

Original Research Article

A comparative study of ultrasound and x-ray in detection, of fracture callus in tibial shaft fractures, treated by unreamed interlocking nailing

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ABSTRACT

Background: Trauma is a major health problem in young adults and adolescents. It is a major cause of disability with fracture being a leading contributor to hospital cost and lost productivity in the workplace. Comparative study of ultrasonography and radiography in the early detection of fracture callus in tibial shaft fracture treated by unreamed static interlocking nailing.

Methods: All skeletally mature patients admitted to Krishna Kumar Orthopedic Hospital, Nagercoil were included in our study from 2007 to 2008. 21 patients totally, who had sustained an acute fracture of the tibial shaft and who were treated by statically locked unreamed interlocking nailing were candidates for the study.

Results: The mean±standard deviation for ultrasound and X-ray method of detection fracture callus in fractures shaft of tibia treated with static interlocking nailing are 4.82±1.01 and 7.05±1.02 respectively which is statistically highly significant. This analysis reveals that ultrasound detects fracture callus much earlier than X-ray.

Conclusions: Ultrasound was able to detect fracture callus in tibial shaft fracture treated by a static unreamed interlocking nail. There was a statistically high significance difference of 2.23 weeks between the two techniques. Ultrasound was done using a 7.5 MHz linear transducer probe. Ultrasound could detect fracture callus at a mean period of 4.82 weeks. Whereas X-rays could detect fracture callus only at a mean period of 7.05 weeks.

Keywords: Ultra sound, X-ray, Tibial shaft fractures, Unreamed interlocking nailing

INTRODUCTION

Tibia shaft fractures are common injuries. Anatomical factors such as poor soft tissue coverage and the increased frequency of high energy injuries result in significant complications and disability.¹ Complications include infection, compartment syndrome, implant fatigue failure and delayed or nonunion. They can markedly influence the individual disability.² Currently, the assessment of fracture healing is based on clinical finding and radiological examination of the fracture site.³ It includes serial physical and radiological examination response to weight bearing and palpation, manual assessment. Plain radiological measurement and health-

related quality of life measurement.⁴ The search for an alternative mode of investigation devoid of the disadvantages of X-ray is continuing. Ultrasonography and resonant frequency imaging are the potential alternatives to radiography for assessing fracture healing.⁵ There are several advantages of ultra-sound over other imaging modalities. It is a non – invasive, painless, portable and cost-effective method of evaluation. It does not emit ionizing radiation. It can be done even for pregnant women. Ultrasonographic images are real-time and or not subject to radiographic magnifications. Images could be done in infinite planes.⁶ Resonant frequency analysis and the impulse response method are the other recently developed modalities of fracture callus detection.

They have some of the advantages of ultrasound but require specialized equipment. These modalities remain experimental at the present stage.⁷ They also have been shown to be unreliable when applied to fracture of long bones stabilized by a static locked un-reamed nail. Interlocking nailing is now the globally accepted treatment protocol for diaphyseal fractures of the tibia and the femur.⁸ It provides the ideal mechanical environment so that the biology can do the best to heal the fracture. But there are occasions where the biology fails, even in the best possible mechanical environment and the fracture union is delayed. Delayed union rate between 40% and 50% have been reported in studies of open tibial fractures stabilized with an unreamed interlocking nail.⁹ The re-union has been reported to be as high as 16% after interlocking nailing of the tibial shaft using a small diameter statically locked nail.¹⁰ However, this correlation could not be applied to predict the outcome of individual fracture.

METHODS

All skeletally mature patients admitted to Krishna Kumar Orthopedic Hospital, Nagercoil were included in our study from 2007 to 2008. 21 patients totally, who had sustained an acute fracture of the tibial shaft and who were treated by statically locked unreamed interlocking nailing were candidates for the study. Inclusion criteria were all skeletally mature acute tibial diaphyseal fracture treated by static unreamed interlocking nailing; all closed unifocal fractures, wedge fractures, comminuted fractures treated by static unreamed interlocking nailing were included; grade- 1, 2 and 3A open fracture treated by static interlocking nailing were also included. Exclusion criteria were grade 3B & 3C open fractures; all the tibial diaphyseal fractures treated by modalities other than unreamed static interlocking nailing like external fixators; all the tibial diaphyseal fractures treated by reamed static interlocking nailing; tibial diaphyseal fracture nonunions treated by interlocking nailing, presence of infections at the fracture or the incision site.

Method of study

The interlocking nailing surgical procedure was performed on a standard radiolucent operating room table with the patient's leg draped free from the knee. Fracture reduction was done manually after passing a 7 size reamer to create a passage in the medullary cavity for the unreamed orthofix interlocking nail. An 8 mm/9 mm

diameter solid core interlocking nail was used and static interlocking was performed in all cases. The patient was discharged on the 9th or 10th POD after suture removal and followed up routinely at 2-week intervals (i.e.) at the end of 2nd, 4th, 6th and 8th postoperative weeks. Radiographs and ultrasound films were taken. Ultrasound studies were performed using a Siemens acoustic imaging ultrasound machine with a 7.5 MHZ linear transducer. The tibia was oriented horizontally for this study. Silicon gel is used to ensure good contact between the skin and probe. Three portals (anterolateral, anteromedial and anterior) were used encompassing approximately 270 degrees of the total circumference of the tibia across the entire length of the fracture site. The echogenicity of the soft tissue in the fracture gap was compared with the echogenicity of the tibialis anterior muscle and the tissue was described as either hypo/hyper/isoechoic. Standard ultrasound pictures were taken for normal tibia along the above three portals which served as the standard. The posterior aspect of the tibia could not be visualized because of the gastroc-soleus muscle mass. The fracture gap is seen as containing hypo/isoechoic material. The overlying muscle is seen. The nail (represented by the echo marked by the arrow) is visualized. These ultrasound findings constitute "a negative (callus not formed) examination" ultrasonographically fracture callus appearance was defined as the progressive appearance of the hyperechoic tissue in the fracture gap. Fracture union was defined as the progressive appearance of the hyperechoic tissue filling the fracture gap, obscuring the view of the intramedullary nail through all three portals on ultrasound imaging, i.e. a positive nail disappearance sign.

Statistical analysis

Data were entered using Microsoft Excel and analyzed using STATA software. A continuous variable was analyzed using the student 't' test which was used to determine the significant difference.

RESULTS

All skeletally mature patients admitted to Krishna Kumar Orthopedic Hospital, Nagercoil were included in our study from 2007 to 2008. 21 patients totally who had sustained an acute fracture of the tibial shaft and who were treated by statically locked unreamed interlocking nailing were candidates for the study.

Table 1: Age group distribution.

Age group	10-20	21-30	31-40	41-50	51-60	61-70	>70
Number of patient	2	8	7	1	2	0	1

In the present study, the age- group ranged from 18 to 82 years in Table 1. The mean age was 34.7 years and there were 18 males compared to 3 females. The major group was in the 21 to 30 age group- 38%. Neither age nor sex

was a factor affecting the earlier detection of fracture callus either by the ultrasound or radiological examination. But age was general patient related variable which influenced fracture healing

Table 2: Fracture pattern.

Types of fractures	Percentage (%)
Comminuted	6 (28.5)
Butterfly	5 (24)
Oblique	5 (24)
Transverse	3 (14.5)
Spiral	2 (10)

Table 2 shows out of these 21 cases, 6 patients (28.5%) were comminuted fracture butterfly fracture pattern was present in 5 patients (24%). oblique fracture pattern was also present in 5 patient (24%). 3 patient (14.5%) had transverse fractures and the remaining 2 patients (10%) had spiral fractures.

Table 3: Types of fractures.

Fracture type	Cases
Closed	13 (61.9)
Open	8 (38.1)

Table 3 shows out of 21 patients, 13 patients (61.9%) were closed and the remaining 8 patients (38.1%) were open. Out of these 8 patients who had an open fracture, 4 were Grade-I open injuries, 3 were grade –II open injuries and one was grade– III A open injury.

Table 5: X-ray and ultra sound detection of cases.

Method of detection	Observation	Mean	Standard error	Standard deviation.	95% confidence interval
Ultra sound	17 patients	4.82 weeks	0.246	1.01	4.30-5.34 weeks
X ray	17 patients	7.05 weeks	0.249	1.02	6.50-7.60 weeks

DISCUSSION

The development of software applications that assist the radiographic evaluation of fracture healing could advance clinical diagnosis and expedite the identification of effective treatment strategies.¹¹ A radiographic feature regularly used as an outcome measure for basic and clinical fracture healing research is new bone growth or fracture callus. In this study, we developed OrthoRead, a portable software application that uses image-processing algorithms to detect and measure fracture callus in plain radiographs.¹² An anatomical feature on radiographs that has clinical relevance to fracture healing is new bone growth or fracture callus.¹³ Fracture callus is a heterogeneous tissue composed of hyaline cartilage, fibrous tissue, and woven bone that forms near the fracture site. The callus will eventually bridge the fracture gap and remodel into strong lamellar bone. The size of callus formation in radiographs is predictive of bending stiffness and thus relates to mechanical stability at the fracture site.¹⁴ Recently, callus formation has been incorporated into standardized scoring systems to assess healing in fractures of the tibia and pelvis. However, a

Table 4: Associated comorbids symptoms.

Symptoms	No. of patients
Head injury	2
Polytrauma	10
Diabetes	3
Infection	3
Heart disease	4
Intact fibula	3
Malnutrition	1
Nil	4

In Table 4, of this 21 patient polytrauma was present in 10 patient in 10 patients, diabetes in 3 patients, infection in 3 patients, heart disease in 4 patients, intact fibula in 3 patients. Head injury was present in 2 patient. malnutrition was present in 1 patient. There was no comorbidity, percentage data could not be calculated.

In Table 5, the mean±SD for the ultrasound-ray method of detection fracture callus in fracture shaft of tibia treated with static interlocking nailing are 4.82±1.01 and 7.05±1.02 respectively which is statistically highly significant. This analysis reveals that ultrasound detects fracture callus much earlier than X-ray.

software standard for detecting fracture callus in plain radiographs has not yet been established, and most methods of measuring callus are qualitative in nature.¹⁵ In the pilot study by Berkes et al, all the 14 fractures were treated with small diameter unreamed inter-locking nails of size 8 or 9.¹⁶ Bhandari out of 14 cases, 7 were simple and 5 were comminuted. There were also 2 segmental fractures. They did not raise any question regarding difficulty in fracture callus detection and the visualization of the IM nail by ultrasound. In the follow- up study by the same group, out of 47 patients with 51 fractures 10 were spiral fractures, 2 were oblique, 3 were transverse, 23 fractures were comminuted and 3 were segmental fractures. In the follow- up study too, they did not raise any question about any difficulty of detecting fracture callus and visualization of the intramedullary nail by ultra-sound.¹⁷ But since our follow up period was only 8 weeks, 8 patients out of 21 patients in our present study did not show ultrasound fracture union. They did not have the ultrasound ‘nail disappearance sign’ within the observed 8 weeks, which meant an incomplete fracture union.¹⁸ The other 13 cases showed fracture union as per the protocol. Out of the 8 cases which did show the nail

disappearance sign, 3 were comminuted and 4 were oblique fractures and 1 was a butterfly fracture. Of these 8 patients, not showing full fracture union i.e. negative nail disappearance sign, callus could not be detected at all by radiological means in 4 fractures, of which 2 were oblique and 2 were comminuted. Complete fracture union (callus in 3 out of the observed 4 cortices) could not be detected by X-rays within the observed 8 weeks in any of the fracture pattern.¹⁹ Intact fibula did not hinder fracture union and callus was detected by ultrasound. It was not a factor in the ultrasound detection of fracture callus. Out of the 3 cases, where the fibula was intact, fracture callus was detectable by ultrasound by the 6th week in 2 cases and the 4th week in the 3rd case.²⁰ Of the 10 cases with polytrauma in 5 patients callus was detectable by ultrasound by the 6th week, in 2 patients by the 4th week and by the 8th week in the remaining 3 patients. Polytrauma did not affect fracture healing. Of the 17 cases where callus could be detected by both ultrasound and X-ray within the study period of 8 weeks, the mean \pm standard deviation for ultrasound was 4.82 weeks \pm 1.01 and that of X-ray, 7.05 weeks \pm 1.02. The 95% confidence interval was 4.30 weeks to 5.34 weeks for an ultrasound. It was 6.50 to 7.60 weeks for X-ray. The 'P' value was less than 0.0001 which was statistically highly significant. This shows that the ability of ultrasound to detect fracture callus precedes the ability of X-ray to detect the fracture callus by 2.23 weeks. This is a significant length of time because secondary procedure could be planned earlier to prevent non-union. Graduated weight bearing could be initiated early. This is comparable with Moed, Berton et al 'pilot study in which ultrasound could detect complete fracture union by 38 days but X-ray only by 127 days. In the same groups follow up study, the average time to fracture healing as determined by the ultrasound criteria (6.5 weeks) was significantly shorter than the 19-week average found by the radiological analysis ($p < 0.001$, two-sided paired t-test). In the canine study done by the same group, the fracture was evident by ultrasound criteria at an average of 5.6 weeks and radiological methods by 7.3 weeks. The difference between the time to fracture union as determined by the ultrasound vs. plain radiography was significant ($p = 0.05$, Wilcoxon rank sum exact test).²¹ Young et al s by Ilizarov method showed that ultrasound could detect new bone at the distraction site early as 1 week and not later than a 16th week. It also preceded its appearance on X-ray by 4 to 16 weeks.²² Our present study has focused only on fracture callus detection by ultrasound and X-ray. It did not focus on fracture union. Fracture union could not be measured, as the case was followed only for 8 weeks postoperatively. Fracture union is indicated by 'the Nail disappearance sign' and was seen only in 13 cases (61.9%) out of a total of 21 cases within the follow-up period of 8 weeks. but X-ray could not detect fracture union in any of the observed fractures as no fractures as no bridging callus was found in 3 out of observed cortices within the follow-up period of 8 weeks.

CONCLUSION

Complete fracture union could be judged by the ultrasound in 62.9% of cases, but none by X-ray techniques. This was because each case was observed for only 8 weeks. This indicates that further longitudinal studies with longer follow up period are needed to assess complete fracture union. We conclude that ultrasound could be used to follow bone fracture union in tibial shaft fracture, after intramedullary nailing, because it is cheap, has minimal operator dependence and has no ionizing radiations.

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