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Use of elastic nailing for the treatment of paediatric long bone fractures in community hospital settings

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ABSTRACT

Background: Long bone fractures in the paediatric population are treated with elastic intramedullary nailing. Nailing techniques and hardware have evolved significantly since its initial introduction in the early 1980s and they are considered a reliable method in treating these fractures. In Greece, the surgical management of these fractures is usually performed by specialist surgeons in tertiary paediatric hospitals.
Technique: With this retrospective study we investigate the operative management of paediatric and adolescent long bone fractures treated by general Orthopaedic surgeons in a community hospital. Our aim is to assess whether elastic intramedullary nailing is a reliable and appropriate treatment in community hospital settings.
Patients and methods: We retrospectively reviewed 58 patients with a total of 75 fractures that have been managed operatively in our hospital from February 2006 until February 2015. There were 6 femoral, 7 tibial, 27 radial shaft, 4 radial head, 23 ulna and 8 humeral fractures. The mean age was 10.6 years (range 4 -17 years) and the male to female ratio 4:1.

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Results and Conclusion: All fractures where anatomically reduced, there were four cases of skin irritation at nail insertion and two delayed unions in femoral fractures that resolved without compromise. The range of motion returned to levels equal to the uninjured side. There was one case of leg length discrepancy due to a femoral fracture that was subsequently managed with a distal femoral epiphysiodesis. Our series had no significant deviations from the bibliographic average in terms of functional and aesthetic result, complications and bed stay compared to major health centers in Greece and abroad.

KEY WORDS: intramedullary nailing, children, fracture, district hospital

Introduction

Elastic intramedullary nailing[1, 2] is a reliable method for the treatment of diaphyseal fractures of the long bones in children over five years old[3-5] involving the femur, tibia[2, 6, 7], humerus[8] and unstable fractures of the forearm[6, 9, 10]. Most of the techniques used in adults for the management of these fractures (plates, locking nails) are not suitable for the immature skeleton leading to significant complications. External fixation is linked with a higher risk of refracture and pin track infection[11]. Rigid nailing may lead to epiphyseal growth disturbances, as in the greater trochanter, or avascular necrosis (AVN) of the femoral head if the blood supply is disrupted [12, 13]. Plate fixation on the other hand is linked with material failure, infection, increased blood loss and leg length discrepancies due to hypertrophy; it may also require a second intervention for implant removal[14].

The main purpose of this study is to highlight that elastic intramedullary nailing can be successfully applied in community hospital settings in our country, where specialized health care is mostly available in major urban centers. This can lead to increased socioeconomic cost[15, 16], or suboptimal management. In forearm fractures for example, when conservative management is the treatment of choice, there is an 11% and 2% chance for a second and third manipulation respectively while other complications include a 3% risk for delayed union and up to 50% aesthetic or functional deficit[17].

Materials and Methods

We retrospectively reviewed 58 children with 75 long bone fractures that underwent elastic intramedullary nailing from 2006 to 2015. The procedures were performed by a team of 5 general orthopaedic surgeons one of which had fellowship training in paediatric orthopaedics. There were 27 radius and 23 ulna fractures, 4 fractures of the radial head, 8 humeral fractures, 6 femoral fractures and 7 fractures of the tibia. There were two open fractures, a tibia and a radius, and three children had multiple injuries. Three pathologic fractures were excluded from the study. The mean age of the patients was 10.6 years (range 4 to 17 years), and the male to female ratio 4:1. The mean postoperative follow-up was 46 months (range, 24 -115 months). The reduction was performed using a closed technique except for the fractures of the forearm, 40% of which had to be opened (n=12). The implants used were titanium elastic intramedullary nails[12](Depuy Synthesm J&J Medical Devices, USA). Numbers of nails per anatomic region and insertion points (**Table 1**) are in accordance to what has been previously described by other authors[3, 18]. The diameter of the nail corresponded to 40% of the internal diameter of the medullary canal[19] and the introduction site was in the metaphysis of the bone. The approach was done with a small incision and the nail was inserted with the use of a drill or awl at a 45° angle under fluoroscopic control. The postoperative immobilization protocol was splinting for 3 weeks in forearm fractures, sling for 2 weeks in humerus fractures, non-weight bearing in femur and tibia fractures until the radiographic appearance of satisfactory bone healing; usually 8 to 10 weeks post-surgery. The average hospitalization time of the patients was

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Table 1 Nail insertion per anatomic region

Fracture location	Number of nails	Cephalocaudal Insertion	Mediolateral insetion	Principles of the technique
Femur	2	Distal (Supracondylar)	Medial and lateral	First choice for nail insertion
		Proximal (Subtrochanteric)	Lateral	Alternative option if fracture site is distal
Tibia	2	Proximal	Medial and lateral	Greater distance between the two nails should be at the fracture site
Radius	1	Distal	From styloid process or dorsally (Lister's tubercle)	Dorsal insertion associated with postoperative discomfort in the wrist and damage of the EPL
Radial head	1	Distal	From styloid process or dorsally	Can be assisted with percutaneous insertion of K-wire at the fracture site in order to move the displaced radial head medially
Ulna	1	Distal	Radial side of the metaphysis	Preferred option when dealing with radius & ulna fracture
		Proximal		Distal part of the metaphysis
Humerus	2	Distal	Lateral	2 to 3 cm proximal to physis with attention to the radial nerve

Table 2 Summary of cases and results

Fracture location	Design	Size	Patient demographics		Post operative immobilisation protocol	Outcome measures	Results
			Mean age (range)	M:F ratio			
Femur	Retrospective case series	6	9 (8-10)	4:2	Non weight bearing until signs of radiographic healing	Radiographic union, ROM, complications	Radiographic healing 12 weeks, 1 bony overgrowth secondary to nail and subsequent epiphysiodesis, 2 cases of delayed union managed conservatively, 1 case of skin irritation, 1 superficial soft tissue infection leading to earlier removal of nail (4 months)
Tibia	Retrospective case series	7	10.4 (6-14)	6:1	Non weight bearing until signs of radiographic healing	Radiographic union, ROM, complications	Radiographic healing 9 weeks, 1 case of skin irritation
Radius	Retrospective case series	27	11.2 (4-16)	24:3	Splint for 4 to 5 weeks	Radiographic union, ROM, complications	Radiographic healing 6 weeks, no complications
Radial head	Retrospective case series	4	9.75 (7-14)	1:3	Splint for 2 weeks	Radiographic union, ROM, complications	Radiographic healing 4 weeks, no complications
Ulna	Retrospective case series	23	10.75 (4-17)	20:3	Splint for 4 to 5 weeks	Radiographic union, ROM, complications	Radiographic healing 6 weeks, no complications
Humerus	Retrospective case series	8	10.75 (5-15)	5:3	Sling for 3 weeks	Radiographic union, ROM, complications	Radiographic healing 4 weeks, 1 case of skin irritation
Total		75	10.6 years (4 -17)	60:15			

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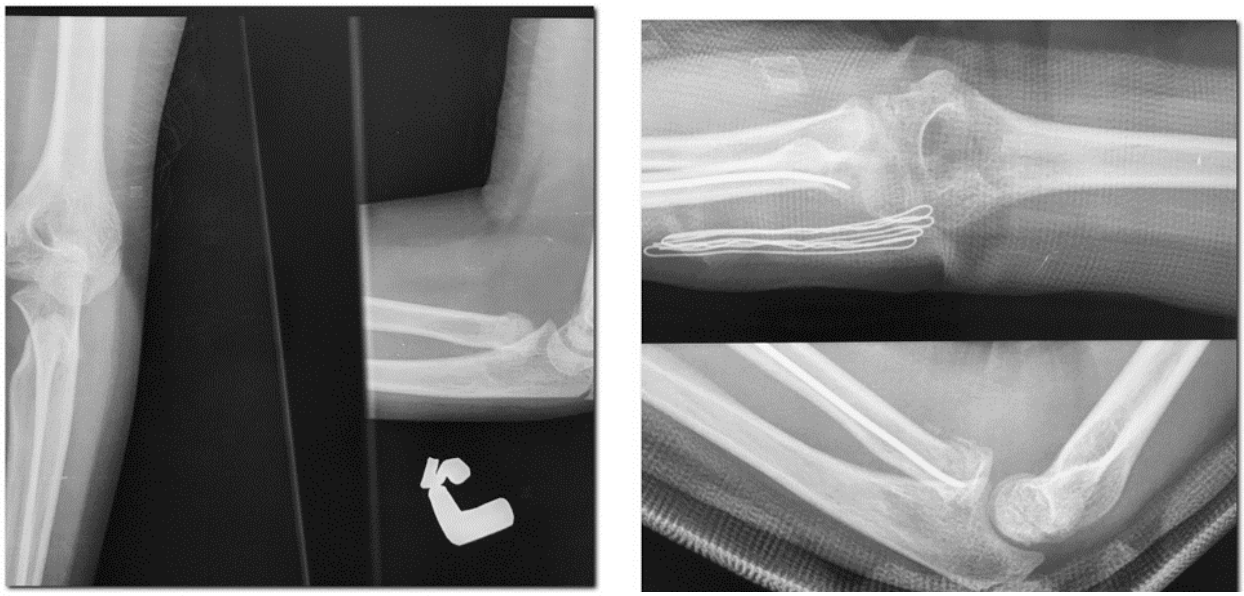
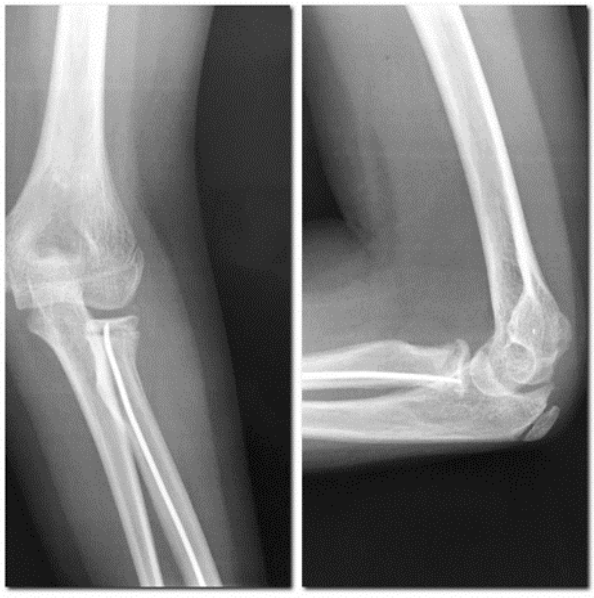


Picture 1,2. *Radial head fracture before and after ESIN placement*

1.1 days. Upper limb injuries were admitted for a day, while those of the lower extremities 2 to 3 days depending on mobilization potential. The elastic nails were removed 6 months postoperatively in order to minimize the possibility of a refracture[20]. The removal procedure was performed under local anesthesia and sedation in forearm, humerus and tibia fractures and under general anesthesia for the femoral fractures.

Results

A summary of our cases and complications that occurred during the course of treatment is shown in **Table 2**. The mean radiographic healing time was 6 weeks for the forearm, 4 weeks for the head of the radius **(figures 1,2,3)**, 4 weeks for the humerus, 8 to 10 weeks for tibial and femoral fractures. Most of the patients had no need for specific post-operative physiotherapy. The range of movement (ROM) returned to normal within 3 months in all upper limb injuries **(figures 4, 5)** and it took up to 3 months after full weight bearing was initiated for the lower extremities. In one case of persistent limping and clinical leg-length discrepancy in a 12 year old girl with a femoral fracture we performed a scanogram that revealed a 2.05 centimeters lengthening despite the anatomic reduction. A distal femoral epiphysiodesis was performed that resulted to a 1.75 cm leg length discrepancy as the growth plates were close to skeletal maturity **(figures 6, 7)**.



Picture 3. *Radial head fracture signs of radiographic healing*

Nonunions were not noted. There were two cases of delayed union involving two distal third femoral fractures. Radiographic bone healing was evident

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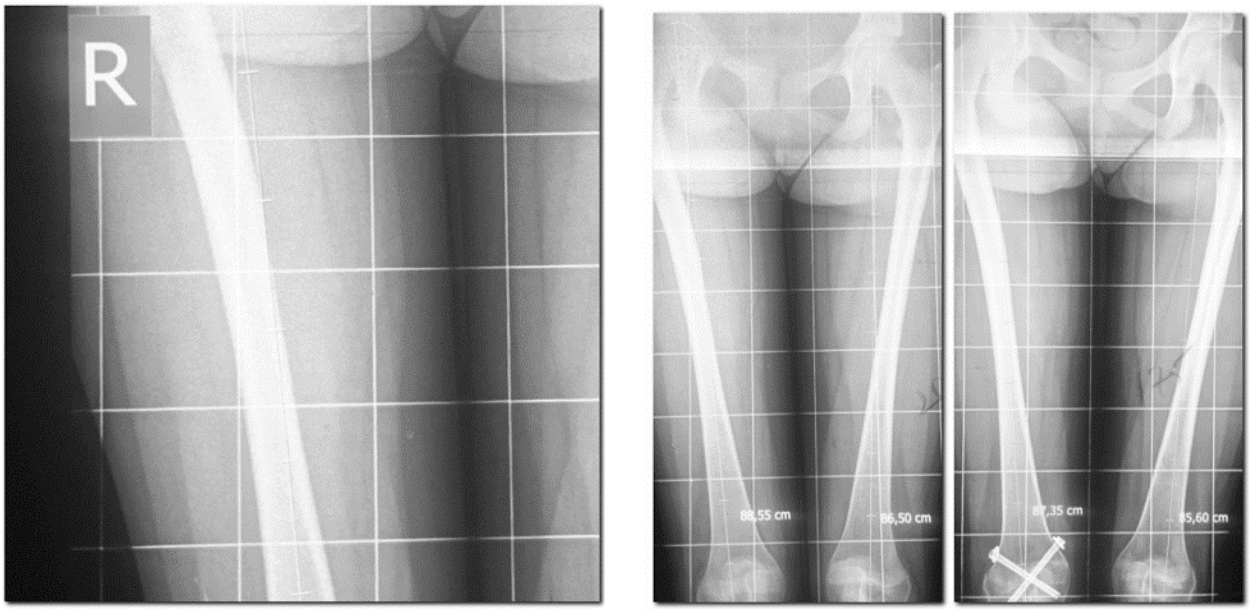
Picture 4,5. *ROM Radial head fracture*



Picture 6. *Radiographic healing of the femur (left)*

Picture 7. *Leg length discrepancy after a midshaft femoral fracture before and after distal epiphysiodesis (right)*

after at least 4 months. Minor complications in this series included 4 cases of soft tissue irritation with breaking of the skin in one of them but no signs of deep tissue infection or osteomyelitis. The wound healed without further treatment after an earlier than planned nail removal 4 months post injury. There was no case of postoperative rotational asymmetry, loss of rotational alignment or significant leg-length discrepancy during the follow up period (average 46 months).

Discussion

Flexible intramedullary nailing is a minimally invasive technique with a small number of complications[21-23] and shorter hospital stay. Its wide use since its introduction has shown that it is an alternative

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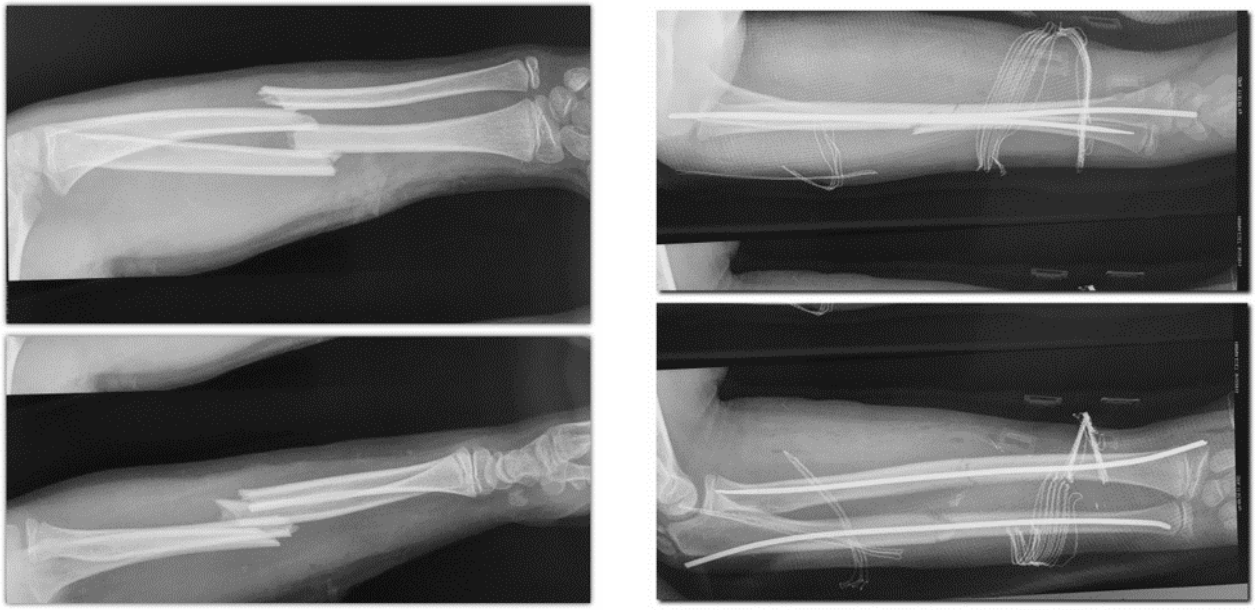
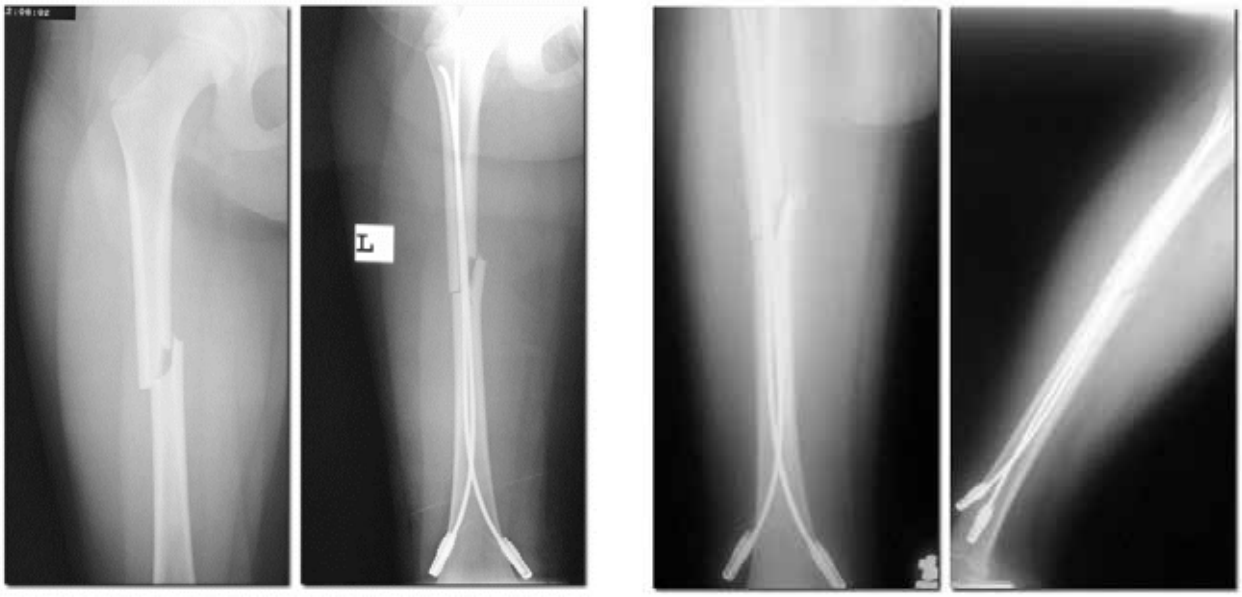


Picture 8,9. *Forearm fracture before and after ESIN placement*



Picture 10. *Femoral midshaft fracture, before and after ESIN placement (left).*
Picture11. *Radiographic healing signs (right).*

to both conservative management[24] and more invasive techniques[25] for long bone fractures in children. Apart from the lower refracture rate, fewer infections and better cosmetic result, another issue to consider is the psychosocial cost to the patient and family due to prolonged immobilization with casting[16] as well as the economic cost of an urgent referral to a tertiary care center. In our country the management of these injuries is mostly performed in specialized paediatric hospitals. The main reason is the lack of experience in managing these injuries due to the lower volume of patients in rural areas with less dense populations.

The results of this paper reflect our experience after ten years of using elastic intramedullary nails to treat long bone fractures in children and adoles-

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cents. The postoperative follow up findings and the number of complications were consistent with those already published by other authors[21]. Although we accept the limitations in respect to the total number of cases, multiple fracture sites and lack of a comparison group, the data of this series has shown no significant deviation from the average in terms of functional outcome, complication rate and hospital stay compared with larger institutions in Greece[26, 27] and abroad[1, 6, 21].

All but one of the surgeons had no previous experience in elastic nailing for paediatric fracture management. Although our results were generally excellent we can make a few remarks in regard to future application of the technique from general orthopaedic surgeons in community hospital settings. We found that fractures of the forearm were the most technically challenging. The lack of major complications in this series is attributed to the low threshold for open reduction. After three unsuccessful attempts, open assisted reduction was performed, bearing in mind radiation exposure and the possibility of damage to the soft tissues following the "3 pass rule" as described by other authors[28]. This resulted in an anatomic or near anatomic reduction and very good function **(figures 8, 9)**. In radial head fractures repeated manipulations should be avoided; assisting the reduction with the use of a blunt K-wire is an additional way to achieve a better outcome. It is common for the radial head to reduce spontaneously with the introduction of the elastic nail without the need to rotate it along its axis. A greater number of complications were seen in femoral fractures with skin irritation being the most common. These are larger bones surrounded by bulkier muscles, which require two larger, less flexible nails (4mm) **(figures 10, 11)**. Preoperative planning, proper nail selection and accurate pre-bending were crucial in achieving greater distance between the nails at the level of the fracture reducing it by offering trifocal buttressing. In adolescents the use of a traction table facilitates reduction under fluoroscopy. There was one case of leg length discrepancy that was subsequently treated by distal femoral epiphysiodesis and two cases of delayed union of distal third femoral fractures in overweight adolescents due to instability of fixation despite larger nail size. The latter can be attributed to the inadequate purchase of the nail in the distal fragment. In retrospect we believe that the nails in the distal third femoral fractures should have been introduced in an antegrade manor in order to achieve more nail length distal to the fracture. This was due to the initial lack of experience with this type of injury. Despite that, they had an excellent outcome since these were older children that were able to comply with weight bearing restrictions.

The general orthopaedic surgeon managing diaphyseal fractures in children has to follow and respect the basic principles of the technique and progress steadily through the expected learning curve[18] since most complications are related to the incorrect application of the method[22]. Provided the above conditions are met, elastic intramedullary nailing can be successfully used to address childhood trauma in community hospital settings.

Declarations

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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