Severe Pelvic Bleeding: The Role of Primary Internal Fixation

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Abstract
Pelvic ring injuries form part of the spectrum of polytrauma and must be considered a potentially lethal injury with mortality rates of 10–20%. The stabilization of the unstable pelvic ring in acute resuscitation of multiply injured patients is now conventional wisdom. We aimed: (1) to design a new iliosacral (IS) screw, (2) to prove the clinical advantages of this new implant, and (3) to work out the optimal surgical strategy using this implant. Taking the demands of the above mentioned data into account, a 10 mm 2.8 mm-cannulated iliosacral screw seemed to be optimal for the special requirements. Before industrial production, finite element analysis (FEA) was performed to find out whether these screws would be enough to stabilize the posterior pelvic ring alone or not. Clinical experience led to the modification of the set of instruments, which finally yielded handy tools and implants. Building further on the surgical skills and experiences gained (by the surgeons and the O.R. personnel), we increased our capacity to perform more and more immediate pelvic fixations. Emergency pelvic stabilizations were performed in patients with pelvic injuries who had hemodynamic instability, despite immediate shock management during the diagnostic period. During the last eleven years, 244 patients with Tile B3 and C pelvic injuries have been stabilized with 10-mm diameter cannulated IS screws percutaneously posteriorly. Forty-eight hemodynamically unstable patients were stabilized in the first 2 h with iliosacral screw fixation. The percutaneous pelvic ring stabilization with 10-mm cannulated screws proved strong enough in bothersome cases as well.

Key Words
Pelvis · Finite element analysis of pelvic injuries · Emergency pelvic fixation · Emergency iliosacral fixation

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Introduction

The risk of hemorrhage makes major pelvic fractures one of the most serious skeletal injuries, usually resulting in high mortality rates. Furthermore, pelvic fractures often accompany other major traumatic or multiple traumatic injures and thus can add to overall mortality. Mortality following pelvic fractures has declined dramatically in recent years due to improved methods of hemorrhage control and general management of trauma [1–3]. However, about 10% of these patients still die, even with these advances, and most due to hemorrhage. Although high-energy pelvic fractures are often accompanied by injuries that are too serious for salvage, a percentage of these patients probably could be saved if the hemorrhage was more effectively controlled. The questions to be answered in pelvic fracture management are: exactly what is bleeding, and what technique should be used to stop the hemorrhage?

Stability

The management of pelvic injuries depends on the type of instability. Unstable injuries often require surgery, while stable injuries are generally managed nonoperatively. Unfortunately, post-pelvic injuries are rarely stable, but vary from completely stable to totally unstable. Each fracture is unique, and has its own individual instability, and the surgeon must assume the level of instability in each particular case.

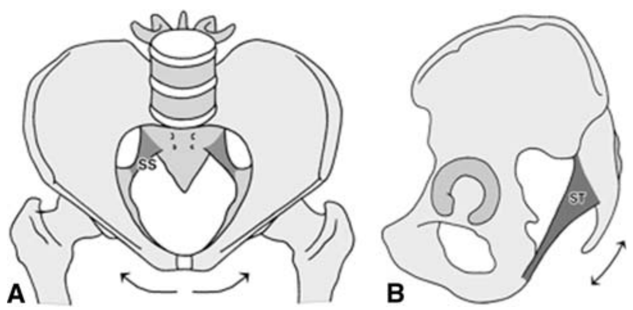


Figure 1. Illustration of the mechanical role of the sacrospinous (*SS*) and sacrotuberous (*ST*) ligaments.

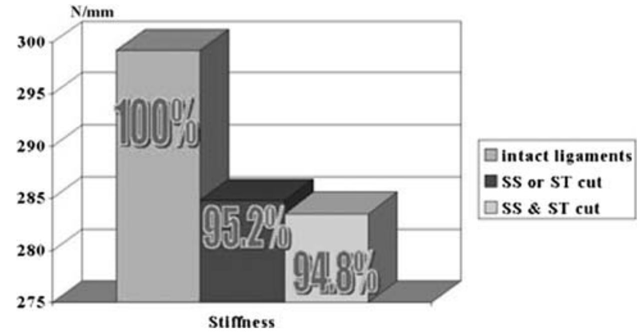


Figure 2. Comparison of the mean pelvic ring stiffness for the intact pelvis in the bilateral stance (100%) with the stiffness of the pelvic ring when sequentially one SS or ST (95.2%) or both SS and ST (94.8%) ligaments are cut.

Biomechanical Considerations

In order to better understand the pelvic injury classification and management rationale, a knowledge of pelvic biomechanics is essential. By definition, the stable pelvis can withstand physiological loads without dislocation of its components. It is more sensible to declare that the pelvis is unstable when it displaces under minimal load (i.e., patient bed rest). One of the most important treatment goals is prevention of dislocation.

The bony pelvis has no natural stability, but rather its integrity is secured by numerous strong ligaments. Anteriorly are the pubic symphyseal ligaments, and posteriorly are the anterior sacroiliac ligaments, interosseous ligaments, and the posterior sacroiliac ligaments. Inferiorly, the sacrotuberous (ST) and sacrospinous (SS) ligaments cross from the ilium to the sacrum and are continuous with the pelvic floor (Figure 1). The ligaments maintaining the posterior complex are among the strongest in the body. The posterior part of the innominate bones, the sacrum, and the ligaments forming the sacroiliac (SI) joints are known as the posterior weight-bearing complex. This area is crucial for normal weight-bearing. The complex can be injured by direct ligamentous tears, or fractures through the ilium or sacrum. The extent of dislocation indicates the energy of the injury. Any injury in this area creates variable instability. The grade of instability depends on the area of the damage. Sacroiliac joints can withstand loads of 1,440 N without failure. The majority of studies demonstrate that the sacroiliac joint only moves a few millimeters. In addition, biomechanical tests prove that the normal pelvis can withstand vertical loads of 3,630–5,837 N without failing [4].

Tile [5, 6] described the role of the major pelvic ligaments. Disrupting the pubic symphysis allows the iliac wings to rotate outward slightly. The symphysis can widen 25 mm, but the anterior sacroiliac ligaments and the additional remaining pelvic ligaments avoid further rotational dislocation. Since the sacroiliac ligaments stay behind intact, dislocation of the sacroiliac joint is not possible. If the anterior sacroiliac ligaments are then cut, the iliac wings can continue to rotate laterally, opening the pelvis like a book, until the posterior spines touch the sacrum. The intact interosseous and posterior sacroiliac ligaments, however, continue to prevent anterior/posterior and cephalic/caudal dislocations of the sacroiliac joint. When these ligaments are disrupted, all stability is lost, and the pelvic bones are free to move in any direction.

The role of the sacrotuberous and sacrospinous ligaments is not so clear. Tile suggested that these ligaments contribute to both rotational and vertical pelvic stability [5, 6]. Compared to the contributions of the other major ligaments, their role is most likely relatively small (Figure 2) [5, 7–10].

Based on these anatomic considerations, it is practical to classify pelvic stability into three categories: stable, partially stable, and unstable. The stable pelvis cannot dislocate in any direction, meaning that the posterior complex is intact. At the other end of the spectrum is the unstable pelvis, which can shift in any direction and requires the posterior weight-bearing complex to be totally disrupted. The partially stable pelvis is midway between these two, thus allowing rotational pelvic ring displacements but not translational movements through the posterior complex. For example, if the pelvis can open and close like a book, but the posterior weight-bearing complex cannot vertically displace, then we are talking about a complete injury to the anterior pelvis and a partial injury to the posterior weight-bearing complex.

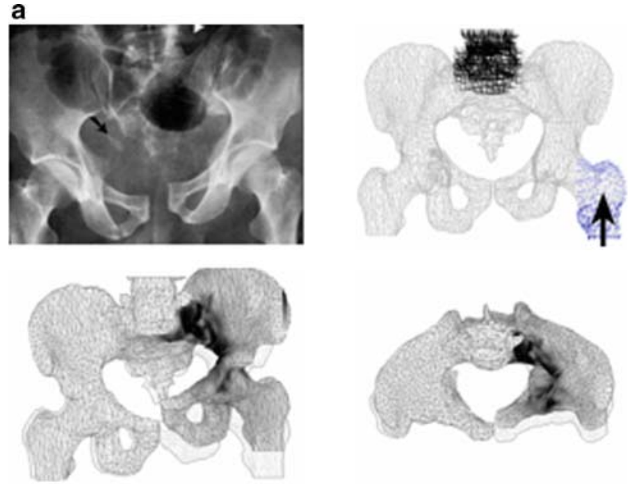
The Orthopedic Trauma Association (OTA) classification comes from a system described by Tile and Pennal [5, 6] in 1980. Pelvic injuries are classified into three basic categories: (A) completely stable, (B) partially stable, and (C) completely unstable. Another classification system, recommended by Burgess and Young [11], considers the mechanism of injury to be associated with different fracture types. This classification is predominantly helpful in relation to pelvic bleeding, since it offers the surgeon a better way to connect injury severity and direction with bleeding. The grade of instability provides an idea of the force that disrupted the pelvis, and the mechanism provides the direction of that force through the body. The four main mechanisms are anteroposterior compression (APC), lateral compression (LC), vertical shear (VS), and combined mechanical injury (CMI). The APC and LC categories are further divided into classes 1, 2 and 3, according to the degree of instability, with 1 being stable, 2 partially stable, and 3 totally unstable [12]. Cadaver-CT-based finite element analysis (FEA) has been performed and analyzed to demonstrate the main mechanisms of pelvic injuries [13, 14].

Lateral compression forces are directed laterally from one or both sides of the pelvis, causing vertical compression fractures in the sacrum posteriorly and oblique fractures of the rami anteriorly. Occasionally, the posterior spine of the ilium will fracture, resulting in a crescent fracture. Rarely, the anterior disruption will be through the symphysis, resulting in an overlap of one pubic body with the other [13, 14].

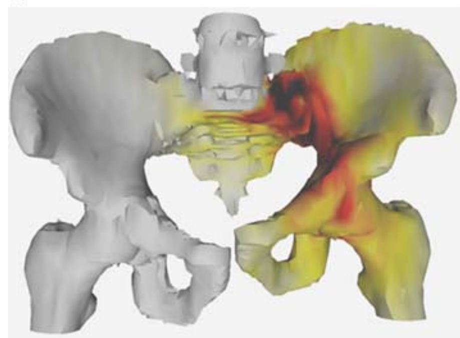
Anteroposterior forces have a tendency to split open the pelvis. Forces in the anterior–posterior direction, striking the posterior spines, tend to rotate the iliac wings outward while disrupting the pubic symphysis and sacral–iliac joints. Anterior–posterior forces may cause the same rotatory forces by striking the anterior iliac wings or by causing extreme external rotation of the hips. In any case, the result is the same: the pelvis is opened anteriorly, like a book.

Vertical shearing forces tend to translate one hemipelvis superiorly, dividing the SI joint. Anteriorly, this can result in disruption of the pubic symphysis, the rami or both. Occasionally, the direction of the deforming force is not obviously indicated by initial X-rays. The mechanism in these cases is described as a combined mechanical injury (CMI). By definition, all pelvic injuries in this category are unstable, with complete disruption of the posterior sacroiliac complex [13, 14] (see Figures 3a, 3b).

a



b



Figures 3a and 3b. a) Vertical shear injury typically occurs when falling from a height onto one leg. b) To simulate a vertical shear injury, our mechanical model was prepared in the following way: the spine region was fixed and force was applied to the femur pointing upwards [13].

Clinical Consequences

The direction of the force causing the injury provides an idea of its stability. Lateral compression forces have a tendency to collapse the pelvis. This typically results in fractures to the pubic rami and sacrum, but frequently leaves the posterior ligaments intact. Anterior–posterior compression forces and rotational forces have a tendency to disrupt the anterior ligaments, but leave the posterior ligaments intact. Vertical forces have a tendency to harm the posterior ligaments directly; however, any mechanism can lead to a totally unstable pelvis if the energy is sufficiently large. Regardless of the direction of the force, a disruption of the posterior pelvic ring is a warning sign of a high-energy injury, and the surgeon must be careful to exclude associated injuries. Gross instability can be detected by manually stressing the pelvis, but it is frequently difficult to clinically feel the instability. The most reliable radiographic sign of instability is severe displacement in the pelvic ring. Dislocations greater that 1 cm at the posterior complex suggest total instability [15]. When a large gap is seen on the CT scan across the sacrum or SI joint, it also suggests total instability. Additional radiographic signs indicative of instability are avulsion fractures of the ischial spine or lumbar transverse processes. Determining pelvic instability based solely only on clinical and radiographic findings is a difficult task in some patients, and further assessment under anesthesia and fluoroscopy is used to verify if stress maneuvers cause large displacements in the pelvic ring.

Sources of Bleeding

Arteries

Arterial injuries are commonly identified during pelvic angiography after trauma, and there is some data indicating that embolization reduces mortality. However, Agolini et al. examined 806 patients admitted with pelvic fractures, 35 of whom underwent pelvic angiography. Only 15 patients (< 1.9% of all pelvic cases) required embolization [1, 2, 4].

Veins

Similarly, numerous authors have proposed that venous bleeding is mainly responsible for blood loss associated with pelvic fractures [1, 2, 12, 16]. Connolly and Hedberg evaluated a group of 200 patients with pelvic injuries. Five among the 30 deaths were considered to have resulted from pelvic hemorrhage [4]. The source of bleeding was typically the ''plexus of veins and arteries lining the side walls of the pelvis,'' with contributions from both torn and punctured (by bone fragments) veins and arteries.

Bones

Huittinen and Slatis [17] dissected 27 cadavers who died from bleeding following pelvic injury. The victims were studied with plain X-ray films, contrast arteriography and dissection. Contrast outflow in the injured region occurred in 23 of 27 victims, and all in close proximity to the posterior pelvic ring. Evaluating the X-ray data and position of contrast leakage with direct inspection during dissection, some important discoveries were made. Firstly, the degree of bony and vascular damage was greater than the plain films suggested. Second, the ''leakage'' from a fractured cancellous bone, the sacrum in posterior fractures, was a major cause of bleeding, even in ''minor'' fractures. The identification of torn anatomically specified arteries was only possible in 3 of 17. Based on this data, the correct repositioning of a dislocated pelvic fracture is preferred when attempting to control severe bleeding.

In summary, three types of blood loss are considered in pelvic fracture: arterial bleeding resulting from damage to any pelvic arteries, venous hemorrhage resulting from tearing of veins, especially in the posterior venous plexus, and blood flow directly from fractured cancellous bone. It is obvious that the therapy for each of these bleeding sources would be different. In view of the fact that it is impossible to determine the major source of the damage, it is important to deal with both arterial and venous (bony) damage. Undoubtedly the most essential procedure is to manage the patient's capability to clot bleeding vessels. Beyond that, arterial injuries are best managed by embolization, and venous injuries are best controlled by providing some kind of surgical intervention, such as tamponade, C-clamp insertion or acute percutaneous iliosacral fixation [18–21].

How Fracture Pattern Shows a Relationship with Blood Loss

Patients with high-energy pelvic fractures have the greatest chance of bleeding and dying. However, they also have the maximum number of associated injuries. Even though high-energy fracture patterns are more likely to bleed, not all high-energy fractures accomplish massive hemorrhage. Obviously, high-energy injuries confirmed by radiographic pelvic instability are more likely to lose blood than stable injuries. The pelvic ring becomes totally unstable when the posterior sacroiliac complex is disrupted, such as in APC3, LC3 and VS injuries. These fracture patterns suggest that the pelvis has absorbed a high-energy impact. In addition, it appears that in injuries where the pelvic floor has been disrupted, such as with unstable anterior–posterior compression injuries, and occasionally with VS injuries, there is more likely to be serious bleeding than in LC injuries, where the pelvic floor remains intact (''high-risk'' fracture patterns). These tendencies, which associate fracture pattern with risk of bleeding, help the surgeon to change his/her index of suspicion, although it is important to keep in mind that fracture pattern does not absolutely predict bleeding [1, 5, 6, 17].

Management Protocols

There is no commonly approved protocol for managing pelvic bleeding. At the combined meeting of the OTA and AAST in 2000, a panel of professionals, including orthopedic surgeons, general surgeons and radiologists, was assembled in an attempt to achieve some standardized protocol when dealing with bleeding from pelvic fractures [22]. The entire transcript of this meeting is accessible at http://www.hwbf.org/ota/s2k/panel/pfset.htm.

They all agreed that there were no perfect data representing the efficiency of any intervention to control hemorrhage associated with pelvic ring injuries. The most appropriate interventions depended on the professional's field. The radiologist and the general surgeon believed that angiography was the most essential intervention and should not be delayed by stabilizing the pelvis. The orthopedic trauma surgeons had a tendency to try pelvic stabilization of some kind (either by external fixation or sheet binder) as the most important intervention. Pohlemann, from Germany, felt that urgent stabilization, followed by pelvic packing when necessary, offered the greatest chance of stopping the hemorrhage. The Advanced Trauma Life Support (ATLS) manual outlines that early resuscitation is essential and encourages preliminary pelvic stabilization by simple methods, such as sheet wrapping. The most recent ATLS manual (8th edition) does not suggest or support either angiography or external fixation as the primary intervention, thus avoiding this controversial topic.

Based on the OTA review panel, the available literature, and advanced discussions during trauma conferences, two common protocols are accepted in the United States. Resuscitation is the first step in everyone's practice. Following this, the patient either undergoes angiography or gets an external fixator for pelvic stabilization. If angiography is chosen as the first step and it is unsuccessful, the pelvis is stabilized. If pelvic stabilization is unsuccessful as a first step, the patient goes to angiography.

Following the protocol used at our university, and based on my research and clinical practice, we begin with resuscitation and then stabilize the pelvis with sheet wrapping or a pelvic inflatable belt. This can be done rapidly while resuscitation is started. If the patient continues to bleed, an urgent CT scan with contrast material is performed. If active bleeding is recognized on the CT scan, immediate angiography with embolization, especially among patients with "low-risk" pelvic fracture X-ray patterns and when another source of bleeding is excluded, are done. Patients with "high-risk" fracture patterns on pelvic X-ray require immediate posterior and anterior stabilization. Generally, minimally invasive procedures are carried out using an external fixator and percutaneous iliosacral screw fixation. If the patient has any obvious uncontrolled bleeding after these procedures then an angiography or pelvic packing is indicated. In reality, resuscitation, simple stabilization, immediate anterior and posterior stabilization and angiography almost always control the bleeding, and pelvic packing has been used in only a few cases [19, 20, 23, 24].

Management Choices

Embolization

Embolization of bleeding arteries by interventional radiologists has been a part of the standard procedure for managing pelvic fractures for several years, and a number of studies have indicated that the procedure is efficient [1–3, 16]. Randomized studies do not exist for ethical reasons.

External Fixation or Other Outer Stabilization

A number of studies suggest that stabilizing unstable pelvic fractures with quickly applied external fixators reduces shock and mortality.

Riemer et al [25] demonstrated a lower mortality with a pelvic fracture protocol that used early stabilization with external fixation. They found that mortality rates in pelvic ring injury patients fell from 26% in 1981 to 6% in 1983–1988 among the same injury severity score (ISS) patients. This paper offers unproven support for external fixation.

External fixation is assumed to provide tamponade, by decreasing the pelvic volume and room for blood loss. Moss and Bircher [26] evaluated volume changes in the true pelvis occurring with progressive displacements in the pelvic ring using cadaver models. In general, volume increases were less than previously supposed, and far less than the usual replacement requirements for major fractures.

The expected blood loss in pelvic fracture is over 10 units. However, the Second Pelvic Acetabular Course (1994) declared that increasing the volume of the pelvic cavity is not solely responsible for bleeding, since it contributes an additional volume increase of only 55% in severely injured patients with pelvic separation. This still does not totally clarify the blood loss. The bleeding from the spongious bone is an additional cause of continuous hemorrhage. Closing the ring with the help of external fixators in an open book-type fracture is a good way to stop the bleeding. However, in C-type fractures, this technique is regularly insufficient since the external fixators are not able to control the motion in the posterior pelvic region [20].

Grimm et al. [27] also verified that the volumetric capacity available for blood with pelvic fractures is

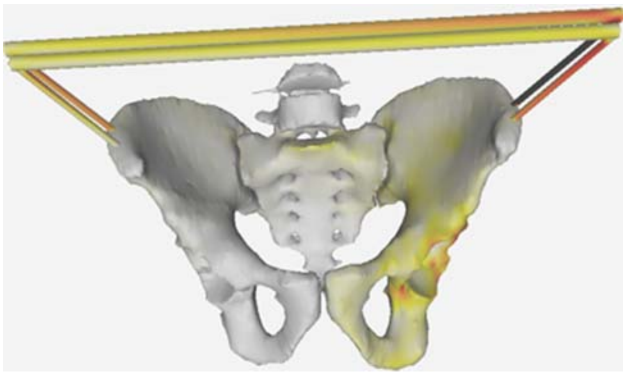


Figure 4. Finite element analysis (FEA) was performed on a one leg stance stress model. Open-book injury fixed with iliac wing frame. No displacement at the pubic symphysis (PS) region.

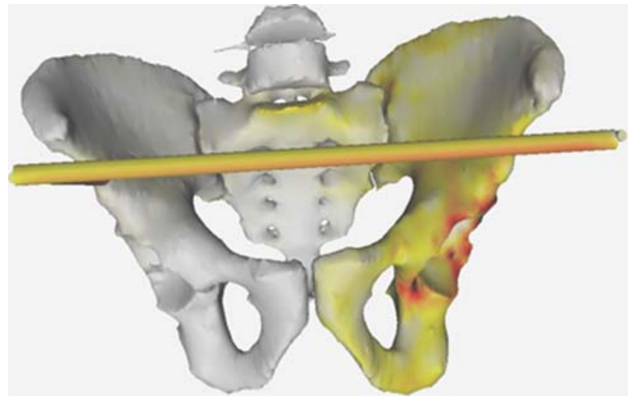


Figure 5. FEA was performed on a one leg stance stress model. Open-book injury fixed with suprapubic frame. No displacement at the PS region [20].

much larger than the true pelvis. They measured the intrapelvic pressure of fluid with and without simulated pelvic fractures. The intact pelvis required 8 l of fluid to increase pressure to 50 mmHg. Pressures in the injured pelvis did not achieve this level, even following 20 l of fluid-filling. The utilization of external fixators produced just a small increase in intraperitoneal pressure. Dissection showed that liquid not only filled the true pelvis, but also the retroperitoneal space, the perineum and the thighs. These results suggest that hemorrhage basically bleeds into a free space, and external fixation only provides a minimal advantage. It has also been recommended that stabilizing the pelvis reduces the motion among bony fragments and lets bony surfaces form clots. However, biomechanical evidence clearly demonstrates that either iliac or suprapubic insertion of external fixation modestly reduces the motion at the posterior ring among C-type pelvic injuries.

Although external fixation may provide useful stabilization for isolated anterior (Figures 4, 5) injuries, it probably does not prevent significant bony motion for pelvic fractures that are posteriorly unstable (see Figures 6, 7). This led to the development of clamps that are designed to stabilize the posterior pelvis (see Figure 8), such as the Ganz clamp [28]. However, there has been little experience with these clamps, and reported complications are high [28–30]. The emergency pelvic clamp would be helpful in these cases as well, but these clamps could increase the risk of definitive posterior stabilization procedures later, and it only takes a little less time to apply them.

Recently, a number of surgeons have proposed simply wrapping a sheet tightly around the pelvis at the level of the trochanters. The enormous benefit of this technique is that it can be applied very quickly, with

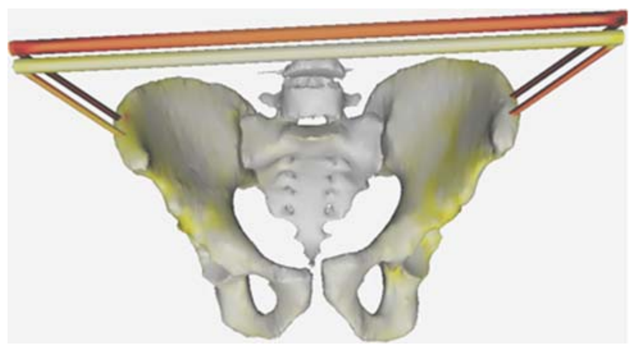


Figure 6. FEA was performed on a one leg stance stress model. Vertical shear injury fixed with iliac wing frame. Note the remarkable displacement at the PS and sacroiliac (SI) regions.

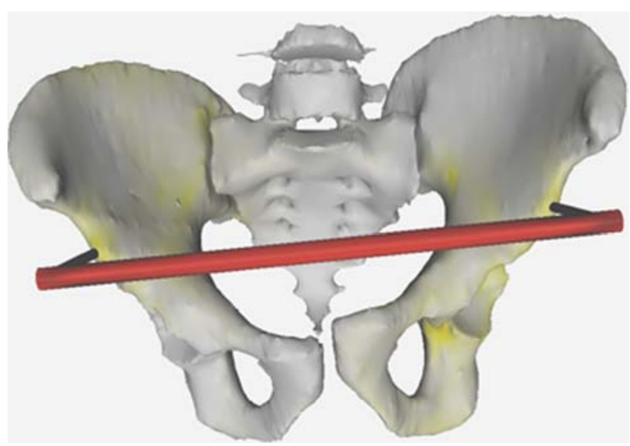


Figure 7. FEA was performed on a one leg stance stress model. Vertical shear injury fixed with suprapubic frame. Note the similar displacement at the pubic PS and SI regions.

minimal risk [18]. However, a sheet binder can cause skin necrosis and abdominal compartment syndrome if left in place too long (Figure 9). In practice, the sheet

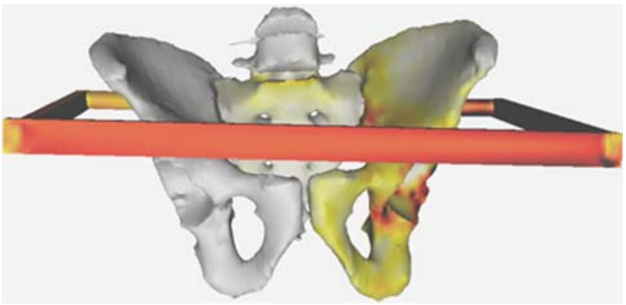


Figure 8. FEA was performed on a one leg stance stress model. Vertical shear injury fixed with Ganz clamp. No significant displacement at the PS and SI regions.

Figure 9. Sheet around the pelvis was left for more then 10 h, and helped to cause abdominal compartment syndrome and skin necrosis. Care must be taken to release the pressure gradually.

binder should be removed as early as a few hours after the trauma. If the patient continues to lose blood, a different intervention is required, and our preferences are described below.

Urgent Posterior Stabilization with Percutaneous Iliosacral Screws

Stabilizing the posterior pelvic ring in C-type pelvic fracture patients can be an essential life-saving procedure.

Since these patients are usually polytrauma or multiply injured victims, a rapid, minimally invasive, ''damage control''-like, definitive stabilization procedure is desired. Percutaneous iliosacral screw insertion would be a good choice for this, but the commonly used conventional 6.5- and 7.3-mm screws have some well-known disadvantages and complications (like screw bending, breakage or loosening) [31]. In order to provide enough pelvic stability, two ordinary screws must be inserted into the first, or the first and the second, vertebral bodies. However, these facts greatly increase the risk and the surgical procedure time for iliosacral screw insertion.

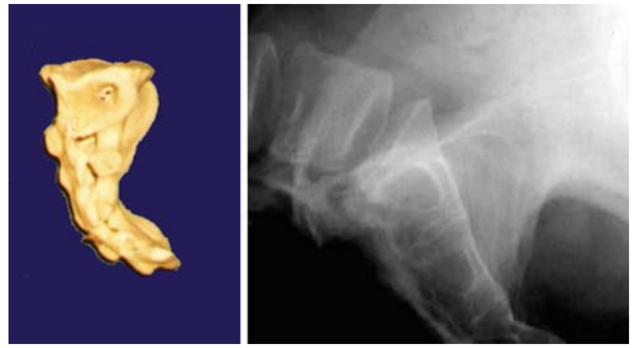
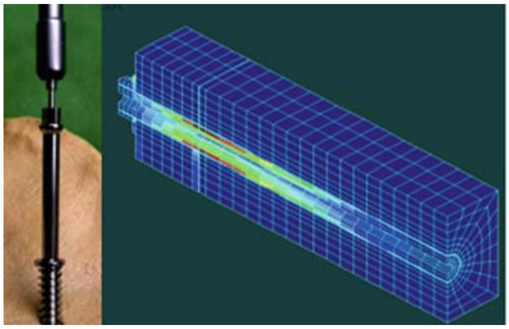


Figure 10. Synthetic bone model and the lateral sacral X-ray clearly show an oval area, the so-called ''safety zone,'' which is at the level of the first sacral peduncle.

In order to solve this problem, 12 years ago we designed a new type of iliosacral screw. The goal was to design a cannulated screw that is strong enough on its own for definitive fixation of the posterior pelvic ring. Also, the K-wire that fits into the cannulated screw should be strong enough to hold the provisional reduction of the posterior pelvic ring. Designing a proper screw requires knowledge of average sacral dimensions (Figure 10). Based on our finite element studies [14], the 10-mm cannulated iliosacral screw seemed to be optimal for immediate single-screw stabilization (Figure 11).

Patients with unstable pelvic disruption are at much greater general risk than those with a stable pelvis. In Tile's prospective study of 100 patients, 12 of 15 deaths were in the unstable group. Their blood transfusion requirements were three times greater (15.5 units vs. 5.5 units), their ISS score was 37 (as against 29 in those with stable pelvis), and their overall complication rate was three times higher [29, 30, 32, 33]. Patients suffering from massive hemorrhage due to pelvic fractures require massive fluid replacement, as outlined by the American Surgeons' ATLS protocol. Fracture stabilization belongs to the resuscitative phase of management. The expected blood loss in pelvic fracture is > 2,000 ml (10 units). Bleeding from the spongious bone is an additional cause of continuous hemorrhage. Closing the ring with the help of external fixators in an open-book injury is a good way to stop the bleeding. However, in C-type fractures, this method is usually insufficient since external fixators are



Prestress	10mm-s	7,3mm-s
0 N	734MPa	2360MPa
100 N	715MPa	2290MPa
500 N	725MPa	2180MPa

Risk of metal failure:
>828MPa

Figure 11. FEA results show that the measurable stress in 10-mm diameter screws was below the failure risk in all tested conditions (which means that the fracture site has no compression, or has 100 or 500 N compression) during 500 N axial loading. Conventional screws (7.3 mm cannulated) showed three times more stress during loading for the same pre-stress conditions. MPa = megapascals; N = newtons.

unable to control the motion in the posterior pelvic region.

With the development of image control guidance systems, percutaneous fixation of an unstable posterior pelvic ring injury will become safer, and it may become the method of choice for early stabilization. Reduction is easier in the early phase than later on. Vertical displacement is reduced by means of axial traction. Rotational displacement is reduced with an iliac-wing Schanz screw used as a joystick. Direct pressure with a soft tissue protector on the outer surface of the iliac wing is also helpful for reduction. Protocols and guidelines should ensure accurate placement of percutaneous fixation devices in an acute multiply injured patient with an unstable pelvic ring.

During the last 11 years, 244 patients with Tile C pelvic injury have been stabilized with 10-mm diameter cannulated iliosacral screws percutaneously. Forty-eight hemodynamically unstable patients were stabilized in the first 2 h with iliosacral screw fixation. No patient suffered metal failure. The average OP time of the posterior stabilization was 17 min. The average duration of fluoroscopy use was 41 s. A total of four patients died, but none of these deaths were due to fracture-related complications [19, 20, 23, 24].

Immediate posterior pelvic stabilization, together with appropriate or temporary anterior stabilization, was sufficient to control posterior bleeding. The stabilization of the hemoglobin level during the surgery was monitored. The data from this clinical study showed that the percutaneous pelvic ring posterior stabilization with 10-mm cannulated screws was adequate, even for bothersome cases (Figure 12). This procedure can be performed in hemodynamically unstable patients with pelvic C-type injuries when a transiliosacral, transalar or transforaminal instability is present. In transforaminal sacral injuries, care must be taken to avoid nerve root damage by applying too much pressure at the fracture site. The emergency pelvic clamp would be helpful in these cases as well, but these clamps could increase the risk of definitive posterior stabilization procedures later, and only save a little time, but can cause numerous complications. The pelvic reduction and percutaneous iliosacral stabilization can be performed most easily in the first couple of hours following the pelvic injury, given a definitive treatment for the patient. Unless the stabilization is performed within this period, the accumulation of air in the bowel interferes with fluoroscopy imaging during surgery (Figure 13).

Pelvic Packing

Some trauma centers in Europe have promoted pelvic packing for many years [22]. Surgeons in the United States have been very hesitant to try this technique. Early efforts at direct surgical control of pelvic bleeding were a disaster [23, 34]. Pelvic packs provide indirect tamponade. In addition, supporters of the technique are quick to point out that a fractured pelvis must be stabilized in some way in order to provide a stable surface to pack against. Packing is a well-known technique for controlling bleeding when ligation is impossible, for example in liver injuries. We have not used this technique, because our application of immediate pelvic stabilization or (rarely) embolization effectively controls pelvic hemorrhage.

Summary

When managing pelvic ring injuries, the key biomechanical consideration is stability. The determination of

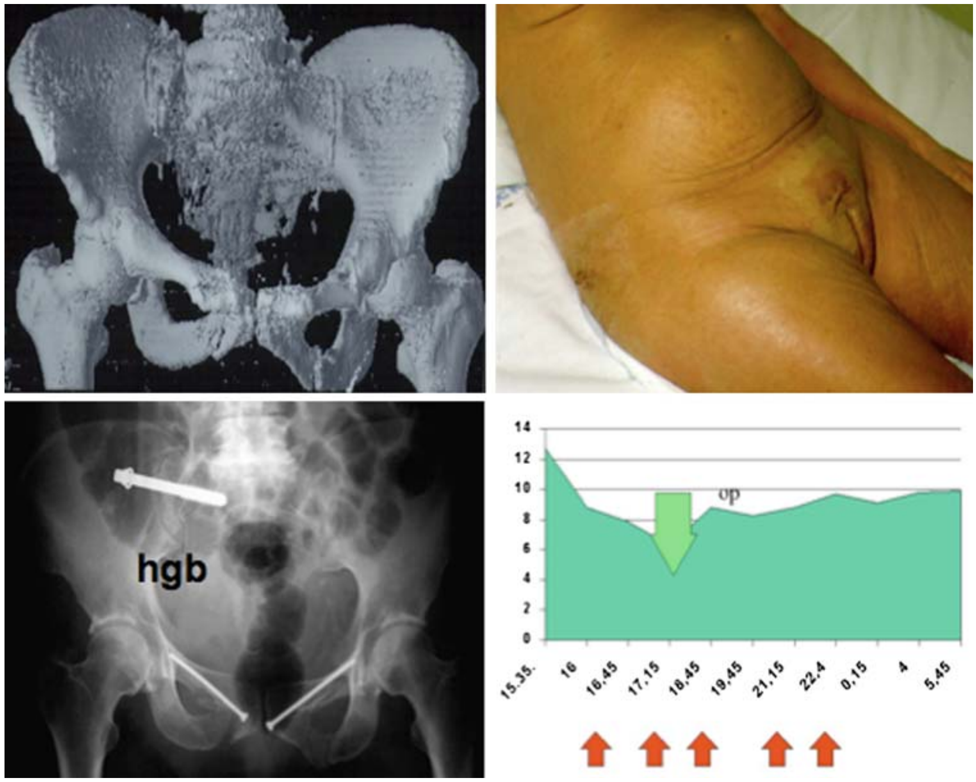


Figure 12. Case of a 47-year-old female who jumped from the second floor. ISS 35 (Sézary–Baccaredda syndrome, immunosuppression, steroid therapy), immediate surgery decreased the need for transfusion.

Figure 13. No disturbing air in the first 1–2 h.

pelvic stability and the related injury classification aid in the selection of the proper treatment. However, pelvic stability is just one factor to consider when deciding upon the appropriate treatment. Hemorrhage resulting from pelvic injury remains a significant causative factor of mortality. The first step in managing a patient with a pelvic injury is to provide adequate resuscitation, and to treat coagulation deficiency. Injured arteries, veins and bony structures are all likely sources of blood loss. Embolization is the approved management for arterial bleeding. Pelvic fractures that are considered unstable on X-ray are more likely to lose blood, and require intervention more than stable fractures. Mechanical interventions via external fixation or pelvic binder, pelvic C-clamp and immediate percutaneous iliosacral fixation are considered to be the best methods of controlling hemorrhage from venous and bony surfaces.

Conflict of interest statement

The authors declare that there is no actual or potential conflict of interest in relation to this article.

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