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Original Article

Complications of Elastic Stable Intramedullary Nailing for treating paediatric long bone fractures

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ABSTRACT

This study reports the complications observed in children with long bone fractures treated using Elastic Stable Intramedullary Nailing (ESIN). One hundred and sixty-four ($n = 164$) fractures in 160 patients under the age of 16 years formed the basis of our review. This included 108 boys and 52 girls with the median age of 11 years and median follow up of 7.5 months. The analysis included fractures of the radius/ulna, humerus, femur and tibia. All pathological fractures were excluded. In this series 54 patients (34%) had complications however majority of these were minor complications with irritation due to prominent nail ends being the commonest complication. No long-term sequelae were encountered in our patients.

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1. Introduction

Various methods are used to treat paediatric long bone fractures and these include traction,¹ splints/orthosis, plaster casts,² external fixation,³ open reduction and internal fixation using plates and screws⁴ or intramedullary stabilisation with a rod.⁵ These modalities are not without complications.^{6–8} In addition some require prolonged hospital stay, periods of inactivity and aesthetically unsatisfactory scars.

Following reports by Sicilia et al in 1977⁹ and subsequently by the group from Nancy¹⁰ in the 1980's the method of Elastic Stable Intramedullary Nailing (ESIN) has gained popularity and is now a well recognised method for treating paediatric long bone fractures. The reasons for acceptance of this technique include; surgery is minimally invasive, no absolute indication for postoperative immobilisation using casts, shorter hospital

stay, early recovery of joint motion and return to physical activity.^{11,12}

In addition the complication rates have been reported to be minimal.¹³ A review of the English literature has revealed that most of the reports regarding complications associated with this method relate to its use for treating femoral and tibial fractures.^{14–16}

The purpose of the study is to report the complications associated with the use of ESIN for treating fractures of the femur, tibia, humerus and radius/ulna in children.

2. Patients and methods

The medical records of all children less than 16 years old presenting to our institution between January 2001 and

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December 2007 with fractures of the humerus, radius/ulna, femur and tibia requiring treatment using ESIN were identified from the hospital admissions database and included in the study. Patients with fractures of the radial neck, supracondylar humeral fractures and pathological fractures were excluded. In addition patients who did not complete their follow up care at our hospital were also excluded.

The orthopaedic team reviewed all the patients on admission. The details of the surgical procedure were explained to the patients and their parents and informed consent obtained. Surgery was carried out under general anaesthesia and performed in a similar fashion by the surgeons who were either consultants or paediatric orthopaedic fellows. The technique used was as described in previous reports.¹³ We used titanium elastic nails (Depuy, Warsaw, Indiana) for all patients. In cases of failed closed reduction, open reduction of the fracture was undertaken utilising a short skin incision over the fracture site. All the patients were followed up till the nails were removed after fracture union. Union was defined as the identification of bridging callus at 3 cortices on anteroposterior and lateral radiographs.

Delayed union is defined as slower than normal progression to union and thus a failure to demonstrate complete union on X-rays taken after a specified time period following the fracture. This would be 15 weeks for the humerus and 12 weeks for the radius/ulna.^{17,18}

Clinical data collected from the medical records included age of the patients, gender, mechanism of injury, type of fractures and associated injuries. Other information collected included joint range of motion, angular and rotational malalignment of the limb, time to nail removal, intra- and post-operative complications.

Anteroposterior and lateral radiographs were carried out at regular intervals and analysed for change in alignment of the bone segments, fracture shortening, change in nail position and length of nail extruding outside the bone.

The mechanism of injury was classified as follows:

1. Simple fall – fall from standing height
2. Fall from a height greater than standing
3. Sports related injury
4. Road traffic accident (RTA).

Open fractures were classified according to the Gustilo and Anderson classification.¹⁹

Using Moroz's classification²⁰ the complications were further subdivided into those that settled and did not require unplanned surgery, and those requiring a further hospital admission and an unplanned surgical procedure.

Statistical analysis was undertaken using SPSS version 14.0 (SPSS, Chicago, Illinois). The Students *t* and Chi-Square Tests were used to analyse the variables that predisposed to nail irritation. The Chi-Square Test was also used to analyse the effect of patient age on complications.

3. Results

Over the seven-year period 200 fractures in 188 children were treated by ESIN. One Hundred and sixty-four ($n = 164$)

fractures in 160 patients were the focus of this study. One hundred and eight (108) patients were boys and 52 girls. The median age of the patients at the time of surgery was 11 years (range, 4–16 years).

The commonest mode of injury was a simple fall and this was observed in 68 patients (42%) (Fig. 1). Over a quarter of the patients whose fractures were caused by sports injuries were related to the use of trampolines. Twenty-one (21) patients had fractures that were caused by road traffic accidents and 11 (52%) of them had associated injuries that were significant – a second fracture in 4, head injury in 8, pulmonary contusion/pneumothorax in 2 and intra-abdominal injury in 1. Eight fractures (5%) were open, six were Gustilo type 1 and two were type 2.

Eighty percent of the patients were operated on within 24 h of the injury. In the remaining 20% surgery was delayed by a mean of 2.8 days. This was due to reasons such as failure of non-operative treatment, medical problems and other injuries.

The length of hospital stay following surgery varied between 2 and 3 days for humeral and forearm fractures and 4–6 days for femoral and tibial fractures.

In this series 54 patients (34%) had complications. The number of complications for each anatomical segment is depicted in Fig. 2. Forty ($n = 40$) out of the 54 patients had a complication that did not require unplanned surgery while 14 had a complication that required additional unplanned surgery. None of the patients has been left with long-term problems.

The type and distribution of complications by bone segment is depicted in Figs. 3–6. Prominent nail ends causing pain and other symptoms was the commonest complication in our series – 30 patients (19%). We examined the following factors – length of nail extruding outside the bone, type of nail tip (ball or cut end), degree of the bend to the end of the nail and the use of nail caps to ascertain the risk of developing problems due to prominent nails.

The extruding nail length was measured on both anteroposterior and lateral radiographs that were to scale.

There was no statistical significant difference (p value = 0.08, Chi-Square Test) between nails with ball tips or those with cut ends causing symptoms. Though we did not use many end caps none of the 13 fractures treated with end caps developed symptoms from prominent nail ends.

Statistically the variable that predisposed to symptoms associated with prominent nail ends was the length of the nail extruding outside the bone.

Fig. 1 – Mechanism of injury.

Fig. 2 – Number of complications related to the number of fractures per anatomical segment.

The mean length of extruding nail was 2.2 cm (SD 0.5) for those who developed nail irritation compared to 1.4 cm (SD 0.3) for those who did not develop irritation ($p < 0.05$, Students T Test). The risk of nail irritation in all fractures was significant if the extruding nail length was greater than 2 cm (3.5% if < 2 cm, vs 56% if > 2 cm).

The effect of patient age on complications was assessed for all fractures by dividing the patients into two groups; those whose age was less than 10 years and those greater than 10 years. There was a significant difference in the issues relating to bone healing (non-union, delayed union) with the older age group having more complications than the younger age group ($p = 0.003$, Chi-Square Test). There was however no significant difference in the other complications between the two groups.

3.1. Femoral fractures

Forty-seven (47) femoral fractures were treated by ESIN in our institution over the study period. The median age of the patients was 9 years (range, 4–14 years). A quarter (25%) of all the femoral fractures were caused by road traffic accidents. All the fractures were closed and treated by retrograde nailing. None of our patients were very heavy.

Complications were observed in 13 patients (27%) with femoral fractures (Fig. 5) and like the humerus and radius/ulna

Fig. 4 – Complications in radius/ulna fractures.

the commonest complication was due to prominent nail ends causing symptoms. This was observed in 7 of the 13 patients.

In 3 of the 7 patients with symptoms due to prominent nail ends surgery was required to trim the nail ends to alleviate their symptoms. This was because the respective fractures had not healed sufficiently to remove the nails. In the remaining 4 patients their symptoms settled once the nails were removed after fracture union.

Loss of fracture alignment occurred in 6 patients who all had spiral fractures of the diaphysis. Two (2) of the 6 required further unplanned surgery as the limb alignment was not acceptable (greater than 10° in the coronal and sagittal planes). These patients were 13.2 and 14 years old respectively. The younger patient required revision nailing while the older one underwent treatment using an external fixator and osteotomy as the fracture had almost united.

A review of the radiographs of the 2 patients who required further surgery showed the nails had unequal curves. We believe this in addition to the unstable fracture pattern permitted translation at the fracture site and resulted in rotational mal-alignment.

In the remaining 4 patients (median age – 7 years) further surgery was not required as the loss of fracture alignment did not worsen over time and the limb alignment was acceptable at the final follow up.

Fig. 3 – Complications in humerus fractures.

Fig. 5 – Complications in femur fractures.

Fig. 6 – Complications in tibia fractures.

Five patients had a limb length discrepancy (LLD) with the affected side being short. The median LLD assessed using CT scanogram was 1.7 cm (range, 1–2.4 cm) and none of the patients have required further surgery to equalise leg length. Only one of these five patients had a LLD > 2 cm.

The median time to radiological union was 12 weeks (range, 10–15 weeks) and the nails were removed at a median time of 6 months (range, 5–16 months).

3.2. Tibial fractures

Eleven ($n = 11$) tibial fractures were treated by ESIN in our institution over the study period. The median age of the patients was 12 years (range, 9–14 years). Seven fractures were diaphyseal, 2 involved the proximal metaphysis and the remaining 2 the distal metaphysis.

Road traffic accidents were responsible for 5 fractures (45%). Two of the five fractures were open (Gustilo type 2).

Complications were observed in 5 patients (45%) (Fig. 6) and the 4 complications discussed below occurred in patients with fractures caused by RTA's.

Loss of fracture alignment, the most common complication was noted in 2 patients at 2 weeks following ESIN. Both patients had closed diaphyseal oblique fractures. The first a 13-year-old required closed manipulation of the tibia under anaesthesia and immobilisation in a plaster cast, while the second (14-year-old) required immobilisation in a wedged plaster cast.

A hypertrophic non-union occurred in a 14-year-old patient with an open mid diaphyseal fracture. Union was achieved by removing the nails and stabilising the fracture non-union with a circular external fixator. In addition the fibular was osteotomised.

A closed distal metaphyseal fracture in an 11-year-old mal-united in 10° valgus and 30° external rotation. The mal-union was corrected by undertaking an osteotomy. This was stabilised with a compression plate and screws.

Unlike other anatomical segments, prominent nail ends was not a common complication. Only 1 patient had this complication in this group.

All the complications were in children at the upper end of the age range with a median age of 13 years. The median time to nail removal was 4.5 months (range, 4–10 months).

3.3. Humeral fractures

Ten (59%) of the 17 humeral fractures in this study were diaphyseal; the remaining 7 involved the proximal metaphyseal region. The median age of the patients was 14 years (range, 11–16 years).

All the fractures were closed and the majority were the result of a sports related injury. Six ($n = 6$) patients (35%) with humeral fractures had complications (Fig. 3).

Prominent nail ends causing pain and limitation to elbow joint range of movement was the commonest complication and observed in 5 out of the 6 patients with complications.

Two of the five patients required early unplanned surgery. The offending nails were removed in one patient as the overlying skin had broken down and in the other the nail ends were trimmed, as the respective fracture had not united sufficiently to remove the nails. In the 3 remaining patients with prominent nail ends unplanned surgery was not required as their symptoms settled.

The only other complication observed was a delayed union in a 15-year-old female with a closed diaphyseal fracture following a RTA. The fracture subsequently united at 12 months following the injury without the need for surgical intervention or other treatment.

There was no statistical difference in complication rates between fractures of the diaphyseal and proximal metaphyseal region.

Excluding the patient with the delayed union the median time to radiological fracture union was 8 weeks (range, 6–11 weeks) and the median time to nail removal was 4 months (range, 2–7 months).

3.4. Radius and ulna fractures

In this series 89 forearm fractures were treated by ESIN. The median age of the patients was 12 years (range, 8–15 years). Seventy-nine ($n = 79$) of the fractures involved the diaphysis of both bones, while 6 involved only the ulna and 4 the radius. Sixty-four of all forearm fractures (72%) were the result of a simple fall and 6 of them were open (Gustilo Type 1).

Open reduction of the fractures was required in 25 cases (28%) and in 75% of those requiring open reduction both the radius and ulna were exposed. Patient age, mechanism of injury and fracture pattern had no correlation with the need for open reduction.

Complications occurred in 30 patients (34%) (Fig. 4). The commonest complication, prominent nail ends causing symptoms was observed in 17 of the 30 patients. In the majority of cases this was noted with the radial and not the ulnar nail. However the only case requiring early unplanned surgery for this complication was because of breakdown of the skin over the ulnar nail. We believe this arose because the patient kept resting his arm on a hard surface. In the remaining 16 patients with prominent nail ends their symptoms settled following removal of the nails after fracture union.

Nerve palsies occurred in 4 patients with closed radius/ulna fractures (2 ulnar, 1 superficial radial and 1 posterior interosseous nerve). None of the nerve palsies were iatrogenic and no patient required unplanned surgery. In all the

4 patients full recovery of nerve function occurred within 6 months of the injury.

Soft tissue infection occurred in 3 patients with closed fractures. The respective infections settled with a course of oral antibiotics. There was no case of osteomyelitis.

Ulna non-union was observed in 2 adolescent patients (aged 11 and 14 years respectively) who had closed radius/ulna fractures caused by a simple fall. In both patients the radial fractures had united. Further surgery was required in these patients and involved removal of the nails, iliac crest bone grafting and stabilisation of the non-union site with a compression plate and screws.

A 9-year-old boy fell four weeks after ESIN for fractures of the radius and ulna. This subsequent injury resulted in re-fractures with a severe deformity of the forearm as the nails used to treat the initial fracture had bent by approximately 60°. Under general anaesthesia the deformed forearm was gently manipulated (with the nails in situ) to correct the deformity. An above elbow plaster cast was then applied to immobilise the forearm. The final outcome was good.

Excluding the cases of non-unions the median time to radiological union was 7 weeks (range, 6–11 weeks) and the nails were removed at a median time of 6 months (range, 4–7 months).

4. Discussion

Since flexible intramedullary nailing gained popularity as an effective method for treating long bone fractures in children a number of authors have discussed the ease of use and reported outcomes^{21–23} but fewer have discussed the complications.^{16,24} This review was carried out to analyse and report the complications we observed with the use of ESIN for treating paediatric long bone fractures over a 7-year period.

In this series the overall rate of complication was 34%. The majority of complications (74%) were minor and did not require additional unplanned surgery. In addition no patient was left with any complication or disability at the final review.

The commonest complication was prominent nail ends causing pain due to skin irritation. In some cases temporary limitation to movement of the adjacent joint and skin break down was noted. This complication was observed in 30 patients (19%).

For the ease of analysis further discussion is carried out under the respective anatomical segments.

4.1. Femoral fractures

The reported complications following the treatment of femoral fractures using ESIN include symptoms due to prominent nails, soft tissue infection, osteomyelitis, loss of fracture alignment, mal-union, delayed union, non-union, compartment syndrome and fractures.^{13,14,16,21,24,25} In this study 13 of the 47 femoral fractures (28%) treated by ESIN had a complication. This compares favourably with the reported complication rates of 12–62%.^{14,16,21,24}

Prominent nail ends causing symptoms was the most common complication in our series with an incidence of 15%. The reported incidence ranges from 7 to 48%.^{14,16,21,24} The

following factors have been suggested to predispose to complications associated with prominent nail ends¹³:

- Knee movement commencing very soon after surgery
- Distal nail migration as unstable fractures shorten or angulate
- Long extruded nail lengths
- Acute angles to the distal end of the nails
- Cut nail ends (jagged)
- Nails inserted to close to the distal femoral physis

In this series the only variable that was directly related to patients developing symptoms due to prominent nails was an extruding nail length > 2 cm and as such we recommend that the extruding nail length is kept to < 2 cm.

However the following may also help reduce symptoms due to prominent nail ends^{13,25}:

- Nails not inserted to close to the distal femoral physis
- Distal nail ends are not bent acutely
- The nail ends are cut smoothly. There are currently nail cutters that facilitate this
- Allowance is made for impaction of the nail end
- A protective nail cup is used
- The combined diameter of the nails make up 80% of the canal diameter

The treatment options for prominent nail ends causing symptoms include conservative measures or surgery to trim the nail end or remove it. The option chosen will depend on the severity of pain, the integrity of the overlying skin and the extent of fracture healing. In the event of skin break down we recommend a surgical option (trim or remove) to prevent infection/osteomyelitis developing. Sink et al¹⁴ reported that 6 patients (15%) in their series underwent surgery to shorten or remove prominent or exposed nails around the knee. It was not clear from their report how many nails were trimmed or removed. Lascombes et al¹³ reported that 4% of their patients with femoral fractures require trimming of prominent nail ends. In our series 3 patients (6%) required surgery to trim prominent nail ends as the respective fractures had not healed sufficiently to remove the nails. The overlying skin had not broken down in any of these patients.

Loss of fracture alignment was the only other complication observed in our femoral fracture group. In the literature this complication has been recognised in larger patients, patients with unstable fracture patterns, inappropriate nail size/curve and patients who had no postoperative immobilisation (hip spica or HKAFO).^{14,16,24} The reported use of post-operative immobilisation (hip spica HKAFO) after ESIN for femoral fractures ranges from 0 to 52%.^{21,24,26} In our series the complication of loss of fracture alignment was observed in 6 patients (13%). Though none of the 6 patients were very heavy they all had unstable fracture patterns (long spiral fractures) and none had any postoperative immobilisation (hip spica or HKAFO).

In addition we observed that the 2 patients of the 6 who required additional unplanned surgery to correct the fracture mal-alignment were older children and had nails with unequal curves. We believe that is complication and the

unplanned surgery may have been avoided if we had used nails with equal curves and had instituted some form of immobilisation in the early postoperative phase.

We did not observe any of the other reported complications such as soft tissue infection, osteomyelitis mal-union, delayed union, non-union, compartment syndrome or fractures in our series of femoral fractures treated by ESIN.

4.2. Tibia fractures

Elastic nails are used to treat unstable tibial shaft fractures in children with ages ranging from 4 to 16 years and the overall reported complication rate varies from 26 to 66%.^{15,27–30}

Our complication rate was 45%. This high rate may in part be attributed to the small number of tibial fractures ($n = 11$) treated in our institution over the study period.

The reported complications include loss of fracture alignment, mal-union, delayed union, non-union, infection, neurovascular injury, prominent nails causing symptoms, premature physeal closure and leg length discrepancy.^{15,27–30}

Loss of fracture alignment requiring further treatment was observed in 2 patients (18%) in our series. Both patients had closed oblique fractures of the diaphysis. The first was treated by close reduction and cast immobilisation while the second required wedging of the plaster cast. Vallamshetla et al²⁹ reported this complication in 2 patients (4%), one with a proximal oblique fracture and the other with a long oblique one at one week following ESIN. In both patients revision surgery was undertaken and the respective fractures were stabilised with a plate and screws. Sankar et al²⁸ also noted this complication in 2 patients (10%). The first had an open transverse mid shaft fracture and the second a closed long oblique diaphyseal fracture. In both patients the loss of alignment was treated by repeat closed reduction under general anaesthesia. We believe this complication if recognised early can be treated satisfactorily by applying a wedged plaster cast or alternatively by closed reduction and cast immobilisation.

Studies on ESIN for tibia fractures have revealed varying rates of mal-union of 0–11%.^{15,27–30} Sankar et al²⁸ reported no cases of mal-union. This they believed was because their patients were immobilised in a long leg cast for 6 weeks thus enabling the maintenance of fracture reduction hence preventing mal-union. Goodwin et al²⁷ stated that their most common complication following ESIN for tibia fractures was mal-union with a rate of 11%. Our mal-union rate was 9% (1 patient). Reviewing the literature on mal-unions following ESIN for tibial fractures it is not clear what factors predispose to this complication. Lascombe¹³ has suggested that the triangular cross-section of the tibia compared to the other long bones makes it difficult to obtain and maintain a perfect fracture reduction with ESIN. He advocates attention to operative detail and supplementary immobilisation of the limb in a plaster cast for 3 weeks.

Non-union though uncommon has a reported incidence of 0–8%.^{15,28–31} O'Brien et al³¹ reported no cases of non-union in their study of tibial fractures treated by ESIN, but it should be noted that most of their patients had closed fractures. Srivastava et al³⁰ reported 2 patients (8%) with non-unions. Both had open fractures, the result of road traffic accidents. This is in keeping with our finding. The only patient in our series with a non-union had an open fracture following a RTA.

Prominent nail ends causing symptoms is not as common as has been reported following femoral fractures. Though Sankar et al²⁸ reported an incidence of 26% most authors report no or a low incidence of this complication.^{15,29,30} Only 1 patient in our series has this complication and did not require unplanned surgery.

We had no cases of soft tissue infection/osteomyelitis. The reported incidence of this complication varies between 0 and 8% and a number of authors have stated that the risk is high with open fractures.^{15,27,29,30}

4.3. Humeral fractures

The only complications observed in our series of humeral fractures were delayed union and symptoms due to prominent nails. Five of the 17 patients (30%) with humeral fractures had symptoms due to prominent nails. Rajan et al³² reported this complication in 3 out of their 14 patients with humeral fractures treated by ESIN. The subcutaneous nature of the lateral edge of the distal humerus (the entry point for the nails) makes this complication inevitable. We however believe that it can be avoided by applying most of the suggestions described in the section on femoral fractures.

We did not observe any case of radial nerve injury though this complication has been reported in the literature.^{32,33} It has been suggested that radial nerve injuries occur when the ends of the nails transgress the soft tissues at the fracture site (diaphyseal fractures) during nailing.¹³ We suggest that care is taken not to repeatedly violate the soft tissues with the nail ends during surgery.

4.4. Radius/ulna fractures

Symptoms due to prominent nails, nerve injury, non-union, soft tissue infection, delayed union, loss of fracture alignment and re-fracture with the nails in situ were the complications observed in our series of radius/ulna fractures treated by ESIN.

The commonest complication (19%) by far was due to prominent nail ends and this complication was observed in children at the younger end of the age spectrum with a median age of 10 years. Lascombes et al¹¹ have reported an incidence of 8%. In addition to keeping the extruded nail length short, preferably 2 cm or less the suggestions made in respect of femoral fractures may also help reduce the complications due to prominent nails.

Nerve injuries have been reported following the treatment of forearm and humeral fractures using ESIN.^{13,32} All 4 nerve palsies observed in our series were transient and involved fractures of both forearm bones. The mechanism of injury was a simple fall in all 4 cases. We advocate that nerve injuries are observed for up to 6 months as most of them recover without the need for surgical exploration.

Non-unions though uncommon have been reported following the treatment of ulna fractures using ESIN.^{34,35} We observed Ulna non-unions in 2 patients who had closed fractures of the radius/ulna treated by closed reduction and ESIN. Both patients required further unplanned surgery with a good outcome. Ogonda et al³⁴ have suggested that ulna non-unions can be caused by fracture distraction as the ulna nail is impacted. This we believe was the case in our patients and

suggest that the ulna fracture site is screened under x-ray while impacting the ulna nail to make sure the fracture is not distracted thus preventing this complication.

Ulna fractures treated by ESIN may progress to delayed union.^{35,36} This has been observed in the older child with open fractures or fractures requiring open reduction.³⁶ Though we had a much higher rate of open reduction (28%) compared to 12% reported by Lascombes et al,¹¹ we only observed one case of delayed union - a 14-year-old with a closed fracture of the radius/ulna treated by open reduction and ESIN. This subsequently united without the need for surgical intervention at 8 months after the injury.

Re-fractures may occur after nail removal^{11,36} hence Lascombes et al¹¹ have advocated that forearm nails are not removed earlier than 6 months post injury to avoid this complication. We did not observe this complication in our series though some nails were removed before the 6-month mark. We however advocate that forearm nails are not removed before 6 months from injury.

Soft tissue infection around prominent nail ends is encountered³⁶⁻³⁸ but generally settles after hardware removal; however osteomyelitis and septic arthritis are uncommon.¹³ In this series we had 3 cases of soft tissue infection following the treatment of forearm fractures. There were no cases of osteomyelitis or septic arthritis.

5. Conclusion

Though this report suggests we had a reasonable number of complications using the technique of ESIN for treating long bone fractures in children the majority were minor and could be avoided. It is a well-established technique that is safe, minimally invasive, does not interfere with growth, and is associated with short hospital stays and a rapid return to daily activity. We believe that understanding the principles of this technique is paramount to achieving good results.

Conflicts of interest

All authors have none to declare.

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