THERMAL NECROSIS AFTER TIBIAL REAMING FOR INTRAMEDULLARY NAIL FIXATION

A REPORT OF THREE CASES

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We present three young men who sustained closed diaphyseal fracture of the tibia and later developed severe osteocutaneous necrosis induced by heat during intramedullary reaming. They all had a narrow medullary cavity and in all a tourniquet had been used. Each developed a pretibial cutaneous blister soon after operation. In the following month severe osteomyelitis ensued, requiring segmental resection and osteocutaneous reconstruction.

CASE REPORTS

Between 1990 and 1995 three patients, one from our own department (case 1) and two referred from elsewhere (cases 2 and 3), presented with deep osteocutaneous necrosis after reaming of the medullary cavity of the tibia for intramedullary nail fixation. Two of the fractures were transverse and one was spiral. In all three patients the fractures were closed (Gustilo and Anderson 1976), the medullary cavity was narrow and a tourniquet had been used to achieve a bloodless field during the operation.

Case 1. A 19-year-old man sustained a spontaneous transverse fracture of the left tibia while jogging, classified as 42-A3.1 according to Müller et al (1990) (Fig. 1a). At operation difficulty had been encountered in advancing the reamer distal to the fracture. Nine years earlier, an osteoid osteoma had been excised from this site, resulting in sclerosis and partial occlusion of the medullary cavity.

At the first change of dressing a pretibial cutaneous blister measuring \( \frac{2}{3} \times 2.5 \) cm was seen over the midshaft. This enlarged over the next two months to a deep soft-tissue ulceration which was not controlled by local measures (Fig. 1b). Osteomyelitis developed due to \( \text{Staphylococcus aureus} \) which did not respond to systemic antibiotics. Sequestration occurred (Fig. 1c) and the implant had to be removed with debridement of bone and soft tissue at four months after the original operation. A hemisoleus flap and cancellous bone graft were used.

Case 2. A 32-year-old man was hit by a car and sustained a spiral fracture of the shaft of the right tibia (42-B1.1) (Fig. 2a). On the same day, the fracture was stabilised by reamed intramedullary nailing, but difficulty was encountered in reaming the medullary cavity. At the age of 18 years, the patient had fractured his right tibia which had been treated by osteosynthesis of the tibial shaft with a plate.

At the first change of dressing, a pretibial blister measuring \( 3 \times 3 \) cm was noticed. During the following two months this developed into a deep soft-tissue ulceration (\( 3 \times 4 \) cm) exposing the surface of the tibia. Osteomyelitis developed due to \( \text{Proteus mirabilis} \) infection and two
months later an area of bone sequestration was demonstrat-
ed by scintigraphy (Fig. 2b). Antibiotics did not control the
infection. The implant was removed and a segment of the
necrotic tibia 11.5 cm long was excised. An osteocutaneous
reconstruction was carried out using a vascularised fibular
graft and a flexor hallucis longus flap.

Case 3. An 18-year-old man sustained a closed transverse
fracture of the shaft of the left tibia (42-A3.3) while playing
soccer (Fig. 3a). At operation the same day attempts failed
to pass even the smallest reamer down the narrow intra-
medullary canal, and the fracture was eventually fixed by a
plate. There had been no previous injury to the tibia.

At the first change of dressing, a cutaneous blister meas-
uring $3 \times 3$ cm was seen over the anteromedial aspect of
the shin. This developed into an ulcer extending to the
bone. An attempt was made to cover the defect by a
fasciocutaneous flap. This was unsuccessful and four
months after the initial operation the patient was referred to
us. He was found to have deep soft-tissue ulceration,
osseous sequestration (Fig. 3b) and severe osteomyelitis
due to infection with *Citrobacter diversus* which did not
respond to systemic antibiotics. Segmental resection of
8 cm of the necrotic tibia was undertaken followed by
reconstruction using a vascularised osteoseptocutaneous
fibular graft.

**DISCUSSION**

The current understanding of the biology of bone has
emphasised the need for preservation of bone integrity and
protection of the soft tissues when undertaking internal
fixation (Mast, Jakob and Ganz 1989; Gautier, Perren and
Ganz 1992). Our patients have demonstrated compromise
of these principles by thermal injury due to inadequate
reaming of narrow medullary cavities and prevention of
heat transfer by convective blood flow (Sundén 1967;
Leunig et al 1994) resulting from the use of a tourniquet.

Cellular necrosis due to heat is immediately evident with
temperatures above 70°C (Berman et al 1984; Eriksson,
Albrektsson and Albrektsson 1984), whereas the minimum
critical temperature for delayed death of osteocytes, not
seen until three weeks or more after injury, is much less at
around 47°C (Eriksson and Albrektsson 1983). Exposure to a temperature of 47°C for one minute causes bone resorption and subsequent replacement and also disturbs the middle- and long-term anchorage of implants (Eriksson and Albrektsson 1983). Detritus and necrotic tissue provide favourable conditions for bacterial growth, eventually leading to abscess formation with spread by way of the Haversian and Volkmann canals. The destruction of the skin barrier due to blistering and cutaneous ulceration removes the major local defence against bacteria, and may contribute further to the development of osteomyelitis. Analysis of blister fluid has shown a low opsonic activity against bacteria due to a marked decrease in the level of immunoglobulins and complement components, resulting in severe impairment of both cellular and humoral local immunity (Deitch, Dobke and Baxter 1985).

In our patients estimation of the intramedullary temperatures induced during reaming can be made from the appearance of the cutaneous blister which requires dermal temperatures of at least 53°C (Stoll and Greene 1959), and from the thermal properties of bone and soft tissues (Clattenburg et al 1975; Biyikli, Modest and Tarr 1986). The calculated intramedullary temperatures exceeded 100°C. These theoretical considerations are supported by direct measurements of temperature elevation during orthopaedic cutting or drilling procedures (Krause et al 1982; Eriksson et al 1984). Heating of tissue above 100°C should be absolutely avoided since this will cause evaporation of water and subsequent charring, which significantly attenuates the thermal conductivity and capacity of the heated tissue (Clattenburg et al 1975).

Important features which allow bone to withstand thermal damage are the relative water content (about 35%) and the movement of fluid within living bone. In our patients, the latter had been compromised by reaming and the use of a tourniquet. Cortical reaming impairs the local endosteal blood supply and perfusion of the diaphyseal cortex by producing an increase in the intramedullary pressure, occlusion of vessels by fat emboli and bone particulate debris, interruption of vessels and thermal injury (Schemitsch et al 1995). The use of a tourniquet eliminates convective heat transfer by shutting down the global blood flow of the whole limb (Klenerman et al 1980). The importance of an intact blood circulation has been demonstrated by studies on thermal conductivity which showed a fourfold difference between dry and living bone tissue (Sundén 1967).

Susceptibility to infection after internal fixation is a result of the mechanical and biological state of the fixation (Curtis et al 1995) and the physicochemical properties of the implant (Elek and Conen 1957; Gristina 1987). When there is an abundant vascular supply and normal sufficient soft-tissue coverage local infection is often responsive to antibiotic therapy (May et al 1989). In our patients osteonecrosis led to deep infection and required large-scale resection (Hertel, Pisan and Jakob 1995). If reamed intramedullary nailing is undertaken a full history must be taken and the diameter of the intramedullary canal must be assessed on preoperative radiographs. Avoidance of the use of a tourniquet and care with reaming will lessen the likelihood of heat-induced osteocutaneous necrosis.

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