removal (mean=41). Furthermore, 12 out of the 14 patients who did not experience disturbance by the implants were overweighted and/or older than 50 years.

**Conclusion:** A CT-scan and hardware removal surgery may be scheduled in advance 12 months after lumbopelvic fixation surgery, since most of the patients will have achieved full bony consolidation and will have a disturbance up to this point. This strategy should especially apply to young and healthy-weighted patients.

# 1 Introduction – Theoretical Background

## 1.1 Anatomy of the pelvis

The bony pelvis is formed by the sacrum and the coccyx in the back and by two big hip bones to the front and the sides. (Figure 1) While the anterior and lateral sides are completed by the abdominal muscles, the bottom is closed by the pelvic floor. The pelvis itself is a ring-construction that makes up the bottom end of the trunk. Since it is tightly connected to the spine it carries the weight of the upper body and forwards it to the lower extremities. (1,2)

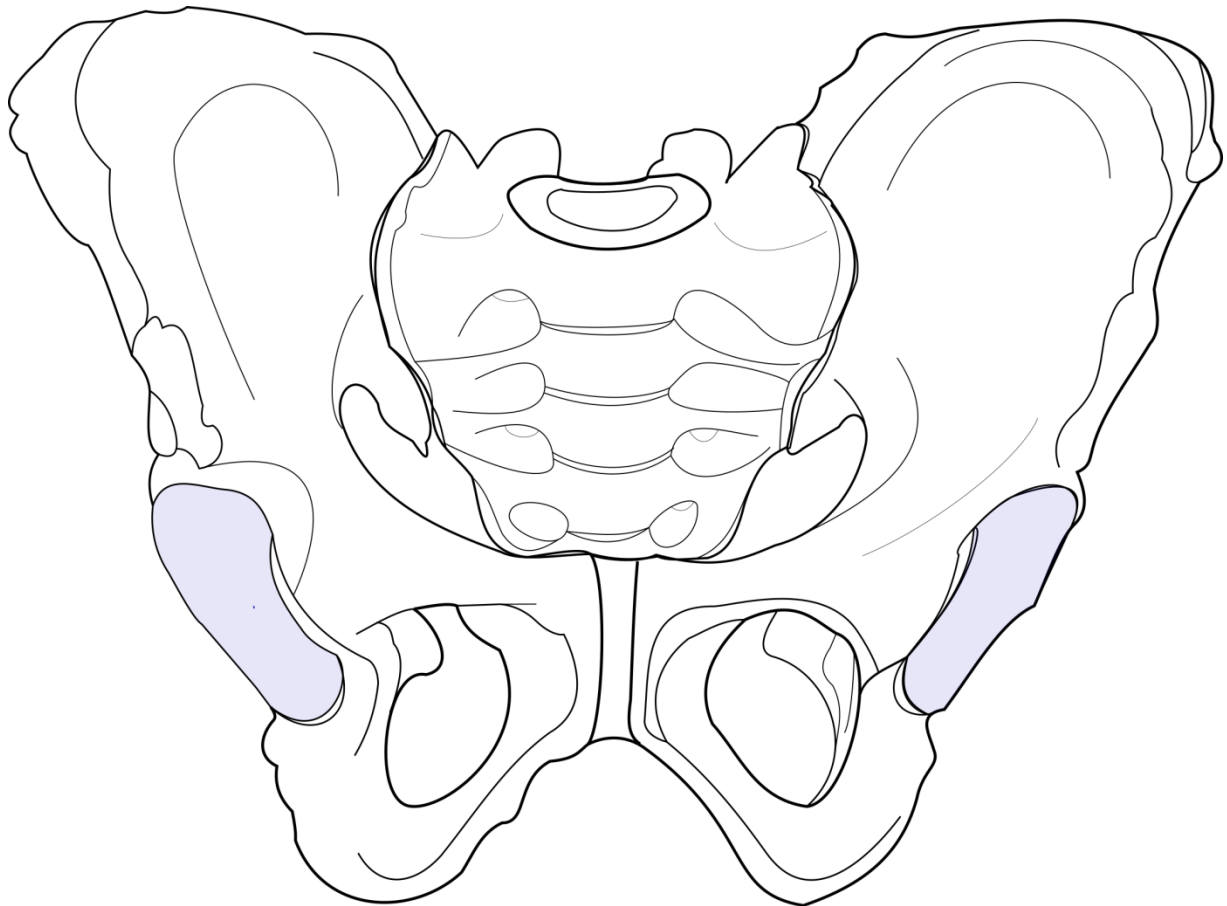


Figure 1; The pelvis of a male based on (2)

### 1.1.1 Os Coxae

The hip bone is composed of three bones:

- Ilium
- Ischium
- Pubis (pubic bone)

In children, these bones are separated from each other by a Y-shaped cartilaginous growth plate that fuses between the ages of 18 to 20 years. (Figure 2) All bones together form the acetabulum with their corporal parts. The acetabulum is bounded by the acetabular margin and contains a semilunar joint surface (=lunate surface) that allows carrying the femoral head. In the upright position, the load of the upper body is transferred to the thighbone via the acetabular roof, which is the widest area of the semilunar joint surface. (1,2)

### 1.1.2 Ilium

The os ilium consists of:

- the body  
and
- the ala (wing)

The body of the ilium makes up the biggest part of the acetabulum and the acetabular roof. The cranial part of the ala is formed by the iliac crest. The iliac crest begins at the anterior superior iliac spine (ASIS) and ends at the posterior superior iliac spine (PSIS). These two bony projections play a major role in lumbopelvic fixation surgery and serve as landmarks for screw placement (see chapter "Surgical procedure"). (3) The outer surface of the ala is called gluteal surface and serves as origin for the muscles of the same name.

On the inside of the ala lies the iliac fossa, which reaches to the arcuate line that

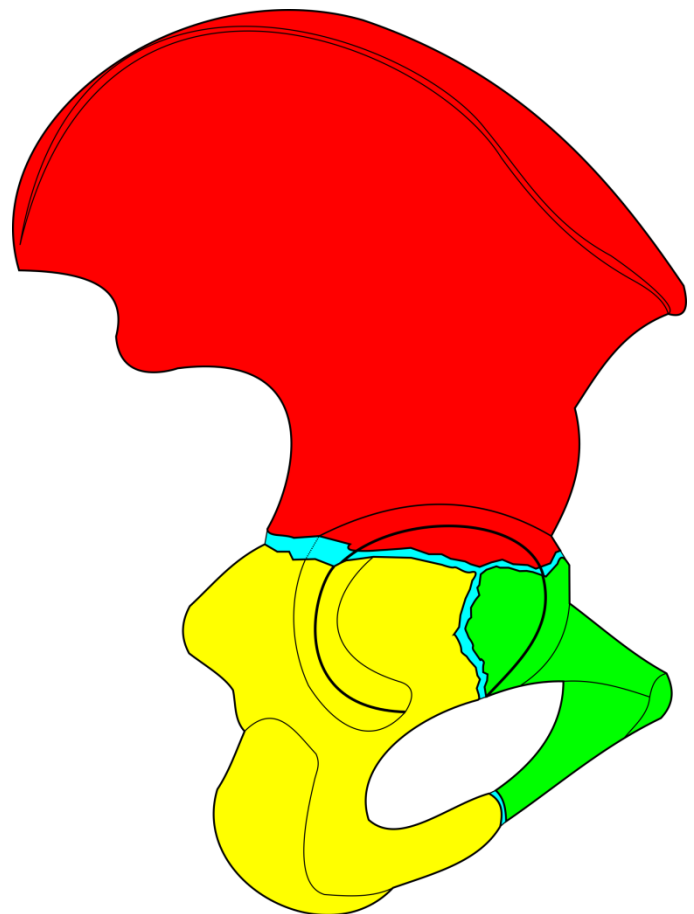


Figure 2; Ilium (red), Pubis (yellow), Ischium (green), growth plate (blue) based on (2)

forms a part of the borderline between lesser and greater pelvis. The sacropelvic surface faces the sacrum and is divided into the iliac tuberosity and the auricular surface. The interosseus sacro-iliac ligaments use the iliac tuberosity as insertion, while the auricular surface is part of the sacro-iliac joint. (1,2)

### **1.1.3 Ischium**

The ischium is divided into:

- the body  
and
- ramus

It makes up the back part of the acetabulum with its body, while the ramus is part of the dorsal segment of the obturator foramen. The most prominent characteristics of the ischium are the ischial spine that separates the greater sciatic notch from the lesser sciatic notch and the ischial tuberosity that carries the weight of the body when seated. (1,2,4,5)

### **1.1.4 Pubis**

The pubis is made up of:

- the body
- superior  
and
- inferior pubic ramus

The pubic bone with its body forms the anterior part of the acetabulum and its two rami delimit the obturator foramen anteriorly. The superior pubic ramus extends from the body towards the symphysis, where it merges into the inferior pubic ramus. The symphyseal surface is the medial surface facing the pubis of the other side. (1,2)

### **1.1.5 Sacrum**

The os sacrum evolves from five sacral vertebrae and four intervertebral discs that fuse together. It has the shape of a wedge, which apex is orientated to the bottom and has a connection to the os coccygis. Its base is at the cranial top, where it

forms a joint with the vertebrae of L5. The smooth anterior surface (pelvic surface) is concave, while the dorsal surface is rough and convex. On the dorsal surface a single median sacral crest, paired intermediate and lateral sacral crests can be found. They resemble the residual parts of the merged spinous, articular and transverse processes. In between the intermediate and lateral sacral crests lie the posterior sacral foramina. The sacral canal is the extension of the vertebral canal and ends in the sacral hiatus on the bottom of the sacrum. Ligaments connect the sacral tuberosity with the iliac tuberosity on the ilium, while the auricular surface is facing the auricular surface of the ilium. (Figure 3) (1,2)

### 1.1.6 Coccygis

The os coccygis consists of 3 to 6 elements that resemble the remnant of a tail spine. Only the first element has the character of a vertebra. (1,2)

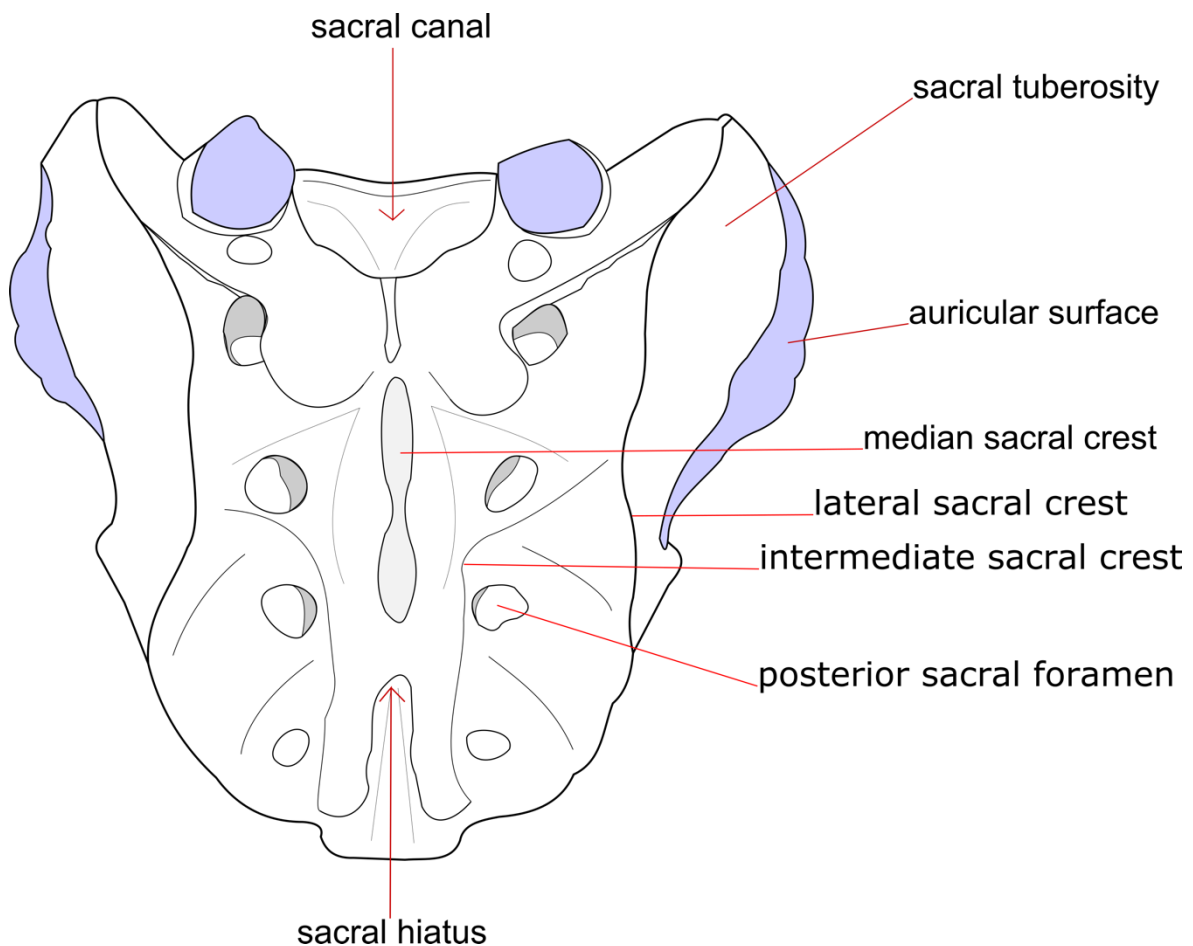


Figure 3; Sacrum from the back based on (2)

## 1.2 Important ligaments and joints in the pelvic region

### 1.2.1 Pubic symphysis

The pubic symphysis is the connection between the pubic bones of each side. Both symphyseal surfaces are covered with a thin layer of hyaline cartilage and are connected to each other via the interpubic disc, which is made up of fibrocartilage. Inside of the interpubic disc liquid can be found in a small gap. The superior pubic ligament is the upper, while the inferior pubic ligament is the bottom boundary of the symphysis. Both ligaments strengthen the connection between the ossa coxae, together with the interpubic fibrocartilage. The pubic symphysis is under tensile stress, when standing in an upright position or in compressive and bending stress when walking. Given all of these forces impacting the symphysis it is no wonder that in case of a disruption, anterior pelvic ring instability is the result.

(1,2)

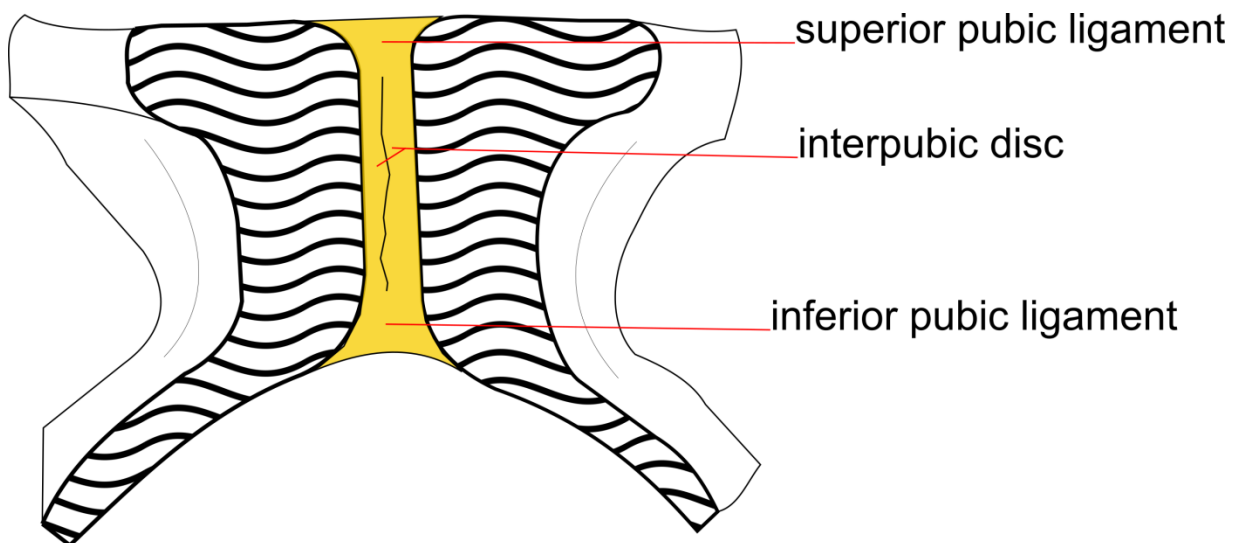


Figure 4; Pubic symphysis based on (2)

### 1.2.2 Sacroiliac joint

Due to the strong ligaments that surround the sacroiliac joint it can be seen as an amphiarthrosis (= a joint that is only slightly movable and tightly connected). The auricular surfaces of ilium and sacrum make up the joint surfaces. The sacroiliac joint is made up of hyaline cartilage as well as fibrocartilage and is protected by five ligaments:

- Anterior sacroiliac ligaments

- Posterior sacroiliac ligaments
- Interosseous sacroiliac ligaments
- Sacrotuberous ligament
- Sacrospinous ligament

Compared to the other ligaments the anterior sacroiliac ligaments are weak and can be found on the pelvic (front) side of the joint. The stronger posterior sacroiliac ligaments have shorter and longer fibers. The longer fibers cover the shorter ones and both help to weaken compressive stress over the joint surfaces. Between the iliac and the sacral tuberosity the interosseous ligaments can be found. Of utmost importance are the sacrotuberous ligament and the sacrospinous ligament that both secure the joint tightly, enabling a well-functioning posterior pelvic ring. Both ligaments have their origin on the sacrum, while the sacrospinous ligament ends in the ischial spine and the sacrotuberous ligament inserts in the ischial tuberosity. (1,2,5,6)

### **1.2.3 Lumbosacral joint**

The lumbosacral joint is the junction formed between the vertebra of L5 and the cranial sacrum. On the one side it has all features (e.g. ligaments etc.) that a facet joint needs, but on the other side it has a stronger inclination than usually. To prevent the vertebra from slipping off the sacrum it is secured via the iliolumbar ligament. It is a strong ligament that has its origin in the costal process of L4 and

L5 and inserts in the iliac crest as well as the iliac tuberosity. (2,5)

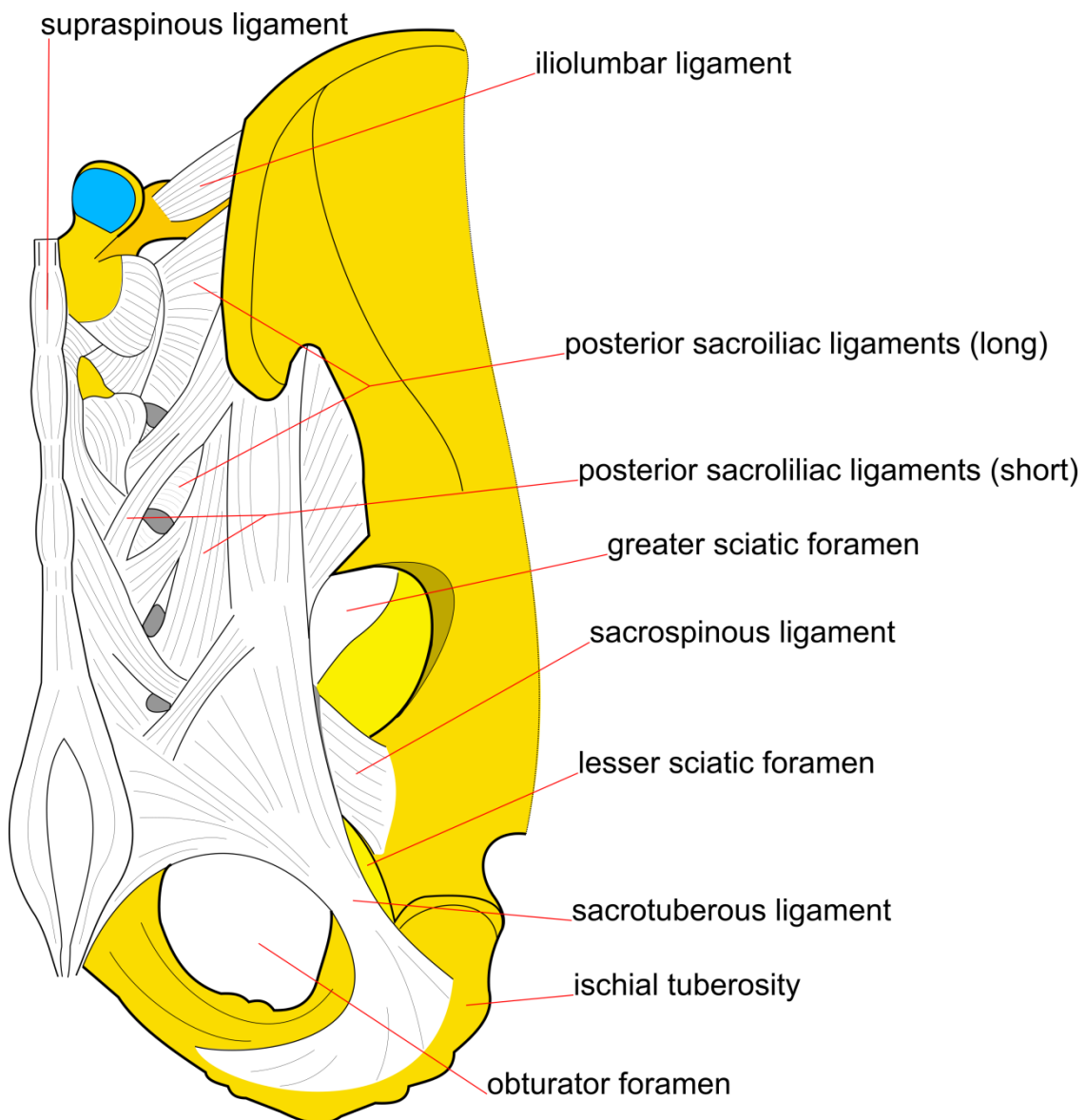


Figure 5; Pelvis from the back with ligaments based on (2)

### 1.3 Sacrococcygeal articulation

The sacrococcygeal articulation can either be a diarthrosis or a synchondrosis (= sacrococcygeal symphysis). It can be moved passively and plays a major role when giving birth by moving the coccyx in the dorsal direction, in order to make up space for the baby.

Three ligaments are important, when looking at the sacrococcygeal articulation:

- The anterior coccygeal ligament,
- the deep posterior sacrococcygeal ligament
- and
- the superficial posterior sacrococcygeal ligament.

The anterior coccygeal ligament extends from the anterior surface of the last sacral vertebra to the anterior surface of the coccyx. The posterior surface of the last sacral vertebral body is connected to the coccyx by the deep posterior sacrococcygeal ligament, while the superficial posterior sacrococcygeal ligament lies to the side of it. (1,2)

#### ***1.4 Mechanical properties of the pelvis***

The pelvic ring is alternately exposed to pressure-, bending-, tensile- and shear-loads depending on which position the body is in. Therefore, it makes sense to look at the mechanical properties of each situation (sitting, standing, and walking) on its own. Beforehand it is important to note that in any position of the body the sacrospinous and sacrotuberous ligaments play an important role. As the weight of the body is putting force on the structures of the lumbosacral joint, the sacrum would make a forwards rotation if the sacrospinous and –tuberous ligaments were not there to successfully stop this movement. (2,4,6)

### 1.4.1 Mechanical properties of the pelvis, when standing

When standing in an upright position, the pelvis is inclined forwards and downwards. So, the weight from the trunk is directed through the sacroiliac joint and led into the lower extremities. While the femoral heads are put under pressure, the pubic symphysis is torn apart (via tensile forces). However, the interpubic disc and the pubic ligaments prevent this from happening. (2,4)

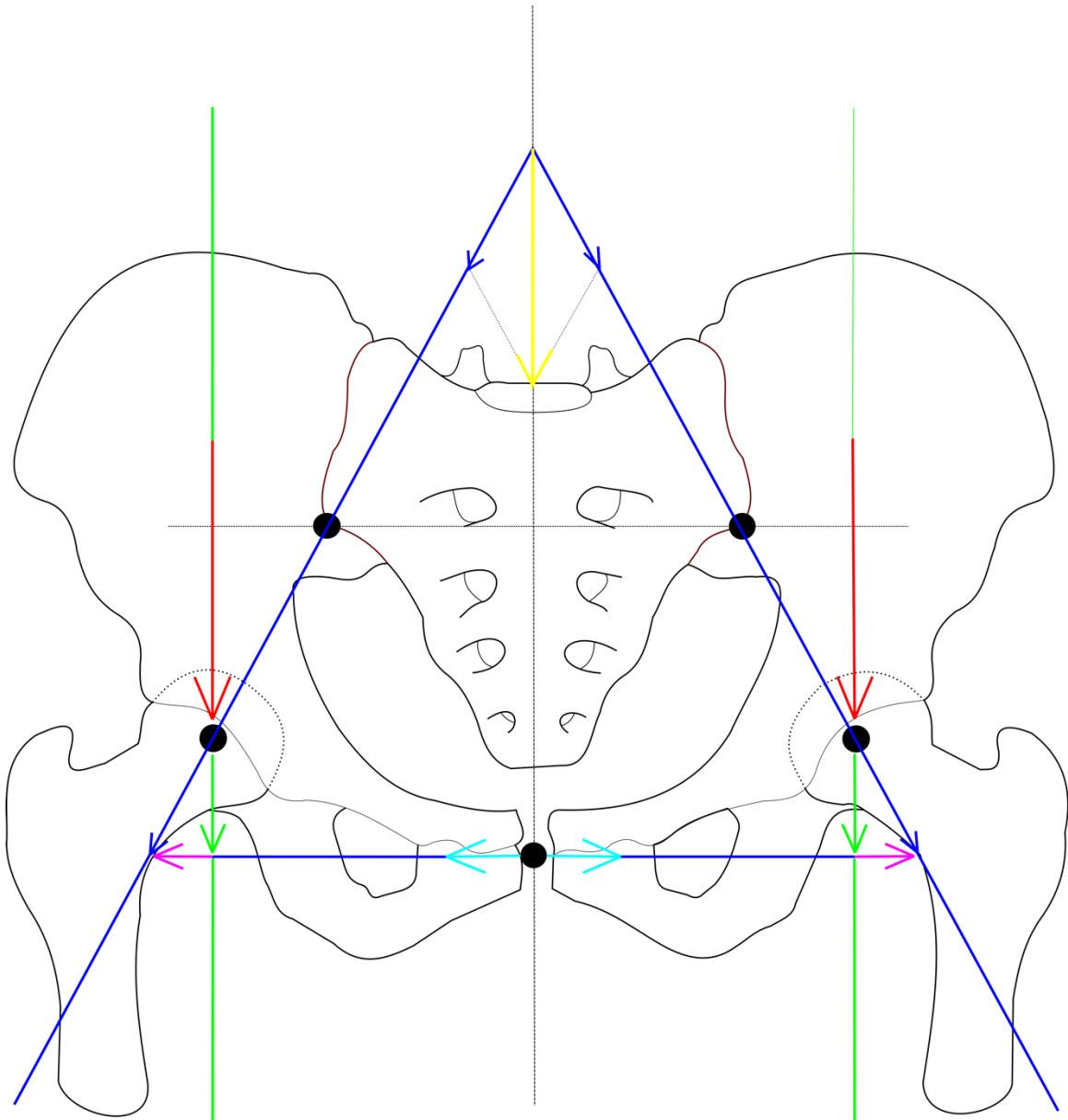


Figure 6; Stress on the symphysis when standing on two feet. The weight of the body (yellow arrow) can be divided into two partial loads (blue arrow) that go through the iliosacral joints into the hip joints. The result is a force (green) that stresses the femoral head, while the symphysis is torn apart (light blue arrow). Based on (4)

### 1.4.2 Mechanical properties of the pelvis, when sitting

When seated, the forces are directed to the ischial tuberosity and the pubic symphysis is compressed (via pressure loads). (4)

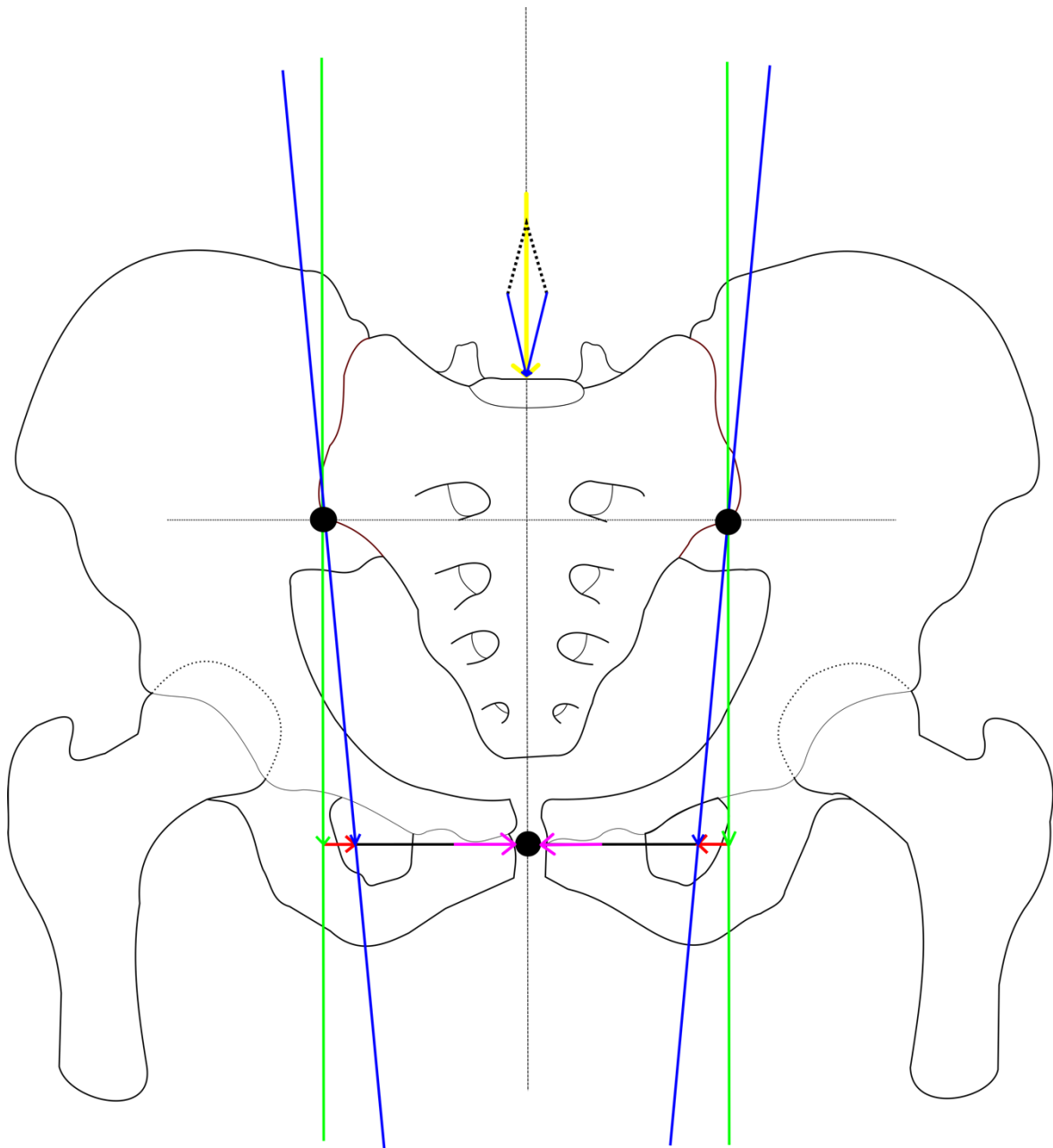


Figure 7; Stress on the symphysis when sitting; The partial loads (blue) are directed towards the ischial tuberosities. A vertical force (green) results and since the ischial tuberosities lie medial to the iliosacral joints a small transversal directed force compresses the symphysis. Based on (4)

### 1.4.3 Mechanical properties of the pelvis, when walking

When walking, the forces are directed only through one leg (=standing leg), whereas the other (=free leg) swings forward without touching the ground. So, a complex lapse of different forces affecting the anatomical structures is the result.

For example, when standing on one leg, the pubic symphysis is subjected to compressive- and shear-forces. (1,4)

## **1.5 The muscles of the pelvis**

### **1.5.1 Muscles of the back**

There are two muscles that need to be taken into consideration, when thinking of the muscles that originate in the pelvis from the back. The latissimus dorsi muscle is part of the superficial muscles of the shoulder girdle and originates in the thoracolumbar fascia, the spinous processes of vertebrae TH5-12 through L1-5, the supraspinous ligaments, the inferior angle of the 9<sup>th</sup>-12<sup>th</sup> rib, the iliac crest as well as the dorsal surface of the sacrum. The latissimus dorsi muscle has a lot of functions concerning the movement of the shoulder. Nevertheless for our considerations the parts that have their origin in the thoracolumbar fascia, iliac crest and the sacrum are of the most importance, since they enable extension and lateral flexion of the spine, especially when the shoulder joint is fixated (as a gymnast does on a pommel horse) .

Secondly, the erector spinae muscles are a group of muscles that go from the back of the head to the sacrum and are located on the left and right side of the spine. The lateral column of these muscles is of special interest, since it has parts that originate in the sacrum and the ilium, while also enabling lateral flexion when contracted unilaterally and extension of the spine when contracted bilaterally. (2)

### **1.5.2 Abdominal muscles**

As already mentioned above, the anterior and lateral sides of the pelvic region are completed by abdominal muscles. The abdominal muscles are:

- the external oblique,
- internal oblique,
- transverse abdominal  
and
- rectus abdominis muscle

These muscles are involved in trunk movements, by acting partly as antagonists and synergists with the muscles of the back. They adjust the position of the pelvis and thorax against each other. When the thorax is fixated, they lift up (flexion of)

the pelvis and vice versa. Additionally, they antagonize the dorsiflexion of the spine by the erector spinae muscles, while they support the unilateral contraction of the same muscles. (2)

### **1.5.3 Muscles of the hip**

The hip muscles originate over a wide surface on the pelvis and insert into the proximal femur in the area of the greater or lesser trochanter. The insertion of the hip muscles crosses the origins of the thigh muscles in the region of the hip joint.

There are two main functions of the hip muscles:

1. The hip muscles move the pelvis and the free extremity against each other, while also
2. stabilizing the pelvic ring in cooperation with the free lower extremity when standing on one or on two feet.

The hip muscles can be divided into inner and outer muscles. The inner hip muscles are represented through the iliopsoas muscle, which is made up of:

- The psoas major muscle
- Iliac muscle  
and
- in some cases (30%) the psoas minor muscle.

All together they work as strong flexors in the hip joint, as well as adduction and external rotation. When laying on the back these muscles enable the trunk to be set upright.

The outer hip muscles are made up of:

- the gluteus maximus,
- gluteus medius,
- gluteus minimus,
- tensor fascia latae,
- piriformis
- internal and external obturator,

- superior and inferior gemellus,  
and
- quadratus femoris muscle.

The first three muscles are put together as gluteal muscles, while the gluteus maximus muscle is seen as antagonist to the iliopsoas muscle and therefore performing strong extension in the hip joint, as well as preventing to tip forward when walking upright, the gluteus medius and minimus muscles are working as abductors in the hip joint. They stabilize the pelvis in the frontal plane, while also ensuring the pelvis not to sink to the side of the free extremity, when standing on one leg or when walking. If, the gluteus maximus muscle is not working properly, getting up or climbing up stairs can become impossible. (2)

#### **1.5.4 Muscles of the thigh**

The muscles of the thigh originating from the pelvis either insert distally to the femur (→ adductors) or they cross the knee joint and reach the proximal end of the lower leg bones (→ flexors or extensors). There are three fascial compartments of the thigh that separate the muscle groups from each other by intermuscular septa:

The medial compartment → “Adductors”:

- the pectineus,
- gracilis,
- adductor longus,
- adductor brevis  
and
- adductor magnus

perform an adduction of the thigh in the hip joint.

Muscles of the anterior compartment of the thigh extend the knee, while also flexing the hip. This is especially true, when it comes to the quadriceps muscle, that is made up of the:

- rectus femoris,
- vastus lateralis,

- vastus intermedius  
and
- vastus medialis muscle.

The sartorius muscle on the other side does a flexion in both hip and knee joint, but is also part of the anterior compartment of the thigh.

The posterior compartment of the thigh → “Flexors”:

- The biceps femoris,
- semitendinosus  
and
- the semimembranosus muscle,

are known for their function as flexors in the knee and extensors in the hip joint. (2)

### **1.5.5 The pelvic floor**

The pelvic floor is the bottom end of the pelvic cavity (lesser pelvis). It is made up of many muscles that work together as a unit. One can differentiate between the muscles of the pelvic diaphragm and the urogenital diaphragm. The rectum passes through the pelvic diaphragm, whereas the urethra and vagina cross the urogenital diaphragm in women and the urethra alone in men. On the one hand the pelvic diaphragm contains the levator ani muscle, coccygeus muscle and the external anal sphincter that are very important for defecation and anal continence. On the other hand the urogenital diaphragm is made up of:

- The (superficial + deep) transverse perineal muscles,
- external urethral sphincter,
- ischiocavernosus muscle  
and
- bulbospongiosus muscle

These muscles especially ensure physiologic urination and sexual function.

Exercising pelvic floor muscles may prevent or ease symptoms of urinary or faecal incontinence and may reduce pain and disability in chronic back pain. (1,2,7,8)

## **1.6 The vascular system in the pelvic region**

### **1.6.1 Arteries**

Both the external and internal iliac arteries derive from the common iliac arteries, which themselves bifurcate at the aortic bifurcation and therefore originate from the aorta.

The main artery for the organs of the pelvis, the buttock and genitals is the internal iliac artery. The internal iliac artery divides into a posterior and anterior division.

The following derive from them:

Anterior parietal branches:

- Obturator artery
- Inferior gluteal artery

Posterior parietal branches:

- Iliolumbar artery
- Lateral sacral artery
- Superior gluteal artery

Anterior visceral branches:

- Umbilical artery
- Inferior vesical artery
- Uterine artery (female)
- Middle rectal artery
- Internal pudendal artery

As one can see, the posterior division only features parietal branches. The obturator artery crosses the obturator canal, together with the nerve and vein of the same name and supplies the muscles of the medial compartment (adductors) with blood. The bladder is provided with blood by the superior vesical arteries that originate from the umbilical artery and the inferior vesical artery. The iliolumbar artery supplies the iliopsoas muscle, while the lateral sacral artery nourishes the erector spinae muscles, and the superior and inferior gluteal artery the gluteus maximus muscle.

The external iliac artery bifurcates from the common iliac artery at the height of the sacroiliac joint. It supplies the abdominal wall with some of its branches and goes

under the groin ligament to form the femoral artery. As a result the external iliac artery is one of the main arteries that provide blood to the lower extremity. (2,6) Especially, in unstable pelvic ring injuries bleeding increases the mortality greatly. The above mentioned iliac vessels are a common source of bleeding, as well as the pre-sacral venous plexus and large cancellous bone surfaces. (9)

### **1.6.2 Veins**

The internal iliac vein forms the common iliac vein together with the external iliac vein that is coming from the thigh. The common iliac veins of both sides merge into the inferior vena cava that goes alongside the aorta. The parietal branches of the pelvic arteries are commuted by veins. These veins are usually doubled in peripheral areas to form the:

- Superior and inferior gluteal veins
- Iliolumbar veins
- Lateral sacral veins
- Obturator veins

The internal pudendal artery is accompanied by a vein of the same name that takes up the deep veins of the penis (clitoris), posterior scrotal (labial) veins and inferior rectal veins to enter the pelvis via the infrapiriform foramen and lead into the inferior gluteal vein. Several venous plexus are formed in the pelvis e.g. the vesical or prostatic venous plexus that communicate with each other. (6)

*“The presacral venous plexus results from anastomoses between the lateral and median sacral veins, and courses into the pelvic fascia covering the anterior aspect of the body of the sacrum.” –*

*Baqué et al. (10)*

### **1.6.3 Lymphatic vessels**

Most of the lymphatics are located right next to the big vessels and they share the same name. The lymph nodes are formed into groups for example the inguinal or sacral lymph nodes. (6)

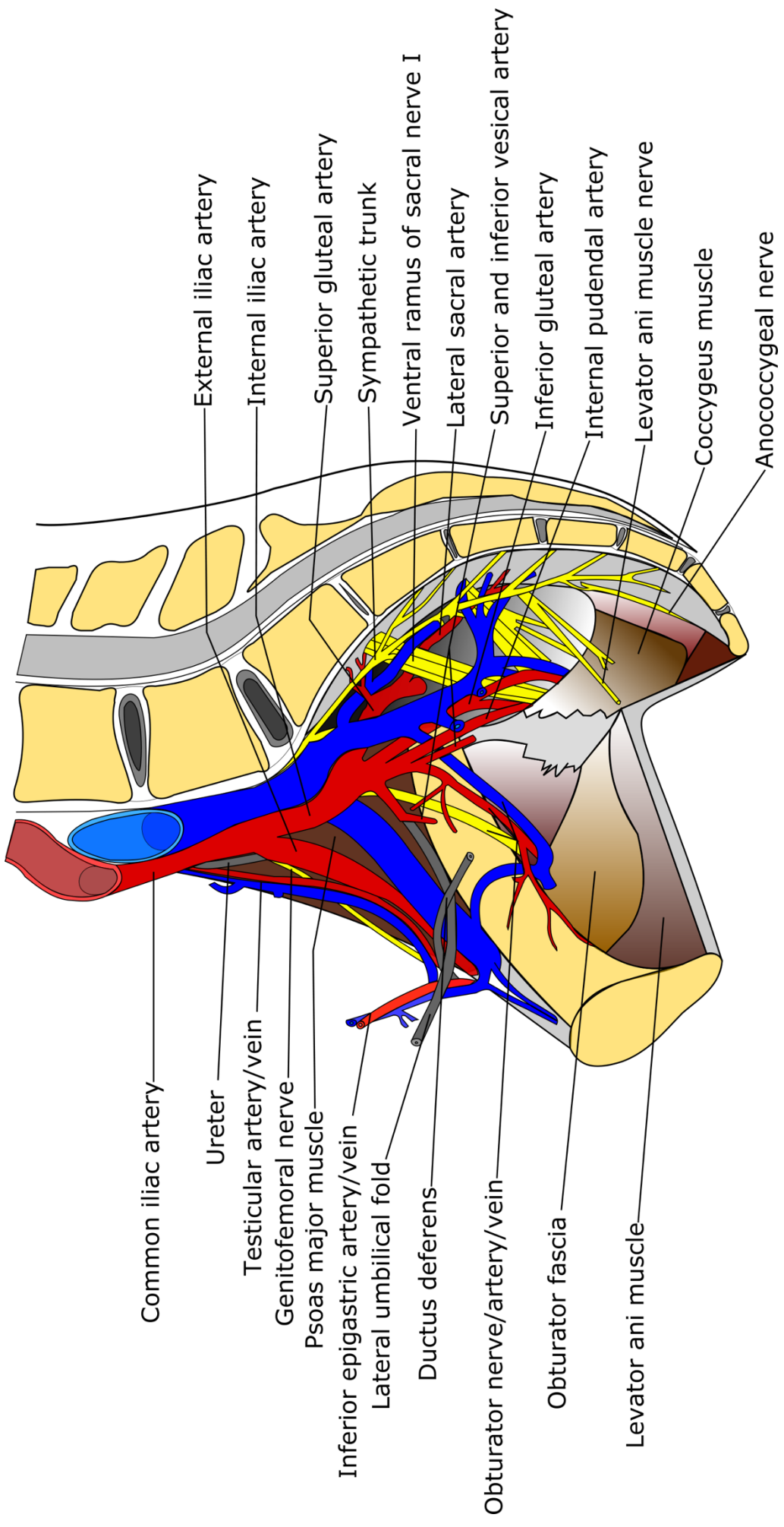
## **1.7 The nervous system in the pelvic region**

The spinal nerves of the pelvis originate from the lumbosacral plexus. It is made up of the ventral branches of the spinal nerves beginning from the segment of L1 downwards. The lumbosacral plexus itself consists of three parts. The upper part is called lumbar plexus and derives from the first to fourth lumbar segment, but also takes up some fibers from the segment of TH12. Its branches supply the leg and the abdominal wall, while only one branch (the obturator nerve) enters the lesser pelvis and leaving it through the obturator foramen, without giving away any fibers. The obturator nerve supplies the sensory innervation of the skin of the medial part of the thigh, as also playing a role in innervating the adductor muscles. (6)

The caudal portion of the lumbosacral plexus is represented by the sacral plexus. Its roots come from the segments of L4, L5 and the sacral segments. The sacral plexus holds the ischial and pudendal plexus. The ischial plexus originates from the caudal segments of L4 and L5, as well as the sacral segments of S1 and S2 with the cranial parts of S3. There are numerous nerves that derive from the ischial plexus for example the biggest and most widely known one is the sciatic nerve, which leaves the pelvis through the infrapiriform foramen and works as the sensory innervation of the foot and almost all of the lower leg, while also innervating muscles of the posterior, anterior and lateral compartments of the leg (via tibial nerve and common peroneal nerve). Other nerves of the ischial plexus are the inferior and superior gluteal nerve and the posterior cutaneous nerve of thigh. The pudendal plexus is mainly originated from the segments of S3 and S4, but is also made up of fibers from all sacral segments. It forms the pudendal nerve, which splits up caudal of the pelvic floor. The inferior rectal nerves, the perineal nerves and the dorsal nerve of the penis (clitoris) are all branches of the pudendal nerve. They innervate the skin of the genitalia (penis, clitoris, labia etc.), the muscles of the erectile tissue and muscle that are important for defecation such as the external anal sphincter. (6)

The coccygeal plexus originates from the segment of Co1 (= Coccygeal nerve) and the segment of S5. Together with other fibers from the sacral segments it innervates the skin in the area of the coccyx. (6)

Understanding the autonomic nervous system in the pelvic region is of utmost importance when talking about pelvic ring injuries and their complications. The bladder for example is innervated via the vesical plexus that is composed of sympathetic fibers of the segments of T11-L2 and parasympathetic fibers of the segments S2-S4. The sympathetic parts control the sphincter of the bladder exit, while the parasympathetic fibers innervate the muscles that empty the bladder. The same mechanisms can be found in the act of defecation. The parasympathetic parts control the defecation itself, as sympathetic fibers innervate the internal anal sphincter. Together with the external anal sphincter that is innervated via somatic nervous fibers it ensures anal continence. (2)  
(Figure 8 shows important structures in the pelvic region aiming to visualize the close proximity of large vessels and nerves)



Common iliac artery

Ureter

Testicular artery/vein

Genitofemoral nerve

Psoas major muscle

Inferior epigastric artery/vein

Lateral umbilical fold

Ductus deferens

Obturator nerve/artery/vein

Obturator fascia

Levator ani muscle

External iliac artery

Internal iliac artery

Superior gluteal artery

Sympathetic trunk

Ventral ramus of sacral nerve I

Lateral sacral artery

Superior and inferior vesical artery

Inferior gluteal artery

Internal pudendal artery

Levator ani muscle nerve

Coccygeus muscle

Anococcygeal nerve

Figure 8; The pelvic region visualized with important structures based on (6)

## **1.8 Different types of pelvic ring injuries according to the “AO/OTA Fracture and Dislocation Classification”**

The AO/OTA Fracture and Dislocation Classification is aimed to standardize fracture classification. It enables the clinician to accurately describe fractures using a standardized language. Each bone or region of the human body is identified with a number e.g. number 6 is the pelvis. One can then specify the location of the fracture/s by adding a number to the code that stands for a segment or specific region. When talking about pelvic ring fractures, it would be number “61” or when it comes to fractures of the acetabulum it would be “62”. However, the clinician can even describe the severity of the fracture, by adding a letter e.g. A, B, or C. Generally speaking A-type fractures are simple, while C-type fractures are complex.

In pelvic ring injuries A-type fractures are defined as fractures that still result in an intact posterior arch (=61A AO/OTA). B-type fractures are characterized as injuries that present with an incomplete disruption of the posterior arch (=61B AO/OTA), whilst C-type fractures mean a complete disruption of the posterior arch (=61C AO/OTA).

However, the clinician can describe the fracture even in more detail by adding another digit that stands for a group of injuries such as innominate bone avulsion fractures. Also, a subgroup can be defined that specifies on the location where the fracture can be found e.g. the anterior superior iliac spine or the characteristics e.g. open book fracture.

As an example, the code 61A2.1 means: The patient has a fractured pelvis (“6”), the fracture is affecting the pelvic ring (“61”), the posterior arch is intact (“61A”), it is an innominate bone fracture (“61A2”) of the iliac wing (“61A2.1”). (Figure 9) (11)

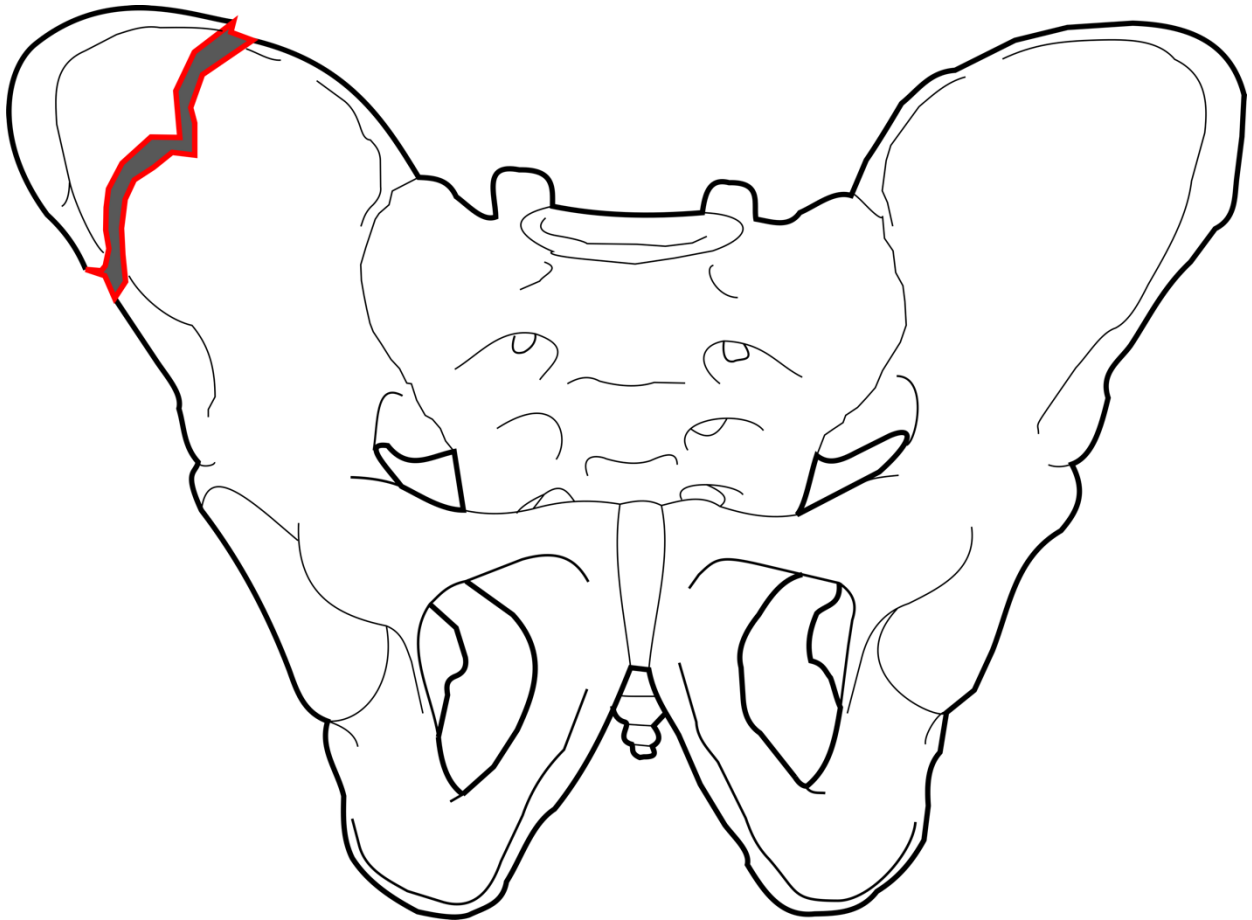


Figure 9; 61A2.1 fracture based on (11)

### **1.9 Acute treatment of pelvic ring injuries**

After the initial primary survey, where possible life threatening injuries are identified and immediately treated the second survey follows. The second survey makes sure that every injury is detected. Wounds, deformities, swollen and bruised areas, urethral bleeding etc. can be signs of pelvic ring injury. If possible, asking the patient if he/she is in pain in the pelvic region is also considered to be helpful. In pelvic ring injuries, a general physical examination of the pelvic region and an AP pelvis X-Ray are done. Physical examination is performed by palpating the pubis, iliac wings and posterior pelvis for tenderness. In addition, compression of the pelvis or rotating the iliac crests externally can identify tenderness and/or bony instability. If the examination and/or the AP pelvis X-ray are abnormal, further

evaluation with CT scan are necessary. Note that pelvic binders can lead to false negative AP X-rays. (12)

Acute pelvic treatment mainly focuses on prevention of exsanguination. Bleeding can be reduced by reducing pelvic deformity and by adding stability. Therefore, a pelvic binder or wrap is applied as early as possible in the primary survey.

Methods that help stop bleedings are:

- Extraperitoneal pelvic packing
- Angio-embolization
- Emergency stabilization with a C-clamp
- External fixation

The last two are used to stabilize the pelvis, especially when a laparotomy and/or pelvic packing is/has been done. Extraperitoneal pelvic packaging is a surgical method. Either a horizontal ("Pfannenstiel") or vertical incision is performed proximal to the pubic tubercle. The horizontal incision is preferred when there is no obvious evidence of abdominal bleeding. After proper dissection of the extraperitoneal tissue, as many gauzes as possible are put in the retroperitoneal space to put pressure on the blood vessels. After 24-48 hours, a "second look" needs to be done, either the gauzes can be removed, or if the bleeding is still active they should be replaced. Angio-embolization is a minimally invasive technique that requires an interventional radiology specialist that allows to selectively embolize affected blood vessels, especially arteries. In general, it is less effective in venous bleedings. (13-16)

However, considerations if pelvic packing or angio-embolization fit best could be:

- *“The condition of the patient*
- *When the patient is in extremis, angiography takes too long*
- *Availability of direct angiography or an operating room*
- *Availability of adequate personnel to perform angio-embolization*
- *When a laparotomy is mandatory, extraperitoneal packing could be part of the same procedure*

*Combining the two techniques (extraperitoneal pelvic packing and angio-embolization) is an option.” – Banerjee (AO Surgery Reference) et al. (13)*

### **1.10 Treatment of different types of pelvic ring injuries according to the “AO/OTA Fracture and Dislocation Classification”**

A-type fractures are presenting with a stable pelvic ring. That way they need the least effort in treatment. Pattern, stability and displacement of the fracture, but also individual patient-related factors, hospital capacities and skill are considerations that need to be taken into account, when deciding if a nonoperative or operative approach fits best. Not only in stable, but also in unstable fractures the goal for the treatment should be that fractures heal, the patient gains back proper function, the therapy is reasonable for the patient and after all, that it happens in an acceptable amount of time. Nonoperative treatment is characterized by early mobilization, physiotherapy and follow-up examinations e.g. 2, 6 and 12 weeks after the incident including X-rays. In A-type sacral injuries sitting on a donut cushion is considered to be pain relieving for the patient and in most cases the only treatment necessary, depending on the displacement of the sacrum. If, initial protection by using devices like walkers or crutches are generally useful is debatable. It depends on the patient and individual tolerance to full-weight-bearing. However, after confidence is gained back full-weight-bearing should be aspired.

In cases of large displacement or a sacral plexus nerve root deficit in sacral fractures, Open Reduction and Internal Fixation (ORIF) surgery is done. (17-20)

As B-type fractures are partially stable a nonoperative approach can be successful, but only in minimal displacement and stable conditions. However, a follow-up examination is recommended 2-3 weeks after the incident, since the displacement could progress and a correction of a consolidated malunion would be more challenging. (20)

In partially stable injuries also external fixation with or without traction play a role. Indications for external fixation without traction are:

- *"For correction of significant internal rotation deformity and/or related lower extremity shortening*
- *Insufficient lower extremity external rotation*
- *Pubic ramus fractures which align satisfactorily with external fixator distraction*
- *Progressive deformity or risk thereof" – Banerjee et al. (21)*

Usually external fixation consists of pins (Schanz-type pins) that are drilled into the supraacetabular region/ iliac crest and then connected to each other via a connecting rod ensuring that the anterior pelvic ring is stable. The external fixation does not stabilize the posterior ring in a great way, so that often additional stabilization/fixation of the posterior ring needs to be done. (22)

Adding traction to an external fixation is advisable in pelvic injuries with extensive vertical displacement. It should be used if the patient's condition does not allow definitive surgical treatment of the pelvic ring, either as temporary solution until the patient gets well enough or as definitive treatment. However, if external fixation with traction serves as definitive treatment it is associated with pressure wounds, pulmonary complications and higher risk of losing initially satisfactory reduction. (23)

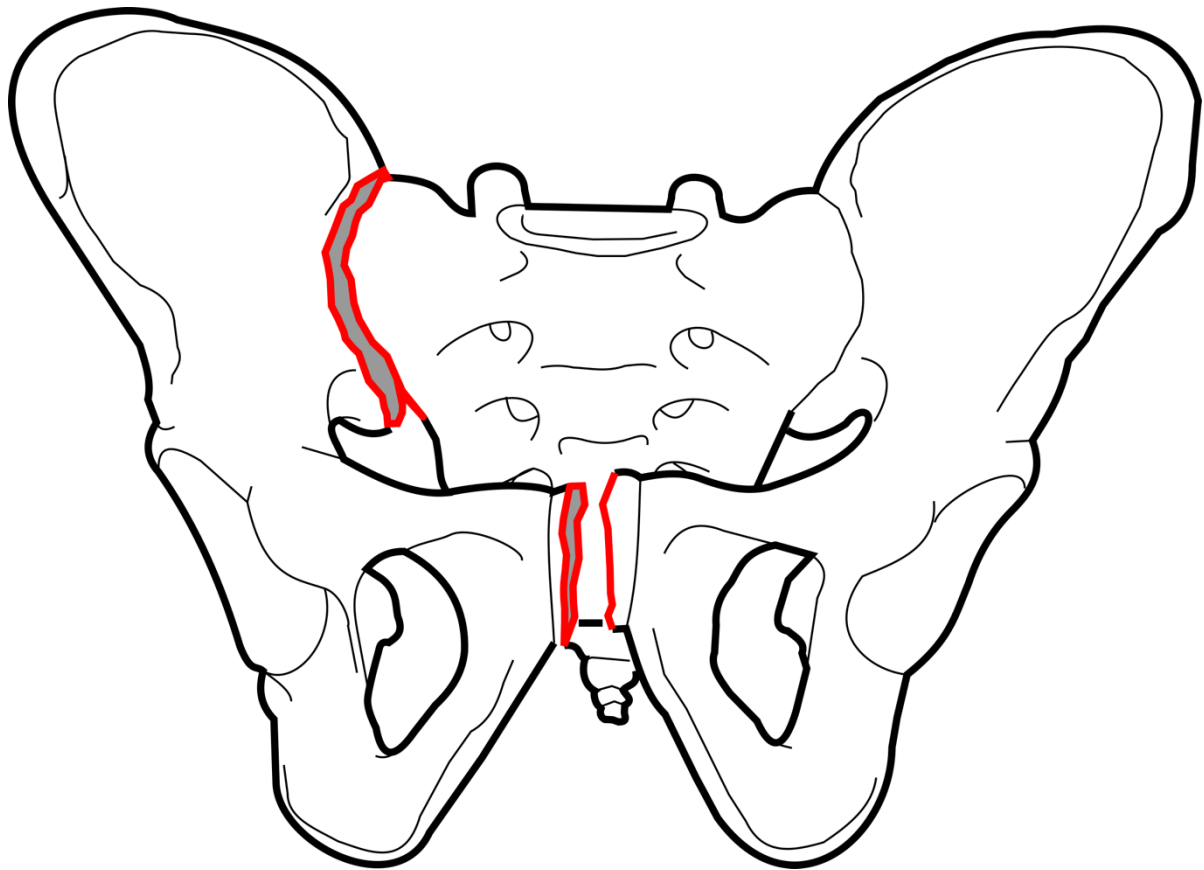


Figure 10; B-type fracture based on (11)

Managing C-type fractures is considered to be very challenging for the clinician. As already mentioned above external fixation with traction can be used as treatment option. However, definitive repairs are of utmost importance for a satisfactory outcome. The main focus lies on Open Reduction and Internal Fixation (ORIF) techniques, such as triangular osteosynthesis, lumbopelvic fixation, plate fixation etc. or minimally invasive osteosynthesis procedures like Iliosacral screw (ISS) fixation. Whatever technique is used depends on the patient's condition and injuries, but also on the skill and availability of the trauma center/surgeon. The ISS fixation is used in sacral fractures or sacro-iliac joint disruptions that are reduced satisfactorily. The reduction must be achieved prior to ISS fixation surgery. If the displacement is greater than 5mm additional open reduction with posterior plate fixation is recommended. Generally speaking ISS fixation is a percutaneous procedure that requires fluoroscopic guidance to safely place the screw. In unstable injuries the ISS can be accommodated by another screw, lumbopelvic fixation or anterior arch fixation or as mentioned above posterior plates. (24)

Triangular osteosynthesis uses lumbopelvic fixation and transverse sacral alar fracture fixation e.g. ISS or sacral plate. Highly unstable, vertical shear sacral alar fractures may need triangular osteosynthesis in order to prevent vertical displacement. First the ISS is/are placed and the pelvis is approached posteriorly to the sacrum. After pedicle screws are drilled in L4 and L5, the iliac pedicle screw is placed and the connection rods are inserted. (A more detailed description of the surgical procedure for lumbopelvic fixation can be found below)

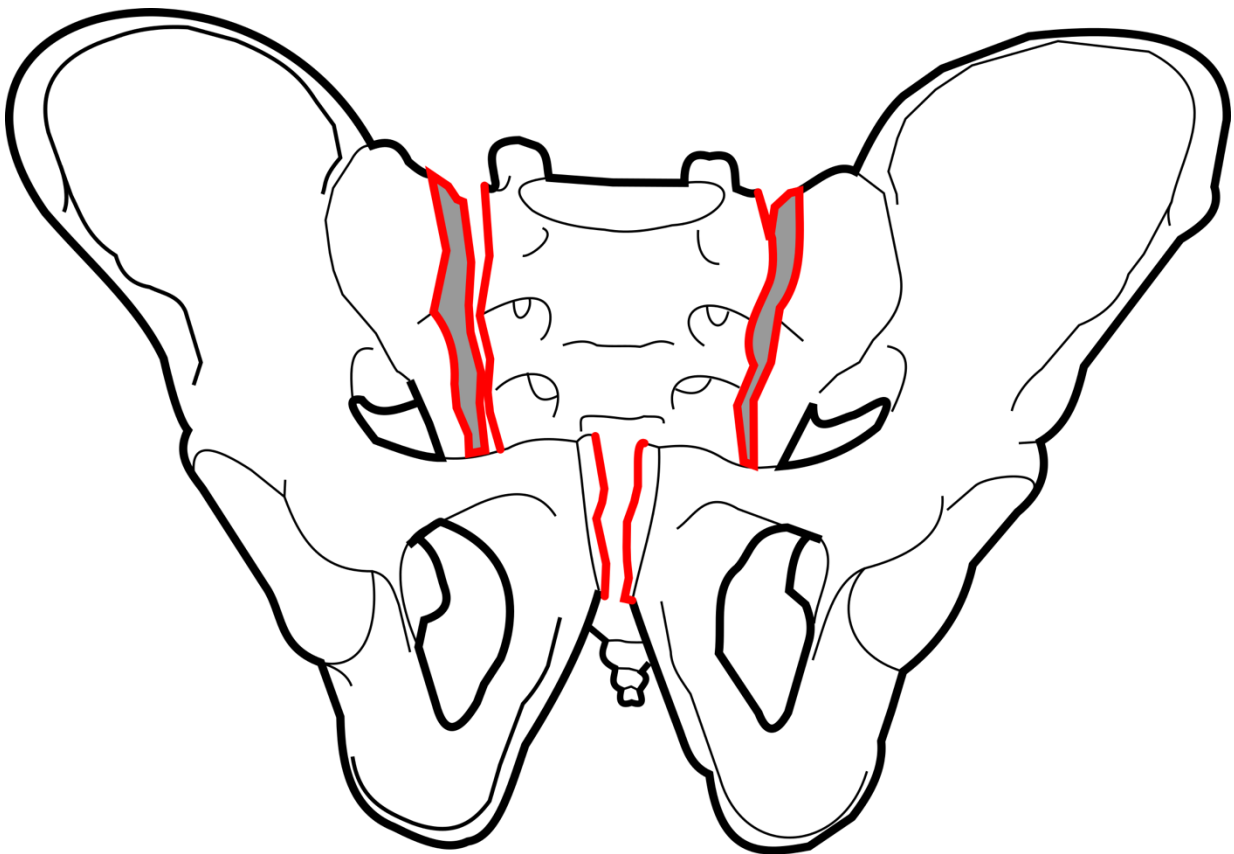


Figure 11; C-type fracture based on (11)

### **1.11 Epidemiology of pelvic ring fractures**

A prospective study conducted by *Balogh et al.* in Australia suggests that the incidence of pelvic ring fractures is around 23 per 100 000 persons. From the 23 per 100 000 persons, respectively 10 per 100 000 experience high-energy fractures, as well as another 10 per 100 000 persons face low-energy fractures. The remaining 3 per 100 000 persons undergo prehospital death. (25)

*Gänsslen et al.* could observe that the majority of pelvic ring injuries in their study group of over 3000 patients were classified as A-type injuries (54,8%), following B-type injuries with 24,7% and C-Type with 20,5%. In almost two thirds of cases patients were multiply injured, whereas most common single lesions were sacral fractures, ischiopubic bone fractures and transiliosacral instabilities. (26)

## 2 Material and methods

### 2.1 Patients

This retrospective study includes all patients that received lumbopelvic fixation at the department of orthopedics and traumatology of the LKH Universitätsklinikum Graz from January 2013 until October 2019, due to unstable pelvic ring fractures caused by trauma. Patients had to be at least 18 years old and the fracture had to be classified as C-type fracture according to the AO/OTA classification. Follow-up was at least a year postoperative or until metal removal. In total 75 patients received lumbopelvic fixation. However, 13 patients were lost to follow-up, due to them receiving postoperative care in another hospital/ their native country. 4 received lumbopelvic fixation for other reasons e.g. Failed Back Surgery Syndrome or sacroiliac pseudoarthrosis. 4 patients died in the course of time, but no death was related to lumbopelvic fixation surgery. One patient was underage. 53 patients met the inclusion criteria. (Figure 12) The author of this diploma thesis reviewed all medical records and original radiographic data retrospectively in a non-blinded fashion to identify:

1. Sex
2. Age at the time of surgery
3. BMI
4. Type of fracture according to AO/OTA classification
5. Mechanism of trauma
6. Accompanying injuries
7. Number of days between traumatic incident and lumbopelvic fixation
8. Number of days until the patient was discharged
9. Number of postoperative days until full weight bearing was possible
10. Early complications, such as infection
11. Late complications, focused on implant breakage
12. If the osteosynthesis material was disturbing for the patient and when it appeared to be so

13. If bony consolidation has taken place and when (determined via CT scan or X-Ray)
14. If the osteosynthesis material was removed and when
15. If the Patient was satisfied with the outcome.

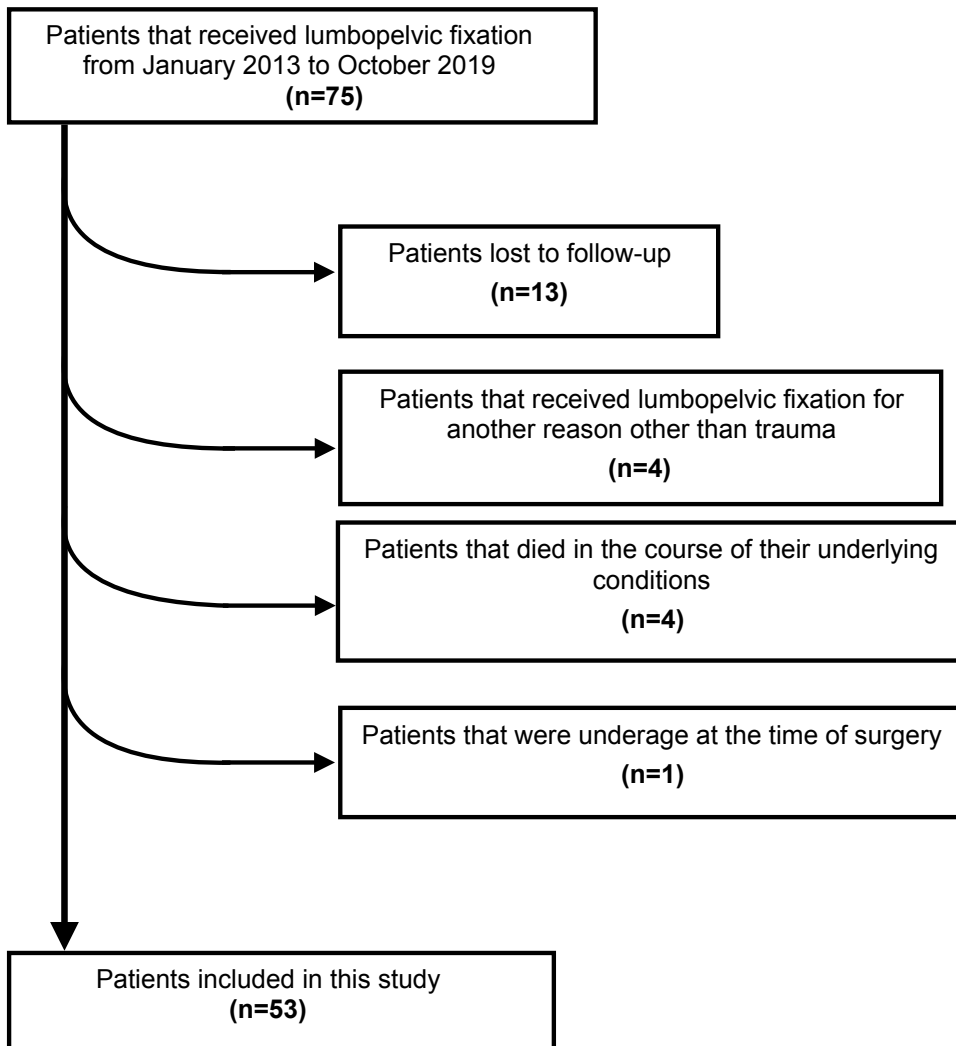


Figure 12; Study patient flow chart

## **2.2 Surgical Procedure**

Lumbopelvic fixation in unstable pelvic ring fractures should be performed as soon as possible, at least within two weeks after the traumatic incident. The patient is placed in prone position and a pillow is fitted under the belly, while the arms are headed towards the cranial direction. After sterile washing and covering is done, an incision of 2- 3cm length, lateral to the pedicle wall of L4/L5 is made. Under fluoroscopic guidance, introducer needles are positioned in the pedicle of L5. Afterwards guide wires lead the way for the screw placement. However, in cases of lumbosacral lordosis or sacralization of L5, the pedicle of L4 is approached. Next the iliac screw is placed. Therefore a 2 cm long incision is made about 1 cm medial to the posterior superior iliac spine (PSIS). The screw should be drilled in the canal that is formed between the PSIS and the anterior inferior iliac spine (AIIS), which is a path that is about 130 mm long, usually fitting 100 mm long screws. To ensure right screw placement, fluoroscopic control in a standard lateral and obturator oblique-outlet view can be used. The standard lateral view gives information about the screws position in relation to the acetabulum and the sciatic notch, while the obturator oblique-outlet view shows the characteristic “teardrop” figure, which appears as a result of the PSIS and the AIIS aligning over each other and can be interpreted as a frontal view of the mentioned canal. Is the screw, or in the beginning the guide wire within this “teardrop” figure it is placed properly. (3) After both screws are placed the reduction procedure can be done. This works best, when the screw insertion drivers of the screws are used as handles. Beforehand a rod is attached to the pedicle screw. Reduction can be done now.

When the reduction is satisfactory, the rod is passed and set screws are placed to secure the reduction. After final tightening the wound is closed. (3,27-29)

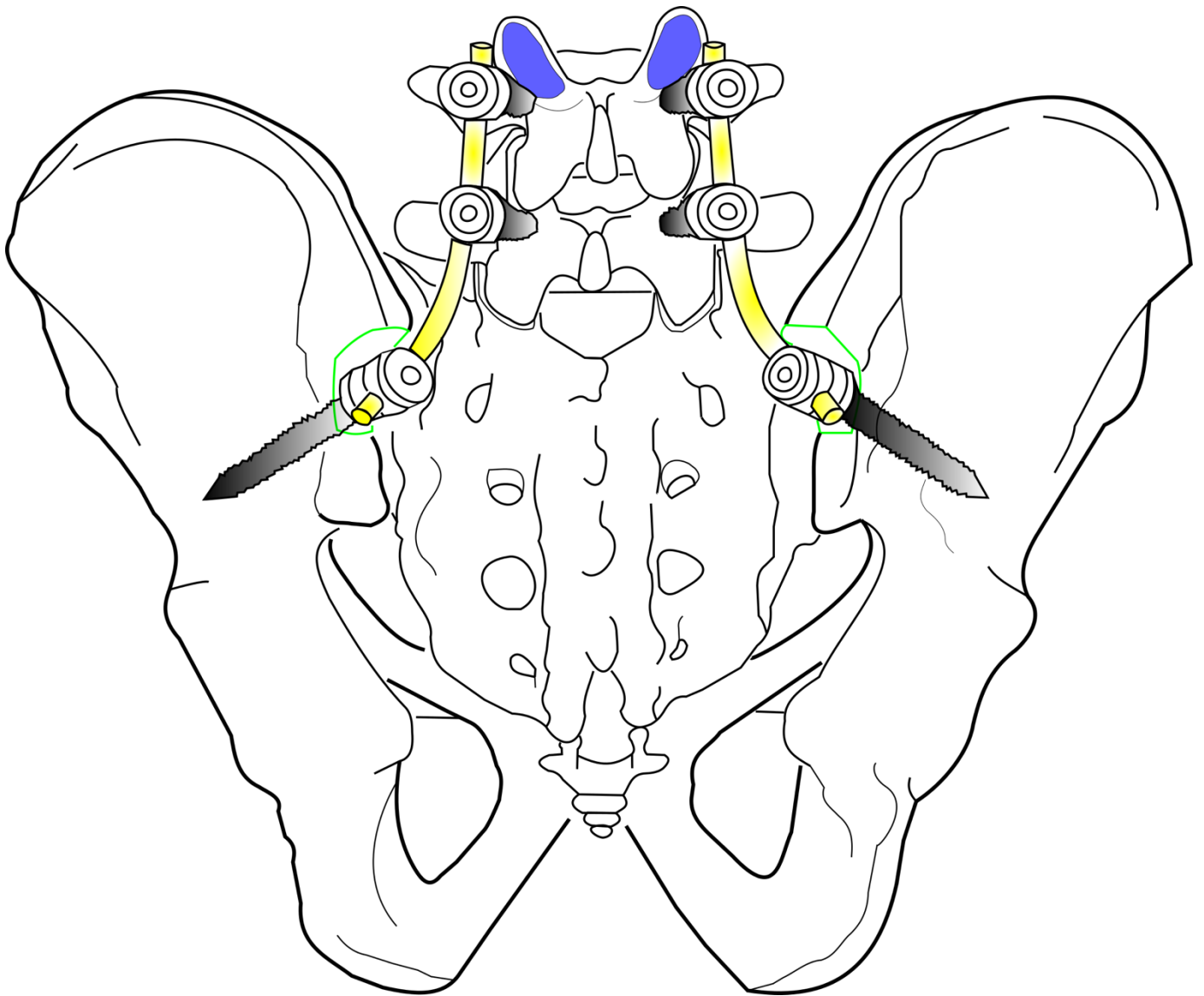


Figure 13; Lumbopelvic fixation instrumentation seen from the back based on (41)

### 3 Results

#### 3.1.1 Sex and age distribution

58% (n=31) of the patients included in this study are male, while 42% (n=22) are female. When it comes to the age, it ranges from the youngest patient being 19, whereas the oldest is 85. Mean age is 46 years with men being slightly older (mean=47y) than women (mean=44y). (Figure 14)

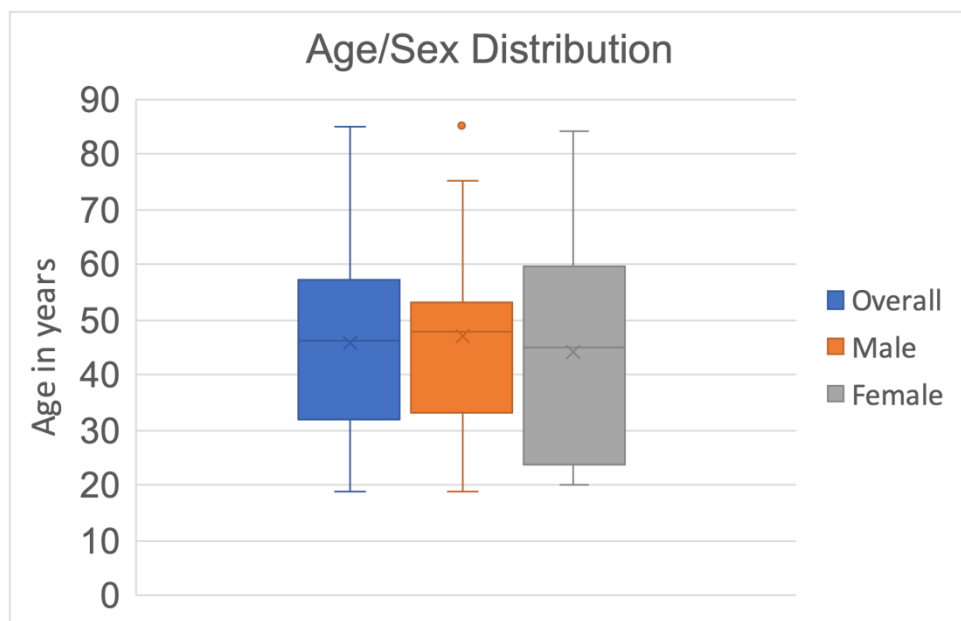


Figure 14; Age/Sex distribution

#### 3.1.2 Causes of injury

The most common cause of injury in this study group is related to road accidents and it makes up a total of 39,62% (n=21). 9 of these occurred when driving a car, especially when the drivers came off the road and hit stationary objects. 8 out of the 21 were hit by cars as pedestrians or as cyclists and 4 were related to motorbike accidents, by hitting other vehicles, as pillion passenger or with high speed on a racing track. Injuries from road accidents are followed by trauma caused by fall with 38,85% (n=19). 16 of those were associated with fall from great height ranging from 3 to 10 meters, while the remaining 3 were caused by low-energy falls as they appear in elderly people and/or patients with osteoporosis. Work-related injuries make up 16,98% (n=9). These can be divided into injuries that are the result of getting overruled by heavy machinery (n=6), such as

tractors, trailers or excavators and getting hit by heavy objects like falling trees (n=3). Injuries related to skydiving or paragliding represent the least common cause of injury in this study group with a total of 7,55% (n=4). (Figure 15)

Cause of injury		Total	Percentage
Fall	From great height	16	30,19 %
	Low-energy falls	3	5,66 %
Road accidents	In car	9	16,98 %
	As a pedestrian/by bicycle	8	15,09 %
	Motorbike	4	7,55 %
Work-related injuries	Overrunned by heavy machinery	6	11,32 %
	Hit by heavy object	3	5,66 %
Injuries related to Paragliding/ Skydiving	Paragliding	3	5,66 %
	Skydiving	1	1,89 %

Figure 15; Causes of injury

### 3.1.3 Length of time between trauma and lumbopelvic fixation

Patients got surgery as soon as their vital parameters and organ function allowed. Some patients had external fixation to bridge the time between definitive treatment and injury. The median length of time between trauma and lumbopelvic fixation was 6 days, while 90 % of the patients underwent surgery within 19 days [Range: 0d-95d]. There was one patient where a conservative treatment was established first, but failed and resulted in surgical treatment 95 days after the traumatic incident.

### 3.1.4 Length of time between lumbopelvic fixation and discharge

Patients were averagely discharged on the 21<sup>st</sup> postoperative day, while median length of time until discharge was the 16<sup>th</sup> postoperative day with more than 75% of patients leaving the department before the 34<sup>th</sup> day. The length of stay ranges from 1 to 81 days after surgery.

### 3.1.5 Lumbopelvic fixation instrumentation removal

Most of the patients requested hardware removal, due to pain in the region where the iliac screws lied or generally speaking in the in region where operation has taken place. Others had infections or hardware had breached (for more details,

see chapter “Complications”). 16 out of the 53 patients (30,19%) did not require hardware removal. The group “No hardware removal” was older on average (mean=57), while the group “Hardware removal” was younger (=mean 41). However, age does not have a major effect on the length of time, between lumbopelvic fixation and date of hardware removal surgery. If the study group is divided into patients over 50 (n=10) and under 50 years of age (n=27) that had instrumentation removal done, the median duration of time until instrumentation removal in the group >50 is 372d, while it is 394d in the group <50. Mean time between lumbopelvic fixation and removal in the group >50 is approximately 422d and in the group <50, 411d. The mean and median length of time between lumbopelvic fixation and date of hardware removal surgery amongst all ages is 414d and 383d.

### 3.1.6 Bony consolidation

Bony consolidation in patients was examined with CT scan or x-ray by either a doctor of radiology or traumatology. In 43 patients (81,13%) full bony consolidation could be obtained, with a median duration of 267 days. 65,12% (n=28) of these patients got bony consolidation within a year after surgery. In 23 cases a CT scan of the pelvis was done, while 9 of these scans could confirm full bony consolidation and 1 partly bony consolidation. There is one patient, whose fractures were not consolidated even after 850 days. (Figure 16)

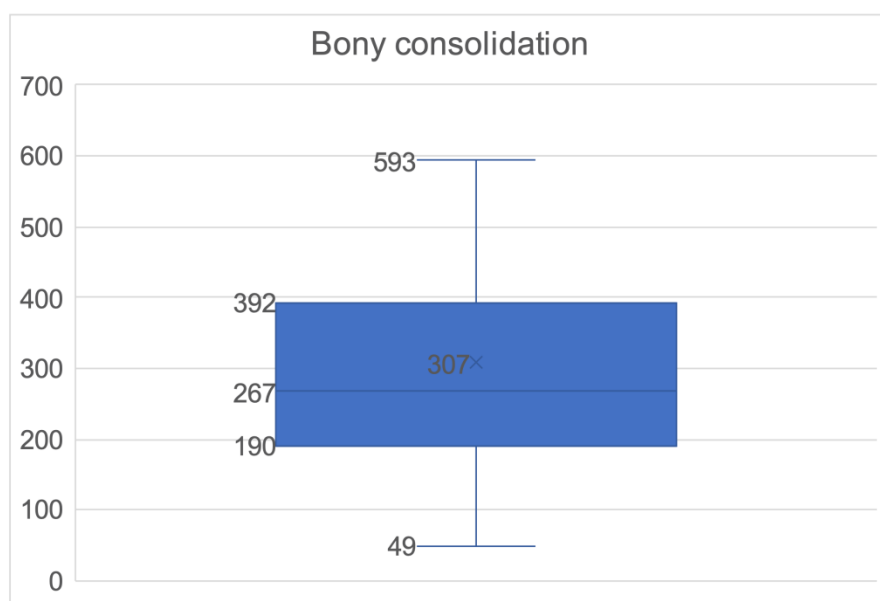


Figure 16; Bony consolidation over time in days

### 3.1.7 Disturbance by osteosynthesis material

One of the parameters that were conducted in this study was the number of days it took between surgery and a disturbance that was caused by the osteosynthesis material and led to lumbopelvic instrumentation removal. A disturbance was defined as: Pain by screws or generally pain sensation in the region were the instrumentation laid, lack in range of motion or other reasons such as complications that led to hardware removal (for more details see chapter “Complications”). In 39 patients (73,58%) a “disturbance” was documented, while 37 of these (69,81%) required hardware removal. The remaining 2 patients did not receive hardware removal surgery, as a result of personal choice not to do so. The median length of time until a disturbance was noted were 236 days, with 2 patients having complications after 879 and 1013 days, because of hardware failure (879 days) and pain (1013 days). (Figure 17)

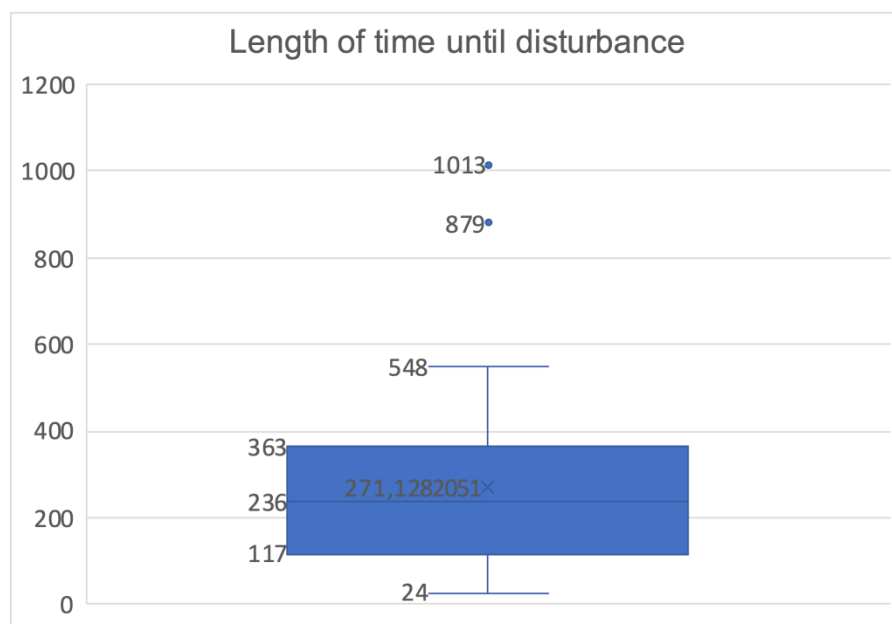


Figure 17; Length of time until disturbance in days after lumbopelvic fixation

### **3.1.8 Disturbance, bony consolidation and hardware removal in context**

As already mentioned 37 patients (69,81%) required hardware removal. In 6 of these patients the moment in time, when a disturbance occurred is unknown. So, 31 patients (58,49%) remain to evaluate the connection between the length of time until a disturbance occurred, bony consolidation was achieved and the instrumentation was removed. In 10 of these patients bony consolidation has already taken place as a disturbance occurred, so the hardware was removed as soon as possible. On the other hand, there were 19 patients that presented with a disturbance and it took a larger amount of time until the instrumentation got taken out. 12 out of the 19 patients have not had bony consolidation and therefore had to wait. However, as soon as their fractures consolidated they had hardware removal surgery. 7 out of the 19 patients did not receive instrumentation removal surgery, although their fractures were already consolidated due to personal choice, bed capacity or more important other injuries that made surgery not possible at that time. In the remaining 2 cases, there was no bony consolidation documented. However, hardware removal surgery was necessary because of complications (hardware failure and infection). (Figure 18)

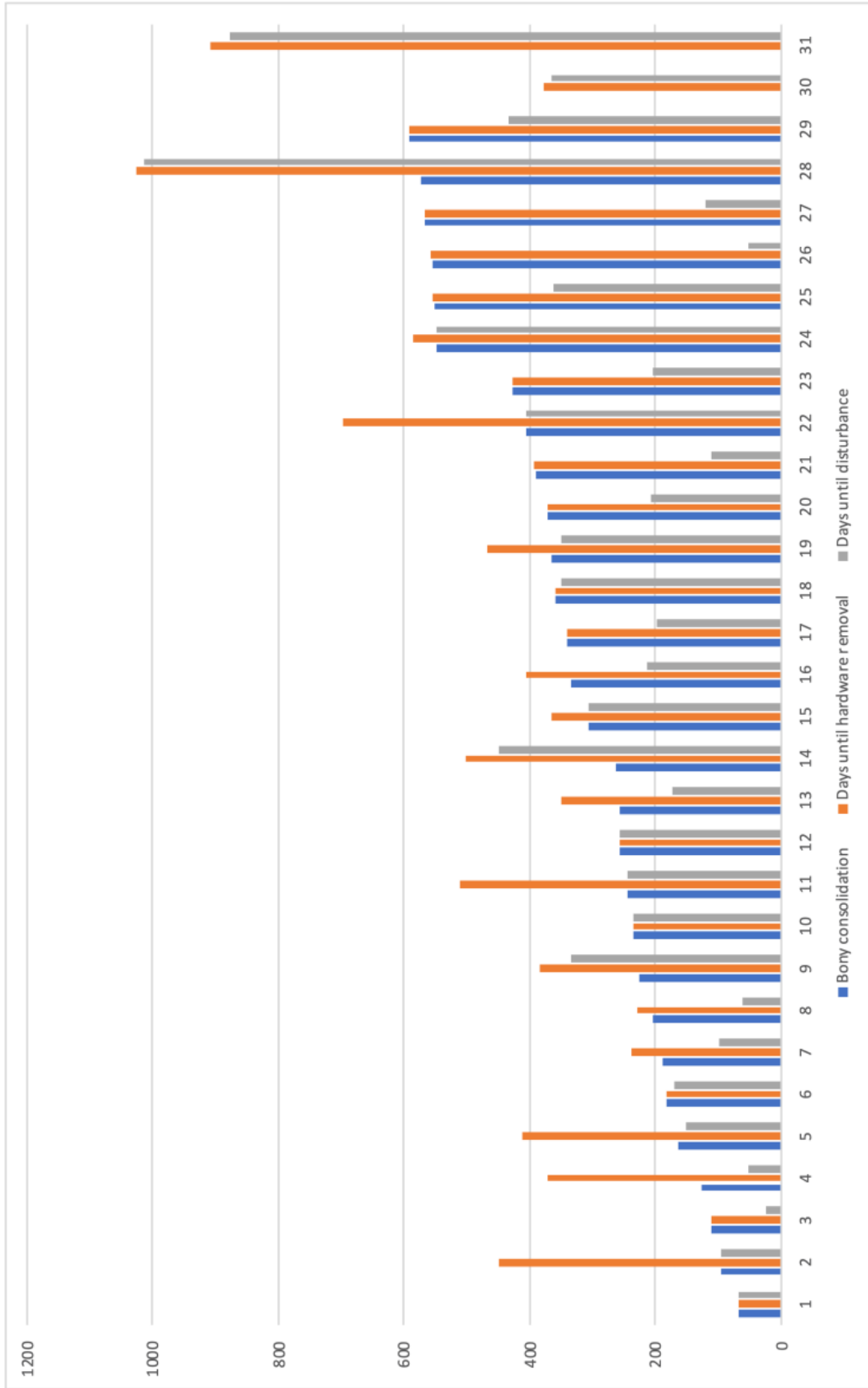


Figure 18; Disturbance, bony consolidation and hardware removal in context

## **3.2 Complications**

Complications were divided into early and late complications. Early complications were classified as incidents that occurred within the in-patient stay, late complications as all disturbances that happened afterwards.

### **3.2.1 Early complications**

20,75 % of the patients (n=11) suffered from early complications. The most common disturbances (7,55%, n=4) were caused by infection. One of these patients had an infection that led to loosening of the implant, after pus was evacuated the connecting rod was revised and fixated again. The same patient also suffered from deep vein thrombosis postoperative and initially presented with Morel Lavalle lesion. She was also diagnosed with pseudoarthrosis of the SI joints after 370 postoperative days. The instrumentation was never removed to date due to severe spondylolisthesis. Another patient had to undergo multiple surgeries that were associated with a perianal abscess, which resulted in a fistula, one year (367 days) after lumbopelvic fixation that opened itself into the area of the lumbar spine, causing an infection of the instrumentation and its removal. The remaining two patients had early infections (14<sup>th</sup> and 16<sup>th</sup> postoperative day), which were treated surgically with Redon's drain, lavage and smear collection followed by treatment with antibiotics. Three patients (5,66%) had wound healing disturbances, with one of them having decubitus 24 days after the operation, that ultimately led to hardware removal on the 113<sup>th</sup> postoperative day, despite adequate conservative treatment. The second one had a mucoserous spot on the right ilium that was treated conservatively until the patient developed a spondylodiscitis (L5/S1) that led to instrumentation removal on the 69<sup>th</sup> postoperative day. In case of the third patient, surgeons noticed necrotic spots in the area of the right ilium screw that even reached the fascia. Debridement of the necrotic tissue was done. Later the same patient presented with the cross connector palpable and almost coming through the skin, which led to hardware removal soon after. One patient (1,89%) suffered from pneumonia, one (1,89%) had pulmonary embolism, one (1,89%) had recurring fecal incontinence and another (1,89%) had revision surgery after secondary dislocation of anterior pelvic ring fractures.

### 3.2.2 Late complications

Also 12 patients (22,64%) had late complications, with most of them facing implant breakage (9,43%, n=5) or loosening (1,89%, n=1). One of these patients had pseudoarthrosis, as a result of implant loosening and brakeage of the right connecting rod. The remaining 4 cases of implant breakage were caused by failure of the connecting rod, while another patient had to face loosening of a screw. 2 patients (3,77%) had an infection (as already mentioned in “Early Complications”), one (1,89%) a dislocation of a fracture fragment, one (1,89%) had to face possible skin lesions with the hardware almost coming through the skin, one had (1,89%) decubitus as already mentioned in “early complications” and another (1,89%) had to face pseudoarthrosis of the SI-joints.

In total, 5 of the 12 patients had early and late complications, with all early complications resulting in late complications. (see Figure 19)

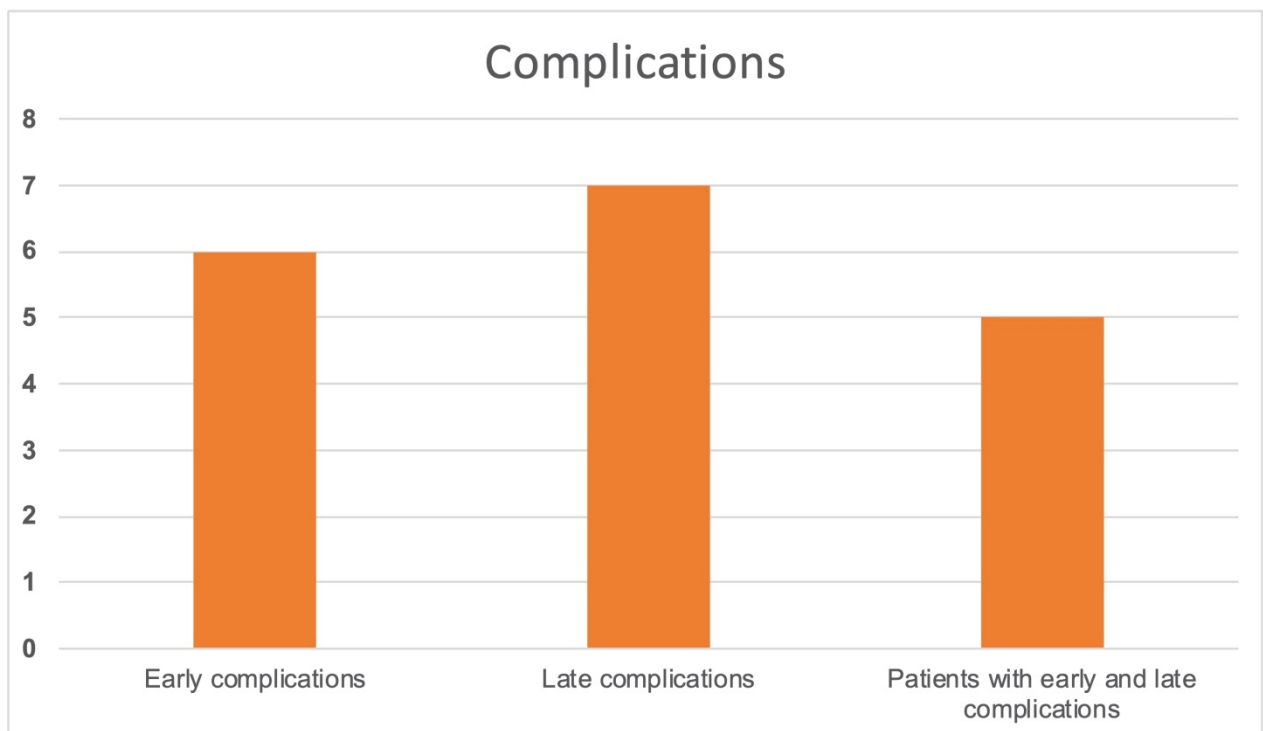


Figure 19; Number of patients facing complications

### 3.2.3 BMI and complications

The mean BMI of the study group is 26 (dispersion=5), while median is 25. To put the aspect of obesity and complications in context, overweight/obese patients (BMI > 25) and healthy weighted/underweighted patients (BMI < 25) can be put in a group. The number of early, late and early complications that resulted in late complications can be evaluated in each of the two groups. There are 27 patients in group "BMI < 25" with a total of 9 patients having complications and 26 in group "BMI > 25" with 9 patients facing complications postoperatively. As already mentioned before, infections and implant breakage/loosening make up the most common causes for postoperative issues. 4 patients in the group BMI > 25 had infection of the instrumentation after surgery, while there was only one person in the group BMI < 25. Furthermore this person had the infection more than 60 days after receiving lumbopelvic fixation, whereas the other patients developed it within their post-surgery hospital stay. The number of implant breakage/loosening in the group BMI < 25 is 4, whilst it is 2 in the group BMI > 25.

## 4 Discussion

Unstable pelvic ring fractures are of low incidence and are therefore rarely reported in the literature, especially when it comes to the relatively new method of lumbopelvic fixation. (27) However, these injuries are associated with high-energy trauma and have been a challenge in trauma surgery ever since, especially due to the fact that most of the patients are polytraumatized and in an unstable state. So, the comorbidities and mortality of these types of injuries are very high. (30-32) However, early lumbopelvic fixation lays the foundations to a stable pelvic ring that allows other co-injuries to be treated and is a method that enables early weight-bearing. (27,33-37)

When it comes to our results with disturbances by osteosynthesis material, we could observe that 39 of our 53 patients (73,58%) complained about painful and prominent implants. By contrast *Sagi HC et al.* reported disturbances caused by implants in 38 out of 40 patients (95%), that were treated with triangular osteosynthesis (= a combination of lumbopelvic fixation and iliosacral screw placement). (27,37,38) Unfortunately, they did not include any information about

their patients' age or BMI in their original article, since we could see that out of the 14 patients that have not felt a disturbance by the implants, 12 were overweight (BMI > 25) and/or older than 50 years. Moreover, they described that patients were typically in pain after stabilization and another rise in complaining about low back pain could be seen at the 4- to 6-month mark, when patients got more physically active again. In our study group half of the patients expressed pain later, around 8 months (median = 236d) after surgery, while after a year 75% did so (75% of patients in pain = 363d). Since most of our patients that were unbothered by the implants were aged over 50 or overweight it would be interesting to see, if their activities of daily living (ADL) differed from the younger and healthy weighted patients so that pain could not develop in the same way, or if a higher amount of soft tissue around the implants prevents developing pain. Compared to transiliac plate fixation, *Boudissa et al.* reported that 4 out of their 10 patients treated with posterior transiliac plating in vertically unstable sacral fractures had hardware removal surgery due to discomfort. However, it would be interesting to compare the occurrence of disturbances in lumbopelvic fixation versus transiliac plate fixation in a study with a comparable patient population. (39)

When it comes to hardware failure we could see that in 9,43% of the patients (n=5) implanted metal broke and in one case (1,89%, n=1) it loosened. However, in one of the patients with hardware breakage also loosening of the opposite iliac screw and bilateral screw loosening in L4 occurred. *Bellabarba et al.* reported that in 6 out of their 19 patients ( $\approx$  31%) at least one broken rod could be observed, which is about three times the percentage that was seen in our study group. (40) By contrast, *Sagi HC et al.* reported that 15% of cases resulted in implant loosening (37) and *Williams et al.* noted two broken screws in 15 patients, while it is unclear if the screws broke in one patient or in two patients separately (28). So the incidence of hardware failure is very variable in the literature. However, an incidence of around 10-15% seems suitable for lumbopelvic fixation, since our study used a higher number of patients and a minimum follow-up of 12 months. This also correlates with *Sagi HC et al.* even though they used triangular osteosynthesis. (37) Interestingly higher BMI (>25) does not appear to have an impact on the parameter, since most of our cases in hardware failure were reported in the group BMI < 25.

Postoperative infections appeared in 5 patients (=9,43%), while one was caused by a wound healing disturbance and resulted in spondylodiscitis. As the above mentioned literature, we could also see that degloving injuries (like Morel Lavalle) are prone to develop postoperative infections. (20,22)

## **5 Conclusion**

Lumbopelvic fixation is a safe surgical method for unstable pelvic ring fractures, with the advantages of immediate full weight-bearing, even in obese patients. The complications are low and fractures consolidate well. However, most of the patients treated with this method need hardware removal surgery. Our data shows that the points in time when disturbances with the implanted hardware appear or when bony consolidation is achieved are variable. One year after surgery bony consolidation could be observed in most patients. Therefore, a CT-scan of the pelvis could be scheduled 12 months after the date of surgery, as well as a date for hardware removal surgery could be scheduled in advance. This strategy should especially apply to younger and healthy-weighted patients, since we could see that older and over-weighted patients do not necessarily require hardware removal, also accompanying injuries should be taken into consideration, since they are also a reason not to remove the implants.

Given that this is a retrospective study some of the parameters that were looked at were difficult to evaluate. For example, if the patients that received lumbopelvic fixation were happy with the procedure. In order to investigate this parameter a questionnaire that patients fill out would be necessary like the Short Musculoskeletal Function Assessment (SFMA) scoring. A prospective study with given parameters that need to be looked at would solve these problems.

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