Cement Spacers With Antibiotics for the Treatment of Posttraumatic Infected Nonunions and Bone Defects of the Upper Extremity

Christian Allende, MD

Abstract: Treatment of patients with posttraumatic infected nonunions or highly contaminated open fractures with segmental bone loss of the long bones of the upper extremity is demanding. The use of a 2-stage reconstruction technique, being the first stage characterized by thorough debridement, copious lavage, soft tissue coverage, and placement of a cement spacer with antibiotics at the infected site, and the second stage by cement spacer removal, internal fixation, and placement of bone graft with local antibiotics, is presented. We carried out this technique in 20 cases, in 12 cases the cement was molded to fit the defect and placed as a solid interposition mass, in 3 cases it was placed lateral to the affected bone, and in the remaining 5 cases a Rush nail covered with a cement mantle was used. Follow-up averaged 18 months. All nonunions and fractures healed after an average of 5 months. Disabilities of the arm, shoulder, and hand (DASH) score at last follow-up in nonunions averaged 14 points and 21 points in bone losses. Although generally 2 surgical procedures are needed, 1 to cure or prevent infection and another to achieve bony union, this approach for complex open fractures with segmental bone loss and for infected nonunions of the long bones of the upper extremity represents a valid treatment alternative.

Key Words: infected nonunion, open fractures, cement, upper extremity, local antibiotics

(Tech Hand Surg 2010;14: 241–247)

HISTORICAL PERSPECTIVE
Successful treatment of complex open fractures with segmental bone loss and of infected nonunions of long bones of the upper extremity represents a great challenge to the orthopedic surgeon. Their treatment aims at preventing or controlling infection, achieving adequate stability and restoring bone continuity. Infections of the upper extremity are mostly secondary to severe open fractures with extensive comminution and segmental bone loss or after internal fixation of comminuted closed fractures. They are frequently associated with bone and soft tissue loss, internal fixation loosening or breakage, poor vascularity of the bony fragments, drainage from sinuses, osteopenia, osteomyelitis, adjacent joint stiffness, deformities, length discrepancies, earlier surgeries, and resistant polybacterial infection. Cement spacers release high doses of local antibiotics with minimal systemic distribution. Bactericidal antibiotic concentration is known to be present around antibiotic bone cement up to 6 weeks. The elution of antibiotics from cement spacers follows a biphasic pattern, with an initial rapid phase and a second phase after 5 to 10 days. When the cement spacer is removed a pseudosynovial membrane rich in growth and osteoinductive factors is formed, which protects and helps revascularize the bone graft.

Cement and cancellous bone graft are effective local antibiotic delivery systems to prevent and combat infections. Actual available evidence suggests that staged reconstruction (debridement, antibiotic beads, and planned secondary fixation) allows achieving union in 93% to 100% of cases and persistence of infection is present only in 0% to 18% of cases, significantly better that 1-stage strategies and 2-stage strategies without the use of cement beads. The combination of local and systemic antibiotic treatment seems to be better than either one of them alone. Cement containing sufficient concentrations of antibiotics to achieve local control of infection are not commercially available and they need to be prepared by the surgeon using different antibiotics. The use of cement spacers have mechanical advantages, as they allow filling dead spaces avoiding invasion of the affected area by poorly vascularized fibrous tissue, they increase stability and they aid in maintaining normal anatomy (bony length and alignment, helping in the improvement of the trophism at the bone ends), while preparing the bed for the application of bone grafts.

Adhesive antibiotic concentration in bone, when administered systematically, requires high doses for a prolonged period of time, increasing its risk of toxicity and representing an important expense for the treatment. In long defects, it can be difficult to maintain the axis of the limb when using an external device; the advent of new advances in osteosynthesis techniques and materials such as the use of bridge plating, locked plates, or locked blade plates help increase the stability achieved in these lesions. Bioabsorbable delivery vehicles for the administration of local antibiotics and even to promote the union are being developed. Clinical experience using BMP-7 to accelerate bone healing in these cases has not been encouraging.

INDICATIONS AND CONTRAINDICATIONS
Twenty consecutive patients presenting posttraumatic infected nonunions (13 cases) or combined open fractures with segmental bone loss (7 cases) of the long bones of the upper extremity, and treated surgically in 2-stages (being the first stage characterized by debridement, soft tissue coverage, and the placement of a cement spacer with antibiotics at the infected site and the second stage by cement spacer removal, internal fixation, and the placement of bone graft with local antibiotics) between 1995 and 2009, were evaluated (Table 1). Nonunions affected the humerus in 6 cases, the ulna in 4 cases, and the radius in 3 cases; all nonunions were classified as atrophic. Open fractures with bone loss were located at the radius in 3 cases and at the ulna in 4 cases; all 7 patients with...
open fractures with bone loss had severe concomitant soft tissue lesions that made primary bone reconstruction not recommended. Patient’s age averaged 36.5 years (range, 11 to 69). Two patients were female and 18 were male. The size of the bony defect averaged 2.5 cms (range, 0 to 7). Time between the original trauma and revision surgery in nonunions averaged 9.23 months (range, 3 to 28). No patient had known allergies to antibiotics.

### TECHNIQUE

Initial treatment in all patients consisted in thorough debridement of avascular, necrotic, and infected tissues (until bleeding tissue was evident at the bony and soft tissue margins), copious wound irrigation, removal of all earlier internal fixation, opening of the medullary canal, soft tissue coverage, and placement of the cement spacer with only gentamicin in the first 7 operated cases (0.5 grams of gentamicin every 40 grams package of cement), and in the remaining 13 cases vancomycin powder was also associated with the spacer (2 grams of vancomycin every 40 gms package of cement) to increase its bactericidal spectrum. In nonunions, samples for cultures were obtained from the bone and soft tissues.

The cement is prepared in the operating room under sterile conditions, on a separate table, by a surgeon not involved in the debridement. Once thorough debridement of the bone and soft tissues and copious lavage are carried out, the instruments used are removed, and the involved limb is draped again, and the surgical team changes gowns and gloves. In 12 cases, the cement was molded to fit the defect and placed as a solid interposition mass (Figs. 1A–E); in 3 cases it was placed lateral to the affected bone (Figs. 2A–E); and in the remaining 5 cases a stainless steel nail was used to aid in achieving stability. In the case affecting the humerus, the nail was completely covered with cement and placed intramedullary,26 and in the cases affecting the ulna, the nail was covered with cement only in the area corresponding to the bony defect whereas the proximal and distal segments of the nail placed intramedullary were not covered by cement owing to the small diameter of the medullary canals (Figs. 3A–E). The nails were prepared using the different sizes of sterile plastic tubes usually used for pleural drainage, cut to the length of the involved bone segment; the plastic tubes allowed achieving a uniform cement mantle circumferentially around the nail. The cement and antibiotic powders were mixed, and then prepared in a standard manner, and introduced in a semiliquid state into the plastic tube using a 60-mL syringe. The nozzle of the 60-mL syringe is used to insert the cement into the plastic tube, filling its entire length. Once the tube was filled with the cement, a stainless steel Rush or Kirschner nail was introduced. The plastic tubes are split longitudinally using a sharp knife and removed once the cement sets (8 to 10 min).8,27 In the case in which the nail was completely covered with cement, the nail did not

### TABLE 1. Patients and Treatment

<table>
<thead>
<tr>
<th>Non-union (Cases)</th>
<th>Sex</th>
<th>Age (y)</th>
<th>Location</th>
<th>Stage I: Stabilization</th>
<th>Definitive Fixation</th>
<th>Bone Graft</th>
<th>Defect Size (Centimeters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>69</td>
<td>Humerus proximal 1/3</td>
<td>Rush nail covered with cement</td>
<td>Locked blade plate</td>
<td>Morcellized allograft</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>17</td>
<td>Humerus distal 1/3</td>
<td>Brace</td>
<td>4.5-mm LC-DCP</td>
<td>Cancellous</td>
<td>4.5</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>31</td>
<td>Humerus distal 1/3</td>
<td>External Fixator</td>
<td>1 reconstruction plate and one 4.5-mm DCP</td>
<td>Corticocancellous</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>36</td>
<td>Humerus distal 1/3</td>
<td>External Fixator</td>
<td>2 reconstruction plates</td>
<td>Corticocancellous</td>
<td>1.5</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>11</td>
<td>Ulna diaphysis</td>
<td>Cast</td>
<td>3.5-mm LCP</td>
<td>Cancellous</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>46</td>
<td>Radius diaphysis</td>
<td>Cast</td>
<td>3.5-mm LC-DCP</td>
<td>Cancellous</td>
<td>7</td>
</tr>
<tr>
<td>7</td>
<td>M</td>
<td>52</td>
<td>Ulna diaphysis</td>
<td>Rush nail covered with cement</td>
<td>3.5-mm LC-DCP</td>
<td>Cancellous</td>
<td>1.5</td>
</tr>
<tr>
<td>8</td>
<td>M</td>
<td>20</td>
<td>Ulna diaphysis</td>
<td>Rush nail covered with cement</td>
<td>3.5-mm LCP</td>
<td>Cancellous</td>
<td>5</td>
</tr>
<tr>
<td>9</td>
<td>F</td>
<td>56</td>
<td>Distal radius</td>
<td>External Fixator</td>
<td>Locked distal radius T plate.</td>
<td>Corticocancellous</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>M</td>
<td>13</td>
<td>Humerus diaphysis</td>
<td>Brace</td>
<td>4.5-mm LC-DCP</td>
<td>Cancellous</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>M</td>
<td>34</td>
<td>Radius diaphysis</td>
<td>Cast</td>
<td>3.5-mm LCP</td>
<td>Cancellous</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>M</td>
<td>46</td>
<td>Ulna diaphysis</td>
<td>Cast</td>
<td>3.5-mm LC-DCP</td>
<td>Cancellous</td>
<td>1.5</td>
</tr>
<tr>
<td>13</td>
<td>M</td>
<td>15</td>
<td>Humerus diaphysis</td>
<td>Cast</td>
<td>None</td>
<td>None</td>
<td>0</td>
</tr>
<tr>
<td>Bone Loss (Cases)</td>
<td></td>
<td></td>
<td>Ulna diaphysis</td>
<td>Rush nail covered with cement</td>
<td>3.5-mm LCP</td>
<td>Cancellous</td>
<td>6</td>
</tr>
<tr>
<td>14</td>
<td>M</td>
<td>23</td>
<td>Ulna diaphysis</td>
<td>Rush nail covered with cement</td>
<td>3.5-mm LCP</td>
<td>Cancellous</td>
<td>2</td>
</tr>
<tr>
<td>15</td>
<td>M</td>
<td>34</td>
<td>Radius diaphysis</td>
<td>Cast</td>
<td>3.5-mm LC-DCP</td>
<td>Cancellous</td>
<td>3</td>
</tr>
<tr>
<td>16</td>
<td>M</td>
<td>28</td>
<td>Ulna diaphysis</td>
<td>Rush nail covered with cement</td>
<td>3.5-mm LCP</td>
<td>Cancellous</td>
<td>3</td>
</tr>
<tr>
<td>17</td>
<td>M</td>
<td>53</td>
<td>Ulna diaphysis</td>
<td>Cast</td>
<td>3.5-mm LC-DCP</td>
<td>Cancellous</td>
<td>1.5</td>
</tr>
<tr>
<td>18</td>
<td>M</td>
<td>31</td>
<td>Ulna diaphysis</td>
<td>Cast</td>
<td>3.5-mm LCP</td>
<td>Cancellous</td>
<td>2</td>
</tr>
<tr>
<td>19</td>
<td>M</td>
<td>57</td>
<td>Radius diaphysis</td>
<td>External Fixator</td>
<td>External Fixator</td>
<td>Corticocancellous</td>
<td>4</td>
</tr>
<tr>
<td>20</td>
<td>M</td>
<td>37</td>
<td>Radius diaphysis</td>
<td>Cast</td>
<td>3.5-mm LC-DCP</td>
<td>Cancellous</td>
<td>2.5</td>
</tr>
</tbody>
</table>
protrude proximally or distally, and it was inserted with the same technique used for undreamed humeral nailing. In the cases involving the ulna, the nail was left protruding proximally and distally to the cement, allowing the placement of the uncovered extremes of the nail endomedullary at the proximal and distal ends of the bony defect (Figs. 3A–E). It is helpful to maintain a low room temperature while preparing the cement as it allows increasing the working time.

Stability was augmented by the use of an external fixator, brace or cast (Table 1). When external fixators are placed with cement spacers, they are placed to neutralize forces, whereas the cement spacer is applied in the defect to maintain bony length and it is through the cement that forces travel (Figs. 1C, D). In no case cement beads strings were used. After cement application the wounds were closed without placing drainages. During the immediate postoperative period all patients received oral antibiotics (ciprofloxacin and clindomycin), followed by culture-specific antibiotics, according to the results from the samples sent at the time of surgery; the type and time of oral antibiotic treatment was managed by the infectious disease department. The interval between the first and second operation was decided according to the clinical, laboratory, (negative C reactive protein and sedimentation rate at least 2 weeks after oral antibiotics abolition) and radiological parameters (no periosteal reaction or bone resorption signs). Results were evaluated using the Disabilities of the Arm, Shoulder, and Hand Questionnaire (DASH).
RESULTS

Follow-up averaged 18 months (range, 10 to 96). The interval between the first and second operation averaged 8.5 weeks (range, 4 to 15). All nonunions and fractures healed after an average of 5 months after definitive surgery (range, 3 to 8). DASH score at last follow-up in nonunions averaged 14 points (range, 0 to 26), and in bone loss DASH score averaged 21 points (range, 8 to 43). The most frequently cultured microorganism in the nonunions was staphylococcus aureus (6 patients), followed by enterococcus (5 cases, 1 with mixed flora enterococcus and pseudomona) and staphylococcus epidermidis in the 2 remaining nonunions. Different types of implants and bone grafts were used (Table 1); they varied according to the affected bone, localization, and type of bony defect, quality of soft tissue bed and patient’s desires and characteristics. The different bone grafts used were always mixed with 2 grs of vancomycin before their placement. In one case, a 15-year-old boy, in which the cement spacer was placed...

FIGURE 2. A 34-year-old male, 5 months after both the forearm bones fracture. A, Bone resorption at the fracture site of the radius, 1 screw interposed in the defect and active drainage from the incision. B, Placement of the cement spacer lateral to the fracture site after implant removal and debridement. C, Membrane formed after removal of the cement spacer. D, Placement of cancellous bone graft mixed with antibiotics and stabilized with an LCP. E, Anteroposterior x-ray showing bony union.
lateral to the infected nonunion, primary union was achieved and only cement spacer removal was necessary (Figs. 4A–E). The tissue formed surrounding the cement was not removed in any case (Fig. 2C), and the histologic evaluation carried out in nonunions at the time of cement removal showed a pseudo-synovial membrane rich in vascularization as earlier described by Pelissier et al.10

Complications
In one nonunion affecting the humerus, the endomedullary nail covered with cement broke at the nonunion site at the time of extraction, but it was easily removed. There was no case of cement-nail debonding (separation of the cement from the nail). In 1 patient the culture done in the second and definitive surgical procedure was positive for pseudomonas, this nonunion healed without complications probably because of the association of local vancomycin placed at the time of bone grafting and systemic culture-specific antibiotics. One patient developed a transitory radial nerve neurapraxia with complete recovery 2 months after the surgical procedure. One patient with a nonunion at the distal third of the humerus needed implant removal 22 months after the surgery because of discomfort caused at the level were the radial nerve crossed over the plate. Two patients with bony defects at the ulna diaphysis, in which the implant laid subcutaneous, needed implant removal.

CONCLUSIONS
In the presence of open fractures with bone loss and infected nonunions careful debridement has to be carried out to remove necrotic, infected, and avascular tissues, and earlier implants when present, and after that debridement the surgeon must decide whether the reconstruction will be done in 1 or 2 stages, and the type of stabilization to be used. The combination of local and systemic antibiotic treatment in staged reconstructions of open fractures and infected nonunions of long bones of the upper and lower extremities was developed to decrease the number of surgical procedures and the time needed to control infection and achieve bony union. It allowed avoiding or controlling infection, improving biology at the bone ends and achieving union in all cases of our series. Springer et al28 reported using up to 10.5 g of vancomycin and 12.5 g of gentamicin without adverse effects, and bactericidal levels of elution at 4 months has been reported when combining vancomycin and tobramycin29; there is no established standards to select the type of antibiotics to be used and their optimal dosis recommended in highly contaminated fractures or infected nonunions, as the surgeon must decide according to the patients allergies, earlier bacterial cultures, and most frequently isolated germs. The decision whether to place the spacer intramedullar, at the defect site, or lateral to the affected bone will vary according to: (a) the affected bone, (b) the earlier fixation method, and (c) whether there is a bone defect or good bone contact without bone loss. Placement of cement spacers with antibiotics improves and reduces the time needed to control infection, improves trophism of bone ends and facilitates secondary application and incorporation of bone graft. Although generally 2 surgical procedures are needed, 1 to cure or prevent infection and another to achieve bony union, this approach for complex open fractures with segmental bone loss and for infected nonunions of the long bones of the upper extremities represents a valid treatment alternative and confirms that cement associated with local antibiotics is effective to prevent and combat the infections.

FIGURE 3. A 23-year-old male, farm injury, ipsilateral scapular fracture, and diaphyseal humerus fracture, all stabilized at initial treatment. A, Severe forearm soft tissue lesion, with segmental ulnar nerve and artery loss. B, Radius diaphyseal fracture, ulnar segmental bone loss, and fracture of the radius styloid with dislocation of the wrist. C, An LC-DCP plate was used to stabilize the radius diaphyseal fracture and 2 k-wires to stabilize the styloid fracture, a 2.0-mm K-wire covered with cement was placed in the segmentary defect of the ulna, and the soft tissues were covered with a free parascapular flap. D, x-rays showing bony union after the placement of cancellous autologous bone graft, compacted using a 10-cc syringe, mixed with antibiotics and stabilized with a long 3.5-mm LCP. E, Aesthetic appearance of the upper extremity.
REFERENCES


21. Ring D, Allende C, Jafarnia K, et al. Ununited diaphyseal forearm fractures with segmental defects: plate fixation and autogenous...


