Excision of heterotopic new bone around the elbow in patients with head injury: 51 cases

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ABSTRACT

Purpose of the study
Neurogenic paraosteoarthropathy of the elbow is a frequent complication in head injury patients. The functional impairment may be severe. The purpose of this work was to evaluate the efficacy of our medico-surgical approach and to determine indications for surgery.

Material and methods
We analyzed retrospectively a continuous series of 44 patients (51 elbows) with neurogenic heterotopic new bone of the elbow joint managed from 1993 to 2000. The heterotopic bone had developed on a central deficit limb in 70% of the patients. Flexion-extension was limited in all patients, and pronation-supination in nine. The ulnar nerve was compressed by the heterotopic bone in half of the patients. A 3D reconstruction CT-scan with contrast injection was obtained in all patients. We did not use the classical criteria for bone maturation to assess operability. Using an adapted approach, we removed the heterotopic new bone to enable complete elbow motion. Associated procedures were performed in fifteen patients due to persistent intraoperative joint stiffness related to muscle-tendon retraction. We did not prescribe diphosphonates or radiotherapy postoperatively.

Results
At 45 months follow-up, one patient had been lost. Relative gain was considered very good in 34 elbows, good in 13 and fair in 3. There were no cases of lost motion. There were no recurrences causing joint limitation, but two of nine cases of radioulnar synostosis recurred.

Discussion
Neurogenic paraosteoarthropathy of the elbow impairs joint function and may lead to ulnar nerve compression. The goal of surgery is to improve function. The analysis of our results show that early surgery yields good results without complementary treatment, irrespective of the patient's overall functional deficit or cognitive status and irrespective of the localization of the heterotopic bone. The essential prognostic factor for the quality results is the neurological status of the limb, particularly the degree of spasticity and muscle-tendon retraction.

Key words: Neurogenic ossification, elbow, ulnar nerve, entrapment, head injury.
INTRODUCTION

Neurogenic heterotopic ossification or neurogenic para-osteoarthropathy (POA) is a frequent complication after brain injury. The functional impact can be significant, sometimes leading to irreversible neurological damage for example after nerve entrapment. The purpose of this study was to analyze long-term gains in joint motion and function after excision of the heterotopic bone. Our goal was to determine the precise indications and therapeutic modalities. We conducted our study among patients who had undergone surgical resection of elbow ossifications followed by rehabilitation in the physical therapy unit at the Raymond Poincaré Hospital in Garches France.

MATERIAL AND METHODS

This retrospective analysis included a consecutive series of 51 elbows (44 patients) operated on by the same surgeon between 1993 and 2000 for neurogenic POA. All had experienced brain injury at the mean age of 32.5 years (range 19-62). Male gender predominated (40 men, 4 women). Both elbows presented heterotopic new bone in seven patients. At review, mean follow-up was 45 months (range six months to four years). Fifty elbows (43 patients) were reviewed. One patient was lost to follow-up.

The POA had developed after coma in all patients. The coma was secondary to head trauma for 46 elbows (41 patients), a vascular event in two elbows (rupture of aneurysm in two patients), and a medical cause for two elbows (one patient given prolonged intensive care for severe pneumonia). Mean duration of coma was 37 days (range 4 days to 4.5 months). The initial Glasgow score was less than 7 in all patients.

Preoperative clinical and radiographic assessment was noted in all patients.

Preoperative clinical assessment

The clinical assessment aimed at determining the patient’s overall neurological status before surgery and specifically the neurological status of the limb involved and the functional impact of the POA.

The Garland et al. (1) classification was used to assess overall neurological status. This classification defines five stages according to cognitive impairment and overall function (table I).

The preoperative neurological assessment showed a harmonious distribution of the 44 patients: stage I: five patients (7 elbows); stage II: 9 patients (10 elbows); stage III: 12 patients (13 elbows); stage IV: 8 patients (9 elbows); stage V 10 patients (12 elbows).

Neurological deficits of the upper limb were noted as central or peripheral depending on the results of the physical examination and the electromyography, which was performed if there was doubt concerning nerve compression by

<table>
<thead>
<tr>
<th>Stage</th>
<th>Cognitive impairment</th>
<th>Functional deficit</th>
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<tbody>
<tr>
<td>Stage I</td>
<td>Mild</td>
<td>Mild</td>
</tr>
<tr>
<td>Stage II</td>
<td>Mild</td>
<td>Moderate</td>
</tr>
<tr>
<td>Stage III</td>
<td>Mild</td>
<td>Severe</td>
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<tr>
<td>Stage IV</td>
<td>Moderate / severe</td>
<td>Mild / moderate</td>
</tr>
<tr>
<td>Stage V</td>
<td>Moderate / severe</td>
<td>Severe</td>
</tr>
</tbody>
</table>

Functional deficit: mild: patient can walk without assistance with or without distortion and spastic disorder scored 0 or 1; moderate: patient walks with a walking aid, is independent in a wheelchair, requires minimal assistance for transfers or has moderately severe hemiparesia or moderate tetraparesia; severe: daily assistance required, severe hemi or quadriplegia

The functional impact of the POA on the elbow joint was assessed by measuring joint motion with a goniometer. POA-related pain was noted. Joint motion (flexion-extension) ranged from 0° to 95°, with a mean of 18°. Twenty-three elbows presented a bony bridge with complete ankylosis. For the 28 elbows with flexion-extension, mean range of motion was 32° (10°-95°). Elbow position was noted. For 31 elbows, the position was around 90°. For 16, it was in the extension range and for four, in the flexion range. Pronosupination was deficient in nine elbows (17.5%). Severe pain was noted in 6 elbows with recently developed POA (less than one year). Functional impairment depended on the level of activity and the overall neurological status. For each patient, we noted the type of impairment and the benefit to be expected from a gain in elbow motion. For 21 elbows (18 patients), the goal was to facilitate nursing care (dressing, transfers to bed or wheelchair, personal hygiene). For 30 elbows (26 patients), the goal was to achieve functional improvement with useful gain in joint motion to meet the patient’s needs (generally eating and dressing movements).

Preoperative radiographic assessment

Standard x-rays of the elbow with spiral computed tomography (CT) scans after contrast injection and 3D recon-
struction were performed in all patients in order to elaborate the surgical strategy.

On the 3D reconstructions, three main categories of heterotopic new bone were identified, depending on the localization of the ossification: posterior, anterior, and both anterior and posterior. In 40 elbows (78%) the ossification was posterior. Three groups were defined: posteromedial (n = 25; 49%), often filling the ulnar nerve groove with subsequent ulnar nerve compression (fig. 1); purely posterior (n = 12; 23%), often filling the olecranal fossa with injury of the brachial triceps tendon (fig. 2); posterolateral (n = 3; 6%), exclusively humeroradial and often limiting pronation supination. The localization was anterior in 8 elbows (16%) where the new bone was implanted on the anterior metaphyseodiaphyseal aspect of the humerus, on the coronoid process, or the anterior metaphyseodiaphyseal aspect of the ulna (fig. 3). For three elbows (6%) the ossification was both anterior and posterior around the humeroradial joint. The new bone often infiltrated the joint capsule, generally in a very localized zone. Intra-articular damage was noted in three elbows. All three were ankylosed due to limited synchondrosis (n = 2) and overall joint space narrowing (n = 1, recurrent POA at six years).

Operative technique

The goal of surgery was to restore complete joint motion (pronation, supination, flexion-extension > 100°) and nerve-vessel release. Surgery was performed under general anesthesia in all patients. Patient position depended on the surgical approach: supine position for medial, lateral or anterior approaches; lateral decubitus for posterior approach. A high tourniquet was installed in all cases. The skin incision was adapted to the topography of the POA as well as any associated joint stiffness (particularly shoulder stiffness) which affected the patient’s position on the operative table. A medial or lateral incision was used alone for posteromedial or posterolateral localizations respectively and a double incision if the ossification was both anterior and posterior. An anterior incision was used for anterior localizations (fig. 4) and a posterior incision if the POA was posterior or posteromedial in a patient with a stiff shoulder compromising the medial approach.

The approach was lateral for 5 elbows, medial for 15, double for 3, anterior for 8 and posterior for 21.

Although the heterotopic bone could not be completely removed, we tried to excise all blocks limiting joint motion. The olecranal fossa was cleared and the medial lateral ligament was released if necessary. The olecranon did not have

Fig. 1.– Transversal CT image of a posteromedial new bone deposit forming a groove around the ulnar nerve.

Fig. 2.– 3D reconstruction of a posterior POA of the elbow filling the olecranal fossa.

Fig. 3.– 3D reconstruction after contrast injection showing an anterior humeroulnar ossification: note relations with vascular elements.
to be remodeled and the coronoid process was not resected. We attempted to achieve complete flexion-extension and optimal pronation. Hemostasis was checked again after removing the tourniquet. Section cuts were waxed and aspiration drains were installed.

For 15 elbows, soft tissue release was necessary because muscle tendon retraction persisted with joint stiffness intraoperatively. When the passive extension deficit persisted after removal of the heterotopic bone due to flexor retraction, lengthening by intra-muscular tenotomy was necessary, particularly for the brachial muscle in 7 cases. For one patient, adequate extension could only be achieved after associated release of the brachial biceps and the brachioradial muscle. Brachial triceps lengthening was performed in 7 cases with posterior or posterior and anterior POA because the flexion deficit persisted after excision of the heterotopic bone due to branchial triceps retraction.

When the ossification had infiltrated the joint capsule, we performed a capsulectomy limited to the zone involved. For two cases, capsulectomy involved the entire anterior aspect of the capsule. In the others, partial capsulectomy was performed. There were no cases with a retracted infiltrated capsule causing residual stiffness.

Regarding the medial localizations, we did not observe any cases with lamination of the medial lateral ligament, but rather the development of the heterotopic bone on either side of this ligament. This generally produced a windshield wiper effect rather than ligament distension. We did not have any surgery-related injury to the medial lateral ligament.

Post-operative care

After surgery, all patients were referred to the physical medicine and functional rehabilitation unit of the Ile-de-France neuro-orthopedics network. Joint mobilization was started early, on the second postoperative day. Posture braces were used if compatible with the patient’s behavior. A physical therapist installed flexion-extension postures twice daily until skin healing. Beyond this time, elbow mobilization alone, without postures, was used. The arthromotor, which would not be appropriate for all patients, was not used. Rehabilitation exercises were always performed below the pain threshold. Patients were given analgesics and anti-inflammatory drugs for twelve days, with ice packs on the elbow. In order to avoid hematoma formation, aspiration drains were maintained as long as there was an aspiration product. Diphosphonates were not prescribed and postoperative radiotherapy was not used.

Outcome assessment

Gain in joint motion was noted. The goal was to achieve a useful range of motion in the context of the patient’s overall neurological status.

Gain in joint motion was assessed using the Deburge criteria presented at the SOFCOT in 1970 [Kerboull and Deburge (2)]. This system defines improvement as the percent gain in motion relative to the deficient state (the difference between the preoperative motion and normal elbow range of motion, ca. 140°) [Gacon et al. (3), Garland (4)]. According to this system, outcome was considered as:

- very good for > 70% improvement;
- good for 40 to 70% improvement;
- fair for 20 to 40% improvement;
- poor for < 20% improvement;
- worse if range of motion was lost.

We searched for statistical correlations between the postoperative results and time to surgery, POA topography, overall neurological status, neurological status of the operated limb, and types of soft tissue procedures performed. Chi-square test was used for qualitative variables and Student’s t test for comparisons between means. P < 0.05 was considered significant.

To determine patient operability, we considered bone maturation values (serum alkaline phosphatases, hydroxyprolinuria) and "cold" bone scintigraphy.

RESULTS

Mean joint motion (flexion-extension) for the studied elbows was 18° preoperatively and 105° at last follow-up, giving an absolute gain of 87° (range 20°-135°). For the non-ankylosed elbows, the gain was from 32° to 108°. For the ankylosed elbows, the gain was from 0° to 97° (fig. 5).

In terms of relative gain, using the Kerboull and Deburge (2) criteria, outcome was very good for 35 elbows (87% mean relative gain) (70% of operated elbows), good for 12 (63% mean relative gain) (24% of operated elbows), poor for 3 (6% of operated elbows). None of the elbows lost joint motion.

At last follow-up, we noted two cases of partial recurrence with POA noted on the elbow x-rays. In one patient,
bone had been deposited in the anterior brachial muscle on a prior POA but with no impact on joint motion. In the other patient, there was recurrent radio-ulnar ossification which blocked pronation-supination. The three poor results involved patients with spastic hypertonia (two patients including one with dislocation of the radial head following resection of the radial annular ligament) or joint stiffness (one patient) related to intra-articular cartilage damage. This later patient underwent a subsequent procedure with a distractor. The gain finally obtained could not be sustained over time and the patient presented 30° flexion-extension at one year. Pronation-supination improved in 7/9 patients: in four the mean range was greater than 120°, in three there was a partial gain with mean range of 63°. For two elbows, there was no improvement due to recurrent radio-ulnar synostosis which was superior in one case due to blocked pronation (no functional impact). In the other patient, release was not warranted. There was one case of elbow instability after osteonecrosis of the humeral condyle.

We assessed outcome according to time from trauma to surgery. Mean gain in patients whose surgery came less than a year after trauma (24 elbows, 48% of reviewed elbows, including 9 elbows with delay to surgery less than six months) was 86°, for an overall improvement of 79%. For those with a time to surgery of more than one year (20 elbows), absolute gain was 91° and relative gain 90%. The difference was statistically significant.

Statistically, the localization of the heterotopic bone did not appear to affect outcome. For posterior localizations, there was an 86° gain in joint motion with a 73% improvement. The figures were 81° and 77% for postero medial localizations, 89° and 69% for anterior localizations, and 72° and 63% for anterior and posterior localizations. There was no significant difference in gain in motion nor in relative improvement according the localization of the POA.

Functiona improvement in flexion-extension is presented in Table II according to the patient’s initial cognitive and functional status. There was no correlation between the postoperative function and the preoperative Garland stage.

Conversely, regarding central neurological deficit of the operated limb which persisted at last follow-up, we found that when the POA occurred on the side of a pyramidal syndrome (30 elbows) the absolute gain was 79° for a relative gain of 63%. For patients with no central deficit (20 elbows), absolute gain was 91° and relative gain 90%. The difference was statistically significant.

An associated soft tissue procedure also appeared to affect outcome. All four patients who underwent brachial triceps lengthening presented decreased muscle force (grade 3 for one and grade 4 for three) and had a residual extension deficit (mean 24°, range 10°-45°). Conversely, outcome was significantly different in the seven patients who underwent a procedure on the flexors. Their mean flexion was 124° (range 115°-135°) and their mean extension -16° (range 0° to -30°) with no effect on flexion muscle force. We did not have any case with lengthening of all the elbow flexors.

There were six early postoperative complications:

- wound dehiscence (n = 1) and hematoma (n = 2) requiring revision but with no functional impact;
- inflammatory episode (n = 2) requiring an interruption of the physical therapy exercises without early POA recurrence. These two patients had massive spastic hemiplegia. Both had limited joint motion due to hypertonia and soft tissue retraction. In one patient, extension remained limited at -40°; in the other, the elbow was stiff and held at nearly 90° permanently; there was no radiographic evidence of recurrence at one year.
- anterior dislocation (n = 1) of the radial head at day 6 postop due to major hypertonia of the brachial triceps which had been missed preoperatively due to the elbow blocked in extension.

The nursing care objectives were reached for all patients thanks to the gain in joint motion in all patients. For the functional needs, outcomes were less than expected because of the central neurological deficits on the operated side which did not allow reaching the desired objectives.

**Table II. Gains in joint motion (flexion-extension) according to Garland stage.**

<table>
<thead>
<tr>
<th>Garland stage</th>
<th>Absolute gain</th>
<th>Relative gain</th>
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<tbody>
<tr>
<td>Stage I</td>
<td>95°</td>
<td>82%</td>
</tr>
<tr>
<td>Stage II</td>
<td>79°</td>
<td>77%</td>
</tr>
<tr>
<td>Stage III</td>
<td>88°</td>
<td>75%</td>
</tr>
<tr>
<td>Stage IV</td>
<td>77°</td>
<td>71%</td>
</tr>
<tr>
<td>Stage V</td>
<td>75°</td>
<td>73%</td>
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Absolute gain in flexion-extension was measured in degrees. Relative gain in percentage.
DISCUSSION

Several important elements must be considered for the therapeutic strategy in patients with neurogenic POA of the elbow: the characteristics of the osseous deposit, its effect on the elbow joint, and the neurological context. Correct therapeutic strategy is required for quality long-term results.

Flexion-extension results in our series were analyzed in terms of gain in motion. Gain in elbow motion is of particular importance for functional recovery of the upper limb after bony deposits stiffen the joint. It is however insufficient to evaluate the functional impact of the surgical procedure. The range of motion must also be taken into consideration as well as elbow stability. We had two cases where 50% gain was achieved but where flexion was limited to 100°, greatly hampering function. There was only one unstable elbow resulting from partial necrosis of the humeral trochlea. Despite good gain in range of motion, this elbow had no usable force.

We noted that the patient’s preoperative status in terms of cognitive and overall function was not correlated with gain in motion. This demonstrates that good elbow function can be achieved in patients with a functional deficit and severe cognitive impairment. Several authors are in agreement with this [Roberts (5)] but not all [Garland et al. (1), Ippolito et al. (6), Rigaux et al. (7)]. A severe deficit is not a contraindication for arthrolysis since it is not a prognostic factor. In our opinion, this type of indication is indicated to avoid irreversible injury caused by ulnar denervation subsequent to bone compression.

Conversely, a central deficit on the operated side was an important prognostic factor since functional outcome was significantly more favorable in elbows without motor deficit. The effect of a neurological deficit on the functional outcome can be explained by the difficult postoperative rehabilitation in patients with a spastic limb, which predominated in the flexors in our series. In order to improve spasticity, which can worsen after surgery, we have developed an associated medical treatment for patients undergoing excision of heterotopic bone from a spastic neurological elbow: botulinum toxin injected in the flexors (brachial biceps, brachial muscle) or musculocutaneous nerve block using an implantable chamber [Denormandie et al. (8)].

Each localization is particular because of its relations with neighboring tissues. A spiral scan with 3D reconstruction after contrast injection is the ideal imaging method. We have used it systematically for preoperative planning. This enables a precise localization of the heterotopic bone and an assessment of its impact on the joint (degree of ossification, status of the joint line), as well as its relations with vascular (fig. 2) and nervous (fig. 3) bundles. We record an electromyogram if there is clinical or radiological doubt about nerve entrapment. Compression of a nerve, generally the ulnar nerve, is an indication for surgery to achieve early neurolysis without transposition at the same time as excision of the heterotopic bone. This attitude is also advocated by others [Keenan et al. (9), Chao et al. (10)].

We did not take into account criteria of bone maturation (normal serum alkaline phosphatase level, hyperprolinuria, "cold" scintigraphy) to determine when patients should undergo surgery. Others have reported that the rate of recurrence does not change with bone maturation or radiological criteria [Rigaux et al. (7), Benezech-Lefevre et al. (11), Chantraine and Minaire (12)].

Time from trauma to surgery did not appear to affect outcome. This enables early surgery. Our results were in agreement with others [Rigaux et al. (7), Berard et al. (13), Berard and Cypres (14), Fyon et al. (15), Lecuire et al. (16), Mc Auliffe and Wolfson (17), Pelissier et al. (18), Summerfield et al. (19)] who also found that POA surgery can be performed before one year.

We tend to limit indications for lengthening the brachial triceps muscle to patients with major muscle retraction because of the loss of muscle force.

We do not prescribe diphosphonates nor postoperative radiotherapy because of the lack of proven efficacy [Berard and Cypres (14)]. Our approach appears to be satisfactory since we have not had any recurrences.

CONCLUSION

We reviewed 51 elbows in 44 patients who underwent surgical excision of heterotopic new bone subsequent to brain injury. The indication for surgery was the degree of functional impairment or presence of nerve entrapment, suspected clinically or demonstrated by electromyography. The goal of surgery was to improve function. This retrospective analysis of outcome confirmed that early surgery (less than one year after trauma) is possible and can yield good results. We obtained good or very good results in 47 elbows (92%) and did not have any case of recurrent POA. We found that the essential prognostic factor for quality outcome was the neurological status of the limb, particularly the degree of spasticity and tendon-muscle retraction. Spasticity can be treated with botulinum toxin. We did note however that surgical tendon distension should be reserved for major retraction.

References


