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GENERAL REVIEW • ELBOW - PAEDIATRIC

Risk of ulnar nerve injury during cross-pinning in supine and prone position for supracondylar humeral fractures in children: a recent literature review

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Abstract
Aim of this review article is to evaluate the percentage of ulnar nerve lesion during cross-pinning considering the patient's position (supine or prone) on the surgical bed. Comprehensive research was performed by searching in PUBMED, Cochrane Library, ISI Web of Science, SCOPUS and Clinicaltrials.gov from 2005. Children with extension type supracondylar humeral fractures without clinical signs of ulnar nerve lesion at presentation were included. A total of 28 papers were examined including 2147 patients; 1541 underwent a closed reduction and cross-pinning in supine position and 606 in prone position. Among 1541 patients in supine position, 69 (4.5%) suffered from a ulnar nerve injury while among the 606 patients treated in prone position none ulnar nerve lesions were reported. Despite the apparent safety of prone position, further larger studies, comparing the patient's position on the surgical bed, need to be carried out in order to confirm this likelihood.

Keywords Ulnar nerve lesions · Pediatric supracondylar humeral fractures · Supine and prone position

Introduction

Supracondylar humeral fractures are the most common elbow injury in developmental age, usually secondary to a fall with the elbow in hyperextension and the forearm pronated.

There is no difference in fracture rate between sexes although the left side seems to be more affected than the right [18, 20].

The Gartland classification divided the fractures into three types considering the grade of dislocation, and it helps the surgeons to choose the better approach for each form [12].

In Gartland III fractures, the widely adopted treatment consists of closed reduction and percutaneous pinning by means of Kirschner wires; different configurations of pins have been described but the most used are the lateral and the cross-pinning based on the surgeon's preferences [4].

Moreover, the position of the child on the surgical bed can be supine or prone.

One unresolved issue for those who prefer the cross-pinning (1/3 of surgeons according to a recent POSNA questionnaire) is the risk of an ulnar nerve injury during the insertion of the medial pin [5].

However, those who use the prone position do not report this complication.

The aim of this review article is to summarize the medical literature and evaluate the percentage of ulnar nerve lesions during cross-pinning in correlation with the patient's position (supine or prone) on the surgical bed.

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Materials and methods

Search strategy and selection of studies

We performed a systematic review in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses recommendations [29].

To identify relevant studies, we systematically searched PUBMED, Cochrane Library, ISI Web of Science, SCOPUS and Clinicaltrials.gov, as well as the abstract of the Pediatric Orthopedic Academic Societies from 2005. The year 2005 has been chosen as the beginning of the review because it was the starts of publication of case series regarding the prone position.

The search strategy was carried out without language restrictions from database inception until December 31, 2017. Two researchers (NC, M.D.P) independently screened the titles and abstracts to determine which studies met the inclusion criteria. We retrieved full-text copies of all papers that were potentially relevant. Discrepancies in studies selection and rating were resolved through discussion between review authors.

The following search strategy was used: "(Ulnar nerve AND supracondylar humeral fractures AND (children OR child))".

Criteria for considering studies for this review

Meta-analysis, randomized controlled studies (RCT) and observational studies have been included as well as technical trick articles which were considered eligible for this review.

Inclusion criteria: Children (1–14 years) with extension type supracondylar humeral fractures, classified as Gartland III and IV without clinical signs of ulnar nerve lesion at presentation.

Those cases with hand ischemia at presentation have been excluded, because the surgical approach to the neurovascular bundle is usually anterior with the patient in supine position.

No language restriction was placed on the included studies.

In cases where inadequate information was provided (i.e., position of the patients was not clear), the authors were contacted to clarify or provide additional information. In the absence of informative studies comparing the two surgical approaches, we have decided to also use observational information studies describing a single technique.

Types of interventions

Supracondylar humeral fractures, surgical approach with patient in supine position or surgical approach with patient in prone position.

Primary outcomes

We included the following as primary outcome:

- Number of ulnar nerve injuries.

Moreover, we considered the following as secondary outcomes:

1. The age of patients who suffered from nerve injuries
2. Swelling of the elbow at presentation (Y/N)
3. Experience of the first surgeon (junior or senior)
4. Time of the procedure (day or night)

Assessment of risk of bias

Two authors (MGC, NC) independently appraised the risk of bias of the included studies using the Cochrane Collaboration's tool through six aspects of potential bias; random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, and selective reporting [17]. The risk of bias was categorized as high, low, unclear.

Two authors of the group (N.C. and M.G.C.) read the article extracting the data and a third one (M.D.P.) checked the results of their analyses.

Statistical analysis

Data are described as absolute and relative frequencies for categorical variables, while means, standard deviation (SD) and median and range are used for continuous variables.

Review Manager version 5.3 software was used to perform statistical analysis [33]. The standard methods of the Cochrane Collaboration were used to synthesize the data. For categorical data, we calculated relative risk (RR). Mean and standard deviation (SD) were obtained for continuous data and analysis performed using MD and weighted mean difference (WMD) when appropriate. For each measure of the effect, the 95 percent confidence intervals (CIs) were calculated.

In the second section of analysis, the χ^2-test or the Fisher exact test was used to compare differences between two groups. A p value less than 0.05 was considered statistically

significant, and all p values were based upon two-tailed tests. Statistical analyses were performed using SPSS for Windows (SPSS Inc, Chicago, Illinois USA).

Results

We identified one RCT [36] and two observational studies [11, 15] comparing surgical approach with patient in supine or prone position for inclusion in this review. One ongoing study (NCT00358787) was found on the clinical trials registries [30]. A total of 133 patients were included in our analysis, of which 61 (45.9%) underwent a closed reduction and cross-pinning in supine position, while 72 (54.1%) patients received the same treatment in prone position. Both Venkatadass and Fowler did not reported ulnar nerve injuries neither in the supine position nor in the prone position. Guler was not informative. The quality of the studies was low due to limitation in the study design (Fig. 1).

Due to the lack of complete statistical data comparing the two different approaches (prone vs supine), we have decided to investigate in all the studies that deal with supracondylar humeral fractures (surgical approach with patient in supine or in prone position) the number of ulnar nerve injuries, summarizing them in a narrative review.

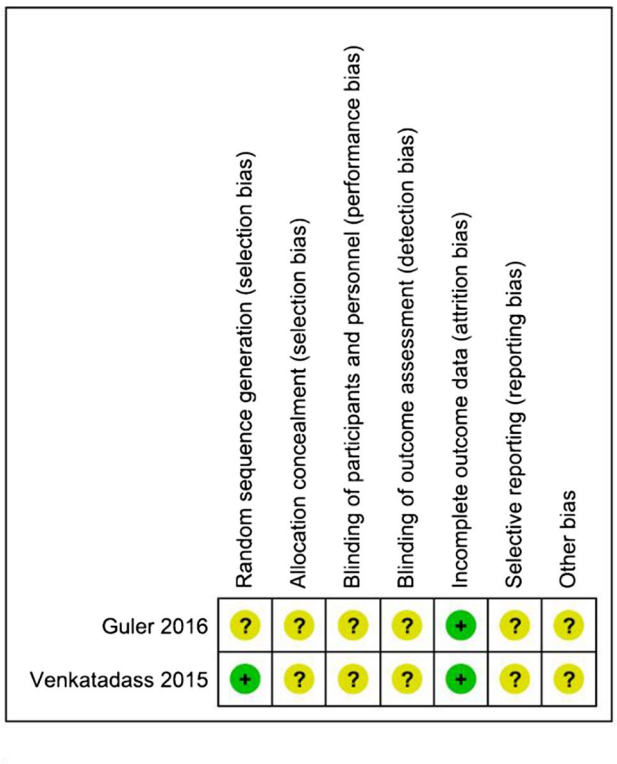

Fig. 1 Risk of bias summary

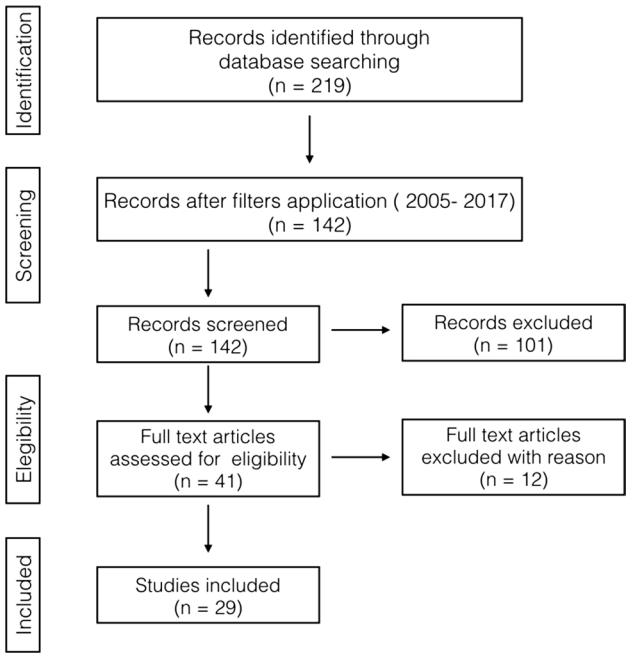

Fig. 2 Study flow diagram shows methods of data retrieval

In total, we identified 28 papers for inclusion in this review: 27 papers referred to observational studies [2, 3, 6, 7, 9–11, 13–16, 19, 21–28, 31, 32, 34–37] and one paper referred to completed RCTs [38] (Fig. 2).

A total of 2147 patients were included in our analysis, of which 1541 (71.8%) underwent a closed reduction and cross-pinning in supine position, while 606 (28.2%) patients received the same treatment in prone position. Relevant characteristics of included studies are listed in Tables 1 and 2. Among 1541 patients in supine position, 69 (4.5%) suffered from an iatrogenic ulnar nerve injury, while among the 606 patients treated in a prone position no ulnar nerve lesions were reported ($p = 0.0001$).

No data have been found on the incidence of lesions relatively to the following outcomes:

- Swelling of the elbow
- Experience of the surgeon (junior or senior)
- Time of the operation (day or night)

Discussion

As well known, the prone position for the treatment of supracondylar fractures has both advantages and disadvantages [8].

However, to our knowledge, this is the first paper which has analyzed the relation between the risk of ulnar nerve injuries in supracondylar humeral fractures treated with

Table 1 Characteristics of included studies. Cross-wires—supine

Study	Year of publication	Study design	No of patients	Age (year) Mean ± SD/Median (range)	Male/female	Ulnar nerve injuries
Anwar W	2011	Obs	25	6.5 (3–12)	32/12	1
Barlas K	2006	Obs	43	7.2 (2–14)	36/7	0
De Las Heras S	2005	Obs	77	6.7 (1–13)	56/21	2
Devkota P	2008	Obs	79	7.7 (1.6–13)	NR	7
Eidelmannn M	2007	Obs	67	5.8 (2.5–11)	42/25	0
Fowler TP	2006	Obs	6	NR	NR	0
Gaston RG	2010	Obs	57	6.2	31/26	2
Green DW	2005	Obs	65	4.5 (1–11)	NR	1
Guler O	2016	Obs	29	6.6 ± 1.4 (4–9)	16/13	NR
Kalender O	2008	Obs	473	6 (4–8)	276/197	25
Karapinar L	2005	Obs	61	7.6 (2–13)	41/20	2
Khan AQ	2007	Obs	30	NR	NR	1
Khan MS	2005	Obs	20	(3–12)	NR	1
Kocher MS	2007	Obs	24	5.7 ± 1.6	13/11	0
Kwak-Lee J	2014	Obs	47	5.4 (1.6–10)	NR	0
Li YA	2009	Obs	42	6.9 (2–12)	23/19	3
Mahmood S	2013	Obs	30	NR	NR	0
Maity A	2012	Obs	80	6.2 ± 1.8	48/32	0
Ozcelik A	2006	Obs	90	6.1 ± 3.2	54/36	18
Pandey S	2008	Obs	30	< 12	NR	1
Rjal KP	2006	Obs	40	6.5 (2–12)	24/16	0
Sibinski M	2006	Obs	65	6.7	31/31	4
Singh S	2013	Obs	15	7.9 ± 3.3	10/5	0
Tripuranemi KR	2009	RCT	20	5.5 (15 month–11 years)	NR	1
Venkatadass K	2015	RCT	26	7.7	21/5	0

NR not reported, *Obs* observational study, *RCT* randomized controlled trial

Table 2 Characteristics of included studies. Cross-wires—prone

Study	Year of publication	Study design	No of patients	Age (year) Mean ± SD/Median (range)	Male/female	Ulnar nerve injuries
De Pellegrin M	2008	Obs	45	6.5 (3–12)	32/13	0
Havlass V	2008	Obs	455	7.5 (3–14)	261/194	0
Venkatadass K	2015	RCT	26	6.8	20/6	0
Kai Kao H	2014	Obs	34	5.2 (1–12.7)	22/12	0
Fowler TP	2006	Obs	19	NR	NR	0
Guler O	2016	Obs	27	6.9 ± 1.5 (4–9)	15/12	NR

NR not reported, *Obs* observational study, *RCT* randomized controlled trial

cross-pinning and the position of the patient on the surgical bed.

As well known, the peculiar anatomy of the ulnar nerve around the elbow exposes it to a risk of injury during or after a medial pinning.

The cubital tunnel, which holds the ulnar nerve, extends between the medial epicondyle and the olecranon.

The ulnar nerve enters the tunnel via the medial intermuscolar septum and the arcade of Struthers and leaves it distally via the humeral heads of flexor carpi ulnari. The roof of the tunnel is formed by the arcuate ligament of Osborne.

Although the aforementioned anatomical structures should maintain the nerve fixed in the tunnel,

hypermobility is common especially during elbow flexion, leading to a nerve subluxation over the medial epicondyle [39].

The anatomy of the cubital tunnel and the nerve hypermobility therefore explain its increased vulnerability during a medial pinning carried out with the elbow in hyperflexion.

The majority of surgeons prefer to perform the reduction and osteosynthesis in supine position probably because they are more confident and consider it faster than turning the patient to prone.

One of the criticisms directed at this technique is the necessity of elbow hyperflexion during the pin insertion, which might expose the ulnar nerve to injury by the Kirschner wire, especially when swelling of the elbow does not allow easy identification of the right insertion point on the medial epicondyle (Fig. 3).

This risk would stem from the hypermobility of the nerve, which tends to slip anteriorly out of the cubital tunnel, passing over the medial epicondyle, especially when the elbow runs to hyper flexion.

Considering elbow flexion as the key to a good reduction and osteosynthesis in supine position, Green et al. suggested a mini-open access over the medial epicondyle in order to identity the bone, protecting the cubital tunnel at the same time.

However, there is still no consensus on the efficacy of this approach [1].

On the other hand, reductions in prone position would seem to be safer for the ulnar nerve because the realignment happens with the aid of gravity, avoiding the need for hyperflexion to maintain the reduction during the pinning.

Moreover, the position of the elbow with the patient in prone should not lead to subluxation of the ulnar nerve, allowing the surgeon to fix the medial side of the fracture safely.

In spite of this potential advantage, the prone position has two disadvantages:

1. A theoretically greater difficulty for the anesthesiologist to manage the airway
2. The necessity to turn the patient again if the neurovascular bundle needs to be explored.

In our review, ulnar nerve injuries only occurred in patients who underwent a closed reduction and cross-pinning in supine position.

The incidence of ulnar nerve injury in this population was 69 cases out of 1541 patients (4.5%) while among the 606 patients treated in a prone position, no ulnar nerve lesions were reported.

Our study has some limits

First of all, there are only three studies (one RCTs Venkatadass 2015 and two observational studies Fowler 2006, Guler 2016) which compare the two positions; among these, Guler's study does not report any information on nerve injuries, whereas Fowler and Venkatadass report no iatrogenic ulnar nerve injury.

The other included studies described a single surgical approach, and the majority of articles referred to the use of the supine position.

Considering that a large number of analyzed articles have been published by groups working in North America, where the supine position is widely used, this could account for the different number of patients in that cohort.

The second limit regards the absence of information about the experience of the surgeon who performed the procedure as well as the time (day or night) of the operation.

It would be interesting to know if there is a difference in the incidence of nerve lesions between groups of patients treated by young or old surgeons and between daily or nightly procedures.

In conclusion, the choice of how to treat a supracondylar fracture is significantly influenced by the type of the

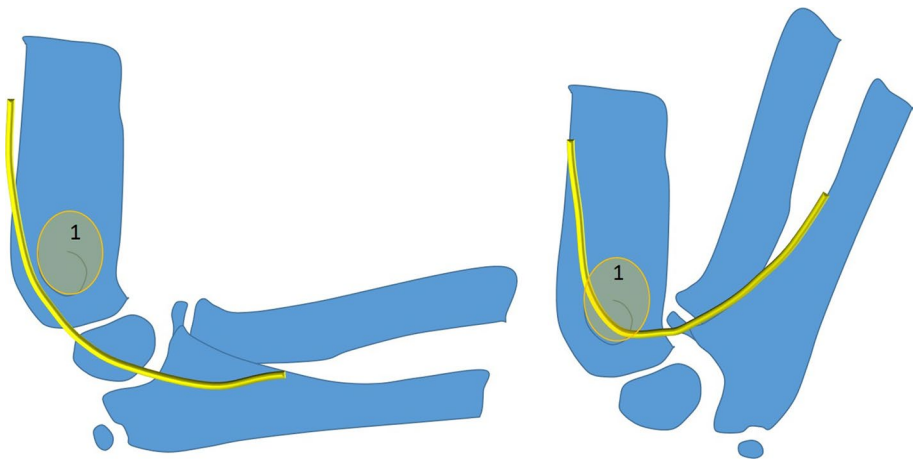

Fig. 3 Pinning area of the medial humerus region (1). In case of hypermobility, the ulnar nerve can slip anteriorly overlapping this area with a risk of its potential injury. In prone position technique, elbow hyperflexion is not needed for reduction maneuvers and pinning

fracture, the presence or absence of a vascular issue as well as the habits of the surgeon and the anesthesiologist.

The analysis of the current literature does not allow us to state which of the two techniques is the safest.

For this reason, we have tried to analyze upsides and downsides of the both surgical approach in preventing ulnar nerve injuries and cross-fixation with the patient in the prone position might seem to be safer.

However, further larger studies comparing the two techniques are necessary.

Compliance with ethical standards

Conflict of interest The author(s) declare that they have no competing interests.

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