



SYSTEMATIC REVIEW

REVISED Lateral versus posterior surgical approach for the treatment of supracondylar humeral fractures in children: a systematic review and meta-analysis [version 3; peer review: 2 approved]

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Abstract

Background: Supracondylar humeral fracture (SHF) is the most common type of fracture in children. Moreover, lateral and posterior surgical approaches are the most frequently chosen approaches for open reduction surgery in displaced SHF when C-arm is unavailable. However, previous literature showed mixed findings regarding functional and cosmetic outcomes. Currently, no systematic review and meta-analysis has compared these two procedures.

Methods: Our protocol was registered at PROSPERO (registration number [CRD42021213763](https://doi.org/10.1186/1745-2974-4-2021213763)). We conducted a comprehensive electronic database search in MEDLINE, EMBASE, and CENTRAL. Two independent reviewers screened the title and abstract, followed by full-text reading and study selection based on eligibility criteria. The quality of the selected studies was analyzed with the ROBINS-I tool. Meta-analysis was carried out to compare the range of motion (functional outcome) and cosmetic outcome according to Flynn's criteria. This systematic review was conducted based on PRISMA and Cochrane handbook guidelines.

Results: Our initial search yielded 163 studies, from which we included five comparative studies comprising 231 children in the qualitative and quantitative analysis. The lateral approach was more likely to result in excellent (OR 1.69, 95% CI [0.97-2.93]) and good (OR 1.12, 95% CI [0.61-2.04]) functional outcomes and less likely to result in fair (OR 0.84, 95% CI [0.34-2.13]) and poor (OR 0.42, 95% CI [0.1-1.73]) functional outcomes compared to the posterior approach. In

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terms of cosmetic results, both approaches showed mixed findings. The lateral approach was more likely to result in excellent (OR 1.11, 95% CI [0.61-2.02]) and fair (OR 1.18, 95% CI [0.49-2.80]) but less likely to result in good (OR 0.79, 95% CI [0.40-1.55]) cosmetic outcomes. However, none of these analyses were statistically significant ($p > 0.05$).

Conclusion: Lateral and posterior surgical approaches resulted in satisfactory functional and cosmetic outcomes. The two approaches are comparable for treating SHF in children when evaluated with Flynn's criteria.

Keywords

supracondylar fractures, humeral fractures, lateral approach, posterior approach, children

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REVISED Amendments from Version 2

This newer version provided a clearer explanation of the four surgical approaches' disadvantages (medial and anterior approaches' disadvantages are explained in the introduction part, while posterior and lateral approaches' disadvantages are explained in the discussion part).

Any further responses from the reviewers can be found at the end of the article

Introduction

Supracondylar humeral fracture (SHF) is an elbow injury in children that most often requires surgical therapy. Nearly 60-70% of all elbow injuries occur in children aged five to seven.¹ In the USA, it is reported that 25-40% of the incidence of SHF occurs in children's playgrounds.² From all the injuries to the elbow joint that can occur in children, 85% occurs in the distal humerus area, and 55-75% of the total fractures of the distal humerus are fractures of the supracondylar humerus. The annual incidence of SHF in the US is estimated at 177.3 per 100,000 children. Moreover, the incidence of trauma as the leading cause of SHF has a seasonal distribution. The literature shows that SHF is more frequent in the summer and is more common in the left elbow or non-dominant limb.³ In addition, SHF may give rise to an emergency, namely compartment syndrome. This life and limb-threatening complication occurs in 0.3-1% of all SHF cases. A study conducted by Houshian et al. shows that elbow fracture incident is 308/100,000 per year; supracondylar humeral fracture comprises 58% of all incidents.^{4,5}

Treatment choices for SHF in children can be classified into non-operative and operative treatment. In cases where the fracture configuration is not displaced (Gartland type 1) or minimally displaced (Gartland type 2), the primary treatment choice is non-operative. Whereas, in displaced fractures (Gartland type 3 or 4), the gold standard is operative treatment with closed reduction techniques and percutaneous pinning with Kirschner wire insertion (CRPP). However, when these attempts fail, the next step is to perform an open reduction and internal fixation (ORIF) to obtain an optimal reduction. Anatomical restoration of displaced fractures is important since it will affect the outcome on the function of the elbow joint.^{6,7} Nevertheless, CRPP is often unfeasible in regions/countries with limited settings due to the unavailability of intraoperative fluoroscopic imaging (i.e., C-arm). Thus, open reduction surgery is the only choice in this situation.³¹

There are various surgical approaches in open reduction surgery for SHF. Several approaches that are commonly used are lateral, medial, anterior and posterior approaches. As they can only provide visualization to some part of the fracture site, a combination of them is often performed. The three operating approaches (lateral, medial, posterior) can include fairly straightforward operating technique, except the anterior approach. A lateral approach is often used because this approach causes relatively less destruction to important neurovascular structures and soft tissues but still gives enough exposure to reposition the fracture site. Sometimes, this approach can be combined with a medial approach if necessary, but that will add another scar and also extensive soft tissue exposure. Another approach that can be performed is the anterior approach, which possesses several advantages, one of which is evacuating the hematoma at the fracture site because usually, the hematoma will accumulate in the anterior side of the fracture site. However, the downside of the anterior approach is its challenging technique because there will be quite a number of neurovascular structures (i.e., median nerve and capitellar blood supply) that require extra caution, making the surgery less straightforward.⁸ Moreover, the posterior surgical approach is also often used due to its simplicity as it does not require much neurovascular structure identification, resulting in a shorter surgery time. Thus, the anterior approach is technically more demanding than the posterior approach, especially because simultaneous reduction and manipulation of the K-wires seems challenging.³¹

To date, there is no definite consensus on which operating approach should be used as the main approach in open repositioning surgery for SHF treatment in children. Thus, it is our aim to carry out a comprehensive systematic review to determine the best surgical approach in SHF, especially comparing those that are often chosen practiced worldwide (including in limited settings), namely the posterior and lateral surgical approaches, in order to achieve the goal of high patient satisfaction.

Methods**Protocol and registration**

We followed PRISMA and Cochrane handbook guidelines for conducting a systematic review of interventions. Our protocol has been registered at PROSPERO (registration number CRD42021213763).

Table 1. Flynn's criteria.⁹

Result	Rating	Functional factor: Motion loss (Degrees)	Cosmetic factor: Carrying-angle loss (Degrees)
Satisfactory	Excellent Good Fair	0-5 5-10 10-15	0-5 5-10 10-15
Unsatisfactory	Poor	Over 15	Over 15

Eligibility criteria

This research is a systematic review and meta-analysis that includes a direct comparative study between lateral and posterior surgical approaches for supracondylar humeral fractures (SHF) in children. We included original clinical studies which were written in English and available in full-text. However, we did not include the following types of articles: abstract conferences, letters to editors, summaries of meetings, expert opinions, book chapters, study protocols, technical reports, narrative reviews, systematic reviews, meta-analyses, case reports, studies with incomplete data, duplication of publications, experimental studies on animals, and cadavers, laboratory (*in vitro*), and computational studies.

The population used in this study were children diagnosed with supracondylar humeral fractures who underwent open reduction and internal fixation surgery using a lateral or posterior surgical approach. Patients who underwent conservative treatment or surgeries with other approaches were not included in this review. We also excluded the studies that used combined approaches. The primary outcome assessed in this study was functional and cosmetic outcomes according to Flynn's criteria⁹ (Table 1).

Literature search

We conducted an electronic literature search in MEDLINE (from 1966 until 1 November 2020), EMBASE (from 1947 until 1 November 2020), and The Cochrane Central Register of Controlled Trials (CENTRAL) (from inception until 1 November 2020) using free-text keywords and subject subheading (Medical Subject Headings (MeSH) for MEDLINE and Emtree for EMBASE). Our search strategy can be seen in Extended Data.³⁰ The PICO concept (Patient, Intervention, Comparison, Outcome) was used in conceptualizing this research strategy:

- P: children diagnosed with supracondylar humeral fractures requiring open reduction and internal fixation surgeries,
- I: open reduction and internal fixation with a lateral or posterior approach,
- C: as explained in Intervention (I),
- O: Flynn's criteria evaluation.

Selection process and data extraction

Study references obtained from the search were transferred to Mendeley software version 1.19.8 (Elsevier, United Kingdom) to detect duplicates. Two independent reviewers screened the references by title and abstract based on the eligibility criteria using Rayyan[®] webpage,¹⁰ and labelling was carried out using 'include', 'maybe', and 'excluded features'. Potentially eligible studies or studies that remained unclear were included in the full-text reading. Any disagreement that arose was resolved by a third reviewer. Studies that were excluded at the full-text reading stage were recorded and provided with reasons. The flow of the study selection process is presented in the PRISMA flow diagram.

The selected studies were extracted using Microsoft Excel[®] software. We collected the following data: author, year of publication, title, type of study, patient demographics (sex, age), SHF classification, follow-up duration, surgical approach, functional and cosmetic outcome based on Flynn's criteria, and authors' conclusions.

Bias analysis

Bias analysis was carried out using the risk of bias tools formulated by the Cochrane group. For Randomized Controlled Trial (RCT) studies, we used the second version of the Cochrane tool, Risk of Bias (ROB).¹¹ Potential causes of bias were assessed with signaling questions to detect biases caused by the randomization process, deviation from initial intervention intent, missing data, measurement of outcomes, and reporting of selective bias. For non-RCT studies, we used ROBINS-I

(Risk of Bias in Non-randomized Studies of Intervention).¹² The component of the assessment was the same as the measurement of bias using the ROB, but there were additional biases such as bias in patient selection and bias due to confounding factors. Meta-analyses were conducted only with studies that had a moderate or better risk of bias.

Synthesis of results

We assessed odds ratios (ORs) with a 95% confidence interval (CI) for the data. Heterogeneity (inconsistency) was analyzed using the Chi^2 and I^2 tests. A low p-value result ($p < 0.1$) of the Chi^2 test indicates significant heterogeneity. Because the Chi^2 test has a low detection ability in a small sample of data, we also used the I^2 test to assess heterogeneity. An I^2 test score of more than 50% has significant heterogeneity. Statistical analyses were performed using the **Review Manager (RevMan)**[®] version 5.3 (Nordic Cochrane Center, Denmark). If the heterogeneity test results showed no significant heterogeneity, we planned to use the fixed-effect models. Otherwise, the researchers used random-effect models to process the data. Subgroup analyses were also planned to explore the causes of high heterogeneity¹³ based on the type of study (RCT and non-RCT). When we encountered an unclear (inconclusive) decision, we carried out a sensitivity analysis test by repeating the meta-analysis with other effect magnitudes (risk ratio/RR, odds ratio/OR, and mean difference) and alternative statistical models (fixed and random effects models).¹² To ensure a reliable meta-analysis result, we did not include studies that have a high risk of bias.

Results

Selection process

Our initial electronic search results yielded 163 studies that matched the search keyword algorithm in the three major databases. The duplication removal process resulted in a total of 102 studies. The remaining studies were then screened by title and abstracts that had conformity to the inclusion and exclusion criteria. At this stage, we excluded 84 studies that were deemed irrelevant. The remaining 18 studies were then read as full-text articles to assess their suitability for this study. We excluded 13 studies due to several reasons: six studies were case series studies; three studies used a different operating approach from the main study; one study was an article review; one study was found to be not in accordance with the objectives of this study; one study was not supracondylar humeral fractures (different population); and one last study was not in English. Finally, five studies that were suitable for this review were chosen. A brief description of the study search is presented in [Figure 1](#).

Description of the included studies

The five studies included were all retrospective, case-control studies conducted in Turkey,^{14–16} Thailand,¹⁷ and France¹⁸ between 2004 and 2013. The earliest study was initiated by Bamrunghin in 2004,¹⁷ while the latest study was conducted by Basaran et al.¹⁸ and Uzer et al.¹⁴ in 2010. The total number of patients in this study was 231 patients. One study¹⁵ did not specify the sex distribution of the patients. Of the five other studies included in this study, it was found that 119 patients (62%) were male, and 72 patients (38%) were female. All patients were children diagnosed with displaced supracondylar humeral fractures.

All patients in these studies had surgical management performed in the operating room using either a lateral or posterior operative approach to perform open repositioning of the fracture and then fixed with Kirschner wire to maintain the repositioning. After being operated on, the operated limb was supported with a back slab. All patients in this study were subjected to periodic examinations at the polyclinic for functional and cosmetic measurements using Flynn's criteria. The follow-up time in each study was different, ranging from 6-7 months¹⁸ until up to 50 months¹⁶ following the surgery.

Risk of bias analysis

Overall, the five included studies had a moderate risk of bias. The summary of the risk of bias analysis using ROBINS-I tool can be seen in [Table 2](#).

- Confounding bias

This bias can arise if the interventions and outcomes have a different relationship from the cause due to confounding factors. Examples of common confounding factors are the presence of comorbid diseases and differences in socioeconomic status (including access to health insurance), which affect changes in the choice of intervention and changes in outcomes that are different from conditions in general.^{12,13} In this study, the authors found there was no risk of confounding factors.

- Bias in the selection of research subjects

The author found there were two studies^{14,17} that had a low risk of bias in the selection of study subjects. In these studies, the researchers included all patients who met the inclusion criteria (patients with displaced supracondylar humeral



PRISMA 2009 Flow Diagram

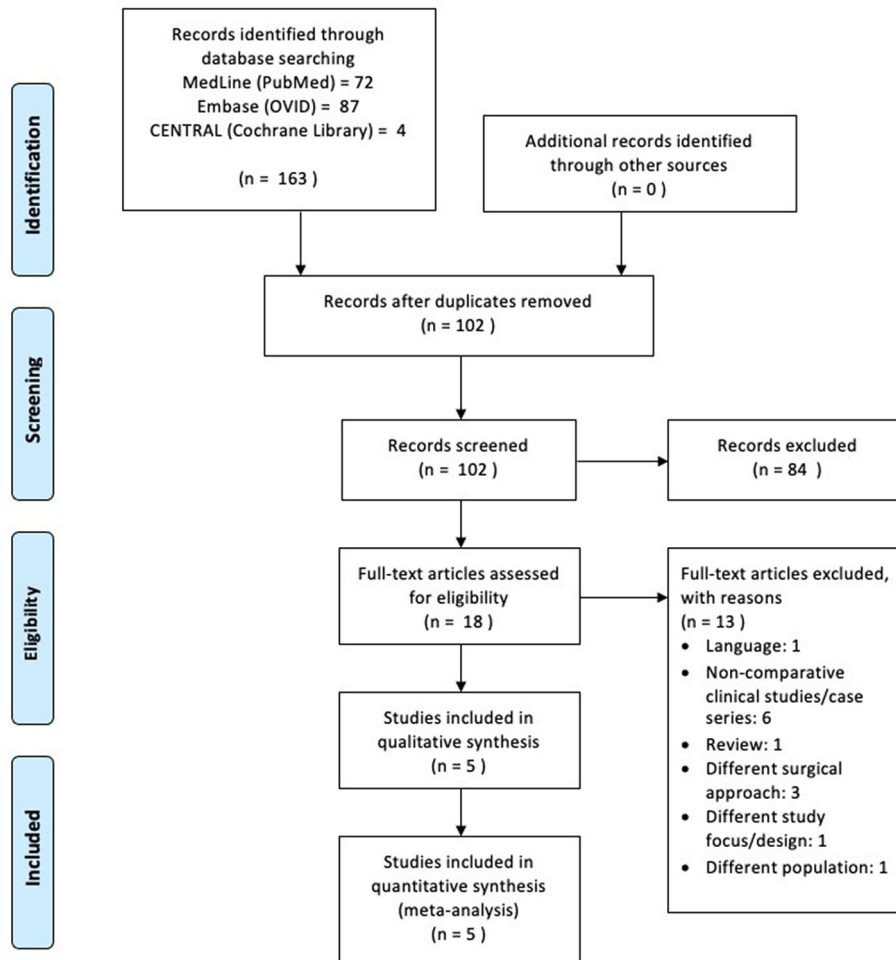


Figure 1. The workflow of this review.

fractures who were operated on with open reduction and percutaneous K-wire fixation posteriorly and laterally). Meanwhile, the other three studies^{15,16,18} had moderate bias because, despite the well-described inclusion criteria and subject selection flow, the number and reasons for exclusion of some subjects were not well defined.^{12,13} Therefore, the authors judged the possibility of bias in the selection of research subjects in these four studies.

- Bias in the classification of the intervention group

Bias in the classification of the intervention group is low if the definition of the intervention is well explained and the definition of the intervention is only based on the information gathered at the time of the intervention (not determined later).^{12,13} The authors assigned a low degree of bias to this category because all studies adequately explained the definition and operational approach of the two intervention groups. Additionally, the definition of the intervention was taken at the time the operation was performed (recorded in the operation log), thereby reducing the risk of bias. Therefore, the authors found no bias in misclassifying the intervention group.

- Bias due to deviations from previously planned interventions

Deviations from previously planned interventions can occur when the patient does not adhere to the prescribed intervention or when the patient can change/switch intervention groups during the study period (in other words, there

Table 2. Risk of bias of the included studies.

Author, Year	Bias due to confounding	Bias in selection of participants into the study	Bias in classification of intervention	Bias due to deviation from intended interventions	Bias due to missing data	Bias in measurement of outcomes	Bias in selection of the reported result	Overall risk of bias
Bamrungthin, 2008	Low	Low	Low	No information	Low	Low	Moderate	Moderate
Basaran et al., 2014	Low	Moderate	Low	No information	Low	Low	Moderate	Moderate
Kizilay et al., 2017	Low	Moderate	Low	No information	Low	Low	Moderate	Moderate
Turkmen et al., 2016	Low	Moderate	Low	No information	Moderate	Low	Moderate	Moderate
Uzer et al., 2017	Low	Low	Low	No information	Low	Low	Moderate	Moderate

is a protocol violation).^{12,13} The authors considered this bias as not having sufficient information because all studies included in this study were retrospective studies of medical records, and there was no predetermined protocol. Therefore, it was quite difficult to judge whether there was a protocol violation or not.

- Bias due to missing/incomplete data

This type of bias occurs when a large number of patients experiences loss of follow-up after they are included in the study (90-95% data availability is deemed sufficient), or when participants are excluded from the analysis by the principal investigator without clear justification/reasons.^{12,13} The study conducted by Turkmen et al.¹⁶ was considered to have a moderate bias due to incomplete data. Investigators in this study noted that they excluded a number of patients due to incomplete data or loss to follow-up but did not adequately explain the numbers. The other four studies^{15,16,18,19} were considered to have a low bias because all the required data were presented in full.

- Bias in outcome measures

Bias in the measurement of results is categorized as low if it meets the following criteria: (i) the method of measuring the results used by all groups is equal and equivalent; (ii) the measurement of the results is objective (cannot be influenced by the knowledge of the type of intervention received by the research subject) or the outcome assessor does not know the type of intervention received by the research subject; and (iii) the existence of an error in measuring the results is not related to the intervention.^{12,13} The authors considered the five studies as having low bias because they met all of the above criteria.

- Bias in the selection of reported results

The authors found that all studies included in this study had a moderate bias in the selection of reported results. This bias was assessed by matching the results of reports or scientific articles published in peer-reviewed journals with the protocols registered before the study was conducted (for example, registering clinical studies on clinicaltrials.gov).^{12,13} Since all five studies are retrospective, there will always be a bias in this category. However, the risk of bias was categorized as moderate (not serious/high risk) because, in the methodology section, all studies clearly explained the method of measurement and statistical analysis used.

Qualitative synthesis

The patient demographic and surgery outcomes of the included studies are presented in [Tables 3](#) and [4](#).

Flynn's criteria divides the results of the evaluation into two major groups: satisfactory and unsatisfactory. The summary of the lateral surgical approach outcomes from the included studies is presented in [Figure 2](#). Overall, the lateral surgical approach resulted in 98% functional satisfaction and 99% cosmetic satisfaction. Meanwhile, the posterior surgical approach resulted in 94% functional satisfaction and 99% cosmetic satisfaction ([Figure 3](#)).

Quantitative synthesis

Meta-analyses were conducted to quantify the difference between the two surgical approaches. We divided the meta-analyses based on the subgroup grading of Flynn's criteria (excellent, good, fair, poor). Overall, all of the data included in the meta-analyses had low heterogeneity ($I^2 < 50\%$), which means that our data were consistent.

Functional outcome

[Figure 4](#) shows the functional outcome of the meta-analysis in the excellent subgroup, while [Figure 5](#) shows the meta-analysis' functional outcome in the good subgroup. The lateral approach was 69% (OR 1.69, 95% CI [0.97-2.93]) and 12% (OR 1.12, 95% CI [0.61-2.04]) more likely to result in excellent and good results, respectively, compared to the posterior approach. However, these differences were not statistically significant ($p = 0.06$ and $p = 0.72$, respectively).

Moreover, the lateral approach resulted in lower fair and poor results by 16% (OR 0.84, 95% CI [0.34-2.13]) and 58% (OR 0.42, 95% CI [0.10-1.73]), respectively, compared to the posterior approach ([Figure 6](#) and [Figure 7](#)). However, these differences were not statistically significant ($p = 0.72$ and $p = 0.23$, respectively).

Cosmetic outcome

In terms of cosmetic results, both approaches showed mixed findings. The lateral approach was more likely to result in excellent (OR 1.11, 95% CI [0.61-2.02]) but less likely to result in good (OR 0.79, 95% CI [0.40-1.55]) cosmetic

Table 3. Patient demographic. L: Lateral surgical approach, P: Posterior surgical approach, NI: No information.

Author, Year of Publication	Country	Study period	Study design	Patient demographic						Fracture classification	Follow-up duration (Months)		
				Total patients	Male		Female		Age (years)		L	P	
					L	P	L	P	L				P
Bamrungthin, 2008	Thailand	2004-2007	Retrospective, Case-Control	82	18	34	12	18	7.2 ± 3.2	6.04 ± 1.5	7.0 ± 1.2	7.6 ± 2.2	
Basaran et al., 2014	France	2010-2011	Retrospective, Case-Control	24	11	8	1	4	3.7 ± 1.7	7 ± 2.8	8.1 ± 2.6	7.5 ± 2.5	
Kizilay et al., 2017	Turkey	2007-2012	Retrospective, Case-Control	40	NI	NI	NI	NI	6.87 ± 2.81		31.71 ± 16.5	31.71 ± 16.5	
Turkmen et al., 2016	Turkey	2008-2013	Retrospective, Case-Control	38	5	18	3	12	7.9 (range 5.1-12.7)	7.8 (range 5.1-12.7)	50.32 (range 16.8-86.4)	50.41 (range 16.8-86.4)	
Uzer et al., 2017	Turkey	2010-2012	Retrospective, Case-Control	47	14	11	8	14	7.3 (range 2-13)	7.3 (range 2.5-14)	12	12	

Table 4. Patient Outcomes based on Flynn's criteria. L: Lateral surgical approach, P: Posterior surgical approach.

Author, Year of Publication	Flynn's Criteria												Satisfactory result						Author's conclusion			
	Excellent			Good			Fair			Poor			Functional		Cosmetic							
	L	P		L	P		L	P		L	P		L	P	L	P						
Bamrungthin, 2008	17	32	18	34	7	10	6	10	5	8	8	5	7	1	2	1	1	29	50	30	51	No significant difference
Basaran et al., 2014	5	5	9	10	7	3	2	2	0	1	1	1	0	0	3	0	0	12	9	12	12	No significant difference
Kizilay et al., 2017	7	6	11	21	3	16	0	7	0	3	0	1	1	1	4	0	0	10	25	11	29	No significant difference
Turkmen et al., 2016	6	21	6	21	2	9	2	9	0	0	0	0	0	0	0	0	0	8	30	8	30	No significant difference
Uzer et al., 2017	13	17	12	13	7	6	6	7	2	2	2	4	5	0	0	0	0	22	25	22	25	No significant difference

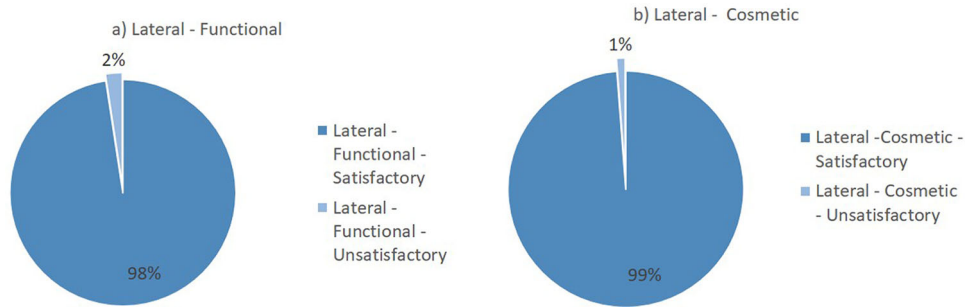


Figure 2. Outcomes of the lateral surgical approach based on Flynn's criteria: (a) functional outcome and (b) cosmetic outcome.

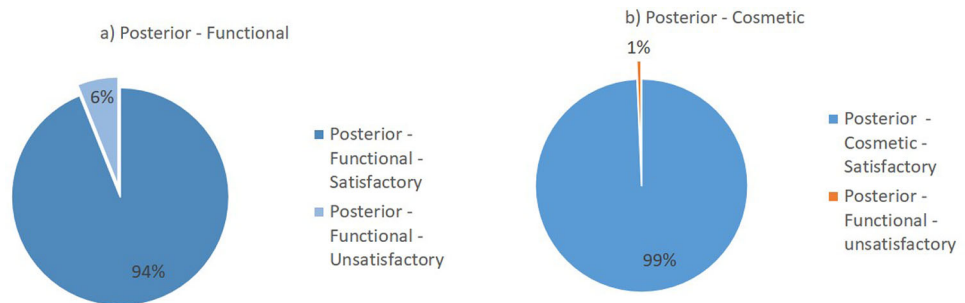


Figure 3. Outcomes of the posterior surgical approach based on Flynn's criteria: (a) functional outcome and (b) cosmetic outcome.

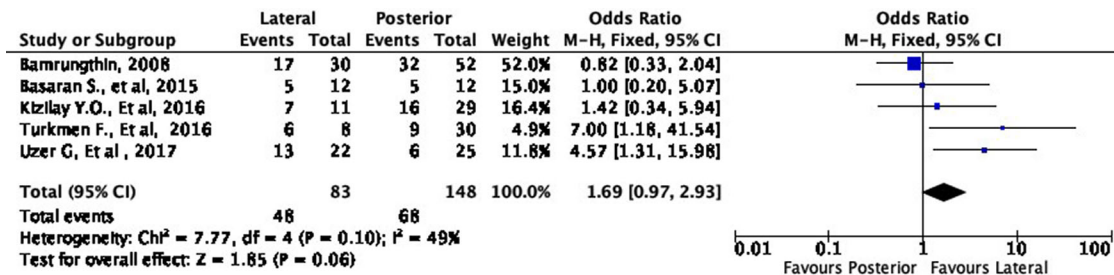


Figure 4. Comparison of functional outcome in the excellent subgroup.

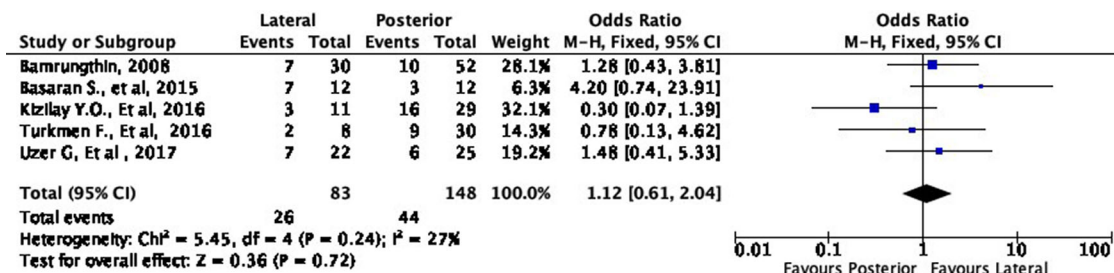


Figure 5. Comparison of functional outcome in the good subgroup.

outcomes compared to the posterior approach (Figure 8 and Figure 9). Interestingly, the lateral approach was also more likely to result in a fair (OR 1.18, 95% CI [0.49-2.80]) cosmetic outcome than the posterior approach (Figure 10). However, none of these findings were statistically significant (p = 0.73, p = 0.49, and p = 0.71, respectively). In other words, the cosmetic outcome was relatively comparable amongst the two approaches. We did not perform a meta-analysis for the poor subgroup as only one study¹⁷ reported the poor outcome; thus, it could not be compared.

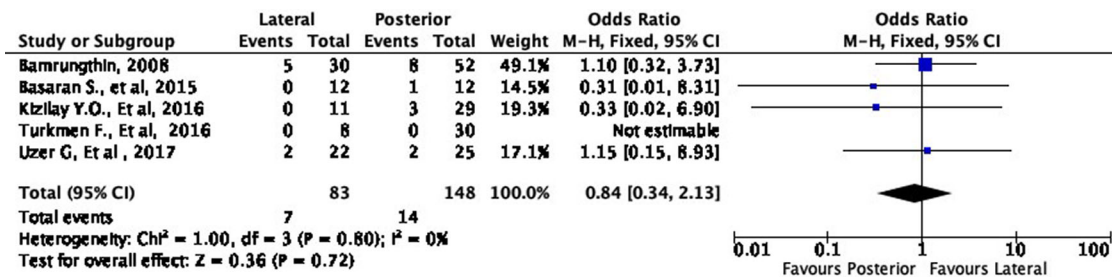


Figure 6. Comparison of functional outcome in the fair subgroup.

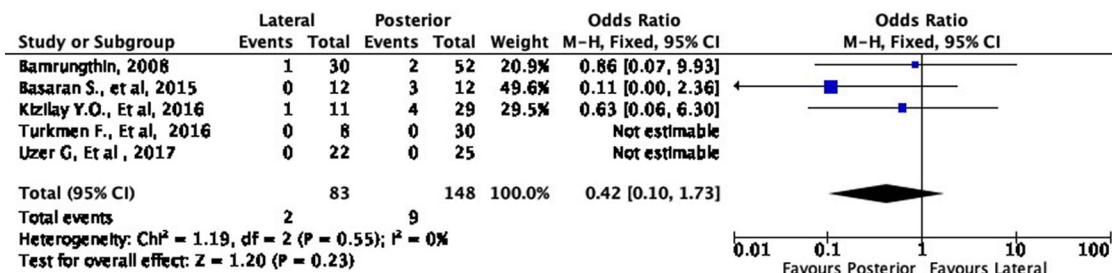


Figure 7. Comparison of functional outcome in the poor subgroup.

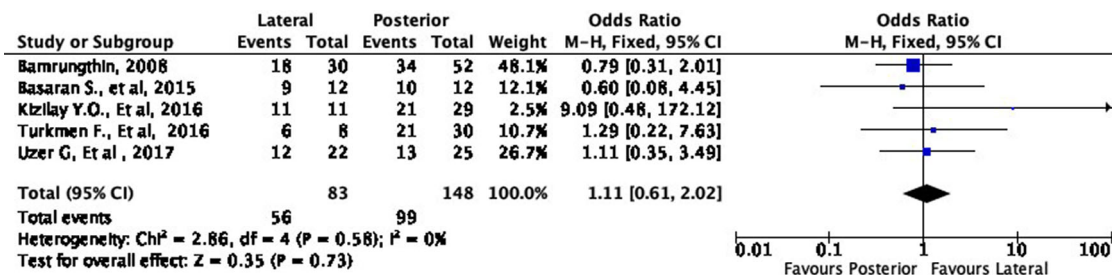


Figure 8. Comparison of cosmetic outcome in the excellent subgroup.

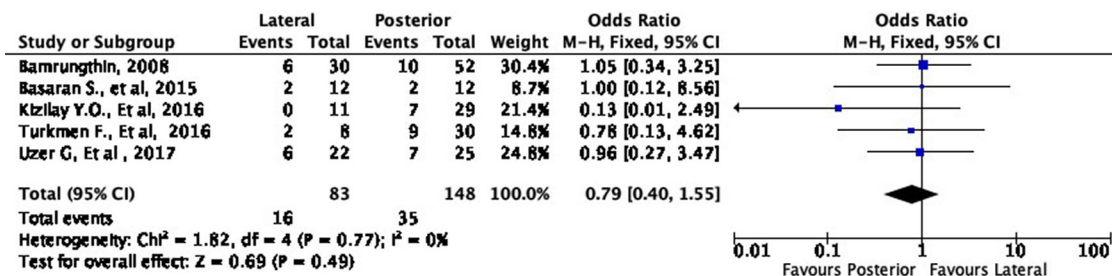


Figure 9. Comparison of functional outcome in the good subgroup.

Discussion

Supracondylar humeral fracture (SHF) is a type of elbow injury in children that most often requires operative therapy than other injuries. 60 to 70% of all elbow injuries in children occur between five and seven years of age.¹ The SHF types that often require ORIF are those that fall into Gartland classification type 3 or 4. There is a shift from the fracture location in these types, making the configuration very unstable. Moreover, the unsuccessful reduction of minimally displaced fractures (i.e., Gartland type 2) also needs ORIF.⁷

The high incidence of SHF makes the decision of which surgical approach to perform crucial. Surgical approaches to manage elbow injuries can be performed with the anterior, lateral, medial, or posterior approach. There is no clear

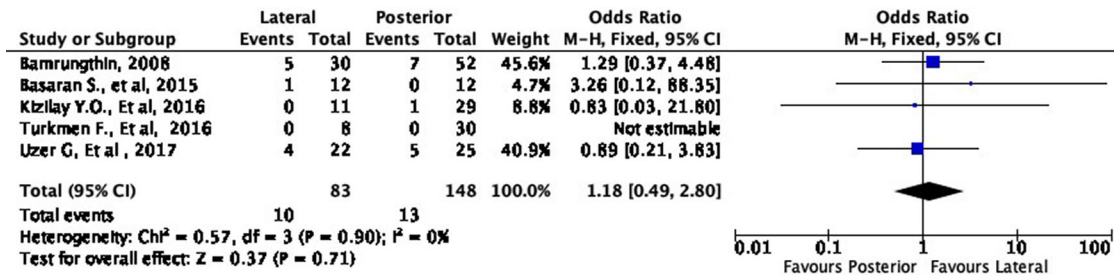


Figure 10. Comparison of functional outcome in the fair subgroup.

evidence of which approach is superior based on the functional, cosmetic, and radiological outcomes. Some of the surgical approaches that are commonly performed are the lateral and posterior approaches. Our study found that the lateral approach gave superior results to the posterior approach in the excellent subgroup assessment using Flynn's criteria for functional and cosmetic outcomes. It was also superior in the good subgroup for functional outcome. However, these differences were not statistically significant. A lateral approach is an approach with the least exposure to the elbow's essential structures than other approaches. It also has fewer surgical wounds that could interfere with elbow joint range of motion.²⁰

This study also found that the lateral approach resulted in fewer poor outcomes than the posterior approach as evaluated using Flynn's criteria in the functional and cosmetic assessments. In other words, the lateral approach had an overall better result than the posterior approach, but this difference was not statistically significant. There is a considerable amount of damage to the triceps muscle in the posterior approach, which can interfere with the muscle's function postoperatively, causing as high as 6% muscle strength reduction compared to preoperative conditions.¹⁵

The lateral surgical approach is quite popular because it has the least risk of damaging vital structures such as the ulnar nerve, brachial artery, and capsule ligament at the elbow compared to other surgical approaches. From the cosmetic point of view, the lateral approach's surgical wound is preferred because it is less visible than the other approaches. Moreover, the lateral approach is a safe approach due to the good visual field of the elbow anatomy and adequate exposure to the radiocapitellar compartment. This approach is easily carried out through the internervous plane, which minimizes nervous injury so that the risk of iatrogenic nerve damage is minimal. Besides, the lateral approach has a better fracture perspective than other approaches.²⁰⁻²³

In addition, the lateral approach is safer because less soft tissue is dissected, avoiding ulnar nerve damage. In cases requiring ORIF, the lateral approach is minimally invasive with minimal soft tissue dissection compared to the posterior approach. This is associated with the dissection or division of the triceps muscles, which often experiences more postoperative adhesions.²³ However, soft tissue swelling is frequently found in the lateral approach, especially when combined with the medial approach to obtain better surgical exposure. Still, there is no consensus on which approach is superior.²⁴ In addition, patients treated with a lateral approach tend to have fewer unstable fractures, complications, and re-operations. Previous research has shown that the lateral approach results are very satisfying, which shows that approximately 67-91.8% of them were successful.²⁵ This finding is similar to the study conducted by Sarrafan et al., who reported that 90.9% of 33 patients who underwent the lateral approach obtained excellent results.²³

Meanwhile, on the other hand, the posterior surgical approach is popular because it has a shorter operating time compared to other approaches.¹⁹ However, this surgical approach is sometimes avoided by some surgeons because the triceps muscle is damaged in the process of reaching the fracture line.²⁶ Nevertheless, a study conducted by Chen et al. reported the posterior approach's superiority compared to anterior and medial approaches in terms of surgery duration and blood loss during elbow surgeries. They found that the shortest surgery duration was the posterior approach (62.9 ± 7.4 minutes), which was shorter than the anterior and medial approaches (64 ± 7.6 and 73.7 ± 7.3 minutes, respectively). Besides, the posterior approach resulted in less blood loss compared to the anterior and medial approaches (135.8 ± 44.7, 147.1 ± 42.7, and 171.3 ± 34.6 ml, respectively).²⁷

In the present study, both lateral and posterior surgical approaches resulted in satisfactory results in more than 90% of the cases analyzed. Although the posterior approach has been associated with several complications such as decreased strength of triceps muscles, previous studies have shown that the functional and cosmetic results were comparable to medial and lateral approaches. Moreover, the posterior approach's advantage such as a wider surgical field of view allows

a trouble-free reduction process, resulting in shorter surgery time. Thus, the posterior surgical approach should always be considered whenever appropriate.²⁸

The limitation of the current study is the language restriction to only English-language articles; thus, we may have missed other eligible studies written in other languages. Another limitation is the low number of studies that were included in the analysis. Moreover, all of the included studies were level III studies. Thus, the present review's evidence level may not be the highest, as we did not find any randomized controlled trials (RCTs). However, we believe that our search strategy was comprehensive and robust. Moreover, we conducted a thorough bias analysis based on the Cochrane recommendation. Thus, our results represent the current best evidence on this topic. Future studies should conduct high-quality original research, preferably RCT, to provide better evidence. Moreover, a study comprising a direct comparison of all existing approaches for SHF management is still needed.

Conclusion

Both lateral and posterior surgical approaches resulted in satisfactory functional and cosmetic outcomes according to Flynn's criteria. The two surgical approaches were comparable in terms of giving desirable functional and cosmetic outcomes for the management of SHF in children. However, the choice of surgical approach preference should be based on surgeons' consideration in accordance with their experience and expertise.

Reporting guidelines

Figshare: PRISMA checklist and flowchart for 'Lateral versus posterior surgical approach for the treatment of supracondylar humeral fractures in children: a systematic review and meta-analysis'. <https://doi.org/10.6084/m9.figshare.14740545.v1>.²⁹

Data availability

All data underlying the results are available as part of the article and no additional source data are required.

Extended data

Figshare: Appendix 1 search strategy. <https://doi.org/10.6084/m9.figshare.14740584.v1>.³⁰

Data are available under the terms of the [Creative Commons Attribution 4.0 International license](https://creativecommons.org/licenses/by/4.0/) (CC-BY 4.0).

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Prateek Behera 

Department of Orthopaedics, All India Institute of Medical Sciences (AIIMS), Bhopal, Bhopal, Madhya Pradesh, India

The authors have explained their points well. I still consider that the authors should modify the following sentence of the discussion: "the posterior surgical approach should always be considered whenever appropriate" as "the posterior surgical approach could be preferred whenever appropriate". "always" is a strong word in scientific writing and should be used judiciously.

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Pediatric Orthopaedics, Deformity Correction and Complex Trauma.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Version 2

Reviewer Report 14 December 2021

<https://doi.org/10.5256/f1000research.79450.r100535>

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Prateek Behera 

Department of Orthopaedics, All India Institute of Medical Sciences (AIIMS), Bhopal, Bhopal, Madhya Pradesh, India

The authors have edited the text to make it more relevant now. However, a few concerns still remain.

1. They have mentioned the indications for CRPP as Gartland Type 3 and 4 fractures but as is well known, Gartland Type 4 fractures are diagnosed during surgery for Gartland Type 3 fractures when the surgeon finds out that the fracture is unstable in both flexion and extension. Thus, it is an intra-operative diagnosis. One does not diagnose Type 4 fractures on injury films. Considering that the authors have mentioned the argument that open reduction is used in situations where the C arm is unavailable, I believe using Type 4 along with Type 3 as an indication is inappropriate. The surgeon can never diagnose a Type 4 fracture in absence of an intra-operative C arm.
2. In the introduction, there is a spelling mistake when the authors have used the term 'medical' instead of 'medial'.
3. The authors have mentioned the disadvantage of the anterior approach as being more challenging but have not mentioned those of the other approaches. A reader deserves a balanced analysis and thus, they should mention the disadvantages of other approaches too. Injury to the capitellar blood supply is one such disadvantage for example.
4. The inference made in favor of the posterior approach in the discussion as "Thus, the posterior surgical approach should always be considered whenever appropriate" is inappropriate in my opinion as the results of the lateral and posterior approaches both based on this study are comparable.

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Pediatric Orthopaedics, Deformity Correction and Complex Trauma.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 18 Dec 2021

komang irianto, Airlangga University, Surabaya, Indonesia

The authors would like to thank Dr Prateek Behera for the meticulous reviews. Our responses for the remaining concerns are:

1. We agree with the reviewer's comment that Gartland type 4 fractures are mostly diagnosed during surgery when instability is found (during reduction attempts/manipulation) in both flexion and extension in Gartland type 3 fractures. Nonetheless, as recent literature has shown encouraging results regarding predictive preoperative radiographic features of Gartland type 4 fractures¹⁻³, the authors suggest that the assumption of "not being able to diagnose Gartland type 4 fracture in the absence of an

intra-operative C arm" should be reconsidered.

Mitchell *et al.* identified five significant preoperative radiographic features associated with an increased likelihood of Gartland type 4 fractures. The most strongly associated feature was flexion angulation of the distal fragment (OR 17, 95% CI [4.9-59], $p < 0.001$), followed by valgus angulation (OR 5.6, 95% CI [1.6-20], $p = 0.008$), lateral translation of distal fragment in the coronal plane (OR 4.1, 95% CI [1.6-11], $p = 0.004$), the presence of osseous apposition between proximal and distal fracture fragments (OR 4.0, 95% CI [1.8-9.0], $p = 0.001$), and propagation of the fracture line toward proximal segment's diaphysis (OR 9.2, 95% CI [1.6-53], $p = 0.01$).¹

Likewise, Barik *et al.* reported that a preoperative radiographic finding manifesting as valgus angulation of the distal fragment $\geq 17^\circ$ was a significant predictor of Gartland type 4 fractures (OR 20.22, $p < 0.001$, sensitivity 88%, specificity 81%)². Meanwhile, Soldado *et al.* recommended that Gartland type 4 fractures should be suspected when the distal fragment is vertically aligned in lateral radiographs despite complete cortical disruption³.

In light of the justification above, the authors believe that Gartland type 4 is an appropriate indication along with type 3 in this study.

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2. We would like to thank the reviewer for his correction. We have amended the typing mistake in the newer version.

3. The disadvantages of the four approaches are explained in several parts of the manuscript. In the Introduction part (Paragraph 3), the authors have mentioned the disadvantages of the medial approach (i.e., extensive soft tissue exposure/more scars) and anterior approach (i.e., neurovascular injury risks). However, we did not specify the neurovascular structure that could be injured in the previous version. We have amended the text by including median nerve and capitellar blood supply injury risks in the anterior approach.

Meanwhile, the disadvantages of lateral and posterior approaches are stated in the Discussion part:

- Paragraph 5 of the Discussion part (highlighting the disadvantage of the lateral approach): "...soft tissue swelling is frequently found in lateral approach."

- Paragraphs 6 and 7 of the Discussion part (highlighting the disadvantages of the posterior approach): "...the triceps muscle is damaged in the process of reaching the fracture line" and "...the posterior approach has been associated with several complications such as decreased strength of triceps muscles."

4. The sentence in paragraph 7: "Thus, the posterior surgical approach should always be considered whenever appropriate" is an adjunct to the whole paragraph in discussing the posterior approach and not to conclude that the posterior approach is superior to the lateral approach. In the Conclusion part, we have mentioned that since "The two surgical approaches were comparable in terms of giving desirable functional and cosmetic outcomes for the management of SHF in children", we concluded that "The choice of surgical approach preference should be based on surgeons' consideration in accordance with their experience and expertise."

Competing Interests: None

Version 1

Reviewer Report 21 September 2021

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Prateek Behera 

Department of Orthopaedics, All India Institute of Medical Sciences (AIIMS), Bhopal, Bhopal, Madhya Pradesh, India

Based on the provided objectives of the study, the authors have attempted to find out the best approach for open reduction of the supracondylar humerus (SCHF) in children. While the authors have followed all the recommended steps for conducting a systematic review, the actual usefulness of this review for a practicing pediatric orthopedic surgeon dealing with SCHFs is a bit limited. The reasons for this observation are mentioned below:

1. The study looks at only two approaches for a common fracture - the lateral and posterior approaches - but has missed out on the anterior and medial ones. The indications for an open reduction include irreducible fractures and fractures with neuro-vascular involvement. Wingfield *et al.*¹ have described the details of how an open reduction becomes necessary in many cases and how an approach can be chosen. In their review, they have mentioned the advantages and disadvantages of different approaches in detail. Reitman *et al.*² studied their patients with SCHF and have mentioned that they prefer to approach through the ruptured periosteum so as not to injure the intact periosteum. If one follows this concept, then also the anterior approach might be the commonest one to be used. Thus, there is a selection bias in the study with the choice of approaches being only two. Ideally, the authors

should have chosen studies on all the approaches and then performed the analysis. The result coming out of that comprehensive systematic review and meta-analysis would be the one that most pediatric Orthopaedic surgeons would like to see.

2. The stated objective of the study was to identify the best approach. Ideally, the best approach would be the one with the least difficulty in exposure, the best chances of providing a near anatomical reduction, the least number of complications, the best post-operative radiological outcome, and the best clinical and functional outcomes. Unfortunately, this study has tried to answer the research question using only one tool - the clinical and radiological outcome (using the system proposed by Flynn *et al.*). The authors should have included the complications, fixation failures, and other related issues in addition to the Flynn criteria.

In view of the two major points made above, in my opinion, the authors should be encouraged to expand the scope of the analysis and include all the approaches and focus on difficulties encountered, complications, reduction quality, loss of reduction, and clinical and functional outcomes. This would make the study more useful.

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Are the rationale for, and objectives of, the Systematic Review clearly stated?

Partly

Are sufficient details of the methods and analysis provided to allow replication by others?

Yes

Is the statistical analysis and its interpretation appropriate?

Partly

Are the conclusions drawn adequately supported by the results presented in the review?

Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Pediatric Orthopaedics, Deformity Correction and Complex Trauma.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.

Author Response 13 Nov 2021

komang irianto, Airlangga University, Surabaya, Indonesia

RESPONSE TO REVIEWERS

Dear Dr. Prateek Behera,

The authors would like to thank you for reviewing our submission.

Questions:

1. The study looks at only two approaches for a common fracture - the lateral and posterior approaches - but has missed out on the anterior and medial ones. The indications for an open reduction include irreducible fractures and fractures with neuro-vascular involvement. Wingfield *et al.* have described the details of how an open reduction becomes necessary in many cases and how an approach can be chosen. In their review, they have mentioned the advantages and disadvantages of different approaches in detail.
2. Reitman *et al.* studied their patients with SCHF and have mentioned that they prefer to approach through the ruptured periosteum so as not to injure the intact periosteum. If one follows this concept, then also the anterior approach might be the commonest one to be used. Thus, there is a selection bias in the study with the choice of approaches being only two. Ideally, the authors should have chosen studies on all the approaches and then performed the analysis. The result coming out of that comprehensive systematic review and meta-analysis would be the one that most pediatric Orthopaedic surgeons would like to see.

Answer:

As stated in the manuscript, we compared the results of lateral and posterior approaches, given that the two approaches are the most common approaches performed by surgeons in a limited setting where C-arm is unavailable. The gold standard management of supracondylar fracture, which is closed reduction followed by percutaneous pinning, could not be performed. The open surgery is planned based on the clinical pathway of supracondylar fracture. Anterior approach is mandated when vascular lesion is suspected. We have added this information to the manuscript.

Question:

1. The stated objective of the study was to identify the best approach. Ideally, the best approach would be the one with the least difficulty in exposure, the best chances of providing a near anatomical reduction, the least number of complications, the best post-operative radiological outcome, and the best clinical and functional outcomes. Unfortunately, this study has tried to answer the research question using only one tool - the clinical and radiological outcome (using the system proposed by Flynn *et al.*). The authors should have included the complications, fixation failures, and other related issues in addition to the Flynn criteria.

Answer:

The main outcomes of supracondylar humeri management are function and cosmetic as established by Flynn *et al.*, where surgeons and patients could objectively evaluate the outcomes. The follow up time in months was reported by all included studies. The fixation failure, skin tract infection, and other related complications had been treated promptly and were considered a part of the functional and cosmetic outcomes.

Competing Interests: no conflict of interest

Reviewer Report 19 August 2021

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Yudha Mathan Sakti

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Congratulations on the paper, the controversies regarding the topic of comparing approaches for supracondylar fractures in children is clinically relevant.

This study has an interesting background that evaluates the management of supracondylar humeral fracture (SHF) in children with the main concern of chosen approaches. Focus descriptions of comparing the lateral and posterior approaches for SHF with systematic review can be applied for decision making in the clinical setting; therefore, making this study a valuable contribution for managing SHF as the most common type of fracture in children.

Specific description regarding the study may improve the narrative and enlighten better of the objective.

Introduction:

- The significant importance of good management for SHF is needed and well described in the introduction. The authors also describe the type of approaches and options to use and their limitation. Improvements are needed to describe the benefits and shortcomings in each approach to better explain the objective of this paper in comparing the lateral and posterior approaches.

Methods:

- The inclusion criteria used to select the studies to be enrolled in this paper is rigorous and well thought; however, the authors' reason to use Flynn's criteria as a comparative measure between studies is needed.
- Description of whether each of the chosen papers directly used the criteria or the authors' method of conclusion to generate the papers' findings to be put in Flynn's classification is still needed.

Results:

- Robust evaluation and selection are showed with the final 5 case-control studies included in

this study. Description and bias evaluation is beneficial and creates a strong perspective to support the findings.

- From Table 4 (Patients' outcome based on Flynn's criteria), the authors conclude no significant difference on each functional and cosmetic findings between each paper in the qualitative analysis. This result is well depicted and described the objective of this study. Despite the findings, the authors' method on how to conclude each paper in the qualitative evaluation is needed to provide a better description.
- Classifying each functional and cosmetic result from each paper and quantitatively compare them give a good insight into this literature review. These findings will give a beneficial perspective between the two approaches with methodical guidance led by this study.

Discussion and Conclusion:

- The study answered the objective with good methodical reasoning. Significant knowledge and rationale of each approach is well described. Advantages and limitations for each approach is thoroughly explained with correlation to this study's finding. Overall, this study will give valuable inputs and contributions to clinicians based on the conducted literature review.

Are the rationale for, and objectives of, the Systematic Review clearly stated?

Yes

Are sufficient details of the methods and analysis provided to allow replication by others?

Yes

Is the statistical analysis and its interpretation appropriate?

Yes

Are the conclusions drawn adequately supported by the results presented in the review?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Orthopaedic and traumatology

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