The management of infection in arthroplasty of the shoulder
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The management and outcome of treatment in 42 patients (49 shoulders) with an infected shoulder prosthesis was reviewed in a retrospective multicentre study of 2343 prostheses. The factors which were analysed included the primary diagnosis, the delay between the diagnosis of infection and treatment and the type of treatment. Treatment was considered to be successful in 30 patients (71%). Previous surgery and radiotherapy were identified as risk factors for the development of infection. All patients with an infected prosthesis had pain and limitation of movement and 88% showed radiological loosening. In 50% of the shoulders, the antibiotics chosen and the length of treatment were considered not to be optimal. The mean follow-up was 34 months. Antibiotics or debridement alone were ineffective. In acute infection, immediate revision with excision of all infected tissue and exchange of the prosthesis with appropriate antibiotic therapy gave the best results. Multidisciplinary collaboration is recommended.

Patients and Methods
Between 1991 and 1999, 2343 prostheses were implanted and the patients were recruited for this multicentre study. Table I shows the pathology; 49 patients developed a deep infection. Twenty-two had undergone previous surgery at least once (between one and three procedures); five of these had undergone two operations before the arthroplasty and two had undergone three procedures. Of these 16 prior procedures, ten were themselves revision procedures.

Five patients were lost to follow-up and two died, thus 42 patients were available for clinical and radiological evaluation. The patients were classified according to the time interval between arthroplasty and the diagnosis of infection, according to Sperling et al.¹ In 12 patients the infection was ‘acute’ (diagnosed within two months of surgery), in six ‘subacute’ (diagnosed between two and 12 months of surgery) and in 24 ‘chronic’ (diagnosed at least 12 months following surgery). Among these 24 patients, four infections were considered to be secondary to haematogenous spread, as there was a symptom-free period of more than one year.

There were 19 women and 23 men. The mean age at the time of revision for infection was 64 years (36 to 87), and the dominant shoulder was involved in 36 patients. The mean follow-up was 32 months (12 to 96).

Diagnosis. The diagnosis of infection was based on the following clinical symptoms and investigations: 1) the pres-
ence of a sinus; 2) serum leucocyte count; 3) erythrocyte sedimentation rate; 4) C-reactive protein (CRP); 5) pre-operative and peri-operative joint aspiration cultures and cultures of surgical specimens; 6) loosening of the components on standard radiographs (defined as a complete lucent line >1 mm around one or both components) and periosteal reaction; and 7) three-phase bone isotope scanning.

All infected patients presented clinically with a decreased range of movement and pain.

**Treatment.** We were able to define six groups according to the treatment given. All surgical procedures were conducted with antibiotic prophylaxis. Group 1 received antibiotic therapy only; group 2, resection arthroplasty; group 3, debridement and lavage (either open or arthrosopic); group 4, removal of the prosthesis, and replacement with an antibiotic-loaded cement spacer; group 5, one-stage revision and group 6, a two-stage revision.

Three patients could not be included in any of these groups; one underwent an arthrodesis; one had a plate fixation for a fracture distal to the prosthesis and one had a lavage without debridement and removal of a loose glenoid component. The details of antibiotic administration were recorded including type, dose and duration, varying as they did, with bacteriological analysis.

**Methods of analysis.** The functional results were evaluated according to the score of Constant and Murley. The results of treatment were evaluated using the seven factors listed above. Patients who had no positive criteria were considered to be free from infection. When any doubt existed the patient was regarded as infected. In the final evaluation, the patients were separated into two groups, according to whether the treatment of infection was successful or not. The rates of infection were related to the time of onset (acute, sub-acute, chronic), the primary diagnosis and the type of treatment given.

**Results**

The 49 infected shoulder prostheses represent a rate of infection of 1.8% for primary and 4% for revision procedures. The results of treatment in the 42 patients evaluated at the latest follow-up showed 30 to be free from infection (71%); nine patients had persistent chronic infection and three had possible infection (29%). There was precise information about the antibiotic treatment in only 30 of the 42 patients. The duration of antibiotic treatment after surgery varied with a mean of 3.9 months (0.01 to 16.6) for the entire series. For acute infections it was 1.6 months (0.01 to 2.8), and for both sub-acute and chronic infections it was 5.1 months (0 to 16.6). In 15 patients (50%) this treatment bore no relationship to the bacteria found in cultures, nor to the bony-penetration properties of the antibiotic. In three patients the duration of treatment was less than three weeks. Pre-operative antibiotic treatment prevented identification of the organism in five of six patients, which led to a non-specific post-operative regimen.

### Table II. Functional results for the 42 patients with infection following shoulder replacement arthroplasty

<table>
<thead>
<tr>
<th></th>
<th>Pre-operative mean (range)</th>
<th>Post-operative mean (range)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior forward elevation (degrees)</td>
<td>60 (10 to 130)</td>
<td>74 (10 to 160)</td>
<td>10 to 160</td>
</tr>
<tr>
<td>External rotation 1 (elbow at side) (degrees)</td>
<td>11 (-20 to 80)</td>
<td>14 (-15 to 60)</td>
<td>-15 to 60</td>
</tr>
<tr>
<td>Pain (of 15 points)</td>
<td>4.4</td>
<td>10.8</td>
<td>0 to 15</td>
</tr>
<tr>
<td>Activity (of 20 points)</td>
<td>5.3</td>
<td>9.9</td>
<td>0 to 20</td>
</tr>
<tr>
<td>Mobility (of 40 points)</td>
<td>8.9</td>
<td>14.2</td>
<td>0 to 40</td>
</tr>
<tr>
<td>Strength (of 20 points)</td>
<td>1.6</td>
<td>2.9</td>
<td>0 to 14</td>
</tr>
<tr>
<td>Absolute Constant score (of 100 points)</td>
<td>20.2</td>
<td>37.7</td>
<td>6 to 81</td>
</tr>
</tbody>
</table>

The functional results of all 42 patients showed a mean Constant score of 20 points before revision for infection, and 38 points after (Table II). The mean active elevation was 74°. All patients presented with pain and limitation of movement and 21 had a sinus.

**Laboratory investigations.** A blood profile was obtained in 24 patients. The mean leucocyte count was 7945 cel/ml (5200 to 14 900 cel/ml), the mean ESR was 55 mm/hr (18 to 118) and the mean CRP was 45 mg/l (0.5 to 333). Pre-operative aspiration of the joint, carried out in eight patients, produced a positive culture in four.

There was radiographic evidence of loosening in 37 of 49 infected prostheses (75.5%); in ten there was loosening on the humeral side, 15 showed loosening on the glenoid side and 12 showed loosening on both sides.

Three-phase bone isotope scanning was undertaken in 11 patients; it was positive in eight in whom bacteria were identified from peri-operative cultures. One patient, where no bacteria were found from peri-operative cultures had received pre-operative antibiotic therapy and in two patients, data were missing. Bone isotope scanning was negative in three patients, of whom two had identified bacteria (Corynebacterium and *Staphylococcus epidermidis*). In the third patient no organism was found, but this patient had received pre-operative antibiotic therapy.

The bacteria identified from peri-operative cultures were *Staph. epidermidis* (nine), *Propionibacterium acnes* (seven), *Staphylococcus aureus* (five), coagulase-negative staphylocci (three), Corynebacterium (three), Streptococcus (two) and *Staphylococcus albus* (one). In two patients multiple organisms were found. In six patients no organism was found and in eleven data were not available.

**Relationship to time.** Acute infection was diagnosed in 12 patients at a mean interval of one month (0.23 to 1.85) following surgery. Despite the early diagnosis (Table III), the mean delay before reoperation was relatively long, nine months (0.26 to 30). Four patients had a debridement and washout; two had a resection arthroplasty; two had a two-stage revision; two underwent removal of the prosthesis with implantation of a permanent spacer; one received antibiotic treatment alone and one underwent osteosynthesis of a humeral fracture with debridement and washout. Of these
12 patients, four required further surgery. At final follow-up, there was persistent infection in one patient and another had continuing disabling pain.

Subacute infection was diagnosed in six patients (Table III) with a mean interval of 6.4 months (2.9 to 11.8) and a delay to reoperation of ten months (3.6 to 18.7). One patient received antibiotic treatment alone; two had an open debridement and washout; one a one-stage revision, and two had a two-stage revision. Further surgery was required in one patient. At the final follow-up two patients had persistent infection.

Chronic infection was diagnosed in 24 patients (Table III) with a mean interval of 24 months (12 to 43.3) and a delay to reoperation of 32.7 months (14 to 54.7). Three patients received antibiotic treatment alone; eight had a resection arthroplasty; one an open debridement and washout; one an arthroscopic washout; one a one-stage revision; seven a two-stage revision; one underwent removal of the prosthesis with implantation of a permanent spacer; one an arthrodesis and one had a loose glenoid component removed with debridement and washout. Further surgery was required in two patients. At the final follow-up, six patients had persistent infection and two patients remained under suspicion.

Of the patients with a chronic infection, at least four had been infected by an haematogenous route, with a mean delay to diagnosis of 17 months and reoperation of 33 months (Table III). A two-stage revision was carried out in one patient within a week of the diagnosis. The other three patients underwent revision between one and 34.6 months, undergoing respectively a two-stage revision, a resection arthroplasty and a removal of the prosthesis with implantation of a permanent spacer.

**Relationship to primary pathology.** The outcome related to the primary pathology is shown in Table IV. Certain diagnoses imply an increased risk of infection; in particular, avascular necrosis secondary to radiotherapy carries a 25% incidence of infection. Previous surgery is a risk factor for infection as demonstrated by the high percentage of infection seen after shoulder arthroplasty undertaken for failed previous surgery.

**Relationship to the method of management.** For the five patients who received antibiotic treatment alone (group 1), the mean Constant score was 23 at the time of diagnosis and rose to 49 at the latest follow-up (Table V). Eradication of the infection was achieved in two patients, two remained infected and one possibly infected. In these five patients the infections were sub-clinical with negative biochemical markers.
For the ten patients who underwent resection arthroplasty (group 2), the mean Constant score was 16 at the time of diagnosis and rose to 30 at the latest follow-up. This increase was mainly due to improvement in the pain score, which rose from 3 to 11.5 points; mobility increased from 8 to 10.5. Eradication of infection was achieved in seven patients, two remained infected and one possibly infected. None of these patients required further surgery.

For the six patients treated by open debridement and lavage and the two by arthroscopic washout (group 3), no improvement in function was found. The Constant score rose from 26.5 at the time of diagnosis to 27 at the latest follow-up. Infection was eradicated in seven patients and persisted in one. Five required further surgery. Of the six open washouts, four were undertaken late (with a mean delay of 16.4 months) and these remain infected. The two successful procedures were undertaken at eight days. The two arthroscopic washouts undertaken at 3.3 and 15.5 months failed to eradicate the infection. They subsequently required open debridement and a resection arthroplasty.

For the three patients who underwent one-stage revision (group 4), the mean Constant score was 35.5 at the time of diagnosis and improved to 66 at the latest follow-up. The mobility score was 24 at follow-up, which was the highest amongst the six groups. The infection was eradicated in all and none required further surgery. The causative organisms were *Staph. epidermidis* (one), *Staph. albus* (one) and *Propioni bacterium acnes* (one).

For the ten patients (group 5) who underwent two-stage revision (Fig. 1), the mean Constant score rose from 15 to 35 points. The mobility score was 13 at follow-up. The infection was eradicated in six patients, three remain infected and one possibly infected. One required further surgery.

In three patients (group 6) the prosthesis was replaced by a spacer (Fig. 2). The mean Constant score rose from 26 to 38. The infection was eradicated in all.

**Discussion**

The incidence of infection in this series, 1.86% for primary and 4% for revision prostheses, is comparable with that found in the literature which varies between 0% and 0.9% for primary prostheses and 0% and 15.4% for revision prostheses. The treatment of infection was successful in 71% of patients which is inferior to other series of infected shoulder prostheses and inferior to the outcome after the treatment of infected hip and knee prostheses. This was, however, a multicentre study comprising 57 surgical teams without a standardised treatment protocol.

We found that patients with an acute infection were reoperated upon late. Even though the infection was diagnosed before the second month, the mean delay before reoperation was nine months, which may explain why 20% of the
patients were still infected at the latest review (Table III). Acute infection compromises the function of a shoulder arthroplasty; the mean Constant score was only 38 at the latest review. By contrast, in the two patients who were reoperated with an early washout on the eighth day postoperatively, function was preserved and the infection eradicated.

Secondary haematogenous spread with early diagnosis and treatment gave similar results as acute infections. A mean delay between the diagnosis of secondary infection and its treatment was 15 months. Only one patient was treated within a week of infection by two-stage revision.

The clinical tendency was to misdiagnose chronic infection or if the diagnosis was made, to delay before reoperating. This ‘wait and see’ approach is revealed in this series with a mean delay of further surgery of two years. An infected shoulder prosthesis is less disabling than an infected hip or knee prosthesis, because scapulothoracic movement is preserved and the arm needs to bear no weight. Most patients with an infected shoulder prosthesis came back for review because of stiffness or pain, without clinical signs of infection. These features should raise suspicion of infection.

In ten patients, the surgeon opted to undertake a resection arthroplasty immediately. In three others, a resection arthroplasty was carried out after the failure of an earlier procedure. Therefore, 13 patients (30%) underwent a resection arthroplasty which corresponds with other series. A resection arthroplasty does not, however, guarantee eradication of infection which persisted in 30%. Furthermore, resection gives a poor functional result with a mean Constant score of 30 points at the latest review (Table V).

If after successful treatment of an associated infection a hip or knee prosthesis has some limitation of movement adequate function is usually retained, whereas adequate function of the shoulder requires an excellent range of movement. In the light of the results presented in our series, it seems that prosthetic revision in one or two stages with a short delay gives the best compromise between the eradication of infection and the preservation of function. The limitation of this technique is that a badly damaged rotator cuff does not allow the reimplantation of an unconstrained prosthesis.

In order to diagnose and confirm an infection some authors recommend pre-operative aspiration, which allows identification of the causative organism and appropriate antibiotic selection. In our study, only eight pre-operative aspirations were made, with four positive results; three one-stage revisions were done without knowledge of the organism. Pre-operative antibiotic treatment prevented identification of the organism in five of six patients and thus required blind post-operative antibiotic treatment. Bacteria sensitive to antibiotics have been successfully suppressed allowing a one-stage revision to be undertaken. In this series, we found a number of infections due to propionibacterium in accordance with the literature.

We were able to obtain precise information concerning the antibiotic treatment in only 30 patients and in 15 of these the regimen was less than ideal with regard to duration, sensitivity spectrum or bony penetration. For example, aminoglycosides such as Gentamicin are active in situ as in a spacer, but do not have good bony penetration when prescribed systemically. With regard to the choice of antibiotic, a multidisciplinary approach with microbiologists is essential.

Infection of a shoulder prosthesis compromises the functional result with a mean of 38 points on the Constant score at the latest review. This was due to a prolonged delay between the diagnosis of infection and further surgery, inadequate surgical procedures and inappropriate antibiotic therapy, leaving persistent infection or possible infection in 29% of cases. Antibiotic treatment or debridement alone did not eradicate infection.

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References