

Management of Haemodynamically Unstable Pelvic Fracture.

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Introduction

Pelvic ring fractures represent from 2% to 8% of all skeletal injuries and they are often associated with high-energy trauma. Frequently these lesions are the result of motor vehicle accidents or falls from height.^{1,2,3,4,5,6}

Haemodynamically unstable pelvic fractures are a diagnostic and therapeutic challenge for trauma team. For example, blood loss from cancellous bone surfaces, presacral venous plexus and/or iliac arterial or venous branches may cause hypotension and lead to haemorrhagic shock.

It has to be noted that pelvic fractures happen when an excessive force is applied to human body, therefore they are usually associated with extrapelvic haemorrhage from other lesions (chest 15%, intra-abdominal 32%, long bones 40%)⁷. In literature it is reported a mortality rate over 40%: exsanguinating is identified as the major cause of death during the first 24h after injury, while multi-organ failure (MOF) causes the majority of deaths there-after.^{8,9}

As reported by Tile¹⁰, the two most important factors influencing the management of pelvic injuries are the patient's hemodynamic status and the stability of the pelvic ring.

Therefore, pelvic lesions can be classified into 4 types:

1. Stable haemodynamics and stable pelvic injury
2. Unstable haemodynamics and stable pelvic injury
3. Stable haemodynamics and unstable pelvic injury
4. Unstable haemodynamics and unstable pelvic injury

Patients are considered haemodynamically unstable when, despite cardio-pulmonary resuscitation assistance, it is not possible to reach a target systolic blood pressure of

90 mmHg, and pelvic trauma is, together or not with other traumatic lesions, responsible for this haemodynamic status.

Pelvic instability is defined as the inability of the pelvic ring to withstand physiological walking load, and it is the result of high-energy pelvic trauma. Injuries involving posterior structures are responsible for the greatest amount of blood loss.

11,12,13,14.

Unstable pelvic ring fractures associated with haemodynamic instability are a rare condition, that occur in less than 10% of all pelvic trauma and it is associated with a high mortality rate. Isolated pelvic fractures are responsible of a small number of deaths (less than 1.5% of all pelvic trauma), while haemodynamically unstable pelvic fractures are responsible for a significantly higher mortality rate (30-58%).¹⁵

Currently there is no consensus among authors regarding the optimal management and treatment of haemodynamically unstable pelvic fractures, however the immediate identification and control of blood loss is universally recognized crucial for patient's survival.

Management of haemodynamically unstable pelvic fractures

The initial management of a patient with multiple injuries and suspected pelvic fracture can be challenging for the trauma team; and it should follow specific advanced Trauma Life Support (ATLS) guidelines.

Ertel¹⁶ and other authors described an efficient guide for the management of these fractures, by mean of a series of staged sequential procedures, regarding evaluation and treatment of critical patients and establishing priorities.

Modern protocols¹⁷ dispose that primary care should follow the Advanced Trauma Life Support (ATLS) resuscitation guidelines and subsequently a clinical evaluation together with basic imaging, including chest (CXR), pelvis (PXR) and lateral cervical spine radiographs, is necessary.

It is recommended to perform the latter within 10 minutes after the admission to the emergency room and an evaluation for intra-abdominal bleeding using a focused abdominal sonography for trauma (FAST) or diagnostic peritoneal lavage (DPL) within 15 minutes.

FAST is considered positive when fluid in one or more of the four standard views is detected¹⁸. DPL is considered positive if more than 10 mL of blood is obtained by aspiration¹⁹.

Anteroposterior (AP) radiographs of the pelvis should be performed as soon as possible to determine the extent of pelvic injury^{20,21,22,23}. Anterior injuries (pubic symphysis diastasis/ pubic branches fractures) are more easily identified than those affecting posterior structures, which may be missed in up to 22% of cases. Mears and Rubash²⁴ showed that a gap of 3 cm at the pubic symphysis may increase the volume of the pelvis as much as 1.5 liters.

Authors were able to identify extrapelvic bleeding sources only in the 30% of hemodynamically unstable patients, so it is very important to evaluate carefully chest radiographs and ultrasounds of the pericardium to exclude other possible intrathoracic injuries.

An accurate physical examination may reveal the presence of a palpable haematoma above the inguinal ligament, on the proximal thigh, and/or over the perineum (Destot sign) that may indicate pelvic fracture with associated bleeding. In addition, it is possible to discover an ecchymosis in the flank (Grey Turner sign), which is frequently associated with retroperitoneal bleeding.

The pelvic springing test aims to detect pelvic ring instability by applying alternating compression and distortion over the iliac wings. Unfortunately this maneuver is a poor predictor of the presence of pelvic fractures and it may dislodge eventually formed adherent clots, resulting in a further exacerbating blood loss. Nevertheless, the pelvic springing test can be very painful when performed on the conscious patient, therefore it should be avoided.^{25,26}

During primary inspection, an airway is secured and resuscitating assistance begins with intravenous crystalloid solutions injection while hypotension is intentionally maintained until all sources of blood loss have been identified and controlled.^{27,28,29}

Urgent haemostasis is the most important factor determining the survival of patients with pelvic fractures: in fact, it limits the detrimental effects of both haemorrhagic shock and high volume resuscitation.^{14,30}

Once the pelvis fracture is identified as the major source of blood loss, component therapy simulating whole blood is promptly administered to the patient with transfusion of packed red blood cells (PRBC), fresh frozen plasma (FFP) and platelets ideally in a 1:1:1 (pack) ratio.^{29,31,32,33,34,35,36,37}

Venous bleeding usually decreases when pelvic ring injuries are stabilized, by applying a longitudinally folded bed sheet around the pelvis of the patient, or an external fixator, or a pelvic C-Clamp or other pelvic binders if they are available.^{1,9}

Although there is evidence that all these methods allow a stabilization of the pelvis and the formation of blood clots, especially in open book fractures³⁸, it is controversial whether they are able to create a tamponade effect, since the retroperitoneum is disrupted.^{39,40} The “splinting” of pathological pelvic motion is more likely to be the mechanism that favours haemostasis.

Both improvised and commercially available binders stabilize the pelvis and allow clot formation. Pelvic binders may control the pelvic volume enlargement of “open-book” injuries,³⁸ but there is no consensus whether they can create a tamponade effect, since the retroperitoneum is disrupted.^{39,40} (Fig. 1)

Pelvic binders allow a free access to the abdomen, pelvis and lower extremities, they do not require special training for their positioning and they are generally free from complications when used for a short period. ATLS guidelines recommend that placement of pelvic binders should be performed before the admission to hospital, since there is evidence that they significantly decrease the need for blood transfusions and length of hospitalisation compared to external fixation.²

Long periods of tight immobilisation may cause tissue necrosis, nerve injuries and/or abdominal or extremity compartment syndrome, although this time course is not well defined.^{41,42,43,44}

Nevertheless in case of ineffective high-pressure bleeding local compression or tamponade, especially in patients so-called “in extremis”, it is frequently necessary to perform immediate life-saving procedures, such as thoracotomy and/or laparotomy, aortic clamping and abdominal/pelvic packing.

In case of “partial responder” or persistent shock, it is necessary to temporarily or definitively stabilize the pelvis and the surgeon, while choosing the most suitable device, must remember that anterior external fixators stabilize efficiently Type B pelvic dislocations, but are less adequate for posterior stabilization. Indeed in Type C injuries pelvic C-clamp should be preferred.

In type B pelvic lesions positioning an anterior external fixator usually restrains blood loss by direct compression of bleeding vessels in the fracture site. This device can be also applied in sacro-iliac joint disruptions associated with rotationally unstable pelvic fractures which involve also partial disruption of the posterior elements. Unfortunately, stability and bleeding control for vertically unstable patterns with complete disruption of the posterior elements are limited.⁴⁵ The external fixator can be placed with pins in the iliac crests or in the supra-acetabular region. There is a slight biomechanical advantage to supra-acetabular pin placement, but there is no data suggesting that this technique actually improves survival.^{46,47,48,49,50}

In those patients with posterior pelvic ring disruptions, the major source of bleeding is often from the cancellous bone and/or the presacral venous plexus.⁵¹ In these injuries, rapid reduction and posterior stabilisation can be performed with the pelvic C-clamp, which consists of two pins applied to the ilium in the region of the SI joints. It may be applied in the emergency department, but it is preferable to place the device in the operating room under fluoroscopic control.^{45,52} Moreover, it may be superior to other forms of pelvic fixation since it directly addresses the most frequent bleeding site(s). However, the C-clamp requires specific training for its successful application

and serious complications (fracture displacement, pin site infection or perforation, nerve injury) have been reported from its use.^{1,53,54,55}

Pelvic laparotomic packing as described by Ertel et al. may be attempted to favour tamponade of bleeding after skeletal fixation has been achieved. This procedure has met some success when performed in those patients who are too unstable for immediate transportation to angiography.^{56,57} However, direct ligation of bleeding pelvic vessels should not be attempted as results have been universally poor.^{58,59}

The majority of these patients will still have arterial bleeding that will continue unabated by packing alone. Therefore, patients affected by persistent hypotension and/or high necessity for blood transfusions after PPP or retroperitoneal pelvic packing, will need transcatheter arterial embolization (TAE) for definitive arterial bleeding control.

Transcatheter angiography is highly sensitive and specific for intra-abdominal bleeding, but haemodynamic instability limits the use of CT scan in this patient population. In fact, for those suitable to undergo pelvic CT angiography, this imaging may be more sensitive for arterial injury than catheter based angiography.⁶⁰

Up to 76% of patients who have persistent haemodynamic instability despite resuscitation assistance with two units PRBC/FFP, pelvic compression and exclusion of associated injuries, have acute arterial bleeding and should undergo angiography if immediately available.^{14,51,52}

The success rate of TAE when bleeding is identified in the setting of pelvic fracture has been reported to be from 85 to 100% and is a reasonable safety procedure.^{63,64}

TAE appears to work by stopping arterial bleeding and allowing the haematoma to tamponade the venous component of haemorrhage. Early angiography, especially when performed within 3 hours from admission in this specific group of patients, appears to confer a survival advantage and it may be assumed that this benefit derives from rapid interruption of arterial bleeding and transfusions need.^{14,61,62,65} Once stabilized, the patient can be transferred to the intensive care unit and prepared for the definitive treatment of injuries. (Fig. 2)

Management of pelvic fractures

The management of pelvic ring injuries from resuscitation to hospital discharge has evolved dramatically in the last decades due to improved surgical techniques, diagnostic and interventional radiology.

Pelvic ring injuries have been assessed by several classifications; some of these take into account the integrity of the posterior sacro-iliac complex, most important for the retention of pelvic stability (Pennal / Tyle)¹⁰, whereas other classifications have been focused on the injury mechanism (Young-Burgess)¹¹. Four different type of forces have been considered: lateral compression, antero-posterior compression, vertical shear and combined mechanical.

Young-Burgess Classification¹¹

	<i>Descriptions</i>	<i>Treatment</i>
APC I	Symphysis widening < 2.5 cm	Non-operative. Protected weight bearing
APC II	Symphysis widening > 2.5 cm. Anterior SI joint diastasis ② ②. Posterior SI ligaments intact. Disruption of sacrospinous and sacrotuberous ligaments. ②	Anterior symphyseal plate or external fixator +/- posterior fixation
APC III	Disruption of anterior and posterior SI ligaments (SI dislocation). Disruption of sacrospinous and sacrotuberous ligaments. APCIII associated with vascular injury ② ②	Anterior symphyseal multi-hole plate ② or external fixator and posterior stabilization with SI screws or plate/screws
LC Type I	Oblique or transverse ramus fracture and ipsilateral anterior sacral ala compression fracture.	Non-operative. Protected weight bearing (complete, comminuted sacral component. Weight bearing as tolerated (simple, incomplete sacral fracture). ②
LC Type II	Rami fracture and ipsilateral posterior ilium fracture dislocation (crescent fracture). ②	Open reduction and internal fixation of ilium
LC Type III	Ipsilateral lateral compression and contralateral APC (windswept pelvis). Common mechanism is rollover vehicle accident or pedestrian vs auto.	Posterior stabilization with plate or SI screws as needed. Percutaneous or open based on injury pattern and surgeon preference.
Vertical shear	Posterior and superior directed force. Associated with the highest risk of hypovolemic shock (63%); mortality rate up to 25%	Posterior stabilization with plate or SI screws as needed. Percutaneous or open based on injury pattern and surgeon preference.

Tile classification¹⁰:

A: stable

- A1: fracture not involving the ring (avulsion or iliac wing fracture)
- A2: stable or minimally displaced fracture of the ring
- A3: transverse sacral fracture (Denis zone III sacral fracture)

B - rotationally unstable, vertically stable

- B1: open book injury (external rotation)
- B2: lateral compression injury (internal rotation)
 - B2-1: with anterior ring rotation/displacement through ipsilateral rami
 - B2-2-with anterior ring rotation/displacement through contralateral rami (bucket-handle injury)
- B3: bilateral

C - rotationally and vertically unstable

- C1: unilateral
 - C1-1: iliac fracture
 - C1-2: sacroiliac fracture-dislocation
 - C1-3: sacral fracture
- C2: bilateral with one side type B and one side type C
- C3: bilateral with both sides type C

Stable Injury (Group A)

It includes skeletal lesions that do not alter the stability of the pelvic ring.⁶⁷

The subgroup A1 includes avulsions, which usually occur in adolescents and may involve the anterior superior iliac spine, anteroinferior iliac spine, the pubic spine, the iliac crest and the ischial tuberosity. Generally, treatment is conservative although surgery may be necessary in case of high functional demands of the patient or highly displaced fragments.

The subgroup A2 includes isolated fractures of the iliac crest, minimally displaced pelvic ring fractures and isolated anterior fractures.

When the lesion involves only the iliac district, treatment is usually conservative unless there are evident displacement that require surgical treatment to restore muscle function or for aesthetic reasons.⁶⁸

The patient should be informed of the risks and benefits of treatment and it is important to share the decision. Fig. 3 A/B

Non-displaced fractures or minimally displaced pelvic ring injuries are frequent in elderly patients with osteopenia. Soft tissues are not involved and the displacement of bone is minimal. Treatment is symptomatic and the patient can be mobilized as tolerated. Similar lesions in younger patients are the result of high-energy trauma and hidden instability must be investigated. If there is associated chest trauma there are no contraindications to mobilize the patient to improve pulmonary gas exchange.

Fractures of all pubic rami or butterfly fractures without involvement of the posterior region are rare and are caused by direct trauma. Treatment is conservative unless there are huge displacement or there is damage of the femoral neurovascular structures.

The subgroup A3 includes sacro-coccygeal lesions under the gluteo-sacral arch. Treatment is generally conservative. Transverse sacral fractures are displaced spinal injuries that can be associated with significant neurological deficits.⁶⁷

Partially Unstable Injuries (Group B)

It includes lesions with rotational instability but stable in the vertical direction. The posterior ligament apparatus remains intact but there is a compression of posterior bony structures (usually the sacrum). The rotational instability may be external (B1) or internal (B2).

In lesions B1 (open book injury) the pubic symphysis is torn and the pelvis opens like a book due to a force compressing the anterior-posterior part or to a rotational force applied through the external coxo-femoral joint. The initial traumatic force separates the pubic symphysis, and determines the laceration of the pelvic floor and of the anterior sacroiliac ligaments. Treatment depends on the extent of symphysis diastasis.⁶⁸

If it is less than 2.5 cm, muscles, fascia and ligaments of the pelvic floor are generally intact. The treatment is conservative and often the symphysis gap decreases over time. In case of diastasis greater than 2.5 cm, the pelvic floor is torn, including the sacrospinous and the sacrotuberous ligaments. The pelvis opens up to the point where the posterosuperior iliac spine rests on the sacrum.⁶⁷

Usually there are associated massive bleeding and visceral damages. It is essential to restore anatomical volumes to reduce pelvic bleeding. If specific devices are unavailable, the closure of the pelvis can be obtained by placing the patient in the lateral decubitus position and / or internally rotating limbs. Nowadays temporary systems closing pelvis (pelvis binder) are frequently used, and they are easy and quick to apply but extremely effective. In order to properly use these systems, they should be applied at the level of the trochanters and kept less than 24 hours to prevent ischemic lesions of the skin.

The definitive treatment is surgical and involves external or internal fixation.

External fixation is a rapid and effective method. Supra-acetabular regions offer greater guarantees for a favorable biomechanical insertion of chips (usually 2 to 6 mm caliber side), which requires the use of fluoroscopy. Full load can be granted immediately as tolerated. The fixator is maintained between 2 and 3 months.⁶⁸

Often the symphysis moderately reopens itself after removal of the implant. It is not indicated to use the external fixator if the skeletal lesion involves the ileum; in this case, it is recommended internal fixation of the symphysis.

Internal fixation is an equally valid therapeutic option especially if the patient has to undergo open surgery to treat any associated injuries of the urinary tract.

Absolute contraindications to internal fixation are fecal contamination and the presence of a suprapubic catheter. The patient may assume immediately the recumbent half seated position, but full load should be delayed for approximately 4-6 weeks.

Lateral compression forces that are transmitted through the ilium or through the femoral head cause B2 lesions (lateral compression injuries). These forces determine a traumatic compressive injury of the SI complex and a posterior sacroiliac lesion in correspondence of the symphysis or branches without damage to the pelvic floor. In this way the vertical stability is maintained.⁶⁷

Most frequent lesions are ipsilateral (ipsilateral lateral compression injuries), caused by an indirect force applied through the femoral head. Often these fractures affect elderly patients. From the pathophysiological point of view, an initial oblique fracture of the ileum and of the ischiopubic branch can lead to a progressive internal rotation of the hemipelvis, resulting in the crushing of anterior sacroiliac joint. Broken branches can damage the bladder. Treatment is conservative with bed rest: in fact the supine position itself usually restores the anatomical framework for elastic recoil of tissues. Thanks to the pathophysiological mechanism, there is no leg length discrepancy. It is considered acceptable an internal rotation up to 30 degrees without

functional sequelae. The compensation mechanism occurs through external rotation of the hip joint.

It is important to mention other two possible lesions of the anterior arch: locked symphysis fracture and tilt. In the first case, treatment is surgical performed through Stoppa's surgical approach, by correcting of deformity with dedicated instruments and fixation with plate and screws or external fixation.

In the second case, the fractured ileopubic branch may be wedged in the perineum leading to dyspareunia in women⁶⁸ or causing a neurological lesion of the obturator nerve. The therapeutic indication is to reduce and synthesize fragments with plates and screws, and to perform a surgical exploration if a neurological deficit is associated.

In B2 Lesions involving contralateral hemipelvis (contralateral lateral compression or bucket handle), the deforming force affects the anterior portion of the iliac crest causing a shift inwards and upwards. They differ from ipsilateral lesions because anteriorly there is an involvement of the opposite side of the posterior injury. Anterior lesion may involve both contralateral branches, the symphysis with braches or all 4 branches. Posterior injury depends on the quality of bone and ligaments. Generally there is a sacral crushing, and sometimes the impaction is so wide that the rotated hemipelvis get blocked in such position.⁶⁷

Conservative treatment is allowed when the deformities are not severe: less than 1 cm of dysmetria and less than 30 degrees of internal rotation.

In the case of polytrauma who have to undergo nursing or in case of displaced deformities, the treatment must be surgical and can use both internal and external fixation.

When a bilateral type B lesion occurs, it becomes a type B3 lesion.

Rotationally And Vertically Instable Injuries (Group C)

In this group, the pelvic ring has a complete anterior discontinuity at the symphysis or at the branches associated to a complete posterior discontinuity at the level of the sacroiliac complex.⁶⁷

The pelvic floor is damaged and is associated with the tear of the sacrotuberous and sacrospinous ligaments. Multidistrict lesions are often associated and if the pelvic lesion is bilateral with sacral damage associated, its stabilization is very demanding.

The maneuvers of pelvic stabilization must take place as quick as possible in order to reduce the pelvic volume and manage the intra-pelvic bleeding, which in most cases is venous. To obtain this, the most effective method in emergency is represented by the pelvic binder (eg. Tpod) which, when applied properly, allows a rapid reduction of the pelvic diameter. Despite this device could be used only for a time limit of 24 hours due to the risk of skin ischemia, it allows the trauma team to stabilize the patient in order to organize the support therapy if possible.

Other systems include the use of the C-clamp or external fixation.

The pelvic clamp or C-Clamp is a device that is applicable in a short time but not without risks. If applied by untrained personnel it can lead to serious neurovascular injuries and to abdominal injuries in case of ignored iliac lesions.

The external fixation is a stabilization technique much more practical and manageable by the majority of orthopedic surgeons. On the other hand it requires fluoroscopy for the positioning of the sovra-acetabuli fiches, unless we are satisfied only by the bilateral iliac hold with the risk of a construct biomechanically instable.

Long-term pelvic external fixators are not sufficient to contrast the vertical forces, even if using additional femoral fiches in case of unilateral pelvic lesion.

All these methods can be used simultaneously if necessary with the preperitoneal packing and / or angiographic investigations.

When the patient is stable and his clinical conditions allows a definitive treatment, a careful pre-operative planning of lesions and instruments must be performed.

There are several factors that influence the choice of treatment, in particular the morphology of the fracture, the clinical condition of the soft tissues, the age, the bone quality and the functional demands of the patient.

The stabilization of pelvic lesions type C requires an anterior and posterior approach, that could be combined or separated. Stabilization systems vary according to the clinical / surgical instrument and habits of the first operator.

The key point in this surgery is to restore at the beginning the posterior ligamentous system and later the anterior arch.

Lesions of the posterior pelvic side can be treated with different surgical solutions which have to guarantee the reduction and internal fixation, unless there is an impairment of the surrounding soft tissues.

It's possible to use traditional methods of fixation like plates and screws in the iliac or sacro-iliac region or bridging to connect the unstable hemipelvis with the stable one. The biomechanical stability of these lesions is provided by the sacroiliac screws, which are introduced in the hallway S1 under fluoroscopic view, using the percutaneous or open technique. This surgical procedure requires a high skill of the surgeon,⁶⁸ and it is difficult to apply in case of obese patients or in the presence of severe abdominal bloating. Iatrogenic neurological complications involving the L5 and S1 roots are frequent.

In cases where the pelvic lesion is associated with a spinal injury, a single contiguous device can be used to stabilize the lumbar and iliac district together. After applying the pedicle screws, the connection rods could be used to better reduce the hemipelvis. The posterior surgical time must then be completed with an anterior stabilization (using external fixation or internal fixation). Fig. 4 A/B/C

The lesions of the anterior arch can be treated by application of external fixation or internal fixation with plates and screws. In case of reduction and fixation of the symphysis is recommended to use two orthogonal plates.

Conclusion

In conclusion, in order to improve survival and outcome in patients with hemodynamically unstable pelvic fractures, a multidisciplinary approach is needed with well standardized treatment protocols.^{31,66}

Once the patient is stable, is necessary to restore the stability of the pelvic ring using combined techniques of anterior and posterior fixation. However, these are long-lasting and demanding operations, that therefore should be performed in hospital with very high specialization and by experienced surgeons.

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Images:



Fig. 1

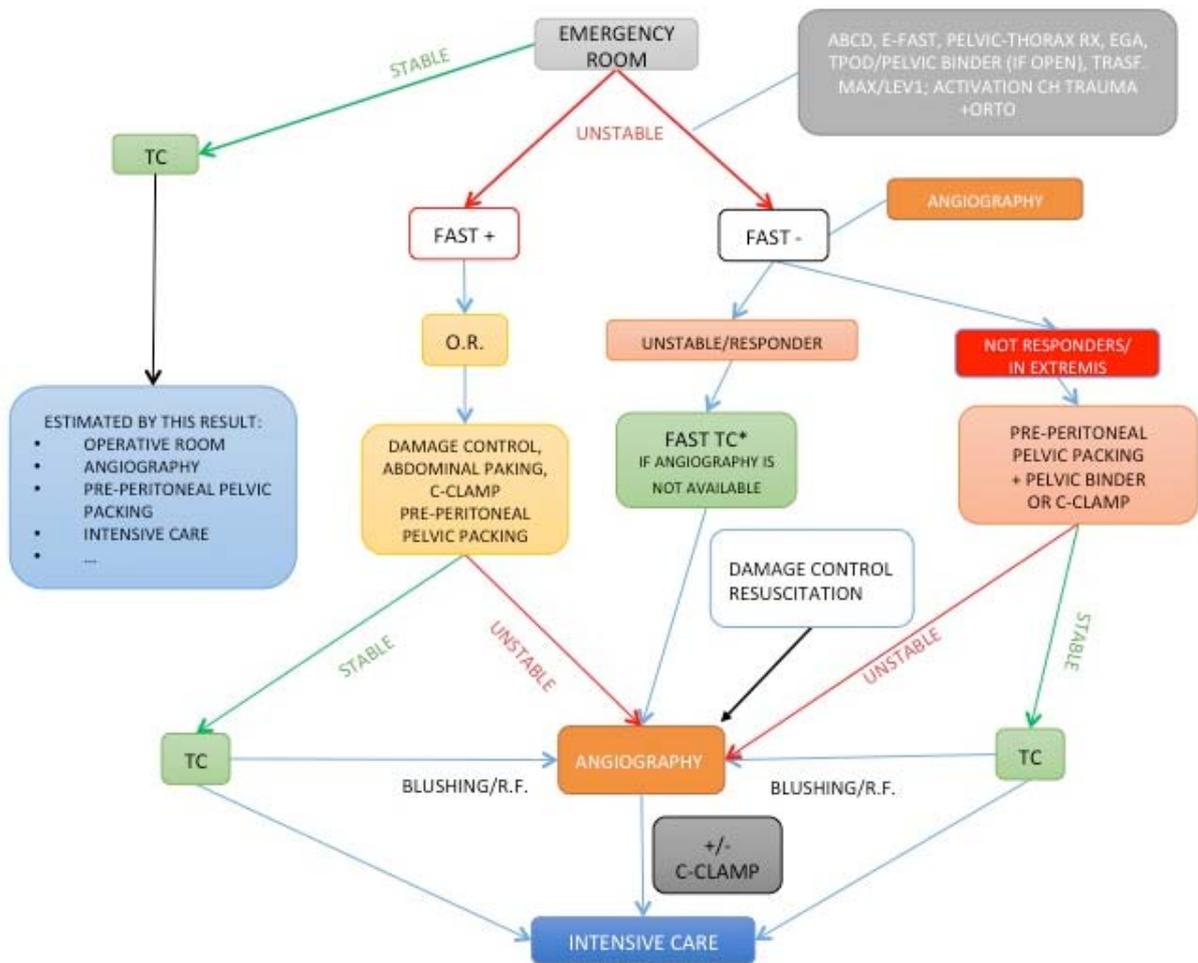


Fig. 2

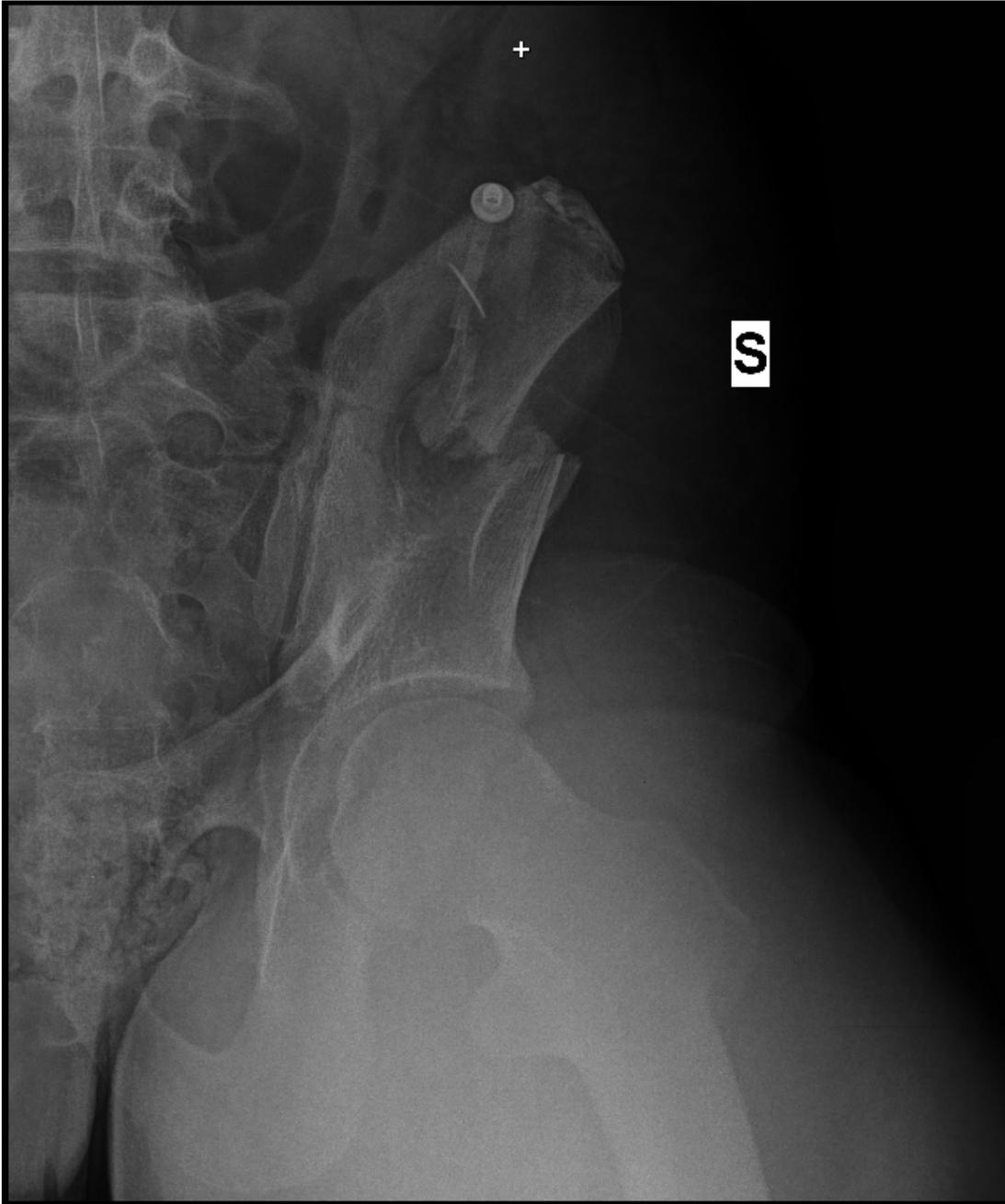


Fig. 3A

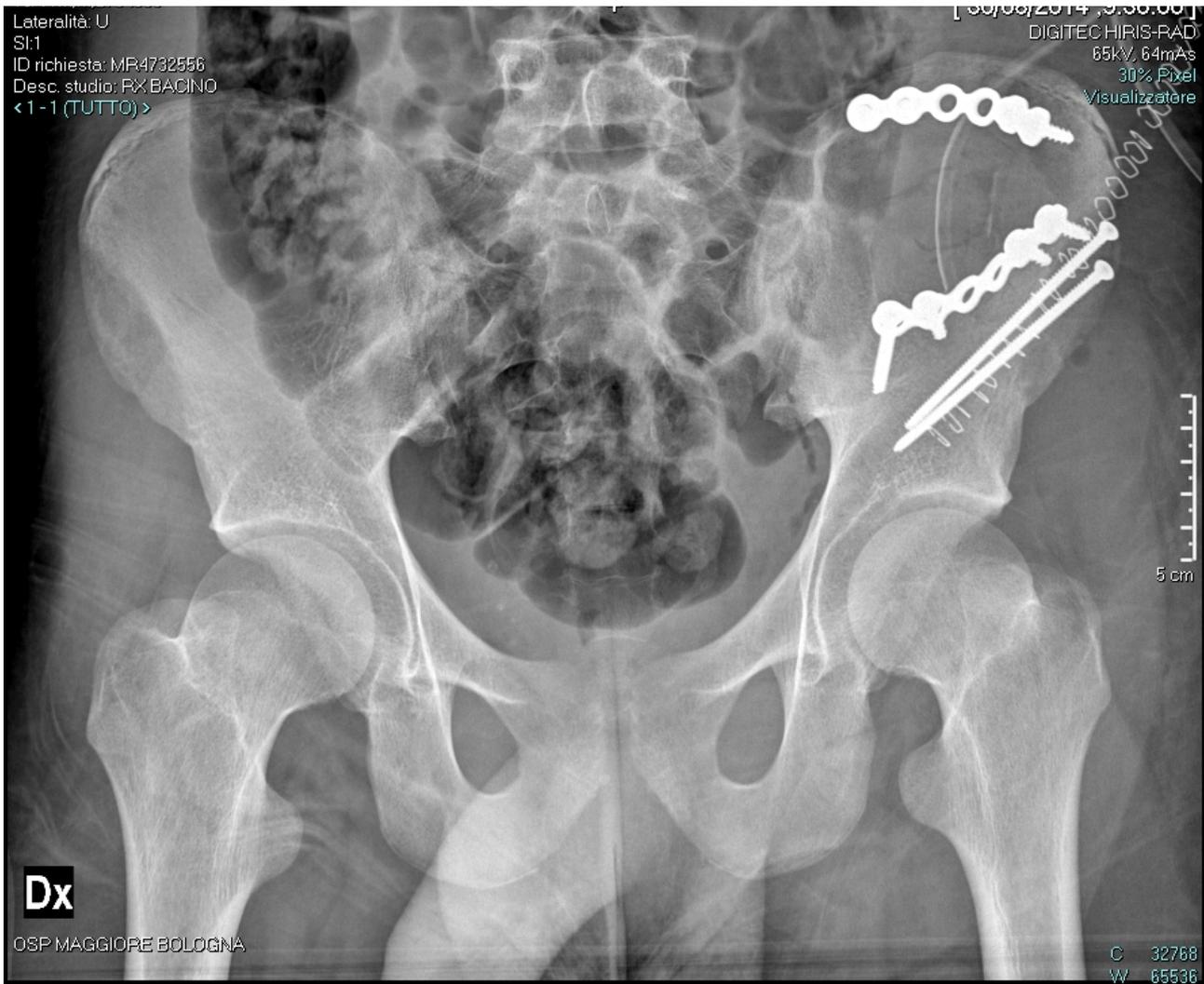


Fig. 3B



Fig. 4A



Fig. 4B

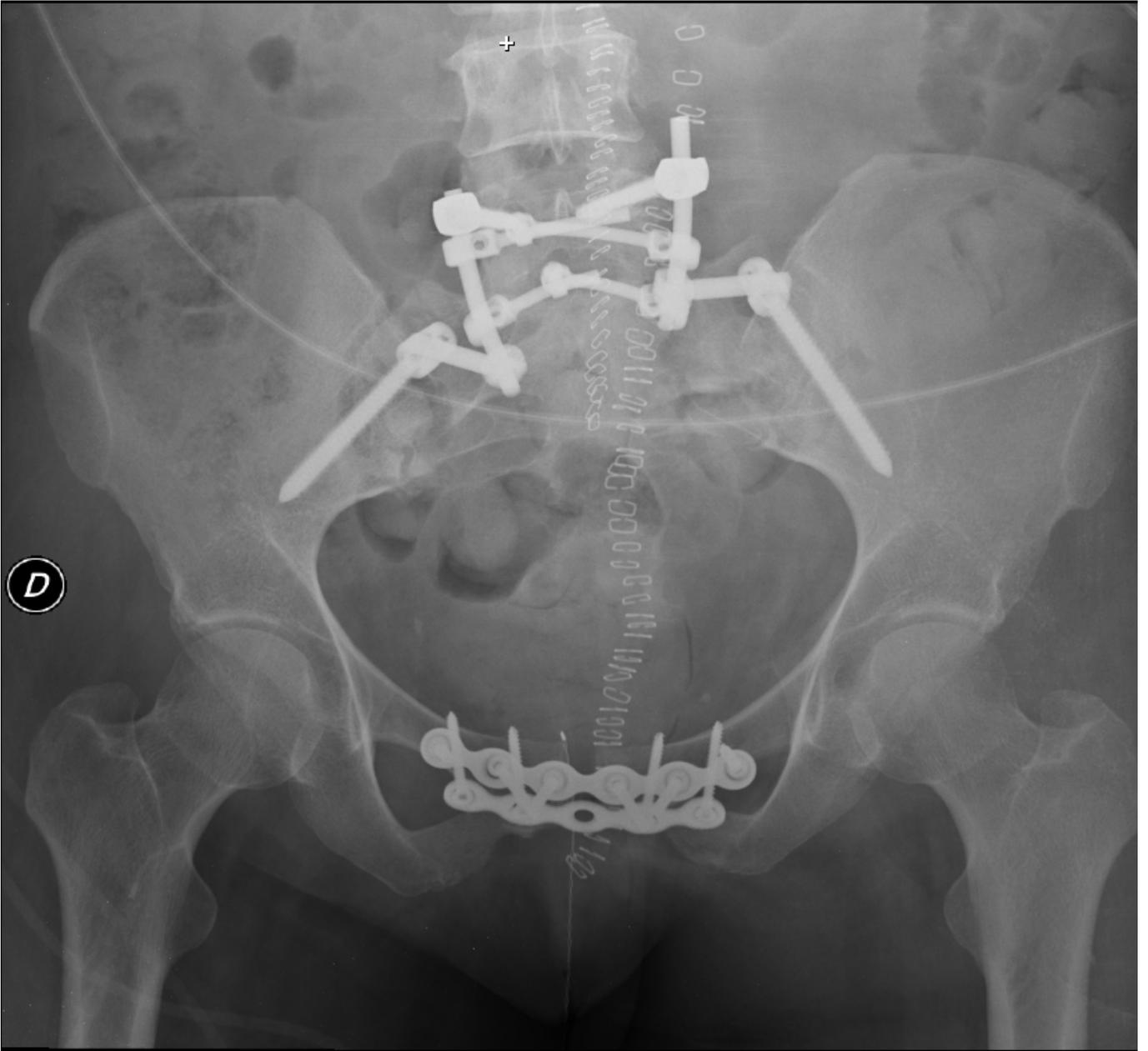


Fig. 4C

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