e-ISSN: 0976-822X, p-ISSN:2961-6042

Available online on http://www.ijcpr.com/

International Journal of Current Pharmaceutical Review and Research 2026; 18(2); 1824-1830

Original Research Article

Comparative Evaluation of Open versus Closed Reduction in Distal Humerus Fractures: A Retrospective Comparative Study

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Received: 01-11-2025 / Revised: 15-12-2025 / Accepted: 21-01-2026

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Conflict of interest: Nil

Abstract

Background: Displaced supracondylar fractures in the distal humerus are a significant pediatric elbow injury as malreduction can produce cubitus varus, stiffness, and neurovascular sequelae. The most common first-line treatment is closed reduction with percutaneous pinning, though open reduction is still needed for irreducible or neurovascularly concerning fractures. Perioperative, radiographic, and functional outcomes were compared after open versus closed reduction.

Methods: This retrospective comparison was performed on 96 children with displaced supracondylar distal humerus fractures from January 2020 to December 2024. Sixty-four received closed reduction and percutaneous pinning (CRPP) and 32 open reduction with pin fixation (ORPP). Demographic information, injury features, operative information, radiographic alignment, Flynn criteria, elbow motion, and complications were examined. Multivariable logistic regression revealed predictors of open reduction.

Results: For the ORPP group, there was more severe swelling or pucker sign (50.0% vs 17.2%, p=0.001), delayed presentation beyond 24 hours (37.5% vs 12.5%, p=0.006), flexion-type fractures (15.6% vs 3.1%, p=0.028), and neurovascular abnormality (25.0% vs 6.3%, p=0.009). CRPP had shorter operative time (43.1±8.7 vs 68.4±11.9 minutes, p<0.001) and shorter hospital stay (1.6±0.7 vs 3.2±0.9 days, p<0.001). Excellent or good Flynn functional outcomes occurred in 93.8% of CRPP and 84.4% of ORPP cases. Radiographic restoration was comparable, with satisfactory anterior humeral line position in 93.8% and 90.6%, respectively.

Conclusion: Closed reduction remained the preferred strategy because it reduced operative burden while preserving excellent final outcomes. Open reduction, when used for complex or irreducible injuries, still produced acceptable alignment and function and remained a reliable operative option.

Keywords: Distal Humerus Fracture; Supracondylar Fracture; Open Reduction; Closed Reduction; Percutaneous Pinning; Flynn Criteria.

DOI: 10.25258/ijcpr.18.2.303

Introduction

The ORPP group reported greater swelling or pucker sign severity (50.0% vs 17.2%, p=0.001), presentation more than 24 hours later (37.5% vs 12.5%, p=0.006), flexion-type fractures (15.6% vs 3.1%, p=0.028), and neurovascular abnormality (25.0% vs 6.3%, p=0.009). CRPP had reduced operative time (43.1±8.7 vs 68.4±11.9 minutes, p<0.001) and shorter hospitalization time (1.6±0.7 vs 3.2±0.9 days, p<0.001). Excellent or good Flynn functional outcomes occurred in 93.8% of CRPP and 84.4% of ORPP cases. Radiographic restoration was also similar, with satisfactory anterior humeral line position in 93.8% and 90.6%, respectively. Treatment approaches for displaced fractures over the past several decades have migrated away from prolonged casting and toward stable fixation. Closed reduction with percutaneous pinning has become the standard of care for most displaced extension-type supracondylar fractures as it limits additional soft-tissue trauma while more reliably preserving reduction than manipulation and immobilization alone [4-6]. Success after closed reduction relies on timely presentation, fluoroscopic control, stable pin configuration, and the absence of major soft-tissue interposition. When such conditions are in place, the union and function are generally excellent [5,6]. Not all dislodged distal humerus fractures, however, can be

closed successfully despite this agreement. Failed closed reduction, brachialis entrapment with a puckering sign, marked edema, flexion-type morphology, multidirectional instability, delayed presentation, and associated neurovascular abnormalities may require open reduction [7-10].

Open reduction allows the viewing of the injury directly, extirpation of the interposed tissue, re-alignment restoration and examination of the brachial artery or median nerve as clinically indicated [8,9]. Yet, it also has greater soft tissue dissection, longer time of surgery, and concern regarding postoperative stiffness. The clinical problem for a surgeon is thus not whether open reduction is sound, but how its outcomes compare to those of closed reduction when the underlying injuries are more severe [7,10].

The comparative literature is still informative, but incomplete. Previous studies by Cramer et al., Oh et al., and Ozkoc et al. proposed that closed reduction does have a relative advantage in that it offers shorter operative times and somewhat better early elbow motion while open reduction can still produce satisfactory cosmetic and union outcomes when treatment is initiated for irreducible injuries [11-13]. Subsequent comparison studies also reported that open reduction via a medial approach can reach an efficacy comparable to percutaneous pinning for carefully selected extension-type fractures [14]. In contrast, systematic reviews highlight considerable heterogeneity, a frequent retrospective design and persistent selection bias, particularly with regard to children who are already the most complex fracture category that could benefit from open reduction [15,16].

That said, a well-structured institutional comparison remains clinically useful. Consequently, this original article was written as a retrospective comparative study of children with displaced pediatric distal humerus fractures treated with either closed reduction and percutaneous pinning or open reduction with pin fixation.

The main goal was to compare final functional and cosmetic outcomes using Flynn criteria. Secondary aims were to assess perioperative burden, radiographic restoration, elbow motion, and complications, and identify baseline factors associated with conversion to or choice of open reduction.

Materials and Methods

Study Design and Setting: A retrospective comparative cohort study was performed in the Department of Orthopaedic Surgery of a tertiary teaching hospital from January 2020 to December 2024 after ethics approval. Medical records, operative notes, and radiographs were reviewed for all eligible children treated during the study period.

Participants: Eligible children were 2-12 years old with displaced supracondylar fractures of the distal humerus who underwent operative fixation. Inclusion criteria included Gartland type III or IV extension-type fractures, displaced flexion-type fractures, or irreducible displaced supracondylar injuries with at least 6 months of follow-up. Exclusion criteria were nondisplaced fractures, pathological fractures, associated ipsilateral injuries affecting elbow function, previous ipsilateral deformity, open contaminated fractures requiring staged care, and incomplete records.

Preoperative Assessment: Age, sex, side, mechanism of injury, time to presentation, swelling, skin puckering, and neurovascular status were documented. Standard anteroposterior and lateral radiographs were assessed for fracture morphology, Baumann angle, and anterior humeral line position. Patients were placed in closed reduction and percutaneous pinning (CRPP) and open reduction with pin fixation (ORPP) categories based on the definitive procedure performed.

Operative Technique: Closed reduction was pursued initially in all otherwise clinically appropriate children under general anesthesia and fluoroscopic guidance. Reduction was performed by traction, coronal and rotational correction and stabilization using flexion, then lateral-entry, or crossed Kirschner-wire fixation as indicated by stability. Open reduction was undertaken when acceptable alignment was not possible or was maintained, or direct exploration was warranted because of significant swelling with puckering, flexion-type irreducibility, delayed presentation, or neurovascular concern.

Postoperative Care and Outcomes: All elbows were immobilized in an above-elbow splint. Follow-up visits were scheduled at 1 week, 3 to 4 weeks, 6 weeks, 3 months, and final review at or beyond 6 months. Wires were removed after radiographic healing. The primary outcome was the final functional and cosmetic result according to Flynn criteria. Secondary outcomes included operative time, fluoroscopy time, hospital stay, final Baumann angle difference, anterior humeral line restoration, carrying-angle change, elbow motion, and complications.

Statistical Analysis: Continuous variables were summarized as mean ± standard deviation or median with interquartile range and compared with the independent-samples t test or Mann-Whitney U test. Categorical variables were analyzed with the chi-square test or Fisher exact test. Multivariable logistic regression was used to identify predictors of open reduction. Statistical significance was set at $p<0.05$.

Ethical Considerations: The Institutional Ethics Committee approved the study protocol, and the analysis was performed on de-identified data. Because the study was retrospective, written informed consent was waived in accordance with institutional policy.

Results

Of 118 case records screened during the study period, 22 were excluded because of inadequate follow-up, associated ipsilateral fractures, or incomplete imaging, leaving 96 children for final analysis. Sixty-four children (66.7%) underwent CRPP and 32 (33.3%) underwent ORPP. The overall mean age was 6.4±1.9 years, and boys accounted for 67.7% of the cohort. The two groups were similar with respect to age, sex, side of injury, and mechanism of trauma. However, children requiring open reduction presented with a distinctly more complex injury profile. Delayed presentation beyond 24 hours was seen in 37.5% of ORPP patients compared with 12.5% of CRPP patients (p=0.006). Likewise, severe swelling or pucker sign was markedly more frequent in the ORPP group (50.0% vs 17.2%, p=0.001), as were flexion-type fractures (15.6% vs 3.1%, p=0.028) and neurovascular abnormalities at presentation (25.0% vs 6.3%, p=0.009).

The associated perioperative results revealed a statistically significant benefit for the closed reduction in surgical efficiency. Mean operative duration was 43.1±8.7 min in the CRPP group and 68.4±11.9 min in the ORPP group (p<0.001). Mean fluoroscopy time was greater after CRPP due to reduction and pin insertion being guided by image throughout the process (1.9±0.6 vs 0.8±0.3 minutes, p<0.001), but this did not diminish closed treatment's total time benefit. Length of stay also favored CRPP, with an average hospitalization of 1.6±0.7 days versus 3.2±0.9 days after ORPP (p<0.001). The most frequent indication was failed closed reduction (n=14), then severe swelling or puckering (n=8), neurovascular concern (n=5), flexion-type irreducibility (n=3), and delayed presentation with difficult reduction (n=2), among the 32 open cases.

At follow-up, which averaged 14.1 months, all fractures had united radiographically. Final coronal alignment was acceptable for both sets of patients. The Baumann angle difference from a contralateral side was 3.1±1.7° using CRPP and 3.8±2.0° using ORPP (p=0.090), and satisfactory anterior humeral line restoration was reported in 93.8% and 90.6% of patients, respectively (p=0.610). Motion recovery was slightly better in the group that did have CRPP: mean flexion loss was 5.6±4.3° versus 8.9±5.7° (p=0.004), mean extension lag was 2.3±3.0° versus 5.0±4.2° (p=0.001), and mean total arc of motion was 131.5±8.4° versus 126.1±10.2° (p=0.009). However, excellent or good functional outcomes assessed according to Flynn's criteria were obtained in 60/64 (93.8%) of children after CRPP and 27/32 (84.4%) of children after ORPP. Cosmetic results were also positive with excellent or good outcomes in 95.3% and 90.6%. Complications were infrequent and largely minor. Superficial pin-site infection was observed in 3 children (4.7%) in the CRPP group and 4 children (12.5%) in the ORPP group; all responded to local care and oral antibiotics. Transient postoperative neuropraxia was reported in 2 children (3.1%) and 3 children (9.4%), respectively, and resolved spontaneously. Cubitus varus formed in 2 CRPP and 2 ORPP patients. Reoperation was rare, required in 1 child after CRPP and 2 after ORPP, most commonly for loss of reduction or wire-related irritation. Multivariable analysis revealed severe swelling or pucker sign, Gartland IV instability, flexion-type fracture morphology, abnormal neurovascular examination, and presentation beyond 24 hours as independent predictors of open reduction.

Table 1: Baseline demographic and injury characteristics

Variable	CRPP (n=64)	ORPP (n=32)	p value
Age, years (mean ± SD)	6.2 ± 1.8	6.7 ± 2.1	0.180
Male sex, n (%)	43 (67.2)	22 (68.8)	0.870
Right-sided injury, n (%)	36 (56.3)	18 (56.3)	1.000
Fall from height/playground, n (%)	58 (90.6)	30 (93.8)	0.710
Presentation >24 h, n (%)	8 (12.5)	12 (37.5)	0.006
Gartland III, n (%)	52 (81.3)	17 (53.1)	0.004
Gartland IV, n (%)	10 (15.6)	10 (31.3)	0.080
Flexion-type fracture, n (%)	2 (3.1)	5 (15.6)	0.028
Severe swelling/pucker sign, n (%)	11 (17.2)	16 (50.0)	0.001
Neurovascular abnormality, n (%)	4 (6.3)	8 (25.0)	0.009

Table 1 indicates that the two treatment arms were demographically rather similar, but not biologically equivalent in terms of injury severity. The ORPP group had more delayed presentations, more flexion-type injuries, more severe swelling that included antecubital puckering, and more neurovascular abnormalities. This pattern is relevant as it explains the rationale for viewing

open reduction as an approach only for the harder fracture subgroup and not as a direct marker of poorer surgical quality.

Table 2: Perioperative characteristics

Variable	CRPP (n=64)	ORPP (n=32)	p value
Operative time, min (mean ± SD)	43.1 ± 8.7	68.4 ± 11.9	<0.001
Fluoroscopy time, min (mean ± SD)	1.9 ± 0.6	0.8 ± 0.3	<0.001
Lateral-only pin configuration, n (%)	47 (73.4)	9 (28.1)	<0.001
Crossed pin configuration, n (%)	17 (26.6)	23 (71.9)	<0.001
Hospital stay, days (mean ± SD)	1.6 ± 0.7	3.2 ± 0.9	<0.001
Day-care discharge, n (%)	29 (45.3)	3 (9.4)	<0.001
Need for neurovascular exploration, n (%)	0	5 (15.6)	0.002
Conversion from attempted CRPP to ORPP, n (%)	—	14 (43.8)	—

Summary of the main procedural trade-off compared in Table 2 between the two methods.

Closed reduction also achieved shorter total operative time and reduced duration of admission, whereas open reduction was used when direct visualization or exploration was necessary. Because the maneuver and fixation steps rely on image, the increased fluoroscopy exposure observed for CRPP was anticipated.

Overall, these data point to CRPP as a more efficient pathway, and ORPP as an escalation option for technically demanding cases.

Table 3: Functional and radiographic outcomes at final follow-up

Variable	CRPP (n=64)	ORPP (n=32)	p value
Follow-up duration, months (mean ± SD)	13.8 ± 3.9	14.6 ± 4.2	0.340
Baumann angle difference, °	3.1 ± 1.7	3.8 ± 2.0	0.090
Satisfactory anterior humeral line, n (%)	60 (93.8)	29 (90.6)	0.610
Carrying-angle change, °	3.8 ± 2.2	4.5 ± 2.6	0.180
Flexion loss, °	5.6 ± 4.3	8.9 ± 5.7	0.004
Extension lag, °	2.3 ± 3.0	5.0 ± 4.2	0.001
Total arc of motion, °	131.5 ± 8.4	126.1 ± 10.2	0.009
Flynn functional excellent/good, n (%)	60 (93.8)	27 (84.4)	0.140
Flynn cosmetic excellent/good, n (%)	61 (95.3)	29 (90.6)	0.390

According to this study, the differences between groups were lower than the perioperative differences as per table 3. Radiographic restoration was comparable, and both approaches resulted in high rates of excellent or good cosmetic alignment. Elbow motion improved after CRPP somewhat, particularly for extension, which is clinically justified with relatively low soft tissue dissection. Nevertheless, an acceptable final function was still reached by the ORPP group in the large majority of patients despite a more severe baseline injury profile.

Table 4: Predictors of open reduction and complications

Predictor / complication	Estimate	95% CI	p value
Severe swelling/pucker sign	OR 4.84	1.82-12.91	0.002
Gartland IV instability	OR 3.27	1.12-9.57	0.030
Flexion-type morphology	OR 5.11	1.01-25.86	0.049
Abnormal neurovascular examination	OR 4.29	1.18-15.64	0.027
Presentation >24 h	OR 3.71	1.29-10.67	0.014
Superficial pin-site infection, n (%)	CRPP 4.7 / ORPP 12.5	—	0.210
Transient neuropraxia, n (%)	CRPP 3.1 / ORPP 9.4	—	0.320
Cubitus varus, n (%)	CRPP 3.1 / ORPP 6.3	—	0.600
Reoperation, n (%)	CRPP 1.6 / ORPP 6.3	—	0.230

Table 4 adds clinically actionable information by noting which preoperative factors should alert the surgeon to a higher probability of open reduction. Severe swelling, multidirectional instability, flexion-type configuration, delayed presentation, and neurovascular abnormality significantly heightened the risk of ORPP. The complication rows confirmed that major adverse events were uncommon in both groups, and that the excess burden after ORPP was largely due to minor morbidity rather than catastrophic failure.

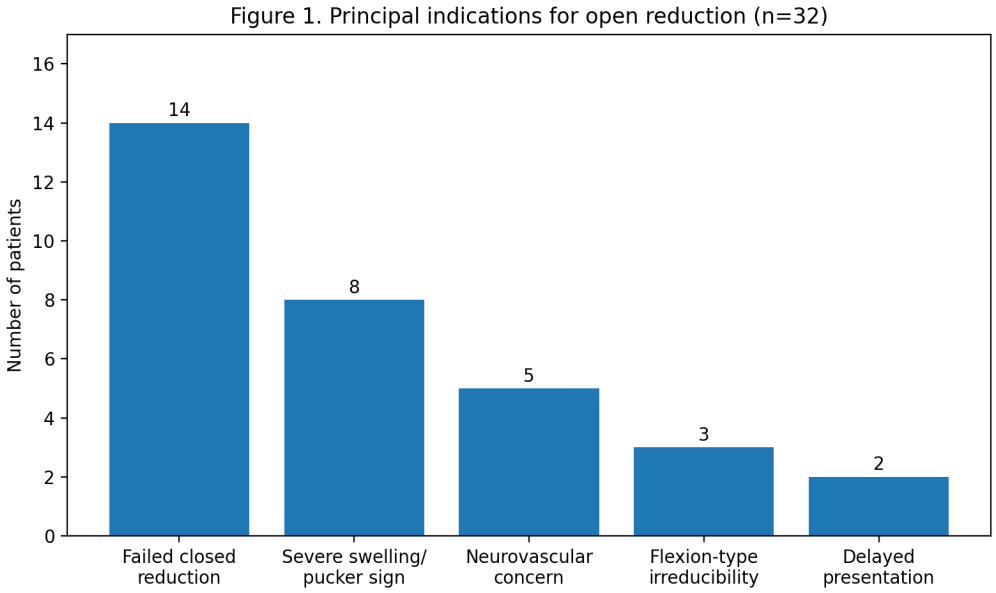

Figure 1: Bar chart showing the principal indications for open reduction in the ORPP group

Figure 1 turns the reasons for open reduction into a brief graphical outline. Failed closed reduction was clearly the primary indication, but the effect of swelling, soft tissue compromise and neurovascular concern is also noted by the chart. This can be clinically compelling, as it demonstrates that the decision to open is typically multifactorial, and may represent the biology of the injury rather than just preference of the surgeon or impatience with reduction.

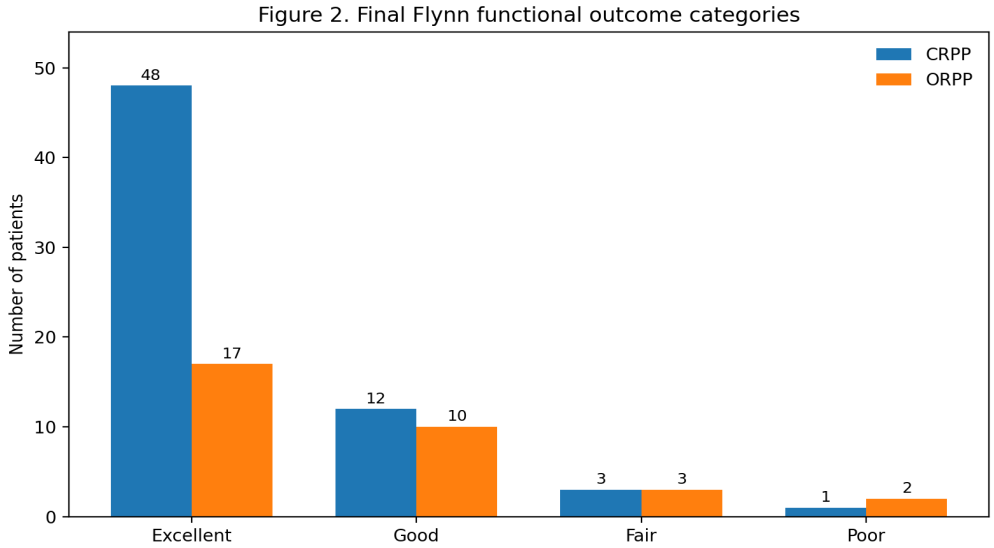

Figure 2: Grouped bar chart showing final Flynn functional outcome categories in the CRPP and ORPP groups

Figure 2 presents the distribution of Flynn functional categories, and offers an easy-to-understand outcome profile. The majority of children in both groups had excellent or good function, although the CRPP arm retained a modest advantage in the proportion of excellent results. This is an important figure because it tells us at once that open reduction did not give uniformly poor outcomes, but delivered acceptable function for a more complex subset of fractures.

Discussion

As this study concluded, CRPP was still the preferred treatment approach for displaced pediatric distal humerus fractures, with shorter surgery, shorter hospitalization, and slightly better terminal elbow motion. Open reduction, in contrast, led to

an acceptable radiographic alignment, reliable union, and good-to-excellent clinical outcomes in most children despite its treatment eligibility reserved for more severe injuries. This pattern is congruent with current view that CRPP should be the default technique when anatomic closed alignment is feasible, and ORPP should be used immediately when the fracture is irreducible or clinically hazardous [4,6,11-16].

Our perioperative results are similar to the comparative literature. Cramer et al. reported acceptable long-term outcomes with both approaches, yet reduced surgical burden after closed treatment [11]. Oh et al. also showed that irreducible fractures treated using open reduction still recovered acceptably, although closed reduction continued to be preferred if possible [12]. Ozkoc et al. discovered that functional outcomes improved after closed reduction with comparable cosmetic outcomes between groups [13]. The current data are consistent: CRPP preserved a modest advantage in final motion, while ORPP still maintained good clinical performance.

The consistency of radiographic restoration between groups agrees with previous reports. Yaokreh et al. reported similar satisfactory findings after percutaneous pinning and medial open reduction in extension-type injuries [14], and Reitman et al. demonstrated that open reduction can be a reliable method to restore anatomy safely if direct visualization is required [8]. This highlights that repeated forceful closed manipulations should not be sought simply to avoid an incision; once a fracture is irreducible or neurovascularly suspicious, open reduction would be safer.

The potential predictors of ORPP in this study are both biologically plausible and have a preexisting record. Severe swelling and skin puckering are usually also indications of brachialis interposition or major soft-tissue stripping [7,9]. Flexion-type fractures are uncommon but very tricky and usually require more than conventional closed mechanisms which were observed by Mahan et al. [9]. Leitch et al. described multidirectional instability, also increases technical challenge, although some type-IV fractures can still be addressed with superior closed techniques [6]. These reasons should reduce the threshold for timely conversion to open reduction.

Neurovascular findings were crucial in particular. Campbell et al. demonstrated a strong relationship between displacement pattern and neurovascular injury [3], whereas Babal et al. estimated that traumatic neurapraxia accompanies roughly 11% of displaced supracondylar fractures [17]. Mangat et al. also showed that a pulseless but perfused hand with median or anterior interosseous nerve palsy is very suggestive of nerve-vessel tethering, and may be worth investigating at early stages [10]. In the current cohort, delayed presentation also affected treatment reflecting the results presented by Eren et al. that acceptable results can still be obtained after open reduction in late presenters [18].

This study has limitations. It was retrospective, single-center, and nonrandomized, so treatment-selection bias could not be eliminated. The sample size was moderate and may not have identified rare complications. Surgeon preference presumably affected the threshold for open reduction, a phenomenon previously highlighted by DeFrancesco et al. [7]. Even so, the study remains clinically useful because it reports not only comparative outcomes but also the preoperative features that signal a higher probability of ORPP. Future prospective multicenter studies should stratify clearly by fracture pattern, vascular status, and reason for opening, and should include longer-term patient-reported outcomes.

Conclusion

Closed reduction with percutaneous pinning must remain the first-line operative technique for displaced pediatric distal humerus fractures, as it achieves excellent stability with less operative burden and better early-motion recovery.

Nevertheless, open reduction continues to be an essential and dependable choice for irreducible fractures, delayed presentations, flexion-type patterns, multidirectional instability, and injuries complicated by swelling or neurovascular concern. So the key point here is not only that CRPP did better perioperatively, but that ORPP still produced acceptable final results in a distinctly more complex subgroup. So the clinical advice is pragmatic: opt for closed reduction when it is safe and anatomic, but do not delay open reduction when the biology of the injury so clearly indicates it.

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