Revision total elbow replacement using the Souter-Strathclyde prosthesis
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The Souter-Strathclyde prosthesis was used in 52 revisions of total elbow replacements (TERs) between August 1986 and May 1997. Of these, 50, carried out in 45 patients, were prospectively followed for a mean of 53 months (14 to 139). The procedure produced reliable relief of pain, and the range of movement was preserved. There was a considerable incidence of adverse events associated with revision (30%), and 12 further procedures have been required. Nonetheless, a revision is the preferred salvage procedure for failed primary arthroplasty in the absence of sepsis.

Since 1981, we have undertaken more than 400 primary total elbow replacements (TERs) and have recently published the survivorship for this procedure of 87% at 12 years.1 A revision replacement has been carried out since 1986 as the standard salvage procedure for a failed primary TER, and a previous early report of the first 25 such operations indicated good long-term relief of pain,2 although, in this series, two different types of implant had been used.

Between July 1986 and May 1997 a total of 61 revision TERs of all types have been undertaken. The Souter-Strathclyde prosthesis has been used for most (52) of these procedures, and virtually exclusively since 1989, irrespective of the primary prosthesis used or the indication for surgery. We prospectively follow all TERs for the lifetime of the implant and now describe our experience with the Souter-Strathclyde implant for revision surgery.

Patients and Methods
We have used the Souter-Strathclyde prosthesis (Stryker UK Ltd, Newbury, UK) for 52 revision procedures in 47 patients. One patient died within the minimum period of follow-up, and one was lost to follow-up, leaving 50 procedures in 45 patients for analysis (Table I). The mean age at revision was 63 years (34 to 85). There were 37 women and eight men. The underlying pathology was rheumatoid arthritis in 39, osteoarthritis in three and post-traumatic arthritis in three. We carried out 31 of the primary arthroplasties at this unit. Eight patients in the series died, but had been followed up for more than two years and are included.

In two patients, both the ulnar and humeral components were revised, but not at the same procedure. Revision of the second primary component after that for a previous single component, was considered to be a separate operation in this series if there had been sufficient follow-up from the time of revision of the second component. We have termed this ‘sequential revision’, to distinguish it from two-staged revision for infection or fracture. Five such sequential revisions were carried out in the two patients. Overall, 19 revisions were other types of primary prosthesis (Fig. 1) and 31 were revisions of Souter components (Table I) (Fig. 2).

Intraoperative problems, noted at the primary TER included one difficult soft-tissue closure, four elbows with instability after reduction, and one intraoperative fracture. Postoperative adverse events included eight dislocations, two intractable infections, three neurological injuries and one postoperative fracture.

Indications for revision. The annual clinical evaluation of TERs includes a subjective assessment of pain at rest and on activity. As an objective measurement, the range of movement is recorded using standard goniometry, and plain radiographs are taken. The assessment includes subjective evaluation of function in a range of daily activities.

The principal indication for revision was pain (Table II), mainly because of aseptic loosening. In 21 patients both humeral and ulnar components were loose, in 14 the humeral component alone, in three the ulnar component alone, and in two the ulna had fractured. In one patient the ulnar loosening was precipitated by a fall producing a periprosthetic fracture.
There were 11 revisions for instability or dislocation, but not all of these were painful. There was one implant failure in the coupling pin of a linked prosthesis. Four patients had more than one indication for revision.

Operative technique. All operations were carried out in a Charnley-Howorth enclosure using body-exhaust suits. Prophylactic intravenous antibiotics were administered before exsanguination and inflation of a pneumatic tourniquet. The posterior approach of Campbell was used in all patients, incorporating any previous surgical scar wherever possible, and taking down a tongue of triceps aponeurosis. The ulnar nerve was simply identified and protected rather than being transposed in 38 of the 51 revisions. The recent introduction of techniques for the ultrasonic removal of cement has greatly facilitated the removal of implanted material, particularly for instability. In such cases, well-fixed cemented all-polyethylene ulnar components were usually quartered and partially drilled out of the ulnar shaft.

Both components were exchanged in 33 of the revisions. This included all 19 obligatory revisions of both components from a non-Souter prosthesis to a Souter implant, carried out for loosening of one or both components. Both components were revised in the two infected primary TERs and in eight with instability. The humeral component alone was revised in 11 patients, all for aseptic loosening in primary Souter TERs. The ulnar component was revised alone in six patients, three for instability, two for loosening sequential to humeral revision or a fall, and one for a peri-prosthetic fracture. The decision not to revise the other component was made at the time of operation.

<table>
<thead>
<tr>
<th>Type of primary prosthesis</th>
<th>Single-stage revisions</th>
<th>Bilateral revisions</th>
<th>Sequential revisions</th>
<th>Total</th>
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<tbody>
<tr>
<td>Souter</td>
<td>22 (22)</td>
<td>4 (2)</td>
<td>5 (2)</td>
<td>31 (26)</td>
</tr>
<tr>
<td>Wadsworth</td>
<td>14 (14)</td>
<td>0</td>
<td>0</td>
<td>14 (14)</td>
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<tr>
<td>Cavendish</td>
<td>1 (1)</td>
<td>0</td>
<td>0</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Kudo</td>
<td>1 (1)</td>
<td>0</td>
<td>0</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Triaxial</td>
<td>2 (2)</td>
<td>0</td>
<td>0</td>
<td>2 (2)</td>
</tr>
<tr>
<td>Capitello-condylar</td>
<td>1 (1)</td>
<td>0</td>
<td>0</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Total</td>
<td>41 (41)</td>
<td>4 (2)</td>
<td>5 (2)</td>
<td>50 (45)</td>
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</table>

Table II. Subjective preoperative and postoperative levels of pain in 50 patients undergoing revision TER

<table>
<thead>
<tr>
<th>Level of pain</th>
<th>Severe</th>
<th>Moderate</th>
<th>Mild</th>
<th>None</th>
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<tr>
<td>Preoperative</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At night</td>
<td>30</td>
<td>12</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>At rest</td>
<td>37</td>
<td>8</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>On activity</td>
<td>42</td>
<td>3</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>At assessment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At night</td>
<td>1</td>
<td>11</td>
<td>1</td>
<td>37</td>
</tr>
<tr>
<td>At rest</td>
<td>4</td>
<td>14</td>
<td>0</td>
<td>32</td>
</tr>
<tr>
<td>On activity</td>
<td>10</td>
<td>9</td>
<td>7</td>
<td>24</td>
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</table>

Fig. 1
Oblique radiograph of a Cavendish TER. Both the humeral and the ulnar components are loose 12 years after primary arthroplasty, although the patient had been symptomatic for some time. There is extensive loss of bone stock.

Fig. 2
Anteroposterior radiograph of a standard Souter-Strathclyde TER. Both components are loose nine years after primary arthroplasty. Loss of bone stock is seen in the supracondylar region.
Humeral revision components included 25 long stems (Fig. 3) and 16 revision stems (Fig. 4). A variety of customised condylar configurations is available with the revision stems, and were used, but only one truly custom-made stem was required. Three standard prostheses were used early in the series, but these components are no longer used for revision. We implanted 32 metal-backed ulnar components and seven all-polyethylene components. Of the ulnar components, 17 were retentive, and 11 were longer stemmed (Fig. 4).

Selection of length of the humeral stem was based on the quality of humeral diaphyseal bone stock proximal to radiological lucencies, perforations or fractures. When possible, the aim was to secure fixation to a distance of at least two diaphyseal diameters beyond the most proximal defect. Similarly, selection of the length of the ulnar stem aimed to bypass the most distal ulnar defect by at least two diameters. Templates allowed preoperative evaluation, but careful intraoperative assessment of cortical integrity was required. Loss of metaphyseal bone stock from the medial or lateral column, or both, required the use of customised revision stem components with additional medial and/or lateral build-up. In practice, these options were rarely used. Finally, when instability was demonstrable during the operation, a linked (retentive) implant was selected.

Perforation of the cortex during the operation occurred on seven occasions (Fig. 5). There were seven major and minor fractures and one nerve injury. In all cases the elbow was stable at the end of the procedure.

Postoperative care was tailored to the perioperative findings. A variety of postoperative regimens was used, the commonest being immobilisation at 90° for three weeks.

Results

Clinical. The level of pain was improved significantly by revision surgery (Table II). Only four patients graded their pain as severe at rest; one also had night pain. At the time of assessment four patients were awaiting sequential single component replacement of their primary arthroplasty, four had had excision arthroplasties, and one had intractable neuralgic pain.

The range of movement was relatively unaltered (Table III). The mean flexion-extension improved by over 9°;
improvements in pronation and supination were marginal. Preoperative loss of extension beyond the functionally useful range (30°) was never regained.

Radiological. We used the technique of Morrey and Bryan for radiological assessment. Radiographs were assessed for lytic zones of $\geq 1\text{mm}$ around more than 50% of either component. Such zones were present in 21 of 35 elbows before revision in which the humeral components were found to be aseptically loose at operation, and in 16 of 24 in which the ulnar component was found to be loose.

Radiographs at the latest follow-up available were reviewed. There was a relative preponderance of significant ulnar lysis (9) over humeral lysis (7). Of the nine loose ulnar components, eight were in single-component (humer-al) revisions.

Adverse events. Significant postoperative problems developed in 15 patients (30%) and eight had 12 further major secondary procedures. These included four cases of deep infection (8%), two of which were in previously infected prostheses. The prosthesis was salvaged by debridement in one. In the other three, the components were removed. A free flap was required after one excision and debridement. One of these patients has subsequently undergone staged reimplantation.

There were three patients with instability (6%). In one, this was present before surgery. The prosthesis was stable at revision but the sensation of instability remained. One elbow could not be corrected for technical reasons and required excision arthroplasty. In one elbow prosthetic reconstruction of the medial collateral ligament was used.

A fracture of the ulna which was sustained in a fall after revision (Fig. 6) failed to unite by conservative measures. The ulnar component was removed and a plate and bone graft were used. The patient awaits a second-stage re-implantation. There were no avulsions of the triceps. Lengthening of the triceps and anterior capsulotomy were carried out in one patient.

Seven patients (14%) developed long-standing ulnar neurological symptoms; one of these has a motor deficit. A temporary neurological deficit, including one in the median nerve developed after three revisions. No radial neuropathy was noted.

At the time of assessment three further ulnar and one further humeral component had loosened subsequent to revision of a single component and were either awaiting sequential revision or had been recently revised. This was in addition to the three components already revised.

Discussion

In agreement with Souter, we have found that the Souter-Strathclyde TER is a relatively successful primary implant in patients with rheumatoid arthritis involving the elbow. A number of complications, however, have been described, particularly aseptic loosening. We have also previously reported preliminary results in revision TER using Wadsworth and Souter components.

The results of our study show that the revision components of the Souter arthroplasty have proved to be satisfactory in the medium term in a large, unselected series of

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Table III. Range of movement (degrees) before revision TER and assessment

<table>
<thead>
<tr>
<th></th>
<th>Before Mean</th>
<th>Range</th>
<th>SEM</th>
<th>At assessment Mean</th>
<th>Range</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexion</td>
<td>121.5</td>
<td>40 to 150</td>
<td>37.7</td>
<td>125.9</td>
<td>100 to 155</td>
<td>11.8</td>
</tr>
<tr>
<td>Extension</td>
<td>54.2</td>
<td>90 to 0</td>
<td>29.3</td>
<td>48.8</td>
<td>110 to 0</td>
<td>19.6</td>
</tr>
<tr>
<td>Pronation</td>
<td>55.0</td>
<td>0 to 90</td>
<td>31.2</td>
<td>61.4</td>
<td>0 to 90</td>
<td>17.7</td>
</tr>
<tr>
<td>Supination</td>
<td>55.5</td>
<td>0 to 90</td>
<td>61.1</td>
<td>0 to 90</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Fig. 6

Radiograph showing periprosthetic fracture of the ulna after a fall. The ulna continued to be symptomatic, and the prosthesis had to be removed so that the ulna could be plated and bone-grafted.
primary TERs, which have failed for a variety of reasons. Specifically, it gives good relief of pain, and the range of movement is maintained. Nonetheless, a relatively high incidence of complications occurred including problems with the ulnar nerve in 14%, infection in 8% and instability in 6%.

There are very few comparable studies in the English language literature. In earlier series, from four units including our own, the numbers were smaller and a variety of implants were used in the revision procedure.\(^2,3,5,6\)

The more recent series from the Mayo Clinic is the most analogous in many respects, although the 41 cases were less dominated by rheumatoid arthritis, and revision for infection was excluded.\(^7\) The range of movement obtained in our series is worse, which may reflect this factor, although the surgical approach used by this group is different. Both series report reliable relief of pain. We have not encountered radial neuropathy to the same extent, and we do not routinely explore the radial nerve during humeral extraction of cement. Ulnar neuropathy is more common in our series, and anterior transposition is not carried out routinely at revision. We report a slightly higher proportion of further surgical intervention.

Rates of infection are comparable with those reported elsewhere. In the 48 non-infected revisions, infection de novo occurred in two (4.2%). In the two patients in whom deep infection was present before reimplantation, the infection could not be abolished, and the patients required excision arthroplasty. Our experience is similar to that of Ferlic and Clayton\(^6\) in this respect. Out of 14 revisions in this series, the 11 for aseptic loosening or instability were successfully reimplanted, but three due to infection were revised to an excision arthroplasty. A similar approach is described in the earlier series from the Mayo Clinic.\(^3\)

The low rate of dislocation after revision in our series is gratifying. Unconstrained prostheses were used in more than half of the procedures, and instability was the primary indication for a number of them. We have concerns with regard to the use of fully-constrained ulnar components since we feel that they may contribute to early loosening. The long-stem metal-backed retentive ('snap fit') Souter ulnar component is fully constrained anatomically. We no longer use this component, preferring a semi-constrained version with a built-in varus-valgus play of 7°.

It is questionable whether reimplantation of a single component should be regarded as a revision. There is a difference in the incidence of revision between the Souter-Strathclyde ulnar and humeral components. Since the prosthesis is not linked, single-component revision is often possible. We feel that it is reasonable therefore to consider the survival of these components separately. Single-component revisions of sufficient follow-up have been included in the series on that basis. We have constructed a Kaplan-Meier cumulative survival curve, which uses revision of either component, death or loss to follow-up as endpoints (Fig. 7).

The assessments used for each sequential revision are the latest available, as these best reflect the behaviour of the revised implant. Since May 1997 and the end of the assessment period, more sequential component revisions were completed in patients included in this study as single-component revisions. These did not have sufficient follow-up, and therefore prerevision measurements have been used. Consequently, we emphasise that the data as presented are therefore an instantaneous picture.

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