One-stage revision for patients with a chronically infected reverse total shoulder replacement

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We retrospectively reviewed 11 consecutive patients with an infected reverse shoulder prosthesis. Patients were assessed clinically and radiologically, and standard laboratory tests were carried out. Peroperative samples showed Propionibacterium acnes in seven, coagulase-negative Staphylococcus in five, methicillin-resistant *Staphylococcus aureus* in one and Escherichia coli in one. Two multibacterial and nine monobacterial infections were seen. Post-operatively, patients were treated with intravenous cefazolin for at least three days and in all antibiotic therapy was given for at least three months. Severe pain (3 of 11) or severe limitation of function (3 of 11) are not necessarily seen. A fistula was present in eight, but function was not affected. All but one patient were considered free of infection after one-stage revision at a median follow-up of 24 months, and without antibiotic treatment for a minimum of six months. One patient had a persistent infection despite a second staged revision, but is now free of infection with a spacer. Complications included posterior dislocation in one, haematoma in one and a clavicular fracture in one. At the most recent follow-up the median post-operative Constant-Murley score was 55, 6% adjusted for age, gender and dominance.

A one-stage revision arthroplasty reduces the cost and duration of treatment. It is reliable in eradicating infection and good functional outcomes can be achieved.
osteoarthritis with a cuff tear in four, post-traumatic osteoarthritis with malrotation in one, post-traumatic ankylosis in one and ankylosing spondylitis in one.

The affected shoulder had been operated on a median of four times (2 to 7) prior to the one-stage revision procedure. In this group six patients were initially treated at our centre and five elsewhere. Other risk factors were dental extraction without antibiotic prophylaxis (patient 2), cardiovascular disease (patient 7) and chemotherapy with a central venous catheter (patient 9) (Table I). Most of the patients were treated elsewhere for their initial pathology and were referred for the treatment of the deep peri-prosthetic infection. All patients presented with an obvious clinical picture of infection with swelling, redness or a sinus. They were classified into three groups: acute infection, subacute infection and late infection.10 In three patients the time between the primary arthroplasty and diagnosis of infection was less than three months (acute infection). All three had been treated unsuccessfully by debridement with retention of the prosthesis. In seven patients the time to diagnosis was between three and 12 months (subacute infection). In one patient the time to diagnosis was more than 12 months (late infection) (Table II). The median time between the primary arthroplasty and the diagnosis of infection was four months (2 to 13). The median time to exchange surgery was 15 months (3 to 30) (Table I). The length of this interval, median time to exchange surgery (15 months), was due to the good function of the patients with a fistula and the unsuccessful treatment with antibiotics and/or pulsatile lavage prior to referral to our centre.

Patients with a painful, swollen, red, tender and stiff shoulder and those with a fistula were investigated further. Standard laboratory tests such as the CRP, ESR and WBC were carried out. Anteroposterior and axial radiographs were assessed for prosthetic loosening, dislocation and osteomyelitis. If the clinical picture and the laboratory tests indicated an infection, surgery was undertaken. When there was a fistula without altered laboratory tests, operation was also undertaken. Pain, activities of daily living, range of movement and strength were assessed using the Constant-Murley score (CS).18 During the operation between four and eight samples were taken from the tissue around the baseplate and cultured so that the antibiotic sensitivities could be determined. Post-operatively, serial anteroposterior and axial radiographs, and determination of the CRP, ESR and WBC were undertaken regularly. The functional outcome was assessed using the CS.

Operative technique. All patients are operated on, under general anaesthesia and positioned supine in the beach-chair position. Whenever possible, the skin incision follows the previous one via the deltopectoral groove. If there is a fistula it is excised with wide resection of the surrounding skin. A slightly curved clavicular osteotomy (Fig. 1) is performed parallel to the insertion of the deltoid muscle, as described by Redfern, Wallace and Beddow.19 The osteotomy fragment is hinged on the acromioclavicular joint (Fig. 2) to improve superior access to the shoulder. The interval between the deltid and pectoralis major is developed lateral to the cephalic vein, if still present. The lateral side of the coracoid process is released of all fibrotic and infected tissue until the superior tubercle of the glenoid and the glenosphere are identified. All the subacromial tissue is thoroughly resected, creating space for the reverse prosthesis to move. The polyethylene inlay is disengaged, after which the glenosphere is disconnected from its baseplate, creating more space and allowing adequate movement of the upper arm to ease further resection of infected tissue. The entire humeral epiphysis is then dissected until fresh bleeding bone is seen all around the prosthesis. This includes a thorough synovectomy and removal of prominent inferior bone. The humeral prosthesis is then removed using the standard extractor. If necessary, a proximal humeral longitudinal osteotomy is performed to allow extraction. We always need to remove some bone around the prosthetic epiphysis to enhance correct positioning of

<table>
<thead>
<tr>
<th>Number</th>
<th>Age (yrs)</th>
<th>Gender</th>
<th>Initial aetiology</th>
<th>Risk factors</th>
<th>Time to exchange surgery (mths)</th>
<th>Follow-up (mths)</th>
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<tr>
<td>1</td>
<td>62</td>
<td>M</td>
<td>Post-traumatic OA &amp; CTA</td>
<td>Asthma, previous shoulder surgery</td>
<td>3</td>
<td>13</td>
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<td>2</td>
<td>51</td>
<td>M</td>
<td>Ankylosing spondylitis (Bechterew)</td>
<td>Dental extraction without AB prophylaxis</td>
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<td>3</td>
<td>79</td>
<td>M</td>
<td>Post-traumatic OA &amp; CTA</td>
<td>Previous shoulder surgery</td>
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<td>24</td>
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<tr>
<td>4</td>
<td>53</td>
<td>M</td>
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<td>Previous shoulder surgery</td>
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<td>12</td>
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<td>77</td>
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<td>CABG &amp; AMI</td>
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<td>M</td>
<td>CTA &amp; OA</td>
<td>Melanoma vs jugularis catheter</td>
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<td>36</td>
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<td>8</td>
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<td>Previous shoulder surgery</td>
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<td>Melanoma vs jugularis catheter</td>
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<td>Post-traumatic OA &amp; CTA</td>
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<tr>
<td>11</td>
<td>74</td>
<td>M</td>
<td>CTA &amp; OA</td>
<td>CABG &amp; AMI</td>
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* OA, osteoarthritis; CTA, cuff tear arthropathy
† AB, antibiotic; CABG, coronary arterial bypass graft; AMI, acute myocardial infarction
the extractor for the humeral prosthesis. Preparation of the medullary canal requires a radical excision of infected tissue, including all the cement if present. The humeral shaft and its surroundings are irrigated with pulsatile lavage. The osteotomy is closed with one or two Ticron 5 (Tyco Health Care, Norwalk, Connecticut) cerclage sutures. No bony protection of the humeral shaft was needed to prevent further fracturing of the humeral diaphysis. The glenoid baseplate is removed with a torque-wrenched T-handle to prevent further distortion of the glenoid process. All the inflamed tissue around the baseplate is then resected. Special attention is paid to the inferior part of the glenoid, where extensive synovitis is usually seen, especially in the presence of severe scapular notching. This pseudo-capsule is then detached from the lateral scapular pillar, which always needs to be identified for correct placement of the inferior screw of the new baseplate. Resection of a scapular spur may be necessary.

A new glenoid baseplate is implanted, in slight varus angulation, to increase prosthetic contact between the humeral and glenoid components. Initially we used a non-hydroxyapatite (HA)-coated baseplate with antibiotic-

Table II. Relationship between presentation and outcome

<table>
<thead>
<tr>
<th>Number</th>
<th>Infection acute/late</th>
<th>Per-operative bacteria</th>
<th>Draining sinus (Y/N)</th>
<th>Pre-operative</th>
<th>Time to normalisation of CRP and ESR (mths)</th>
<th>Complications</th>
<th>Adjusted CS</th>
<th>CS</th>
<th>Adjusted CS</th>
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<td>1 Acute</td>
<td>S. aureus</td>
<td>Y</td>
<td>1.9</td>
<td>35</td>
<td>4</td>
<td>45</td>
<td>54</td>
<td>55</td>
<td>66</td>
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<td>2 Acute</td>
<td>Propionbact. sp.</td>
<td>Y</td>
<td>3.6</td>
<td>35</td>
<td>7</td>
<td>55</td>
<td>58</td>
<td>61</td>
<td>64</td>
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<tr>
<td>3 Subacute</td>
<td>Propionbact. spec./E. Coli CNS†</td>
<td>Y</td>
<td>2.0</td>
<td>/</td>
<td>1</td>
<td>37</td>
<td>50</td>
<td>40</td>
<td>54</td>
<td></td>
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<tr>
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<td>Propionbact. sp.</td>
<td>N</td>
<td>2.6</td>
<td>20</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>14</td>
<td>16</td>
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<tr>
<td>5 Subacute</td>
<td>Propionbact. sp. Y</td>
<td></td>
<td>7.5</td>
<td>73</td>
<td>2</td>
<td>55</td>
<td>61</td>
<td>63</td>
<td>86</td>
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<tr>
<td>6 Late</td>
<td>CNS</td>
<td>Y</td>
<td>0.4</td>
<td>8</td>
<td>3</td>
<td>22</td>
<td>31</td>
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<td>7 Subacute</td>
<td>Propionbact. sp.</td>
<td>Y</td>
<td>0.3</td>
<td>21</td>
<td>1</td>
<td>61</td>
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<td>74</td>
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<tr>
<td>8 Subacute</td>
<td>CNS</td>
<td>N</td>
<td>1.0</td>
<td>15</td>
<td>1</td>
<td>40</td>
<td>54</td>
<td>64</td>
<td>85</td>
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<tr>
<td>9 Subacute</td>
<td>Propionbact. sp</td>
<td>Y</td>
<td>0.2</td>
<td>/</td>
<td>1</td>
<td>63</td>
<td>67</td>
<td>81</td>
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<tr>
<td>10 Subacute</td>
<td>CNS</td>
<td>Y</td>
<td>1.5</td>
<td>9</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>28</td>
<td>28</td>
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<tr>
<td>11 Subacute</td>
<td>Propionbact. sp.</td>
<td>N</td>
<td>9.2</td>
<td>47</td>
<td>Persisted elevated</td>
<td>57</td>
<td>75</td>
<td>55</td>
<td>72</td>
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*CS, Constant-Murley score
† CNS, coagulase-negative Staphylococcus
impregnated cement, but subsequently employed four screws to fix a standard cementless HA-coated baseplate. A gentamycin-impregnated membrane (Duracoll, Innocoll Inc., Athlone, Co. Westmeath, Ireland) was always placed between the baseplate and the glenosphere. After a trial reduction the largest glenosphere (42 mm) is mounted on the baseplate. The humeral component is inserted with gentamycin-impregnated cement. Joint tensioning and stability assessment is performed with particular care, using trial reductions, and the polyethylene inlay is adjusted to obtain maximum stability. The prosthesis is considered stable when no opening wedge can be created between the glenosphere and the polyethylene at the time of the mobility testing. Inadequate soft-tissue tensioning is overcome using a modular humeral lengthener rather than a retentive cup. The clavicular osteotomy is closed with three Dexon (Syneture) threads, with each thread going twice around the clavicle (Fig. 3) to allow immediate active movement. A standard layered closure is used without a suction drain, in order to maximise the concentration of the local antibiotics.

Antibiotic regimen. Initially cefazolin 2 g was given intravenously every eight hours. When the sensitivities of the cultured specimens were available, five patients were treated with cefazolin 3 × 2 g/day, three with cefazolin 3 × 2 g/day combined with cefuroxime 3 × 1.5 g/day, two with vancomycin 2 g/day and one with vancomycin 2 g/d in combination with cefuroxime 3 × 1.5 g/d. Intravenous antibiotic therapy was given for at least three days and was switched to oral treatment when the patient was discharged. Patients were discharged if no wound complications occurred and their inflammatory markers were improving. The oral regimes were amoxycillin-clavulanate 3 × 2 g/day in three patients, cefaclor 3 × 500 mg/day in three, linezolid 2 × 600 mg/day in two, clindamycin 3 × 600 mg in one, clindamycin 3 × 600 mg combined with linezolid 2 × 600 mg/day in one, and cotrimoxazole 2 × (sulfamethoxazole 800 mg + trimethoprim 160 mg)/day in one. The antibiotic therapy was stopped when the CRP and ESR had returned to normal for six weeks, the post-operative course was uneventful and the operation wound was healed. The median duration of antibiotic therapy was for three months (three to nine).

Delta 3.2 RSR (Depuy, Warsaw, Indiana) was used in six patients and the DeltaXtend RSR in five. A proximal humeral osteotomy was necessary to remove the humeral component in seven cases. In the first five patients a custom-made non-HA-coated baseplate was fixed with a non-approved fixation method. This baseplate had the same dimensions as the conventional baseplate. It was fixed with four screws and gentamycin-impregnated cement around the central peg. In six patients an HA-coated non-cemented conventional baseplate was implanted. In all patients a 42 mm glenosphere was used. The polyethylene inlay had a 3 mm (two patients), 6 mm (five patients) or 9 mm (four patients) lateralisation. A humeral lengthener was required in seven patients: in one, two lengtheners were used. In all patients the humeral component was introduced with gentamycin-impregnated cement (Palacos, Zimmer Inc., Warsaw, Indiana).

Post-operative rehabilitation. The post-operative management after RSR is individualised. An adduction sling is used only for comfort, and immediate active exercises are allowed. Continuous passive movement is started on the first post-operative day with a shoulder Kinetec machine up to the limit of pain. Isometric elbow, wrist and hand exercises are performed to prevent stiffness and minimise swelling. Patients are instructed not to make sudden movements with the operated arm. Three weeks after surgery supervised active mobilisation begins in the hydrotherapy pool. A rehabilitation programme is continued for three months.

Results

Between March 2005 and June 2007, 11 consecutive patients with a deep periprosthetic infection of an RSR were treated with a one-stage revision. All but one (patient 11) were free of infection and a fistula at a median follow-up of 24 months (12 to 36), and had been without antibiotic treatment for a minimum of six months.

Before operation a draining fistula was present in eight patients of whom only one (patient 10) had severe limitation of function and severe pain. The median pre-operative CS for the fistula group was 45 (3 to 63) and the adjusted score for age, gender and dexterity (aCS) was 54% (3% to 73%). In three patients there was no draining fistula. They had severe limitation of function and severe pain, except patient 11, who had little pain but considerable swelling and only fair function. The median pre-operative CS for the non-fistula group was 42.5 (5 to 57) and the aCS was 54% (5% to 75%) (Table II). Local temperature, tenderness and erythema were not always present.

The pre-operative radiographs did not show any signs of loosening. This finding was confirmed intra-operatively, where none of the components were loose. The post-operative radiographs showed no signs of infection or prosthetic loosening in any patient.
Pre-operatively, the level of CRP was elevated in eight patients. The median CRP was 1.9 mg/dl (0.2 to 9.2) (reference < 0.5 mg/dl) (Table II). The pre-operative ESR was elevated in seven. In all the cases where the CRP or ESR was not elevated or not available, a fistula was present. The median ESR was 21 mm/hr (8 to 73) (reference 15 mm/hr) (Table II). The pre-operative WBC was a median of 7380 μl (4890 to 8640) (reference 4 to 10 x 10⁶).

The pre-operative samples identified a multibacterial infection in patients 3 and 5. The causal micro-organisms were Propionibacterium acnes, coagulase-negative Staphylococcus and E. coli in patient 3, and P. acnes and coagulase-negative Staphylococcus in patient 5. A monobacterial infection was identified in per-operative samples in the other nine patients. Five shoulders had a P. acnes infection, three a coagulase-negative Staphylococcus infection and one a methicillin-resistant Staph. aureus infection (Table II).

Early complications (< 2 months): were seen in three patients, patient 5 had a posterior dislocation five weeks after revision, which was successfully treated with closed reduction. Patient 7 had a post-operative haematoma that was washed out and debrided, and patient 11 had a fracture of the clavicle in a fall one month post-operatively. Open reduction and internal fixation was performed. Four months later his revised RSR was infected. The per-operative samples identified Propionibacterium spp. A gentamycin-laden cement spacer was inserted and when the infection had resolved a reverse prosthesis was inserted, unfortunately without definitive cure. Propionibacterium species were cultured again and the patient was treated with a further gentamycin spacer. With this spacer he has had no evidence of infection for over ten months. All the data used for this patient were obtained before his two-stage revision.

Outcome was measured using the CS. Pre-operatively the median CS was 45 (3 to 63), the aCS was 54% (5% to 67%). The mean CS at the latest follow-up was 55 points (14 to 81) and 66% (5% to 86%) for the aCS (Table II). The mean gain of the CS was 10 (-2 to 28) and 12% (-3% to 31%) for the aCS.

Patients with a high pre-operative CS and aCS scores had high post-operative scores. This could be seen in patients 1, 2, 3, 5, 7, 8, 9 and 11, where the median pre-operative CS was 45 (37 to 63) and the median aCS was 56% (50% to 75%) (Table II). In these patients the median post-operative CS was 58 (40 to 81) and the median aCS was 69% (54% to 89%) (Table II). Patients 4, 6 and 10 had a low pre-operative CS and aCS, with a median CS of 3 (3 to 22) and a median aCS of 5% (3% to 31%) (Table II). In these patients the post-operative CS and aCS stayed low. The median post-operative CS was 28 (14 to 29) and the aCS was 28% (16% to 41%) (Table II).

Discussion

Infection is a rare complication of shoulder arthroplasty, more frequent in RSR (5.1%) than in TSR (0.7%). The options for treatment are a long course of intravenous antibiotic therapy, arthroscopic lavage or open debridement with retention of the prosthesis, resection arthroplasty, one-stage revision, two-stage revision, arthrodesis or amputation. The two-stage procedure is the best in terms of functional outcome and eradication of infection.

No specific literature is available on the treatment of infected RSR, and a similar approach to that used for an infected anatomical TSR has been employed. This study shows favourable results for function and abolition of infection with a one-stage revision arthroplasty followed by a long period of antibiotic treatment. A one-stage revision of an anatomical TSR has proved effective for the treatment of infection, but not to restore good function. A probable explanation might be that debridement of the rotator cuff impairs its function. Revising an anatomical TSR to a reversed design can overcome this problem and is advocated by Cuff et al, who found no statistical difference in function between the two-stage and one-stage revision groups. They attribute this success to aggressive debridement of the infected shoulder. They resected all the infected tissues, including the rotator cuff, but cautiously preserved the deltoid muscle. An RSR can provide good shoulder function with only a functioning deltoid. We believe that the good function is due to the design of the prosthesis, which does not require a rotator cuff. Thus, the surgeon can perform a thorough resection of the rotator cuff without compromising function. The more thorough the resection of infectious tissue, the smaller the chance of the infection reoccurring. The restoration of a stable fulcrum using an RSR has been shown in the treatment of tumours of the shoulder. Apart from the beneficial effect in the treatment of infection, the radical resection creates space for the reversed prosthesis, which has a hinged instead of a spinning rotation.

In contrast to the findings of Cuff et al, we only had two early complications, one haematoma and one dislocation. They were successfully treated with an early arthroscopic lavage and closed reduction with an abduction pillow for six weeks, respectively. The third complication, a fractured clavicle due to a fall, may be a consequence of the clavicular osteotomy which we used.

Our results indicate that good pre-operative function is predictive of good post-operative function, with little or no pain. Pre-operative stiffness is a negative predictive factor for the final outcome. The evidence for this statement can be gleaned from Table II but it does not reach statistical significance owing to the small sample size.

In this study of patients with clinically overt signs of infection, two distinct clinical manifestations of an infected RSR were encountered. The first resembles an infected anatomical TSR with pain, swelling and tenderness, and severely impaired function. The second is a well-functioning shoulder without pain but with a draining fistula. Treatment of the second group with a two-stage revision appears unnecessary. A single-stage revision avoids the risk of erosion of the glenoid process by the antibiotic spacer.
shortens the treatment significantly, with less patient morbidity, lower medical costs and a shorter duration of disability.

As more patients are treated with RSR it is to be expected that the number of infections will also increase. We have demonstrated that a one-stage revision for RSR is reliable in eradicating infection, and good functional outcomes can be achieved. The Constant-Murley scores of both our groups increased. The weakness of this study is that the series is small, retrospective, and with a short follow-up. All patients are still under close follow-up to assess possible recurrence of the infection.

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References