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Percutaneous Reduction and External Fixation for the Treatment of 2-part Surgical Neck Fractures of the Proximal Humerus

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Abstract

Background: Most proximal humerus fractures (4-5% of all systemic fractures) can be treated without surgery through early mobilization. However, the management of displaced fractures remains a subject of debate.
Objectives: To evaluate the outcomes of closed reduction and percutaneous pinning for two-part surgical neck fractures of the proximal humerus.
Methods: This was a retrospective analysis of 19 patients (8 men and 11 women with a mean age of 21.9 years) undergoing treatment in the Third Hospital of Hebei Medical University from January 2017 to December 2018 for surgical neck fractures of the proximal humerus. In 7 cases, the tails of Kirschner wires were linked with bone cement to prevent withdrawal after closed reduction and percutaneous pinning. The tails were attached to the unilateral external fixation in the other 12 patients to promote stability. A paired t-test was used to compare Constant scores.
Results: The mean Constant score after operation was 82.4 at 3 months, 93.4 at 6 months, and 93.7 at 1 year. The score improved significantly from 3 to 6 months in both the bone cement and external fixation groups ($P<0.05$). The rate of K-wire loosening was lower with external fixation versus bone cement (8.3% vs 57.1%, $P=0.038$).
Conclusion: The closed reduction and percutaneous pinning method showed good outcomes for two-part surgical neck fractures. External fixation provides better stability compared to cement fixation alone. This minimally invasive approach is an alternative to open reduction in selected patients.

Keywords: Bone fractures, Closed fracture reduction, Fracture fixation, Humeral fractures

1. Background

Proximal humerus fractures account for approximately 4-5% of all systemic fractures (1, 2). The majority of these fractures (49-85%) have low or no displacement and can be effectively treated non-operatively with early mobilization (3, 4). However, the treatment of displaced proximal humeral fractures (displaced beyond 45 degrees of angulation or by >1 cm of displacement) is highly contestable (5).

Non-operative treatment has historically been the standard of care for minimally displaced fractures. However, surgical treatment is often taken into account for displaced fractures to restore anatomy and allow early rehabilitation. Operative options include open reduction and internal fixation as well as hemiarthroplasty. While these techniques reliably restore anatomy, they are also associated with extensive dissection and disruption of the soft tissue envelope around the humerus, which can lead to complications (6, 7).

More recently, interest has grown in performing closed reduction and percutaneous fixation technique as it is less invasive while still achieving anatomic reduction and stable fixation (8). Multiple fixation methods have been described, including Kirschner wires, intramedullary nails, and locking plates (9, 10). Specifically, closed reduction and percutaneous pinning offer reliable fixation with minimal dissection (6, 11).

Neviaser described closed reduction and percutaneous fixation for the treatment of proximal humeral epiphyseal fractures in children (12). Several researchers have used this approach to treat adult proximal humeral fractures (13). This approach not only preserves the soft tissues and reduces wounds but also allows for early mobilization toward the restoration of the shoulder joint function as soon as feasible (14). Both open reduction and internal fixation procedures necessitate substantial incisions in the soft tissue, which pose a risk of compromising the blood supply to the bone fragment. Another therapeutic option is the implantation of locking intramuscular nails, which can be performed using a microsurgical method, although the rotator cuff can be compromised (15, 16).

2. Objectives

To the best of our knowledge, limited studies have been dedicated to evaluating the outcomes of closed

reduction and percutaneous pinning for two-part surgical neck fractures of the proximal humerus. The purpose of this study was to examine the radiographic outcomes, functional outcomes, and complication rates after the surgical treatment of these fractures with closed reduction and percutaneous pinning. We aimed to provide evidence to support closed reduction and percutaneous pinning as an effective treatment option for this subset of proximal humerus fractures that achieves stable fixation while avoiding more invasive procedures.

3. Methods

3.1. Study design and setting

The participants were selected through the convenience sampling method. This interventional retrospective study was conducted between January 2017 and December 2018 at the third hospital of Hebei Medical University on 19 patients who received closed reduction and percutaneous fixation for two-part surgery on proximal humerus neck fractures.

The eligible patients were those with displaced two-part surgical neck fractures with a follow-up of > 1 year, whereas the exclusion criteria were pathological fractures, osteoporosis, cardiopulmonary disorders, and cerebral disorders that impaired treatment and prognosis.

3.2. Surgical Methods

The patients were subjected to the operation while they were sitting on a beach chair, with the injured sidearm free to move. The anteroposterior and axillary views of the upper end of the humerus were easily acquired with the C-arm image intensifier situated cranially. The initial step was to implant 1 or 2 smooth Kirschner wires (2.0-mm) into the humeral head under fluoroscopy to regulate rotation. Secondly, the traction of the injured limb or Schanze was fastened at the fracture's distal end. The Kirschner wires inserted in the humeral head were utilized as a joystick to regulate rotation and aid in fracture reduction. If the conventional closed reduction strategy failed to achieve a sufficient reduction, the forceps were utilized to assist fracture reduction through a minor percutaneous incision to pry (Figure 1. B-C). Two or three 2.5-mm Kirschner wires were put into the humeral head from the fracture's distal lateral cortex (anterograde needles), after which two 2.5-mm Kirschner wires were reinserted (retrograde needles) to promote stability when an acceptable reduction was attained under fluoroscopy. We termed this step as “cross-fixed”. We mostly employed two procedures to anchor the Kirschner wires after fracture fixation. To avoid withdrawal, the tails of Kirschner needles were linked with bone cement in seven patients (Figure 2. D-H). Later, some enhancements were made to the same patients. In the remaining 12 patients, bone cement was used to link the Kirschner wire to the external fixator, which increased the stability of the fixation (Figure 1. E-G). Following fixation, fluoroscopy was employed to ensure that the Kirschner wires had not entered the joint, and shoulder mobility was assessed to ensure fixation stability. Following surgery, the afflicted upper limb was immobilized in a sling. Pendulum motion, passive motion, and active movement of the shoulder joint occurred shortly after the procedure.

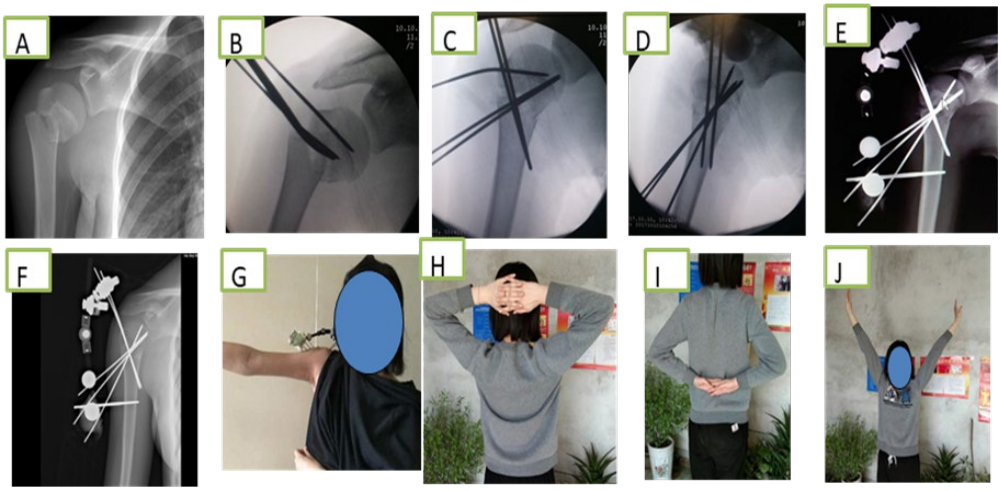

Figure 1. Follow-up of the patient with Kirschner wire combined with a unilateral external fixator

Figure 1 displays a fracture of the proximal humerus caused by a fall in a 14-year-old female (Figure 1. A). There was difficulty in reduction during the operation, the forceps were inserted into the fracture end through a small incision to pry to assist the reduction (Figure 1. B). The Kirschner wires were connected to the external fixator to increase the stability of the fixation (Figure 1. C-E). At a mean

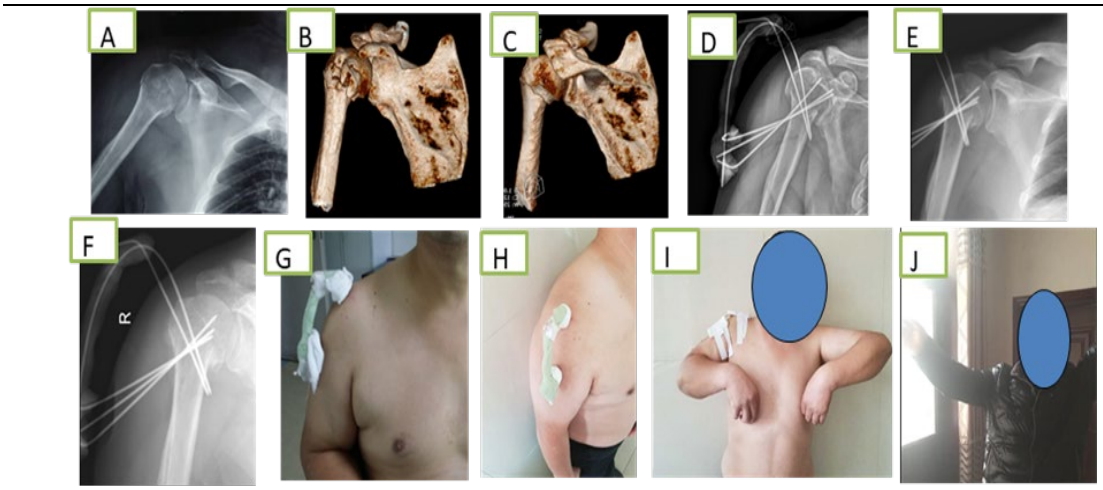

Figure 2. Follow-up of the patient with Kirschner wires linked with bone cement

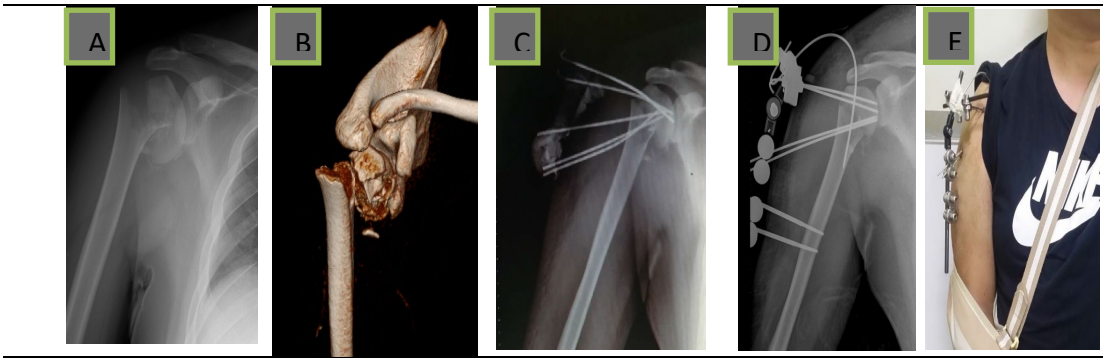

Figure 3. The Kirschner wire and bone cement replacement with an external fixator after their failure

follow-up of 8 weeks, when the signs of healing were observed on the radiographs, the K-wires were removed (Figure 1. F). The general appearance of the patient is illustrated in Figure 1. G. At the 15-month follow-up, the shoulder joint function was in good condition (Figure 1. H-J).

After the procedure, the X-ray of the shoulder joint was re-examined until the fracture was mended.

Figure 2 shows a fracture of the proximal end of the right humerus caused by a traffic accident in a 46-year-old male (Figure 2. A-C). After closed reduction and percutaneous pinning, the tails of Kirschner wires were connected with bone cement to prevent withdrawal, and the postoperative X-ray results demonstrated good reduction (Figure 2. D). During the follow-up (2 weeks after the operation), it was found that the Kirschner wire withdrew a little along the humeral head direction; however, the reduction was not lost, and no special treatment was given (Figure 2. E). The external fixator was removed after 9 weeks postoperatively when the patient visited the outpatient clinic for follow-up (Figure 2. F-H). The abduction function of the affected shoulder was weaker than that of the healthy side when the external fixator was removed (Figure 2. I), At 14 months follow-up, the functions of both shoulder joints were the same (Figure 2. J).

Figure 3 illustrates a fracture of the proximal humerus due to a fall in a 23-year-old male (Figure 3. A, B). The Kirschner wires were fixed with bone cement; nonetheless, the reduction was lost during the final stability test of the shoulder joint (Figure 3. C). After reduction, Kirschner wires were combined with a unilateral external fixator to fix it (Figure 3. D), and the curative effect was satisfactory (Figure 3. E).

The quality of fracture reduction was assessed using Neer classification (17). Reduction satisfaction was defined as a displacement of < 5.0 mm and an angle of < 20°. Constant-Murley scores (CMSs) were used to evaluate the shoulder joint function.

The CMS is a questionnaire employed to assess disabilities associated with shoulder injuries (18) and is the most widely used scale for the evaluation of various shoulder disorders (19). It consists of four components: pain (with a maximum score of 15 points), activities of daily living (with a maximum score of 20 points), range of motion (with a maximum score of 40 points), and strength (with a maximum score of 25 points). A higher total score corresponds to better functional quality, ranging from a minimum of 0 to a maximum of 100 (20).

3.3. Statistical analysis

Statistical analyses were conducted using SPSS, version 23.0 (SPSS, Inc., Chicago, IL, USA). The K-wire loosening rate, pin infection rate, and other count

data were expressed as percentages (%) and were analyzed by the Chi-square test. Constant scores at 3 months, 6 months, and 1 year were analyzed by paired samples t-test. A p-value of < 0.05 was considered statistically significant.

3.4. Ethical considerations

This study was approved by the Institutional Review Board at the Third Hospital of Hebei Medical University. Written informed consent was obtained from all participants. Patient data was anonymized and de-identified prior to analysis. This study was conducted in accordance with the Declaration of Helsinki.

4. Results

There was a total of 19 individuals with proximal humeral fractures, comprising 8 men and 11 women. These included 6 cases on the left side and 13 cases on the right side, with a mean age of 21.9 years (range: 14-46 years). The mean number of days between injury and surgery was 3.9 (range: 3-9 days). A fall was the mechanism cause of injury in 16 cases, with one instance of shoulder dislocation. There were 3 cases of traffic collision injuries, one of which was exacerbated by a brachial plexus injury. According to the Neer classification system of proximal humeral fractures, all of the patients had two-part surgical neck fractures with > 1 cm separation or 45° angulation. In 19 patients, we employed different fixation patterns and constantly optimized the fixing procedure following closure reduction and percutaneous pinning. In 7 patients, we applied bone cement to mend their needle ends, while we used Kirschner wire coupled with a unilateral external fixator in 12 patients. The general data of the cases are tabulated in Table 1.

Table 1. Clinical details and functional results

Age (years)/gender	Side	Mode of injury	Interval to intervention	Method of fixation	Reduction quality	Follow-up	Radiological union	Constant score (3 m/6 m/1 y)	Complication
20/F	R	Fall	6	Kirschner/Bone cement	Satisfactory	24	9	84/94/94	K-wire loosening
18/M	R	Fall	4	Kirschner/Bone cement	Satisfactory	18	8	82/94/94	Pin infection
24/F	L	Fall	3	Kirschner/Bone cement	Satisfactory	22	8	80/92/92	K-wire loosening/Pin infection
16/F	R	Fall	4	Kirschner/Bone cement	Satisfactory	14	9	82/96/96	None
22/F	R	Fall	3	Kirschner/Bone cement	Satisfactory	15	7	84/92/92	Pin infection
46/M	R	Traffic accident	9	Kirschner/Bone cement	Satisfactory	16	9	82/94/94	K-wire loosening/Brachial plexus injury
18/F	L	Traffic accident	3	Kirschner/Bone cement	Satisfactory	15	8	84/94/96	K-wire loosening/Pin infection
21/M	R	Fall	3	Kirschner/External fixator	Satisfactory	16	7	80/92/92	None
16/M	R	Fall	3	Kirschner/External fixator	Satisfactory	12	8	86/94/94	Pin infection
18/F	L	Fall	3	Kirschner/External fixator	Satisfactory	14	7	84/96/96	None
23/M	R	Traffic accident	4	Kirschner/External fixator	Satisfactory	12	8	82/92/92	Pin infection
18/F	R	Fall	4	Kirschner/External fixator	Satisfactory	14	8	80/94/94	None
19/M	L	Fall	3	Kirschner/External fixator	Satisfactory	12	7	82/92/92	None
14/F	R	Fall	4	Kirschner/External fixator	Satisfactory	15	8	82/94/94	None
28/F	L	Fall	3	Kirschner/External fixator	Satisfactory	12	9	80/90/92	Pin infection
24/F	R	Fall	4	Kirschner/External fixator	Satisfactory	12	8	82/92/94	None
23/M	R	Fall	6	Kirschner/External fixator	Satisfactory	17	7	84/96/96	Displacement/Re-fixation
24/M	L	Fall	3	Kirschner/External fixator	Satisfactory	14	8	82/92/92	Pin infection
24/F	R	Fall	3	Kirschner/External fixator	Satisfactory	16	7	84/94/94	None

Every patient was followed for a mean of 15.3 months (range: 12-24 months). According to Neer reduction criteria, all fractures were adequately reduced, and no displacement was noted throughout the follow-up period. All of the patients' fractures healed subsequently. The mean duration for recovery was 7.9 weeks (range: 7-9 weeks). The mean Constant score of the shoulder joint function after the operation was 82.4 (range: 80-86) at 3 months, 93.4 (range: 90-96) at 6 months, and 93.7 (range: 92-96) at 1 year. The Constant scores of patients were significantly different between 3 months and 6 months (P=0.000); nevertheless, there was no significant difference between 6 months and 12 months (P=0.083) (Table 2). These findings revealed that the shoulder joint function improved fast and with a favorable prognosis. In four of the seven patients who were fastened with bone cement, Kirschner wire withdrawal occurred, although the quality of the reduction was unaffected. Only one patient with external fixator fixation experienced Kirschner wire removal, which necessitated no surgical correction The rate of K-wire loosening in group B, was significantly lower than that in group A (P=0.038) (Table 3). Eight patients (4 in each group) developed infections (redness, warmth, inflammation, fever, and chills); however, they all recovered following a local dressing change and removal of the pin tract. During the follow-up period, no radiological evidence of avascular necrosis of the humeral head or glenohumeral osteoarthritis was recorded in any of the patients.

Table 2. Comparison of shoulder function scores by closed reduction and percutaneous pinning

Functional comparison	t-statistic	P-value
Between 3m and 6 m	-28.4	0.000
Between 6 m and 1y	-1.837	0.083

Table 3. Comparison of postoperative complications between the two groups

Group	K-wire loosening	Pin infection
Group A (n=7)	4 (57.1%)	4 (57.1%)
Group B (n=12)	1 (8.3%)	4 (33.3%)
P	0.038	0.377

Group A = Kirschner wire paired with bone cement fixing
Group B = Kirschner wire paired with an external fixator

5. Discussion

Proximal humeral fractures can be treated conservatively or surgically. Conservative treatment has favorable long-term outcomes but requires strict patient compliance as extended immobilization can lead to various issues, including joint stiffness, malunions, and deformity (21, 22). The surgical intervention aims for anatomic reduction and stable fixation to relieve discomfort and promote early mobilization. However, open reduction surgery is more stressful and carries risks of wound infection and humeral head ischemic necrosis (23).

In a study conducted by Clavert et al., open reduction and internal fixation were performed on 73 patients. They reported various complications after open reduction, including malunion, nonunion, avascular necrosis, and revisions, with a mean Constant score of 62.3. The absence of firm fixation for the humeral head via intramedullary nail fixation can easily lead to humeral head collapse and malunion, while also causing rotator cuff damage and poor recovery of the shoulder joint function. This contrasts with the good shoulder performance observed in the present study, which is due to the use of different methods (24).

Nolan et al. treated 18 patients with intramedullary nails, 9 of which were caused by humeral head collapse with varus or greater tubercle displacement, resulting in malunion with evident acromion impact. Only 4 patients achieved outstanding shoulder function scores due to the discomfort and stiffness of the shoulder joint caused by the loss of the rotator cuff during the procedure (25).

Neviaser was one of the first to describe the percutaneous reduction technique for treating proximal humeral fractures in children using an anterograde parallel needle threading approach. Krappinger later expanded on this by adding a pin inserted into the anterior cortex (7). This approach has been extensively employed in the treatment of proximal humeral fractures in adults and is the current gold standard for percutaneous pin reduction. Vicenti et al. discovered a “Safe Zone” for pin insertion during autopsy. The proximal lateral pin should be inserted at or near a spot twice the distance between the superior aspect of the humeral head and the inferior-most edge of the humeral head. At 20 mm from the most inferior side of the humeral head, the larger tuberosity pins should engage the cortex of the humeral neck (26). Nonetheless, several researchers continue to depict it as a contentious, difficult-to-learn methodology (27-29).

Early closed reduction approaches may result in instability and reduction loss. Rodia et al. successfully treated 51 patients using a surgical approach, without requiring revision therapy; however, 5 complications were identified. They suggested that combining Kirschner wires with other external fixation methods could minimize reduction loss in osteoporotic patients (30). Seyhan et al. treated 36 patients using a retrograde percutaneous method, emphasizing the effectiveness of the "joystick approach" for reduction. They achieved a mean follow-up Constant score of 93.4 and found that 3- and 4-part fractures and displacement of the larger tuberosity were rare in closed reduction and percutaneous procedures. Closed reduction and percutaneous fixation are based on good reduction and fixation maintenance to achieve a favorable prognosis. These results

confirm the findings of the present study and are in line with the present study (29).

We pioneered closed reduction and cross-fixation using Kirschner needles with attached tails. This technique improves fixation stability and avoids needle location mismatch with external fixators. The first 7 patients treated at our facility were fastened with bone cement following closed reduction and percutaneous fixation to avoid nail pullout. However, when the stability of one of these patients was evaluated during the procedure, the fracture was discovered to be displaced again. We could however improve our therapeutic choices after re-fixation. The reduction was well-maintained since the cross Kirschner wires were coupled with a monolateral external fixator (Figure 3. A-E).

Kristianse et al. suggested a closed reduction of proximal humeral fracture paired with an external fixator (31). Following Carlos Martin's improvements, the most generally used external fixators in the world now include the Hoffmann external fixator, the AO external fixator, and the Ilizarov external fixation system. The downside is that the process is complicated and the equipment is costly. Moreover, the termination location of the wire should be perfectly aligned with the external fixator. Using our technology, the Kirschner wires may be punctured at will and finally repaired with bone cement; this would not only efficiently maintain the reduction but also drastically reduce the nail pullout rate. A follow-up study demonstrated that the fixation effect was consistent. The adequacy of fracture reduction and subsequent stable fixation is the most essential challenge during closed reduction and cross percutaneous fixation. We believe that the "joystick" approach and the prying method of hemostatic forceps are quite beneficial in fracture reduction. The presence of osteoporosis, severe fracture comminution, or humeral head dislocation complicates the task of minimizing the two-part fracture. When closed reduction fails, open reduction must be employed. Although we achieved success with this procedure in patients with concomitant shoulder dislocation, the process is quite challenging, and it is suggested to revise the surgical strategy after unsuccessful efforts. During our follow-up, we discovered that the mean fracture healing time was 7.8 weeks (7-9 weeks), demonstrating an optimal duration for both fracture healing and shoulder function rehabilitation.

Closed reduction with cross percutaneous fixation, as described in this article, provides the advantages of reduced stress, a faster healing period, and a faster functional return. When used in conjunction with a monolateral external fixator, the Kirschner wire pullout rate could be reduced. It can be utilized as an alternative to surgical neck fractures of the proximal humerus in 2 halves.

6. Conclusion

Closed reduction and cross percutaneous fixation in the treatment of surgical neck fractures of the humerus has a significant therapeutic impact, with reduced surgical trauma. According to the results of this study, it can eliminate the need for a second surgery to remove the internal fixation. External fixators used in tandem can improve stability and decrease withdrawal rates. However, we still advocate the conventional treatment approaches, such as open reduction plate fixation or intramedullary nail fixation, for older patients with osteoporosis or 3-4 partial fractures, when the reduction is difficult with the presently proposed approach.

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Footnotes

Conflicts of Interest: None to declare.
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Ethical considerations: This study was approved by the Institutional Review Board and the Ethical Committee of the hospital.

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