Schandelmaier et al. [72] in their study of 2002, considered the indication for operative treatment glenoid fractures of Goss type II to V *with fragment displacement of more than 5 mm*.

Anavian et al. [2] in 2012, indicated operation for glenoid fractures *with a step-off or gap in the articular surface of 4 mm or more*.

Tatro et al. [78] in 2018, also added to Anavian's criteria *involvement of 25% of the articular surface*.

Authors dealing with anterior glenoid fractures [1, 50, 51, 69, 73, 84] used open, or arthroscopic, operation in cases when *the separated fragment carried at least 20-25% of the articular surface and was displaced by at least 4 mm, or in case of instability of the glenohumeral joint after reduction*.

Specific features of indication criteria

The overview shows that agreement has been currently reached for the following three general parameters:

- *displacement of fragment by more than 4 to 5 mm,*
- *involvement of at least 25-30% of the articular surface,*
- *persisting subluxation, or dislocation, of the humeral head.*

In addition to the size of the separated articular surface, it is necessary also to take into account the overall size of the fragment, the bone quality (osteoporosis) and the location of involvement of the glenoid fossa. The most significant, in terms of the joint congruity and stability, is the so-called *circular area*, particularly its anteroinferior quadrant. By contrast, the superior pole of the glenoid bearing about 20% of the articular surface is less of an indication (Fig. 14-19).

Specific features of individual types of injuries to the glenoid must also be taken into account when considering operative treatment.

In anterior glenoid fractures, the main objective is to restore stability of the glenohumeral joint, as these fractures are usually associated with anterior dislocation of the glenohumeral joint and injury to the labro-ligamentous complex. Glenohumeral instability results from two causes.

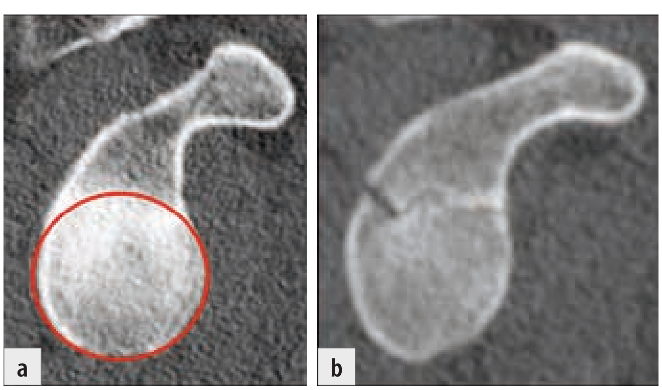

Fig. 14-19 The circular area and its importance for assessment of the size of the separated articular surface of the glenoid: **a)** intact glenoid, the circular area (marked in red) encompassing the load-bearing surface of the glenoid; **b)** a fracture of the superior glenoid with a minimal involvement of the load-bearing surface of the glenoid.

The first cause is *ligamentous instability* caused primarily by injury to the labro-ligamento-tendinous complex of the anterior part of the joint capsule, with separation of only a narrow circumferential part of the glenoid. The articular surface of the glenoid fossa is minimally affected. The aim of operation is a firm reinsertion of the labrum and the joint capsule to the glenoid rim [57, 75].

The other cause is *bony instability*, when the separated fragment, as a rule anteroinferior, bears more than 20-25% of the articular surface. An extreme, differing in the type of mechanism, are split fractures caused by a direct impact of the humeral head on the glenoid fossa. Separation of a larger fragment in any case markedly reduces the articulation area of the intact part of the cavity. The aim of the operation is anatomical reduction and stable fixation of the fragment, restoring the initial capacity of the articular surface, and congruence and stability of the glenohumeral joint.

In posterior glenoid fractures, the situation is similar to the preceding type. However, these fractures are, in practice, very rare and only a few reports of their operative treatment have been published [64].

Superior glenoid fractures have several specific features in terms of operative treatment. The first of them is the connection between the separated fragment and the acromion and the lateral clavicle through coracoid ligaments. These ligaments are in most cases intact and prevent marked displacement of the fragment. A few reports on rupture of the coracoclavicular ligament in cases of associated AC dislocation may be found in the literature [5, 88]. We also found it in one of our cases (Fig. 14-11). Another specific feature is the above-described type of displacement of the fragment, i.e., varus tilt, angulation of the articular surface with only a small step-off (Fig. 14-10). Therefore, superior glenoid fractures are not associated with glenohumeral instability. The third specific feature may be considered the location and course of the fracture line. The fracture line passes usually transversely and slightly obliquely through the upper third of the glenoid fossa (75% of cases), outside of, or on the periphery of, the circular area, i.e., outside the main contact surface with the humeral head. As a result, a greater displacement may be tolerated in this location than in the central part of the circular area. For these reasons, a majority of superior glenoid fractures are treated non-operatively. Operative treatment should be considered very carefully. In a number of cases, the main reason for operation is not incongruity of the articular surface, but the associated injuries, primarily AC dislocation, or a displaced fracture of the lateral clavicle.

Inferior glenoid fractures must be, besides the size of the separated articular surface and the shape of the glenoid fragment, checked also for a fracture of the infraspinous part of the scapular body, which is present in more than 84% of cases. The fracture line almost always passes through the circular area. Therefore, in inferior glenoid fractures, separation of the distal third of the articular surface is much more severe, in terms of joint congruence and stability, than separation of the upper third of the articular surface in superior glenoid fractu-

15

FRACTURES OF SCAPULAR PROCESSES AND ANGLES

Scapular process fractures described in the literature include fractures of the coracoid, the acromion and the lateral scapular spine [1, 10, 149]. In 1996, Goss [60] added a group of "*avulsion fractures*" to them, i.e., fractures of the superior angle and the superior border of the scapular body. We [14] have included in this group also fractures of the inferior angle of the scapula, because all these structures serve solely for the attachment of muscles, or ligaments, and are not involved in transmission of compressive forces from the glenoid to the scapular body. Fractures of processes and angles of the scapula are therefore considered by a number of authors to be avulsion fractures resulting from the pull of muscles and ligaments [23, 76, 85, 192, 200].

Studies published in the literature have paid considerable attention to fractures of the coracoid, acromion and the lateral spine, in the last two decades primarily in connection with injuries to so-called superior shoulder suspensory complex (SSSC) [9, 13, 103, 108]. However, they are mostly case reports, larger series were published only sporadically [3, 15, 50, 77, 78, 139, 140].

A separate issue is raised by os acromiale [72, 165, 191, 197]. Fractures of the superior angle and the superior border of the scapula are insignificant in practical terms [23, 141, 192]. Fractures of the inferior angle in adults are rare, although they may cause difficulties [84, 173].

HISTORY

Probably the oldest known fracture of a scapular process in a human being was published by Baudouin [16] in 1909. It was found in a man from a Neolithic grave who sustained a fracture of the surgical neck and a fracture of the coracoid (**Fig. 15-1**).

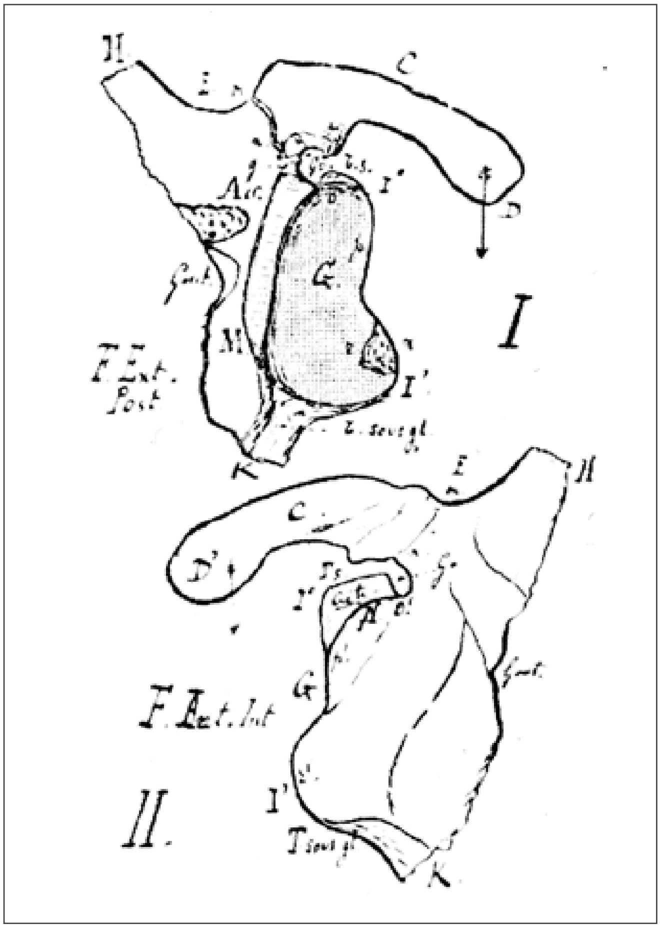

Fig. 15-1 Drawing of the Baudouin's finding of a fracture of the coracoid and the surgical neck in a man from a Neolithic grave, published in 1909. Reprinted from [16].

Fractures of the acromion and the coracoid were known already to ancient authors [157], due to their ease of diagnosis, In the modern literature, Petit [150], in 1723, was the first to discuss fractures of the coracoid, acromion and scapular spine. In 1751, Du Verney [47] described a fracture of the coracoid associated with a fracture of the surgical neck of the scapula on the basis of autopsy. In 1822, Astley P. Cooper [32] published a case of a fracture of the acromion, including its drawing. Fractures of the coracoid and of the acromion were described and depicted in a textbook and atlas published by Malgaigne respectively in 1847 [119] and 1855 [120]. Throughout the whole 19th century there appeared numerous case reports on fractures of scapular processes [10, 71, 80, 83, 90, 172, 173]. An exception was Callaway [29] who presented in his dissertation thesis of 1849 a series of 8 acromial fractures and also described coracoid fractures in detail.

In 19th century, several cases of fractures of the superior and inferior angles were recorded [65, 71, 173]. For instance Harris [71], in 1892, published, on the basis of a clinical examination, a fracture of the superior angle of the scapula in a patient who was hit by a train.

Autopsy findings: South [172], in 1839, described in a great detail an autopsy finding in a patient with a fracture of the coracoid and the acromion. Bransby B. Cooper [33], in 1842, reported a case of combined fractures of the coracoid base, the acromion and the proximal humerus. Holmes [80], in 1858, published an autopsy finding in a patient with an isolated fracture of the coracoid. Kelly [90], in 1869, presented an autopsy

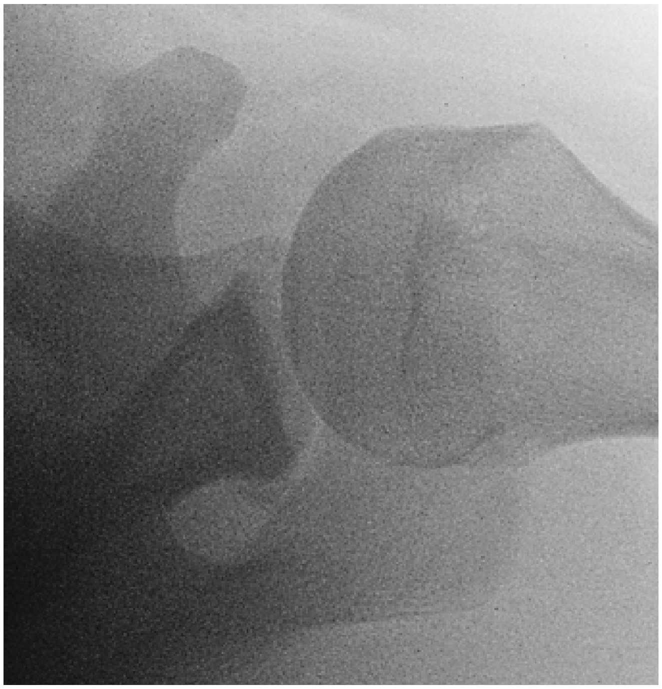

Fig. 15-18 Axillary radiograph of the coracoid.

the given structure. Motion of the shoulder joint is painful and, in consequence, its examination is often impossible. Attempts at extension of the elbow may also be painful, suggesting an injury to the coracoid (pull of the biceps brachii). Examination should include vascularity and innervation of the extremity (injury to the axillary artery, or the brachial plexus) [127, 139].

Radiological examination

The basic radiological examination includes a radiograph of the entire shoulder girdle, including the SC joint, and both Neer views. These radiographs will usually clearly show a majority of fractures of the processes and the neighboring structures. We carefully assess the mutual relationship of the lateral clavicle, the acromion and the coracoid.

Coracoid fractures are problematic as some of them may be missed on the anteroposterior radiograph of the shoulder joint [189]. They can, however, usually be well-seen in the Neer II ("Y") view. Some authors recommend special views, such as the axillary view (**Fig. 15-18**), but they may be difficult to obtain due to pain on abduction of the shoulder joint as required for such a procedure [22, 28, 52, 168].

Other authors have found useful ultrasonography or MRI, showing also the condition of the surrounding soft tissues, the rotator cuff in particular [25, 28, 56]. However, ultrasonography requires an experienced specialist and MRI is limited by its availability and cost.

A realistic image of the fracture anatomy is provided by CT scans, including standardized 3D CT reconstructions. They are beneficial mainly in cases of involvement of more structures of the shoulder girdle, or more parts of the scapula. Suspected stress fractures, not shown by a radiograph, were previously an indication for scintigraphy [196], but today for MRI [177].

In any case, all identified coracoid fractures should be checked for a potential injury to other structures of the scapula SSSC or the glenohumeral joint.

CLASSIFICATIONS

Classifications of acute process fractures emerged as early as at the beginning of 20th century. The first classification of the acromion was published by **Mencke** [128] in 1914 who distinguished between three patterns: *1- a well-marked fracture of a considerable portion of the acromion, 2 – physeal separation, 3 – a sprain fracture*.

In 1915, **Tanton** [178] divided fractures of the coracoid into *fractures of its base or its beak*, and fractures of the acromion into three patterns: *1 – fractures of the rim, 2 – fractures in the acromioclavicular region, 3 – fractures of the base of the acromion*.

The currently used classifications appeared within a short time interval as late as in the last decade of 20th century [51, 60, 100, 137-139]. One of the reasons was probably a small number of the cases published until then, most of which were case reports and few series included more than 10 patients [50, 100, 137-139].

Ogawa's classification of coracoid fractures

Ogawa et al. [137, 138] published the first version of their classification in 1990. Based on an analysis of 37 fractures, they divided the whole series into four groups (**Fig. 15-19**), with the fifth group being unclassified fractures.

In 1996, Ogawa et al. [139] analyzed a series of 67 coracoid fractures. The cohort comprised 55 men and 12 women, with a mean age of 37 years (range, 14-72). A total of 35 of the fractures were sustained in traffic accidents, 23 fractures in falls, 2 fractures were caused by a direct blow, and 3 fractures by unidentified mechanisms. Three patients were known to have renal osteodystrophy before the injury. Associated injuries to the shoulder girdle were found in 60 patients, including 39 cases of AC dislocation; 14 fractures of the clavicle, of which 12 frac-

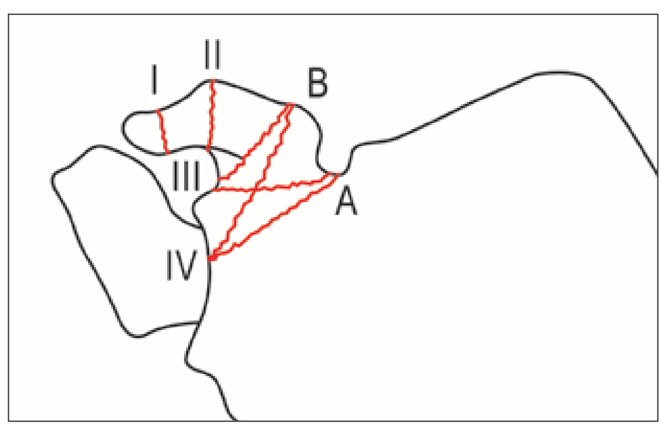

Fig. 15-19 The original Ogawa's classification of coracoid fractures. **I** – fracture of the tip, **II** – fracture of the beak, **III A + B** – variants of an extraarticular fracture of the base; **IV** – intraarticular fracture of the base. Modified according to [138].

tures involved its lateral part; 13 acromial fractures; 5 fractures of the scapular spine; 3 injuries to the rotator cuff; 3 cases of anterior dislocation of the glenohumeral joint; 2 fractures of the anterior rim of the glenoid; and 2 proximal humeral fractures.

The authors divided coracoid fractures into two types based on the course of the fracture line in relation to the attachment of the coracoclavicular ligament (Fig. 15-20):

- **Type I** – the fracture line passed behind the attachment of the ligament – 53 cases, of which 17 cases were intra-articular fractures (superior glenoid fracture).
- **Type II** – the fracture line ran anterior to the attachment of the ligament – 11 cases.

The type of 3 fractures could not be reliably determined. Operative treatment was used in 31 type I and only in 3 type II fractures.

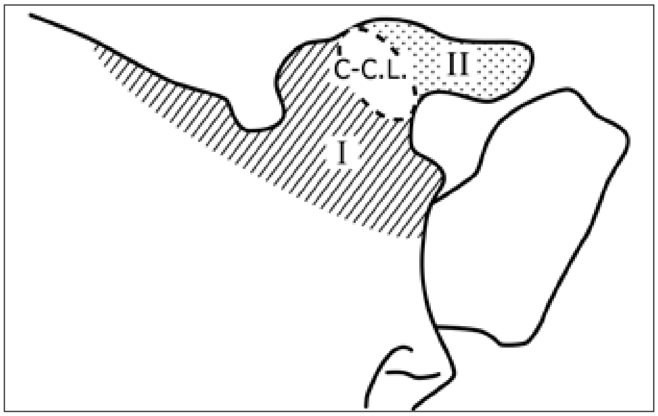

Fig. 15-20 Ogawa's reduced classification of coracoid fractures. **I** – fracture posterior to the attachment of the coracoclavicular ligament, **II** – fracture anterior to the attachment of the coracoclavicular ligament. Modified according to [139].

Eyres' classification of coracoid fractures

Eyres et al. [50], in 1995, divided coracoid fractures into five types on the basis of an analysis of a cohort of 12 patients, 8 men and 4 women, with a mean age of 34 years (Fig. 15-21):

- **Type I** – tip, or epiphyseal, fracture,
- **Type II** – mid-process,
- **Type III** – basal fracture,
- **Type IV** – superior body of scapula involved,
- **Type V** – extension into the glenoid fossa.

AC dislocation was found in 3 cases, and a fracture of the lateral clavicle, a fracture of the proximal humerus and glenohumeral dislocation in one case each.

Goss' classification of coracoid fracture

Goss [59], in 1996, divided coracoid fractures into three basic types, without specifying the number of cases analyzed.

- **Type 1** is defined as an avulsion fracture of the coracoid tip, caused by pull of the conjoint tendon of the coracobrachialis and the short head of the biceps brachii. The fracture line passes distal to the attachment of the coracoclavicular ligament. Displacement may be significant, but does not require operative treatment.
- **Type 2** is a fracture running between the coracoid attachments of the coracoclavicular and coracoacromial ligaments. The fracture results both from a direct blow (by the humeral head) or an indirect trauma, and is usually markedly displaced. The avulsed part of the coracoid is pulled distally by the conjoint tendon and is rotated laterally by the pull of the coracoacromial ligament.
  Note: Definition of this type does not respect the anatomical reality, as the coracoid attachment of the coracoacromial ligament is quite broad, extending between the tip and the base of the coracoid (Fig. 2-30).
- **Type 3** includes fractures of the coracoid base and is the most frequent of all types. These fractures are caused mostly by impact of the humeral head and are usually only minimally displaced, due to the stabilization effect of the coracoclavicular ligament.

A specific variant of type 3 is an intra-articular fracture of the coracoid base. According to Goss, the fracture line passes along the original physeal line between two ossification centers of glenoid fossa. *"Displacement is usually minimal and the fragment displaced medialy creating a negative articular defect."*

Goss [60] also discussed associated injuries to the shoulder girdle and, in this context, he mentioned the hitherto published cases, specifically AC dislocation, an acromial fracture, a fracture of the surgical neck of the scapula and a fracture of the lateral clavicle.

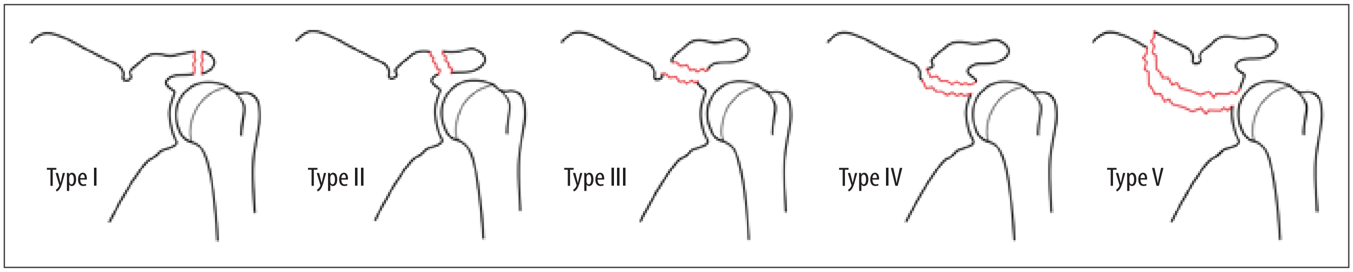

Fig. 15-21 Eyres' classification of coracoid fractures. **Type I** – tip or epiphyseal fracture, **Type II** – mid-process (fracture of the beak), **Type III** – basal fracture, **Type IV** – superior body of scapula involved, **Type V** – extension into the glenoid fossa. Modified according to [50].

Ogawa-Naniwa's classification of the acromion and the lateral spine

In 1997, these authors [140] developed a common classification for fractures of the acromion and the lateral spine based on the review of a group of 37 patients, 28 men and 9 women, with a mean age of 37 years (range, 17-72), of which 13 were treated operatively. The method of radiological examination, particularly the use of CT, was not mentioned. Fractures were often associated with other injuries to the shoulder girdle: a coracoid fracture in 19 cases, AC dislocation in 18 cases, a clavicular fracture in 4 cases and an injury to the brachial plexus in 4 cases.

According to the course of the fracture line, the authors identified three groups of fractures (Fig. 15-29):

- **Group I** – the medial part of the fracture line involved the posterior edge of the articular surface of the acromion. This type was found in 8 patients.
- **Group II** – the medial part of the fracture line was situated anteromedial to the acromial angle. This type occurred in 20 cases and in two variants. In *subtype A* (13 patients), the posterior part of the fracture line passed lateral to, while in *subtype B* (7 patients) medial to the acromial angle.
- **Group III** – the fracture line descended from the scapular spine to the spinoglenoid notch. This type was identified in 8 cases.

In the conclusion, the authors proposed division into two types only, with type I involving "the anatomical acromion" and type II including medially located fractures descending to the spinoglenoid notch, i.e., fractures of the lateral spine (Fig. 15-30).

Fractures of the acromion and of the lateral spine – the authors' own classification

Based on the review of 3D CT reconstructions of 35 fractures of the acromion and the lateral spine (Tables 15-3, 15-4), we have modified the classification developed by Ogawa and Naniwa (Figs. 15-31, 15-32):

Fractures of the acromion involving its anterior or lateral half, when the separated fragment bears less than a half of its surface (Figs.15-32 through 15-34). We recorded 6 such cases in our series.

Fractures of the acromial angle affecting approximately the triangular area forming a transition between the acromion and the lateral spine, when the posterior part of the fracture line runs usually no more than 1 cm medial, or lateral, to the acromial angle. The fracture line is straight, or V-shaped. This type was the most frequent and was seen in 16 cases (Fig. 15-35).

Fractures of the lateral spine are located in the area between the acromial angle and the medial edge of the spinoglenoid notch (Fig. 15-36). The course of the fracture line is variable; in a majority of cases it descends to the base of the lateral spine, without involving the scapular body (Fig. 15-37). We have identified a total of 13 such fractures.

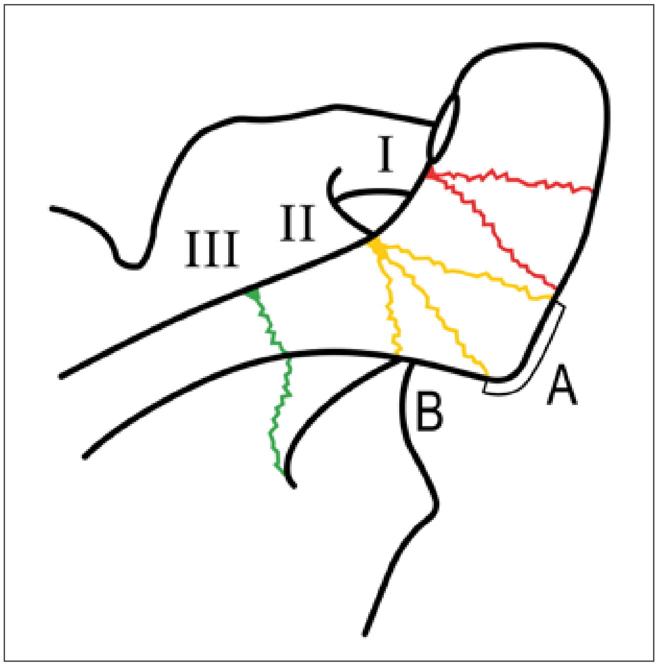

Fig. 15-29 The original Ogawa's classification of acromial fractures. I – medial end of the fracture line adjoined the posterior edge of the acromioclavicular joint, II – fractures in which its medial end was located anteromedial to the acromial angle (A – the fracture line is located anterior to the acromial angle, B – fracture line is located medial to the acromial angle), III – fracture line extends to the spinoglenoidal notch. Modified according to [140].

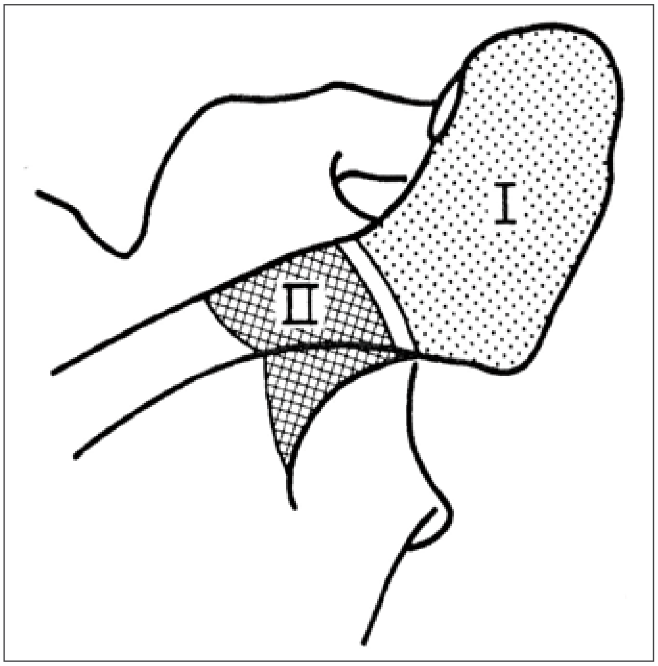

Fig. 15-30 The Ogawa's reduced classification of acromial fractures. Type I – fractures consist of those of anatomic acromion and extremely lateral scapular spine, Type II fractures compromise those located in more medial spine and descending into spinoglenoid notch. Modified according to [140].

Total	Male	Female	Age	R/L	Ac	AA	LS	Co	SG	AG	IG	TG	AC	Cla	PH	SC
35	28	7	47	15/20	6	16	13	7	5	1	1	3	7	3	3	1

Table 15-3 Basic characteristics of fractures of the acromion and the lateral spine. **AA** – fractures of the acromial angle, **Ac** – fractures of the anterior, or lateral half, of the acromion, **AC** – AC dislocation, **AG** – fracture of the anterior glenoid, **Cla** – clavicular fracture, **Co** – coracoid fractures, **IG** – fracture of the inferior glenoid, **LS** – fractures of the lateral spine, **PH** – fracture of the proximal humerus, **R/L** – right/left side, **SC** – dislocation of the sternoclavicular joint, **SG** – fracture of the superior glenoid, **TG** – fractures of the entire glenoid.

Type	N	Male	Female	Age	R/L	Co	SG	AG	IG	TG	AC	Cla	PH	SC
Ac	6	3	3	47	3/3	0	0	0	0	2	1	0	0	0
AA	16	16	0	41	6/10	6	4	1	1	1	4	2	2	1
LS	13	9	4	47	6/7	1	1	0	0	0	2	1	1	0

Table 15-4 Basic characteristics of fractures of the acromion and the lateral spine depending on the fracture pattern. **AA** – fractures of the acromial angle, **AC** – AC dislocation, **AG** – fracture of the anterior glenoid, **Cla** – clavicular fracture, **Co** – coracoid fractures, **IG** – fracture of the inferior glenoid, **LS** – fractures of the lateral spine, **PH** – fracture of the proximal humerus, **R/L** – right/left side, **SC** – dislocation of the sternoclavicular joint, **SG** – fracture of the superior glenoid, **TG** – fractures of the entire glenoid.

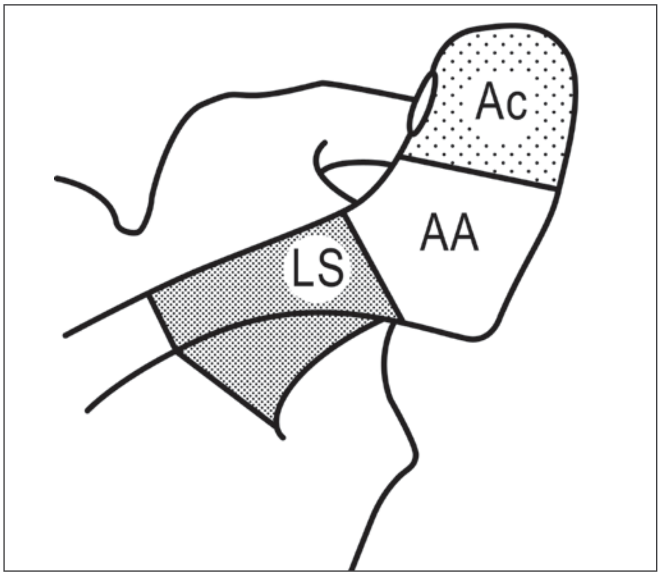

Fig. 15-31 Acromial fractures – the classification developed by the authors. **AA** – fractures of the acromial angle, **Ac** – fractures of the anterior half of the acromion, **LS** – fractures of the lateral spine.

Analysis of classifications of the acromio-spinal fractures

One of the major problems of acromio-spinal fractures is terminology. Both Kuhn et al. [100] and Goss [60] use the term "acromial fractures", although a number of fractures described by them affected the area medial to the acromial angle, i.e., the lateral scapular spine. Only Ogawa et al. [140] distinguish between three anatomically different areas of the acromio-spinal complex. Another problem is the diagnostics of the analyzed fractures. Kuhn et al. [100] were the only ones to describe their method of radiological examination. None of the authors mentioned the use of CT [60, 100, 140].

Kuhn's classification is based primarily on displacement of fragments and reduction of the subacromial space; anatomy of the fracture is not that important to the authors. An exact assessment of displacement, including reduction of the subacromial space, with the use of radiographs only, is highly problematic. The relevance of this reduction is also questionable. In addition, the classification neither respects the anatomical difference between the acromion and the lateral

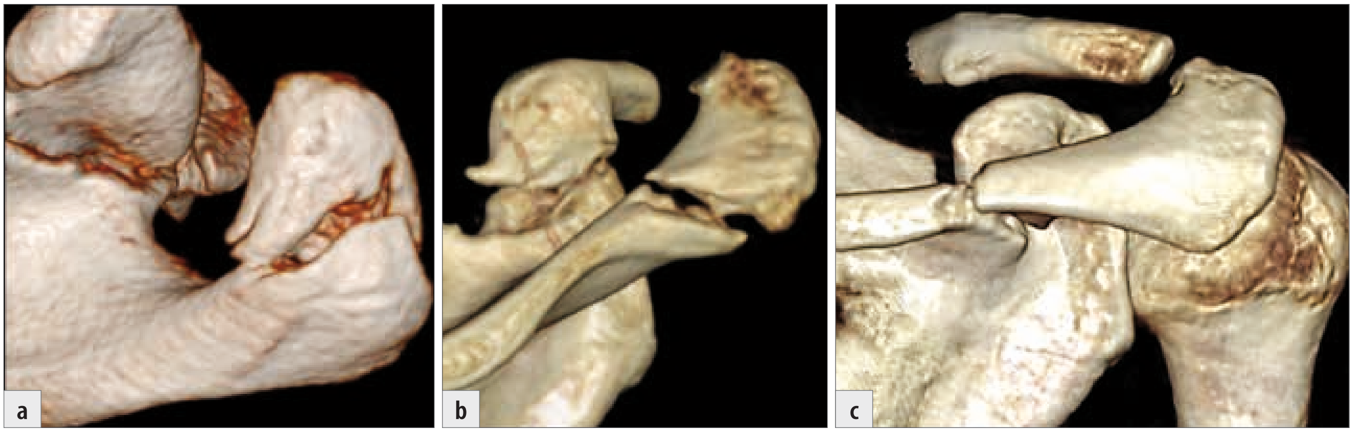

Fig. 15-32 Acromial fractures – the classification developed by the authors, on 3D CT reconstructions: **a)** fractures of the anterior half of the acromion; **b)** fractures of the acromial angle; **c)** fractures of the lateral spine.

rare (Fig. 15-15). Cabot et al. [27] described a fracture of the lateral spine combined with breaking of the medial spine out of the scapular body.

TREATMENT

Fractures of processes were initially treated non-operatively, but in the recent decade the number of reports of their operative treatment has markedly increased [3, 30, 75, 77, 78, 89], even if predominantly in the form of case reports. Studies of larger series are sporadic [3, 77, 78]. For these reasons no consensus has yet been reached concerning the method of treatment of process fractures [75].

Indications

Clear, generally accepted indication criteria for treatment of process fractures are still awaited. A literature review has shown that individual authors treat the same injuries in different ways and achieve the same, in their view, very good results [3, 50, 60, 77, 78, 138-140].

Goss [60] recommends managing these fractures non--operatively in all patients, except for athletes and manual workers. In cases of delayed treatment he suggests operation if a fragment that failed to re-attach, causes soft tissue irritation. However, he has not specified particular indications for operative treatment.

Kuhn et al. [100] select for operation only fractures of the acromion that compromise the subacromial space, without mentioning any other displacement, or its extent.

Exact criteria have been presented only by Anavian et al. [3] and Hill et al. [77, 78] who recommend operation in case of displacement of fragments of more than 1 cm alone, or in combination with an SSSC double lesion.

Nevertheless, the situation is rather more complicated. When deciding about the method of treatment of fractures of individual processes, it is necessary also to assess, besides displacement, injuries to other structures of the shoulder girdle. These injuries are often the main reason for operative treatment, rather than fractures of processes that, if isolated, could be managed non-operatively. The following overview presents the experience of individual authors in the treatment of various types of scapular process fractures.

Isolated fractures of the coracoid may be treated either non-operatively [19, 52, 63, 203] or operatively, mainly in athletes and physically active patients [5, 20, 42, 102].

Isolated fractures of the acromion and the lateral spine may be treated non-operatively in cases of a minimal displace-

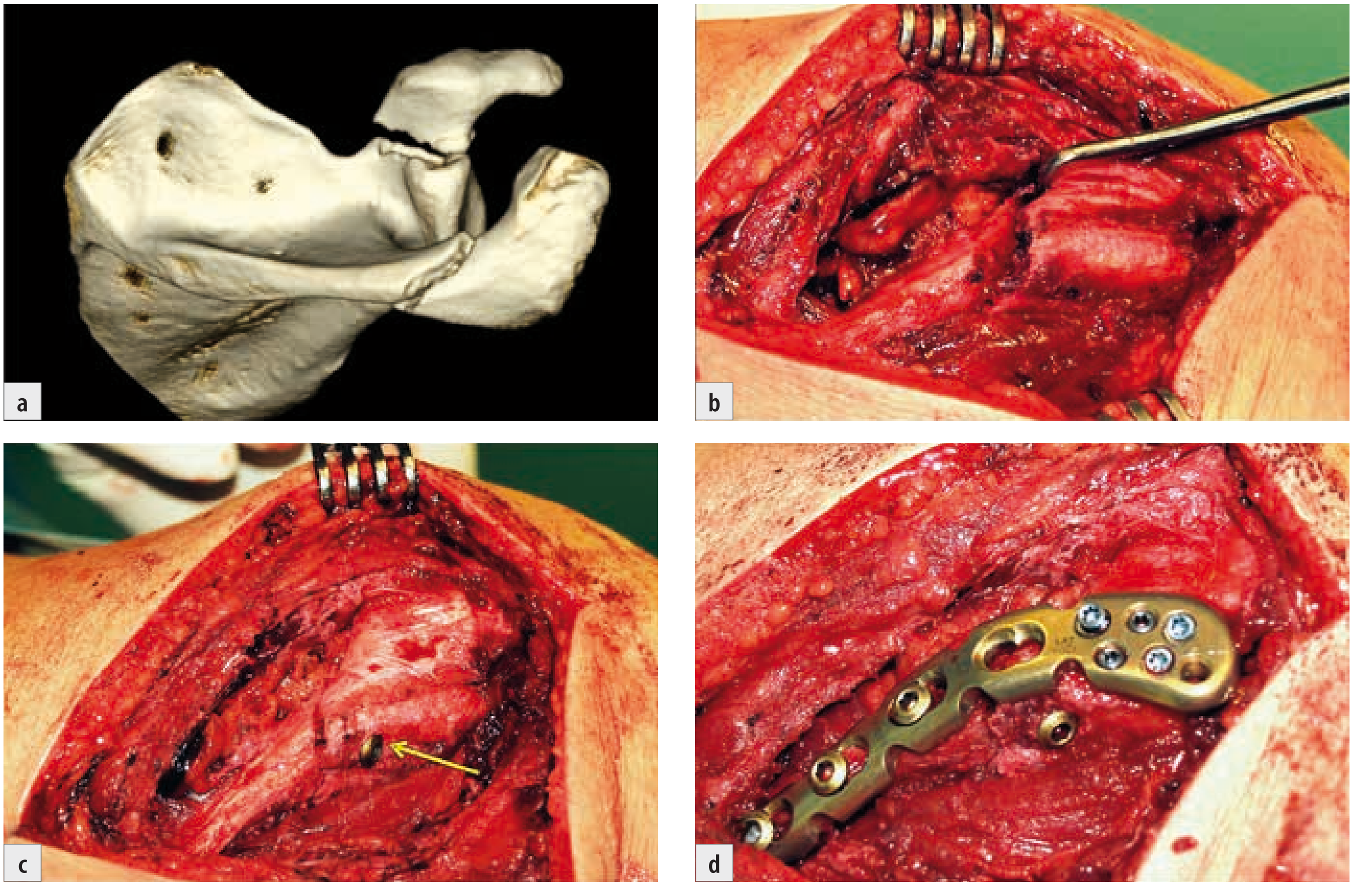

Fig. 15-38 Internal fixation of the acromial angle: a) fracture of the acromial angle and coracoid base on 3D CT reconstruction; b) revision of the fracture from the posterosuperior approach; c) reduction and fixation of the fragment with a lag screw (yellow arrow); d) completion of stabilization with a locking lateral clavicle plate. The coracoid fracture was reduced indirectly by pull of the coracoacromial ligament and left without internal fixation. Both fractures healed in an anatomical position.

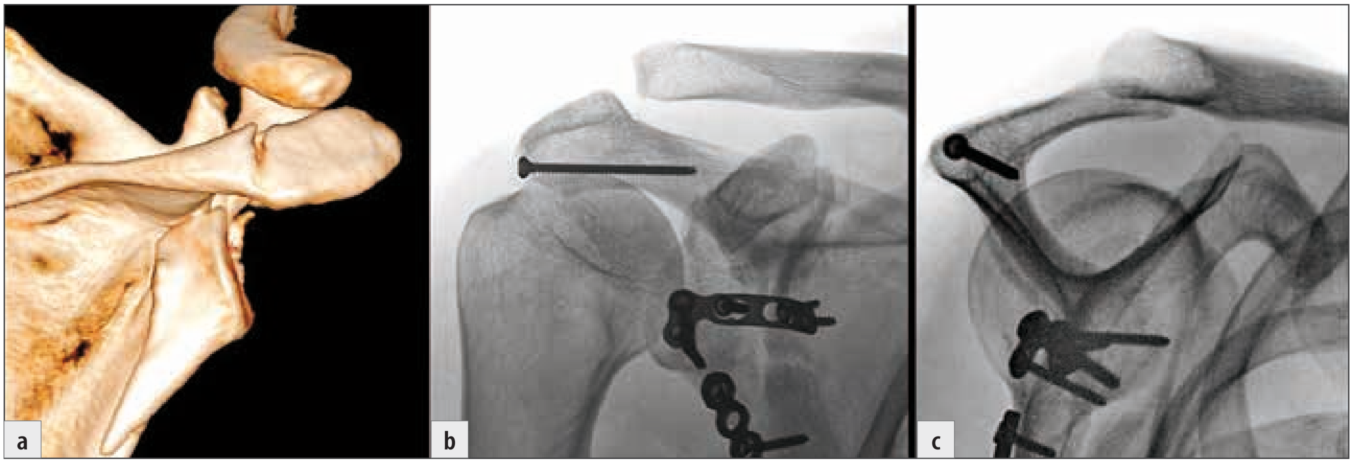

Fig. 15-42 Internal fixation of a fracture of the acromial angle with a lag screw: **a)** fracture of the acromial angle accompanying a total glenoid fracture; **b+c)** postoperative radiograph. Both fractures healed in anatomical position, with fully restored function of the shoulder joint.

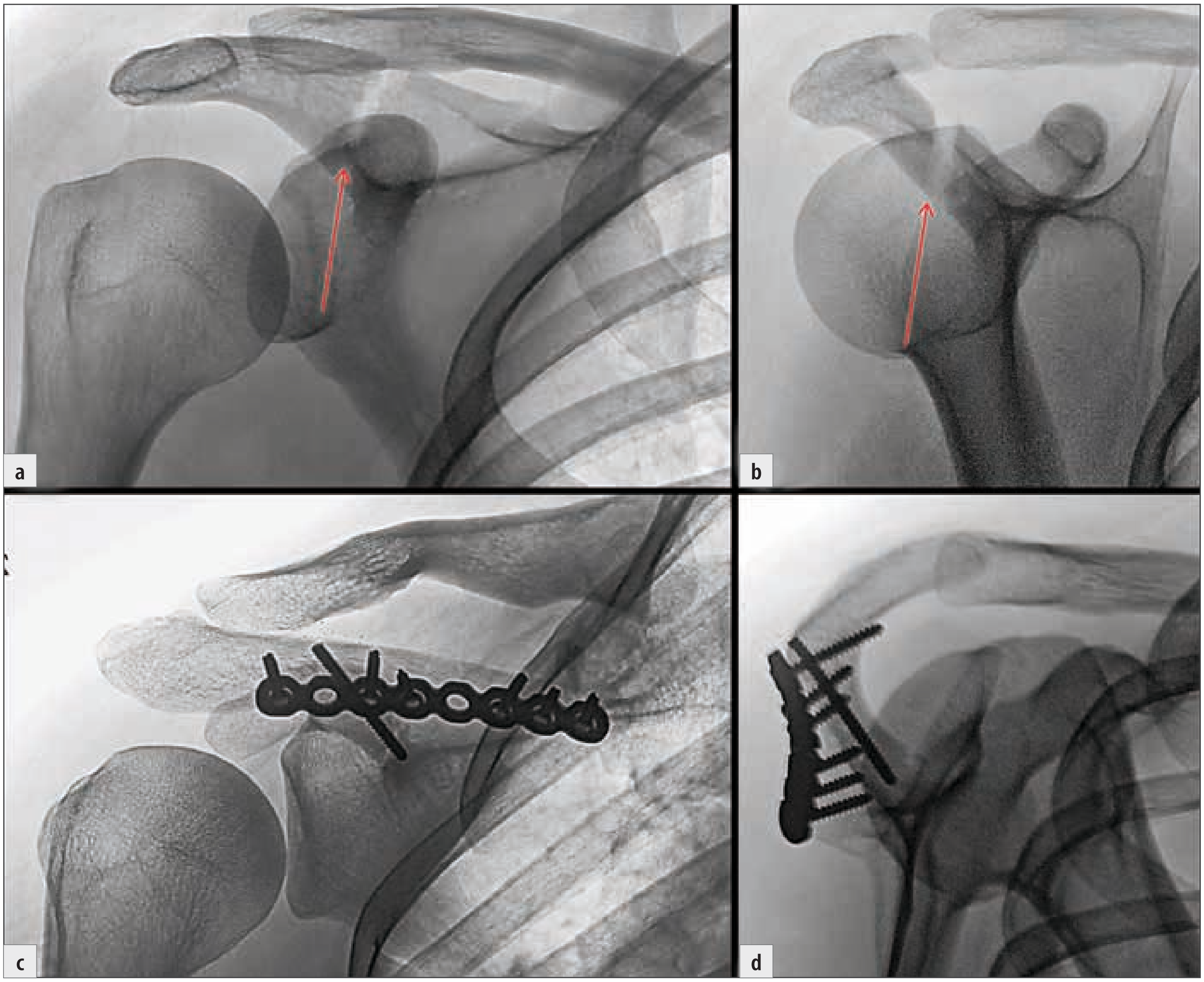

Fig. 15-43 Internal fixation of the lateral spine: **a+b)** preoperative radiograph, the red arrow indicates the fracture line; **c+d)** postoperative radiograph, internal fixation performed with lag screw and neutralization plate. During tightening of the screw, the screw head broke off.

	N Fxs	Total	Male	Female	R/L	Age total	Age male	Age female	Co	Ac/LS	Cla	AC	SC	PH
N	74	67	54	13	24/43	46	44	51	39	35	9	13	1	6

Table 15-5 Basic characteristics of process fractures, including associated injuries to the shoulder girdle. **AC** – AC dislocation, **Ac/LS** – fractures of the acromion or the lateral spine, **Cla** – fracture of the lateral clavicle, **Co** – coracoid fractures, **N** – number of patients, **N Fxs** – total number of fractures, **PH** – fractures of the proximal humerus, **R/L** – right/left side, **SC** – sternoclavicular dislocation, **Total** – total number of patients.

Type	N	Male/Female	Age	R/L
Total	67	54/13	46	24/43
Co	39	29/10	43	11/28
Ac/LS	35	30/5	47	15/20
AC	13	12/1	43	4/9
Co+Ac/LS	7	7/0	34	3/4
Cla	9	6/3	51	4/5
PH	6	2/4	61	3/3

Table 15-6 Comparison of basic characteristics of injuries in individual groups of fractures. **AC** – all process fractures associated with AC dislocation, **Ac/LS** – all fractures of the acromion or the lateral spine, **Cla** – all process fractures associated with a lateral clavicle fracture, **Co** – all coracoid fractures, **Co+Ac/LS** – combined fractures of the coracoid and the acromion or the lateral spine, **PH** – all process fractures associated with a fracture of the proximal humerus, **R/L** – right/left side.

AC dislocation was managed by tension band wiring in 4 patients, with a hook plate in 1 case and using K-wires alone in 1 case. Fractures of the acromial angle were treated with a plate in 3 cases, the same procedure was used in 2 fractures of the surgical neck of the scapula; a fracture of the proximal humerus was stabilized by a Philos locking plate and a fracture of the anterior glenoid by lag screws.

A coracoid fracture was treated in only 2 cases, i.e., once in combination with AC dislocation and once in combination with a fracture of the anterior glenoid, always using a 3.5-mm lag screw. In none of 39 cases was the coracoid fracture the primary indication for operation.

Quite different was the situation in 10 operatively-treated fractures of the acromion and the lateral spine. Fractures of the anterior, or lateral, half of the acromion were treated in 2 cases, using a pair of lag screws. In 3 fractures of the acromial angle and in 4 fractures of the lateral spine we used various types of 2.7-mm and 3.5-mm reconstruction, or T-plates. A locking plate, shaped for the lateral clavicle, was chosen in 1 case, namely for a fracture of the acromial angle combined with a fracture of the coracoid base. Although we did not fix the latter fracture, both fractures healed without complications.

So far, we have not evaluated and published in detail the results of operations, except for patients with fractures of the surgical neck of the scapula. Nevertheless, we may present at least the following basic facts.

All operatively-treated patients with fractures of the processes had healed, including the coracoid fractures that were not fixed during operation, due to another injury to the shoulder girdle. No infection was recorded. More serious complications included diastasis of the AC joint after early removal of K-wires in a combined fracture of the acromial angle (fixation by a reconstruction plate), the coracoid base fracture (untreated) and AC dislocation of type IV of the Rockwood classification. In 2 cases combined with a fracture of the proximal humerus, patients developed posttraumatic arthritis. The first case was a 70-year-old female patient with a fracture of the proximal humerus combined with a fracture of the coracoid tip and the superior glenoid, treated with internal fixation of all three fractures. The other case was a 56-year-old female patient with a fracture of the base of the lateral spine and a fracture of the humeral head, where only the scapular fracture was treated. The fracture of the humeral head was revealed on the CT finding scheduled for replacement of the proximal humerus in a second phase (**Fig. 15-44**). However, the patient refused the replacement because of insignificance of subjective complaints.

OS ACROMIALE

When dealing with fractures of processes, we must not forget about os acromiale which is often confused with an acromial fracture. Rarely does a fracture of the acromion, or of the lateral spine, occur simultaneously with os acromiale (**Fig. 15-47**). The literature also contains several reports of separation of os acromiale due to a trauma [117, 156].

History

Os acromiale was described for the first time by Cruveililher [36] in 1849. It was dealt with in detail by Gruber [62] in 1863 (**Fig. 15-48**) and McAlister [125] in 1897. At the beginning of 20th century, the issue of os acromiale appeared in the radiological literature [95, 112, 136]. For orthopedic surgeons it was brought into focus by a Liberson's study [111] of 1937. Mudge et al. [132], in 1984, were among the first to point out the relationship between os acromiale and a lesion of the rotator cuff. From the 1990s, the number of studies dealing with os acromiale as the cause of a painful shoulder began to grow [72, 117, 165, 167, 175, 187, 202, 208]. Lyons [117] in 2010 described a fracture of os acromiale as a part of the floating shoulder. The existing anatomical findings were summarized by Yammine [208] in 2014 and the clinical significance of os acromiale was discussed by Hasan et al. [72] in 2018 and Viner et al. [191] in 2020.

Anatomy

Os acromiale results from failure of fusion between individual ossification centers of the acromion. There are four ossification centers of the acromion, i.e., *preacromion, mesoacromion,*

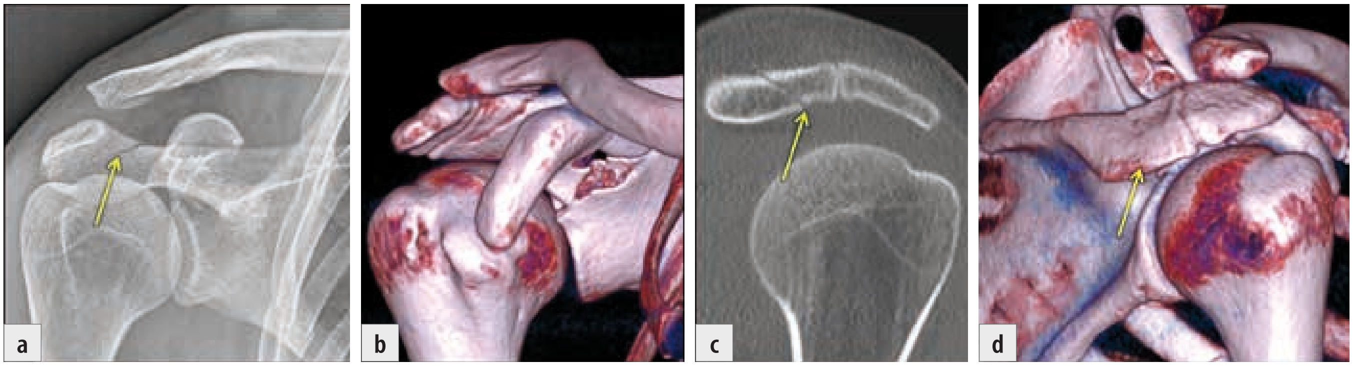

Fig. 15-47 Fracture of the acromial angle associated with os acromiale: **a)** radiograph, the yellow arrow shows the fracture line in the acromial angle, the line of os acromiale cannot be well seen, while the fracture of the superior glenoid is clearly visible; **b)** 3D CT reconstruction, fracture line and the line of os acromiale are clearly visible; **c)** 2D CT reconstruction, the two lines can be well seen; **d)** 3D CT reconstruction, posterior view, the fracture line indicated by the yellow arrow is almost invisible.

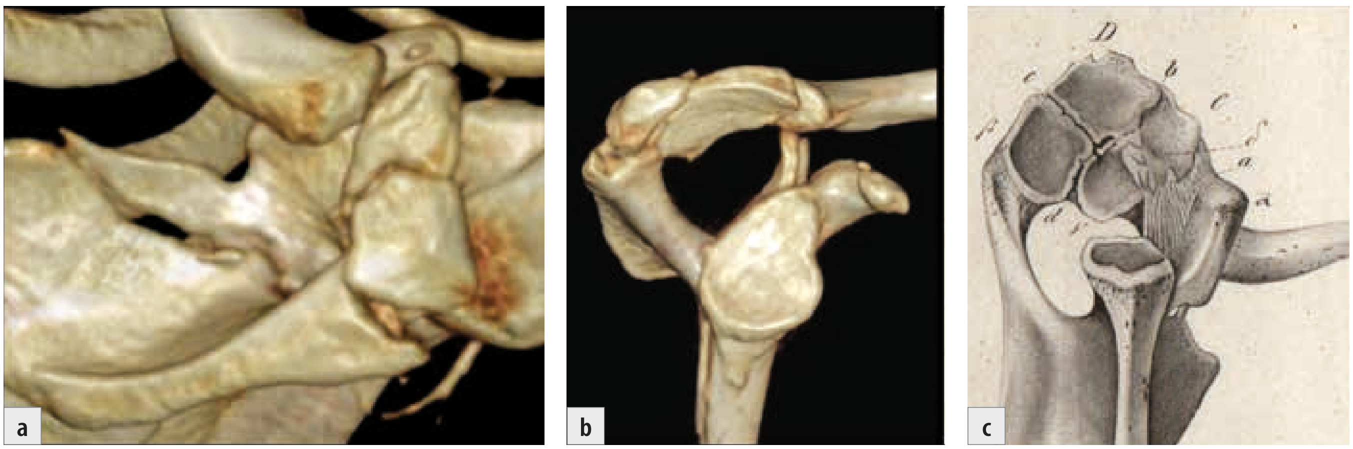

Fig. 15-48 Os acromiale and comparison with Gruber's original description: **a+b)** a double os acromiale, when trauma caused separation in the original physis; **c)** Gruber's original drawing reprinted from [62].

metacromion, and *basiacromion* (**Fig. 15-49**). Ossification centers appear at the age of 10 to 16 years and fuse between 16 and 25 years [146, 202]. Failure of fusion occurs between metacromion and mesoacromion in 75% of cases (**Fig. 15-50**). The findings obtained to date suggest a developmental disorder [208].

Epidemiology

The incidence of os acromiale was studied both on bone specimens [208] and radiographs [111, 112]. The data obtained vary somewhat, as it may be easily overlooked on radiographs [72, 111, 208]. According to anatomical studies, os acromiale can be seen in about 7% and according to radiological studies, in about 4% of individuals. In black populations its incidence is approximately 3 times higher than in white populations; the difference between men and women is not significant [72, 208]. About one third of cases show bilateral incidence of os acromiale [72, 208].

Clinical examination

A stable os acromiale is usually asymptomatic; it is mostly detected as an incidental finding on a radiograph. Clinical problems arise from a so-called unstable os acromiale, due to pathological motion at the synchondrosis. It is manifested by

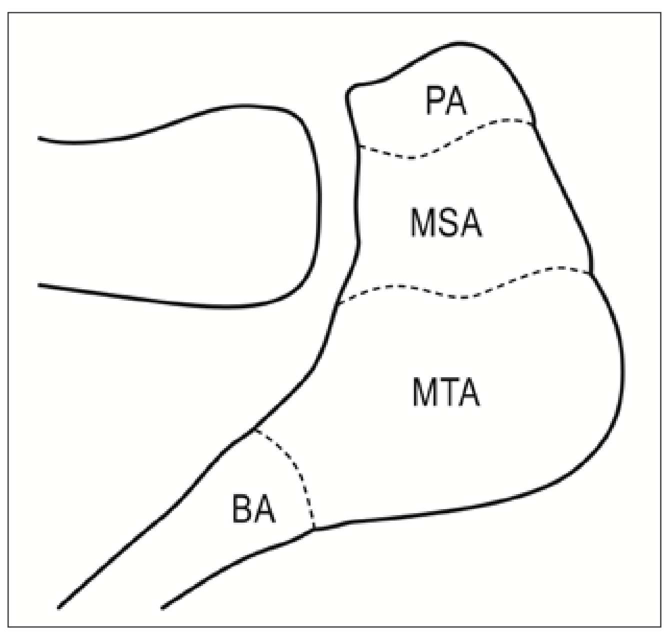

Fig. 15-49 Developmental zones of the acromion leading to os acromiale, according to Köhler and Zimmer. Modified according to [95]. **BA** – basiacromion, **MSA** – mesoacromion, **MTA** – metacromion, **PA** – preacromion.

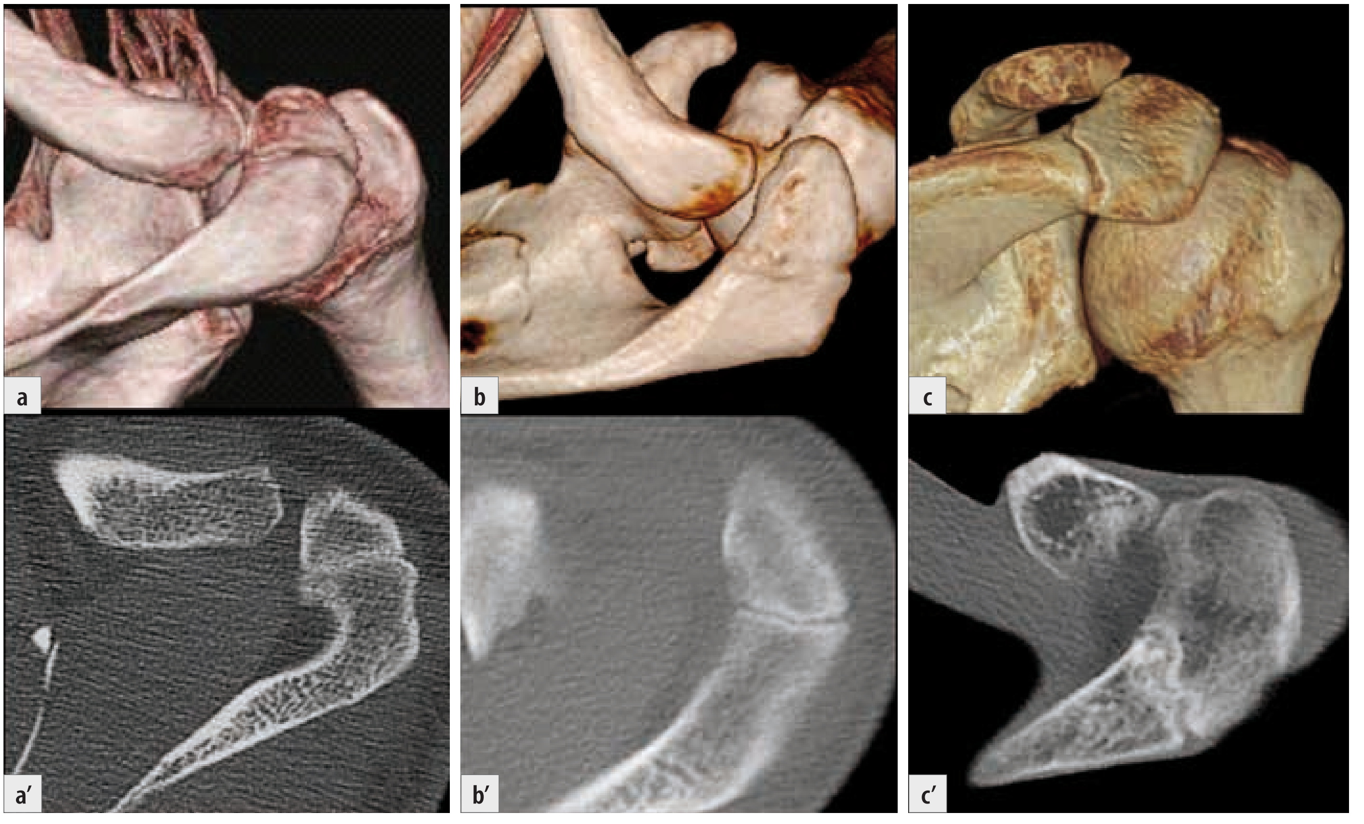

Fig. 15-50 Variability of os acromiale: **a+b)** incomplete fusion between mesoacromion and metacromion; **c)** incomplete fusion between metacromion and basiacromion.

pain resulting from degenerative changes directly in the synchondrosis, or caused by irritation of the rotator cuff. Rarely, there may occur a traumatic separation of os acromiale [156]. Therefore, it is essential to take a detailed medical history in order to distinguish between a coincidental finding of os acromiale and a symptomatic unstable os acromiale [72].

During the examination it is necessary to identify a maximal area of tenderness and its location in the region of the AC joint, the anterior rim of the acromion, or just over the synchondrosis [72]. Palpation may also reveal pathological motion of the os acromiale associated with pain. We test the range of motion or, where appropriate, the painful arch of motion, which is typical of a lesion of the rotator cuff. An important sign, in this respect, is weakening in abduction, or external rotation.

Radiology

As a first step, radiographs of the shoulder joint are obtained in the anteroposterior and Y-views, and in case of doubt an axillary view. Lee et al. [109] described a "double density" sign, i.e., a cortical ring visible on the AP or Y-views. If need be, CT or MRI examination is undertaken [187, 202]. An advantage of MRI is a simultaneous capturing of the state of the rotator cuff and other soft tissues of the shoulder joint.

Os acromiale differs from a fracture by the course of the fracture line, which is not straight in most cases (**Fig. 15-47**). Os acromiale must be distinguished from a nonunion of the acromion after a previous fracture. For this reason, it is useful to check the patient's medical history.

Treatment

During the choice of treatment, it is necessary to differentiate between traumatic changes and an unstable atraumatic os acromiale.

Traumatic separation requires reduction and internal fixation, preferably by cannulated screws in combination with tension band wiring (**Fig. 15-51**) [74, 167].

A symptomatic unstable os acromiale is treated initially non-operatively, i.e., by non-steroidal anti-inflammatory drugs, adjustment of physical activities, physiotherapy, or, where necessary, by a local corticosteroid injection. Should these measures fail, it becomes necessary to use operative treatment. A smaller os acromiale is excised either arthroscopically, or by an open procedure. Larger fragments should be re-fixed, preferably using lag screws [72, 175, 185, 191, 197].

Authors' own series

In a series of 519 scapular fractures, we found 7 (1.3%) cases of os acromiale, 6 in men and 1 in a woman, with a mean age of 46 years. The right side was affected in 3 and the left side in 4 cases. In 4 cases, the os acromiale was coincidental with scapular body fractures, in 1 case with fractures of the inferior glenoid involving the infraspinous part of the scapular body. In 2 cases we diagnosed os acromiale in a fracture of the superior scapula: the first case was a combined fracture of the superior glenoid, the lateral spine, the superior border

16

COMPLEX SCAPULAR FRACTURES

Fractures of the scapula are divided, according to involvement of its individual anatomical parts, into four basic groups, i.e., fractures of the scapular body, the neck, the glenoid and the processes. In addition, there are cases in which one, or more, fracture lines pass through several anatomical parts of the scapula. Previously, they were referred to as *comminuted,* or *multi-part fractures* [9, 12, 13, 16-19]. Currently, they are termed "complex" injuries. However, their exact definition is still awaited in the literature.

In our previous studies, we included complex fractures in the category of two-pillar fractures of the scapular body, or total glenoid fractures [3-5]. The latest detailed analysis of our series has revealed that these injuries have certain specific features that single them out as a separate group.

BASIC CHARACTERISTICS

Complex scapular fractures are the most severe injuries to the scapula. They are caused by high-energy trauma, leading to breaking of both pillars, with involvement of both the supraspinous and infraspinous fossae. According to involvement of the glenoid, we distinguish between complex extraarticular and intraarticular fractures.

Extraarticular fractures are always associated with separation of the lateral scapular spine as a separate fragment from the scapular body, or of the coracoid from the glenoid fragment, sometimes with separation of both. This is the difference between these injuries and two-pillar fractures of the scapular

Fig. 16-1 Difference between a two-pillar fracture of the scapular body and a complex extraarticular fracture of the scapula: **a)** a two-pillar fracture of the scapular body, with the lateral scapular spine and the coracoid being part of the glenoid fragment; **b)** a complex extraarticular fracture of the scapula, the lateral scapular spine forms a separate fragment; the glenoid fragment carries only the coracoid; **c)** a complex extraarticular fracture of the scapula combined with a clavicular shaft fracture; the coracoid is separated from the glenoid fragment.

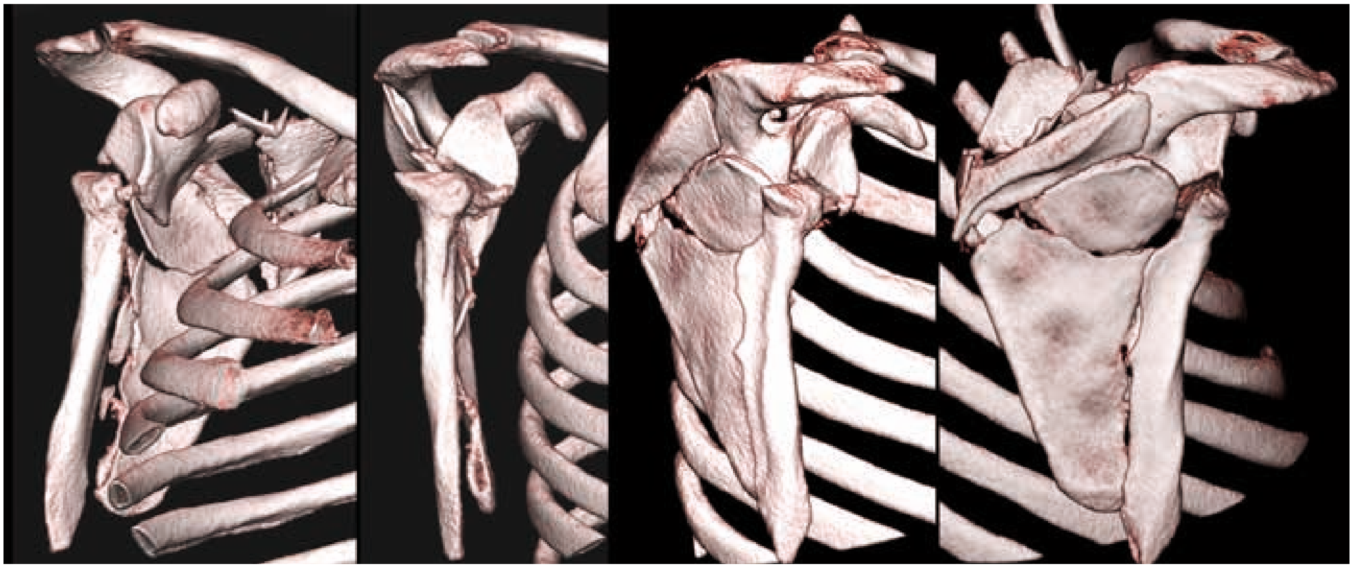

Fig. 16-2 A complex intraarticular fracture of the scapula. The glenoid is split into two parts, the upper part is formed by the glenoid, the coracoid and the lateral scapular spine.

Fig. 16-3 The glenoid fossa is split into two large fragments and one minor, peripheral fragment (yellow arrow).

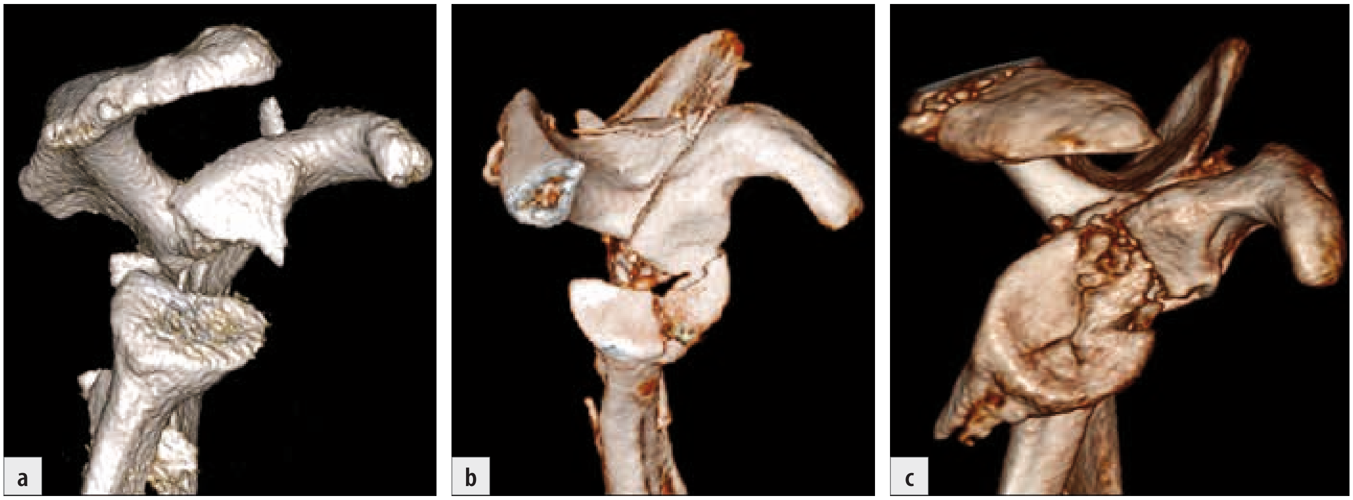

Fig. 16-4 Different patterns of glenoid fossa fractures: **a)** a two-part fracture; **b)** a three-part fracture; **c)** a comminuted fracture.