We identified 25 children (10 girls and 15 boys) who had been treated with single bone intramedullary fixation for diaphyseal fractures of both forearm bones. Their mean age was 10.75 years (4.6 to 15.9). All had a good functional outcome. We conclude that in selected children, single bone intramedullary nailing is a suitable method of treatment for diaphyseal fractures of both bones of the forearm.

The most common fractures in children seen in the Accident and Emergency department involve the arm. Distal (epiphyseal and metaphyseal) radial fractures are the most common followed by supracondylar humeral fractures. Diaphyseal fractures of the forearm account for approximately 13% of all paediatric fractures.1,2 The majority are minimally displaced or incomplete and suitable for conservative management, with or without manipulation. A small proportion (3% to 4%) are unstable and require operative intervention. Previous authors have suggested that treatment with intramedullary fixation including elastic stable intramedullary nail (ESIN) fixation is satisfactory.3-7 A number have reported the results of single bone plate fixation suggesting that it is not always necessary to plate both bones.8-10 Our aim was to determine whether the principle of single forearm bone plate fixation could be applied to intramedullary fixation.

Patients and Methods
ESIN (using C-nail, McKinnon Medical, Doddington, UK) is preferred to plate fixation in our unit for the small proportion of diaphyseal forearm fractures in children who require operative treatment (Fig. 1). We reviewed the notes and radiographs of all children who underwent ESIN of the forearm between September 1996 and April 2001. In total, 55 patients were identified who had completed treatment for fractures of the radius and ulna with ESIN fixation (including implant removal). In 25 patients both bones were fixed with an ESIN. In this group there were 21 boys and four girls with a mean age of 10.7 years (5.4 to 15.2). The left arm was involved in 14 and the right arm in 11. A further 25 patients were managed by single bone fixation. In this group there were 15 boys and ten girls with a mean age of 10.75 years (4.6 to 15.9). The left arm was involved in 16 and the right arm in nine.

Five patients with radial neck or Monteggia/Galeazzi variants were also managed by single bone fixation.

The pattern and distribution of the fractures is shown in Table I. All patients underwent an initial attempt at closed reduction. In the single bone fixation group there were 21 patients in whom it was not possible to achieve a stable reduction and they underwent fixation under the same anaesthetic. In four patients the initial reduction appeared stable but radiological review in a plaster cast after seven days revealed loss of reduction. These patients underwent fixation within the subsequent 72 hours and in each the radial fracture was fixed. In the group in which both bones were fixed there was only one patient who underwent an initial manipulation in whom the position was subsequently lost. He underwent fixation a week later.

All operations were carried out under general anaesthesia, with a standard distal approach to the radius or a proximal approach to the ulna as described by Lascombes et al.3 In some patients closed nailing was not possible and a limited open approach was used. The block to successful closed reduction was removed and the nail passed in the normal manner. The bone with the greater deformity was nailed first. At this stage the forearm was screened using fluoroscopy through a full range of pronation and supination. In patients with no loss of reduction during this manoeuvre the fixation was defined as stable and
the other fracture was not fixed. In arms, where on rotation the fracture displaced or underwent rotation, the other fracture was fixed. Post-operatively the arm was rested in a below-elbow cast, as we have found this more acceptable to the patient than leaving the arm free. Patients were informed at the time of surgery that they would need to attend hospital for a day for removal of the implant under general anaesthesia when the fractures were united.

**Results**

The patients who underwent single bone fixation can be divided into two groups depending on whether the radius or ulna was fixed. In 18 only the radius was fixed and in seven the ulna. In the radial group one patient had an oblique fracture of both bones, two had an oblique fracture of the radius and one of the ulna. In the ulnar group all the fractures were transverse. Closed reduction was achieved in 14 fractures (five of seven of the ulnar group and nine of 18 of the radial group). In those forearms where an open reduction was required a short longitudinal incision was made directly over the fracture site (in all but one the reason for opening the fracture site was recorded as soft tissue interposition, the other was a fracture fragment obstructing the medullary canal). In the both bone fixation group it was possible to achieve closed reduction in 20 of the 25 fractures.

There were 16 patients in whom it was necessary to open the fracture site. In nine where the radius alone was fixed satisfactory reduction was achieved after exploration of the fracture. Three of these patients had undergone initial closed manipulation with loss of reduction (one had persistent angulation at the fracture site on follow-up). In one of these nine patients the indication for exploration of the fracture site was debridement of an open fracture. In the two patients with fixation of the ulna only who required open reduction no complications or loss of movement were encountered. In the five patients with fixation of both bones who required open reduction, two had both bones explored, one had only the ulna explored with no further complications, and two had only the radius explored one of whom lacked 30° of supination at final follow-up.

The last outpatient follow-up visit was at a mean of nine months (6 to 20) after injury for the single bone fixation group by which time the nail had been removed. At this stage 20 of the 25 patients had a full range of movement of the wrist and elbow and a normal arc of pronation and supination. Five patients had a reduction of pronation and supination; two with 10° loss of supination, one with 15°

### Table I

Fracture level with reference to type of fixation, for diaphyseal fractures of both bones of the forearm. The level of the fracture relates to the third of the diaphysis involved

<table>
<thead>
<tr>
<th>Ulnar level</th>
<th>Radius only fixed</th>
<th>Ulna only fixed</th>
<th>Both bones fixed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Proximal</td>
<td>Middle</td>
<td>Distal</td>
</tr>
<tr>
<td>Proximal</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Middle</td>
<td>2*</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>Distal</td>
<td>0</td>
<td>2</td>
<td>3†</td>
</tr>
</tbody>
</table>

* one ulnar greenstick fracture
† two ulnar greenstick fractures
loss of supination, one with 5° loss of pronation and one with a loss of 15° of pronation and supination. The loss of movement was not related to the time to surgery, open or closed nailing, age of patient, or level of fracture. Loss of movement was recorded in four patients in the group where only the radius was fixed compared with one in the group where only the ulna was fixed.

At the last follow-up of those who had both bones fixed, a mean 10.5 months after injury (5 to 22), three patients lacked 5° of supination, one lacked 20° of supination, one lacked 15° of pronation and one lacked 20° of pronation and 20° supination. The loss of movement was not related to the time of surgery, open or closed nailing, age of patient or level of fracture.

Following fixation there was no deep infection, compartment syndrome, non-union or re-fracture. Removal of the nail failed in one ulnar nail, where the exposed end of nail broke, and in one radial nail due to bony overgrowth. Fail-
ure of extraction did not appear related to the interval between nailing and implant removal. One radial nail extraction was complicated by a superficial wound infection which resolved with oral antibiotics.

The patients (or their parents) were contacted by telephone and asked whether they still had pain, weakness, paraesthesiae in the distribution of the superficial radial nerve, limitation of movement or impaired function. The mean time of this follow-up was 2.75 years (0.58 to 5.08). We were unable to contact one patient in the radial group, but review of his notes did not demonstrate any significant problems at the time of discharge. None of the patients had pain in the forearm or numbness in the distribution of the superficial radial nerve following surgery. One in the ulnar group had some loss of movement, principally a reduction of pronation and supination, but did not feel that this limited function. Another in the ulnar group had some aching and weakness after writing, but no other limitation of activity.

Discussion

Most forearm and wrist fractures in children can be managed satisfactorily in a cast, with or without manipulation.11-13 There are however, a number of indications for operative management of fractures of both bones of the forearm. Those include open fractures, irreducible fractures, unstable fractures, pathological fractures, neurovascular compromise, and malunited fractures.14-17 A number of authors have discussed the outcome of managing diaphyseal fractures of both forearm bones by single bone fixation. Flynn and Waters9 reported 17 patients treated with single bone fixation using a plate or an intramedullary nail with excellent results. Bhaskar and Roberts8 reported 20 children who had plating of both bones and 12 who had plating of only the ulna. They did not observe any difference in functional outcome, rotational movements or residual angulation and concluded that if reduction and fixation of the ulnar fracture alone restores acceptable alignment of the radius in patients with unstable fractures of the forearm, operation on the radius can be avoided. Kirkos et al16 reported excellent results in 50 children with a mean age of 11 years who had unstable diaphyseal fractures of both bones of the forearm treated by plate fixation of the radius alone. There are reports of single bone fixation among series describing forearm nailing, but no previous studies which specifically deal with single bone fixation using ESIN.

It has been suggested that immobilisation in a cast is not necessary when both of the forearm are fixed.12 The need for immobilisation following single bone fixation is, therefore, a theoretical disadvantage. There was, however, no morbidity from immobilisation when either one or both bones was fixed. The use of a cast offers more support to the injured arm and reduces the risk of further injury before union of the fracture occurs.

We conclude that fixation of both bones using an ESIN is not always necessary for children with unstable diaphyseal fractures of both bones of the forearm. It is possible to manage selected patients satisfactorily with single bone fixation followed by cast immobilisation. We suggest that after the bone with the greater initial displacement has been fixed, stability is checked clinically and radiologically through the full range of pronation and supination. In those forearms where both bones are well aligned and stable a cast is applied without fixation of the other bone. Our findings suggest that either bone can be fixed so long as the criteria described above are met. The algorithm shown in Figure 2 is, therefore, proposed for the management of diaphyseal fractures of both bones of the forearm in children.

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

References