Closed double-lumen suction irrigation in the management of chronic diaphyseal osteomyelitis

LONG-TERM FOLLOW-UP

Between November 1994 and June 1999, 35 patients referred to our Problem Fracture Service with chronic diaphyseal osteomyelitis were treated using a closed double-lumen suction irrigation system after reaming and arthroscopic debridement of the intramedullary canal. This is a modified system based on that of Lautenbach.

Between June and July 2007 the patients were reviewed by postal questionnaire and telephone and from the case notes. At a mean follow-up of 101 months (2 to 150), 26 had no evidence of recurrence and four had died from unrelated causes with no evidence of recurrent infection. One had been lost to follow-up at two months and was therefore excluded. Four had persisting problems with sinus discharge and one had his limb amputated for recurrent metaplastic change.

Our results represent a clearance of infection of 85.3% (29 of 34), with recurrence in 11.8% (4 of 34). They are comparable to the results of the Papineau and Belfast techniques, but with considerably less surgical insult to the patient.

Chronic osteomyelitis remains a major cause of morbidity.1 It is difficult and challenging to manage and has considerable health-economic implications in terms of the use of antibiotics, hospital stay and theatre time.2-4

The operative treatment of chronic osteomyelitis in long bones involves three principles, namely, bony debridement, the management of the dead space and soft-tissue resection with subsequent cover. Papineau et al5 described a technique of excision and bone grafting, but secondary infection remained a problem.6 The experience of McNally et al7 led to the development of the Belfast technique and in other parts of the world a modified Papineau technique has been used. These strategies incorporate two stages. A radical debridement of bone and soft tissues with management of the dead space, often using gentamicin beads is followed three to six weeks later by further debridement and bone grafting. McNally et al7 reported a success rate of 92% with a mean follow-up of 49 months and Esterhai et al7 an overall success rate of 62%.

Medical management has usually involved the administration of high-dose parenteral antibiotics for at least six weeks in hospital or, more recently, the use of a restricted range of long half-life antibiotics at home. A short course of parenteral antibiotics at operation followed by oral antibiotics for a further six weeks has also been used.8 Other non-surgical efforts, including the use of hyperbaric oxygen have given disappointing results.9 The selection of systemic antibiotics is difficult because superficial and sinus isolates, other than Staphylococcus aureus, correlate poorly with deep bone isolates and emerging antibiotic resistance makes the empirical choice of antibiotics increasingly difficult.10 Microbial diagnosis and testing of antibiotic susceptibility are important to prevent recurrence of infection after surgery. In established osteomyelitis a local environment of poor perfusion, sequestration and a biofilm limits the value of the conventional systemic delivery of antibiotics.1

Drainage systems following surgical debridement offer greater flexibility in the selection and delivery of antibiotics than the use of gentamicin-loaded cement.11 The instillation of antibiotics is frequently hindered by blockage of the drain and has lost popularity.12-15 The Lautenbach system, using a closed double-lumen tube delivering antibiotic locally, followed by suction, has been used in the treatment of infected hip replacements.16 Hashmi, Norman and Saleh17 described a series of 17 patients with post-traumatic osteomyelitis who were treated by this method. After a mean follow-up of 75 months, they achieved a success rate of 94.4%. All their patients remained free from infection, but two underwent amputation for other reasons.
We describe a prospective study using a modified system of closed double-lumen suction-irrigation drains for the management of patients with either primary or secondary chronic diaphyseal osteomyelitis with a mean follow-up of 101 months (2 to 150).

Patients and Methods
The senior author (JBR) provides a Problem Fracture Service available for tertiary referral. Between November 1994 and June 1999 all new referrals with chronic osteomyelitis were recruited. Following informed consent, clinical assessment and radiography were used for pre-operative planning. The level of CRP was taken as the baseline marker for activity of disease.18,19

There were 35 consecutive patients (26 males, 9 females) with a mean age of 41 years (15 to 69). One patient was lost to follow-up with no reported problems at two months and was excluded from the final results.

The initial operation involved debridement and the collection of multiple deep samples for culture and histology. The tissues were transported to the laboratory as dry specimens moistened in 0.9% saline or brain-heart-broth. Deep swabs were transported in charcoal transport medium. Further tissue samples were preserved in Formol saline for histological evaluation.

At operation, sinus tracks and any attached fibrous tissue were excised after injection of Methylene Blue to aid identification. All internal fixation devices were removed and double-ended reaming was performed through entry points at the proximal and distal ends of the affected bone. In the femur, these portals were the tip of the greater trochanter and the lateral femoral condyle. In the tibia, a parapatellar incision was used as a midline proximal portal and the medial malleolus as a distal portal. Reamers of increasing size were used until cortical bone was met in the mid-diaphysis from distal and proximal directions. Lavage was continued until all fine debris had disappeared from the effluent. The ability to ensure adequate debridement was enhanced by the use of osteoscopy whereby an endoscope inserted into the intramedullary canal ensured that healthy bleeding could be seen along the endosteal surface and further sequestra removed.20

Following debridement, a closed double-lumen suction-irrigation system was introduced through a subcutaneous tunnel (Fig. 1). This low-volume system was constructed by threading an epidural catheter through the connector of an intravenous giving set (the connecting pipe to a bag of fluid). A low-pressure drain was then connected. This created a double lumen with the fine internal catheter for the delivery of antibiotic and thrombolytic agents and the wider surrounding catheter for intermittent suction. No taps or T-tubes were included in the system.

Post-operatively, suction was applied for 30 minutes every four hours. This was followed by the instillation of antibiotic through the central lumen followed by 1 ml of streptokinase (2000 units in 1 ml) to keep the central lumen patent. The suction system was then clamped for the next three and a half hours.

The streptokinase was given every four hours for the first week, then only if required to maintain unrestricted flow for the instillation of antibiotic. The selection of antibiotic was according to the cultures of the samples obtained at operation. Usually, and always if earlier samples indicated that methicillin-resistant *Staphylococcus aureus* (MRSA) was present, teicoplanin (1 ml of a solution of 8 mg/ml) was used. Flucloxacillin (1 ml of 100 mg/ml) was used in some cases. When Gram-negative aerobic organisms were present, 1 ml of gentamicin at 10 mg/ml was added. Intravenous vancomycin, sometimes supplemented with rifampicin or, one on occasion sodium fusidate, was administered for infection with MRSA and oral ciprofloxacin for Gram-negative infection. Rifampicin or metronidazole was given orally, but not locally, for anaerobic infections. Cephalexin, amoxycillin and coamoxiclav were given on single occasions.

Every week, 1l of Hartmann’s solution was infused through each drain over one hour with suction applied. A sample of the suction fluid was then collected and sent for microbiological examination. Irrigation was continued for three weeks.
Treatment with antibiotic was reconsidered on clinical grounds if any new or resistant isolate was grown from the suction fluid. Relief from pain post-operatively, and a falling CRP were found to be good prognostic indicators. However, if the suction fluid did not clear visibly or the CRP had not improved, further debridement was undertaken. In most cases, oral antibiotics were continued for six weeks after discharge. This was usually flucloxacillin regardless of the initial aetiology of the infection, although some additions and substitutions were made.

Surgical success was defined as healing of the lesion without formation of a sinus or re-operation within the period of follow-up.7 Patient success was defined as a self-assessment of satisfaction and the absence of pain, sinus or re-operation. Bacteriological success was defined as no further growth from the site of the infection three months after the initial operation.

The patients were sent a questionnaire in June and July 2007, with further follow-up by telephone if no response had been obtained, and the case notes were analysed for further information if necessary. The questionnaire contained questions regarding pain, sinus problems, further antibiotic treatment or surgery and the EQ5D21 with a visual analogue score for pain.

**Results**

The presenting symptom was pain in 10 (30%), a persisting sinus in 19 (55%) and a fear of a further flare-up in five (15%). Osteomyelitis had been present clinically for a mean of ten years (1 to 50) before referral. The osteomyelitis was primary in seven patients and secondary to trauma or previous surgery in 19. Nine other patients had an infected nonunion, five of whom had bacteriological confirmation of infection at operation.

A total of 14 patients had metalwork in situ at referral; eight had an intramedullary nail, two a plate and screws, one an external fixator and one a tension band wire. A sequestrum was present in 25 despite all having had debridement operations previously. The mean number of previous operations to eradicate infection was five (1 to 13), the last being between six months and two years earlier (mean 1.1 years). The femur was involved in 20 cases, the tibia in 13 and the humerus in two. The mean level of CRP at presentation was 74 mg/l (5 to 158).

All cases were confirmed as osteomyelitis by histopathological examination. The bacteriological growth from earlier or current operations was monomicrobial in 15 and polymicrobial in seven (Fig. 2). In 13 cases no initial bacteriological diagnosis had been made, and in some antibiotics used after earlier biopsy were probably responsible for the negative cultures. A microbiological diagnosis was therefore achieved initially in 22 patients (62.9%). Of the 11 Staph. aureus strains, three were MRSA, and of the 11 Gram-negative aerobes, three were Pseudomonas aeruginosa. Two of the three MRSA, one coagulase-negative staphylococcus and three of five enterococcal infections were associated with metalwork in situ. Subsequent weekly fluid cultures after the antibiotics had been washed out showed a change in the isolate in 14 patients (Fig. 3). In addition four Staph. aureus isolates (two MRSA), five Gram-negative aerobes (coliiforms and Pseudomonas), single isolates of Lancefield group-B streptococcus, anaerobes and Candida and two isolates of coagulase-negative staphylococcus were recovered. The number of

![Diagram](https://example.com/diagram1.png)

*Fig. 2* Details of the initial microbiological findings (CNS, coagulase-negative staphylococcus).

![Diagram](https://example.com/diagram2.png)

*Fig. 3* Details of the microbiological findings during treatment showing changes in the isolates (CNS, coagulase-negative staphylococcus; GBS, group-B streptococcus).
patients from whom no isolate was made decreased from 13 to eight.

One patient, who developed established Gram-negative superinfection when no such organism had previously been present, had received initial teicoplanin, which has no activity against Gram-negative aerobes. Only this patient, of the five with Gram-negative aerobic isolates detected after the start of treatment, received antibiotics active against Gram-negative aerobes. Three patients with bacteriological failure developed further infection and required re-operation. Four others with bacteriological failure, all with *Staph. aureus* infection (two MRSA), did not require further surgery. Overall, ten patients (28.6%) failed to achieve bacteriological success at the first operation. The patient with *Candida* superinfection did not require antifungal therapy. There was no overall association between the implicated microbial flora and the need for re-operation.

In 28 patients (80.0%) the antibiotic given through local irrigation was teicoplanin and in seven (20.0%) it was flucloxacillin. Gentamicin supplemented the other agent in seven patients (20%) and no patient who received gentamicin developed Gram-negative superinfection. Further antibiotic cover was provided by systemic treatment in 27 patients during their admission and after discharge. Five were given antibiotics as in-patients only. Three were given no systemic antibiotics at any stage. Surgical stabilisation, if required, was undertaken when the patient was considered to be free from infection.

Following the initial debridement and irrigation, seven patients required a further cycle of debridement and irrigation during the same admission. One required a sequestrectomy and the others had only repeat debridement and replacement of the irrigation system. Six patients required one further cycle and two a further Lautenbach cycle at a later admission. Three of these six patients had an infected nonunion compared with five of 29 patients who did not require further intervention. Problems encountered during treatment were system blockage in eight of 35 patients (22.9%), which responded to irrigation and addition of streptokinase, and re-fracture in two, in both of whom healing occurred after further operative intervention.

Initial follow-up was carried out at a mean of 44 months (2 to 69) when the mean CRP level was 6 mg/l (1 to 25). A total of 27 patients (77.1%) had resolution of their presenting symptoms of pain and discharge and they considered the treatment to be a success. Eight required re-operation which was successful in six.

At a mean follow-up of 101 months (2 to 150), 26 patients from the original 35 had no signs or symptoms of further infection. Four had died at between 70 and 135 months after treatment with no evidence of further infection. One who was lost to follow-up at two months was excluded. Therefore, 29 of 34 patients (85.3%) had no recurrence of infection.

Four patients developed further problems with a persisting sinus requiring antibiotics. Initially their CRP level had become normal (54 mg/l to 115 mg/l decreasing to 1 mg/l to 9 mg/l). In all, *Staph. aureus* (2 MRSA) was cultured in the three months after operation, three in association with coliforms and *Pseudomonas* and two with anaerobes. Three patients had a sequestra at the initial operation. Their sinuses recurred between 58 and 142 months after treatment, and hitherto they had been free from symptoms. No bacteriological results were available from these sinuses.

One patient, who had metaphasic change in his initial biopsies, was symptom-free for 73 months, before further metaphasis was noted in his femur. Although he underwent a total femoral replacement he ultimately required amputation at 130 months after the original Lautenbach treatment, when further metaphasic change was found in the surrounding soft tissues.

**Discussion**

Although our results appear to be encouraging, with a success rate of 85%, we interpret them with care since osteomyelitis may be quiescent for several years before re-emergence, as was shown by one of our patients who had a 50-year history of recurrence, and a similar case described by McNally et al.7

Excision and delayed bone grafting were successful in 92% and 62% of the series of McNally et al7 and Esterhai et al17 respectively, and we have compared our results with these. Closed double-lumen suction irrigation offers several advantages over the extensive two-staged Bel-fast technique. Our method involves only one planned operation since the drainage systems can be removed on the ward at the completion of treatment. Nine of our patients had to return to theatre for further debridement and irrigation, which meant that the mean number of operations per patient was 1.3 (1 to 3). The reduction of further exposure to anaesthesia, with the inherent risks and costs, is important in this group of patients which on average had five previous surgical attempts to eradicate infection.

Extensive resection of bone to ensure removal of sequestra recognises the practical problem of adequate surgical debridement. This is confirmed in our series in which 25 patients (71.4%), despite previous operations, still had areas of dead bone or free sequestra. Radical removal of such bone may require bone grafting. The use of optical aids to illuminate and visualise the intramedullary environment improves the identification of sequestra and allows more accurate bone resection.20 Even with this method however, there may be residual problem areas as was shown by the requirement of further debridement in seven of our patients. Bone grafting was not needed and so the problems of pain at the donor site, a second operation site and delayed second stage were avoided.

We feel that the modification using streptokinase and a small- rather than the previously reported large-volume antibiotic irrigation system, is important. This means that the main disadvantage of these systems in which blockage produces an early technical failure has been overcome. We
experienced intermittent blockage in nine of our patients but this was resolved in the ward, using streptokinase.

It is possible that streptokinase may also remove adherence receptor sites such as fibronectin for staphylococci and may thereby reduce the chance of the re-establishment of persistent infection or biofilm, in which sessile organisms are much more resistant to antibiotics than is suggested by conventional tests. The suction aspect of the system provides a ‘safety net’, by allowing the microbiology, volume and appearance of the drainage fluid to be checked. The avoidance of taps, large-volume dead spaces, weekly subcutaneous tunnelling of the drain and continuous irrigation, all lessen the chances of superinfection. The system also offers opportunities to recover further organisms from deep tissues. Some of these represent superinfection, but others may reflect organisms from the original infection which had not responded to local and systemic chemotherapy. Patients with such organisms appear to be more likely to require further surgery, but this may be an indicator rather than a cause of such requirement. The Lautenbach treatment allows reassurance that changing organisms and sensitivities can be managed, as occurred in 15 of our cases. Clear drainage after three weeks of treatment suggests that healthy granulation tissue has formed. If cloudy drainage persists then further debridement can be undertaken early during the same admission, thereby allowing the cumulative benefit of proactive rather than delayed reactive surgery.

As described by Cierny a patient with an infected nonunion is the most difficult to treat, even by this method. However, those patients in whom the fracture healed, but who developed osteomyelitis after intramedullary nailing, seem to have responded well to our regimen with only one requiring re-operation. It may thus be considered that in the case of infected nonunion, radical bone excision, stabilisation, grafting or callotasis may provide the solution.1,2

The use of systemic antibiotics alone to treat chronic osteomyelitis is disappointing. Our findings do not confirm that the use of a Lautenbach technique restricts systemic antibiotic usage. Unless MRSA is present, when we continue to use intravenous vancomycin, all other adjunctive antibiotic therapy was given orally. The use of rifampicin was restricted to cases in which MRSA was present, but ciprofloxacin was used for Gram-negative aerobes and metronidazole for anaerobes. The major part of ciprofloxacin usage was in susceptible staphylococci after removal of the drain. It was unclear as to whether this was necessary, but it was felt to be sensible with such a recalcitrant infection.

The empirically-based selection of systemic antibiotics or general use of gentamicin-impregnated cement beads has been shown to encourage the emergence of resistant strains, especially small-colony variants of staphylococci, which are difficult to detect and characteristically are thymine- or menadione-dependent.3,4 The former organisms are characteristically resistant to cotrimoxazole as well. The Lautenbach technique allows the use of multiple agents. Some organisms (anaerobes, enterococci and streptococci) are intrinsically resistant to gentamicin and others often have acquired resistance (staphylococci, including MRSA). Vancomycin should not be used locally because of its low pH (< 3.5) but teicoplanin is a neutral solution and can be used in this way. It is our preferred routine agent. We seldom use ciprofloxacin, not least because of the increasing prevalence worldwide of MRSA. We use gentamicin routinely to eliminate the problems of unexpected initial or later Gram-negative infection.

We confirm the encouraging findings reported by Weber and Lautenbach in the use of local instillation of antibiotics. The method described is reproducible and adaptable. Previously reported problems of lumen blockage and technical failure have been overcome by the use of a double-lumen vacuum system and intermittent instillation of streptokinase. There is a high satisfaction among patients, a low initial failure rate and continued pleasing results, consistent with the early results of Hashmi et al.7

**Supplementary Material**

A table showing the clinical details and outcome of the 35 patients who underwent the Lautenbach treatment is available with the electronic version of this article on our website at www.jbjs.org.uk

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

**References**


