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Original Article

New insight into the classification of middle clavicle fracture with ipsilateral distal clavicle injury

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Abstract: Recently, many studies have focused on the occurrence of middle clavicle fractures with ipsilateral distal clavicle injury (MCFIDCI). This evidence shows that such a compound injury is common in clinical practice. However, existing classification of clavicular fractures does not account for the accompanying injury. In this retrospective study, we analyzed the data of middle clavicle fracture cases in our hospital from January 2021 to December 2023 and classified them as MCFIDCI according to clinical and imaging characteristics. Additionally, the characteristics of the included cases were analyzed. In total, 354 patients with middle clavicle fractures were included in this study. 23 cases (6.5%) met the inclusion and exclusion criteria for MCFIDCI (16 men and 7 women, mean age, 37.3 ± 11.6 years). These cases included 19 acromioclavicular joint dislocations, 3 distal clavicular avulsion fractures with acromioclavicular joint dislocation, and 1 distal clavicular head fracture. Notably, 10 patients were misdiagnosed before surgery, whereas 5 were diagnosed with delayed dislocation. According to our classification method, 11 cases were type Ia, 2 cases were type Ib, 2 cases were type IIa, 3 cases were type IIb, 5 cases were type IIIa, and 1 case was type IIIb. In conclusion, because of the injury mechanism and unique anatomical features, MCFIDCI is often misdiagnosed. In our study, detailed description and category of this injury were included, which could improve our understanding of this injury and reduce the rate of misdiagnoses.

Keywords: Middle clavicle fracture, distal clavicle fracture, acromioclavicular dislocation, coracoid fracture, classification

Introduction

In shoulder injuries, middle clavicular fractures and distal acromioclavicular injuries are common, but these two injuries rarely occur simultaneously in the ipsilateral limb. The first case of middle clavicular fracture with acromioclavicular joint dislocation was reported by Lancourt [1] in 1990. Since then, this composite injury has been regarded as rare and sporadic reports are available. Regretfully, only 30 such cases have been reported in 26 studies. Recently, researchers have focused on MCFIDCI, with Ottomeyer reporting that 6.8% (26/383) of middle clavicular fractures were accompanied by acromioclavicular joint dislocations of varying degrees [2]. Furthermore, our previous findings indicate that this type of compound injury is more common in clinical practice. The rarity of MCFIDCI may be due to frequent missed diagnoses [3]. A considerable number of patients were not found to have a dislocation of the acromioclavicular joint until days or even months after surgery [4]. Notably, the existing classification of clavicular fractures only includes simple middle clavicular fractures without accompanying injury. Therefore, in this study, we aimed to establish a classification method for composite injuries based on imaging features and injury characteristics. We then analyzed the characteristics of patients with MCFIDCI.

Patients and methods

Study Design

This was a retrospective, anonymous analysis of clinical and epidemiological data. All participants were informed of the purpose and con-

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tent of this study, which was approved by the Ethic Committee of Shuguang Hospital affiliated to Shanghai University of TCM (Approval number: 2021-1446-029-01).

Patients

We analyzed the data of 354 patients (195 men and 159 women, aged 18-71 years, with an average age of 34.1 ± 12.3 years) who underwent surgical treatment for middle clavicular fractures at Shuguang Hospital, affiliated with Shanghai University of Traditional Chinese Medicine, between January 2021 and December 2023. The inclusion criteria were patients who underwent open reduction and internal fixation for middle clavicular fractures. The exclusion criteria were patients with postoperative follow-up imaging records less than 6 months, or the operative side of the was fracture or re-injured.

Main observation index of MCFIDCI injury

Acromioclavicular joint dislocation: Diagnostic criteria was based on the Rockwood [5] classification of acromioclavicular joint dislocation. Type I: Normal. Type II: Acromioclavicular joint space is widened, and the clavicle is slightly subluxated superiorly. Type III: The distal end of the clavicle is displaced, and the coracoclavicular interval is increased by 25%-100%. Type IV: The acromioclavicular joint space may be normal or slightly widened in the anteroposterior position, and the displaced clavicle end is posteriorly displaced. Type V: The coracoclavicular interval is increased by 100%-300%. Type VI: The distal end of the clavicle is displaced under the coracoid process.

The diagnostic methods included radiography diagnosis for type II, III, V, and VI dislocations (diagnosis of type II dislocation must be compared with the healthy side) and computed tomography (CT) diagnosis for type IV dislocation.

Distal clavicle fracture acromioclavicular joint dislocation: The diagnostic method involved radiography or CT that showed bone cortex discontinuity of the distal clavicle.

Coracoid fracture distal clavicle fracture acromioclavicular joint dislocation: The diagnostic methods included two-dimensional CT images showing discontinuity of the coracoid process and three-dimensional CT showing separation and misalignment of the coracoid [6].

Establishment of the classification methods of MCFIDCI

MCFIDCI was classified into types I, II, and III based on the degree of acromioclavicular joint dislocation, integrity of the coracoclavicular ligament, and associated injuries (distal clavicular fracture or coracoid process fracture). Further details of the classification methods are provided in **Table 1** and **Figure 1**.

Statistics

IBM SPSS Statistics for Windows, version 21.0 (IBM Corp., Armonk, NY, USA) was used for statistical analysis, with measurement data expressed as $x \pm s$. The chi-square test was used to compare the two sample rates, with $P < 0.05$ considered statistically significant.

Results

Case inclusion and characteristics

A total of 354 patints with middle clavicular fractures were diagnosed and operated between January 2021 and December 2023; 23 (6.5%) cases were MCFIDCI (16 men and 7 women, aged 21-67 years, with a mean age of 37.3 ± 11.6 years old). Among them were 19 cases of acromioclavicular joint dislocation, 3 cases of avulsion fracture of the distal clavicle with acromioclavicular joint dislocation, and 1 case of distal clavicular fracture. Characteristics of the 23 patients with MCFIDCI are listed in **Table 2**.

Follow-up information and missed diagnosis

The follow-up time for the 23 patients with MCFIDCI ranged 24-38 months, with an average of 32.7 months. In 10 cases, distal clavicle injury was missed during diagnosis; in 2 of these cases, acromioclavicular joint dislocation was identified during the surgery, prompting a change in the treatment plan (a double-button steel plate was used in one case to reconstruct the coracoclavicular ligament, and a steel wire was used in the other case to encircle the infracoracoid and clavicle). Delayed acromioclavicular dislocation occurred in five patients, with

Table 1. Classification and misdiagnosis analysis of MCFIDCI

Classification	Primary Damage	Subtype	Imaging features	Corresponding to Rockwood classification	Easy to be misdiagnosed	Reasons
I	Incomplete or complete rupture of acromioclavicular ligament and joint capsule; Coracoclavicular ligament is intact.	Ia	The acromioclavicular joint space is normal or widened; slight upward subluxation of the distal clavicle. The coracoclavicular space is normal.	I, II	Yes	The acromioclavicular joint space is normal, or the widening is not obvious.
		Ib	Widening of acromioclavicular joint space and downward displacement of distal clavicle are observed. The coracoclavicular space is normal or smaller; the distal clavicle fracture end is cocked up.	None	No	The distal clavicle is lower than the acromion, indicating acromioclavicular joint dislocation.
II	Complete rupture of acromioclavicular ligament and joint capsule; complete rupture of coracoclavicular ligament; laceration of Deltoid and trapezius attachment points.	IIa	The widening of acromioclavicular joint space and upward dislocation of the distal clavicle are not obvious. Coracoclavicular space is slightly increased.	III, IV	Yes	The downward pulling force of the deltoid and trapezius muscles is not antagonized by the sternocleido-mastoid muscle. Consequently, the widening of acromioclavicular space and upward displacement of the distal clavicle are not obvious.
	Complete rupture of acromioclavicular ligament and joint capsule; complete rupture of the coracoclavicular ligament. Most deltoid and trapezius attachment points are torn.	IIb	The acromioclavicular joint space is widened significantly, with obvious displacement of distal clavicle. The coracoclavicular space is increased significantly.	V	No	Deltoid and trapezius muscles are mostly torn, and the downward pull-ing force is weak. Obvious upward displacement of distal clavicle is observed.
III	Rupture of acromioclavicular ligament and joint capsule; intact coracoclavicular ligament; coracoid fracture.	IIIa	The widening of the acromioclavicular joint space and upward dislocation of the extreme distal clavicle are not obvious. The coracoclavicular space is normal; coracoid fracture is observed.	III, IV	Yes	Coracoid process is pulled downward by the coracobrachial muscle, pecto-ralis minor muscle, and biceps brachii short head tendon, resulting in no obvious displacement of the coracoid process and distal clavicle.
	The acromioclavicular ligament and joint capsule are intact; Fracture of distal clavicle is observed. The cora-coclavicular ligament is intact, and coracoid fracture is observed.	IIIb	The acromioclavicular joint space is normal; the coracoclavicular space is normal. Fracture of extreme distal clavicle and coracoid fracture are observed.	None	No	Tips for fracture of extreme distal clavicle (far from trapezoidal ligament).

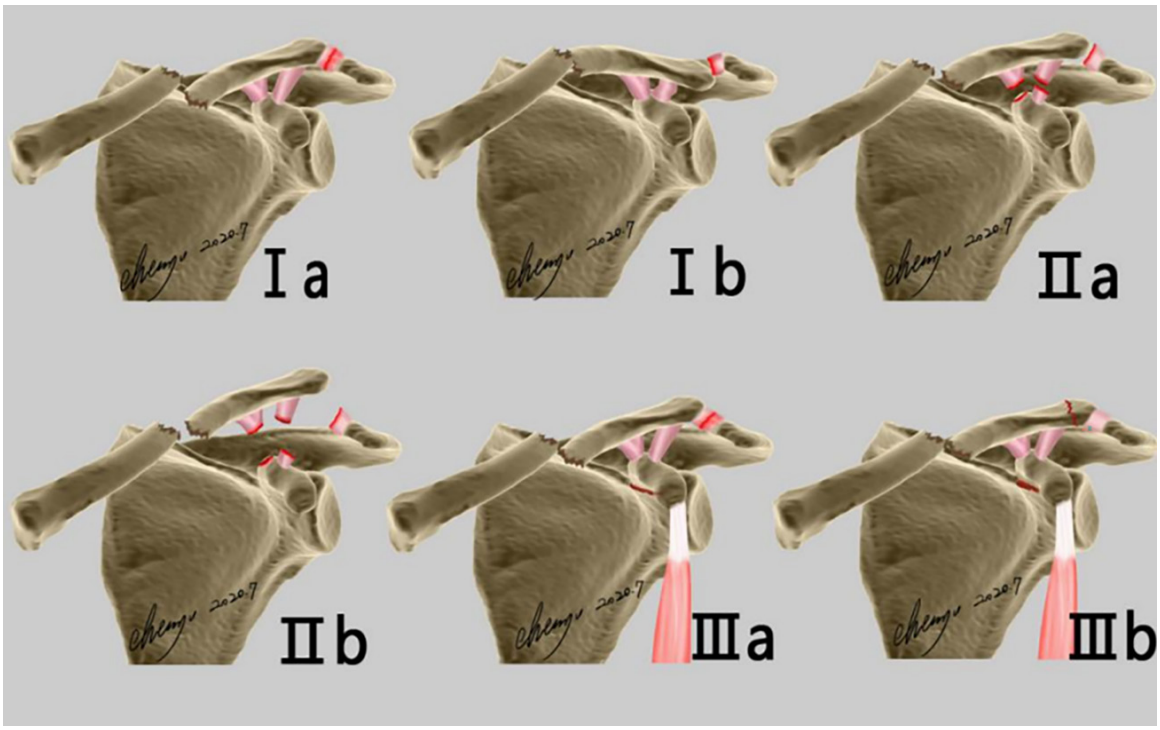

Figure 1. Schematic diagram of middle clavicle fractures with ipsilateral distal clavicle injury classification.

radiography examination revealing no acromioclavicular joint dislocation within 7 days postoperatively. Two patients developed acromioclavicular joint dislocation during the follow-up at 2 months; two cases were identified at 3 months, and one case was observed 4 months after the operation.

Classification

Based on our classification, we categorized 11 patients to type Ia, 2 to type Ib, 2 to type IIa, 2 to type IIB, 5 to type IIIA, and 1 to type IIIB. The preoperative misdiagnosis rates were as follows: type Ia, 36.4% (4/11); type I, 0% (0/2); type II, 100% (2/2); type II, 50% (1/2); type III, 60% (3/5); and type III, 0% (0/1). Reoperative images of typical cases of each subtype are shown in **Figure 2**, and postoperative images of typical cases of each subtype are also shown in **Figure 3**.

Associated injuries

Multiple fractures of the ipsilateral ribs were observed in 26.1% (6/23) of the cases (including one type Ia, one type IIA, one type IIB, two type IIA, and one type IIB). In 8.7% (2/23) of cases, subarachnoid hemorrhage was observed. Statistical results showed that the incidence of ipsilateral rib multiple fractures was 26.1% (6/23) in MCFIDCI cases, significantly higher than that simple mid-clavicle fracture cases (1.5%, 5/331; $P < 0.001$) (**Table 3**).

Discussion

In this study, we established a classification method for composite injuries. We collected the imaging features and injury characteristics, and then analyzed the characteristics of patients with MCFIDCI. Ottomeyer conducted an 8-year follow-up of patients who underwent surgery or conservative treatment for clavicular fractures. In 6.8% (26/383) of patients acromioclavicular dislocation occurred at varying degrees. These cases included Rockwood-type II, III, and V dislocation in 18, 7, and 1 cases, respectively. Among the 18 cases of Rockwood type II dislocation, 88.9% (16/18) were initially misdiagnosed before surgery, and acromioclavicular joint dislocation was discovered during follow-up [2]. Consistent with this finding, we found that among the 354 cases of middle clavicular fractures in the present study, 6.5% (23/354) were accompanied by ipsilateral distal clavicle injury. The missed diagnosis rate was 45.5% (10/22).

Table 2. Characteristics of patients with MCFIDCI

Sex	Age	Cause of injury	Is there any misdiagnosis?	Concomitant injury	Surgical intervention	Rockwood classification of acromioclavicular joint dislocation	Classification
Male	33	Traffic accident	No	None	Anatomical locking plate of the middle clavicle	II	Ia
Male	42	Traffic accident	Yes	Ipsilateral 2-4 rib fracture	Anatomical locking plate of the middle clavicle	II	Ia
Female	38	Traffic accident	Delayed	None	Anatomical locking plate of the middle clavicle	II	Ia
Female	28	Sports injury	Delayed	None	Anatomical locking plate of the middle clavicle	II	Ia
Female	27	Traffic accident	No	None	Anatomical locking plate of middle clavicle	None	Ib
Male	22	High falling injury	No	Ipsilateral coracoid type IV fracture	Anatomical locking plate of middle clavicle	III	IIIa
Male	31	Sports injury	No	None	Anatomical locking plate of middle clavicle	None	Ib
Female	67	Traffic accident	No	None	Anatomical locking plate of middle clavicle	II	Ia
Male	37	Injury from falling	Yes	None	Anatomical locking plate of middle clavicle	II	Ia
Male	30	Injury from falling	Delayed	None	Anatomical locking plate of middle clavicle	II	Ia
Male	53	Traffic accident	No	Ipsilateral 1-4 rib fractures and coracoid type IV fractures	Anterior clavicular reconstruction locking plate + clavicular hook plate internal fixation	V	IIb
Male	51	Traffic accident	No	Ipsilateral 1-8 rib fractures, coracoid type IV fractures and distal clavicle fractures	Anterior clavicular reconstruction locking plate + clavicular hook plate + coracoid hollow screw fixation	None	IIIb
Male	21	Falling from a high place	No	Ipsilateral multiple ribs 1-9, Subarachnoid hemorrhage	Anterior clavicular reconstruction locking plate + clavicular hook plate internal fixation	III	IIIa
Male	52	Injury from falling	Yes	Ipsilateral coracoid type IV fracture and distal clavicle avulsion fracture	Anatomical locking plate of middle clavicle	III	IIIa
Female	25	Sports injury	Yes	None	Anatomical locking plate of middle clavicle	II	Ia
Male	50	Traffic accident	Yes	Ipsilateral 2-3 rib fracture and coracoid type V fracture	Anatomical locking plate of middle clavicle	II	IIIa
Male	43	Traffic accident	Yes	None	Anatomical locking plate of middle clavicle	II	Ia
Female	35	Injury from falling	Delayed	None	Anatomical locking plate of middle clavicle	II	Ia
Male	25	Traffic accident	Delayed	None	Anatomical locking plate of middle clavicle	II	Ia
Male	36	Injury from falling	Yes	None	Anatomical locking plate of middle clavicle	II	IIa
Female	50	Traffic accident	Yes	Ipsilateral coracoid type V fracture, Subarachnoid hemorrhage	Anatomical locking plate of middle clavicle	III	IIIa
Male	32	Traffic accident	Yes	Ipsilateral avulsion fracture of distal clavicle	Anatomical locking plate of middle clavicle + Circular fixation of clavicular coracoid process with steel wire	V	IIb
Male	29	Falling from a high place	Yes	Ipsilateral 2-3 rib fracture and distal clavicle avulsion fracture	Anatomical locking plate of middle clavicle + reconstruction of coracoclavicular ligament with double button plate	III	IIa

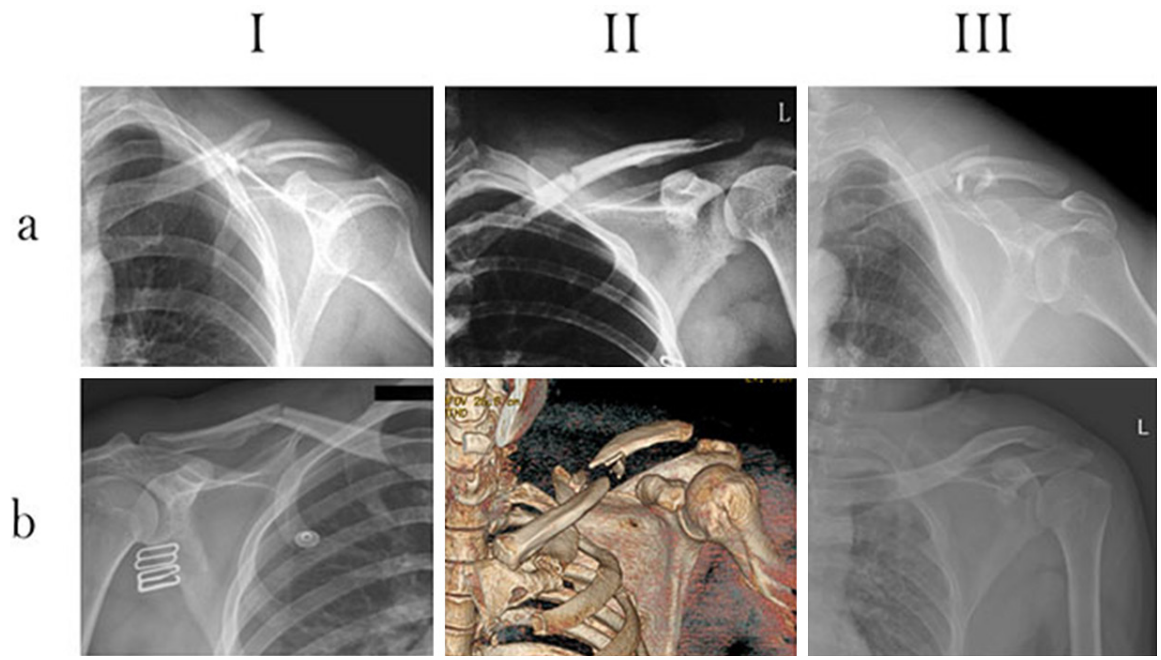

Figure 2. Preoperative schematic diagram of middle clavicle fractures with ipsilateral distal clavicle injury classification.

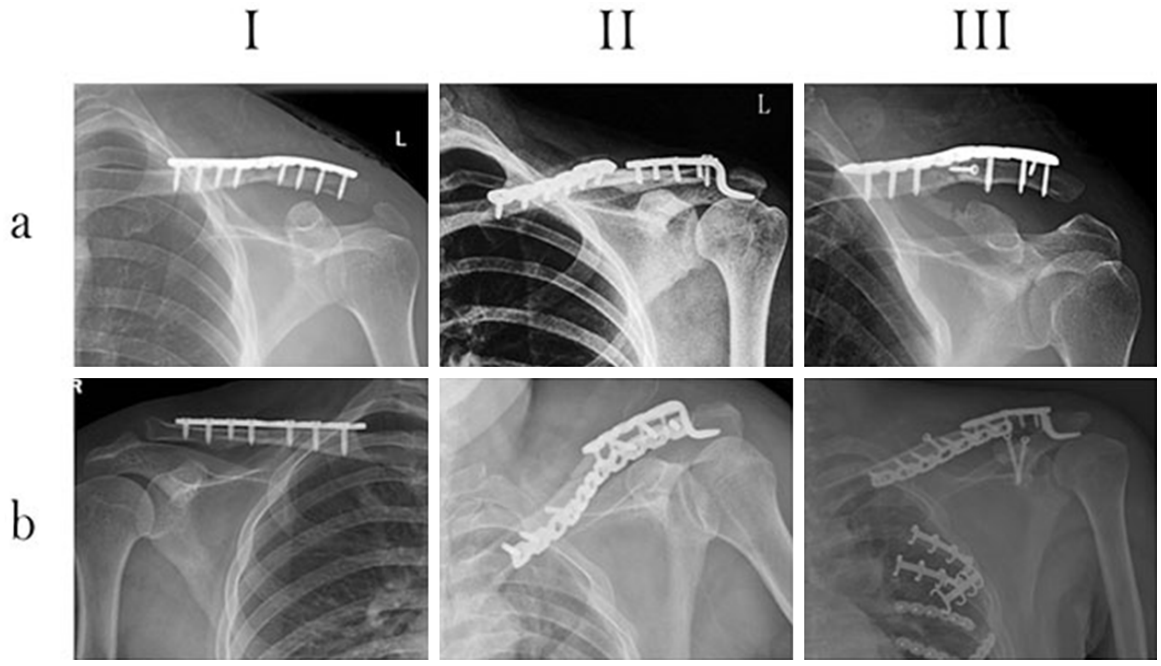

Figure 3. Postoperative schematic diagram of middle clavicle fractures with ipsilateral distal clavicle injury classification.

The high misdiagnosis rate of MCFIDCI is inextricably linked to the intricate periclavicular anatomy [7]. In such compound injuries, when a fracture takes place in the mid - clavicle, the distal clavicle is no longer subject to the upward pull of the sternocleidomastoid muscle. Even if the coracoclavicular complex is completely compromised, the downward forces exerted by the deltoid and trapezius muscles maintain the distal clavicle fracture either in position or with

Table 3. Statistical analysis of the rate of MCFIDCI and simple mid clavicle fracture with ipsilateral rib multiple fractures

		Whether there is an ipsilateral rib fracture (cases)		Total
		Yes	No	
Middle clavicle fracture accompanied by ipsilateral distal clavicle injury (cases)	Yes	6	17	23
	No	5	326	331
	Total	11	343	354
	X^2	=43.143	*P*	< 0.001

only minimal displacement. Once the clavicular fracture is stabilized, the upward traction from the sternocleidomastoid muscle leads to upward displacement of the distal clavicle. During surgery, because the patient is lying supine and under anesthesia, acromioclavicular joint dislocation often goes unnoticed. It becomes clearly visible on the postoperative standing radiograph, however the prime opportunity to rectify the misdiagnosis has already passed.

Previous clavicle fracture classification [8, 9] only included the simple middle clavicle fracture. The subtype was according to the degree of comminution, which could not reflect the severity of associated injuries (such as distal clavicle fracture and acromioclavicular joint dislocation). In the study by Ottomeyer [2], it was reported that 6.8% (26/383) of patients with middle clavicle fractures were accompanied by acromioclavicular joint dislocations of varying degrees. However, in our research, we found that many patients with middle clavicle fractures not only had associated acromioclavicular joint dislocations (19 cases), but also concurrent distal clavicle fractures (4 cases) and/or coracoid fractures (6 cases). The injury mechanism in these cases was the destruction of the scapuloclavicular complex, which was caused by the unilateral shoulder landed from a certain height. Therefore, we collected these injuries together and named them as MCFIDCI. Specifically, MCFIDCI is a severe multiple injury. It involves the middle clavicle fracture accompanied by the coracoid, coracoclavicular ligament, clavicle, acromioclavicular ligament, and acromion. Our classification was based on the degree of injury and the stability of the distal clavicle. In type I, the coracoclavicular ligament is intact and the distal clavicle remains stable, but the acromioclavicular ligament and joint capsule are ruptured. In type II, there is a rupture of the coracoclavicular ligament (trapezoidal ligament and conical ligament), acromioclavicular ligament and capsula articularis, accompanied by a distal dislocation. In type III, the coracoid is fractured, and the distal clavicle is unstable. In our classification, because the dislocation was not obvious, subtype A was prone to missed diagnosis. The misdiagnosis rate for subtype A in our patients was 50% (9/18). In subtype B, dislocation of acromioclavicular joint or distal clavicular fracture is obvious, suggesting coracoclavicular ligament injury, which is less likely to be misdiagnosed.

To reduce the occurrence of misdiagnoses of composite injuries, the following three points should be considered during the diagnosis and surgery. First, an avulsion fracture of the distal clavicle occurring simultaneously with a middle clavicular fracture is highly suggestive of MCFIDCI. Therefore, CT scans of the shoulder joint should be performed. Tenderness and swelling of the acromioclavicular joint and coracoid should be monitored during the physical examination, and the stability of the acromioclavicular joint should be checked during surgery. Second, when using the periosteal dissector to peel off the distal clavicle, the entire distal clavicle can be felt floating up and down as if stepping on a floating bridge, namely the floating bridge sign. Because the connection between the outer clavicle and surrounding structures is damaged in type II and type III injuries (the coracoclavicular ligament connects the acromion outward, the coracoclavicular ligament connects the scapula downward [type III includes coracoid process fracture], and the connection with the sternoclavicular joint inward is broken), the entire distal clavicle segment is in a floating state. Paryavi [10] reported a case of MCFIDCI type IIA injury and mentioned this “floating” clavicle injury. Third, when accompanied by other injuries, especially

in cases of ipsilateral multiple rib fractures, we should pay special attention to the presence of distal clavicular injuries. MCFIDCI has been associated with ipsilateral rib fractures [11-13], craniocerebral trauma [10], and other limb fractures [14-16]. In our MCFIDCI cases, 26.1% (6/23) were accompanied by multiple ipsilateral rib fractures, significantly higher than that in cases without distal clavicle injury.

In our study, two instances of special types of acromioclavicular joint dislocations (type IB) were observed, presenting as a downward dislocation of the distal clavicle. The distal clavicle was significantly lower than the acromion, but higher than the coracoid. Few cases of middle clavicular fractures combined with this type of dislocation have been reported [17-21]. Notably, this dislocation does not conform to the subcoracoid dislocation as described by type Rockwood VI. In this type, although the coracoclavicular ligament is often intact, curling of the ligament occurs below the clavicle. After clavicular fracture and acromioclavicular joint reduction, the length of the coracoclavicular ligament was restored, and the acromioclavicular joint remained stable, typically without further fixation. Therefore, we classified this as a type I stable injury of the coracoclavicular structure.

MCFIDCI is a high-energy composite injury, and its incidence rate is higher than previously thought. This combination of injuries is uncommon, even rare. In clinical practice, it is easy to be missed or misdiagnosed because it is not fully understood. In our classification, injuries with the same mechanism but different imaging manifestations were classified as the same compound injury. Based on the degree and type of distal clavicular injury, the classification includes three main types and everyone has two subtypes (a total of six subtypes). Our classification system can help clinicians better understand compound injuries. For suspected MCFIDCI injuries, magnetic resonance imaging or stress-position radiographic examination should be performed before surgery to reduce the risk of misdiagnosis [22-24].

Conclusions

This study delved into a crucial but often overlooked area of shoulder injury. We devised a novel classification method for compound middle clavicle injuries. This method made use of clinical and imaging characteristics. Our classification elaborates on the diverse subtypes of this injury in meticulous detail. It also helps us understand the causes of missed diagnoses. Besides, it offers guidance on how to minimize them.

Our research furnishes valuable novel perspectives on a particular aspect of shoulder injury. It is bound to pique the interest of orthopedic surgeons, trauma specialists, and researchers in this field.

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Disclosure of conflict of interest

None.

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