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Original article

Radial nerve palsy in surgical revision of total elbow arthroplasties: A study of 4 cases and anatomical study, possible aetiologies and prevention

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ABSTRACT

Background: Damage to the radial nerve in the arm during revision of total elbow arthroplasty is a serious complication; which is still not well documented. The aim of this study was to define a way on how to avoid this complication and to prevent it.
Patients and methods: Four patients underwent radial palsy after revision of total elbow arthroplasty. An anatomical study on 20 upper limbs was performed to define landmarks for the radial nerve in the arm and elbow.
Results: Radial nerve damage occurred near the proximal tip of the stem in all four patients, due to cement seepage caused by cortical effraction in two patients, and to damage caused by the retractors in the two other patients. The anatomical study made it possible to specify landmarks for the radial nerve in relation to the humerus. A high-risk area located 14 cm away from the tip of the olecranon fossa, and 15.5 cm from the medial epicondyle, was identified.
Conclusion: A high-risk area for the radial nerve was defined and suggested targeted landmarks with a posterior proximal counter-incision situated at about 14 cm above the olecranon fossa.
Level of evidence: IV.

1. Introduction

Although an improvement may be noted in the long-term results of total elbow arthroplasties for which the main indications fall into the context of rheumatoid polyarthritis [1–3], but its indications are increasing in distal humerus fractures in elderly patients. The longevity of these implants is still insufficient compared with that observed for other arthroplasties. This is even more notable in cases of post-traumatic arthritis [4–6]. Surgical revision of total elbow arthroplasties (RTEA) may be the source of numerous complications related to insufficient bone stock, loss of substance of the soft tissues and of the triceps tendon, risk of sepsis and possible difficulties of removing cement [7]. The radial nerve is intimately linked to the humeral shaft [8], which is a common site for loosening with semi-constrained total elbow arthroplasty [9–11] and is therefore exposed to the risk of an instrument going off-course or cement extravasation. Damage to the radial nerve in the arm during surgical revision of the elbow arthroplasty represents a serious complication with very little data published on the subject: only one series including 7 cases focuses on aetiological factors [12]. The aim of the present study was to identify the high-risk area for the radial nerve during a surgical revision of an implant in order to expose and protect it by means of an anatomical study.

2. Patients and methods

2.1. Clinical series

Four patients (Table 1) treated for postoperative radial nerve palsy in two specialised surgery centres by two surgeons in the context of surgical revision of a long-stemmed semi-constrained cemented total elbow arthroplasty with radial head resection,

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Table 1
Preoperative data.

Patient number	Age, original diagnosis	Original implant design	Indication for revision
1	41 y, RA	Coonrad-Morrey	Aseptic loosening of the humeral implant
2	62 y, RA	Coonrad-Morrey	Aseptic loosening of the humeral implant
3	58 y, RA	Coonrad-Morrey	Peri-prosthetic fracture (humeral shaft)
4	52 y, PTA	Discovery	Aseptic loosening of the humeral implant

RA: Rheumatoid arthritis; PTA: Post-traumatic arthritis.

Table 2
Technical variables.

Patient number	Tourniquet time (min)	Power tools	Perforation	Ultrasound	Radial nerve exposure	Mechanism of radial nerve palsy	EMG findings	Outcome of radial nerve (months after surgery)
1	115	No	Yes	No	No	Cement extrusion	No activity, complete radial denervation	No recovery
2	130	No	Yes	No	No	Instrument off-course	No activity, complete radial denervation	No recovery
3	140	No	No	No	No	Probable retractor damages	Severe radial neuropathy	Recovered (5 months)
4	105	No	No	No	No	Probable retractor damages	No activity, complete radial denervation	No recovery

were retrospectively reviewed. Three patients had required revision surgery for their arthroplasty in these centres. One patient who underwent surgery in another institution was referred to our centre for management of radial nerve palsy. All patients were women with a mean age of 53.5 years old [range 41–62]. Three patients had undergone a cemented semi-constrained total elbow arthroplasty in the context of evolved rheumatoid arthritis and one patient in the context of post-traumatic arthritis with postoperative radial nerve palsy. The indication for revision surgery was aseptic loosening of the humeral implant in 3 cases and a peri-prosthetic fracture of the humeral shaft in one case. Of the 4 revised implants, 3 were Coonrad-Morrey (Zimmer, Warsaw, IN) and one was Discovery (Biomet, Warsaw, IN).

The three Coonrad-Morrey and the Discovery humeral component implants were replaced by a long-stemmed model. The intervention was carried out with a pneumatic tourniquet inflated to 250 mm Hg for an average duration of 120 minutes [range 95–165]. A transtricipital Gschwend approach [13] was carried out in 2 cases and a posterior Bryan-Morrey12 type approach in 2 cases. The cement on the humeral shaft was removed by non-motorised manual methods with a cold light projector and without locating the radial nerve. No ultrasounds cement removal device was used. All patients presented complete sensory-motor radial nerve palsy immediately after surgery. An early exploration (on day 3 after surgery) was performed in 2 cases. Postoperative physiotherapy following surgical revision of the elbow arthroplasty was not modified by the onset of radial nerve palsy. Clinical, radiographic and electrophysiological follow-up was carried out in all four cases.

2.2. Anatomic study

This study was carried out on 20 upper limbs coming from 10 fresh non-preserved corpses. The dissection protocol was similar for each anatomical subject, using the wide cutaneous posterior median approach. The posterior side of the humerus was approached successively by the Bryan-Morrey approach and the triceps splitting approach depending on the side (the right side for Bryan-Morrey approach and the left side for the Gschwend approach) whilst respecting the distances from the radial nerve with its surrounding tissues so as not to modify the measurements obtained during the different stages of dissection.

Measurements were taken for the radial nerve using fixed reference points easily identified during surgical revision of the arthroplasty (the tip of the olecranon fossa and the tip of the medial epicondyle). These reference points were compared to the stem lengths of the semi-constrained humeral arthroplasties, 10, 15 and 20 cm for the Coonrad-Morrey® arthroplasty (Zimmer, Warsaw, IN, USA) and 10 and 15 cm for the Discovery® arthroplasty (Biomet, Warsaw, IN, USA), measured for both prosthesis, from the tip of the olecranon fossa. It was thus possible to define the surface landmarks for the radial nerve in the arm and at the elbow in order to specify the areas at risk (instruments going off track, extravasation of the cement...) during the process of replacing the humeral implant.

3. Results

3.1. Clinical series

Radial nerve palsy was diagnosed within the first 3 days after surgery. Early surgical exploration (2 to 3 days postoperatively) was carried out in 2 patients (indication for postoperative X-Rays when perforation of the humerus around the proximal tip of the stem due to cement removal was observed) and allowed the finding of a damaged radial nerve (a burn in one case and a contusion injury without section in the other case, approximately at 15 cm from the olecranon fossa corresponding with the length of the stem) for which it was impossible to carry out any primary repair. All results are presented in Table 2.

In two cases, a perforation of the humerus around the proximal tip of the stem due to cement removal was identified on postoperative X-Rays. One case of radial nerve damage was attributed to the instrument going off-course during cement removal, and one case to cement extravasation causing a thermal injury on the

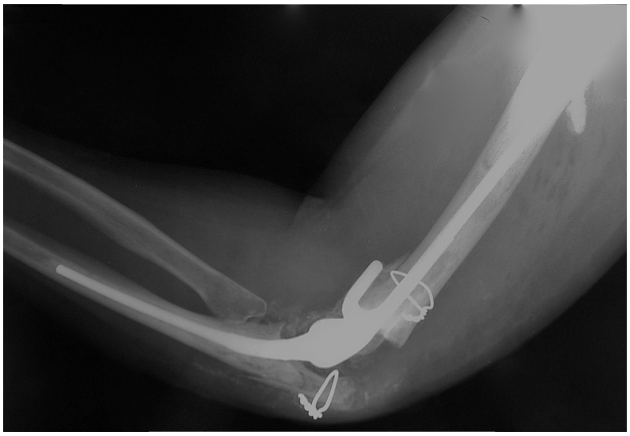

Fig. 1. Postoperative X-Rays: cement extravasation.

radial nerve (Fig. 1). Neither of these two patients recovered spontaneously.

In the 2 other cases, for which there was no bone damage seen on the X-Rays, the nerve lesions were probably due to the retractors on the proximal part of the dorsal approach although this was impossible to confirm. One patient recovered spontaneously after 5 months.

Two of the three patients who did not recover underwent palliative surgery by means of a tendon transfer to restore the wrist, thumb and long finger extension. The procedure was carried out after a timelapse of 6 months in the first case and 7 months for the second case. Concerning this last patient (rheumatoid arthritis), although no recovery was observed, no transfer was carried out considering that the patient had non-functional fingers and an underlying wrist arthrodesis. For both patients who underwent surgery, the tendon transfers included the pronator teres to the extensor carpi radialis brevis in order to reanimate the wrist extension. The extension of the long fingers and thumb was restored in one patient with the single transfer of the flexor carpi radialis onto the extensor digitorum communis and the extensor pollicis longus and, in the other patient, with the double transfer of the flexor carpi radialis onto the extensor digitorum communis, and of the palmaris longus onto the extensor pollicis longus.

With a mean follow-up of 84.2 months, the healing after the tendon transfer in the patient with the elbow post-traumatic arthritis led to recovery of wrist extension, as well as a metacarpophalangeal extension of 0° for the thumb and fingers and a complete finger flexion. In the other patient treated with tendon transfer (rheumatoid arthritis), recovery of the joints and tendons was as good as possible according to the according to the rheumatoid arthritis status of wrist, finger and thumb. At the latest follow-up, the mean Mayo elbow score was 73 [range 55–85]. The mean mobility of the elbow was a flexion-extension range of 93° [range 50–120], with complete pronation and supination except for one case, in which there was an absence of pronation. Concerning the pain assessment, the mean score using the visual analogous scale was 3.5 [range 2–7].

3.2. Anatomical study

Two posterior approaches to the elbow were studied to define the landmarks between the radial nerve and the humerus as well as the most suitable approach for exploring the radial nerve peroperatively.

With the Bryan-Morrey approach, the extensor mechanism detached from the proximal ulna and including the anconeus, is reflected laterally to the lateral epicondyle. The emergence of the radial nerve was easily visualised on the diaphysis, located on its medial border, opposite the intermuscular septum at an average of 18.5 cm [range 17–21] from the medial epicondyle, and 17.4 cm [range 15.9–19.9] from the olecranon fossa. It was possible to explore the course of the radial nerve until the point where it gives off the branches to the medial head of the triceps and anconeus, situated 1 or 2 cm distally.

With the Gschwend approach, the triceps was split in the middle of the olecranon. At the level of the olecranon the extensor apparatus was elevated with a thin layer of bone bilaterally with a sharp cisel. The radial nerve emerged on the diaphysis under the triceps brachii before perforating the lateral intermuscular septum with an average of 15 cm [range 13.5–16] from the medial epicondyle, and 13.8 cm [range 12.3–14.8] from the olecranon fossa (Fig. 2). This approach systematically crossed the division branches of the radial nerve to the medial head of the triceps and the anconeus, the division being higher up, situated at around 2 cm proximally, in the posterior and medial part of the humerus. With this approach, the radial nerve may easily be explored and mobilised.

Finally we noted that, in 10 cases, the radial nerve was found directly in contact with the bone and, in the 10 other cases, a fine layer of triceps was interposed between the latter and the humeral shaft, thus offering relative protection against diaphyseal off-tracking.

Our results allowed the identification of a high-risk area located at about 14 cm [range 13–15.5] away from the tip of the olecranon fossa, and at 15.5 cm [range 14.5–16] away from the medial epicondyle where the radial nerve presents a large contact area with the posterior side of the humerus (Fig. 2).

4. Discussion

The reasons for revising total elbow arthroplasties are well documented. A loosening occurring either on the ulnar or on humeral shaft is the main indications for the revision surgery. The surgical revision of the humeral shaft of the arthroplasty represents an extra risk for the radial nerve due to its proximity to the humeral shaft on its posterior side. The risk of radial nerve palsy during revision of total elbow arthroplasty has not been widely studied in the literature. Recently, Throckmorton et al. [12] evaluated this risk as being 2.7%, at the same time identifying the causes of nerve damage. Very few series relate this much-feared complication. Zook and Ward [14] published one case of radial nerve damage whilst the humeral medullary canal was being cleaned, the radial nerve being trapped in the humeral shaft due to an old fracture.

Fitting a new long humeral stem therefore requires the removal of the existing cement beforehand. Various techniques have been described, but they all seem to be risky for the radial nerve. In a recent clinical cadaveric study [15], the ultrasound was found to be a risk for the radial nerve. In that study, after one case of radial nerve palsy following a cement ablation procedure by ultrasound, biopsies revealed necrosis areas affecting the bone and the surrounding soft tissues. In that cadaveric study, the authors showed that the use of ultrasound may lead to thermal damage of the neighbouring tissues. These results were also analysed by Throckmorton et al. [12] who observed in their series one case of definitive radial nerve palsy caused by the use of ultrasound.

Motorised or manual cement extraction was also shown to be a risk for the radial nerve, in two main situations. Nerve damage may be due to direct injury because of an instrument going off-course associated with the humerus perforation, especially in patients often presenting some degree of fragility in their bones (rheumatoid arthritis, osteoporosis). Another cause of nerve damage is cement extrusion via the bone perforation leading to the thermal injury of the radial nerve.

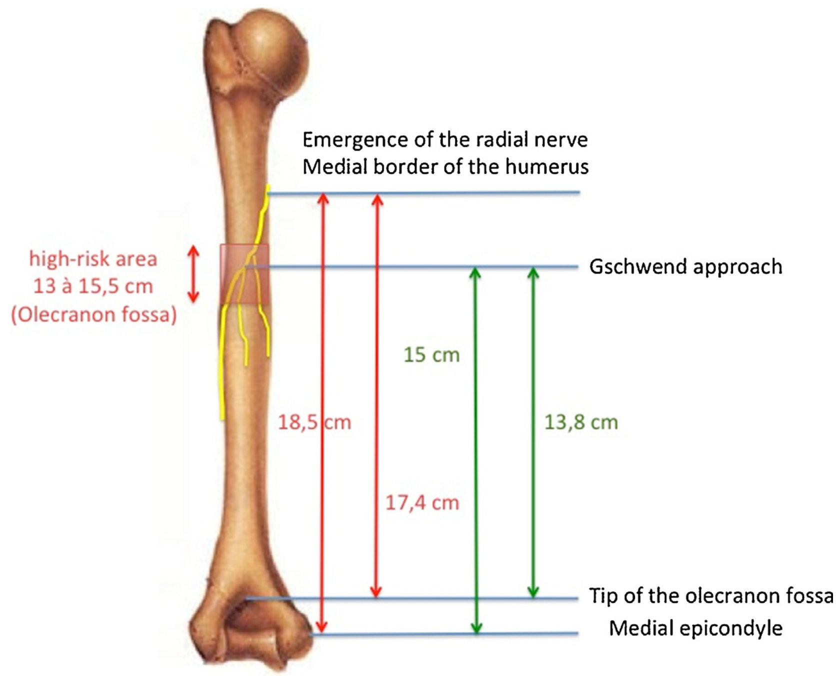

Fig. 2. Relationship between the radial nerve and the humerus (medial epicondyle and olecranon fossa) with high-risk area for the radial nerve.

Throckmorton et al. [12] specified that exposing the radial nerve is an major point for recovery in cases of postoperative radial nerve palsy. It is essential to visualise and protect the radial nerve and not just “feel around” for it, in order to prevent irreversible damage.

In our series, we observed two cases of definitive radial nerve palsy: one attributed to an instrument going off-course and one attributed to cement extravasation causing a thermal injury to the radial nerve. Both radial nerve injuries were located within the posterior surface of the humerus, and these could have been avoided by locating the radial nerve and thus protecting it. In the 2 other cases, the cause evoked for radial nerve damage was the stretching by the retractors on the proximal part of the dorsal approach, although this was impossible to confirm. The damaged area of the radial nerve was located on the posterior side of the humerus in the most proximal part of the approach. Although the retractors play a role in protecting the radial nerve keeping it away from the humeral diaphysis, this type of damage by stretching and compression presents a genuine danger during the various surgical techniques, as described in the literature [12,14,15,7].

A high-risk area was thus identified in our study. It was located at about 14 cm [range 13–15.5] from the tip of the olecranon fossa, and 15.5 cm [range 14.5–16] from the medial epicondyle. This high-risk area corresponded to the sites of radial nerve damage observed in our clinical series, and to an area where the nerve presents a large area of contact with the posterior side of the humerus.

Very few anatomical studies have yet been published concerning the posterior approach to the humerus [16–18] and their interest in exploring the radial nerve. Two studies by Gerwin et al. [16] and Guse et al. [8] made it possible to define where the radial nerve was situated in relation with the humeral diaphysis depending on what type of posterior approach was being used. In our study the radial nerve crossed the posteromedial edge of the humerus at about 20.7 cm from the medial epicondyle. Ahora et al. [19] showed in a cadaveric study that the mean distance of the radial nerve from the apex of the triceps aponeurosis was 2.5 cm, which correlated with the patients' height and arm length. The apex of the triceps aponeurosis always present in case of elbow revision arthroplasties appeared to be a useful anatomic landmark for localization of the radial nerve during the posterior approach to the humerus.

We have studied two posterior approaches by which the humerus can be exposed for total elbow arthroplasty. The Bryan-Morrey [17] approach reflecting the extensor apparatus lateral to the lateral epicondyle, and the triceps splitting approach to the humerus. With the Bryan-Morrey approach, the radial nerve was found at about 18.5 cm from the medial epicondyle, and at 17.4 cm from the olecranon fossa at the point where it crossed the medial side of the humerus. With the trcieps splitting technique, the nerve was approached at about 14 cm from the tip of the olecranon fossa, and 15 cm from the medial epicondyle. This distance was situated in a high-risk area identified by the damage made to the radial nerve. The tip of the olecranon fossa and the medial epicondyle were interesting landmarks, and often identifiable in the revision of total elbow arthroplasty, making it possible to approach the radial nerve with precision in this at-risk area. With both these approaches, it was possible to inspect, and thus prevent, any likelihood of peroperative damage.

However, extensive exposure of the triceps is needed. Bryan and Morrey [17] proposed a proximal extension of the skin incision and a limited transtricipital counter-incision proximal to the approach, allowing the visualization and protection of the nerve during cement removal. A peroperative X-ray destined to see whether the humerus has gone off-course with cement leakage is a possible option, although exposing and then protecting the radial nerve systematically seems to be the most reliable solution to avoid this complication.

The analyses of the different series of radial paralyses constituted following surgical revision of a total elbow arthroplasty, it appeared interesting to take a look at the evolution and management of this complication. In our series, three cases out of four showed an unfavourable evolution. Similarly to Throckmorton's study, no spontaneous recovery was observed following extravasation of the cement. One definitive paralysis was attributed to an instrument going off-course with bone perforation seen on the X-rays. Out of the 2 female patients who had damage presumably caused by the retractors, only one recovered spontaneously at 5 months follow-up. This also seemed to be the case in the

Throckmorton study although the team was unable to specify clearly the exact mechanism of the radial nerve palsy. Three cases of radial nerve palsy out of 7 in the Throckmorton's series were attributed to the pneumatic tourniquet with 2 spontaneous recoveries.

The use of a pneumatic tourniquet could act as a point of fixation for the radial nerve onto the humeral shaft, and the nerve could be elongated by the lateral retractor. For this reason and because of the possibility of a peroperative shaft fracture associated with the duration of the procedure, the tourniquet may be dangerous in this kind of procedure.

Early surgical exploration in our series (cases where the humerus was perforated) revealed no serious reparable damages to the radial nerve (a burn in one case and a contusion injury without section in the other case) and therefore did not lead to any intervention for nerve repair. The absence of early exploration may be debatable considering the small number of cases presented in our series. However, even if nerve disruption had been found, the potential extent of the nerve damage, the age of the patients and their poor capacity for nerve regeneration, would not have led to functional recovery by nerve grafting. Therefore, early exploration does not appear to contribute a great deal. Finding serious nerve damage early on does not necessarily mean that tendon transfers can be carried out. To do this, it is necessary to wait for complete recovery of the joint mobility. In the absence of exploration or serious nerve damage, tendon transfer might be performed when it is already too late for spontaneous recovery.

From a therapeutic perspective, determining the prognosis as early as possibleis essential. It would appear that this depends on the aetiology of the radial nerve palsy. A postoperative ultrasound scan might make it possible to specify the type of nerve damage and therefore quickly inform the patient about follow-up and management.

The lesion seemed to be irreversible in cases of cement extravasation, making it possible to propose tendon transfer surgery secondarily to a patient for whom a nerve graft does not lead to a good functional result. Palliative treatment is given credit in the context of faster, more reliable results.

When paralysis was caused by the retractors or by the pneumatic tourniquet, a spontaneous recovery was observed in four cases out of seven in both the Throckmorton's and our series. In these conditions, clinical and electromyographic supervision is justified. In the absence of clinical or electrical recovery of the brachioradialis and the radial extensors of the wrist after a timelapse of 5 to 6 months, a tendon transfer was proposed, depending on the patient's functional requirements and the recovery of his/her mobility [20,21].

Damage to the radial nerve can be prevented by locating it proximally if cement removal in the mid-shaft of the humerus is anticipated [17]. A proximal extension of the triceps exposure or a more limited transtricipital counter-incision proximal to the approach proposed by Bryan and Morrey [17] may allow the visualization and protection of the nerve during cement removal. It is thus possible to define a high-risk area for the radial nerve for the surgical revision of semi-constrained total elbow arthroplasties, and to suggest targeted landmarking with a proximal counter-incision in the triceps at an average of 14 to 17.5 cm above the olecranon fossa, and at 15 to 18.5 cm from the medial epicondyle on the posterior surgical approach to the arm.

5. Conclusion

The likelihood of radial nerve palsy during revision surgery on semi-constrained total elbow arthroplasties is low. However, the occurence of such complication often leads to a major handicap in patients who are already fragile. It is essential to underline that the prognosis of recovery depends on the cause of the damage. We show in our study that the most serious lesions seem to be those linked to a cement extrusion or to an instrument used to remove the cement going off-course.

High-risk areas for the radial nerve were therefore defined from the tip of the olecranon fossa, and from the medial epicondyle. Also, such damage may be prevented by locating the radial nerve with a short transtricipital counter-incision proximal to the approach, so that the at-risk area may be protected.

Disclosure of interest

The authors declare that they have no competing interest.

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