Total elbow replacement for the management of the ankylosed or fused elbow

J. P. Peden, B. F. Morrey
From Mayo Clinic, Rochester, United States of America

This study reports our experience with total elbow replacement for fused elbows. Between 1982 and 2004, 13 patients with spontaneously ankylosed elbows were treated with a linked semi-constrained non-custom total elbow implant. The mean age at operation was 54 years (24 to 80). The stiffness was a result of trauma in ten elbows, juvenile rheumatoid arthritis in one, and rheumatoid arthritis in two. The patients were followed for a mean of 12 years (2 to 26) and were evaluated clinically using the Mayo Elbow Performance Score, as well as radiologically.

A mean arc from 37° of extension to 118° of flexion was achieved. Outcomes were good or excellent for seven elbows at final review. Ten patients felt better or much better after total elbow replacement. However, there was a high complication rate and re-operation was required in over half of patients. Two developed peri-operative soft-tissue breakdown requiring debridement. A muscle flap with skin grafting was used for soft-tissue cover in one. Revision was undertaken in one elbow following fracture of the ulnar component. Three patients developed a deep infection. Three elbows were manipulated under anaesthesia for post-operative stiffness. Prophylactic measures for heterotopic ossification were unsuccessful.

Total elbow replacement for the ankylosed elbow should be performed with caution. However, the outcome can be reliable in the long term and have a markedly positive impact on patient function and satisfaction. The high potential for complications must be considered. We consider total elbow replacement to be an acceptable procedure in selected patients with reasonable expectations.

Spontaneous fusion of the elbow following infection, trauma or rheumatic disease causes severe functional limitations. Analysis of compensatory movement after arthrodesis of the elbow shows compromised ability, despite a significantly increased dependence on spine and wrist movement. The shoulder plays only a modest compensatory role.

Through modifications in implant design and operative techniques, total elbow replacement (TER) is a reliable long-term option for many pathological conditions. Elbows with degenerative arthritis which progress to fusion or fibrous ankylosis often have severe bony deformities and soft-tissue contractures. There is limited information about the long-term effectiveness of converting a fused elbow to a TER. The purpose of this study was to focus on this indication for TER, present important technical considerations, and show intermediate to long-term outcomes using a single, non-custom, linked, semi-constrained implant.

Patients and Methods
Between January 1982 and December 2004, 1127 primary and revision TERs were performed in our institution. There were 15 consecutive patients (15 elbows) with spontaneous ankylosis of the elbow. Of these, 11 had bony fusion. Fibrous ankylosis in four patients was defined as range of movement less than 5° or a ‘jog’ of movement. Accurate clinical assessment of movement was complicated by a post-traumatic pseudarthrosis near the elbow in two patients, who were excluded from the study. The resultant series comprised ten procedures performed by a single surgeon (BFM), and one procedure each from three other surgeons. The study was approved by the Institutional Review Board.

Data included patient demographics, operative details and post-operative progress, including immediate or late complications (Table I). Endpoints were defined as death or revision arthroplasty. The patients were contacted at one, two, five, seven and ten years...
post-operatively with a request for clinical and radiological evaluation and completion of a standard questionnaire.

All patients were assessed clinically by a physician (BFM or JP in ten patients, local MD in three patients). No patient was lost to follow-up. The most recent evaluation was a patient-completed questionnaire in four patients and a telephone interview in nine. In the absence of clinical follow-up, the arc of elbow movement was obtained from the questionnaire, in which the patient was instructed to draw their arc of movement on a pictogram of the elbow.

There was a high rate of co-existing pathology in the involved and uninvolved elbows. Various combinations of radioulnar, or radiohumeral, humeroulnar synostoses were seen with complete loss of forearm rotation in five of the ten post-traumatic and one of the three rheumatoid patients. Only one patient had an isolated humeroulnar fusion.

Post-traumatic neuropathies were present in six patients; three had multiple nerve injuries and two had post-traumatic ischaemic Volkmann’s contractures. One developed ulnar neuropathy after surgery.

The goal of treatment was to restore movement and improve function. A semi-constrained, non-custom, linked implant, the Coonrad-Morrey total elbow prosthesis (Zimmer, Warsaw, Indiana) was used in all patients. Cement fixation was employed for both components in all but two younger patients, who had uncemented fixation. Our series comprised one plasma spray, seven precoated and five beaded designs.

Although we do not generally advise prosthetic replacement for post-traumatic arthritis in patients under 60 years of age, for the nine patients in our series under that age, we considered TER to be a more acceptable, consistent, and reliable alternative to resection or interposition arthroplasty.

In each case clinical information was recorded on a standard elbow assessment form to calculate a Mayo elbow performance score (MEPS), which assigns a maximum score of 100 points. This was designed to allow questionnaire-type input rather than personal patient evaluation. Two assessments were carried out, the first at a minimum of two years and the second at final review.

Immediate post-operative radiographs, and those taken at the latest follow-up, were available for all but one patient. Bushing wear was estimated on the anteroposterior radiograph by measuring the angle between a line perpendicular to the axis of the bushings and the longitudinal axis of the proximal segment of the ulnar component. It is recognised that this method only provides information in those with extreme wear. We did not perform fluoroscopically controlled varus/valgus stress radiographs to assess bushing wear. The bone-cement interface was evaluated according to the presence and characteristics of any radiolucent lines on the lateral radiograph. Ectopic radiodensities were classified according to a previous standard based on this location, in or about the ligaments or capsule, at the end of osteotomised bone, as loose fragments, or within muscle.

Operative technique. Osseous distortion and soft-tissue contracture add significant complexity to the procedure (Table I). The mean operating time was 182 minutes (95 to 315), with a mean tourniquet time of 122 minutes (69 to 240). Continuous tourniquet times in excess of two hours were avoided by released recovery periods between 20 and 60 minutes. Judicious and sequential use of the tourniquet to accomplish the surgical goals safely is emphasised. Neurolysis undertaken to liberate nerves encased in bone can lengthen the operation considerably.

Several technical features are noteworthy. The skin incision should ideally incorporate a previous posterior incision. Alternatively, the greatest distance from the previous approach is sought. Management of the triceps depends on

**Table I. Demographic data**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age (yrs)</th>
<th>Gender</th>
<th>Dominant side</th>
<th>Open injury diagnosis*</th>
<th>Previous operations</th>
<th>Position of fusion (°)</th>
<th>Pre-operative pronation/supination (arc) (°)</th>
<th>Months from injury to TER†</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>77</td>
<td>F</td>
<td>L</td>
<td>RA</td>
<td>0</td>
<td>90</td>
<td>50/85 (135)</td>
<td>NA‡</td>
</tr>
<tr>
<td>2</td>
<td>38</td>
<td>F</td>
<td>R*</td>
<td>JRA</td>
<td>0</td>
<td>85 to 90</td>
<td>75/70 (5)</td>
<td>NA</td>
</tr>
<tr>
<td>3</td>
<td>24</td>
<td>F</td>
<td>R*</td>
<td>Post-traumatic§</td>
<td>6</td>
<td>35</td>
<td>-80/80 (0)</td>
<td>59</td>
</tr>
<tr>
<td>4</td>
<td>42</td>
<td>F</td>
<td>L</td>
<td>Post-traumatic§</td>
<td>3</td>
<td>60 to 65</td>
<td>10/20 (30)</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>54</td>
<td>M</td>
<td>R*</td>
<td>Post-traumatic§</td>
<td>2</td>
<td>80</td>
<td>-20/20 (0)</td>
<td>7</td>
</tr>
<tr>
<td>6</td>
<td>45</td>
<td>M</td>
<td>L§</td>
<td>Post-traumatic§</td>
<td>2</td>
<td>30 to 35</td>
<td>20/10 (30)</td>
<td>197</td>
</tr>
<tr>
<td>7</td>
<td>40</td>
<td>M</td>
<td>R</td>
<td>Post-traumatic§</td>
<td>2</td>
<td>80</td>
<td>10/10 (20)</td>
<td>62</td>
</tr>
<tr>
<td>8</td>
<td>64</td>
<td>M</td>
<td>R*</td>
<td>Post-traumatic§</td>
<td>1</td>
<td>45</td>
<td>10/10 (0)</td>
<td>38</td>
</tr>
<tr>
<td>9</td>
<td>67</td>
<td>F</td>
<td>L§</td>
<td>Post-traumatic§</td>
<td>1</td>
<td>70</td>
<td>70/80 (150)</td>
<td>7</td>
</tr>
<tr>
<td>10</td>
<td>57</td>
<td>M</td>
<td>R*</td>
<td>Post-traumatic§</td>
<td>0</td>
<td>90</td>
<td>0/0 (0)</td>
<td>591</td>
</tr>
<tr>
<td>11</td>
<td>55</td>
<td>F</td>
<td>R*</td>
<td>RA</td>
<td>0</td>
<td>90</td>
<td>80/80 (160)</td>
<td>NA</td>
</tr>
<tr>
<td>12</td>
<td>58</td>
<td>M</td>
<td>R*</td>
<td>Post-traumatic§</td>
<td>4</td>
<td>85 to 90</td>
<td>30/30 (60)</td>
<td>35</td>
</tr>
<tr>
<td>13</td>
<td>80</td>
<td>M</td>
<td>L</td>
<td>Post-traumatic§</td>
<td>0</td>
<td>95</td>
<td>0/0 (0)</td>
<td>816</td>
</tr>
</tbody>
</table>

* RA, rheumatoid arthritis; JRA, juvenile rheumatoid arthritis
† TER, total elbow replacement
‡ NA, not available
§ dominant side
§ open injury
the integrity of the distal humerus. If the condyles are present, or if there is significant contracture of the extensor mechanism, a triceps-sparing approach is used12 whereby contractures may be released by entering Kocher’s interval and mobilising anconeus along with the extensor mechanism. This is done by performing an osteotomy from medial to lateral or lateral to medial without disturbing the tendinous attachment. In the most severe cases of triceps contracture, the entire extensor mechanism and anconeus may be elevated from the olecranon. Re-attachment is undertaken with the elbow in 90° of flexion. If the condyles are absent, or if the triceps remain adequately compliant, efforts are made to preserve the existing attachment.

The ulnar nerve must always be identified and protected. If ulnar symptoms are present, the nerve is dissected distally to its motor branches and placed in a protected subcutaneous environment. Ectopic bony entrapment can impede decompression. If the ulnar nerve is asymptomatic, it is identified proximally, its course is defined, and it is protected from the operative field.

An important part of the operation is the determination of the axis of rotation of the implant. In most instances the remnant of the radial head is the landmark used laterally; medially, it is the prominence of the coronoid. The osteotomy begins at this level and curves to emerge posteriorly at a level that ensures the triceps attachment is maintained. Meticulous care is taken to recreate or preserve the olecranon process in order to provide a functional lever arm for the triceps and protect the skin from erosion by the implant.

Although all cases had loss of architecture, a custom device was not necessary. Pre-operative planning allows appropriate sizing of the stem, which frequently needs modifications such as bending or cutting to deal with canal deformity. In cases where ankylosis or fusion has resulted in malorientation between forearm and humerus, special care is taken to release the soft-tissue contracture of the flexors and extensors to avoid an imbalance at the articulation. Similarly, accurate positioning of the implant will avoid the excessive wear that would occur with malorientated components. In some cases shortening of the humerus may be needed to enhance elbow extension. It was not necessary to perform tenotomy of the biceps or brachialis.

A total of 2 cm of shortening is generally adequate to relax the soft-tissue contracture and improve extension by 15° to 20°. As these elbows are ankylosed, there are no relevant cosmetic effects of shortening.

Post-operatively, the elbows are placed in extension splints with anterior plaster support and elevated overnight. Physiotherapy is not prescribed. A programme of static adjustable splinting uses the Mayo Elbow Brace (Air-Cast DJO, Vista, California). A permanent lifting restriction of 5 kg is emphasised and formal strengthening exercises are discouraged. Prophylaxis for heterotopic ossification by single beam external radiation between 600 cGy and 800 cGy is administered to patients with pre-operative moderate to severe ectopic bone and without post-operative wound complications or rheumatoid disease. Four patients received such treatment, supplemented with eight weeks of indometacin in one case.

Manipulation under anaesthesia for peri-operative elbow stiffness is an adjuvant to our post-operative management. Three patients required manipulation for stiffness at a mean of 21 days post-operatively. They retained a total mean arc of 65° at the last follow-up, gaining a mean of 35° from manipulation. This achievement was still a mean of 20° less than the arc for those who maintained their movement through rehabilitation alone. None of the three patients who underwent manipulation developed radiological evidence of ectopic ossification.

<table>
<thead>
<tr>
<th>Case</th>
<th>Implant</th>
<th>Cement</th>
<th>Operation time (mins)</th>
<th>Tourniquet time (mins)</th>
<th>HO* prophylaxis</th>
<th>Intra-operative complication</th>
<th>Peri-operative complication</th>
<th>Late complication</th>
<th>Further operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Beaded</td>
<td>Yes</td>
<td>205</td>
<td>138</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Precoat</td>
<td>Yes</td>
<td>220</td>
<td>115</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ulnar loosening 1</td>
</tr>
<tr>
<td>3</td>
<td>Beaded</td>
<td>Ulna</td>
<td>155</td>
<td>122</td>
<td></td>
<td></td>
<td>Wound necrosis</td>
<td>HO</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>Beaded</td>
<td>No</td>
<td>175</td>
<td>107</td>
<td></td>
<td>Implant malposition</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>Beaded</td>
<td>Yes</td>
<td>315</td>
<td>240</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>Beaded</td>
<td>Yes</td>
<td>210</td>
<td>136</td>
<td></td>
<td></td>
<td>Skin breakdown</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Precoat</td>
<td>Yes</td>
<td>120</td>
<td>69</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>Precoat</td>
<td>Yes</td>
<td>180</td>
<td>117</td>
<td>600 cGy</td>
<td></td>
<td>Deep infection</td>
<td>HO</td>
<td>5</td>
</tr>
<tr>
<td>9</td>
<td>Precoat</td>
<td>Yes</td>
<td>205</td>
<td>126</td>
<td>600 cGy</td>
<td>Lateral condyle fracture</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>Precoat</td>
<td>Yes</td>
<td>95</td>
<td>75</td>
<td>800 cGy</td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>11</td>
<td>Precoat</td>
<td>Yes</td>
<td>117</td>
<td>80</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>Precoat</td>
<td>Yes</td>
<td>229</td>
<td>162</td>
<td>RT † + indometacin</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>13</td>
<td>Plasma</td>
<td>Yes</td>
<td>143</td>
<td>97</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

* HO, heterotopic ossification
† RT, radiotherapy
Results
The MEPS for all patients at a minimum two-year follow-up (mean 3 years; 2 years and 1 month to five years and 6 months) was excellent in five, good in three, fair in four, and poor in one elbow. The mean score was 79 points (50 to 100), which represents a mean improvement of 25 points, or a 46% increase from the pre-operative value. Of the 13 patients, ten were satisfied with their outcome and rated as ‘much better’ in six, ‘better’ in four, ‘unchanged’ in two and ‘worse’ in one.

At the last follow-up at a mean of 12 years (2 to 26), five patients had died of unrelated causes. Two patients developed deep infection and one underwent revision of the ulnar component for aseptic loosening. The MEPS for the remaining 10 patients at a mean of ten years and four months (3 years and 4 months to 22 years and 5 months) was excellent in one, good in six, fair in three and poor in one elbow. The mean score was 74 points (50 to 95), reflecting a mean loss of only four points in seven years. The majority of patients remained satisfied, rated as ‘much better’ in six, ‘better’ in two, ‘unchanged’ in one and ‘worse’ in two, both of whom were dissatisfied with their arc of movement (50° and 55°, respectively). They declined further surgery to resect ectopic bone which appeared to be limiting movement. Overall, the initial outcome was maintained, with satisfactory ratings for seven of 11 patients objectively, and eight of 11 subjectively.

All three patients with moderate neurogenic symptoms pre-operatively had complete relief after ulnar nerve decompression and transposition. One underwent ulnar neureorrhaphy and median neurolysis with sural nerve grafting after her TER, and was free of pain at the last follow-up. Six previously asymptomatic patients developed ulnar nerve symptoms, three mild, and three moderate after restoration of movement. However, no pain was attributed to the ulnar nerve, and symptoms had resolved in all but two at the final assessment. No patient required further management of their nerve.

Among the 13 patients, the mean pre-operative position of ankylosis was 73° (35° to 95°). The mean arc of movement gained was 81°, between 37° of extension (0° to 60°) and 118° of flexion (60° to 150°). Four patients gained an arc of 100° or greater. The improvement in movement measured at one year was maintained for all patients at the 12-year follow-up.

The mean pre-operative arc of forearm rotation was 46° (0° to 160°), with a mean of 20° of pronation (-80° to +80°) and 26° of supination (-70° to +85°). Patients gained a mean of 16° of pronation and 10° of supination for a total mean arc of 72° (0° to 160°). Four of the six patients with a pre-operative synostosis achieved a mean of 39° (30° to 50°).

All patients had a stable elbow pre-operatively by virtue of their fusion. No patient had instability post-operatively.

The most dramatic improvements in MEPS were seen in daily function. Only three of the 13 patients were able to complete any of the MEPS activities of daily living pre-operatively. Post-operatively, all patients were able to complete some, and seven, all activities of daily living, with varying degrees of difficulty. The mean score improved from two points (0 to 5) to 20 points (5 to 25).

Radiological review was possible for all but one patient. The mean radiological follow-up was seven years and eight months (2 years and 2 months to 16 years and 11 months) post-operatively. A non-progressive type-1 radiolucency at the distal humeral interface was present post-operatively in one elbow. Type-3 ulnar lucencies were present in both patients who underwent revision and resection.

Ectopic calcification was evident to varying degrees in four elbows, despite radiation in three (Fig. 1). All four elbows had ectopic bone surrounding the osteotomy sites, with additional radiolucencies in the anterior capsule of one. All elbows had mature consolidated bone behind the humeral flange, and there was no evidence of bushing wear. Whereas limitation of movement may influence the
accuracy of radiological techniques in determining bushing wear, we were able to detect wear in other patients with similar restricted movement, and therefore believe the methods used were consistent with the available standards.

Complications were considered as intra-operative, peri-operative, and late. Four patients were free of complications or any further intervention between the index arthroplasty and final review. Seven elbows required a total of 19 additional operations.

Intra-operative complications, in two cases, were a fracture of the lateral humeral epicondyle which resolved uneventfully, and malposition of the ulnar component with perforation of the posterior cortex in another. Repositioning in a separate operation resulted in excellent function for the next 15 years.

Three patients had a peri-operative complication, including soft-tissue compromise in two and infection in another. One developed skin necrosis requiring debridement and cover with a brachioradialis rotational flap, followed by a myocutaneous latissimus flap after partial failure of the primary flap. Another elbow required debridement and primary closure for superficial skin breakdown.

The peri-operative infection was caused by methicillin-sensitive *Staphylococcus aureus* and was successfully treated with antibiotic-impregnated polymethylmethacrylate beads, bushing extraction, six weeks of intravenous antibiotic therapy and staged re-articulation. Methicillin-resistant coagulase-negative *Staphylococcus* was the organism involved in two other patients who developed symptoms of deep infection at two and 16 years post-operatively, without previous complications. These three patients with deep infections required a mean of four additional operations.

Five elbows developed ectopic calcification. Three of these had minimal loss of movement; resection of a painful bony prominence was undertaken in another elbow which otherwise had excellent movement.

One patient required revision for progressive loosening of a polymethylmethacrylate pre-coated ulnar component which fractured at five years, eight months post-operatively (Fig. 2). The component was revised by an impaction grafting technique, and the post-operative course was complicated by a triceps tendon rupture which required surgical repair. The patient also sustained a peri-prosthetic ulnar fracture the following year because of a fall. At final review 12 years later, the objective rating was excellent and she remained satisfied with her outcome (Fig. 3).

Discussion

Small numbers of cases with ankylosis have been included in the results of several previous studies of TER. Figgie et al presented a group of 19 elbows with various diagnoses treated with several implants, including three types of semi-constrained prosthesis and eight custom designs. A mean arc of movement of 80° (35° to 115°) was maintained at a mean of five and three-quarter years, similar to our results. Their 26% complication rate and 26% manipulation rate also mirror our experience. Further comparison is, however, limited by their use of a scoring system which is less discriminating than the MEPS.

All our patients maintained stability of the elbow, which confirms previous reports that linked devices reliably maintain stability after the extensive soft-tissue and bony resection needed to mobilise an ankylosed joint. This is a major advantage over interposition arthroplasty, which relies on supportive ligaments which are often not only deficient but also function less following
the usual circumferential capsular and ligamentous release.

Albeit advocated for young, high-demand patients, we also assessed distraction interposition arthroplasty using fascial graft in a series of non-ankylosed arthritic elbows. Although the mean age in that group was 21 years younger, their mean MEPS was only 79 points at five years. This figure excluded the four poor results that subsequently underwent TER and was, therefore, inferior to our results for ankylosed elbows.

Age did not appear to prejudice a successful outcome in our series. The long-term survival in the younger patients...
may be related more to an obligatory protective effect secondary to co-existing improvement than compliance with recommended restrictions. For example, the youngest patient in the series underwent TER at the age of 24 years as an alternative to amputation. Over 26 years later she works as a clerk. Although the arm is constrained by a Volkmann’s contracture and a post-traumatic one-bone forearm, she admits to using it to lift her children. Her last radiographs, 26 years post-operatively, showed no signs of loosening or bushing wear (Fig. 4).

Several measures to lessen post-operative ectopic calcification about the elbow are available. However, the response to any such treatment is unpredictable, as seen by the development of ectopic bone in three patients who had received prophylactic radiation. Ring and Jupiter also encountered limited success despite repeat resection and adjuvant radiation therapy in a group of post-traumatic fused elbows. They found more predictable results when treating post-traumatic heterotopic ossification which restricted movement.19

Our study did not use fluoroscopically-controlled anteroposterior views of the elbow, or varus/valgus stress views. Although this type of investigation would provide more accurate wear data, none of our patients showed any adverse bony resorption due to bushing wear. As some of these patients had contractures greater than 20°, the ability to measure wear accurately because of varus/valgus positioning of the implant on the anteroposterior view is compromised.

In conclusion, a non-custom linked semi-constrained TER for the ankylosed elbow can provide reliable and predictable results. The technical difficulties and considerable complication rate should be seriously considered beforehand. Post-operative wound breakdown, stiffness and infection about the multiply-operated elbow are well recognised, and the high complication rate emphasises the need to critically discuss the risk-benefit features of this operation. Nevertheless, our experience suggests that, in selected cases, a joint replacement may be a suitable option when a stable and mobile elbow is crucial for basic activities and expectations are realistic.

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