 Acta Chir Orthop Traumatol Cech. 90, 2023, No. 3, p. 198–205
DOI: 10.55095/achot2023/023

ORIGINAL PAPER
PŮVODNÍ PRÁCE

A Meta-Analysis on Comparison of Open vs Closed Reduction of Gartland Type 3 Supracondylar Humerus Fractures in Children

Metaanalýza srovnání otevřené vs. zavřené repozice suprakondylické zlomeniny humeru typu Gartland 3 u dětí

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ABSTRACT

PURPOSE OF THE STUDY

Although there are numerous studies on outcomes and comparison of open and closed reduction but there is no clarity on relationship between outcomes and complications with type of surgical intervention done for Type 3 Gartland supracondylar humerus fracture. The aim of this study is to compare the outcomes and complications of closed vs open reduction in Type 3 Gartland supracondylar humerus fractures.

MATERIAL AND METHODS

Electronic literature searches of Embase, MEDLINE and the Cochrane Library was conducted in February 2022 using the terms “supracondylar”, “humerus”, “fracture”, “Gartland type 3” and synonymous. The data extracted included the study details, demographic data, procedure performed, final functional and cosmetic outcome according to Flynn criteria and complications of included studies.

RESULTS

Pooled data analysis revealed no significant difference in mean satisfactory outcome rate according to Flynn cosmetic criteria in open group (97%, 95% CI 95.5%–98.5%), as compared to closed group (97.5%, 95% CI 96.3%–98.7%), although a statistically significant difference in mean satisfactory rate according to Flynn functional criteria in open group (93.4%, 95% CI 90.8%– 96.1%) as compared to closed group (98.5%, 95% CI 97.5%–99.4%) was noted. On separate comparison of the two-arm studies, closed reduction favoured better functional outcomes (RR 0.92, 95% CI 0.86–0.99).

CONCLUSIONS

Closed reduction and percutaneous fixation have better functional outcome than open reduction with K-wire fixation. But there was no significant difference in cosmetic outcomes, overall complication rate and nerve injury with either open or closed reduction. The threshold of converting a closed reduction to an open reduction in supracondylar humerus fractures of children should be high.

Key words: supracondylar humerus, open reduction, percutaneous pinning, Flynn criteria.

INTRODUCTION

Supracondylar humerus fractures are the most common fractures around the elbow joint in pediatric population with peak incidence around 5–8 years of age. In Gartland type 3 supracondylar humerus fractures it is difficult to obtain and maintain reduction due to swelling around the elbow, loss of periosteal sleeve and medial wall comminution.

There exists a controversy regarding the management of completely displaced supracondylar humerus fracture (18). Effective treatment is required to prevent long term complications such as cubitus varus and loss of motion. There has been an inconsistency in the recent literature among authors with some advocating open reduction and percutaneous fixation over closed reduction and fixation to prevent these complications in this fracture in order to achieve an anatomical reduction. However, open reduction may not be still able to provide stable reduction and may lead to medial wall collapse and cubitus varus in the future. Moreover, they are also associated with a cosmetic scar and blood loss in the children. These factors have prompted many surgeons to back close reduction over open reduction.

Although there are numerous studies on the outcomes and comparison of open and closed reduction and but there is no clarity on relationship between outcomes and complications with type of surgical intervention done for management of type 3 supracondylar humerus fracture. The aim of this review and meta-analysis is to compare the outcomes and complications of closed vs open reduction in Type 3 Gartland supracondylar humerus fractures.

MATERIAL AND METHODS

This review was performed in accordance to the Preferred Reporting Items for Systematic Reviews and

Meta-Analyses (PRISMA) and Meta-analysis of Observational Studies in Epidemiology (MOOSE) format (Fig. 1). An electronic literature searches of Embase, MEDLINE and the Cochrane Library databases was conducted in February 2022 by two authors (VG, SS). The MeSH terms and their combinations used in the search were as follows: "supracondylar humeral fractures" OR "SCHF" AND "closed reduction" AND "open reduction". We aimed to keep our search strategy fairly general in order to increase our search results. All bibliographies were checked for further relevant studies. Full text articles were obtained for articles after screening of title and abstract.

The inclusion criteria for the final selection included original articles that addressed surgical management of

1) Gartland type 3 fracture,
2) surgery – either closed or open,
3) original article,
4) follow-up more than 18 months,
5) published after year 2000,
6) objective outcome according to Flynn criteria and
7) written in English.

The articles were excluded if one of the following criteria was met

1) less than 5 case subjects,
2) review articles,
3) commentaries and editorials,
4) conference presentations,
5) operative techniques and
6) full text not available.

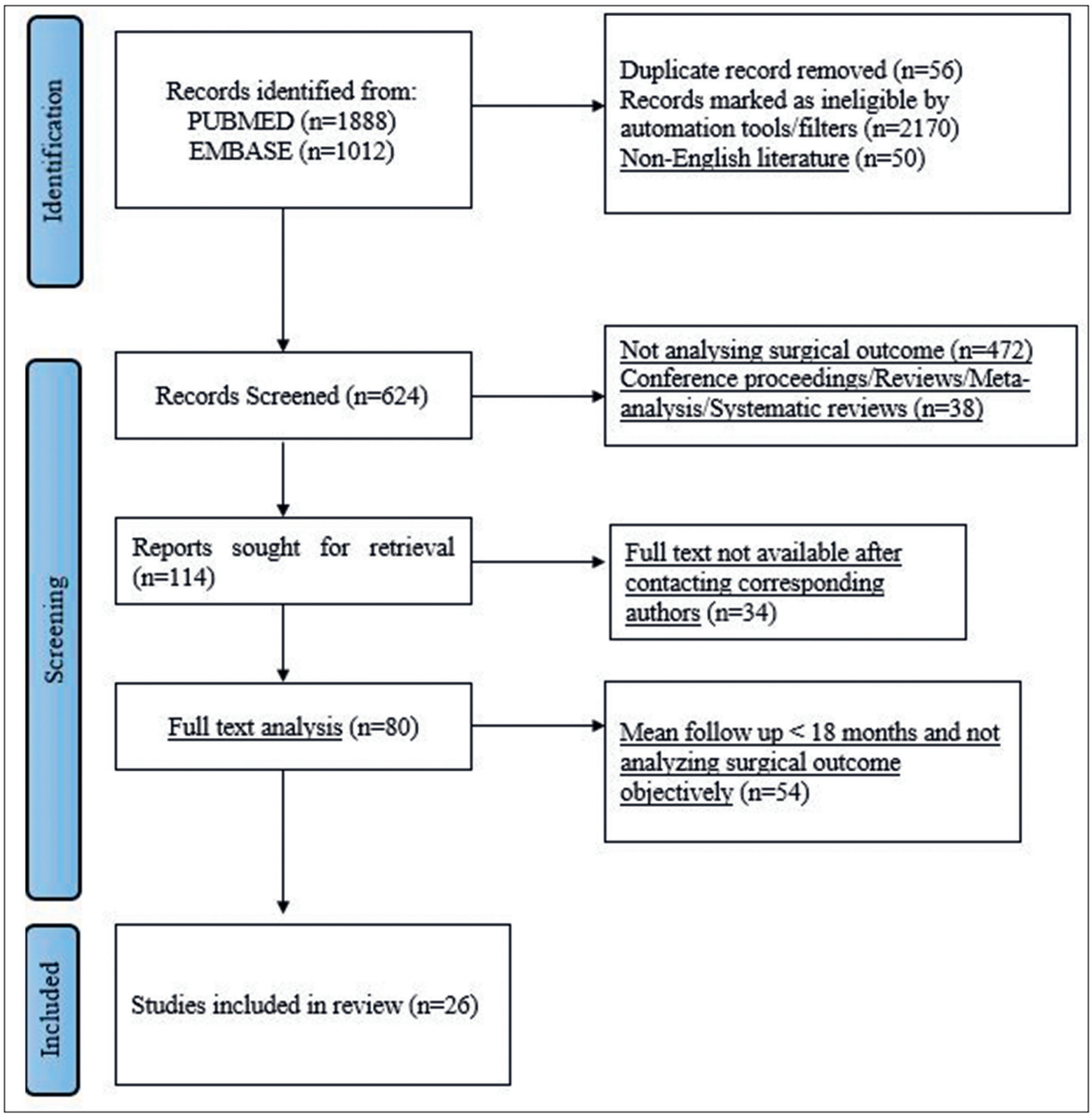

Fig. 1. Flowchart showing methodology followed by authors during systematic review of the literature.

The corresponding authors were contacted by email in case of unavailability of the full text. In the presence of a disagreement about inclusion or exclusion of a particular study, opinion of the senior author (SB, VS) was sought.

The data extracted by 2 authors (VG, SS) included the study details, demographic data, procedure performed, final functional and cosmetic outcome according to Flynn criteria and complications of each included study. The level of evidence of the studies was noted according to the guidelines of Oxford Centre for Evidence-based Medicine. Excellent and good outcome according to Flynn criteria was taken as satisfactory whereas fair and poor outcome was taken as unsatisfactory. In studies providing data about individual patients included in the study, data was extracted from the tables provided. The data was collected on an Excel spreadsheet [Microsoft, USA]. Studies which had two arms of open and closed reduction were considered as two separate studies. Also, the same studies were used to compare the results of open and closed reduction separately.

STROBE guidelines were used for methodological assessment and quality appraisal of the studies involved with 9 out of the 22 checklist items used for the same (37). Each criterion was scored as well described (score 1), partly described (score 0.5) and not described (score 0). In case of disagreement consensus was sought between both the authors (VG, SS). Studies with scores more than 75% of total score of 9 were included for final review. Potential publication bias was assessed by Egger's linear regression test (10). A value of $P < 0.05$ was interpreted as evidence of publication bias.

Before data analysis, a hypothesis for data heterogeneity was postulated. It was hypothesised that the surgical technique used would account for observer heterogeneity. I^2 statistic is a tool to describe proportion of total variation in study estimates considered to be due to heterogeneity and quantifies the inter-study variability. Low, moderate and high heterogeneity was ascribed to I^2 values of 25%, 50% and 75% respectively.

Descriptive analysis using means, standard deviation (SD), and ranges (minimum, maximum) of the pooled data across the included studies were performed. Meta-analysis was performed using the Metafor package in R statistical software v4.0.0 (R Core Team, Vienna, 2020). Analysis was performed using a random-effects model using the DerSemonian Laird method. Subgroup analysis was performed by grouping the studies based on the type of treatment approach used (open vs closed). Pooled data from the eligible studies were also evaluated for occurrence of complication by Mann-Whitney U test. This dichotomized the outcome into presence or absence of complication in the said study. A p-value of less than 0.05 was considered significant.

RESULTS

The initial literature search yielded 2900 articles for consideration (Fig. 1). 114 articles were selected from among these which met the inclusion and exclusion criteria. Of these, 54 articles were excluded because of inadequate follow-up, publication before the year 2000 and inadequate data in the study and in 34 articles the data could not be retrieved. Finally, 26 articles were included for qualitative and quantitative review.

Two of the selected studies were prospective and rest being level retrospective (15, 38). There was no randomised controlled trial among all the studies involved. The studies included had a score of more than 75% of the total score (mean score 7.5) on the STROBE guidelines. All the studies could be classified on the basis of technique used, either open or closed. 8 studies compared the result of open versus closed reduction and these studies were compared separately apart from the meta-analysis involving all the studies (1, 17, 19, 22, 23, 28, 30, 36). The studies on open reduction had a high degree of heterogeneity (I^2=72.09%) as compared to low heterogeneity in studies analysing closed reduction. All the studies had described their final outcome by Flynn cosmetic and functional criteria except one which only used Flynn functional criteria to quantify their results (21). A total of 13 studies were quantitatively analysed for nerve palsy (1, 4–6, 9, 17, 19, 21, 23, 27, 30, 35, 36). 13 studies for complications such as superficial infections, hypertrophic ossificans, wound dehiscence, avascular necrosis of trochlea, hypertrophic scar and compartment syndrome (1, 4, 5, 9, 12, 13, 17, 23, 27, 28, 30, 35, 36).

The total sample size of the studies included in this review were 1531 (838 in open group and 693 in closed group) with Gartland type 3 supracondylar humerus fracture (Table 1). The mean age of the patient in open and closed group were 7.19±1.86 and 6.76±1.30 years respectively. The mean follow-up of the patients in both the group were 47.64±57.27 and 27.73±11.74 months respectively. There was a male preponderance in both the group with 51.98% and 67.13% being males in open and closed group respectively.

25 studies compared the outcome by Flynn cosmetic criteria between open or closed surgical approach used (1, 4–6, 9, 11–13, 15–17, 19, 20, 22–24, 26–28, 30, 31, 34–36, 38). The forest plot revealed no significant difference in mean satisfactory outcome rate according to Flynn cosmetic criteria in open group (97%, 95% CI 95.5%–98.5%), as compared to closed group (97.5%, 95% CI 96.3%–98.7%). On separate comparison of the two-arm studies, there was no significant difference in the outcomes (RR 1 95% CI 0.06–1.044).

26 studies compared the outcome by Flynn functional criteria between open or closed surgical approach used (1, 4–6, 9, 11–13, 15–17, 19–24, 26–28, 30, 31, 34–36, 38). The forest plot revealed statistically significant difference in mean satisfactory rate according to Flynn functional criteria in open group (93.4% ,95% CI 90.8%–96.1%) as compared to closed group (98.5% ,95% CI 97.5%–99.4%) (Fig. 2). On separate comparison of the two-arm studies, closed reduction favoured better functional outcomes (RR 0.92 95% CI 0.86–0.99) (Fig. 3).

13 studies compared the nerve involvement either permanent or transient between open or closed surgical

Table 1. Demographic characteristics of the included studies

Study name	Level of evidence	Strobe score	Age in years(mean)	Sex (M/F)	N*	Follow up in months (mean)	Flynn satisfactory (functional) (n)	Flynn satisfactory (cosmetic) (n)
Udulag et al. (36)	III	8.5	5.96	36M/26F	62	44.59	62	61
Turhal et al. (35)	III	8	7.1	32M/14F	46	28.05	45	45
Hussein Al-Algawy et al. (17)	III	8.5	7	41M/25F	66	24	58	58
Dong et al. (9)	II	7.5	4.2	48M/20F	68	23.07	68	68
Sahin et al. (34)	III	7.5	7.89	39M/28F	67	35.55	64	67
Naik et al.(27)	III	8	6.73	36M/21F	57	23.04	56	56
Li et al. (24)	III	7.5	5	–	64	18	60	60
Kzlay et al. (22)	III	8	6.87	–	70	31.71	61	69
Waikhom et al. (38)	II	8	4.8	24M/28F	52	24	52	52
Guven et al. (16)	IV	8	6.5	11M/38F	49	268.8	41	46
Azhar et al. (5)	IV	7.5	4.8	42M/23F	65	38.4	61	61
Ersan et al. (12)	III	8.5	7.6	48M/36F	84	67.64	83	83
Carvahallo et al. (6)	IV	8.5	5.47	13M/4F	17	29.04	17	17
Fu et al. (15)	IV	8	6.2	26M/30F	56	48	53	53
Suleiman et al. (13)	III	8	9	55M/23F	78	42	76	76
Parmaksizoglu et al. (31)	IV	7.5	6.7	–	23	56.42	22	23
Kazimoglu et al. (19)	III	8.5	Group 1 – 5.9 Group 2 – 6.5	55M/15F	80	29.5	78	76
Ersan et al. (11)	IV	7.5	–	25M/21F	46	18	46	46
Aktekin et al. (1)	III	8	8.18	37M/18F	55	22	41	46
Lee et al. (23)	III	8	6.5	–	95	30	95	90
Ay et al. (4)	IV	8	8.7	35M/26F	61	42	61	61
Ozkoz et al. (30)	III	8.5	8.97	55M/44F	99	31.22	71	83
Oh et al. (28)	III	8	6.4	–	35	22	32	32
Koudstaal et al. (20)	IV	8	11.86	–	58	37.86	49	51
Mulhall et al. (26)	IV	8	5.9	8M/8F	16	31.2	15	14
Kumar et al. (21)	III	8	8.4	45M/17F	62	20.59	62	–

approach used (1, 4–6, 9, 17, 19, 21, 23, 27, 30, 35, 36). The pooled data analysis revealed no statistically significant difference for nerve involvement in open group (4.8%, CI 1.6%–7.9%) as compared to closed group (2.4%, CI 1%–3.8%).

The overall complication included superficial surgical site infection, nerve involvement, hypertrophic ossificans, hypertrophic scar, injury to vessel, compartment syndrome and avascular necrosis of trochlea following surgical treatment. 13 studies compared overall complication rate between open or closed surgical approach used (1, 4, 5, 9, 12, 13, 17, 23, 27, 28, 30, 35, 36). The pooled data analysis revealed no significant difference for overall complication between open (11%, 95% CI [5%–17%]) and closed approaches (11%,95% CI [7%–15%]). There was no significant difference between both the treatment modalities when analysing studies which had compared both the methods (RR 1.23, 95% CI 0.75–2). The results of comparison of functional and cosmetic outcomes alongside associated complications between the open and close reduction subgroups have been summarized in (Table 2).

Table 2. Comparison of functional and cosmetic outcomes alongside associated complications between the open and close reduction subgroups

	Open reduction (%, 95% CI)	Closed reduction (%, 95% CI)	p value
Percentage of satisfactory Flynn score (Cosmetic)	97%, [95.5%–98.5%]	97.5%, [96.3%–98.7%]	>0.05
Percentage of satisfactory Flynn score (Functional)	93.4%, [90.8%–96.1%]	98.5%, [97.5%–99.4%]	<0.05
Complication rate (overall)	11%, [5%–17%]	11%, [7%–15%]	>0.05
Nerve complications	4.8%, [1.6%–7.9%]	2.4%, [1%–3.8%]	>0.05

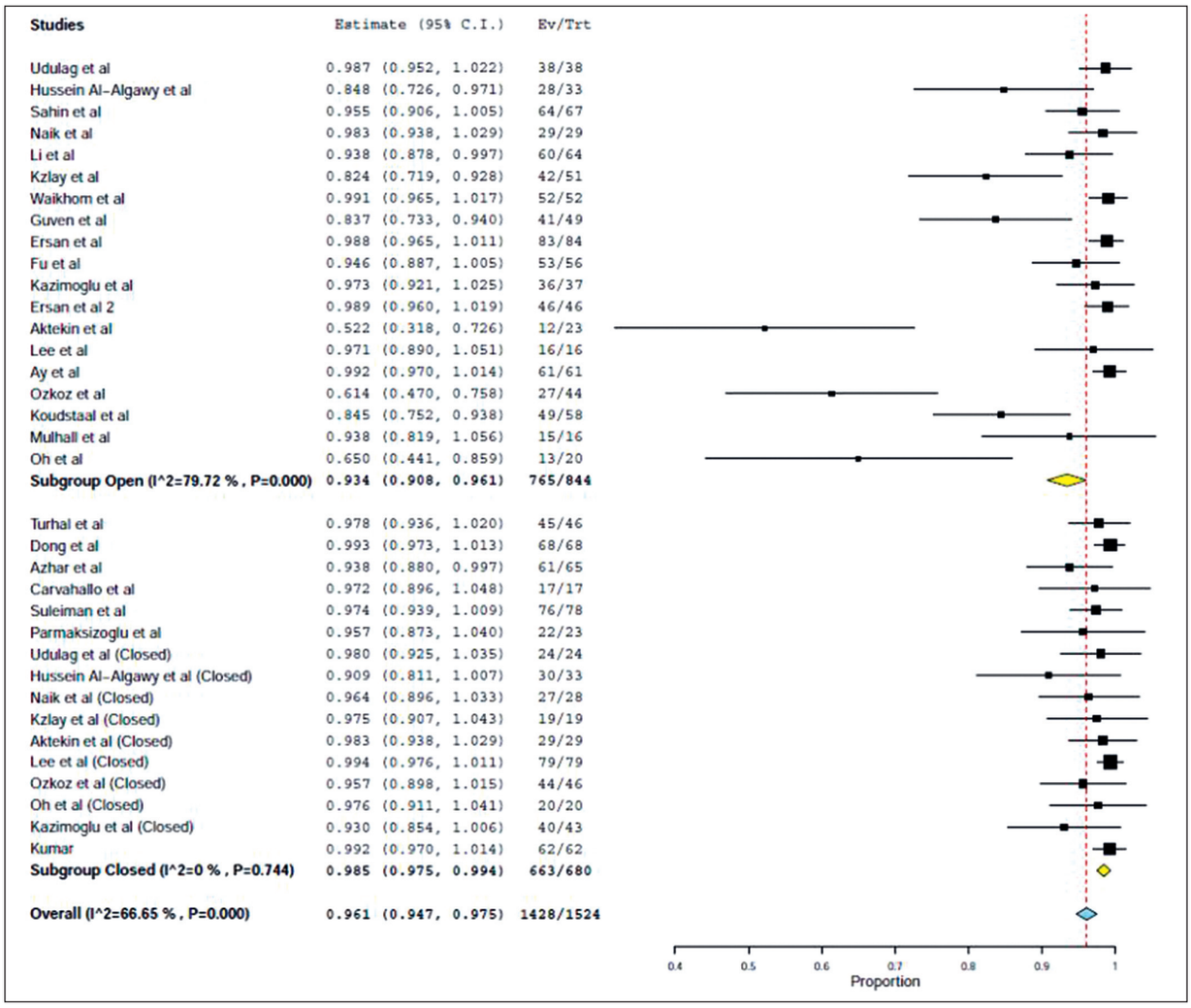

Fig. 2. Proportional meta-analysis showing comparison of Flynn functional outcome in open and closed reduction groups.

Egger's linear regression test was performed to assess publication bias in the analyses of Flynn's criteria (cosmetic and functional). Results revealed that this meta-analysis had no significant publication bias (Flynn criteria (functional) – Coefficient 0.5234808, Standard error 1.75562, p 0.816, Flynn criteria (cosmetic) – Coefficient -0.1185576, Standard error 0.6028971, p 0.862).

DISCUSSION

Severely displaced supracondylar humerus fractures in children are difficult to treat. Closed reduction and casting is not used due to fear of compartment syndrome and medial wall collapse leading to cubitus varus deformity (39). Previously various author's recommended

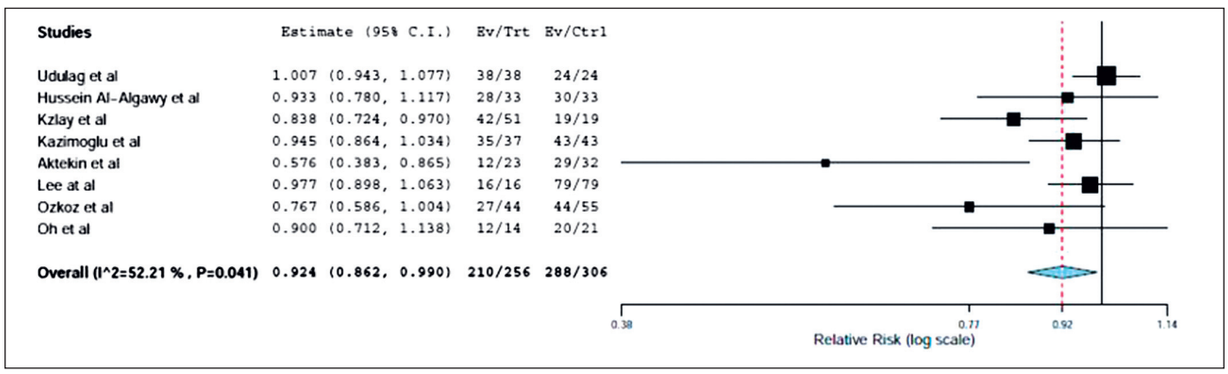

Fig. 3. Pooled relative risk for satisfactory functional outcome in open reduction compared with closed reduction.

using Smith or Dunlop traction technique for treatment of these fracture but these techniques are obsolete now, since it leads to long hospital stays, stiffness and elbow deformity (2, 14, 33). At present, closed reduction with K-wire fixation is widely recommended but it may not result in satisfactory reduction of the fracture fragments due to soft tissue interposition (7, 8). In such instances, open reduction with minimal soft tissue dissection is suggested. Anterior, medial, posterior or lateral approaches can be used to facilitate reduction (29, 32). However, open reduction may lead to cosmetic scar, soft tissue injury, blood loss and prolonged anaesthesia. These factors might force some surgeons to accept suboptimal reduction with closed reduction. The purpose of this meta-analysis was to determine the outcomes and complications of closed vs open reduction in Type 3 Gartland supracondylar humerus fractures in children.

In this meta-analysis, it was found that open reduction did not offer any advantage over closed reduction and percutaneous pinning in terms of Flynn's functional criteria or prevention of complication or nerve palsy. In the previous meta-analysis by Guo et al. which compared the results between open v/s closed reduction, showed no significant difference in either Flynn's functional or clinical outcomes, ulnar nerve involvement or infection with either of the two approaches (25). However, the said study also included Gartland type II supracondylar humerus fractures and compared the results between randomized control trials only. In our study, we have included only type III supracondylar humerus fractures and also observational studies after year 2000.

This study included only those studies which a follow-up of at-least 18 months. This is in contrast to the previous study which included studies with follow-up of less than 18 months. The studies had a mean follow-up of 47.64±57.27 and 27.73±11.74 months in the open and closed approach group respectively. The follow-up in the previous meta-analysis ranged from 3–29.5 months. This is particularly important because authors believe that it takes almost 6–12 months to regain full range of motion after the trauma. Since, loss of range of motion occurs in the plane of movement of elbow joint, any bone ledge will remodel during the follow-up. Any loss of range of motion after that can be due to various factors such as hypertrophic ossificans or soft tissue contracture or due to change in biomechanics of the elbow joint. Our study, showed that there was a statistically significant reduction in functional Flynn outcome in open techniques as compared to closed reduction and percutaneous fixation. This loss of range of motion at elbow joint may be due to soft tissue contracture or by increased bleeding in the muscle around the elbow joint leading to hypertrophic ossification. We also believe that, since most of the surgeons first attempt to do close reduce the fracture, this may also cause increased bleeding in the muscle around the elbow joint.

The overall complication rate in the open and closed approaches were found to be 10.98% and 12.74% respectively. Overall complications included superficial surgical site infection, nerve involvement, hypertrophic ossificans, hypertrophic scar, injury to vessel, compartment syndrome and avascular necrosis of trochlea. Previous meta-analysis only included ulnar nerve involvement and presence of infection in their results (25). They showed infection rate of 7.14% and 6.41% in their study in closed and open group respectively. This analysis, showed infection rate of 6.4% and 8.65% in open and closed group respectively. Both the studies showed no significant difference for infection rate. The overall nerve complication rate in this study was 6.72 % and 3.41 % in open and closed group respectively. This included radial, anterior interosseous and median nerve apart from ulnar nerve. But the previous meta-analysis only included ulnar nerve injury in their study. Both the studies showed no significant improvement in nerve complications. It should also be borne in mind that the documented incidence of primary nerve injury in these fractures is 7–10% and up to 6% for secondary nerve injury and the indication for intervention in these two distinct nerve injury pattern is different (3).

In order to avoid these complications, authors recommend

1) this fracture must be treated on an urgent basis
2) multiple attempts at closed reduction should be avoided
3) limb should not be immobilized in more than 90° flexion
4) K-wires should be buried under the skin wherever possible and
5) active range of motion exercise to be initiated as soon as possible after the radiological evidence of union.

As compared to the previous meta-analysis by Lin-Guo et al., this current review compares all studies, whether comparative or single arm in its analyses (25). 25 articles were analysed in this review as compared to 6 articles analysed in the previous meta-analysis. Most of the studies were retrospective except two (15, 38). There was no randomised controlled trial among all the studies involved. Only 7 of the 25 studies included were comparative studies (1, 17, 22, 23, 28, 30, 36). The studies included had a score of more than 75% of the total score (mean score 7.5) on the STROBE guidelines. Non-English literature was also excluded from this review since an incorrect translation would have led to erroneous results. Selection bias due to non-randomisation is an inherent drawback of the studies included in this review. It must also be noted that the studies included have not stated whether the reduction was performed by a consultant surgeon or a resident. Heterogeneity of the approach, number of K-wire, technique of reduction and fixation could have potentially created a bias in this review. The indications of open reduction in these studies have not been sub-analysed due to lack of clear data. Since closed reduction and pinning has grown to be accepted as the current gold standard in the treatment of supracondylar humerus fractures, and open reduction is usually reserved for serious displaced fractures, flexion-type fractures, nerve injury after closed reduction, open fractures requiring irrigation and debridement and in posterolateral displaced fractures with a high risk of

neurovascular injury, these results should be read with caution since the individual indications for open reduction has not been studied.

CONCLUSIONS

Closed reduction and percutaneous fixation have a better functional outcome than open reduction with K-wire fixation. But there was no significant difference in cosmetic outcomes, overall complication rate and nerve injury with either open or closed reduction techniques. The threshold of converting a closed reduction to an open reduction should be high. Randomised controlled trials with an adequate sample size is the need of the hour to answer the queries definitely regarding the outcomes of open versus closed reduction in supracondylar humerus fractures.

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