THE TREATMENT OF INFECTED AND UNINFECTED NON-UNION

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One hundred and sixteen patients with 129 ununited fractures were treated either by rigid internal fixation and bone grafting or, in 14 tibial non-unions, by posterolateral bone grafting. In 37 actively infected cases this was combined with sequestrectomy and appropriate antibiotics. The final success rate was 98.4%. Technical errors or inadequate immobilisation after operation in patients with severe osteoporosis led to some early failures. No patient had a discharge or evidence of osteomyelitis after removal of metal.

Rigid internal fixation with or without bone grafting is the treatment of choice for established non-union with bone loss when true synovial pseudarthrosis is present, when malalignment or shortening needs correction, and when prolonged immobilisation is either difficult or would lead to unacceptable stiffness in adjacent joints. Active osteomyelitis is not a contra-indication to internal fixation.

Non-union of fractures presents a major challenge to the orthopaedic surgeon, especially when associated with large bone defects, old or active osteomyelitis, or previous operations. The definition of non-union is still controversial. Brighton et al. (1981) defined it as that condition of a fracture in which all demonstrable reparative processes had ceased and bony continuity had not been restored. The AO group (Müller et al. 1979) suggested that failure to unite nine months after injury should be defined as non-union. Bassett, Mitchell and Gaston (1982) agreed that the term non-union could be applied nine months after injury, while between four and nine months the term delayed union was appropriate.

However non-union is defined it needs treatment. At the same time malalignment or shortening may need to be corrected. If joint mobility and disuse atrophy can be improved by early movement, this also is clearly desirable.

The prospective study we describe was designed to evaluate the treatment of infected and uninfected non-unions using rigid internal fixation with bone grafting and early mobilisation or, in the tibia, posterolateral bone grafting.

MATERIALS AND METHODS

This series includes all patients presenting with demonstrable non-union to the senior author (RML) between June 1978 and January 1983. The diagnosis was made by the history, clinical signs and radiography. Only patients with established non-union for over eight months were included: in all cases examination revealed movement, pain on stressing, and local tenderness.

The patients were operated upon by one of the two authors and were reviewed at intervals by one or both of them. There were 116 patients (90 men and 26 women) with 129 non-unions. Their average age was 36.5 years, ranging from 13 to 90 years. The average duration of non-union before operation was 18.9 months, ranging from 8 months to 15 years. The follow-up after operation was from 6 months to 48 months (average 16 months).

Fifty-two fractures were in the upper limb, three were in the mandible and 74 in the lower limb (Table I). Eighty of the 129 fractures were originally closed; 49 were compound, 15 of which had severe bone and skin loss, and 14 had soft-tissue loss. Sixty-eight patients had undergone 138 major operations before referral. These

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Table I. Details of 129 non-unions treated in 116 patients

<table>
<thead>
<tr>
<th>Site</th>
<th>Number</th>
<th>Number failed</th>
<th>Per cent united</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mandible</td>
<td>3</td>
<td>—</td>
<td>100</td>
</tr>
<tr>
<td>Humerus</td>
<td>10</td>
<td>—</td>
<td>100</td>
</tr>
<tr>
<td>Radius</td>
<td>20</td>
<td>1</td>
<td>95</td>
</tr>
<tr>
<td>Ulna</td>
<td>19</td>
<td>2</td>
<td>89</td>
</tr>
<tr>
<td>Metacarpal</td>
<td>3</td>
<td>—</td>
<td>100</td>
</tr>
<tr>
<td>Femur</td>
<td>50</td>
<td>3</td>
<td>94</td>
</tr>
<tr>
<td>Tibia</td>
<td>22</td>
<td>3</td>
<td>86</td>
</tr>
<tr>
<td>Patella</td>
<td>2</td>
<td>—</td>
<td>100</td>
</tr>
<tr>
<td>TOTAL</td>
<td>129</td>
<td>9</td>
<td>93</td>
</tr>
</tbody>
</table>

Two patients, one with non-union of the ulna and the other with non-union of the tibia, refused a second operation; the other seven failures eventually united
had included intramedullary nailing in 35, plating in 34, bone grafting in 10, removal of metal in 8, and internal fixation with screws, wire or other methods in 51. Eighteen patients had become infected as a result of previous surgery. All patients had also been treated in plaster or traction for variable periods.

On presentation 37 fractures were actively infected and discharging, 27 had been infected but were dry when first seen and 65 had never been infected. The infecting organisms isolated from the 37 fractures presenting with active drainage were: *Staphylococcus aureus* in 15 (all resistant to penicillin), *Pseudomonas* in 12, *Staphylococcus epidermidis* in 10, a variety of Gram-positive organisms in 3 and Gram-negative organisms in 14. Several organisms were cultured from many of the patients.

One hundred and nine ununited fractures showed an atrophic form of failed union and 20 showed hypertrophic callus. Thirty-four patients had suffered other serious injuries, including 21 with other fractures, three with renal failure, three with nerve injury, one with arterial injury, two with previous head injuries, two with infected hip and knee joints on the same side, one with a tuberculous hip and previous fusion, and one with Volkmann's ischaemic contracture.

**Operative technique.** Fourteen tibial non-unions were treated by autogenous bone grafting through a posterolateral approach, two of these by a two-stage procedure. Sequestrectomy, removal of previous internal fixation and application of an external fixator were carried out first; 10 days later bone grafting, removal of the external fixator and application of a patellar-tendon-bearing cast were performed.

In all other cases a single-stage operation combined debridement, sequestrectomy (where this was needed), internal fixation and bone grafting. Dynamic compression plates (DCP) were used in 83 patients, medullary nails in 13, and blade plates in 15. Screws were used in two and wires in two. Grossly infected wounds were packed open and allowed to granulate. All other wounds were closed at the first operation.

All 109 atrophic non-unions and 10 of the 20 hypertrophic non-unions were grafted with autogenous corticocancellous bone at the time of internal fixation. **Antibiotics.** All clean cases were given intravenous cephalosporin prophylactically for 24 hours. Previously infected cases were given intravenous antibiotics until the results of all cultures were available, on average five days after operation. If cultures were then positive, the appropriate antibiotic was given intravenously for 10 to 14 days and then orally for four weeks. Patients with open discharging non-unions also were given appropriate antibiotics intravenously for 14 days and then by mouth for four weeks.

**RESULTS**

Clinical union was defined as that which allowed full, unprotected and painless weight-bearing on the leg, or full painless use of the arm. It was achieved in 120 out of 129 fractures (93%) after one operation and in 127 fractures (98.4%) after a second operation in 7 of the 9 failures. Radiographic union was more difficult to assess, especially in the presence of rigid internal fixation, but appearances corresponded with clinical union in all but one.

The type of injury affected the initial healing rate: 95% of originally closed fractures and 100% of compound fractures without tissue loss united, but only 80% of the most severe compound injuries with bone and skin loss healed primarily. Sepsis at presentation also affected the healing rate, 6 of 37 cases of actively infected fractures failing to unite after one operation. All 27 previously infected but dry fractures united, and 62 of 65 (95%) fractures which had never been infected. Of 33 patients who had lost from 1 cm to 14 cm of bone (average 4.4 cm), 32 (97%) healed after one operation. The one patient with bone loss who did not heal refused a further operation as he was comfortable in a short-leg orthosis (Figs 1 and 2).

The location of the non-union in the skeleton had little effect on final healing; although 3 of 22 tibiae failed to unite after the first operation, two united after a second procedure (one patient refused further treatment). Non-union healed better in the arm than in the leg after the first operation, but all who had a second procedure united.

There were only two failures, one in the ulna and one in the tibia; both patients had refused a second
operation. The type of non-union had little effect, the atrophic type healing in 92% and the hypertrophic type in 95% after one operation. Both patients who refused further surgery had atrophic non-union. Success was finally achieved in all 65 of the fractures which had never been infected, all 27 of those which had previously been infected, and 35 of 37 (95%) of those actively infected at the time of operation.

Excluding second operations on failures, which are discussed later, 33 other operations were performed, 30 for removal of metal, two for supplementary bone grafting (Figs 3 to 6) and one for replating a fracture through a screw hole.

The 27 fracture sites which had previously been infected, but which were dry at the time of operation, were all dry without evidence of osteomyelitis at follow-up at least 12 months (average 16.3 months) after operation. Of the 37 fractures which were actively infected at the time of operation, 16 with at least 12 months follow-up (average 15 months) were dry with metal in place. Twelve fracture sites continued to drain until all metal had been removed; all 12 (when followed up at least 12 months after removal of metal) were dry. The other 9 cases have not yet been followed up for 12 months, but none had drained after removal of metal. Nine out of 13 patients actively infected with *Staphylococcus aureus* required removal of metal before they became dry; in *Pseudomonas* infection 5 out of 9 required removal of metal. The time to bony healing of the uninfected cases (3.5 months) was not significantly different from those which were actively infected (4.0 months). The hospital stay was a little prolonged for the actively infected patients (15.3 days) compared with the uninfected and previously infected groups (both 11 days).

**Failures.** After the first operation, nine fractures failed to achieve union, six of which were actively infected at the time of operation, three with more than one organism. Three were infected with *Pseudomonas*, three with *Staphylococcus aureus*, two were infected with other Gram-positive organisms and one with a Gram-negative organism. Of the 12 patients who had *Pseudomonas* cultured from their wounds, three failed to unite. Of 15 with *Staphylococcus aureus* from wound culture, union failed to occur in three. *Pseudomonas* and *Staphylococcus aureus* were the most commonly cultured organisms.

Of the nine fractures which failed to unite after the first operation, five were among 83 which had been treated with dynamic compression plates. Three of the five were replated and bone grafted again, and healed without difficulty. One fracture which was grafted without changing the plate fixation also healed, and one patient with a distal ulnar fracture was satisfied with his
Radiographs of the left femur of a 28-year-old man. Figure 7—Non-union after a closed fracture sustained 22 months before presentation. Figure 8—One year after further closed nailing with a larger nail the fracture is still clinically ununited. Figure 9—One year after removal of the second nail, plating and bone grafting; union is now solid and painless.

Radiographs of the right femur of a 26-year-old woman. Figure 10—At presentation nine months after a closed fracture and internal fixation with a small "K" nail. Atrophic non-union is present. Figure 11—After sequestrectomy, debridement and plating there was a large medial bone deficit which was grafted. The patient was non-weight bearing for four months and then took full weight. Figure 12—One year after plating and grafting. Figure 13—Radiograph taken one week after Figure 12. The plate was replaced and more bone graft applied, producing solid union after a year.
non-union and refused a second operation.

There were two failures from 14 non-unions of the tibia, after treatment by bone grafting through a posterolateral approach and a patellar-tendon-bearing cast. One of these patients refused further operation as he was comfortable in his orthosis (Figs 1 and 2); the second patient underwent dynamic compression plating and healed after a further three months. One of the 13 patients who had intramedullary nailing at the first operation had non-union; he had fixation with a dynamic compression plate and healed within three months of this second operation (Figs 7, 8 and 9). One patient of the 15 treated with a 95° blade-plate healed without further treatment 18 months after his first operation.

Six of the nine failures were considered to be due to technical error. One femoral fracture which required a second plating operation was deficient of callus medially and should have been protected from weight-bearing for a longer period of time (Figs 10 to 13). Non-unions of one radius and of two ulnae which were severely porotic and actively infected at the time of the initial procedure should have been treated with external immobilisation.

One femoral nail which was re-inserted for a subtrochanteric fracture did not secure adequate fixation proximally and non-union persisted (Figs 7, 8 and 9). Union of one hip fracture was delayed for 18 months after a blade plate and graft. No explanation can be advanced for the other three failures after the first operation.

Complications. In one patient avascular necrosis of the femoral head occurred after subtrochanteric osteotomy for an ununited femoral neck fracture (Figs 14, 15 and 16). One patient developed osteomyelitis after operation in a clean field, but the infection resolved after removal of the metal. There was one non-fatal deep venous thrombosis. Two patients suffered refraction through screw holes; in one the ulna required replating (Figs 17 to 20), and in the other the radius healed in a cast. Two patients sustained late fractures distal to their plates and two patients suffered fractures during operation; all these united uneventfully. Of two cross-unions between the forearm bones before fixation, one was resected at the first operation but reformed, while the second, in an infected case, was left untreated.

Function. No patient lost joint movement as a result of treatment. Many patients presented after having had numerous operations and long periods in casts with marked stiffness of the joints above and below the non-union. In patients with non-union of the tibia treated by bone grafting and patellar-tendon-bearing cast, the average period of immobilisation after grafting was four months (range 3 to 6 months); all regained as much movement in the ankle and foot as was recorded before our operation. There was no shortening in any case.

DISCUSSION

In the past six years a large number of papers have been published on the beneficial effect of electrical treatment for ununited fractures (Bassett et al. 1978; De Haas, Watson and Morrison 1980; Paterson, Lewis and Cass 1980; Bassett et al. 1981; Brighton et al. 1981; Brighton 1981; Connolly 1981; Day 1981; Heckman et al. 1981; Peltier 1981; Bassett 1982; Bassett, Mitchell and Gaston 1982; Bassett, Mitchell and Schink 1982; Sharrard et al. 1982; Sutcliffe and Goldberg 1982; Delport et al. 1983). During this same period there have been fewer studies of operative treatment (Weber and Čech 1976; Schumada
and Rybachuk 1978; Witt, Jäger and Wirth 1978; Beckling and Waters 1980; Agiza 1981; Chacha, Ahmed and Daruwalla 1981; Weber and Brunner 1981; Clancey, Wirth, and Hansen 1982). It is difficult to compare results because of differing definitions of non-union and different treatment modalities, but the overall success rate of 98.4% in this series corresponds with the results reported from the University of Munich (Witt et al. 1978) with 95.7% of 117 non-unions healed, and with the series of Weber and Cech (1976) who reported 98.5% of 392 non-unions healed.

Our success rate of 98.4% might have been 100% if the two patients who refused further surgery had undergone a second operation. The failures after the first procedure were largely due to technical errors, the most common being failure to provide external immobilisation for grossly porotic bone. Fracture gaps of as much as 14 cm were treated satisfactorily, and even the presence of active sepsis at the time of operation seemed to have little detrimental effect on union. Clinical signs of osteomyelitis have not as yet recurred in any case after removal of metal or, in most cases, even with the metal in situ.

Conclusions. The follow-up in this series is relatively short in terms of chronic osteomyelitis and in some patients sepsis may recur. Radical debridement is essential in the operative treatment of actively infected non-union of bone; if adequately performed with appropriate drainage, the success rate for infected non-union should approach that for the non-infected case. External immobilisation is necessary when rigid internal fixation is not achieved at the time of operation, but the presence of active osteomyelitis is not a bar to union provided that a radical sequestrectomy is performed.

REFERENCES


