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BONE FIXATION TECHNIQUES IN THE TREATMENT OF COMPLEX FRACTURES IN TRAUMA SURGERY

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Abstract: In this chapter we present some of the osteosynthesis techniques used in the most common complex fractures. We separate the main fractures by region: lower limbs, upper limbs and pelvis. The fractures were classified according to AO classifications and eponyms. The aim of this chapter is to describe to medical students the different surgical techniques used in complex fractures in order to promote bone healing.
Keywords: Fracture fixation;Orthopedic Procedure; Surgical Procedures

FRACTURE OF THE UPPER LIMBS

COMPLEX FRACTURE OF THE HUMERUS

Fractures of the proximal region of the humerus are the seventh most common in adults and account for approximately 80% of all humerus fractures. It occurs predominantly in elderly women with osteoporosis, who are victims of low-energy trauma (falling from a chair height). When present in young adults, it is associated with high-energy trauma (such as motor vehicle accidents).

The most common symptom is pain in the shoulder girdle region. Bone crepitus in cases where bone fragments are deflected and 24-48 hours after the trauma, ecchymosis observed, usually in the axillary region, lateral chest, arm and elbow. To confirm the diagnosis, X-rays are needed in 3 views: true anteroposterior, scapular profile and axillary. A CT scan can be requested if there is a need to better understand the deviation of the fracture and determine its extension to the articular surface, important characteristics that must be identified in order to carry out the best treatment.

Among the various existing classifications, the NEER classification is one of the most important. It takes into account the deviation of the possible fractured segments of the proximal third of the humerus (anatomical neck, surgical neck, greater and lesser tuberosity) and thus knows the vascular conditions of the humeral head, guiding the best treatment. NEER considers these segments to be deviated if they are displaced more than 1.0 cm or angled more 45° in relation to the non-fractured segment. Fractures in 3 or 4 parts are considered complex fractures.

Treatment aims to maintain or restore anatomy and quickly rehabilitate shoulder movements.

Conservative treatment is carried out with non-plaster immobilization (Velpeau sling) and is indicated fractures without deviation, fractures with minimal deviation (those with less than 1.0 cm of separation or 45° of angulation between the fragments), impacted fractures and patients with displaced fractures without clinical conditions for surgical treatment.

Surgical treatment is indicated for the following fractures:

⇒ Fracture in two parts:

- Fracture of the surgical neck or anatomical neck: open reduction and fixation with percutaneous metal Kirschner wires is indicated. In the event of failure of open reduction, open reduction and fixation with a locking plate is performed, especially in osteoporotic humerus fractures. It can develop into aseptic necrosis of the humeral head, and treatment may require resection of the humeral head and replacement with a shoulder prosthesis.
- Fractures of the greater tuberosity with a deviation of more than 5.0 mm require open reduction and internal fixation with screws or non-absorbable wire ties. In the case of a comminuted fracture (with multiple fragments), removal of all the proximal fragments and reinsertion of the supraspinatus tendon directly into the raw region of the distal fragment is indicated.

- Fractures of the lesser tuberosity, when displaced more than 10 mm or blocking internal rotation of the shoulder, are indicated for crude reduction via the deltopectoral groove and screw fixation or resection of the proximal fragment when comminuted and reinsertion of the subscapularis muscle.

⇒ Three-part fracture:

- Fracture of the humeral head and one of the tuberosities (greater or lesser) with one or more unstable fragments. The most suitable approaches are open reduction via the deltopectoral groove for osteosynthesis using a fixed-angle locking plate. If there is comminution, the plate should be tied, avoiding medial deviation of the humeral head.

⇒ Four-part fracture:

- This fracture is associated with a high rate of avascular aseptic necrosis of the humeral head, delayed healing and pseudarthrosis. In young, active patients, treatment includes open reduction and internal fixation, and in elderly patients treatment includes hemiarthroplasty or reverse total arthroplasty. In addition, as with three-part fractures, the use of a fixed-angle locking plate is a choice that allows for better fixation of the fracture.

The most common complications are avascular aseptic necrosis of the humeral head (in 3- and 4-part fractures), joint stiffness, delayed healing, pseudarthrosis, vicious healing and surgical site infection.

COMPLEX FOREARM FRACTURE

Fractures of the forearm account for 14% of all fractures, 76% of which are located in the distal third of the radius. Fracture of the distal third of the radius is one of the most common fractures of the upper limb, and may or may not be associated with a fracture of the radial process. ulnar styloid.

Most common in women aged 50 and over, victims of falls from their own height onto their flattened hand. It can also be involved in high-energy trauma (motorcycle accidents) when it affects young adults.

Clinically, we see increased volume (edema), deformity in cases of dislocations, painful tenderness on palpation of the distal radius and intensely limited active mobility of the wrist joint. It is important to check for peripheral nerve damage by examining skin sensitivity and active mobility of the fingers.

Plain X-rays of the wrist in the posteroanterior and lateral views are usually sufficient to confirm the diagnosis of a fracture of the distal third of the radius, but can be complemented by internal and external oblique views. For a more detailed assessment of the degree of involvement of the radiocarpal, distal radioulnar and scaphosemilunar joints, a CT scan of the wrist is performed.

Treatment of fractures of the distal third of the radius without deviation is carried out conservatively with axillopalmar plaster immobilization in a functional position, i.e. elbow flexed to 90º, forearm in a neutral position (pronation-supination) and wrist in 30º extension, keeping the metacarpophalangeal joints and thumb free.

Fractures in this region of the forearm that have been deviated will be subjected to a reduction incision followed by axillopalmar cast immobilization. If there are one or more radiographic signs of instability (loss of radial length of more than 10 mm, dorsal inclination of more than 25º, metaphyseal comminution, intra-articular fracture with deviation of more than 2.0 mm) this should be treated surgically the method of incision reduction and percutaneous fixation with Kirschner wires, or crudely reduced and fixed with a plate and screws.

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Complex multifragmentary fractures with severe destruction of the distal articular surface of the radius, which may be associated with radioulnar and/or radiocarpal subluxations, should be treated using a combination of surgical techniques such as an external fixator and Kirschner wires, or a plate with screws and an autogenous bone graft taken from the iliac crest (to fill bone gaps caused by the impaction of fragments), with the aim of increasing the stability of this fracture. Some comminuted fractures of the radius with destruction of the articular cartilage may require partial fusion of the wrist or hemi-arthrosplasty instead of open reduction and internal fixation.

Vicious consolidation is the most common complication, but we can also see: joint stiffness, pain in the distal radioulnar joint, tendon rupture by a fragment bone or protruding screws, reflex sympathetic dystrophy, vascular lesions and compressive neuropathy of the median nerve (decreased grip strength).

METACARPAL AND PHALANGEAL FRACTURES

Metacarpal and phalangeal fractures are the most common fractures of the upper limb, and are probably the most common in the skeletal system. They occur most frequently in men between the ages of 20 and 40, victims of accidents at work, sports practices or falls. The distal phalanx is the most frequent site of a finger fracture.

The most common signs and symptoms are pain, swelling, ecchymosis, limited movement and there may be angular or rotational deformity of the finger on the hand. Radiographic evaluation of the hand is carried out using 2 views: posteroanterior and oblique, and for the phalanges we add the profile view. Computed tomography is useful for evaluating a fracture that complexly affects the articular surface.

The treatment of phalangeal fractures is generally conservative (immobilization with a metal splint) as the fractures are often stable. Fixation with Kirschner wires or screws (microfragments) is performed in unstable fractures or those with soft tissue injuries.

Fractures of the neck of the fourth and fifth metacarpal bones, which are the most common metacarpal fractures, when unstable (deviated) or comminuted with soft tissue damage (complex fractures), are treated surgically by the method of transmetacarpal reduction and fixation or with intramedullary Kirschner wires complemented by antebrachial-digital plaster immobilization, or by the external fixator method.

The complications of these fractures are joint stiffness, reduced joint range of motion, infection, vicious consolidation, delayed consolidation or absence of consolidation (pseudarthrosis).

PELVIC FRACTURE

Pelvic fracture is defined as the disruption of cortical integrity or damage to one or more pelvic bones, which often occurs in conjunction with other life-threatening injuries. They can be associated with injuries to the spine or limbs, as well as neurological injuries that can involve the nerve roots from L5 to S5, lacerations to the perineum and hemorrhage (even if the fracture is closed) caused by injury to the superior gluteal artery, injury to the sacral venous plexus and especially intra-abdominal bleeding.

The most widely used classification for pelvic fractures is the division into 3 categories according to the Young-Burgess classification:

⇒ Anteroposterior compression injuries (APC):

This type of injury is caused by a force of external rotation of the hemipelvis resulting in the separation of the pubic symphysis known as an "open book injury". With the progression of this injury, 3 subtypes are identified: I- Diastasis of the pubic symphysis of less than 2.5 cm (isolated rupture of the symphysis ligaments), II- Greater than 2.5 (rupture of the symphysis and pelvic floor ligaments), III- Posterior instability of the pelvic ring (rupture of the symphysis and pelvic floor ligaments and rupture of the sacro-iliac joint ligaments) which has a higher mortality rate caused by hypovolemic shock.

⇒ Lateral compression injuries (LC) - this is the most common and results from trauma caused by internal rotation of one hemipelvis over the other:

They are subdivided into three types: LC Type I (branch fractures with ipsilateral fractures of the sacral wing), LC Type II (branch fractures with ipsilateral fracture of the), LC Type III (ipsilateral lateral compression injury type I or II with a contralateral external rotation injury similar to an APC injury) which commonly causes death from blunt head trauma.

⇒ Vertical shear (VS) or Malgaigne lesions: Injury caused by vertical deviation of the hemipelvis, in which the iliac wing is deflected upwards in relation to the sacrum, causing rupture of the ligaments, the pelvic floor and the strong posterior sacroiliac complex. It is very common in falls from great heights or motorcycle collisions, resulting in unstable injuries, with intense retroperitoneal bleeding and associated injuries.

In the United States, it is estimated that pelvic fractures occur in 37 out of every 100,000 individuals per year. In both the United States and Brazil, the highest incidence occurs in the 18-28 age group and in males due to their greater involvement in automobile accidents (victims of high-energy trauma), falls from great heights and crush injuries. Over the age of 35, women are the most commonly affected due to osteoporosis. Mortality is associated with pelvic injuries at 5% to 30%.

Often caused by recent high-energy trauma (blunt or penetrating). The main mechanisms are road accidents, falling from a height (scaffolding and), crushing (caused by tractors in rural areas or wall in construction), assault with a weapon (blunt or sharp object).

The diagnosis is initially suspected clinically and then confirmed with imaging tests. The patient may present with arterial hypotension, exacerbated pain on palpation of the pelvis, hematoma in the external genitalia (testicular pouch in men and labia majora in women), perineal ecchymosis, mechanical instability of the pelvis and limb length discrepancy.

With regard to imaging tests, eFAST (Extended Focused Assessment with Sonography for Trauma) ultrasound is recommended to assess bleeding from intraperitoneal organs. Anteroposterior radiography of the pelvis in the emergency room is the essential examination for establishing the correct diagnosis and treatment of pelvic injuries. Computed tomography should be performed after the patient's hemodynamic stabilization, in order to assess subluxations of the pelvis, acetabular fractures, bleeding and hemorrhages.

The treatment of complex cases should initially be aimed at controlling hemorrhage and other potentially fatal injuries caused by high impact. Orthopaedic treatment begins with temporary compressive immobilization (pelvic brace or sheet) that wraps the pelvis at the level of the great trochanters, providing pelvic stability, reducing pelvic volume and helping to control bleeding. Another less commonly used technique is the use of a non-invasive pelvic circumferential compression device (PCCD). In vertical shear injuries, pelvic stability is achieved with skeletal traction of the lower limb, so the bi-trochanteric compression technique will not be effective.

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After radiographically identifying the complex pelvic fractures and dislocations causing hemodynamic instability in the emergency room, these patients should undergo external fixation of the pelvic ring in the operating room as soon as possible.

A further assessment to determine the definitive orthopedic treatment should be carried out after the patient's clinical stabilization. Open reduction and fixation of the pubic symphysis with 1 or 2 plates should be performed when the diastasis of this symphysis is greater than 2.5 cm. Crude anterior or posterior reduction of the sacro-iliac joint dislocation and fixation with plates, due to the risk of injury to the L5 root during access, is being preferred to sacro-iliac fixation with a percutaneous cannulated screw.

Stable pelvic injuries are treated conservatively and involve pain control, early physical rehabilitation with physiotherapy and walking with partial weight bearing on the lower limbs with the aid of a pair of crutches.

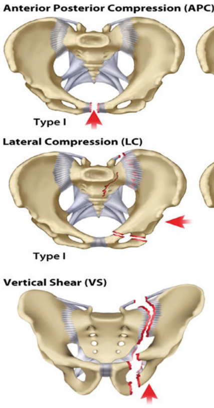

Figure 1: Young Burgess classification for pelvic ring fractures.

Figure 2: Patient in the emergency room after placement of the circumferential compression device (Binder).

Figure 3: Polytraumatized patient with pelvic strap

Figure 4: AP pelvis X-ray: opening of the pubic symphysis and right sacro-iliac dislocation

Figure 5: Fixation of the pubic symphysis with two plates and screws, and fixation of the sacro-iliac joint with a screw.

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LOWER LIMB FRACTURES

Lower limb fractures are less common than upper limb fractures, but they are more complex because they involve the region's joints and soft tissues, as they are mainly caused by mechanisms involving high energy against the limb, such as car accidents, high-performance sports and falls (1).

Tibial fracture:

In relation to lower limb trauma, the tibia is the long bone that suffers the most fractures. This is explained by the bone's vulnerability due to its subcutaneous position on the anteromedial side of the leg, leaving it more exposed to injury (2). We will therefore analyze fractures in this region.

TIBIAL SHAFT FRACTURE

Most closed tibial shaft fractures are caused by low-energy mechanisms. In young patients, the main causes are sports activities and in the elderly, falls from their own height or torsional trauma (3). In addition, 45% of open fractures are tibial shaft fractures, often related to high-energy trauma in adult patients and associated with polytrauma (4).

Tibial shaft fractures result from torsional (indirect) or flexion (direct) mechanisms (4). Direct trauma results in transverse or comminuted fractures. Fractures caused by indirect trauma have a long oblique line (2).

In the clinical assessment, the fact that the anterior tibial crest is subcutaneous helps with identification, and a neurological and circulatory assessment of the affected lower limb is also important (2). The examiner should assess the presence of behavioral syndrome signs (tense compartment, disproportionate pain and paresthesia) which are more common in diaphyseal fractures than in proximal and distal fractures. As imaging tests, radiography is used to diagnose, and it is important to analyze the entire length of the tibia (in two views: anteroposterior and lateral) (3)(1).

Non-surgical treatment is indicated for closed, isolated, stable fractures caused by low-energy mechanisms, using a cruropodal cast with the knee in flexion (2), followed by functional immobilization and subsequent rehabilitation (1).

Surgical treatment is used when the alignment parameters are not acceptable, in open fractures, fractures with compartment syndrome and in polytraumatized patients (3). Osteosynthesis with an intramedullary nail (IM) is a mainstay of treatment, as it has satisfactory union rates and less infection (4). It is contraindicated in patients with bone infection and pre-existing deformity of the tibial diaphysis (3). It is worth noting that its application with closed reductions showed a shorter healing time and less blood loss than open reductions (4). Other alternatives for osteosynthesis: plates with screws and external fixators (1).

TIBIAL PLATEAU FRACTURES

Clinically, it is a common type of fracture and accounts for 18.6% of tibial fractures and almost 2% of all fractures. It currently affects more elderly people with osteoporosis, related to low-energy trauma (5).

The Tibial Plateau is located in the metaphysis of the proximal tibia, its bone is spongy, dense and thin, therefore less resistant to traumatic injuries. Its lateral condyle is more

The medial condyle is more to massive fractures (5). Fractures result from right axial compression, which is more common with the knee under valgus stress than varus (3).

The diagnosis should be suspected in the presence of joint effusion (hemarthrosis), deformity, abnormal mobility and functional impotence of the knee (1). As far as imaging tests are concerned, we can initially use radiography and then computed tomography, which provides a better view of the fracture pattern (3).

The most widely used classification is Schatzker's (Figure 1).

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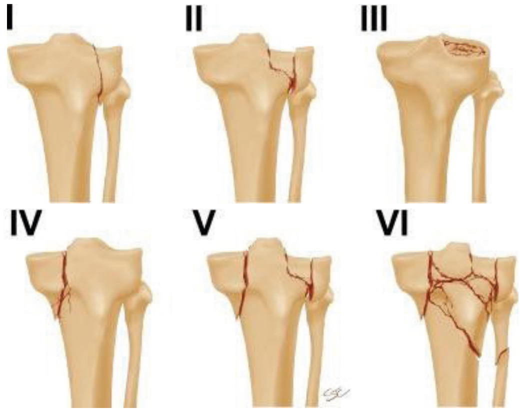

Type 1: Split wedge of the lateral tibial plateau; Type II: Split wedge depression of the lateral tibial plateau; Type III: Pure depression of the lateral tibial plateau; Type IV: Split wedge of the medial tibial plateau; Type V: Bicondylar fracture of the tibial plateau, where there is continuity between the epiphysis and the diaphysis; Type VI: Bicondylar fracture with complete dissociation between the epiphysis and the diaphysis (6).

The treatment aims to restore joint congruence, stability and painless function of the knee.

Non-surgical: Used for stable, non-displaced fractures in which plaster immobilization should be used initially, followed by articulated orthoses, both with total load restriction until the initial formation of bone callus (3).

Surgical: We follow this line of treatment when: Non-surgical treatment fails to maintain anatomical alignment (closed fractures with a depression of 2mm or more of the articular surface) and when there is more than 10 degrees of lateral or medial angulation with the knee extended compared to the contralateral knee (3). The gold standard for treating tibial plateau fractures is open reduction and internal fixation (RAFI) with locked screws and plates, which are important for achieving an adequate mechanical axis and restoring knee joint congruence. In the event of soft tissue damage, opt for the alternative of definitive treatment with a hybrid external fixator (7).

FEMUR FRACTURES

Femoral shaft fractures are more common in younger men, aged between 15 and 25, while proximal femoral fractures (neck fractures and transtrochanteric fractures) are more common in older women with osteoporosis.

As it is the largest and most resistant bone in the human body, fractures in this region are often caused by high-energy accidents, such as being run over, car accidents or motorcycle accidents. However, less frequently, repeated overload can lead to stress fractures, as experienced by athletes who train intensively over and over again (1).

When examining a patient with a suspected diaphyseal fracture of the femur, the principles laid down by the Advanced Trauma Life Support (ATLS) should be followed. On physical examination, swelling or an increase in volume, functional inability to move or bear weight on the leg, intense pain in the region of the femur when attempting to move and the possibility of visible deformities (1).

Non-surgical treatment is performed provisionally using skin or skeletal traction and promotes early stabilization of fractures in the first hours or days, with the aim of minimizing complication rates such as pain, shortening of the femur and mobility at the fracture site.

SURGICAL TREATMENT OF DIAPHYSEAL FRACTURES OF THE FEMUR

Surgical treatment is performed using closed-focus fixation of fractures using the locked intramedullary nail (HIMB) technique. In addition to providing multidirectional stability at the fracture site, it does not impair irrigation in this area, which favors faster healing, unlike the extensive access route used to reduce and fix long bones using the plate and screw technique.

External fixators are indicated for severe open fractures, hemodynamically unstable patients who cannot withstand prolonged anesthesia and fractures associated with vascular lesions, since the muscle fibrosis caused by Schane's pins results limited knee mobility.

ANKLE FRACTURES

They have a common incidence in young men and a high incidence in elderly women due to bone fragility. The incidence of ankle fractures is very high, accounting for 10.2% of all fractures (1).

Most of these fractures are related to low-energy impacts, from falls while standing, and can be influenced by a previous twist or sprain.

The most modern classification to help and categorize these fractures is the AO-OTA, divided into three types among the three main groups, which are fractures of the lateral malleolus, medial malleolus and tibial pilon and their subdivisions with the characteristic of the fracture trace.

The physical examination should be carried out after gathering information about the mechanism of the accident, through signs of swelling, analyzing mobility and checking for the presence of pain during palpation of both ankle malleoli. Three types of X-ray are usually sufficient for diagnosis: AP, lateral and internal oblique (1).

For efficient treatment, it is extremely important to achieve anatomical alignment of the joint structures, length and rotation of the fibula. Conservative treatment is without deviation, with integrity of the syndesmosis at the level of the distal tibiofibular joint or when there are no local or clinical (systemic) conditions that allow osteosynthesis.

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