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Research Article

Appraisal of logicality and safety of intramedullary fixation of paediatric diaphyseal fractures by titanium elastic nails

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ABSTRACT

Background: Since the advent of the flexible intramedullary nailing by the surgeons in Nancy, France 1980, gradually and gradually the conservative treatment of diaphyseal fractures of paediatric long bones is going into oblivion and most of the fractures are now being fixed by titanium elastic nails (TENs), however logics for fixation have never been defined clearly in literature. In this study we appreciated certain features which helped us in appraisal of logicality and safety of intramedullary fixation of paediatric diaphyseal fractures with TENs.
Methods: 41 patients between 5-15 years of age with diaphyseal fractures of different long bones were treated by TENs. The patients were followed up for a mean period of 21.6 weeks.
Results: All fractures united in a mean time of 8.7 weeks, no serious complications, 2 patients showed limb length discrepancy of <2.0 cm. Mean hospital stay was 6 days, supported weight bearing allowed from 2nd or 3rd post-operative day and unsupported within 3-4 weeks, independent toilet use by 15 days, return to school at 2-3 weeks after discharge, parental off-duty only 7-10 days.
Conclusions: The intramedullary fixation of paediatric bones with TENs appears quite logical in terms of fracture stability for early mobilisation, early return to school, lesser hospital stay, and lesser parental off-duty. The technique is safe, does not interfere with fracture healing and does not violate the physis as nails are not passed through the physis.

Keywords: TENs, Logicality, Diaphyseal fractures of long bones, Paediatric bones

INTRODUCTION

Although conservative treatment of diaphyseal fractures of long bones is the gold standard due to enormous remodelling potential of paediatric bones, but there are certain problems encountered by the treating orthopedists as well as by the family members such as longer period of stay at hospital especially in cases of diaphyseal fractures of femur if treated with initial traction of 3 weeks followed by spica cast, loss of reduction needing re-manipulation and casting, angulatory and rotational malunion, delayed mobilization of the patient keeping the child away for a longer period from school and peer group activities, toileting and perineal hygiene problems, breakage and soiling of cast, increased social and economic burden on the family, and requiring one of the parent off duty to look after the child in a setting of nuclear family with both parents working which is very commonly seen in today's scenario.[1-3]

The surgeons in Nancy, France in 1980 based on the concept of Firica developed a technique of flexible stable intramedullary nailing by using two pretensioned nails which work on the principle of three point fixation.[4] Metazieau, Ligier et al observed that properly contoured

titanium nails were able to provide excellent axial and lateral stability to diaphyseal fractures of long bones.[4]

Gradually and gradually due to the encouraging results, the intramedullary fixation with elastic nails, which was originally used for femoral fractures, started becoming the treatment for all paediatric diaphyseal fractures.[5]

In view of the problems encountered with conservative treatment and the shifting trends in the treatment of paediatric long bone fractures, we took up this study to appraise the logicality and safety of intramedullary fixation in paediatric bones.

METHODS

Parents of every patient were counselled in detail regarding the conservative as well as surgical management along with the risks and benefits associated with both types of treatment. Only those patients whose parents appreciated the benefit and risk ratio of both types of treatment and opted for surgical management were included in the study. In total 41 children between 5 to 15 years with a mean age of 9.9 years were included in the study during a period of 2 years from May 2013 to April 2015. The children below 5 years were not selected for TENs fixation due to the smaller volume of medullary canal which may not allow passage of the 2 nails in femur, tibia and humerus, and these children can very well be treated in plaster. Thus the minimum age for femur intramedullary fixation is kept at 5 years and the maximum age is kept at until the closure of proximal physis which usually occurs at about 16 years, after which rigid interlocking nailing can be done without the risk of avascular necrosis of the head of the femur.[5,6] Out of the total number of patients 26 (63.4%) had fracture shaft of femur, 8 (19.5%) had fracture shaft of tibia, 2 (4.9%) had fracture shaft of humerus, and 5 (12.2%) had fracture of forearm bones. 39 (95.2%) fractures were closed and 2 (4.8%) fractures, one tibia and one forearm were open, Gustilo & Anderson grade I and II respectively.

There were 28 (68.2%) boys and 13 (31.8%) girls. Majority of children sustained injury due to fall at home or at school while playing, but 4 patients suffered injury in road traffic accidents. All patients were operated under GA and C-arm control.

The titanium elastic nails were used in all cases; one shot of cefotaxime was given in the OT followed by two doses post-operatively in the ward.

Two fractures of forearm required limited open reduction due to soft tissue interposition. Fractures of humerus, femur and tibia were stabilized by two nails while the fractures of forearm bones were stabilized with single nail in each bone. Post-operatively no external splintage was given for the fractures of humerus, femur and tibia except in one fracture shaft of femur due to heavier body weight of the patient, which was immobilized with POP thigh corset for four weeks. However all forearm fractures were splinted with A/E POP cast (due to the single nail fixation), to control rotation of forearm. Quadriceps drills, knee and ankle mobilization exercises were begun from second post-operative day. Patients with fractures of femur and tibia were made to ambulate with partial weight bearing with the help of walker/crutch support from third post-op. day, while full weight bearing was allowed after 3-4 weeks.

Technique

The patient is anaesthetised and is placed supine on the OT table or on the fracture table in cases of fracture shaft of femur which makes closed reduction much easier.[6] The limb to be operated is prepared and draped. For the humerus and forearm fractures the affected limb is placed on a side table with about 60^0 to 90^0 of abduction at shoulder joint. For making entry portals a small incision is given either in the proximal metaphyseal area below the physis for antegrade nailing, or in the distal metaphyseal area above the physis for retrograde nailing under C-arm control. The soft tissues are separated and spread with the help of blunt tipped pair of scissors. The periosteum is incised longitudinally and entry portal is made with the help of an awl or drill in the centre of the width of the bone in the lateral projection, at a point 2.5 cm away from the physis, first perpendicular to the bone and after piercing the cortex the awl is tilted about 10^0 towards the metaphyseal cortex that makes the passage of nail easier.[7,8] The tip of the nail is bent before insertion. The entire nail is not pre-bent as after touching the opposite intramedullary cortex the nail bends automatically as it is driven inside in the direction of the axis of the bone.

For fracture shaft of femur

Though retrograde as well as antegrade nailing can be done, we preferred retrograde nailing with two TENS of equal diameter one inserted from lateral and one from medial metaphyseal area. Proximally the lateral nail is embedded in the greater trochanter and medial nail is embedded in the neck of femur well short of physis.[7,9]

For fracture shaft of tibia

We preferred antegrade nailing with two TENS of equal diameter one inserted from lateral and one from medial metaphyseal area. Distally both nails are embedded in the distal metapyhsis, just short of distal physis.[7]

For fracture shaft of humerus

Proximal and middle third fractures are treated with retrograde nailing with two TENs of equal diameter inserted from lateral cortex at the elbow above the distal humeral physis through two separate holes made one above the other. Distal third fractures are treated by

antegrade nailing with two TENS of equal diameter inserted from lateral cortex at the level of deltoid insertion through two separate holes made one below the other.[6]

For fracture both bones of forearm

For radial shaft fractures retrograde nailing is done. Though the nail can be inserted either adjacent to the lister's tubercle or from the radial border just above the physis, we preferred the radial border to avoid the discomfort post-operatively during the extension movements of the wrist, which is common if dorsal entry is used. A single nail of 2.0 to 2.5 mm diameter is used due to the small calibre of the medullary canal of radius. For the ulna shaft fractures antegrade nailing is done and the point of entry of the nail is made over the radial border of ulna proximally just distal to the physis, which is easily identifiable just proximal to the head of radius, and antegrade insertion of a single nail of 2.0 to 2.5 mm diameter is done due to small calibre of the canal. The entry point at the tip of olecranon, though may be used, but preferably should be avoided due to the potential risk of physeal injury.[6]

The nail diameter should measure 40% of the narrowest diameter of the diaphysis or $2/5^{th}$ of the internal diameter of the medullary canal[6] or it is determined by measuring the width of the isthmus of long bone, subtracting 20% for the magnification and dividing the remaining by two.[6,7,10] Two nails of equal diameter suitable according to the width of the canal are used.

At the end of the procedure the protruding nails at the entry portals are cut about 1-2 cm long so that the protruded ends lie along and parallel to the bone. The nail ends should not be bent to avoid soft tissue tenting, irritation and skin breakdown.[6,8,10]

RESULTS

During a period of 2 year from May 2013 to April 2015, we managed 41 paediatric diaphyseal fractures by intramedullary fixation with TENs, in the Department of Orthopaedics Subharti Medical College, Meerut.

There were 26 (63.4%) patients of femoral shaft fractures with a mean age of 9.5 years (5 to 14 years), 8 (19.5%) patients had tibia fracture with a mean age of 9.6 years (6 to 13 years), 5 (12.2%) patients were of forearm fractures with a mean age of 12.2 years (11 to 15 years), 2 (4.9%) patients suffered from fractures of humerus with a mean age of 11.5 years (8 to 15 years).

Out of the total 41 fractures, 2 (4.8%) were open, one was Gustilo and Anderson grade I tibia fracture, and one was Gustilo and Anderson grade II forearm fracture.

No post-operative external immobilization was given for fractures of femur, tibia and humerus except in one patient of femur fracture due to heavier built of the patient, which was immobilized with POP thigh corset for 4 weeks. All forearm fractures were immobilized with A/E POP cast for 3 weeks to control rotation as forearm bones were fixed with single intramedullary nail only, due to small calibre of the intramedullary canal of radius and ulna.

All patients with fracture femur and tibia were allowed supported partial weight bearing from 2^{nd} or 3^{rd} post-operative day and independent full weight bearing within 3-4 weeks.

All patients were followed up regularly for assessment of any complication like delayed/non-union, mal-union, mal-rotation, deep infection, restriction of adjacent joint motion and limb length discrepancy.

In our study no case of delayed/non-union, mal-union, mal-rotation and deep infection was encountered. Three patients suffered from skin erosion at the site of insertion of nail due to a little longer protruded nail ends, which healed only after the removal of hardware after radiological union at 6 weeks. 9 patients had mild pain without skin erosion at the entry portals, which subsided within 2-3 weeks' time. 1 patient had restriction of knee flexion beyond 90^0 which was probably due to non-compliance of knee mobilization exercise protocol, this patient was readmitted for physiotherapy and the patient regained full range of motion within 2 weeks. 2 patients of femur fracture showed limb length discrepancy <2 cms.

All fractures showed uninterrupted healing within 6 to 10 weeks, with a mean healing period of 8.7 weeks.

The mean follow-up period was 21.6 weeks (3 to 24 weeks). The hardware removal was usually done after about 6 months but in 3 patients who had skin erosion, the nails were removed earlier after radiological union at 6 weeks. None of these patients suffered from re-fractures despite the early removal of nails.

Return to the school and peer group activities was early, upper extremity fracture patients immediately after discharge from the hospital and lower extremity fracture patients at about 2-3 weeks. All patients regained normal functions of affected extremity.

The mean hospital stay for all fractures was 6 days and during this period patients of femur and tibia fractures were made to learn partial weight bearing ambulation with the help of crutches or walker support and all these patients were also trained to go to the toilet initially with the help of any one of the attendants or nursing staff and then gradually patients were encouraged to use the toilet independently. Independent toilet use was achieved on an average of 15 days in toto, including the training period during the hospital stay.

None of the patient was allowed active participation in sports activity until the hardware removal at about 6 months post-operatively.

Out of 41 patients, 13 belonged to nuclear families with both parents working. These parents required only 7-10 days off duty, that too on alternate days by each parent. Beyond 10 days no parent required off duty as by this time the patients had started walking and using the toilet independently. Rest of the patients belonged to either the joint families or families with one of the parent non-working.

DISCUSSION

There is no controversy about the functional outcomes of conservative treatment of diaphyseal fractures of paediatric bones due to their enormous remodelling capacity, nor there is any disrespect or disagreement regarding the shifting trends towards the surgical treatment of paediatric bone fractures, but instead of being carried away with the shifting trends we decided to appraise whether it is really safe and logical to fix the paediatric bones with titanium elastic nails (TENs), and therefore we carried out this study in which we treated 41 paediatric fractures with TENs in an order to appraise the logicality and safety of the intramedullary fixation with TENs, rather than to compare the results of intramedullary fixation with conservative treatment.[1] We have not done this study to evaluate the functional outcome.

We could appreciate certain attributable features during the follow-up assessment of patients that helped us in appraising the logicality and safety of intramedullary fixation of paediatric bones with TENs. These features were observed as following.

- That most of fractures united within 6 to 10 weeks and the healing of the fractures is not found to be interfered with the intramedullary insertion of TENs.
- That the physis are not violated as TENs are inserted well above or below the physis depending upon retrograde/antegrade nailing and not through the physis.
- That in femur and tibia when fixation is done from medial and lateral metaphyseal area, the two titanium elastic nails inside the medullary canal crossing each other above and below the fracture and touching the bone at three points give sufficient stable fixation with reasonable rotational control.
- Post-operatively no plaster cast immobilization is usually required except in over weight patients, in our study only one patient of femoral shaft fracture required protection during ambulation for 4 weeks with a POP thigh corset due to heavier body built. However in forearm fractures we applied A/E POP cast for 3 weeks to control rotation, as these fractures are fixed with single nails due to small calibre of intramedullary canal.
- Mobilization of adjacent joints and partial weight bearing with crutches or walker support can be started immediately with full weight bearing within 3-4 weeks.
- As the patients are allowed early weight bearing, they also learn to use bathroom earlier.
- The treatment requires shorter hospital stay.
- There is rapid social integration of the patient leading to early participation in peer group activities and early return to school within 3-4 weeks.
- Off duty period for parents is remarkably less as patients achieve early independence for walking and toileting.
- No serious complication is usually encountered.
- The procedure in itself is quite simple, rapid, minimally invasive requiring small incisions with minimal blood loss, and does not have a steep learning curve.

Although few of the above mentioned features are also appreciated in conservative treatment after well performed closed reduction and immobilization in a well moulded cast, but still the major problem remains with mobility, toileting, off duty period for parents and early return of the patient to a normal lifestyle.[2,3,6]

Though the fractures of paediatric bones heal well with conservative as well as surgical treatment, but in view of the aforesaid observations, fixation of paediatric diaphyseal fractures with TENs appears quite logical and safe in terms of achieving early independence of walking and toileting, lesser duration off duty for parents in nuclear families with both parents working and early return to school and peer group activities.

However, while appreciating the advantages of intramedullary fixation with TENs, we must take all the pains to see that practice of closed reduction and cast application does not lose its sheen and therefore the surgical treatment should not be used indiscriminately, rather it should be considered after proper counselling of the parents and assessment of the child and family needs. Because still in our country the pattern of joint families is not completely abolished and the population to which we cater largely belongs to village background where both parents are usually not working and the child in spica cast or in A/K POP cast can be taken care of by the family members but the problems of mobility and early return to school and peer group activities do persist. Therefore the

surgical treatment should be individualised according to the patients and their family's profile and need.

However, this complication should not be taken against the intramedullary fixation if we evaluate the risk and benefit ratio of the procedure, and moreover this complication of limb length discrepancy has also been reported in the literature even with the conservative treatment, when end to end apposition of the fracture fragments is obtained rather than accepting an overriding of ½ an inch.[11]

CONCLUSION

The intramedullary fixation of diaphyseal fractures of paediatric bones with TENs appears quite logical and safe in terms of fracture stability for early mobilisation, early social integration of the child with early return to school, lesser hospital stay, and lesser off-duty period for parents.

The technique also appears logical and safe as it does not interfere with the normal fracture healing, does not violate the physis as nails are passed away from and not through the physis.

However in some cases of femoral shaft fractures some limb length discrepancy may occur, which is a cause of concern and needs a long term evaluation for the assessment of exact limb length discrepancy at skeletal maturity which is not possible in our study because of short term evaluation.

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