Review Article

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Safe leg surgery: the anatomic principles and techniques

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ABSTRACT

The goals of surgical treatment of leg injury are to achieve soft tissue healing, good osseous union and to restore the length of the limb, correct alignment of both bones with their respective joints and normal range of movements of the entire limb at the earliest. Presently, the surgical treatment has been standardised for the tibia fractures for adults and children. Though the surgical progress made in the implants, instruments and techniques, there are considerable surgical complications happening. This article highlights the need of anatomical expertise and safe operative ability for the surgeon.

Keywords: Safe, Surgery, Trauma, Injury, Tibia, Fibula, Complications, Artery, Nerve

INTRODUCTION

The leg injuries are very common at the moment. Road accidents are the most common mechanism of injury and it can be devastating when it is open. The tibial fractures constitute a large number of emergency operations in most trauma centres. There is a significant advancement and justification had been made in the surgical treatment of the leg fractures. The goals of treatment are pain-free function of the lower limb. However, there are substantial complications happening. ¹⁻⁶

The tibia carries nearly five times body weight of axial force during walking. It also is subject to bending and twisting forces, especially when the foot is planted, although its resistance against these loads is far less than with compression. The fibula accounts for 6-17% of the weight bearing load of the leg. The majority of tibial shaft fractures in younger patients result from a direct, high-energy mechanism of injury. These injuries often cause a displaced, communited fracture pattern often accompanied by substantial soft tissue damage. The anterior tibial artery is often damaged in tibia fractures and is the source for significant bleeding and elevated compartment pressure.^{7,8}

neurologic complications in the intramedullary nailing of tibia had been reported as high as 30%.7 The knee pain after nailing is a noted complication.⁹ The incidence of iatrogenic damage to the infra patellar nerve after tilbal nailing is high and lasting. Injury to this nerve is to be associated with anterior knee pain after tibial nailing.9 The septic complications after nailing of the tibia is more than 6%. 10 Fracture healing is delayed in tibia fractures with vascular injury and they have to be managed well. 11-13 The oblique proximal locking screw of the tibial fracture nailing has produced peroneal nerve damage and significant morbidity after surgery.¹² Malrotation remains a commonly reported complication after tibial nailing.3

Open tibial shaft fracture is one of the most common fractures in the road traffic accidents caused by the strong direct force. 14 The rate of complications including osteomyelitis is lower in patients who had soft tissue reconstruction done within 72 hours of open leg injuries. 15 The external fixation is advocated for severe open fractures or in unstable polytraumatized patients for whom prolonged operating is harmful in damage control orthopaedics. 14-20 Safe corridors and zones been advised to

prevent neurovascular complications in the external fixation surgery. ¹⁶ Pin tract Infection with external fixation of paediatric fractures occurred in 50% of the patients. Any pin placed near a joint should be a minimum of 14 mm away from the joint line to prevent joint sepsis. Make sure to avoid the neurovascular structures around the knee (common peroneal nerve, deep peroneal nerve, and popliteal artery). A safe zone refers to such placement of thin wires so as to avoid neurovascular structures and intrasynovial placement to minimize the possibility of septic arthritis. ¹⁷ The Chinese study had proved the external fixation is more effective than internal fixation in reducing the hospitalization time as well as fracture healing time and lowering the total complication rates of paediatric leg fractures. ¹⁵

Proximal tibial fracture is caused by two mechanisms either by strong impact such as road accidents in young individuals or by the relatively weak impact as a fall in elderly people. High-energy tibial plateau fractures are severe injuries frequently associated with a high incidence of infection and soft tissue breakdown. Less invasive stabilization system (LISS) has become accepted for these fractures and has clear biomechanical advantages when compared with conventional plating. It causes considerably less iatrogenic tissue damage when compared with conventional plating. It reduces perioperative complications and lower risk of infection with a shortened operation time.²¹

The infection rate and soft tissue break down is very high for both tibial shaft fractures and tibial plateau fractures especially in the high energy injuries. Utilizing small wires and hybrid external fixation had been reported more beneficial than the plate osteosynthesis in these high energy fractures.²¹

Fractures of the tibial diaphysis remain the commonest injury treated by orthopaedic surgeons. Intramedullary nails have become the treatment of choice both for unstable closed fractures and for low-energy exposed fractures. Success in emplacing the tibial nail depends on the location and on the insertion angle. ²²

Today, the rate of infection after the tibial shaft fracture surgery has increased significantly. Along with other complications these fractures had increased the health care resource use and costs. The incidence of infection and nonunion has decreased with new treatment approaches but continues to be a source of significant morbidity and mortality. The antibiotic management should not exceed 72 hours unless there is spreading sepsis. Though, there are reports in other parts of the world having 35% of infection after tibial fracture surgery, a large multi-centre recent study in India proved there is only 3% of infection occurs following Internal fixation of open and closed tibia fractures. This study affirms with another Indian study that the duration of prophylactic antibiotic use is longer than standard practice in other part of the world, raising concern for the potential development of antibiotic resistant microbes within Indian orthopaedic settings. It is highly recommended to implement antibiotic stewardship programme and implementations of safety bundles in all the health establishments to prevent and manage the surgical site infection. ²³⁻³¹

Though there is little literature on the incidence of isolated fibula shaft fractures, it is really important and typically occurs after a direct injury in sports, after road accident and gunshot wounds. It can be associated with superficial peroneal nerve injury, vascular injury and compartment syndrome.³²

Children of less than 8 years of age can tolerate 100% translation of the tibial shaft and up to 10⁰ of sagittal and coronal angulation. However there are surgical indications for these fractures.^{6,46} As established, the primary goal of surgical fixation of both bones of the leg; either by internal or external modalities is to maintain the length, alignment and making certain of nil rotation of the fracture.

This article explains the safe anatomical approaches and distinctive operation techniques of the leg.

PRINCIPLES OF SAFE TIBIA AND FIBULA SURGERY

Improving patient safety is an increasing priority for surgeons and hospitals since complications can be catastrophic for patients, surgeons and institutions. The following safety facts explain the anatomical knowledge and distinctive techniques for the surgeon in preventing neurovascular complications in various approaches and also performing safe surgery in the leg. 3,16,22,23,33-37,39,43

Applied surgical anatomy of the leg

The leg has a multifarious anatomy which is made up of the tibia, fibula and their intraosseous membrane. They are well surrounded by the spray of important muscles with four compartments (anterior, lateral, superficial posterior, deep posterior) and intimate neurovascular structures (Figure 1 and 2).

The tibia has a large subcutaneous surface making it easy to access. The fibula has close ties to the common peroneal nerve and its branches.

The deep fascia of the leg is a tough, fibrous, unyielding structure that encloses the calf muscle. Two intermuscular septa, one anterior and one posterior, pass from the deep surface of the encircling fasacia to the fibula and enclose the peroneal compartment of the leg.

Common peroneal nerve

The common peroneal nerve begins posteriorly in the thigh and runs from the center of the popliteal fossa laterally and anteriorly together and below the tendon of the biceps femoris. It winds anteriorly around the neck of the fibula and then ramifies in the anterior compartment into a superficial sensory, deep motor and sensory branches.

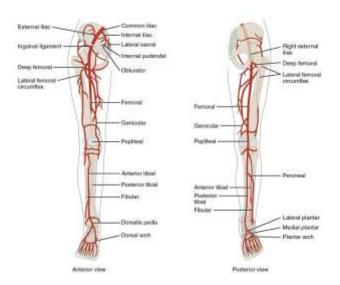


Figure 1: Vascular anatomy of the leg.

Saphenous nerve

The saphenous nerve is purely sensory. It runs distally on the anteromedial side of the thigh and passes the knee joint on the medial side of the patella where it gives off the infrapatellar branch. At the ankle it is anterior to the medial malleolus where it runs together with the long saphenous vein.

Popliteal artery

The popliteal artery traverses the center of the popliteal fossa. It trifurcates at the level of the proximal tibial shaft into the anterior tibial artery, peroneal artery, and the posterior tibial artery.

Knee joint capsule

Pin placement should respect the knee joint capsule and to be placed below 2 cm of the tibial plateau. If a more proximal pin fixation is necessary for very high fractures pin placement should be as anterior as possible due to the shorter extend of the knee joint capsule in this area.

Tibiofibular joint

The common peroneal nerve winds around the fibular neck and then runs anteriorly and distally.

Distal to the tibial tuberosity

To minimize the risk of infection it is best to insert the pins where soft-tissue coverage is minimal. Therefore distal to the tibial tubercle - the safe zones for pin insertion is the tibial crest and the medial face of the tibia. One must be careful and avoid deep penetration beyond the far cortex.

The neurovascular bundle (the anterior tibial artery and vein together with the deep peroneal nerve) runs anterior to the interosseous membrane close to the posterolateral border of the tibia. They are at risk if the pin is inserted in the direction as indicated by the red dotted line approximately half way between the anterior crest and the medial edge of the tibia.

Safety facts in anterolateral approach to the lateral tibial plateau

The superficial branch of the peroneal nerve has an unpredictable course. Hence upmost care is to be given while dissecting posteriorly in this region (Figure 2).

The lateral meniscus at most risk while making the incision of the synovium of the knee joint. It has to be carefully detached for adequate visualisation of the articular surface of the tibia.

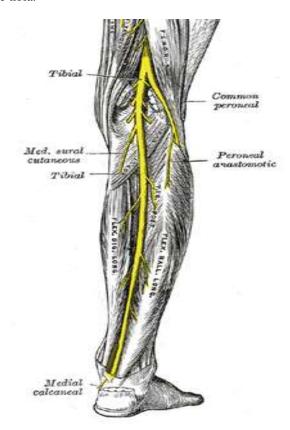


Figure 2: Neurologic anatomy of the leg.

Safety facts in minimal access anterolateral approach to the proximal tibia

The superficial branch of the peroneal nerve as explained before has a variable course. To avoid injuring this nerve, care has to be given while dissecting posterior region.

Excessive internal rotation of the insertion guide in the less invasive stabilization system (LISS) must be avoided as might endanger the popliteal artery.

Safety facts in posteromedial approach to the proximal tibia

The saphaneous nerve and vein come across during the superficial surgical dissection and should be preserved and protected.

Safety facts in anterior approach to the tibia

The long saphaneous vein which runs up the medial side of the calf, is vulnerable during superficial surgical dissection and should be preserved.

Safety facts in minimal access surgery to the distal tibia

The periosteum covering the tibia is critical for the vascular supply of the bone. The plane that lies between the periosteum and the subcutaneous tissues is used in this approach.

Safety facts in posterolateral approach to the tibia

The short saphaneous vein may be damaged when the skin flaps are mobilised.

The branches of the peroneal artery cross the intermuscular plane between the gastrocnemius and peroneus brevis muscles.

The posterior tibial artery and tibial nerve are safe as long as the surgical plane remains on the interosseous membrance and the surgeon should not go into a plane posterior to the flexor hallucis longus and tibialis posterior muscles.

Safety facts in approach to the fibula

The common peroneal nerve is vulnerable as it winds around the neck of the fibula . The key to preserve the nerve is to identify it proximally as it lies on the posterior border of the biceps femoris. It then can be safely traced through the peroneal muscle mass. Retracting the nerve is to be avoided.

The dorsal cutaneous branch of the superficial peroneal nerve is susceptible to injury at the junction of the distal and middle thirds of the fibula.

The subperiosteal dissection in the lateral malleolus region will prevent injury to the branches of the peroneal artery and the short saphaneous vein.

Safety facts in minimal access approach for tibial intramedullary nailing

Under fluoroscopy guidance, the ideal entry point would be medial to the tibial spine in anteroposterior view and immediately adjacent to the anterior margin of the joint surface in the lateral view. The infrapatellar branch of the saphenous nerve is frequently damaged in this approach. If a traction table is used and the thigh rest is placed within the popliteal fossa, compression of the popliteal vein can result which can increase the risk of deep venous thrombosis.

The incision can be lateral, medial parapatellar or transpatellar in approaching the point of entry in the proximal tibia. However the commonest approach is transpatellar.

In the frontal plane, the entry point is located in line with the medullary canal (3 mm medial of the tibial crest). In the sagittal plane, the entry point should be located just distal to the angle between tibial plateau and anterior tibial metaphysis.

If the entry point of tibial nail is too far posterior then damage to the insertion of the anterior cruciate ligament on the tibia will happen. An entry point that is too far anterior will cause splintering of the anterior cortex of the tibia on nail insertion.

For intramedullary flexible nailing insertion in children, paramount care to be taken in avoiding physis injury. The entry point should be 2 cm away from the metaphysis.

TENS work by balancing the forces between the two opposing flexible implants. To achieve this balance, the nail diameter should be 40% of the narrowest canal diameter (Flynn's equation: nail diameter=0.4* the diameter of the medullary canal) and the nails should assume a double C construct. They should have similar smooth curve and same level entry points. The nail end should be left proud and has to be less than 2 cm.

Safety facts in externally fixing the tibia

In paediatric tibial external fixation, the pins have to be placed 2 cm from the physis.

In adults, any pin placed near a joint should be a minimum of 14 mm away from the joint line to prevent joint sepsis.

For bridging external fixators, the pins are placed anteriorly in the tibial shafts.

The neurovascular bundle (the anterior tibial artery and vein together with the deep peroneal nerve) run anterior to the interosseous membrane close to the posterolateral border of the tibia.

Pins must be inserted sufficiently deep to engage in the far cortex. In the far cortex the pins must not protrude so as not to injure the neurovascular bundle or the soft tissues. Drilling a hole in the thick tibial crest may be associated with excessive heat generation and there is a risk the drill bit may slip medially or laterally damaging the soft tissues. As the anteromedial tibial wall provides adequate thickness for the placement of pins, this track is preferable. The Tibia is divided into three segments as illustrated

(Figure 3). An angle (relative to the sagittal plane) of 20-60° for the proximal fragment and of 30-90° for the distal fragment is recommended. Segment one should be dealt as placing the screws obliquely to avoid posterior tibial neurovascular bundle injury. Segment two should have sagittal plane screws and segment three screws must be anteroposterior at the plane between the lateral edge of the tibialis posterior and extensor hallucis longus.

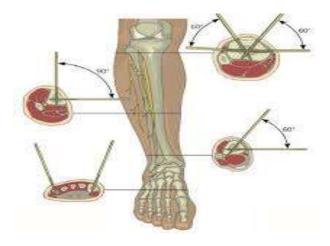


Figure 3: Safe zones of the external fixation of leg.

Safely approaching the compartments of the leg

To decompress the anterior and lateral compartments, a longitudinal incision is to be made on the anterolateral aspect of the lower leg. It has to be started at the level of tibial tubercle and extended up to 6 cm above the ankle. The fascia overlying the anterior and lateral compartments to be incised in the line of skin incision (Figure 4).

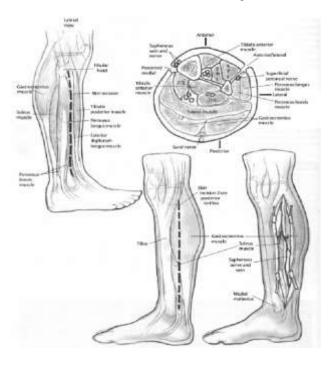


Figure 4: Muscular compartments of the leg.

To decompress the superficial and deep posterior (flexor) compartments a longitudinal incision has to be made on the posteromedial aspect of the lower leg. It starts from the level of the tibial tubercle and distally extends up to 6 cm above the ankle as explained before. Decompressing the deep posterior compartment may involve lifting the soleus muscle of the intermuscular septum and dividing that septum under direct vision, taking care not to injure the posterior neurovascular bundle.

DISCUSSION

Tibial shaft fractures have an incidence of 15% all adult fractures and are high-energy injuries with around 25% being open fractures with significant soft tissue injury. These fractures are prone to other complications as well. Road accidents and fall are the most common mechanisms of these fractures. The lack of a circumferential soft tissue envelope around the tibia makes to get more challenges like infection, non-union. Advanced bone reconstruction and soft tissue surgery is usually required to achieve bone and soft tissue healing. As demonstrated well in the literature, the tibial nail proved to be the most advantageous, since it runs in the biomechanical axis of the lower limb and minimally invasive. Though it was used mainly for the tibial shaft fractures, the recent developments of instrumentations and surgical techniques has made this system can be used to treat fractures of the proximal and distal tibia. 15,40

Distal tibia fractures are complex injuries with a high complication rate. Management of these fractures with or without articular involvement is a therapeutic challenge. Many treatment modalities are available for these fractures such as, conventional open reduction and internal fixation, external fixation with or without limited internal fixation, intramedullary nailing or minimally invasive plate osteosynthesis (MIPO). All of these techniques have advantages and disadvantages. However, the goal of orthopaedic surgeons is to restore the tibial anatomy to fix the epi-metaphyseal block with diaphysis and to avoid complications. Surgical complications been reported in more than 30% of these fractures because of the marginal soft tissue and vascular supply in this area.⁴¹

Plate fixation in distal metaphyseal fractures has a higher risk of delayed union or non-union. However a German study confirmed that the surgical treatment with plate fixation had a complication rate of 12% compared with 25% after intramedullary nailing. The complications of intramedullary nailing of distal third tibial shaft and metaphyseal fractures have a direct impact on ankle and foot function. However, the complications can be well reduced by impacting the undreamed nail till the subchondral bone while maintaining the fracture well reduced and by using multiple distal locking screws in different planes. The pre-existing risk factors such as diabetes or peripheral arterial dysfunction will lead to significant complications.

The non-operative management may be used when there is minimal soft tissue injury and when there is no substantial displacement or deformity of fracture. The upper limits of tolerable deformity are reportedly 50 angulation in the coronal plane, 100 angulation in the saggital plane, 50 rotational deformity and shortening less than 1 cm.²

Because of the lack of soft tissue covering the tibia and a mechanical disadvantages, internal fixation with plates is to be avoided and only to be used in tibial shaft non-unions or for fractures with articular or periarticular extension. External fixation may be used instead of intramedullary nailing in patients with severe soft tissue injury or with damage-control surgery in patients with polytrauma. If converting to an intramedullary nail, the procedure should be performed as soon as possible, preferably within 4 weeks to minimize the likelihood of pin sepsis.²

LISS may be technically demanding, has a long learning curve, expensive and higher radiation exposure. A novel system, U- grooved locking compression plate (U-LCP) had been tried for proximal tibial fractures with a shorter operating time, less radiation exposure, low cost and good functional recovery while compared with LISS.⁴³

The tibial shaft fractures are the third most common long bone fractures in the paediatric age group with an incidence of 15%. They are the second most common fractures requiring hospitalisation after femur fractures. The standard treatment of tibial shaft fractures in children is manipulation and casting. Surgical treatment is indicated for these fractures in polytrauma, neurovascular injury, open injury, and in failure to a satisfactory closed reduction. It is also beneficial in the closed fractures stabilisation following fasciotomy for compartment syndrome. 44,45

Immediate flexible nailing of open paediatric tibial shaft fractures can be safely performed with minimal risk of wound or infectious complications. 47,48 However, the risk of compartment syndrome is high regardless of whether a child has a closed or open tibia fracture and upmost care should be taken in performing flexible nailing in patients who may have closed head injury due to a risk of systemic complications.⁴⁹ Although external fixation in open paediatric tibial fractures is recommended, intramedullary nailing is also an effective method with low complications. Combining pins and flexible intramedullary nails is effective in developing more stability and is not associated with more complications.⁵⁰ It is important that both flexible nails are of equal diameter, since it will produce differential loading of opposite cortices may lead to angular deformity. By principles, the two flexible nails with three point fixation are a simple load sharing devices which would maintain alignment and rotation, allow mobilisation in producing bridging callus and would not cross the physis. It is also easy to insert and remove after bony union. The said features, shorter hospitalisation, lesser complications and excellent functional outcome had

made many surgeons to use this system to treat paediatric long bone fractures.^{44,51}

Pin-tract infection (PTI) is the most commonly expected problem or even an almost inevitable complication, when using external fixation with reported rates 1-100%. Biofilm related bacterial infections are challenging and Staphylococci Aureus is the commonest organism. While applying the pins, they should not drilled through the soft tossues, rather pushed into the near cortex, then drilled through the bone and finally advanced through the opposite soft tissue by tapping with a mallet. Standardised pin site protocols that emcompass an understanding of external fixator biomechanics and meticulous surgical technique during pin and wire insertion, post-operative pin site care and removal could limit the incidence of major infections and treatment failures.⁵³ Secondary nailing after external fixation for tibial shaft fractures should be early, before onset of PTI.52

The incidence of vascular injury in open tibial fractures is 29% and computed tomography angiography (CTA) is therefore a useful test in identifying vascular injuries that may require vascular intervention.⁵⁴ Open fractures of the leg must be given upmost care by the orthoplastic systems and proper documentation including photography before debridement and all key stages of management is recommended.^{31,34}

A comprehensive neurovascular examination must be performed and documented in all leg injuries.³ Also, it is important to institute appropriate interpersonal communications to ensure proper diagnosis and rule out other injuries that could influence a different, may be surgical treatment. This communication amongst surgeons, those in orthopaedics and other specialties can enhance patient-centered care and ultimately lead to improve outcomes.

New advances in managing the implant related infections in tibial surgery are there today. There are more developed external fixators, vancomycin cement, vacuum assisted dressings, perforator and other flaps in reconstructing the soft tissues. The combination of these techniques seems to produce promising outcomes.⁵⁵

CONCLUSION

Today, the surgical management for most of orthopaedic diseases and injuries are well accepted. The leg injuries must be taken upmost care so that the full functional outcome of the entire lower limb is achieved. To avoid the neurovascular and other serious complications, the applied anatomical knowledge with special skills is requisite for the orthopaedic surgeon while operating in the leg.

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