

Original Article

Supraclavicular nerves protection during open reduction and internal fixation

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Received July 15, 2016; Accepted November 29, 2016; Epub May 15, 2017; Published May 30, 2017

Abstract: Our study was to verify whether the approach of protecting supraclavicular nerve could effectively reduce the discomfort caused by iatrogenic injury to the supraclavicular nerve. A total of 37 patients with unilateral midclavicular fractures were enrolled and randomly assigned into the experimental group (patients received meticulous dissection by specially preservation of supraclavicular nerves with diameter > 0.5 mm during open reduction and internal fixation (ORIF)) and control group (patients received conventional ORIF). One year follow-up was performed after operation. Clinical outcomes including intraoperative and postoperative parameters were compared between groups. For the intraoperative parameters, no significant difference was found between groups in operative time ($P = 0.074$). However, the blood loss ($P = 0.004$) was significantly decreased and incision length ($P = 0.008$) was significantly longer in experimental group compared with control group. For postoperative parameters, the time of bone healing was similar between groups ($P = 0.856$). However, the degree and range of skin numbness were significantly decreased by specially preservation of supraclavicular nerves during ORIF compared with conventional ORIF at two weeks and one year after operation ($P < 0.05$). In addition, although no statistical significance ($P = 0.090$), the results also indicated a trend that experimental group had fewer patients with complications related to the supraclavicular nerve injury than control group, including hyperesthesia, Tinel's sign, tenderness, afraid of cold or feel discomfort beneath the incision. The results of this study supported the application of preservation of supraclavicular nerves during ORIF in treatment of midclavicular fractures.

Keywords: Preservation of supraclavicular nerves, midclavicular fractures, skin numbness, open reduction and internal fixation, randomized control trial

Introduction

Clavicular fractures are common injuries, accounting for over 5% of all fractures [1]. Among them, fractures most commonly occur within the middle third of the clavicle, which comprise approximately 80% of all clavicle fractures and exhibit some degree of displacement [2, 3]. Currently, surgery is becoming more and more popular in treatment of clavicle fractures due to the lower rate of nonunion compared with non-operative management [4-6].

The supraclavicular nerve is a sensory nerve with branches in the proximal region of the clavicle and provides sensitivity for the clavicle, anteromedial region of the shoulder and proximal region of the thorax [7, 8]. This anatomy makes them vulnerable to injury in cases of

clavicle fractures or during surgical treatment of such fractures [9-13]. Numbness is the main symptoms of supraclavicular nerve injury after surgery [14, 15]. Although skin numbness is often ignored due to little influence on patients, the long term numbness may imply the permanent damage of nerves and then influence the function of ipsilateral limbs [16]. Meanwhile, supraclavicular nerve injury can also cause severe tenderness, hypersensitivity, and even dysfunction of shoulder [6, 7], which would increase the suffering of the patients and decrease the quality of life. As the popularity of the surgery for treatment of clavicular fractures, surgery caused supraclavicular nerve injury should be considered. Although the surgeons have been suggested to perform surgery with meticulous dissection to prevent transection of nerves [13], there is still no study spe-

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cially investigating the effectiveness of meticulous dissection in avoiding supraclavicular nerve injury during surgical treatment for clavicle fracture.

Open reduction and internal fixation (ORIF) is the standard surgical treatment for displaced clavicle fractures [17, 18]. Meanwhile, plate fixation is recommended due to providing immediate rigid fixation and helping to facilitate early mobilization [15, 19]. Thus, we performed this prospective study to investigate the efficacy of meticulous dissection in a modified ORIF by specially preventing transection of supraclavicular nerves (diameter > 0.5 mm) on relieving postoperative numbness and reducing incidence of complications related to the supraclavicular nerve injury.

Materials and methods

Patients

Between January 2012 and May 2014, 37 patients with unilateral midclavicular fractures, who required ORIF, were enrolled in this study. These patients all met the following inclusive criteria: (1) aged over 15 years old; (2) displaced midclavicular clavicular fracture with no cortical bone contact or shortening of over 15 mm, or the fracture fragments were tenting or compromising the skin with an axial malalignment of over 30°. In addition, the patients were excluded when (1) they suffered fractures over 4 weeks; (2) fractures were open or pathological; (3) they had history of trauma in the ipsilateral arms; (4) they simultaneously had other injuries in ipsilateral arms; (5) there was skin hypoesthesia on location of fractures or ipsilateral arms before surgery. This study was approved by institutional review board (IRB) of Shanghai Jiao Tong University and written informed consent was obtained from each participant.

Study design

These patients were randomly allocated in two treatment teams. The modified ORIF (supraclavicular nerves were specially persevered during surgery) was performed in our treatment team and conventional ORIF was used in the other treatment team. Finally, 19 patients were treated by modified ORIF in our treatment team and assigned into experimental group; 18 patients were treated by conventional ORIF in the other

treatment team and assigned into control group. All the surgeries in experimental group were carried out by a same surgeon. The surgeries in the control group were performed by surgeons who were trained uniformly.

Operative procedure

The modified surgery in experimental group was performed based on the following procedures. After general anesthesia, interscalene block or cervical plexus anesthesia, patients were positioned in a beach-chair semi-sitting position. A longitudinal incision was made in line with the long axis of the clavicle over the fracture site and along the superior border of the bone. The subcutaneous tissue and neck muscles were dissected through the incision. The supraclavicular nerves (diameter > 0.5 mm) were carefully identified and persevered during operation (**Figure 1A**). The location of fracture was explored by dissecting periosteum parallel to clavicle, removing sternocleidomastoid muscle (clavicular head), trapezius muscle, pectoralis major muscle and deltoid muscle through supraclavicular edge. After opening the fracture site, the vessels and nerves below the clavicle were explored. When there were injuries or compression in vessels and nerves, suture repair or relief of compression should be performed. After reduction of fractures, steel plate was bended based on the shape of clavicle and placed on the superior surface of the clavicle. Then, a minimum of three screws were placed proximal and distal to fragments (**Figure 1B**). The vessels, nerves and cupula of pleura were protected by a periosteal elevator during fixation. In oblique or complex fractures, lag screws or number-1 absorbable sutures were used to achieve compression. Artificial bone graft was used in patients with comminuted fractures.

For the control group, the conventional ORIF was performed without specially perseveration of supraclavicular nerves with diameter over 0.5 mm during surgery.

Postoperative care and follow-up

All patients were given arm slings for 2 weeks after ORIF. Meanwhile, anodyne was administered conventionally. Drugs promoting the regeneration of nerves were not used during the whole procedure of treatment. Early mobiliza-

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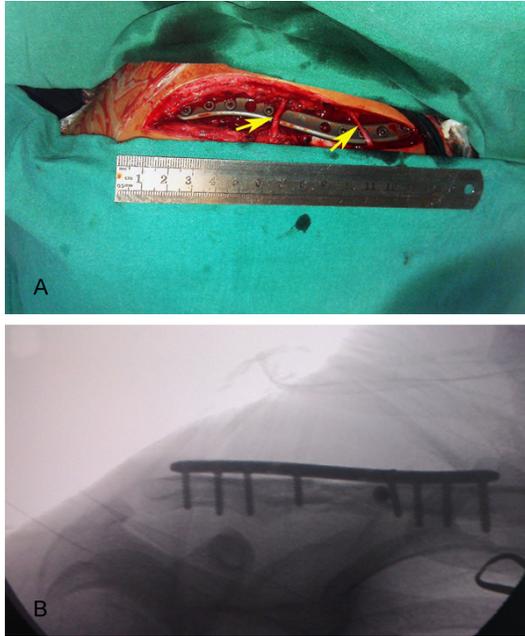


Figure 1. Images during operation. A: The supraclavicular nerve branches were preserved during operation in the experimental group; the position of arrow was supraclavicular nerves. B: Representative computed tomographic image of fixation device.

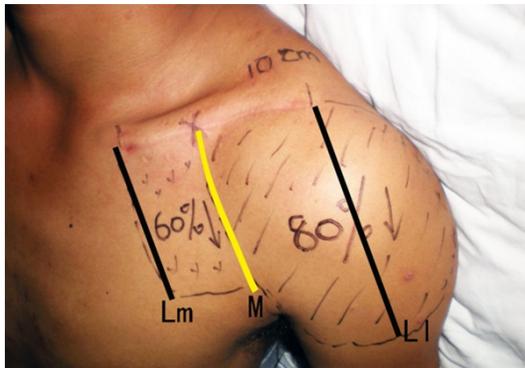


Figure 2. The detection area of numbness and definition of lateral and medial parts. The yellow line of M was the projection of the cephalic vein. The diagonal lines “/” represented the area of lateral part and the crosses “x” represented the area of medial part. In addition, 80% and 60% respectively represented the degree of numbness in lateral and medial parts. The lengths of “L1” and “Lm” respectively represented the range of numbness in lateral and medial parts.

tion and active range of motion exercises were encouraged. In addition, a one-year follow up was performed after operation. The time of bone healing and the complications related to the supraclavicular nerve injury were recorded during follow up.

Evaluation of skin numbness

The wooden end of cotton stick was drew backwards and forwards on the skin near the scar in each patient. Then the patient was asked “if you feel numb”? and “what is the percentage of hypoesthesia or degree of numbness compared with the contralateral skin”? The degree of numbness was divided into three levels: mild (the sense is clear and slightly different from that in contralateral skin, percentage of hypoesthesia: 0%-35%), moderate (the sense is still clear and obviously different from that in contralateral skin, percentage of hypoesthesia: 36%-65%), and severe (the sense is unclear and obviously different from that in contralateral skin, percentage of hypoesthesia: 66%-100%). The level of degree of numbness and percentage of hypoesthesia were all reported by patients themselves based on the above criteria.

In addition, the detection area of skin numbness was divided into two parts (lateral and medial parts) based on the projection of cephalic vein (**Figure 2**). The degree of numbness was detected in both parts. Meanwhile, range of numbness was also measured based on the lengths of “L1” and “Lm” in **Figure 2**.

Statistical analysis

Sample size calculation was performed based on the preliminary experiments. A sample size of 18 patients in each group was calculated to obtain about a 40% reduced range of numbness in lateral parts in experimental group compared with control group, when assuming a type 1 error of 0.05 and power of 80%.

Statistical analyses were performed using SPSS software (version 20.0; IBM, Corp). The normal distribution of continuous variables was tested by the Kolmogorov-Smirnov’s test. When data met the normal distribution, mean \pm SD was used to describe data and the independent sample t test was used for comparison between groups, otherwise median (range) was shown and Mann-Whitney U test was used for comparison between groups. For the classification variables, data were shown as frequency (percentage) and Fisher’s exact test or likelihood ratio test was used to determine the difference between experimental and control groups. All tests were two-sided. A P-value of

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Table 1. Clinical characteristics of participants

Characteristics	Experimental group (n = 19)	Control group (n = 18)	F/t/U	P-value
Age (year)	48.0 ± 17.9	46.8 ± 19.7	0.180	0.858
Gender				
Male	13 (68.4%)	14 (77.8%)	0.714	0.714
Female	6 (31.6%)	4 (22.2%)		
Side of fracture				
Left	10 (52.6%)	12 (66.7%)	0.508	0.508
Right	9 (47.4%)	6 (33.3%)		
Cause of injury				
Traffic accident	7 (36.8%)	9 (50.0%)	0.652	0.515
Fall down	12 (63.2%)	9 (50.0%)		
Time from injury to surgery (day)	4.5 ± 3.7	5.5 ± 3.6	0.819	0.418
Type of fracture				
2A2	3 (15.8%)	4 (22.2%)	0.300	0.764
2B1	6 (31.6%)	5 (27.8%)		
2B2	10 (52.6%)	9 (50.0%)		

For continuous variables, when data met the normal distribution, mean ± SD was used to describe data and the independent sample t test was used for comparison between groups, otherwise median (range) was shown and Mann-Whitney U test was used for comparison between groups. For the classification variables, data were shown as frequency (percentage) and Fisher's exact test or likelihood ratio test was used to determine the difference between experimental and control groups.

less than 0.05 was considered to be statistically significant.

Results

Characteristics of participants

The characteristics of the patients in both groups are shown in **Table 1** and the enrollment of patients was presented in **Figure 3**. The average age in the experimental group was 48.0 ± 17.9 years (range, 16 to 75 years) and in the control group was 46.8 ± 19.7 years (range, 15 to 85 years). According to the Robinson classification system, there were 3 patients with angulated fractures (2A2), 6 patients with simple or wedge fractures (2B1) and 10 patients with multi-fragmentary fractures (2B2) in the experimental group; there were 4 patients with angulated fractures (2A2), 5 patients with simple or wedge fractures (2B1) and 9 patients with multi-fragmentary fractures (2B2) in the control group. The midclavicular fractures in 7 patients (36.8%) of experimental group and 9 patients (50%) of control group were caused by traffic accident. The midclavicular fractures in the rest patients were all caused by full down (experimental group: 63.2%; control group: 50%). No statistical difference was found between groups in age (P = 0.858), gender (P = 0.714), side of fracture (P = 0.508), cause of injury

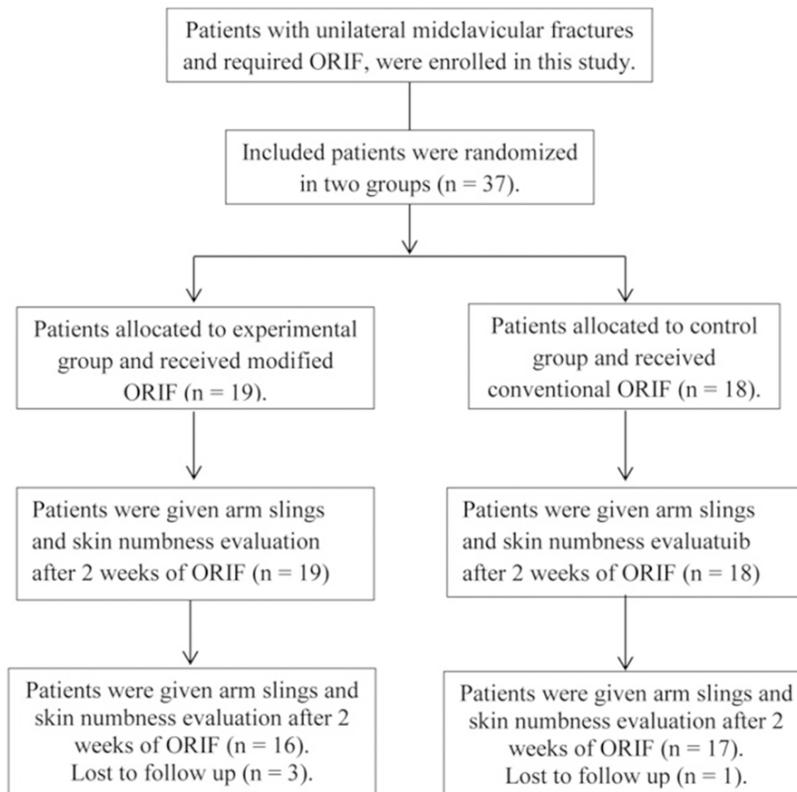


Figure 3. The flow chart for patients recruitment and follow up.

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Table 2. Comparison between the experimental and control groups in intraoperative and postoperative parameters

Parameters	Experimental group (n = 19)	Control group (n = 18)	F/U/t	P-value
Operative time (min)	66 (45-110)	62 (45-80)	3.383	0.074
Blood loss (ml)	20 (20-50)	30 (20-50)	84.500	0.002
Incision length (cm)	12.0 (7.5-16)	10.1 (7.5-14.6)	2.758	0.008
Time of bone healing (week)	16.4 (8-24)	16.0 (8-24)	165.500	0.856
Complications related to the supraclavicular nerve	1 (5.3%)	5 (27.8%)	2.776	0.090

For continuous variables, when data met the normal distribution, mean \pm SD was used to describe data and the independent sample t test was used for comparison between groups, otherwise median (range) was shown and Mann-Whitney U test was used for comparison between groups. For the classification variables, data were shown as frequency (percentage) and Fisher's exact test or likelihood ratio test was used to determine the difference between experimental and control group.

($P = 0.515$), time from injury to operation ($P = 0.418$) and type of fracture ($P = 0.764$).

Clinical outcomes

As shown in **Table 2**, the median operative time was 66 min (range, 45 to 110 min) in the experimental group and 62 min (range, 45 to 80 min) in the control group, showing no statistical differences ($P = 0.074$). However, significant differences between groups were found in other intraoperative parameters (including blood loss and incision length). Results showed significantly less blood loss ($P = 0.004$) and longer incision ($P = 0.008$) in experimental group compared with control group.

At one year follow up, three patients in the experimental group and one patient in the control group were lost to follow-up. For the postoperative parameters, patients in experimental and control groups had similar time of bone healing ($P = 0.856$). Although no statistical significance ($P = 0.090$), the results indicated a trend that there were more patients suffering complications related to the supraclavicular nerve injury in control group (one case of hyperesthesia, two cases of Tinel's sign, one case of afraid of cold beneath the incision, and one case of feel discomfort beneath the incision) compared with experimental group (one case of tenderness on the incision). The reoperation was performed to suture nerve stumps within nerve conduits for the patient with tenderness on the incision. Finally, the tenderness was relieved. In addition, no infection happened during one year follow up (**Table 2**).

The results of numbness were shown in **Tables 3** and **4**. As shown in **Table 3**, at two weeks after operation, there were 10 patients (55.6%)

with severe numbness of lateral part in control group, but only 2 patients (10.5%) with severe numbness of lateral part in experimental group ($P = 0.001$). Similarly, 61.1% of patients ($n = 11$) suffered severe numbness in medial part in control group at two weeks after operation, which was significantly higher than that in experimental group ($n = 1$, 5.3%; $P < 0.001$, compared with control group). After one year follow up, the degree of numbness was partly or completely relieved in some patients, which causing the disappearance of statistically significant difference in degree of numbness in medial part between experimental and control groups ($P = 0.899$). However, there were still 58.8% of patients suffering moderate or severe numbness in lateral part in control group, which was significantly higher than that in experimental group ($n = 3$, 18.8%; $P = 0.043$, compared with control group).

As shown in **Table 4**, the range of numbness in the experimental group was significantly smaller than that in the control group in both lateral ($P < 0.001$) and medial part ($P = 0.002$) at two weeks after operation. After one year follow up, the range of numbness was decreased in some patients, which reduced the average values of range of numbness in each group. However, the range of numbness in each part of experiment group was still significantly smaller than that in the control group (lateral part: $P = 0.004$; medial part: $P < 0.001$).

In addition, we found 2.0 (range, 1 to 4) supraclavicular nerves in each patient during operation. Average diameter of the supraclavicular nerves was 1.5 mm (range, 0.5 to 2.5 mm). However, anatomic distribution of the supraclavicular nerve branches was difficult to determine precisely.

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Table 3. Degree of numbness in lateral and medial parts within two weeks and at one year after operation

Groups		Lateral part				Medial part			
		Experimental Group	Control Group	U	P-value	Experimental Group	Control Group	U	P-value
Degree of numbness at two weeks after operation	Mild	15 (78.9%)	4 (22.2%)	68.000	0.001	16 (84.2%)	3 (16.7%)	46.500	< 0.001
	Moderate	2 (10.5%)	4 (22.2%)			2 (10.5%)	4 (22.2%)		
	Severe	2 (10.5%)	10 (55.6%)			1 (5.3%)	11 (61.1%)		
Degree of numbness at one year after operation	Mild	13 (81.3%)	7 (41.2%)	87.000	0.043	14 (87.5%)	15 (88.2%)	134.000	0.899
	Moderate	1 (6.3%)	7 (41.2%)			1 (6.3%)	2 (11.8%)		
	Severe	2 (12.5%)	3 (17.6%)			1 (6.3%)	0 (0.0%)		

P-value < 0.05 represented significant difference between degree of numbness in experimental and control groups.

Table 4. Range of numbness in lateral and medial parts within two weeks and at one year after operation

Groups	Lateral part				Medial part			
	Experimental Group	Control Group	t	P-value	Experimental Group	Control Group	t	P-value
Range of numbness at two weeks after operation (cm)	4.6 ± 3.0	10.4 ± 3.6	5.313	< 0.001	3.1 ± 2.1	6.0 ± 3.1	3.386	0.002
Range of numbness at one year after operation (cm)	3.2 ± 2.3	6.0 ± 2.8	3.168	0.004	1.4 ± 1.5	4.4 ± 2.6	4.044	< 0.001

P-value < 0.05 represented significant difference between range of numbness in experimental and control groups.

Discussion

In this study, we found that preservation of supraclavicular nerves (diameter > 0.5 mm) during ORIF significantly decreased the degree and range of numbness at two weeks after operation. Although no significant difference in degree of numbness in medial part between groups at one year after operation, the experimental group still had significantly fewer patients with severe degree of numbness in lateral part and smaller range of numbness in each part. In addition, there was a trend indicating the modified ORIF could reduce the incidence of complications related to supraclavicular nerve injury during one year follow up.

The supraclavicular nerve originates from the C3 and C4 nerve roots of the superficial cervical plexus and then is divided into many branches. A previous study found that 97% of samples had medial and lateral branches of supraclavicular nerve and 49% of samples had intermediate branch of supraclavicular nerve in 37 corpses [12]. The intermediate and lateral branches often arise as a common trunk behind the posterior border of the sternocleidomastoid muscle, and then are respectively redivided into 3.4 (1 to 6) and 7 (4 to 12) sub-branches in lateral or middle of clavicle [20]. The branches of supraclavicular nerves are so close to the clavicle that they are easy to be injured during surgical treatment of clavicle fractures. Thus, the meticulous dissection was recommended to prevent supraclavicular nerve injuries [13]. The results of this study supported the application of meticulous dissection by specially preserving supraclavicular nerves with diameter over 0.5 mm.

Although the nerves with diameter over 0.5 mm were preserved in the present study, the nerves with diameter \leq 0.5 mm were too thin to identify and preserve. Thus, the severe numbness in two patients at two weeks after operation in experimental group might be caused by the injury of these thin nerves during operation. Meanwhile, one case of tenderness on the incision in experimental group suggested that meticulous dissection was still not enough to avoid iatrogenic injury. For avoiding these injuries, the exploration of precise anatomical location of these nerves may be helpful to find a more appropriate surgical technique. A previous study reported that the intermediate branch of supraclavicular nerve was nearly per-

pendicular to the long axis of the clavicle [21]. Meanwhile, Wang et al reported that an incision perpendicular to the long axis of the clavicle significantly reduced post-operative numbness compared with an incision parallel to the long axis of the clavicle [11], which may be caused by less injury of intermediate branch of supraclavicular nerve after applying an incision perpendicular to the long axis of the clavicle during surgery. Thus, precise anatomical location should be explored in further studies.

In addition, we also found that although the longer incision, blood loss was significantly less in experimental group compared with control group. Meticulous dissection can not only identify and protect the nerves but also avoid the injury of vessels, which may be the main reason leading to the reduction of blood loss. Besides, although meticulous dissection was performed in the experimental group, the operative time was not significantly prolonged, which may attribute to the skillful operation of the surgeon. Meanwhile, the small sample size may also be the reason leading to no statistical significance in operative time.

Some limitations of the present study should be noted. Due to no standard method currently, we evaluate the degree and range of skin numbness using the method developed by our team. However, the method to evaluate the degree of skin numbness was subjective and to measure the range of numbness was not precise. In addition, only one year follow up was performed. The limited sample size may be the culprit of no statistically significant difference in operative time and incidence of complications related with supraclavicular nerve between groups. Thus, the larger studies with long term follow up should be performed to further verify the advantages of preservation of supraclavicular nerves during ORIF.

In conclusion, the preservation of supraclavicular nerves (diameter > 0.5 mm) during ORIF had effect on relieving the skin numbness in patients with unilateral midclavicular fractures.

Acknowledgements

This work was supported by the Project of Shanghai Municipal Commission of Health and Family Planning [No. 20124360]; Minhang District Leading talent development funds; The hospital advantage discipline construction proj-

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ect of Fudan University [2013FDYSXK03]; Key medical specialty construction plan of the Fifth People's Hospital of Shanghai [2013WYZDK-01].

Disclosure of conflict of interest

None.

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