PERCUTANEOUS INTRAMEDULLARY ROD INTERCHANGE
IN OSTEOGENESIS IMPERFECTA

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This paper describes the design, development and early surgical experience with a stereotactic device to allow closed retrieval and interchange of intramedullary rods in children with osteogenesis imperfecta. This relatively atraumatic procedure may allow more frequent rod interchange than with other techniques, lessening the likelihood of deformity and fracture in the unsupported skeleton when the bone has outgrown the intramedullary rod.

The procedure was developed by design studies in vitro followed by intramedullary rodding of tibiae of New Zealand white rabbits. It has been used in children 12 times, in six tibiae and six femora: 11 rods have been successfully removed, with rod interchange in eight of these cases.

Intramedullary reinforcement of the fragile bones of osteogenesis imperfecta by rodding confers great benefit on the affected child. As the child grows, however, the rod used becomes relatively shorter, so that deformity and fractures may occur in the unsupported bone segment. Either open rod replacement or extensible rods have been used to overcome this difficulty. The useful life of the solid rods has been found to average 2.5 years and of the extensible rods 4.1 years (Marafioti and Westin 1977). Both procedures need major surgery and considerable complications have been reported with the use of extensible rods (Lang-Stevenson and Sharrard 1984). In neonatal rodding (Middleton 1984) the problem of bone overgrowth is even more severe.

Because of these difficulties a system of closed interchange of intramedullary rods has been devised. This paper describes the concept and realisation of the technique, together with early experience in its surgical use.

MATERIAL AND METHODS

The jig. The location and removal of an intramedullary rod required a jig which would serve two functions: the rod needed to be located and a retrieval tool had to be inserted axially to remove it. Such a device was designed and has been described in detail elsewhere (Frost, Middleton and Hillier 1986). In principle it is necessary to erect a line in space, then coincide the sought rod with this line. In practice it is the sighting apparatus, adjustable in anteroposterior and lateral directions, which is moved (Figs 1, 2 and 3).

The line the apparatus produces is formed by two planes intersecting at right angles. These planes are made by x-rays using a mobile image-intensifier. Accurate reproduction of the planes is ensured by the sighting and parallax devices on the jig. The angle of intersection of the planes was chosen as 90°, because anteroposterior and lateral radiographs are well understood, the C-arm swing of the image-intensifier is 90°, and it gives maximal accuracy.

When the object rod is sighted properly in the jig, an outrigger is attached which extends the line outside the limb. Through it a retrieval tool is inserted into the bone, mating with and withdrawing the rod (Fig. 4). A new rod may then be inserted, using the jig to align the bone. The retrieval tool. Various configurations of the rod end and retrieval tool were considered. A flared female threaded junction for the interosseous rod with a pointed-thread cutting tip for the retrieval tool was decided upon. This design gives maximal latitude for mating and keeps the diameter of the growth-plate injury during insertion of the tool to a minimum. In addition, most rods previously inserted are of this nature.

Trials

Inanimate. Initially the jig was developed and tested using a rod clamped in a stand, with light as a radiation source and shadows cast on white cardboard providing the image. The light source was then replaced by x-rays,
Photographs of the stereotactic jig showing: 1, lateral sighting plate; 2, anteroposterior sighting plate; 3, anteroposterior parallax patch; 4, bush with retrieval tool in place; and 5, horseshoe limb clamp.
radiograph of a rod in the sighting device with the drill point mating the right end of the rod.

the image being viewed on the television monitor. Following this the rod was hidden in a cardboard “bone”. Accurate mating of the object and the retrieval tool was thus ensured.

**Animal trial.** Because it was thought that fibrous tissue encapsulation of the rod and filing of the thread by fibrous tissue might have made the junction difficult, a biological trial was needed. Rods were inserted in the lower limb bones of New Zealand white rabbits under general anaesthesia. Femoral and tibial intramedullary rods were tried after exposing the ends of the bones through a knee arthrotomy. The femur proved to be too bowed to accept a rod easily. A 3/32-inch rod passed into the tibia readily (Fig. 5).

**Radiograph of a rod in a rabbit’s tibia.**

Retrieval was attempted at intervals of some months to two years later with varying success. It early became apparent that secure anchoring of the object bone to the retrieval machine was necessary, as operative manipulation moved the bone sufficiently in the field to make accurate matching impractical. Anchoring was achieved by using two horseshoe-shaped clamps based on the central beam of the machine. The bone was fixed to the clamps by percutaneous screws, similar to those of the skull halo, placed to avoid major neurovascular structures.

Successful mating of the rod and retrieval tool required great accuracy. Difficulties encountered included the following:

(a) failure to position the limb appropriately in the jig, that is with the rod approximately horizontal and aligned axially;
(b) failure to position the sighting mechanism accurately over the rod;
(c) failure to fix the limb securely with the clamps; and
(d) failure to position the image intensifier carefully in the central portion of the x-ray beam. If it is not central, parallax errors may occur.

**The child**

Because of the complexity of the apparatus and the need for sterility a precise sequence of procedures was required in the child. The base of the apparatus was fixed to the theatre table. Sterile horseshoe clamps were secured on the central beam. The surgically prepared limb was clamped into the horseshoes using a template to gauge the correct position. The sterile sighting apparatus was erected about the limb. The image intensifier was then positioned. The rod was sighted in two planes, being checked several times to be certain of the exact location. The outrigger was attached, an appropriate diameter bush inserted, and through a small stab wound the bone drilled and the retrieval tool inserted.

For the tibia the approach was via the heel and across the ankle. For the femur the procedure was done with the knee flexed 90° and the distal femur approached through the knee.

**RESULTS**

To date 12 attempts have been made to retrieve rods in children, six tibial rods and six femoral. All but one have been successful. Rod interchange has been carried out in eight cases. The unsuccessful retrieval, the second attempt, was due to difficulty in fixing the femur to the machine with the bone clamps. These clamps were subsequently modified. On occasions failure of exact matching of the rod and tool was dealt with by free manipulation after close approximation.

There have been no operative complications and no cases of sepsis. Hospital stay has been short, usually under one week. Osteoclasis has been required for deformity, being done at the tip of the new rod as it was advanced down the medulla. On four occasions obliteration of the medulla prevented the closed reinsertion of the rod so that open rerodding was performed.
ILLUSTRATIVE CASES

Case 1. This child had four bone roddings performed in the lower limbs at 14 weeks of age. At the age of three years there was overgrowth of bone with considerable deformity (Fig. 6). Using the stereotactic device the femoral rod was located, mated and withdrawn. A new rod was inserted, with osteoclasis to align the femur (Fig. 7).

Case 2. This child, now aged four, had four bone roddings performed in the lower limbs at the age of 12 weeks. His mother has lost count of the number of fractures he had sustained but estimates fifty. The lower limbs have remained relatively undeformed. Closed interchange of the right tibial rod is illustrated (Figs 8 and 9) with some correction of bowing without osteoclasis.

DISCUSSION

The replacement of a major open operation by a closed procedure, albeit a demanding one, deserves consideration in the long-term management of these fragile children. It has been recognised that Bailey-Dubow extending rods, although offering approximately double the useful life of the solid rod, do not lengthen in a significant number of cases (Marafioti and Westin 1977; Lang-Stevenson and Sharrard 1984). In addition, with open rodding each patient has, on average, nearly eight major surgical procedures with bone exposed from metaphysis to metaphysis (Marafioti and Westin 1977) and a considerable time in hospital is needed. By contrast, a successful closed rod interchange is a relatively minor surgical event.

The degree of parental resistance to rodding is not often realised (Osteogenesis Imperfecta Foundation of Australia 1985). The closed procedure vastly improved the family acceptance of the benefits of surgery.

Conclusions. A closed technique of rod exchange in osteogenesis imperfecta has proved successful. It lessens the surgical trauma and we suggest that more frequent and easier rodding could result in less deformity and fewer fractures.

REFERENCES


Osteogenesis Imperfecta Foundation of Australia. Spare the rod and spoil the child? Even Break (Magazine of the OIF A) 1985;91:5-7.