The Delta III reverse shoulder replacement for cuff tear arthropathy
A SINGLE-CENTRE STUDY OF 50 CONSECUTIVE PROCEDURES

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The combination of an irreparable tear of the rotator cuff and destructive arthritis of the shoulder joint may cause severe pain, disability and loss of independence in the aged. Standard anatomical shoulder replacements depend on a functioning rotator cuff, and hence may fail in the presence of tears in the cuff. Many designs of non-anatomical constrained or semi-constrained prostheses have been developed for cuff tear arthropathy, but have proved unsatisfactory and were abandoned. The DePuy Delta III reverse prosthesis, designed by Grammont, medialises and stabilises the centre of rotation of the shoulder joint and has shown early promise. This study evaluated the mid-term clinical and radiological results of this arthroplasty in a consecutive series of 50 shoulders in 43 patients with a painful pseudoparalysis due to an irreparable cuff tear and destructive arthritis, performed over a period of seven years by a single surgeon. A follow-up of 98% was achieved, with a mean duration of 39 months (8 to 81). The mean age of the patients at the time of surgery was 81 years (59 to 95). The female to male ratio was 5:1. During the seven years, six patients died of natural causes. The clinical outcome was assessed using the American Shoulder and Elbow score, the Oxford Shoulder Score and the Short-form 36 score. A radiological review was performed using the Sirveaux score for scapular notching.

The mean American Shoulder and Elbow score was 19 (95% confidence interval (CI) 14 to 23) pre-operatively, and 65 (95% CI 48 to 82) (paired \textit{t}-test, \( p < 0.001 \)) at final follow-up. The mean Oxford score was 44 (95% CI 40 to 51) pre-operatively and 23 (95% CI 18 to 28) (paired \textit{t}-test, \( p < 0.001 \)) at final follow-up. The mean maximum elevation improved from 55° pre-operatively to 105° at final follow-up. There were seven complications during the whole series, although only four patients required further surgery.

Rotator cuff tear arthropathy\(^1\) is present in 2% of the ageing population ( \( \geq 70 \) years old) and can result in severe pain, with a pseudoparalysed arm and difficulty in performing daily activities. Neer, Craig and Fukuda\(^2\) first coined this term in 1983. They described patients with arthritis and massive tears of the rotator cuff leading to superior subluxation of the head of the humerus, acetabularisation of the glenoid and femoralisation of the humerus. The modern concept of cuff tear arthropathy is a combination of arthritis and a massive cuff tear where the joint may remain concentric (Seebauer type 1) or have superior escape (Seebauer type 2).\(^3\)

The initial designs of constrained reverse shoulder replacements (Fenlin, Gerard, Kessel, Kolbel, Liverpool, Neer) had high failure rates and were withdrawn from the market. In 1981, Grammont introduced the concept of a non-constrained reverse prosthesis.\(^4\) The biomechanical concept was that medialisation of the humeral centre of rotation would improve the lever arm and the strength of deltoid, and its distal placement would restore the length-tension curve of the deltoid. Medialising the centre of rotation would reduce the shear forces on the glenoid, preventing loosening. The prosthesis was self-centring, thereby avoiding dislocation of the non-constrained surfaces (Fig. 1). In 1983 he first implanted the ‘Ovoid’ reversed polarity replacement, and in 1986 the prosthesis was modified to a metal or ceramic ball, initially two-thirds of a sphere and 42 mm in diameter, bearing against a plastic trumpet. The reamed glenoid fitted within the metal ball and was fixed with bone cement. However, this form of fixation failed to withstand prolonged use, and from 1991 a second-generation version was used, with a Morse
taper to attach the glenosphere to the baseplate, locked in place with a central grub screw. This design has remained essentially unchanged for 15 years as the Delta III prosthesis (DuPuy International, Leeds, United Kingdom). 5,6

There are few published series of the results of the Grampont reversed polarity shoulder replacement (Table I). Those studies that appear to have sufficient numbers from which to draw sound conclusions are often from various centres with many surgeons, 7,8 each contributing a handful of cases. Others are from a single surgeon treating patients with varying problems, 9,10 including revision surgery, the sequelae of fractures or tumours as well as cuff tear arthropathy. Most studies show good functional outcomes, but have described high levels of complications because of the heterogeneous mix of pathologies. This paper describes the experience of a single surgeon performing the Grammont (Delta III) reversed polarity replacement for cuff tear arthropathy over a period of seven years in a district general hospital.

**Patients and Methods**

Between December 1999 and January 2006, 50 shoulders in 43 patients with rotator cuff arthropathy were replaced by the senior author (TDB) using the Delta III reverse polarity shoulder replacement. The mean age of the patients was 81 years (59 to 95). There were seven men and 36 women. Of these 43 patients, 24 also had a cuff tear in the opposite shoulder. Joint replacements in the lower limb had been carried out in eight patients, and many had ongoing medical problems.

**Surgical technique.** The operations were carried out under general anaesthesia with a scalene block when not contraindicated. In the first 12 patients a superior deltoid split approach was used. Good exposure of the inferior glenoid is critical to the success of this procedure, so as to place the baseplate on the glenoid as inferiorly as possible, and this was difficult to achieve with the deltoid split approach. For this reason the surgical approach was changed to an extended deltopectoral approach for the remaining shoulders. This involves dissection of the quadrilateral space to expose the posterior circumflex vessels and the axillary nerve. This neurovascular bundle is looped with a silastic sling and protected while the inferior and posterior capsule is divided, so that the shaft of the humerus can be translated backwards to gain sufficient exposure of the glenoid for implantation of the uncemented baseplate. In six of the seven men a 42 mm glenosphere, humeral neck and polyethylene liner were used, and in one man and all of the

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**Table I. Single institution studies of more than 20 Delta III prostheses**

<table>
<thead>
<tr>
<th>Authors</th>
<th>CTA</th>
<th>Revision</th>
<th>Follow-up</th>
<th>Age (yrs)</th>
<th>CS*</th>
<th>Elevation (°)</th>
<th>Re-operation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renaud et al 29</td>
<td>21</td>
<td>-</td>
<td>13</td>
<td>67</td>
<td>67/111</td>
<td>-162</td>
<td>10</td>
</tr>
<tr>
<td>Vanhove and Beugnies 29</td>
<td>32</td>
<td>-</td>
<td>31</td>
<td>na</td>
<td>na/60</td>
<td>na</td>
<td>6</td>
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<tr>
<td>Seebauer et ala</td>
<td>7/57</td>
<td>7</td>
<td>18</td>
<td>70.1</td>
<td>94%</td>
<td>145</td>
<td>4</td>
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<tr>
<td>Boileau et al3</td>
<td>21</td>
<td>19</td>
<td>40</td>
<td>na</td>
<td>17/59</td>
<td>55/121</td>
<td>13</td>
</tr>
<tr>
<td>Werner et al7</td>
<td>17</td>
<td>41</td>
<td>na</td>
<td>68</td>
<td>29/64</td>
<td>42/100</td>
<td>39</td>
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<td>Wall et al10</td>
<td>59</td>
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<td>Weissinger et al31</td>
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<td>-</td>
<td>45</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>8</td>
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<tr>
<td>Current study</td>
<td>50</td>
<td>-</td>
<td>49</td>
<td>81</td>
<td>17/59</td>
<td>55/105</td>
<td>8</td>
</tr>
</tbody>
</table>

* CTA, cuff tear arthropathy
† CS, Constant score
‡ na, not available

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**Fig. 1a**
Diagrams showing the biomechanics of a) the normal functioning deltoid: the fulcrum and centre of rotation and normal length tension curves for deltoid (y) and supraspinatus (x) are shown, b) the shoulder with cuff tear arthropathy: the loss of supraspinatus results in loss of the fulcrum, a defunctioned deltoid (y) and pseudoparalysis of the arm, and c) the reverse shoulder prosthesis: the centre of rotation is placed medially and distally (m), restoring the fulcrum and thereby the power of the deltoid.
women a 36 mm implant was used. In 14 patients an uncemented hydroxyapatite coated stem was inserted; the rest were cemented.

**Methods of assessment.** Clinical. All the patients were assessed before operation using the American Shoulder and Elbow Surgeons (ASES) score,\textsuperscript{11} and Oxford Shoulder Score (OSS),\textsuperscript{12} were continually monitored, and then reviewed by a research surgeon (MAN), who had not been involved with their surgery, at a mean of 39 months (8 to 81) post-operatively. They were evaluated by clinical examination, the ASES score, the OSS, the Short-form 36 (SF-36) and with a radiological review.

The ASES\textsuperscript{11} score is a patient-derived assessment which is corrected to give a score from zero (the worst possible) to 100 (the best possible). The OSS\textsuperscript{12} is a verified subjective patient-derived score with a best of 12 and a worst of 60. Pain was quantified pre- and post-operatively using the visual analogue score (VAS) component of the ASES score.

The mean age of the patients at the time of implantation was 81 years (59 to 95). During the seven years of the study six patients died of unrelated causes. A 98% follow-up was achieved. All survivors were invited to a choice of follow-up clinics. Those who failed to attend were contacted by telephone and gave permission for our research surgeon to visit them at home. For these patients, their function and radiographs at the last review were assessed.

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The gain in movement in all planes after operation was measured using a goniometer. Both active and passive movement were assessed in forward flexion, abduction, and external and internal rotation. Rotation was measured with the elbow at the side. Strength was assessed with the arm as close to 90° of abduction as could be achieved in this age group, using the mean of three studies, with resistance against a spring balance maintained for three seconds. This was recorded on the Constant score form.\textsuperscript{13}

Radiological. True anteroposterior and axillary radiographs of the shoulder were obtained at follow-up using a standard technique by the same radiographer in the same radiology suite without the use of an image intensifier. Only those that were exactly in line with the surface of the glenoid were accepted (Fig. 2). Scapular notching was scored by the Sirveaux score,\textsuperscript{8} 0 being no defect; 1, a defect that affects only the lateral pillar of the scapula; 2, a defect in contact with the inferior screw; 3, a defect that extends beyond the lower screw; and 4, a notch that extends to the baseplate. The three patients who were interviewed at home did not have radiographs.

**Statistical analysis.** We used Student’s paired t-test to compare means on the same or related subjects over time or in differing circumstances. A p-value < 0.05 was considered statistically significant.

**Results**

The mean ASES score was 19 (95% confidence interval (CI) 14 to 23) pre-operatively and 65 (95% CI 48 to 82) (p < 0.001, paired t-test) at final follow-up. The mean OSS was 44 (95% CI 40 to 51) pre-operatively and 23 (95% CI 18 to 28) (p < 0.001) at final follow-up.

After operation, 16 patients (44%, 19 shoulders) had no pain, 15 (40%, 17 shoulders) had mild pain and five (16%, seven shoulders) moderate pain. None complained of severe pain. No limitation in activities of daily living was reported in 14 patients (40%, 17 shoulders) but 18 (47%, 20 shoulders) had moderate limitation. The remaining four patients (13%, six shoulders) reported severe limitation. No disturbance in sleep was recorded in 22 patients (65%, 28 shoulders), whereas 12 (28%, 12 shoulders) reported disturbance at times. The remaining two patients (7%, three shoulders) reported severe sleep disturbance.

The mean forward elevation was 105° and abduction 85°. Almost full elevation was observed in ten patients and another 20 could elevate the arm above their heads. Internal rotation to the buttock was attained in 15 shoulders (35%), to T12 in 11 (25%), to the sacroiliac joint in nine (20%) and to waist level in four (10%). The remaining four shoulders (10%) had internal rotation to the greater trochanter, or just very limited internal rotation.

The overall post-operative mean SF-36\textsuperscript{14} scores for both mental and physical health were significantly lower than in the average population. The index group had a mean age of 81 and multiple comorbidities, which would have led to a poor SF-36 score.

Radiological. A total of 44 shoulders had a radiological review, 31 (70%) showing some evidence of scapular notching. There were 13 shoulders with Sirveaux grade 0, five with grade 1, seven with grade 2, 11 with grade 3 and
eight with grade 4. The Sirveaux scores were not recorded for one patient who had loosening of the baseplate, in the patient converted intra-operatively to a Delta II hemiarthroplasty, and in the three patients who were reviewed at home.

**Complications.** There were seven complications during the whole series, although only four patients required further surgery. A fracture of a large, fragile osteophyte on the posterior glenoid rim occurred in two patients during reaming. In the first, the prosthesis was converted to a Delta II hemiarthroplasty, whereas in the second the fracture was ignored, as there was sufficient native glenoid to proceed with a Delta III baseplate. Both patients had a satisfactory outcome.

The majority of the patients had marked acromial erosion. Two had a post-operative fracture of the acromion. The first had the fracture stabilised seven weeks post-operatively, using a hook plate and tension band wiring. Her eventual outcome was good. The second patient refused further surgery. She had the poorest outcome of all the patients, with an OSS of 56 and an ASES score of 20. Two patients developed a deep infection. One (an 83-year-old woman) had previous surgery to the cuff at another hospital, and in retrospect might have had a low-grade infection at the time of surgery, but no cultures were taken at operation. She underwent incision and drainage of a post-operative wound haematoma. Cultures showed coagulase-negative staphylococcus, which was treated with antibiotics. She remained unsatisfied with weak deltoid. The second patient with deep infection (a 91-year-old woman) underwent washout and excision arthroplasty and was treated with antibiotics. She remained unsatisfied with weak deltoid. The second patient with deep infection (a 91-year-old woman) underwent washout and excision arthroplasty and was treated with antibiotics. She continued to have pseudoparalysis, but no further procedure was planned because of her level of medical fitness. The final patient had anterior subluxation of the shoulder joint six years after the primary procedure. At exploration the polyethylene bearing over the humeral stem was found to be worn, although the baseplate remained well fixed to the scapula and there was good glenoid bone stock. The polyethylene bearing was changed.

**Discussion**

The combination of arthritis and an irreparable tear of the rotator cuff occurs in a growing proportion of the population over the age of 80. Standard shoulder replacements only work well in the presence of a functioning rotator cuff, as the bony anatomy of the shoulder is inherently unstable and congruity of the joint is maintained only by the joint capsule. Many designs of non- or semiconstrained prosthesis have been developed, but their outcomes were poor and they have been abandoned. Grammont and Baulot began developing their reverse geometry unconstrained prosthesis in 1985, but the original designs were met with scepticism owing to the failures of previous reverse polarity replacements. However, experience with the present form of this prosthesis has been so encouraging that reverse polarity replacements have become widely used in Europe and they have now been licensed for use in the United States. However, there are few intermediate-term reports on this prosthesis, no long-term results, and published studies have small numbers, diverse pathology and high rates of complications and re-operation.

The Grammont arthroplasty differs from previous designs of reverse prostheses in a number of ways. The glenoid component is a hemisphere of 36 mm or 42 mm in diameter. It is attached to the prepared surface of the glenoid using a baseplate with divergent locking screws. This places the centre of rotation of the joint within the body of the scapula, thereby reducing the loosening forces at the prosthesis-bone interface and increasing its inherent stability. The humeral component contains a shallow cup inclined at 155°. This covers less than half of the large glenosphere, allowing an acceptable range of movement. It also lowers the fulcrum of the joint, increasing the tension in the deltoid and thereby improving the strength of elevation, and uses the deltoid instead of the rotator cuff to maintain stability of the unconstrained joint (Fig. 1). However, concerns remain about the high level of complications recorded in some series, the process of selecting patients suitable for reverse shoulder replacements, and the medium- and long-term survival of the prosthesis, in view of the high incidence of scapular notching seen in reverse shoulder replacements.

Werner et al. reported a complication rate of 51% and a re-operation rate of 39%, but one-third of the patients were undergoing revision surgery. Boileau et al. had a complication rate of 29% and a revision rate of 22%, but their series also encompassed a heterogenous group of patients.

Patient selection is critical to the results of this type of surgery. All our patients had cuff tear arthropathy. Their mean age was 81. Because our selection criteria only included massive cuff tears secondary to arthritis, this series shows better clinical outcomes than most previous studies. Functional scores were improved by 18 of 48 available points on the OSS. Pain improved from 100% with severe pain before surgery to 84% with little or no pain afterwards. Activities of daily living improved from severe limitation in all patients before surgery to 87% reporting little or no limitation afterwards. The mean shoulder elevation improved from pseudoparalysis in all patients to 105° after surgery. No patient lost movement.

Scapular notching remains a concern, with some evidence in 70% of radiographs reviewed. In 18 patients it was minor (Sirveaux grades 0 to 1) and in some progressive. However, although eight patients had Sirveaux grade 4 notching, in none did it reach the central peg. The patients with notching must have some polyethylene wear, and this remains a concern, although we did not see any associated bone destruction. Some concern regarding the long-term survival of these prostheses remains. However, the French multicentre multipathology study with 92% survival without prosthetic removal at ten years, and 84% at 15 years, is reassuring.
Early in our experience it became obvious that the baseplate needed to be placed as inferiorly as possible on the glenoid, which required exposure and release of the inferior capsule. This can only be performed safely if the axillary nerve has been demonstrated prior to the capsule being divided. This meant that the surgical approach changed from a deltoid split to an extended deltopectoral approach in order to expose this nerve and the posterior circumflex vessels.

Our experience with the Delta III prosthesis for patients with pseudoparalysis caused by arthritis, and with a massive cuff tear, has given encouraging results in the short to medium term. Patient satisfaction, freedom from pain, improvement in activities of daily living and functional independence are reflected in the significant improvements in the American and Oxford scores. However, there are few long-term studies on this prosthesis, and it should be used with caution in patients under 70 years of age.

Supplementary material
A further opinion by Mr A. Wallace is available with the electronic version of this article on our website at www.jbjs.org.uk

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References