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Influential factors of subacromial impingement syndrome after hook plate fixation for acromioclavicular joint dislocation
A retrospective study

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Abstract

Subacromial impingement syndrome (SIS) after hook plate fixation for acromioclavicular joint (AC) dislocation was the most common complication. However, the researches on its' influential factors were rare. The purpose of this study was to identify the risk factors by analyzing the influencing factors of postoperative SIS and minimize the incidence of SIS in clinical surgery.

We retrospectively analyzed the prospectively collected data from 330 consecutive patients with AC joint dislocation between August 2014 and August 2017 at our institute. The SIS was presented as the dependent variable at the last follow-up when the internal fixation was removed. The independent variables included age, gender, body-mass index (BMI), smoking status, alcohol consumption, type of injury, Rockwood Classification, site of injury, operation time, injury-to-surgery, the distance between the hook body and the acromion (DBA), the depth of hook tip (DHT), the distance between the hook plate and the humeral head (DHH), the distance between the acromion and the humeral head (DAH), the hook plate angle (AHP) and acromial shape. Logistic regression analysis was performed to identify independent influential factors of SIS.

A total of 312 cases were included and 18 cases were lost. The follow-up rate was 94.5%. In without SIS group, there were 225 cases (123 males and 102 females). In with SIS group, a total of 87 cases were included (56 males and 31 females). The incidence of SIS was 27.8%. DHT (OR = 9.385, 95% CI = 4.883 to 18.040, $P < .001$) and DBA (OR = 2.444, 95% CI = 1.591 to 3.755, $P < .001$) were the significant independent risk factor for SIS of AC dislocation treat with hook plate. DAH (OR = 0.597, 95% CI = 0.396 to 0.900, $P = .014$) and acromial shape with flat and straight (OR = 0.325, 95% CI = 0.135 to 0.785, $P = .012$) were also independent factors of SIS, but they were all protective.

The SIS had a high incidence in fixation of clavicular hook plate for AC dislocation. DHT and DBA were two independent risk factors, DAH and acromial shape with flat and straight were two independent protective factors for SIS. In clinical surgery, we should avoid risk factors to reduce the incidence of SIS.

Abbreviations: AC = acromioclavicular, AHI = acromio humeral interval, AHP = the hook plate angle, DAH = the distance between the acromion and the humeral head, DBA = the distance between the hook body and the acromion, DHH = the distance between the hook plate and the humeral head, DHT = the depth of hook tip, SIS = subacromial impingement syndrome.

Keywords: acromioclavicular joint dislocation, hook plate, influential factor, SIS

1. Introduction

The clavicular hook plate is the primary method to treat acromioclavicular (AC) joint dislocations.[1,2] However, many complications were gradually discovered during the long-term application process, such as postoperative subacromial impingement syndrome (SIS), loosening of internal fixation, acromion and clavicle stress fracture, and other complications.[3–7]

SIS was the most common complication proposed by Neer in 1972.[8] It is a clinical symptom caused by an impact from the subacromial tissue when the shoulder joint moved upward and abducted because of anatomical or dynamic reasons. For the causes of SIS, a large number of scholars have conducted research. Petersson and Redlund-Johnell[9] believed that a decrease in subacromial space might be one reason for the occurrence of SIS. Some scholars believed that the difference in shoulder anatomy was one of the important etiological factors of subacromial impingement syndrome.[10] Elmaraghy et al [11] analyzed the influence of the hook end under the acromion in the subacromial space by a cadaver simulated surgery. They believed that the presence of the hook end increased the risk of SIS. Overall, there are many studies on the causes of SIS, but they lack systematic and comprehensive analyses, large-scale clinical follow-ups, and verification. This was the purpose and starting point of this study. Through follow-up studies on many cases, we identified the risk factors by analyzing the factors influencing postoperative SIS and minimized the incidence of SIS in clinical surgery.

2. Methods

2.1. Design

We retrospectively analyzed prospectively collected data from 330 consecutive patients with AC joint dislocations between August 2014 and August 2017 at Shangyu People's Hospital. All patients were treated with hook plate fixation. The entire process was shown in Figure 1.

2.2. Participants

This retrospective study included 330 patients with AC joint dislocation. AC joint dislocation was classified using the method described by Rockwood et al[12] The inclusion criteria for the research were as follows:

1. acute, AC joint dislocation (grade III, IV, V, and VI) determined according to the classification described by Rockwood et al;
2. no more than 14 days of trauma;
3. signed informed consent;
4. no history of AC joint dislocation or other shoulder trauma; and
5. no previous surgery on the shoulder.

The exclusion criteria were as follows:

1. other types (grade I, II) of AC joint dislocation; and
2. no signed informed consent.

2.3. Intervention

Anesthesia was performed with brachial plexus anesthesia or general anesthesia. At the AC joint, we took an arcuate incision to expose the AC joint, removed the congested and fragmented articular cartilage, selected the appropriate clavicular hook plate, inserted the AC hook plate along the posterior edge of the AC joint, and fixed it with screws. With C-arms and moving the shoulder joint, we ensured that the AC joint was well-replaced and the internal fixation was good. After the shoulder joint was well-passive, the incision was closed layer by layer. The bandage
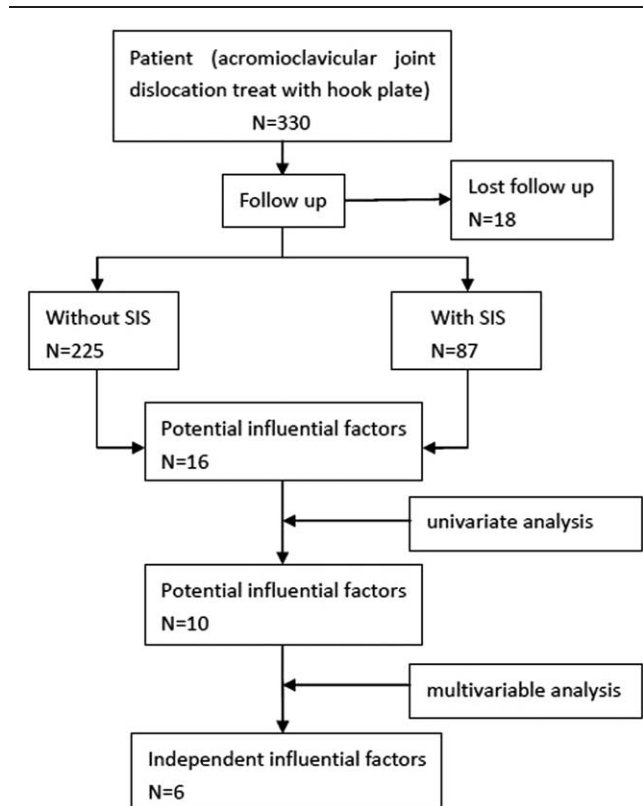

Figure 1. Research flow chart.

was suspended for two weeks, passive exercise was performed within two weeks, active exercise was started two weeks later, and load was introduced three months later.

2.4. Comparison

The patients were divided into two groups based on whether SIS appeared after surgery: patients with SIS and patients without SIS. We analyzed the influential factors of subacromial impingement syndrome by comparing the two groups.

2.5. Main outcome measure
2.5.1. Dependent variable. The diagnosis of SIS at the last follow-up when the internal fixation was removed was the dependent variable. The SIS diagnosis used the diagnostic criteria proposed by Nikolaus et al[13]:

1. tenderness on the outer edge of the acromion;
2. when the upper limb abducted, the pain arc sign was positive;
3. compared with passive activities, the shoulder joint had obvious pain during active activities;
4. the Neer sign was positive; and
5. acromion osteophyte, partial rotator cuff tear or full-thickness tear.

Patients with SIS are confirmed if they met three or more of the above five criteria.

2.6. Independent variables
2.6.1. Patient characteristics. The patient characteristics included are the age at the time of surgery, body-mass index

(BMI), sex, smoking status and alcohol consumption. Age was divided into three categories: less than or equal to 30 y old, more than 30 y old and less than 60 y old, and more than or equal to 60 y old. According to the smoking status, the patients were categorized into two groups: current smokers and current non-smokers. The current non-smokers included the past smokers or those who never smoked.[14] To define the alcohol consumption, the standard we set was alcohol >15 drinks/week. A standard drink is 12 oz of 5% alcohol beer, 8 oz of 7% malt liquor, 5 oz of 12% alcohol wine, or 1.5 oz of 40% alcohol liquor.[15]

2.7. Injury mechanism

The types of injuries were divided into four major categories:

1. car accident;
2. falling;
3. fell and hurt; and
4. other.

According to the Rockwood Classification,[12] all cases were divided into four categories:

1. Rockwood III;
2. Rockwood IV;
3. Rockwood V; and
4. Rockwood VI.

The site of injury was distinguished by the right and left shoulders.

2.8. Surgical factors

The first surgical feature was the operation time, specifically from the beginning of the skin incision to the final suture of the skin. The second was the time from injury to surgery, which was calculated in days.

2.9. Hook plate factors

Regarding the hook plate factors, this research included a total of four items:

1. the distance between the hook body and the acromion (DBA; Fig. 2);
2. the hook plate angle (AHP), which is the angle with the hook plate body and hook tip[16] (Fig. 3);
3. the depth of hook tip (DHT), which was the closest distance from the hook tip to the acromial articular surface (Fig. 4); and
4. the distance between the hook plate and the humeral head (DHH; Fig. 5).

2.10. Anatomical factors

For anatomical factors, the first one was the shape of the acromion. According to the classification method proposed by Bigliani[17] in 1986, the shapes of the acromion were divided into three types. For type I, the acromion was flat and straight. With type II, the acromion was curved. In type III, the acromion was hooked. The second one was the distance between the acromion and the humeral head (DHA; Fig. 5).

2.11. Ethics

The research protocol was approved by the Institutional Review Board for the authors' institute (SYRY170825). Written
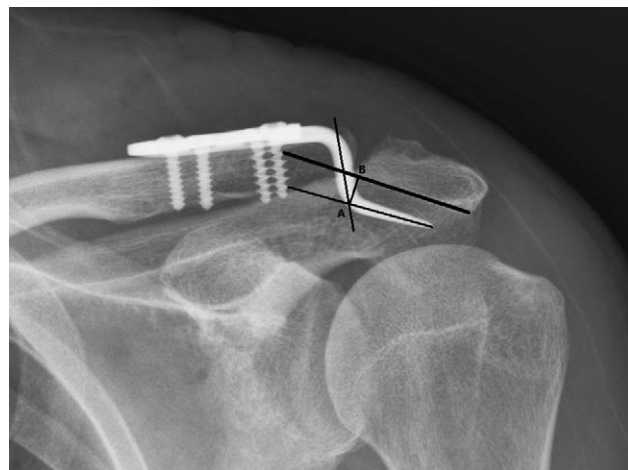

Figure 2. The schematic diagram of DBA. According to the hook tip and the hook body, make two separate midlines crossed at point A, and then make a parallel line along the lower edge of the acromion. Make a vertical line through point A to cross the parallel line at point B. The distance between A and B is DBA.

informed consent was obtained from all of the participants, and the research methods were carried out following approved guidelines.

2.12. Statistical analysis

Means and standard deviations (SDs) were used to describe distributions for continuous variables, and proportions summarize categorical variables. One-way analysis of variance (ANOVA) tests was used to compare the means of continuous and ordinal variables. For categorical variables, the Pearson chi-squared test was used. Binary logistic regression analysis was performed to account for confounding significant variables. A $P < .05$ was considered significant. Odds ratios and 95% confidence intervals were calculated for each of the risk factors included in the logistic regression models. Analyses were performed using SPSS version 21 (IBM).
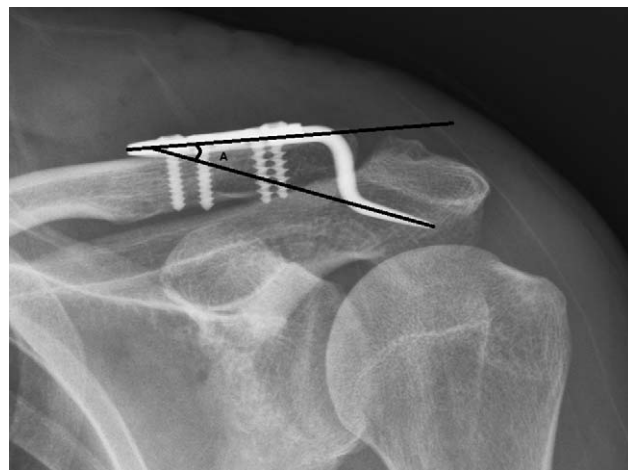

Figure 3. The diagrammatic sketch of AHP. According to the plate body and hook, make a parallel line separately, then two lines crossed and formed an angle called A, it is the angle of Hook and plate (AHP).
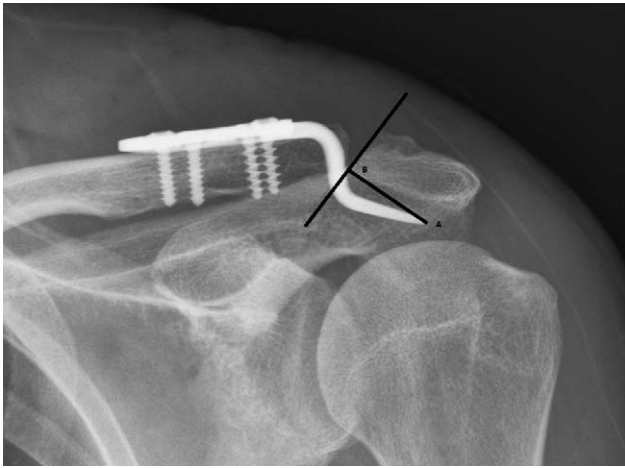
Figure 4. The depth of hook tip. Take the tip of the hook as point A, then make a straight line through point A perpendicular to the parallel line and intersect at point B. The distance between A and B is DHT.

3. Results

3.1. Patient characteristics

A total of 312 cases were included in the follow-up, and 18 cases were lost. The overall follow-up rate was 94.5%. In group without SIS, there were 225 cases in total, including 123 males and 102 females. The median age was 47 years (range: 21–69). In with SIS group, 87 cases were evaluated, including 56 males and 31 females. The median age was 49 years (range: 23–67). The overall incidence of SIS was 27.8% (Figs. 6A & B).

3.2. Influential factors

According to relevant literature reports [9–11,16] and the clinical experience of the research team, we included 16 potential, influential factors in our study: age, gender, body-mass index (BMI), smoking status, alcohol consumption, type of injury, Rockwood Classification, site of injury, operation time, the time
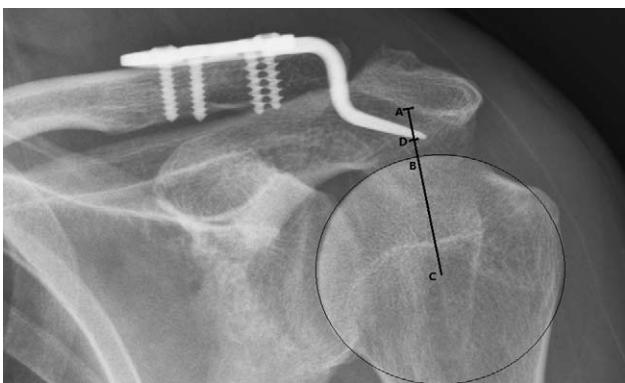

Figure 5. The abridged general view of DHH and DAH. Take the center point of the humeral head as point C and the midpoint of the lower edge of the acromion as point A. The distance between point A and point C is DAH. Make the line between point A and point C, and intersect the lower edge of the hook tip at point D. The distance between point C and point D is DHH.

of injury-to-surgery, DBA, DHT, DHH, AHP, acromial shape, and DAH (Table 1).

The operation time of the two groups was 45.671 ± 8.882 min and 43.126 ± 9.546 min, and this was significantly different ($P = .027$). The time of injury-to-surgery was 4.822 ± 1.909 days and 4.908 ± 1.859 days ($P = .720$). In group without SIS, the DBA was 2.002 ± 0.876 cm, DHT was 3.184 ± 0.562 cm, DHH was 8.204 ± 0.936 cm, DAH was 10.545 ± 1.241 cm, and AHP was 18.284 ± 11.113 degrees. All were significantly different from the SIS group ($P < .05$). According to the acromial shape, 109 cases were flat and straight, 58 cases were curved, and 58 cases were hooked in the without SIS group. The values were significantly different from the SIS group ($P < .01$).

There were 44, 152, and 29 cases in each age level of the group without SIS, and there were 14, 54, and 19 cases in group with SIS. There was no significant difference between the two groups ($P = .138$). Regarding gender, the result was similar ($P = .120$). The BMI, was 23.968 ± 3.913 and 24.528 ± 3.388 in the two groups, which was also not statistically different ($P = .241$). Fighty-eight cases had some smoking history in the group without SIS, and 23 in the SIS group ($P = .249$). Eighty-eight cases reported alcohol consumption in the without SIS group compared to 36 patients in the SIS group ($P = .714$). In the without SIS group, 55 patients had a car accident injury, 45 patients had a falling injury, 113 patients were in the fell and hurt category, and 12 patients reported other injuries. Compared with the SIS group, differences in injuries were not statistically significant ($P = .953$). Regarding the Rockwood Classification, 190 cases were assigned as Rockwood III, 9 cases as Rockwood IV, and 26 as Rockwood V in the without SIS group. Compared with the SIS group, these classifications were not significantly different ($P = .176$). The statistical result of the site of injury was also similar ($P = .583$).

All variables that yielded $P \leq .1$ in the univariate analysis were evaluated in multivariable analysis. Factors with $P > .1$ were not deemed clinically important enough in this context to warrant further investigation. Finally, a total of ten variables were included in the regression analysis: operation time, DBA, DHT, DHH, DAH, AHP, and acromial shape. According to our statistical results, the independent influential factors that affect subacromial impingement syndrome after surgery were DBA (OR = 2.444, 95% CI = 1.591 to 3.755, $P < .001$), DHT (OR = 9.385, 95% CI = 4.883 to 18.040, $P < .001$), DAH (OR = 0.597, 95% CI = 0.396 to 0.900, $P = .014$), and a flat and straight acromial shape (OR = 0.325, 95% CI = 0.135 to 0.785, $P = .012$). DHT and DBA were the obvious independent risk factors for SIS. DAH and a flat and straight acromial shape were independent protective factors for SIS of acromioclavicular joint dislocation treated with a hook plate (Table 2).

4. Discussion

According to many documents and our own clinical experience, we included 16 potential, influential factors, including some of the most basic characteristics of the case, injury factors, morphological characteristics of the shoulder, and matching data of hook plate. Finally, we obtained four independent, influential factors by regression analysis. Among these four factors, DHT and DBA were the significant risk factors. DAH and a flat and straight acromial shape were the two independent protective factors for SIS.
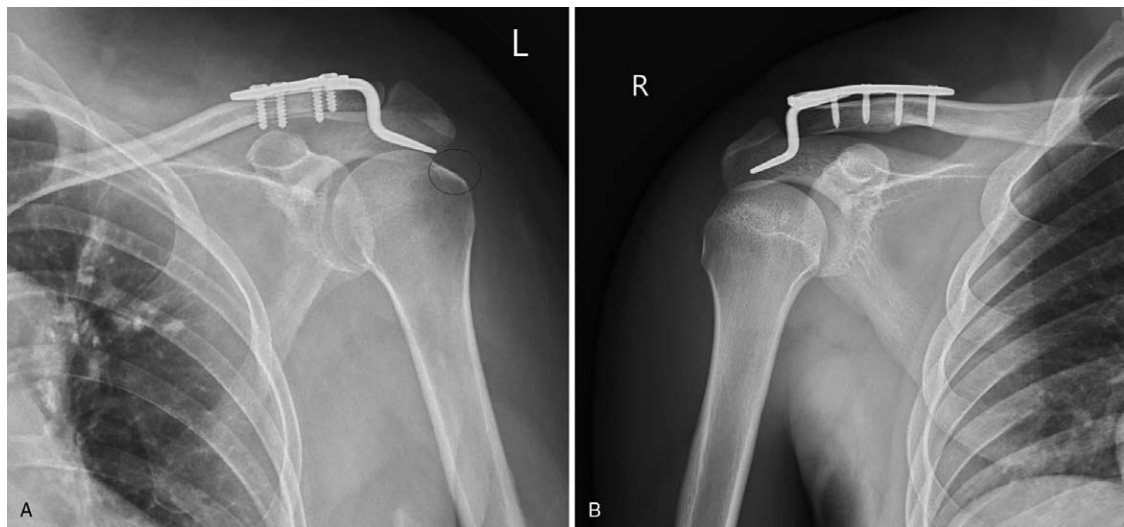
Figure 6. (A). The picture shows the X-ray of SIS group after hook plate fixation. Compared with the without SIS group, the DHT(hook depth) is larger and the DAH is smaller. The shape of the acromion is curved. The black circle shows the cortical sclerosis, which is considered to be caused by the subacromial impingement. (B). The picture shows the X-ray of without SIS group after hook plate fixation.

Table 1

Potential influential factors.

Potential Risk Factors

	Means or Percentage without SIS	Statistics with SIS	P value	
Patient characteristics				
Gender (male/female) (n)	123/102	56/31	$X^2=2.414$	.120
Age (years) (n)				
≤ 30	44	14		
>30 & <60	152	54		
≥60	29	19	$X^2=3.958$	.138
BMI (kg/m^2)	23.968±3.913	24.528±3.388	F=1.380	.241
Smoking history (yes/no)	57/105	23/64	$X^2=1.385$	.249
Alcohol (yes/no)	88/137	36/51	$X^2=0.135$	.714
Injury mechanism				
Type of injury(n)				
Car accident injury	55	22		
Falling injury	45	17		
Fell and hurt	113	42		
Other injuries	12	6	$X^2=0.338$	.953
Rockwood Classification(n)				
Rockwood III	190	68		
Rockwood IV	9	8		
Rockwood V	26	11		
Rockwood VI	0	0	$X^2=3.470$	.176
Site of injury (right/left), n	132/93	54/33	$X^2=0.302$	.583
Surgical factors				
Operation time (min)	45.671±8.882	43.126±9.546	F=4.937	.027
Injury-to-surgery (days)	4.822±1.909	4.908±1.859	F=.129	.720
Hook plate factors				
DBA (cm)	2.002±0.876	2.410±0.807	F=14.177	<.001
DHT(cm)	3.184±0.562	3.967±0.563	F=121.587	<.001
AHP (degree)	18.284±11.113	13.942±4.754	F=7.904	.005
DHH(cm)	8.204±0.936	7.418±0.941	F=44.022	<.001
Anatomical factors				
Acromial shape				
Flat and straight	109	21		
Curved	58	35		
Hooked	58	31	$X^2=15.428$	<.001
DAH(cm)	10.545±1.241	9.546±0.982	F=45.328	<.001

Values are shown as mean ± standard deviation, number (%). P values were calculated using the one-way ANOVA test for means, Pearson's chi-square test for proportions. AHP = the hook plate angle, BMI = body mass index, DAH = the distance between the acromion and the humeral head, DBA = the distance between the hook body and the acromion, DHH = the distance between the hook plate and the humeral head, DHT = the depth of hook tip.

Table 2

Logistic regression analysis.

Variable	OR	95% CI	P value
Operation time	0.972	0.935, 1.011	.159
DBA	2.444	1.591, 3.755	<.001*
AHP	0.980	0.953, 1.008	.156
DHT	9.385	4.883, 18.040	<.001*
DHH	0.686	0.409, 1.152	.154
DAH	0.597	0.396, 0.900	.014*
Acromial shape			
Flat and straight	0.325	0.135, 0.785	.012*
Curve	1.555	0.687, 3.518	.289

* Represents a statistical difference.

Reviewing the existing literature reports, there was very little research regarding risk factors analysis of SIS after hook plate fixation for AC joint dislocation. Lin et al [18] prospectively followed 40 patients who had surgery using the clavicular hook plate. They confirmed that the clavicle hook plate caused SIS and rotator cuff injury by musculoskeletal ultrasound examination. The data also showed that there was an association between subacromial impact caused by steel plates and poor functional scores. The autopsy research by Elmaraghy et al [11] also confirmed that the position of the hook portion of the implant can predispose anatomic structures to the post-operative complications of subacromial impingement and bony erosion. Gu et al [19] performed arthroscopy on 12 patients with pain who had undergone clavicular hook plate fixation. They found that the impingement of the hook to the rotator cuff may be the main cause for the pain of shoulder. Therefore, we must pay enough attention to SIS in the clinical application of clavicle hook plate. At the same time, investigation on the influential factors of SIS are also necessary particularly. Unfortunately, there is no systematic research on the influential factors of SIS. Many scholars had focused on the causes of SIS. The most consistent opinion was that its occurrence was often associated with the shape of the acromion and matching of the clavicle hook plate.[9,10,11] Elmaraghy et al [11] placed the clavicular hook plate on fresh cadaveric specimens to study the position of the hook end of the plate under the acromion. They found that the radian of the hook was located above the head of the humerus. The radian was the part of the clavicle hook from straight to flat. The longer and deeper the hook end would increase the probability of hitting greater tubercles of the humerus when the shoulder joint was abducted. This was in line with our research. Our study found that DHT and DBA were the significant risk factors of SIS and they are the two indicators to measure the length and depth of the hook end. In a recent Cadaveric Study, Vajapey et al [20] also found that the hook plate hit the rotator cuff when the shoulder was abducted / flexed extremely. However, it did not cause bony impingement. This showed that the subacromial space was enough to accommodate the hook body without obvious acromion impingement in an anatomically normal shoulder. The SIS appeared after the clavicle hook plate was implanted, which may be due to abnormalities in the subacromial space. The measurement and evaluation of the subacromial space of the patient was commonly referred to as acromion humeral interval (AHI). Flatow et al suggested that the normal AHI should be greater than 1 cm.[21] If it was less than 1 cm, it was considered a stenosis and the greater tubercles of the

humerus would hit the acromion.[22] Some scholars believed that when AHI > 10.6 mm, the use of clavicular hook plate fixation generally did not cause SIS. If AHI was lower than this value, these would have been recommended to replace it with other fixed methods. This was in line with our research results. Our study showed that DAH had an independent impact on the occurrence of SIS. DAH was the distance from the center of the humeral head to the midpoint of the lower edge of the acromion. It also measured the subacromial space. When the DAH value increased, the probability of SIS occurrence was less. Regarding the morphology of the acromion, our study considered that a flat and straight acromial shape was an independent protective factor. Bigliani et al[17] divided the acromion into three types. Type I was normal acromial anatomy. Types II and III were considered important etiological factors of SIS,[10] especially type III. Akram et al[23] observed 101 patients with shoulder pain and found that majority 57 (56.4%) of the patients had acromion type II (curved), which was the most common cause of shoulder impingement. Gu et al[19] also think that the appropriate hook and plate that fit to the curve of the clavicle as well as the acromion are necessary to decrease the severity of pain. Deng et al [24] studied 24 shoulder joints which were implanted with clavicle hook plates and confirmed that the hook plate matches the acromion and tried to choose a flat and straight acromial shape for AC joint dislocation treatment.

For the first time, our study identified risk factors of subacromial impingement syndrome after hook plate fixation for AC joint dislocation and provided a reference for clinical practice. However, it also had some limitations. A large amount of imaging data was used in this study. Subtle differences in the angle of the X-ray projection would have an effect on the acromial imaging and related measurement results.[25] As our study was a retrospective study, it was affected by certain biases, like selection and recall biases.

Our study initially found that DHT and DBA were significant risk factors. DAH and a flat and straight acromial shape were two independent protective factors for SIS. For a more precise evaluation of influential factors of subacromial impingement syndrome after hook plate fixation for AC joint dislocation, it would be necessary to design a prospective observational study with more patients in future.

5. Conclusions

The SIS had a relatively high incidence in fixation of clavicular hook plate for AC joint dislocation. DHT and DBA were the two independent risk factors. DAH and a flat and straight acromial shape were the two independent protective factors for SIS. In clinical surgery, we should avoid risk factors to reduce the incidence of SIS.

Author contributions

Conceptualization: ding xu, Yulong Shi.
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Resources: Yulong Shi.
Software: Peng Luo, Weigang Lou.
Supervision: Jianming Chen.
Validation: Peng Luo, Weikang Wang.
Writing – original draft: ding xu.
Writing – review & editing: ding xu.

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