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J Hand Surg Eur Vol published online 10 October 2011
DOI: 10.1177/1753193411421094

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Proof - Oct 10, 2011
What is This?
Preventing recurrence of radioulnar synostosis with pedicled adipofascial flaps

J. Sonderegger
Spital Grabs, Departement Chirurgie und Orthopädie, Grabs, Switzerland
S. Gidwani
Guy’s & St Thomas’ Hospitals, London, UK
M. Ross
Brisbane Hand and Upper Limb Research Institute; Department of Orthopaedics, Princess Alexandra Hospital, Brisbane, Queensland, Australia

Abstract
The surgical treatment of post-traumatic radioulnar synostosis is difficult. Recurrence after resection alone is a concern with poor long-term maintenance of forearm rotation. We report on the use of pedicled adipofascial flaps to prevent recurrence and facilitate maintenance of movement in six adult patients with radioulnar synostosis. Five involved the proximal radioulnar joint and one the distal radioulnar joint. In four the flap was based on the radial artery and in two on the posterior interosseous artery. Mean intraoperative supination was 78° and pronation was 76°. Mean follow up was 32 months. At follow-up, mean supination was 71° and pronation was 70°. No patient had radiological recurrence of synostosis. The only complication was a transient posterior interosseous nerve palsy. Pedicled adipofascial flaps are a safe addition to resection alone which may prevent recurrence and maintain the range of forearm rotation achieved at operation.

Keywords
Radioulnar synostosis, pedicled forearm flaps, posterior interosseous artery, radial artery, post-traumatic, adipofascial flaps

Introduction
Severe post-traumatic radioulnar synostosis presents a difficult challenge. The restriction of rotation can be disabling in many activities of daily living. The risk of recurrence of heterotopic ossification after resection of the synostosis alone is a concern, especially for proximal synostosis (Failla et al., 1989; Vince and Miller, 1987). Many treatment options have been proposed. Nonsteroidal anti-inflammatory medication and low dose postoperative irradiation can be used to decrease recurrence (Abrams et al., 1993; Cullen et al., 1994). Artificial or biological interposition material can create a barrier between the raw bony surfaces. Traditionally, interposition material included silicone rubber sheets (Carstam and Eiken, 1971; Schneider and Leyva, 1964), bone wax (Jupiter and Ring, 1998), or soft tissue such as free fat (Jupiter and Ring, 1998; Yong-Hing and Tchang, 1983). However, these interposition materials may not prevent recurrence, as nonvascularized tissue may be eventually replaced by scar tissue. More recently, the use of vascularized muscle interposition (Bell and Benger, 1999; Fernandez and Joneschild, 2004), vascularized free flaps (Friedrich et al., 2006; Kanaya and Ibaraki, 1998; Muramatsu et al., 2004), or vascularized pedicled flaps (Funakoshi et al., 2004; Jones et al., 2004; Jones et al., 2007; Sugimoto et al., 1996) have been used. The efficacy of these methods is variable and surgery is not without complications. Most are case reports or focus on children with congenital synostosis. We report our experience in six adult patients who had a pedicled adipofascial flap to treat post-traumatic radioulnar synostosis.

Method
Ethical approval was not required and appropriate consent was obtained before surgery. Patients signed a generic consent form allowing their details to be used for research purposes. Before surgery the patients were informed of the lack of consensus

Corresponding author:
Mark Ross, Associate Professor Brisbane Hand and Upper Limb Clinic, Level 9, Brisbane Private Hospital, 259 Wickham Terrace, Brisbane Queensland 4001, Australia.
Email: markross@upperlimb.com
regarding the best treatment of severe radioulnar synostosis.

The records of six patients who had surgical treatment for severe post-traumatic radioulnar synostosis between 1999 and 2004 were retrospectively reviewed. Their mean age was 44 (range, 24 to 61) years. The duration from initial injury to surgery was 34 (range, 7 to 84) months and patients had already had two (range, 1 to 5) previous operations.

Preoperative evaluation included standard anteroposterior and lateral radiographs of the forearm and a CT scan of the synostosis. Five patients had complete bony synostosis with no forearm rotation (Figure 1). One patient had severe bridging heterotopic ossification with 25° of supination and no pronation. Five cases involved the proximal radioulnar joint (type III) (Vince and Miller, 1987) and one the distal radioulnar joint (type I). There were no cases of type II forearm shaft synostosis. In most we used an antegrade/proximally based radial artery based flap (Table 2) which has been described as both a fasciocutaneous and an adipofascial flap (Braun et al., 1985). It was harvested in the distal half of the forearm, usually over the distal third of the radius. In this area there are many perforators between the radial artery and the fasciocutaneous flap. While the thickness of fat, which is harvested with the fascial tissue, depends on the morphology of the patient, we prefer to have at least 2–3 mm of fat over the fascia. We harvested a flap measuring approximately 6 cm in width and 10 cm in length. After the flap was defined and the fascial septum and perforators had been isolated the radial artery and veni commitantes were ligated distally and elevated proximally. The radial artery was then dissected back to the proximal aspect of the wound, almost to the level of the cubital fossa. It was usually necessary to divide the recurrent branches of the radial artery, not only to allow positioning of the pedicle without kinking, but also to permit adequate exposure of the proximal radius for resection of the synostosis.

Proximally the radius was exposed through a Henry’s approach in the interval between the radial artery and the radial nerve. We commonly elevated the supinator muscle along the anterior oblique line to expose the radius and the heterotopic ossification was usually located in this region. The synostosis was resected with care taken to define the true bony margins of the radius. Care was also required to identify and preserve the insertion of the distal biceps tendon.
### Table 1. Preoperative patient data

<table>
<thead>
<tr>
<th>No</th>
<th>Age/dominant hand</th>
<th>Occupation</th>
<th>Initial injury and subsequent surgery</th>
<th>Number of previous operations</th>
<th>Synostosis site (Vince &amp; Miller classification)</th>
<th>Injury to index surgery (months)</th>
<th>Preoperative range of motion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>61 Right</td>
<td>Engineer &amp; violin teacher</td>
<td>Fracture/dislocation of right elbow (open). Initial ORIF ulna revised. Bone grafting needed for delayed union.</td>
<td>3</td>
<td>Proximal (III)</td>
<td>7</td>
<td>None</td>
</tr>
<tr>
<td>2</td>
<td>24 Right</td>
<td>Electrical linesman</td>
<td>Fracture right proximal radius. ORIF via Henry approach.</td>
<td>1</td>
<td>Proximal (III)</td>
<td>45</td>
<td>10° fixed</td>
</tr>
<tr>
<td>3</td>
<td>45 Right</td>
<td>Teacher</td>
<td>Fracture/dislocation right elbow. Radial head replacement and lateral ligament complex repair via Kocher approach.</td>
<td>1</td>
<td>Proximal (III)</td>
<td>24</td>
<td>10° fixed 25° to 130°</td>
</tr>
<tr>
<td>4</td>
<td>33 Left</td>
<td>Travel agent</td>
<td>Open right distal radius and ulna fracture. Multiple operations including Sauvé-Kapandji. HO from ulnar stump to radius.</td>
<td>5</td>
<td>Distal (II)</td>
<td>84</td>
<td>5° fixed None</td>
</tr>
<tr>
<td>5</td>
<td>54 Right</td>
<td>Refinery worker</td>
<td>Fracture/dislocation left elbow. Removal of loose bodies and temporary K-wire fixation of ulnohumeral joint.</td>
<td>1</td>
<td>Proximal (III)</td>
<td>10</td>
<td>25° fixed None</td>
</tr>
<tr>
<td>6</td>
<td>48 Right</td>
<td>Labourer</td>
<td>Fracture/dislocation right elbow. Reduced, radial head removed, silastic spacer inserted. Spacer later removed.</td>
<td>2</td>
<td>Proximal (III)</td>
<td>32</td>
<td>10° fixed 55° to 100°</td>
</tr>
</tbody>
</table>

HO: Heterotopic; ORIF: Open Reduction Internal Fixation.
In patients with extensive involvement, when heterotopic ossification enveloped the ulna, we identified and protected the median nerve and, in particular, its anterior interosseous branch. After resection of the heterotopic ossification we confirmed that rotation was restored and assessed the range of supination and pronation. Next, the pedicle was turned around on itself in a retrograde fashion and the fasciocutaneous flap brought into the area where the heterotopic ossification had been resected.

Placing the arm in maximum supination exposed the dorsal edge of the resection margin of the heterotopic ossification on the radius. Three absorbable bone anchors were placed along this margin and used to suture the edge of the fasciocutaneous flap to the bone. The flap was inserted with the superficial surface of the flap facing the bony surface so that fat was opposed to the bone, and so that the pedicle sat on the superficial aspect of the flap as it lay on the radius.

The radius was then pronated fully until the edge of the heterotopic ossification resection was identified on the radial aspect and three further anchors were then used to secure the flap to that resection margin. The intention was for the flap to cover the entire area of raw bone where the heterotopic ossification had been removed from the radius while maintaining mobility of the pedicle to supply the flap in full supination and pronation. Once the flap was secured care was taken to ensure that the radius could supinate and pronate fully without kinking the pedicle. This was achieved by ensuring that the radial artery was mobilized up to the cubital fossa to its bifurcation from the brachial artery, depending on the level of this bifurcation. The wound was then closed over a suction drain.

Results

The mean follow up was 32 (range, 15 to 54) months. During the operation and after excision of the synostosis, supination was 78° and pronation was 76°. The mean duration of surgery was 170 minutes. At final follow up mean supination was 71° and pronation 70° (Table 2). On examination and radiographs there were no signs of recurrent synostosis. There was one complication in a patient who suffered a transient posterior interosseous nerve palsy, which recovered spontaneously after 4 weeks. This patient was treated with a radial forearm flap and not a posterior interosseous flap. There were no infections, and no patient had a haematoma or circulatory problem and there was little deterioration in elbow or wrist range. According to our hand physiotherapists all patients were easy to rehabilitate. Splinting was not used. Range of movement was maintained. All patients reported that they were satisfied with the result and had returned to their previous work. One patient returned to lighter duties within their normal work due to a degenerative ulnohumeral joint.

Discussion

Radioulnar synostosis is a rare but disabling condition. Risk factors for the development of radioulnar synostosis include burns, severe trauma with soft tissue damage, repair of distal biceps tendon rupture, surgical treatment of forearm fractures, skeletal immaturity, and head injury. There is still controversy about the best treatment of post-traumatic radioulnar synostosis. The recurrence rate after excision alone is a concern. Based on the three largest series of patients, the recurrence rate following excision of a primary synostosis was 32% (Fernandez and Joneschild, 2004). Vince and Miller (1987) developed a widely accepted classification system for radioulnar synostosis. Type I synostosis occurs at the level of the distal radioulnar joint, type II in the middle third of the shaft and type III in the proximal third. They reported that five of the 17 synostoses recurred after excision alone. There were no recurrences after excision of 10 type II synostosis. However, two of the three proximal type III and three of the four distal type I synostosis recurred. Failla et al. (1989)
Table 2. Intraoperative and postoperative data

<table>
<thead>
<tr>
<th>No</th>
<th>Surgical approach</th>
<th>Adipofascial flap used</th>
<th>Radial head</th>
<th>Adjuvant treatment or surgery</th>
<th>Final review (months)</th>
<th>Flexion-arc</th>
<th>Flexion-extension arc</th>
<th>Return to work status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Boyd Antegrade</td>
<td>Not excised</td>
<td>Indomethacin, brachial plexus catheter</td>
<td>54</td>
<td>80°</td>
<td>70°</td>
<td>10° to 140°</td>
<td>65° [80°]</td>
</tr>
<tr>
<td>2</td>
<td>Extended Henry</td>
<td>Not excised</td>
<td>Indomethacin, brachial plexus catheter</td>
<td>15</td>
<td>90°</td>
<td>75°</td>
<td>Full</td>
<td>85° [85°]</td>
</tr>
<tr>
<td>3</td>
<td>Anterior Henry</td>
<td>N/A</td>
<td>Indomethacin, brachial plexus catheter</td>
<td>17</td>
<td>75°</td>
<td>70°</td>
<td>10° to 130°</td>
<td>85° [85°]</td>
</tr>
<tr>
<td>4</td>
<td>Boyd and dorsal</td>
<td>N/A</td>
<td>Indomethacin</td>
<td>52</td>
<td>70°</td>
<td>90°</td>
<td>N/A</td>
<td>50° [70°]</td>
</tr>
<tr>
<td>5</td>
<td>Extended Henry</td>
<td>Excised</td>
<td>Indomethacin, brachial plexus catheter</td>
<td>26</td>
<td>80°</td>
<td>70°</td>
<td>40° to 110°</td>
<td>70° [75°]</td>
</tr>
<tr>
<td>6</td>
<td>Anterior Henry</td>
<td>N/A</td>
<td>Ulnohumeral release, indomethacin, brachial plexus catheter</td>
<td>29</td>
<td>70°</td>
<td>80°</td>
<td>40° to 130°</td>
<td>70° [75°]</td>
</tr>
</tbody>
</table>

DRUJ: Distal Radio Ulnar Joint; N/A: Not Applicable; PIA: Posterior Interosseous Artery.
reported poor results after excision of 20 proximal type III synostosis over a 42 year period. The mean range of forearm rotation at follow up was 55°. Only seven patients had a good or excellent result with a range of rotation of more than 60°. Nine patients achieved poor results with remaining forearm rotation of less than 30°. In contrast Jupiter and Ring (1998) reported excellent results in 17 of 18 patients after resection of proximal type III radioulnar synostosis. The first seven patients had interposition of a nonvascularized fat graft after excision, a technique that was discontinued in the remaining ten patients. There was only one recurrence in a patient with an associated head injury. The patients who had excision and interposition of a fat graft achieved a mean forearm rotation of 138°. Those patients without interposition of a fat graft achieved 141°. Kamineni et al. (2002) suggested proximal radial resection to improve forearm rotation in severe post-traumatic proximal radioulnar synostosis. They reported on seven patients with an average forearm rotation of 98° at follow up. This may suggest that a flap or interposition is not needed.

Several artificial and biological interposition materials have been used to prevent reformation of bone between the raw surfaces of the radius and ulna after resection of the radioulnar synostosis. More than 40 years ago, Schneider and Leyva (1964) described the use of silicon interposition in a patient with recurrent radioulnar synostosis. Although several other authors have reported on interposition of thin silicone sheets (Carstam and Eiken, 1971; Failla et al., 1989; Vince and Miller, 1987), the results have not been consistent. Subsequently, artificial interposition materials have been replaced by biological tissue such as the fascia, fat, and muscle. Yong-Hing and Tchang (1983) reported on two cases where a nonvascularized abdominal fat interposition graft was used. Jupiter and Ring (1998), however, could not demonstrate benefit of a nonvascularized fat interposition graft in proximal type III synostosis.

More recently, promising reports on vascularized interposition flaps have been published. Bell and Benger (1999) reported on three successfully treated patients with proximal type III radioulnar synostosis where a vascularized anconeus muscle flap was interposed after resection. The average improvement in forearm rotation was 130°. Fernandez and Joneschild (2004) used a brachioradialis muscle flap in three cases and a flexor carpi ulnaris flap in two cases to prevent recurrent synostosis and also reported excellent results.

Kanaya and Ibaraki (1998) described a free vascularized adipofascial graft from the lateral arm based on the posterior radial collateral artery in seven children with congenital proximal radioulnar synostosis. The average range of rotation at follow up was 71°. Muramatsu et al. (2004) reported on two patients with post-traumatic radioulnar synostosis, where a free vascularized inguinal fat graft was used for interposition. The range of rotation at follow up was 130° in both cases. Friedrich et al. (2006) reported the interposition of a free tensor fascia lata graft in 13 patients. The results were excellent with an average range of rotation of 124°. Although the results of these free vascularized interposition grafts are promising, they require microsurgical skills and could cause donor site morbidity.

Pedicled vascularized interposition grafts, such as a radial forearm flap or a posterior interosseous artery forearm flap, are good alternatives to the previously described techniques. These flaps are relatively easy to harvest, do not require microsurgical anastomosis and are safe. There are only a few case reports on pedicled vascularized grafts for radioulnar synostosis, mainly done in children. Sugimoto et al. (1996) reported on one patient whose post-traumatic type III radioulnar synostosis was treated by excision and interposition of a posterior interosseous forearm flap. However, at 1 year, the range of forearm rotation was only 65°. Funakoshi et al. (2004) described one patient with a congenital radioulnar synostosis, also treated with a pedicled posterior interosseous fat graft. Jones et al. (2004) reported on a patient of a post-traumatic type II synostosis, successfully treated by excision and interposition of a radial forearm adipofascial flap. More recently, Jones et al. (2007) reported excellent results in four children treated using a proximally based posterior interosseous adipofascial flap.

We acknowledge that the harvest of a pedicled adipofascial flap requires an extensive surgical approach compared to that required for excision of the synostosis alone. The sacrifice of the radial artery in the case of a radial artery flap might also be a concern. Although we did not record the additional time taken to harvest the flap, we estimate it to be approximately one hour. The additional scar did not concern any of our patients. For these reasons, this technique could be recommended in selected patients and should not be used routinely in all cases of radioulnar synostosis. We prefer this to resection alone in severe cases with no forearm rotation especially in Type I and III synostosis. Type II synostosis probably does not need an interposition flap. Patients who have a tendency for severe heterotopic ossification, for example after a head injury or severe burns, might also benefit from this technique.

In our six adult patients, we used pedicled adipofascial forearm flaps and had almost no loss of...
forearm rotation from that obtained at operation. This is particularly noteworthy as intraoperative rotation was measured passively and final rotation was measured actively. Our physiotherapist found these patients easy to rehabilitate and did not find range difficult to maintain. We believe that pedicled adipofascial forearm flaps provide an alternative to excision of the synostosis alone in severe cases of radioulnar synostosis.

Funding
This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflict of interests
None declared.

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