Trauma

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The use of external fixation in the emergency department: applications, common errors, complications and their treatment

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- The use of an external fixator (EF) in the emergency department (ED) or the emergency theatre in the ED is reserved for critically ill patients in a life-saving attempt. Hence, usually only fixation/stabilization of the pelvis, tibia, femur and humerus are performed. All other external fixation methods are not indicated in an ED and thus should be performed in the operating room with a sterile environment.
- Anterior EF is used in unstable pelvic lesions due to anterior-posterior compression, and in stable pelvic fractures in haemodynamically unstable patients.
- Patients with multiple trauma should be stabilized quickly with EF.
- The C-clamp has been designed to be used in the ED to stabilize fractures of the sacrum or alterations of the sacro-iliac joint in patients with circulatory instability.
- Choose a modular EF that allows for the free placement of the pins, is radiolucent and is compatible with magnetic resonance imaging (MRI).
- Planning the type of framework to be used is crucial.
- Avoid mistakes in the placement of EF.

Keywords: common errors; emergency department; external fixator

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Introduction

External fixators (EF) are essential tools in trauma emergencies. EF in the emergency department (ED) is used as a provisional method for stabilizing complex, open fractures, for treating fractures in the presence of burns, fractures with significant soft tissue involvement, severe comminuted diaphyseal fractures, difficult joint fractures, some paediatric fractures and serious ligamentous injuries, or while waiting for soft tissue injuries to heal before the fracture can be definitively treated, waiting for the surgical team (appropriate specialists) to be available, or waiting for the patient's transfer to a referral centre.[1–5]

Basic concepts

Temporary EF of the pelvis can be life-saving for a haemodynamically unstable patient. We also use temporary EF in patients with multiple trauma for similar reasons. Rapid and early stabilization of multiple fractures improves patient survival (this is called damage control surgery).[1–5] Damage control surgery is the immediate surgery necessary to save life and limb, putting off other surgical techniques or procedures until the patient's physiological state has improved further (usually after having spent some time in the intensive care unit). Surgical techniques for saving life and limb are indicated in unstable patients or those *in extremis*.

EF stabilizes soft tissues and bone. When applied correctly it provides unimpeded access to bone and soft tissues, both for initial assessment and for secondary surgical procedures. EF is optimal for temporary use. It is applied quickly without the need for intraoperative X-rays and can be subsequently adjusted. For joint fractures, EF can be used for the initial reduction so a computed tomography (CT) scan can then be performed for a more thorough evaluation of the fracture.

EF stabilizes fractures by means of threaded pins implanted into the bone and clamped to rods to build the frame. The small number of basic components and their versatility makes the system extremely adaptable. It is designed to be non-obstructive and strong enough to maintain limb alignment and is also adaptable to a wide variety of injuries and patient conditions.[1–5] The four basic principles of EF consist of adapting to the anatomy of the limb, allowing access to the soft tissues for debridement and secondary surgical procedures, adapting to the requirements of the patient's mechanics and injury, and being as comfortable as possible for the patient.[1–7]

It is important to achieve a rigid EF, which depends on several factors: (1) The distance of the longitudinal linkages (tubes, body, rings) from the bone; (2) the number of tubes; the separation between the tubes; (3) the number of pins and their relationship to the fracture and to each other (greater stiffness with greater number of pins, the closer the pins are to the fractures, and the wider the pins are in each of the principal fragments); and (4) the system's configuration (unilateral or bilateral, uniplanar or biplanar).[1,2] The potential subsequent surgery and its approach need thoughtful consideration before EF is applied.

The use of EF is accepted as a provisional and definitive treatment of fractures, as they may be elderly patients with poor bone quality. Only when the bones are osteoporotic, the pins should be screwed a little more into the distal cortex and can even penetrate slightly through it, as this can increase the stability of the assembly. In 2019, Huang reported that on the fixation of a two-part humeral fracture in elderly patients with osteoporosis, a new EF seemed to be superior to plate fixation regarding load bearing and resistance to torsional stress.[8]

There are many common errors that must be avoided when placing an EF in the ED:[1–7]

(1) Failure to consider the future approach when planning pin placement.

(2) Placing the bars so that they occlude the wounds, preventing them from being monitored and cured.

(3) Using an EF and pins of inadequate sizes for the bone to be treated; for example using a hand EF for a forearm fracture. We recommend a large EF (11 mm diameter bars) for the lower extremities; a medium size EF (bars of 8 mm in diameter) for the upper extremities of adults and for the upper and lower extremities of children and adults of short stature. The ideal size of the pins is 5–6 mm for the pelvis, femur and tibia and 3–4 mm for the forearm.

(4) The bars, jaws or pins contacting the skin.

(5) Crossing the distal cortical bone with the pins, which may cause neurovascular lesions.

(6) Failure to perform a CT scan to better study the fracture after stabilizing it with an EF.

(7) Pins penetrating the joint (which increases the risk of septic arthritis) or the physis in children.

Placement of the external fixator (EF)

The use of EF in the ED or the emergency theatre in the ED is reserved for critically ill patients in a life-saving attempt. Hence, usually only fixation/stabilization of the pelvis, tibia, femur and maybe humerus are performed. All other EF methods are not indicated in an ED and thus should be performed in the operating room with a sterile environment.

The EF is usually placed under general or regional anaesthesia; cloths are placed to leave visible anatomical marks. Ischaemia is not required. Normally the fluoroscope facilitates the placement of the pins. Bone alignment is assessed clinically and with fluoroscopy in two planes.[1–5] The pin placement technique consists of placing two in each of the main bone fragments, one at a distance of 1.5–2.0 cm from the fracture site and the other further away. We must avoid secondary bone damage due to thermal injury. We recommend the use of self-drilling screws. The pins must grip well in both cortical bones without surpassing the distal cortex (in conical pins avoid backing because it would loosen the grip). It is advisable to verify the penetration depth of the screw with the image intensifier. In the pins near metaphyses we must avoid intra-articular penetration. The two pins per main bone fragment are connected with a bar. The bars must pass a little beyond the area of the fracture site so that there is sufficient length for the jaw. Connect the two ends of the bars near the fracture to a third bar. Use the two partial frames as handles to reduce the fracture. Then the reduction is checked with the image intensifier in two orthogonal planes and the jaws are tightened.[1–7]

To increase the rigidity of the frame we can increase the separation between the pins, increase the diameter, the number of pins and the number of bars in each bone segment or increase the fixing planes. The bars should be placed near the longitudinal axis of the bone. We must avoid the jaws preventing the visualization of the fracture site. The biomechanical stability of the EF will decrease if the pin is far from the fracture site and if the bar is far from the bone.[9,10]

It is better to use tapered threaded pins because they generate much greater radial preload. The weakest point of a pin is the thread–shank junction. The ideal penetration of a pin is up to the distal cortical bone; if the pin fails to insert into the distal cortical bone there will be a risk of loosening; and going beyond the distal cortical bone increases the risk of soft tissue injury. The ideal size of the pins is 5–6 mm for the pelvis, femur and tibia, and 3–4 mm for the forearm. The ideal construct for stability consists of placing one pin as close to the fracture as possible, with another pin placed as far removed from the fracture as possible in each of the principal fracture fragments. The pins should be placed so that they do not interfere with

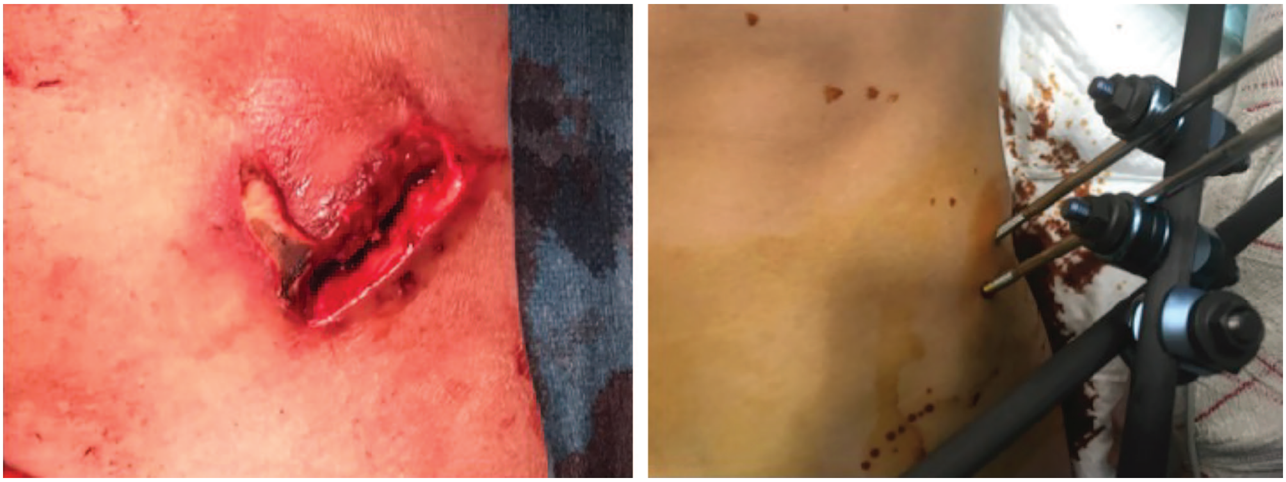

Fig. 1 Unnecessarily long incisions should be avoided as they can cause problems (left). On the right, a correctly placed external fixator (EF) of the pelvis.

the planned definitive fixation. In addition, they should not violate either the fracture site or the joints.[1–7]

Carbon fibre rods are preferred over stainless steel because they are radiolucent and have a much higher modulus of elasticity, even though they are more expensive. It is important that the bar and pins are symmetrical in the clamps. The use of simple clamps is preferred as it allows for multiple degrees of freedom and adaptability in their connection to pins and bars, and titanium clamps are compatible with magnetic resonance imaging (MRI). In the case of joint fractures, a CT scan is performed after the EF is in place.[1–4]

In most cases, the unilateral configurations of the EF are less obstructive and generally sufficient in most trauma situations, and also avoid patient discomfort. With unilateral modular assemblies, manual reduction can be delayed until said frame is assembled and alignment changes are made easier than with a simple unilateral assembly. The modular assembly consists of placing two pins in each of the main fragments. These pins are initially joined by a short bar which, in turn, is connected to an intermediate bar.

When it is necessary to bridge joints, the same principles apply as for the treatment of fractures separately. If the fracture is far enough from the joint and there is good bone quality, it is sometimes possible to apply the EF only to the fractured bone, leaving the next joint free.

Below, each indication is discussed with its source of bleeding and possible parallel intervention (vascular in particular, packing in pelvic fractures, etc.) as well as further complications.

Pelvis

EF controls the pelvic volume in emergency situations (reduces bleeding) and stabilizes the anterior pelvic ring in anterior and lateral compression injuries.[11–21] According to Guthrie et al, initial management is aimed at saving life and this is most likely to be achieved with an approach that seeks to identify and treat life-threatening injuries in order of priority. The role of pelvic binders, angiographic embolization and pelvic packing is paramount.[15] Preperitoneal pelvic packing/external fixation (PPP/EF) for controlling life-threatening haemorrhage from pelvic fractures can be required.[16]

Placement of the pins into the subcortical bone of the iliac crest and parallel to the crest is preferred over placement in the supra-acetabular area or performing an antero-superior/Slätis-type (perpendicular to the iliac crest) frame, because the technique is easier, faster and can be performed without fluoroscopy.[13] A urinary catheter should be inserted before starting. The width of the iliac crest can be felt with the fingers. Generally, a percutaneous introduction with a small incision (5–10 mm) is possible, avoiding large incisions (Fig. 1), 2 cm posterior to the antero-superior iliac spine to avoid injury to the lateral femoral cutaneous nerve. The pin is inserted between the inner and outer table of the ilium directed towards the sacroiliac joint. If the pins penetrate the table it can reduce stability. A second pin is inserted approximately 1 cm posterior to the first pin and then the procedure is repeated on the other side. The pins are connected anteriorly using two rods. We reduce the pelvic fracture by applying lateral pressure on the pelvis or by using the pins, and then the clamps are tightened. An additional rod may be used for added stability. Next, we verify that the hips can flex to 90°.

The clamps should be at least 2 cm from the patient's abdominal wall in both the lying and sitting positions because of the risk of pressure ulcer resulting from abdominal distention and because the patient may require incorporating the bed or sitting (Figs 2 and 3). We prefer to place two short tubes joined together in a V shape.

Fig. 2 The images show a pressure ulcer of the clamps due to abdominal distention in another case of pelvic external fixation (EF).

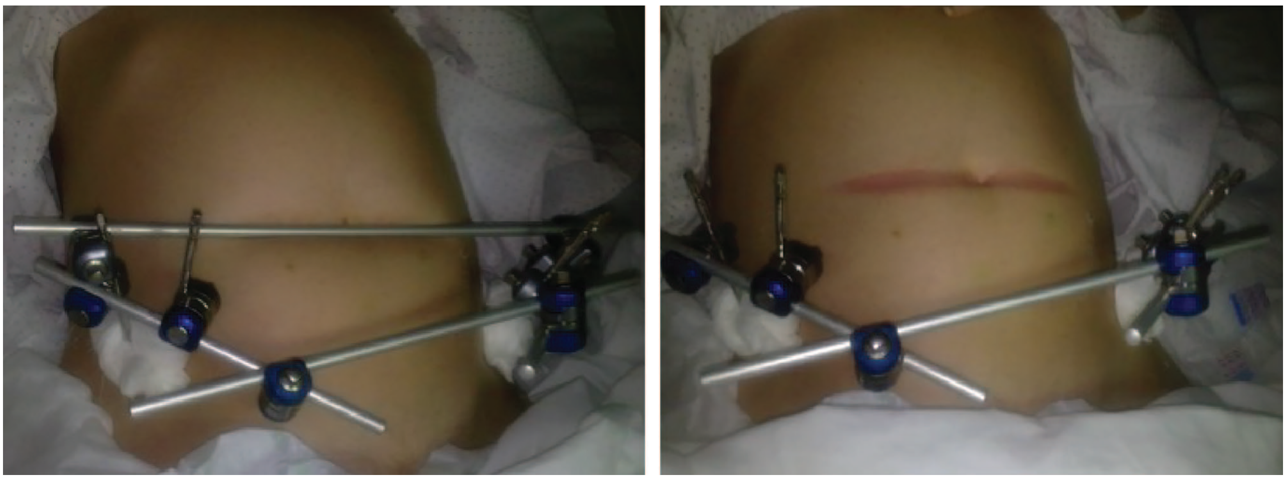

Fig. 3 The images show an ulcer by pressure of the pelvis caused by an external fixator (EF) bar placed due to abdominal distension. In addition, the bar does not allow free access to the abdominal wall for a possible laparotomy.

The placed frame must allow full access to the abdominal wall for laparotomy, if necessary (Fig. 4).

Fig. 4 The image shows a correctly placed pelvic external fixator (EF).

C-clamp

In stable anterior or lateral compression pelvic fractures in which the posterior ligamentous hinge is intact, simple frames are sufficient as an emergency measure and for stabilizing the injury. For more unstable compression or vertical shear injuries, more rigid configurations are necessary. Conventional anterior EF of the pelvis does not allow control of posterior instability of the pelvic ring. Therefore, posterior pelvic EF has been described by the use of C-clamp. The C-clamp has been designed for the stabilization, in the emergency department, of sacral fractures or alterations of the sacroiliac joint in patients with circulatory instability, although it can also be used in open-book pelvic lesions.[22]

We must avoid its use if there are ilium fractures, because there is a risk of perforation through the fracture site. Neither should we use it in comminuted fractures of the sacrum due to the risk of compression of the sacral nerve plexus. The pins are placed in the posterior part of the ilium above the greater sciatic notch with pins placed about 4–5 cm anterior to the posterior iliac spine (in

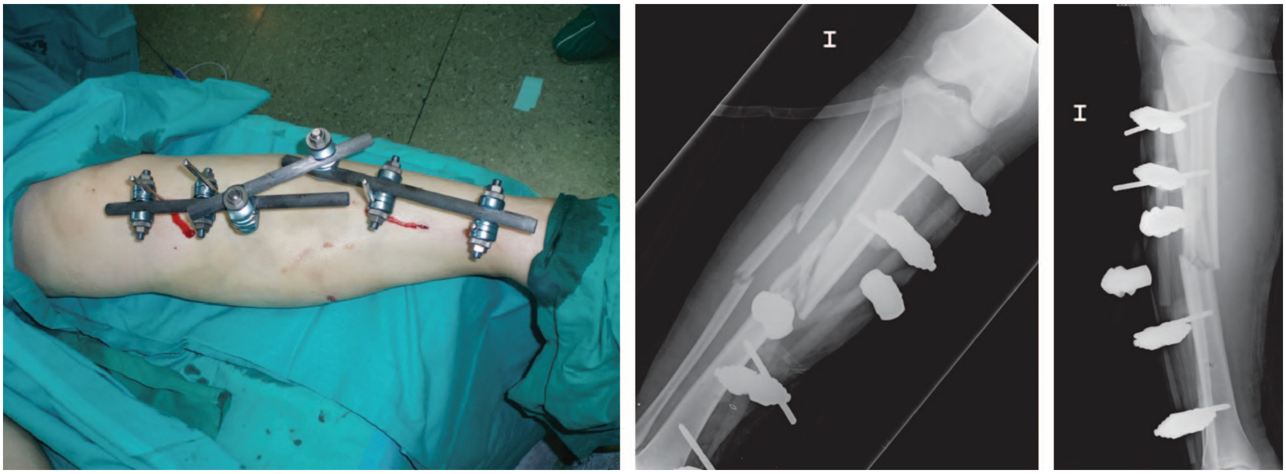

Fig. 5 Photograph (left) and radiographs (right) of a unilateral modular external fixator (EF) in a comminuted fracture of the tibia. The EF facilitates the reduction of the fracture.

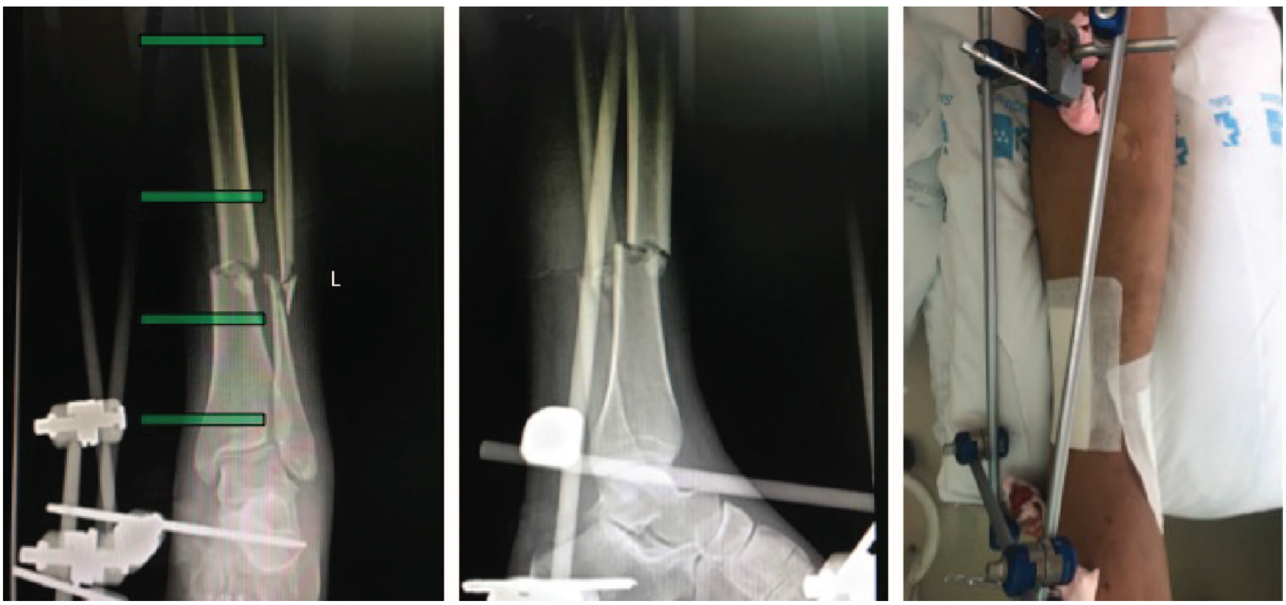

Fig. 6 Fracture of distal tibia treated with an external fixator (EF) bridging the ankle. For better control of the fracture, if the fracture is far enough from the joint and there is good bone quality, it is preferable to place the pins in the distal fragment, leaving the ankle free. On the left, anteroposterior radiograph; in the centre, lateral radiographic image; on the right, clinical image.

dense bone opposite the sacroiliac joint) or in the anterior part of the ilium located 5–6 cm below the iliac crest above the acetabulum. Thus, the anterior pin is far from all the anatomical structures except the hip joint capsule, while the posterior pin is closer to the sciatic nerve and the upper gluteal neurovascular bundle. To avoid complications, the pins should be inserted under fluoroscopic guidance, if available. An alternative to using the C-clamp is to place the pins on the greater trochanter.

Tibia

Most tibial fractures can be stabilized with a unilateral frame in one plane (Figs 5 and 6).[7,23] When treating extra-articular fractures of the tibia, if the fracture is far enough from the joint, with large fragments, and there is a good bone quality, we prefer to place the pins in this fragment to achieve greater stability of the fracture and leave the knee or ankle free, preserving their mobility.

Femur

Femoral diaphysis fractures are difficult to reduce. Modular unilateral EF is generally preferred in these cases; the two pins from each of the main fracture fragments are connected with a short rod, which allows for manipulation and reduction of the fracture; then, the two frames are joined with another rod (Fig. 7). Either a laterally placed

Fig. 7 Image of a unilateral modular external fixator (EF) of the femur. In very proximal femoral fractures, a pin must be placed in the femoral neck to improve the stability of the fracture. When there is a third fragment, care must be taken to avoid moving it with the pin.

neutralization rod or two intermediate bars may be added to increase the stability of the frame. The displacement of additional fragments from comminuted fractures by the pins must be avoided. Very proximal fractures may sometimes require the placement of pins in the femoral neck in the direction of the femoral head in order to achieve better fracture control (Fig. 7).[1–7]

Humerus

In the unilateral modular assembly for the humerus the pins are percutaneously inserted into the lateral region of the proximal third (avoiding injury to the axillary nerve) and in the posterior region of the distal third (avoiding the olecranon fossa) with an angle of approximately 90° between the pairs of pins so as to avoid injury to the radial nerve spiralling around the humeral axis.[6] We use a modular EF consisting of three short bars.

Manual positioning of the pins and the importance of safe zones

Placement of an EF in the ED usually is a hectic environment and the image intensifier is not freely available (in particular it obstructs parallel interventions i.e. abdominal or brain surgery). Thus, the surgeon needs to be able to 'blindly' position the pins if necessary. That is why it is extremely important to know the so-called 'safe zones'. There are safe zones in the limbs through which the pins can be inserted without injuring the vessels, nerves and major muscle–tendon units, or penetrating the joint. In paediatric patients, the epiphysis and the open physis should be avoided.[1] Within these safe zones, EF should be placed so as not to interfere with continued wound care and to allow for new surgical procedures to be performed, if necessary. There are predefined safe zones for the insertion of pins in different regions but a blunt dissection or mini approach for locating nerves in certain regions can be helpful. These safe areas are described for the insertion of the pins but the tip of the pins can also injure neurovascular structures on the opposite side of the bone.[1,2,24]

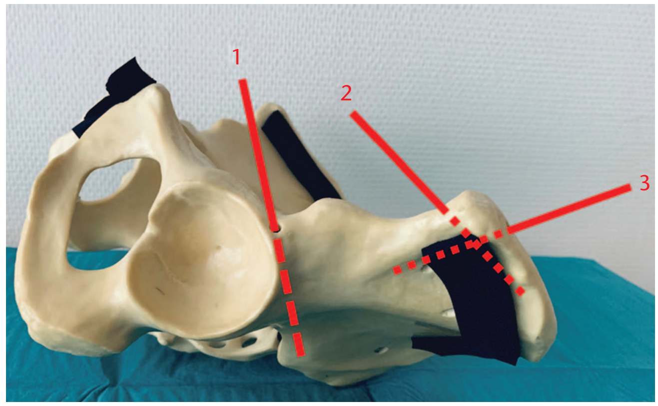

Fig. 8 Image showing the three options for the placement of the external fixation (EF) pins in the pelvis. (1) supra-acetabular; (2) subcristal; (3) antero-superior (Slätis).

Pelvis (safe zones)

For the placement of the external fixation pins in the pelvis there are three options: supra-acetabular, subcristal and antero-superior (Slätis) (Fig. 8).[13,25]

Supra-acetabular placement

Placement of supra-acetabular pins is technically more difficult than in the iliac crest. A pin is placed in each hemipelvis. The entrance is approximately 4 to 6 cm in a caudal direction to the antero-superior iliac spine, and 3 to 4 cm medially. With the patient in the supine position, the alignment to pierce the nails is of an angle of approximately 20° in the cranial direction and 30° inward.

Placement in the iliac crest

Cortical pin penetration is more likely to occur if pin placement begins in the lateral third of the iliac crest, or if the pin is advanced beyond the isthmus of this zone, 5 cm from the crest. Acetabular penetration occurs when the pins are advanced more than 10.5 cm.

Subcristal placement

This placement is less common. The point of entry of the pin is the centre of the antero-superior iliac spine and just lateral to the internal table of the ilium. The pin is placed towards the iliac tuberosity between the two cortices of the iliac bone. Fluoroscopy may be used to confirm the placement, although it is not always necessary. Solomon et al reported low complication rates and easy placement of the pins with less interference with hip flexion.[25] A supra-acetabular pin placement is more stable than pin placement in the iliac crest. With regard to what to treat first in complex pelvic fractures (dorsal or ventral lesions), it is advisable to place a ventral EF in the ED. Although the definitive fixation of complex lesions in the following days falls outside the focus of this article, it is advisable to fix the dorsal lesions first and then the ventral lesions, obviously after removing the ventral EF that was provisionally placed in the ED. In the case of a dorsal dislocation (possible dashboard injury) a bridging external fixation with pin placement in the iliac crest (2x) and femur (2x) should be performed.

Tibia (safe zones)

The safe zone is located anteromedially and varies in extent from an arc of 220° near the tibial plateau to 120° at the level of the ankle. It is recommended to avoid the thick tibial crest because it can slip medially or laterally, and instead to place the pins in the anteromedial wall of the tibia with a trajectory angle (relative to the sagittal plane) of 20–60° for the proximal fragment and 30–90° for the distal fragment. The area of soft tissue through which the pins can be inserted without damaging important structures (vessels, nerves, muscles and tendons) is perpendicular to the anteromedial surface of the tibia. The angles of this safe area vary. Caution should be exercised in the exit of the pins in the postero-external proximal region of the tibia so as not to injure the popliteal artery and vein, or the tibial nerve (Fig. 9).[6,7,26]

Femur (safe zones)

Lateral access to the femur is recommended within an angle of 30°. We must be careful at the exit of the pin in the medial region of the distal third of the thigh as we could enter Hunter's canal and damage the femoral artery or vein. Unlike what happens in the tibia, the circumference of the femur is covered with a thick layer of soft tissue. The area of insertion of the pins should be the plane between the lateral intermuscular septum and the lateral border of the sartorius muscle.[24]

Placement of the pins into the lateral femoral shaft is recommended because it avoids the extensor mechanism, limiting the risk of iatrogenic neurovascular injuries, injuries to other structures and unnoticed knee joint penetration. An alternative is to use anterolateral pins. The safe zone for anterior pin placement is as narrow as 12 cm in length and begins 7.5 cm above the proximal pole of the patella, but it carries a greater risk of injury to the neurovascular structures than more laterally inserted pins; in addition, anterolateral pins may lead to unnoticed knee joint penetration through the supra-patellar pouch, and to heterotopic ossification within the quadriceps muscle with resulting limited range of motion.[24]

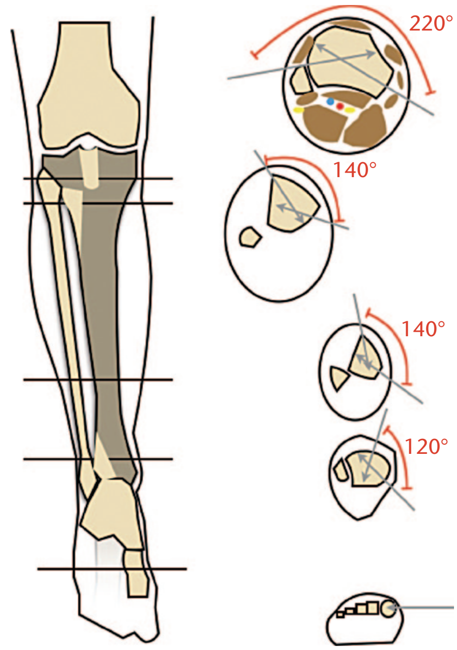

Fig. 9 Safe zones for inserting pins in the region of the tibia. At the proximal level they can be safely inserted in an arc of 220°; just below the tibial tubercle the safety arch decreases to 140°. In the distal third of the leg, the security arch remains 140°, but the tibial artery and the deep peroneal nerve are vulnerable when they cross the lateral cortex of the tibia. Above the ankle joint, the safety arch is 120°. At the metatarsal level we can use a pin to immobilize the ankle and avoid stiffness in equinus. The dark zone indicates the place where the tibia is subcutaneous and where pin insertion is safe.

Humerus (safe zones)

In the humerus, attention must be paid to the radial and axillary nerves. In the distal area, a dorsal approach to the humerus is inappropriate. In the proximal third the pins are inserted in a lateral direction, avoiding injury to the axillary nerve and with a 90° angle between the two pairs of pins. In the distal region the pins are inserted from posterior to anterior in order to avoid injuring the radial nerve and the olecranon fossa (Fig. 10).[6]

Postoperative treatment

After the placement of an EF, percutaneous incisions are left open and treated locally with antiseptic dressings.[1–5] Closing the incisions prevents wound drainage and increases the risk of infection.[1–5] If tension is exerted by

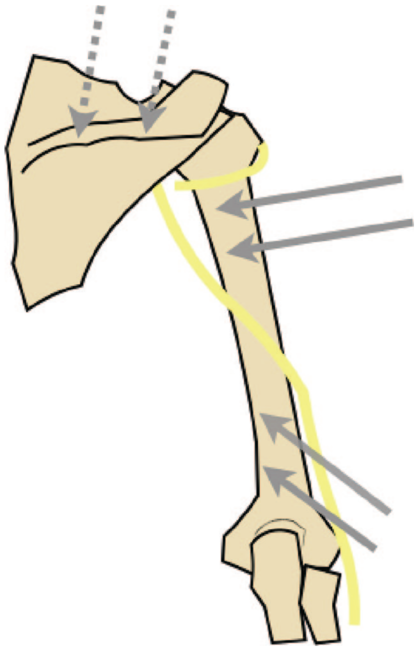

Fig. 10 Scheme showing the location of pins (continuous arrows) in an external fixator (EF) of the humerus. In case of needing to bridge the shoulder, the pins are placed on the spine of the scapula (broken arrows).

the pin on one side of the wound, the incision should be extended. After temporary stabilization and once the patient has been reanimated, EF can be converted to an internal fixation. This is preferred, since prolonged EF can cause discomfort to the patient and increases the risk of developing skin problems and local infections.[1,2] The fixator's connections must be periodically checked and tightened to avoid loosening of the fixator and the subsequent loss of fracture reduction.[2]

Complications

The use of EF involves a series of unique complications. As with any other technique, if we follow the basic principles and use proper technique, complications can be kept to a minimum.[27–31]

Pin infection is the most common complication, which occurs in 30% of cases (Fig. 11). A meticulous technique of inserting the pins and avoiding tension in the skin around the pin helps to prevent it.[30] Although there is no consensus regarding prophylaxis, frequency and method of pin care, or coatings for pins, we recommend a daily treatment with a disinfectant and providing education to patients regarding pin care to prevent infections. There are no high-quality studies on pin infections and there is not enough evidence to formulate a standardized protocol for preventing infections. We must prevent infection of the pins and thus improve the capacity for safe conversion to definitive surgery.

Fig. 11 Superficial pin infection.

The anterior tibial artery and the peroneal nerve deep in the distal third of the leg are the structures that are most often affected. Iatrogenic damage caused by the tip of the pin on the opposite side of the bone has also been observed in the form of pseudoaneurysms and other complications such as partial or complete occlusion of the arteries. The pins inserted through the muscle belly or the tendon will restrict normal movement and can lead to rupture or fibrosis. Compartment syndrome can occur as a result of traversing the muscle compartments with the pins. Pressure ulcers can also occur due to contact of the jaws or bars with the skin, especially in pelvic fixers due to abdominal distention or when incorporating the patient's bed, or the bars that bridge the knee. Fracture through the pins can occur if we make multiple perforations.[30]

Pelvis

Scaglione et al found a high percentage of lesions of other organs (cerebral, thoracic, and abdominal lesions). Most of the patients (80%) who die do so within the first hours after trauma due to a massive haemorrhagic shock.[14] Early mortality after a pelvic fracture is most commonly due to major haemorrhage or catastrophic brain injury.[15]

Burlew et al analysed 75 consecutive patients who underwent PPP/EF (mean age 42 years and injury severity score 52).[16] ED systolic blood pressure was 76 mmHg and heart rate 119 beats/min. Time to operation was 66 minutes, and 65 patients (87%) underwent three additional procedures. Blood transfusion before PPP/EF compared with the first postoperative 24 hours was 10 units versus 4 units (significant difference). The fresh-frozen plasma–red blood cell ratio was 1:2. After PPP/EF, 10 patients (13%) underwent angioembolization with a documented blush; mean time to angioembolization was 10.6 hours (range 1 to 38 hours). Mortality for all pelvic fractures was 8%, with 21% mortality in this high-risk group. There were no deaths due to acute haemorrhage.

Poenaru et al studied polytrauma hospitalized patients with unstable pelvic lesions stabilized with an EF.[17] Superficial pin track infection occurred in three patients. Within the studied group seven deaths were recorded (23%) in patients with extremely severe associated injuries (injury severity score (ISS) over 50), this being the decisive factor that determined the unfavourable evolution in six patients.

Mitchell et al found that of the 129 patients receiving anterior pelvic EF, 14 (10.9%) presented to an ED for problems with their anterior pelvic EF.[18] Of these 14 patients, 7 (5.4%) required readmission, all for infectious concerns necessitating IV antibiotics. Six (4.7%) required formal operative debridement and device removal. Thirteen patients (10.1%) had superficial pin site infections which were successfully treated with oral antibiotics. Reduction was maintained (rated as fair, good or excellent) in all patients with radiographic follow-up ($n = 74$, average radiographic follow-up of 216 days) following removal of their anterior pelvic EF. Thirty-eight patients (30.4%) had their anterior pelvic EF removed in clinic, while 87 (69.6%) had formal removal in the operating room.

In a study of 59 patients with mean age of 38 years and mean Injury Severity Score (ISS) of 28, Tosounidis et al observed that the most common symptomatic complications were pin site infection in 11 (18.6%) and loosening in 5 (8.5%) cases. Forty-four (74.5%) patients had satisfactory functional outcome.[19]

Schmal et al analysed unstable pelvic fractures, which frequently require emergency stabilization using a C-clamp or EF (CC/EF).[22] Patients treated with CC/EF were younger (45 vs 62 years), had more C-type fractures (65% vs 28%), higher ISS (≥ 25 = 63% vs 20%) and displacement (≥ 3 mm = 81% vs 41%), and more complex fractures (32% vs 5%). These features were independent risk factors for complications ($p < 0.001$). While mortality was reduced after CC/EF stabilization by 32%, the risk for general complications was slightly increased. In patients undergoing secondary surgery, CC/EF had no influence on mortality, general complications or infections. Related to preceding C-clamp stabilization, the risk for infection increased from 3.2% to 20.8% in iliosacral screw fixation.

In a recent systematic review, Stewart et al found that type B and double vertical fractures have less redisplacement (43.7% and 68.2% < 5 mm, respectively) than type C fractures (55.7% > 15 mm) regardless of pin placement.[21] More than 50% experience a complication, with the most common being pin site infection (36%) and a trend towards increased infection with increasing pins was seen. Most can be managed with antibiotics alone (93%).

Tibia

Milenkovic et al analysed 32 patients with segmental tibial shaft fractures (AO/OTA 42–C2), with an average age of 43 years.[26] Average time of union was 5.9 months for closed and 6.2 months for open fractures. Average follow-up was 18 months. Nine patients (28.12%) had open segmental tibial shaft fractures (2 Grade I, 2 Grade II, 1 Grade IIIA, 4 Grade IIIB). Union rate was 81.25% (26 cases). Nonunion rate was 18.75% (6 cases) and malunion rate was 3.12% (1 case). Nonunion was higher in patients with open fractures. Compartment syndrome had been diagnosed in six cases (18.75%) with closed fracture, and fasciotomy was performed when external fixator was applied. There were no deep infections. Pin tract infection was present in seven cases (21.85%).

Femur

Staeheli et al reported a case of vascular injury after femoral fracture EF (iatrogenic superficial femoral artery occlusion due to kinking of the artery around an EF pin). The pin was subsequently revised allowing the artery to travel in its anatomic position, restoring perfusion.[27]

Testa et al analysed 83 patients with 87 fractures who were treated with a monoaxial external fixation device. Reported complications included 9.19% delayed union, 1.15% septic nonunion, 5.75% malunion, and 8.05% cases of loss of reduction.[28]

Humerus

Catagni et al studied 84 cases of diaphyseal humeral fractures (24 type A, 38 type B, 22 type C of the AO/OTA classification) treated with EF (Hoffmann II frame).[29] Six of these fractures were complicated with radial nerve palsy. Four cases were open fractures. All reductions were achieved closely or through minimal open approaches. All fractures achieved consolidation with an average of 95 days. The six radial nerve palsies had complete spontaneous recovery. Superficial pin tract infections were observed in 12% of the patients.

Conclusions

EF is a quick method to stabilize fractures and severe soft tissue injuries and carries a low risk of complications.

EF can save the lives of patients with haemodynamically unstable pelvic injuries or patients with multiple trauma. It is necessary to know the biomechanical principles behind EF and to plan the type of frame appropriate for each anatomical area and for each patient. Knowing the safe anatomical areas for pin placement on each bone is critical to avoiding neurovascular injuries. The assembly formed by the EF should be stable, should allow for easy access for wound care and should be as comfortable as possible for the patient. The EF must be compatible with MRI to avoid any delays in performing diagnostic tests; if it is necessary to perform a CT scan to better characterize the fracture, it is better to wait until the EF has been placed.

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ICMJE CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest relevant to this work.

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