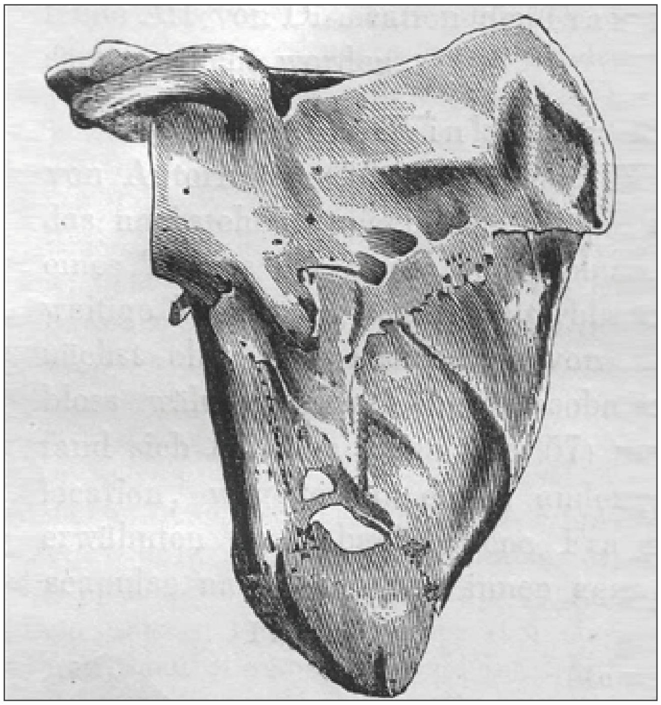

Fig. 12-18 Drawing of a fracture of the lateral pillar reprinted from the Gurtl's textbook [29].

scapula (Fig. 12-19a), i.e., medial to the central weaker part, which always remained intact. Displacement of the fracture in the region of the spinomedial and superior angles of the scapula tended to be minimal.

Fractures involving the central part of the spinal pillar represented the most severe injuries to the scapular body. The fracture line always passed through the central weaker part of the spinal pillar (Fig. 12-19b). Fractures of the lateral pillar were always more displaced than those of the spinal pillar.

This fracture pattern can be also divided according to the shape of the glenoidal fragment, which is important in relation to its reduction and fixation. A large glenoidal fragment was mostly formed by the glenoid, the scapular spine and the coracoid. A medium-sized glenoidal fragment carrying the glenoid and the coracoid, similar to a surgical neck fracture, was less frequent. An exceptional case, in which the fragment of the lateral angle was formed by the glenoid alone (Fig. 12-20), was classified as a comminuted scapular fracture.

TREATMENT

Until recent times, almost all fractures of the scapular body were treated non-operatively [4, 23, 26, 27, 33, 37, 52]. Their analysis has, however, shown poor long-term functional results in those that healed with marked displacement [1, 43]. The cause of unsatisfactory function was a change in the spatial relationship between the glenoid and the infraspinous part of the scapular body, which also had an impact on the rotator cuff muscles [47]. Another cause was the uneven costal surface of the scapular body, impairing its smooth gliding over the chest wall. One of the other negative factors was immobilization of the shoulder joint over several weeks, with several reports of nonunion of the scapular body.

Decision-making about the method of treatment should take into account not only the pattern of the scapular body fracture and its displacement, but also the patient's general condition, age and functional demands.

Fig. 12-19 Types of fractures of both pillars: **a)** fracture involving the medial third of the spinal pillar; **b)** fracture involving the central weaker part of the scapular spine.

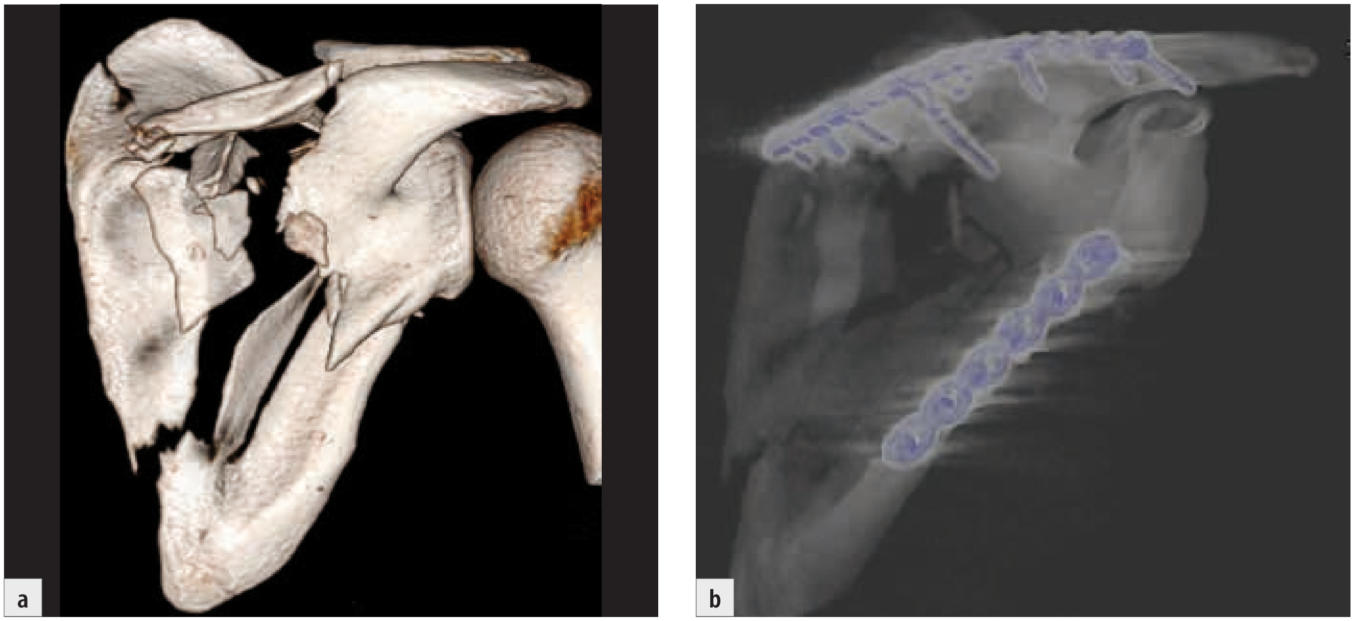

Fig. 12-27 Technique of internal fixation of the spinal pillar: **a)** fracture of both pillars; **b)** after internal fixation with 2.7-mm reconstruction plates.

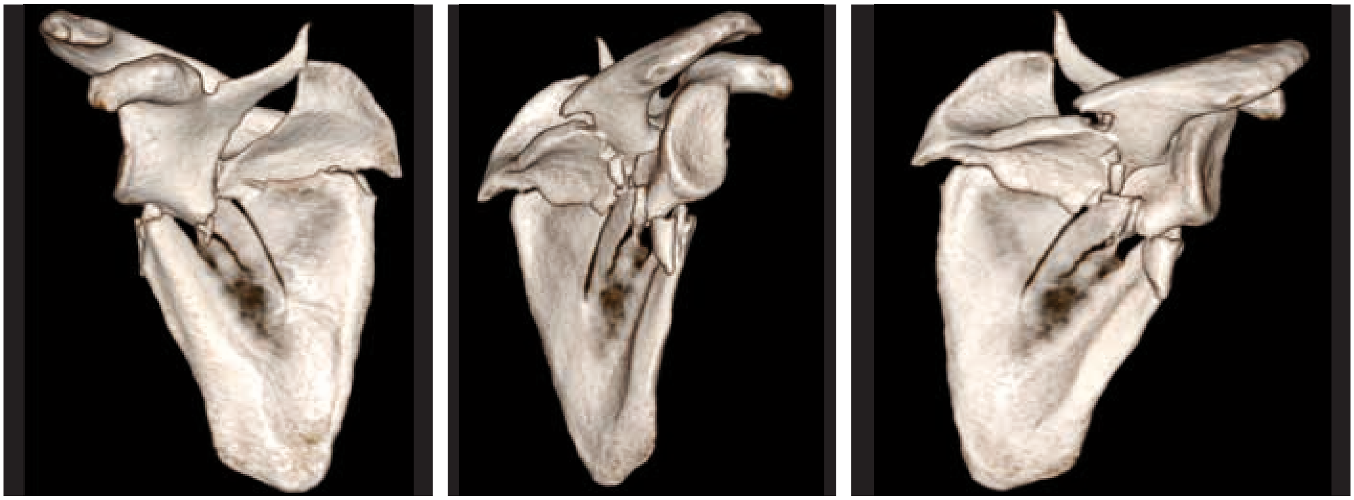

Fig. 12-28 Internal fixation of a comminuted extra-articular fracture of the scapula – 3D CT reconstruction.

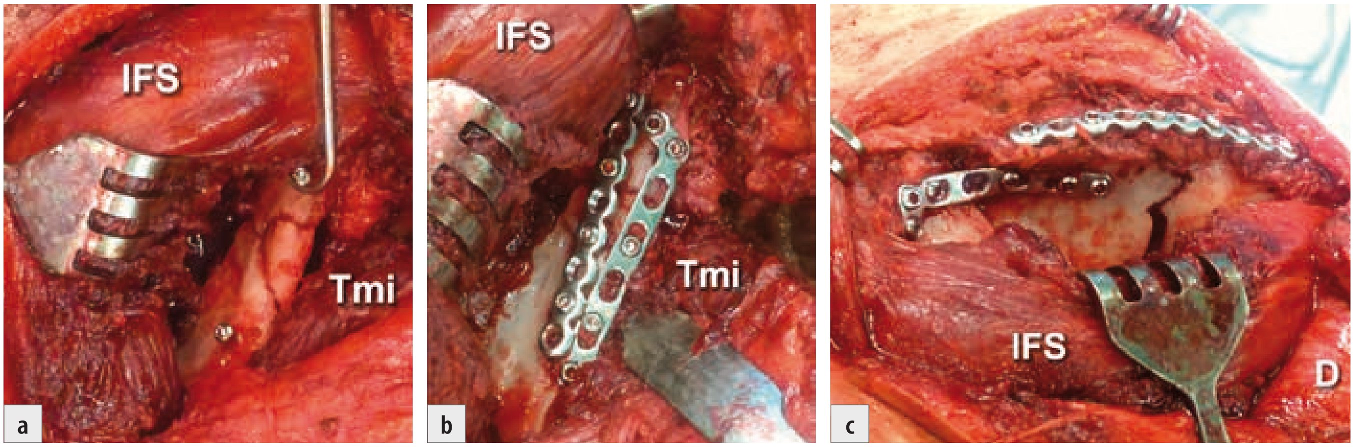

Fig. 12-29 Internal fixation of a comminuted extraarticular fracture of the scapula shown in Fig. 12-28 – technique of internal fixation: **a)** reduction of the lateral pillar; **b)** internal fixation of the lateral pillar with two 2.7-mm plates; **c)** internal fixation of the spinal pillar with a 2.7-mm reconstruction plate and of the spinomedial angle with a 2.7-mm L-plate. **D** – deltoid, **IFS** – infraspinatus, **Tmi** – teres minor.

13

SCAPULAR NECK FRACTURES

Fractures of the scapular neck constitute an important chapter among scapular injuries, intensively debated primarily in association with the so-called floating shoulder [9, 19, 26, 36, 37]. However, they remain the source of a number of issues that are yet to be fully resolved. This applies to their definition, terminology, diagnosis and classification, as well as their incidence rate.

The main source of lack of clarity around scapular neck fractures is the definition of the scapular neck, which is too general. For instance, Goss [28] described the scapular neck as "*a structure connecting the glenoid and the scapular body*". Due to the fact that the inferior rim of the scapular neck is formed also by the subglenoid lateral border of the scapular body, many authors include among scapular neck fractures any fracture line passing through this region [15, 26, 64]. Nevertheless, scapular neck fractures can be defined simply as "*extraarticular fractures of the lateral angle, separating the glenoid from the scapular body*".

Another source of confusion seems to be a non-standardized terminology. A number of authors use the general term "*scapular neck*" or *"glenoid neck"* fractures, without specifying their pattern [12, 15, 21, 54, 56-59, 64, 67, 68].

Diagnosis of scapular neck fractures used to be based in the past solely on plain radiographs that were often misinterpreted. Radiographs only show reliably, but not in all cases, anatomical neck fractures. Fractures of the surgical neck and transspinous fractures of the scapular neck can safely be diagnosed only on 3D CT reconstructions [7, 50]. Many fractures previously classified as those of the scapular neck are actually fractures of the scapular body. Therefore, all facts about scapular neck fractures presented in studies without advantage of CT examination, should be considered unreliable [21, 48, 51, 52].

In order to address all the above-mentioned issues, it is necessary to focus this chapter on fractures of the scapular neck in greater detail, including the history of their investigation [3, 6] and a detailed analysis of our own series.

HISTORY

Scapular neck fractures were discussed in the French literature as early as in 18th century [22, 62]. Du Verney [22], in 1751, was the first to describe, on the basis of autopsy findings, a scapular fracture the course of which corresponded to a surgical neck fracture. The first detailed clinical description and schematic drawing of a scapular neck fracture was published by Cooper [16] in 1822. The author used the term "*scapular neck fracture*" and the drawing shows a surgical neck fracture (**Fig. 13-1**).

Callaway [13], in 1849, discussed the terms "anatomical" and "surgical" necks of the scapula. While he considered the anatomical neck fracture to be non-existent, he presented a drawing of a specimen of a surgical neck fracture (**Fig. 13-2**). Gross [30], in 1859, published a highly realistic drawing of a surgical neck fracture (**Fig. 13-3**), which he called by the same term as Cooper [16], i.e., "*scapular neck fracture*".

Gurtl [32], in 1864, presented a detailed analysis of most of the published cases of scapular fractures, including scapular neck fractures. Unlike in surgical neck fractures, he doubted

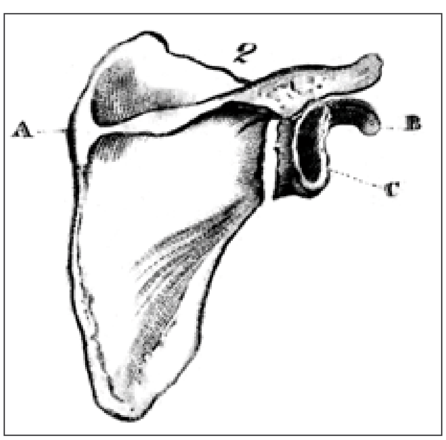

Fig. 13-1 Scapular neck fracture – Cooper, 1822 [16].

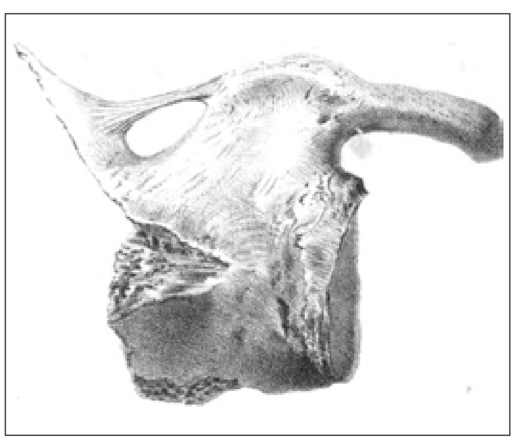

Fig. 13-2 Specimen of a fracture of the surgical neck of the scapula – Callaway, 1849 [13].

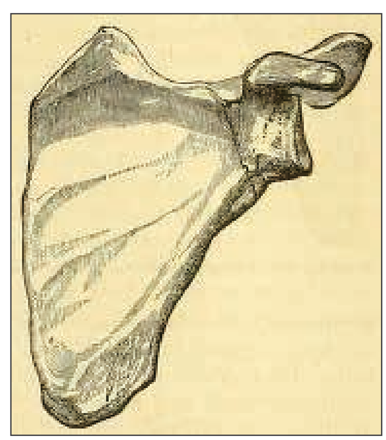

Fig. 13-3 Scapular neck fracture – Gross, 1859 [30].

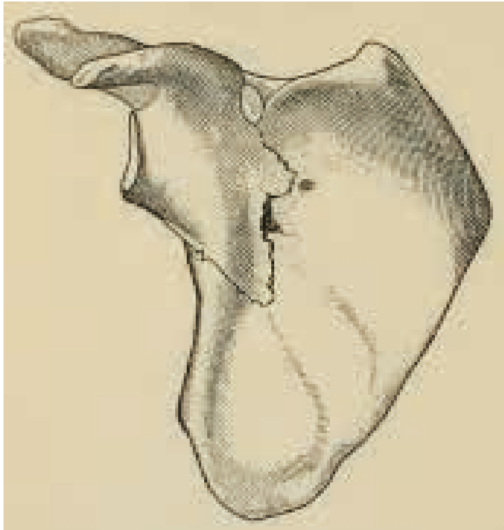

Fig. 13-4 Typical varus displacement of a surgical neck fracture – Morestin, 1894 [51].

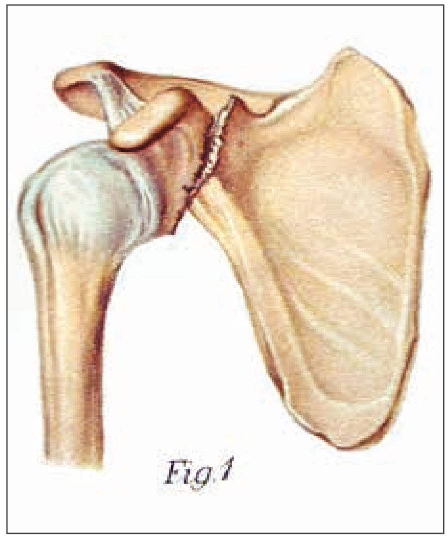

Fig. 13-5 Surgical neck fracture – Helferich, 1897 [35].

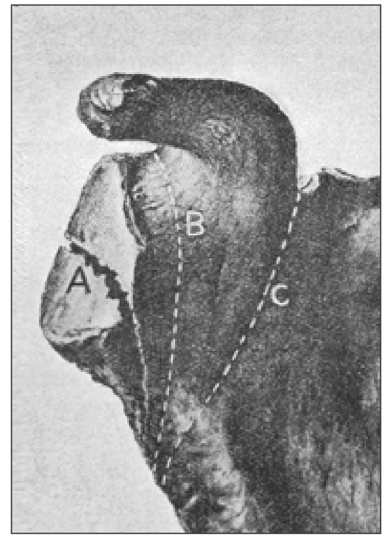

Fig. 13-6 Fractures of the lateral angle of the scapula – Rose, 1901 [66].

the existence of anatomical neck fractures because he did not encounter any bone specimen of this injury.

Scapular neck fractures were dealt with in detail, including experiments, by Cavayé [14] in 1882. Hoffa [39] briefly discussed fractures of the anatomical and surgical necks in his textbook of 1888.

Morestin [53], in 1894, presented a drawing of a typical varus displacement of a surgical neck fracture (**Fig. 13-4**). Helferich [35], in 1897, published a drawing of a displaced surgical neck fracture, including the coracoclavicular ligament (**Fig. 13-5**).

In 1901, Rose and Carless [66] published a drawing of fractures of the lateral angle of the scapula, including the anatomical neck, but without any descriptive text (**Fig. 13-6**). Plagemann [63], in 1911, also included glenoid fractures in anatomical neck fractures. His drawing of an anatomical neck fracture involving the scapular body was later used by Tanton [71] (**Fig. 13-7**) who, in 1913 [70] and in 1915, [71] discussed the importance of the coracoacromial and coracoclavicular ligaments for stability of surgical neck fractures. In addition, he described a transspinous scapular neck fracture as a variant of a surgical neck fracture (**Figs. 13-8, 13-9**).

Hitzrot and Bolling [38], in 1916, published a highly detailed study called "*Fractures of the neck of the scapula*". The authors actually dealt with all types of scapular fractures, including the intraarticular ones. The article also presents a detailed overview of the literature of 19th and the early 20th centuries, on the basis of which they were "*inclined to doubt the existence of such a fracture"*.

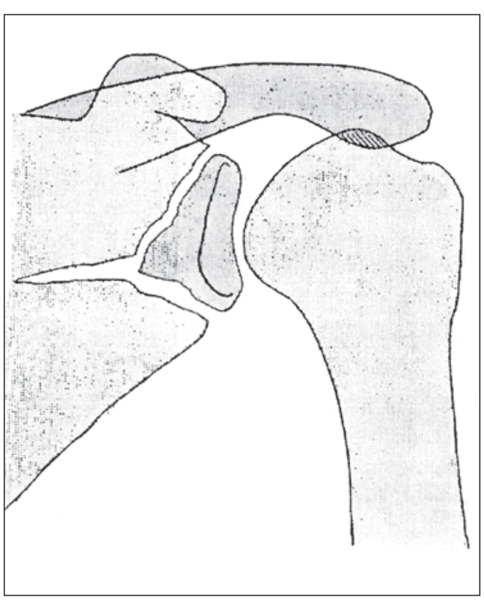

Fig. 13-7 Anatomical neck fracture – Tanton, 1916 [71].

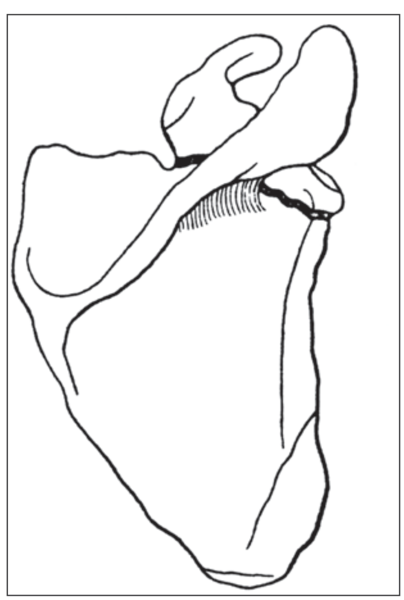

Fig. 13-8 Surgical neck fracture – Tanton, 1913 [70].

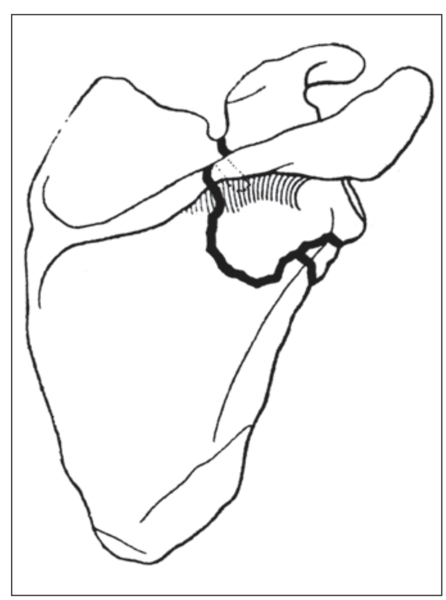

Fig. 13-9 Transspinous fracture of the scapular neck presented as a variant of a surgical neck fracture – Tanton, 1913 [70].

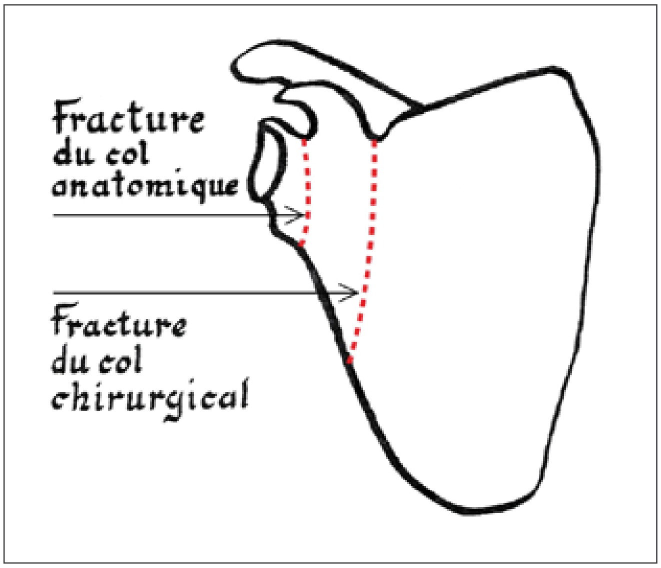

Fig. 13-10 Classification of scapular neck fractures – Decoulx, 1952 [18].

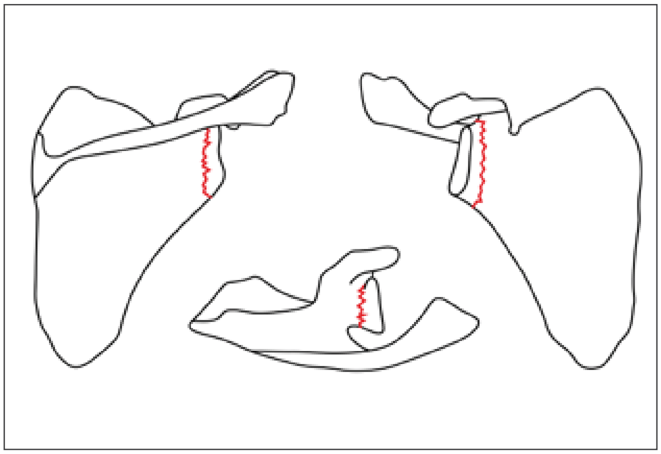

Fig. 13-11 Anatomical neck fracture – Gagey, 1984 [25].

Gioia [27], in 1928, published an extensive, today already forgotten, article on fractures of the surgical neck, in which he described in detail the pathogenesis, pathoanatomy and prognosis, as well as treatment of these fractures. Highly valuable is the historical outline documenting his profound knowledge of the literature, but unfortunately, he did not present exact citations. The article includes also the author's two cases, including radiographs, one of which clearly shows the fracture. Both patients were treated nonoperatively, one with a good and the other with an excellent result.

Perves [61], in 1934, also recorded two cases of a surgical neck fracture, which he treated nonoperatively with a good result.

Idrac [40], in 1935, described, in detail, the operation on a surgical neck fracture via the Dupont-Evrard approach. Internal fixation of the lateral pillar was performed with the use of a Sherman plate. The patient's full range of motion was restored in 5 weeks. In the discussion, the author stated that instability of the glenoid fragment is caused by rupture of the coracoclavicular and coracoacromial ligaments, in combination with the pull of those muscles attached to the coracoid. He mentioned a number of previous studies, particularly those presenting operative treatment of the fracture. In displaced fractures, he recommended internal fixation with sparing muscle insertions as much as possible, which considerably reduces the period of immobilization.

After World War II, fractures of the anatomical and surgical necks began to appear in the classification schemes of a number of authors, the French ones in particular [18, 20, 25, 72], (Figs. 13-10 through 13-12). Gagey et al. [25], in 1984, described a transspinous fracture of the scapular neck, which they called *"fractura transspinale"* (Fig. 13-13).

The first author to present radiographs of a fracture of the anatomical neck was Hardegger [32, 34] as late as in 1984! The first 3D CT reconstruction of such a fracture was published by Jeong and Zuckerman [44] in 2005.

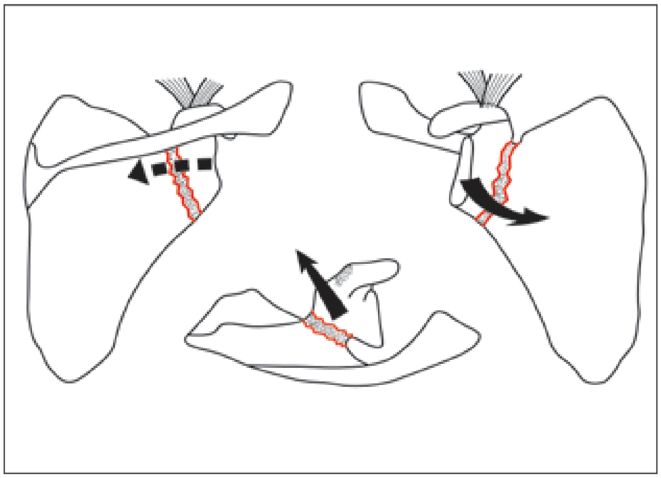

Fig. 13-12 Surgical neck fracture – Gagey, 1984 [25].

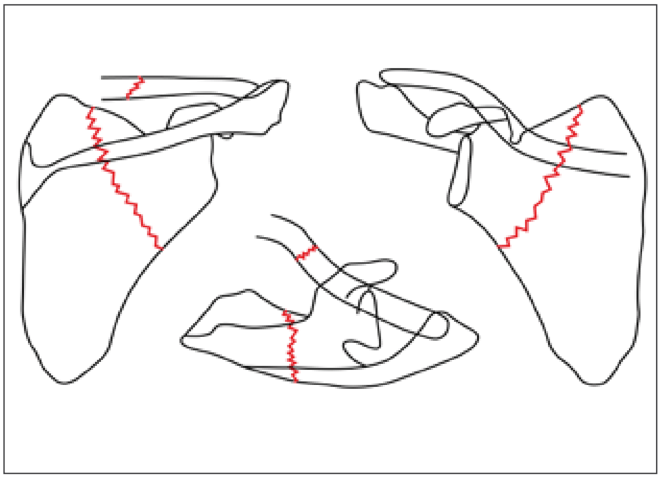

Fig. 13-13 Transspinous fracture of the scapular neck – Gagey, 1984 [25].

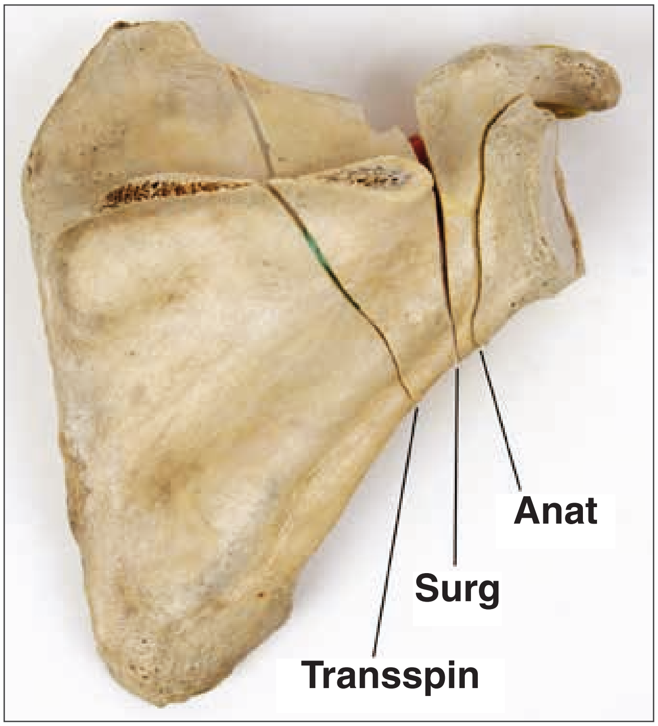

Fig. 13-19 The course of fracture lines of the basic types of scapular neck fractures in an anatomical specimen, the scapular spine was resected. **Anat** – anatomical neck fracture, **Surg** – surgical neck fracture, **Transspin** – transspinous fracture of the scapular neck.

border of the scapular body, as a rule 3-5 cm below the inferior rim of the glenoid. The incidence of such fractures may be influenced by anatomical variability of the coracoglenoid notch.

The glenoid fragment is formed by the glenoid fossa and a spike of the lateral border of the scapular body, usually 3-5 cm long, exceptionally longer. Attached to the fragment are only the long heads of the biceps and triceps.

Undisplaced fractures of the anatomical neck are stable (Fig. 13-20). In case of displacement, the glenoid fragment moves distally and into valgus and, in a majority of cases, the superior pole of the glenoid is rotated anteriorly, while the distal spike of the inferior part of the fragment moves posteriorly (Fig. 13-21) [6, 7, 45]. Arts and Louette [4] described a marked anterior angulation of the fragment with a minimal valgus displacement.

Fractures of the anatomical neck occur as isolated injuries, or in combination with other fractures of the scapula, i.e., infraspinous fracture of the scapular body, a fracture of the superior angle of the scapula, or AC dislocation [10].

SURGICAL NECK FRACTURES

In fractures of the surgical neck, the proximal part of the fracture line passes distally from the scapular notch, or close to it, through the spinoglenoid notch, lateral to the base of the scapular spine towards the lateral pillar of the scapular body, crossing it 3-6 cm below the inferior rim of the glenoid.

The fracture line in the spinoglenoid notch may entrap the suprascapular nerve [7, 11, 23, 69]. A part of the glenoid fragment is the coracoid, which is crucial in terms of the fracture stability and displacement. Fractures of the surgical neck are divided into stable and unstable, depending on the integrity of the coracoacromial and coracoclavicular ligaments, and of the coracoid (Fig. 13-22) [7, 49].

Stable fractures: If the ligaments are intact, the fracture is stable and the displacement of the glenoid in relation to the scapular body is usually minimal. However, in several reported cases, higher energy trauma resulted in posteroanterior translation of the fragments and loss of contact of the glenoid fragment with the scapular body. The glenoid fragment was displaced anteriorly and slightly medially, and its articular surface tilted posteriorly. Nevertheless, the relationship between the coracoid process, the lateral clavicle and the acromion remained unchanged. This type of displacement can be seen mainly in fractures of the sur-

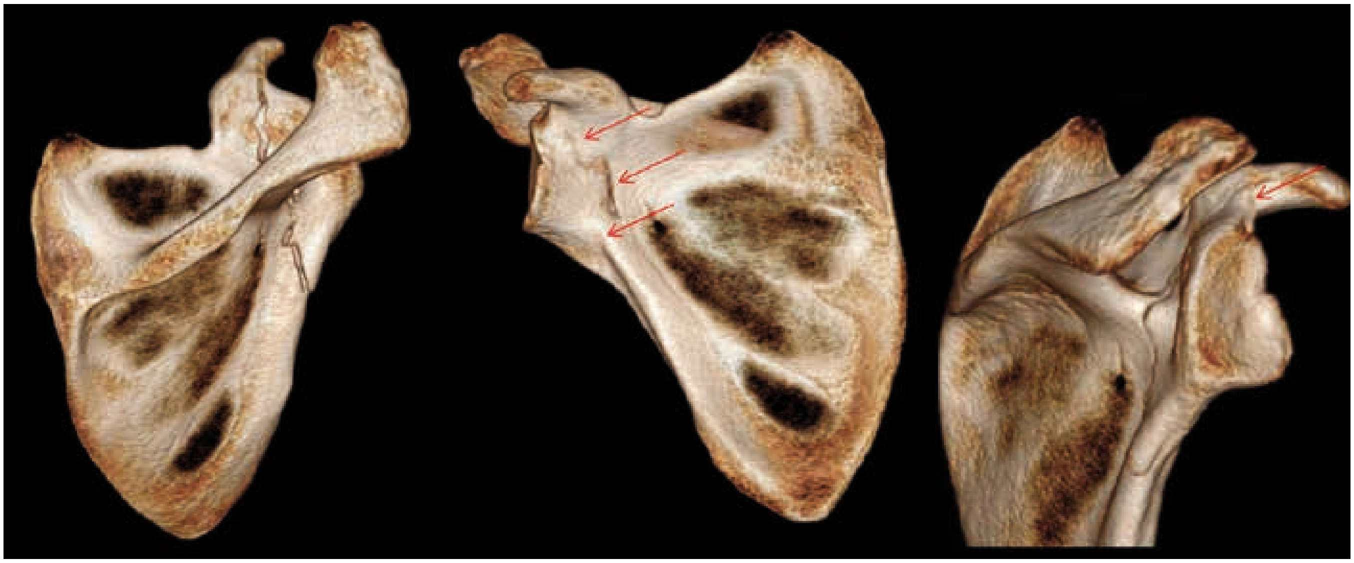

Fig. 13-20 Undisplaced anatomical neck fracture on 3D CT reconstructions. Red arrows indicate the fracture line.

Fig. 13-21 Displaced anatomical neck fracture on 3D CT reconstructions.

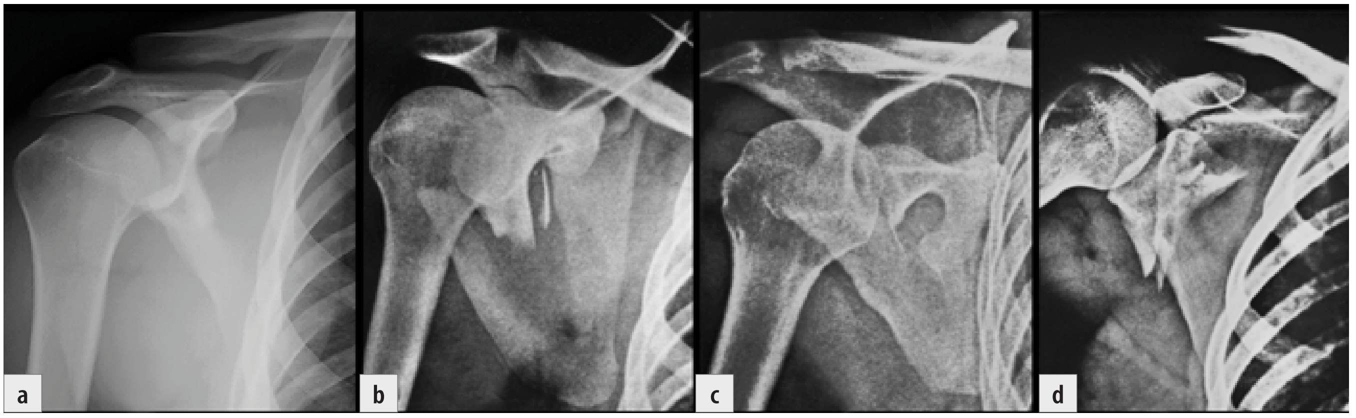

Fig. 13-22 Basic types of surgical neck fractures: **a)** stable fracture; **b)** rotationally unstable fracture (rupture of the coracoacromial ligament); **c)** totally unstable fracture, (rupture of the coracoacromial and coracoclavicular ligaments) – the ligamentous type; **d)** totally unstable fracture (separation of the coracoid) – the bony type.

gical neck that are combined with a fracture of the infraspinous part of the scapular body (**Fig. 13-22a**).

Rotationally unstable fractures: If the coracoacromial ligament is ruptured, the tip of the coracoid is rotated anteriorly and medially by pull of the muscles attached to it. The distance between the tip of the coracoid process and the tip of the acromion increases, but the intact coracoclavicular ligament maintains a normal interval between the coracoid and the clavicle (**Fig. 13-22b**).

Fully unstable fractures: These rare injuries occur in two forms, i.e., the ligamentous or the bony ones, that differ in terms of the type of displacement of the glenoid fragment.

Ligamentous instability results from rupture of both the coracoacromial and the coracoclavicular, ligaments [7, 49]. The glenoid fragment is displaced and rotated distally and medially by pull of the muscles attached to the coracoid process (the conjoint tendon of the short head of the biceps and the coracobrachialis, and the pectoralis minor). The distance between the coracoid and the clavicle significantly increases (**Fig. 13-22c**).

Extraarticular separation of the coracoid base from the upper surface of the neck is an osseous equivalent of rupture of both the ligaments. Therefore, the glenoid fragment is no longer pulled by the coracoid muscles and is displaced distally and into valgus, i.e., similarly as in a fracture of the anatomical neck. The coracoclavicular distance remains normal (**Fig. 13-22d**) [7, 49, 56].

Fractures of the surgical neck may be isolated, or combined with an infraspinous fracture of the scapular body. This type has already been described by Gagey et al. [25] (**Fig. 13-23**). Certain cases show only minimal displacement of the glenoid fragment in relation to the supraspinous part of the scapular body, and displacement of both fragments in relation to the infraspinous part of the scapular body (**Fig. 13-24**). Rarely, the glenoid fragment is displaced in relation to both fragments of the scapular body (**Fig. 13-25**).

14

GLENOID FRACTURES

Glenoid fractures are among the most severe injuries to the scapula. They comprise a heterogeneous group of injuries, the types of which differ by fracture mechanism, the extent of involvement of the articular surface, the anatomy of the glenoid fragment, involvement of the adjacent parts of the scapula and injuries to other structures of the shoulder girdle.

Depending on its extent, the injury impairs, more or less, congruence and stability of the glenohumeral joint. In spite of this, these injuries had been treated for many years non-operatively. Operative treatment began to spread increasingly in as late as the 1980s and the 1990s [7, 8, 33, 42, 47]. Currently there exist a number of studies that have clearly justified this approach to treatment in displaced fractures of the glenoid cavity [1, 2, 34, 35, 37, 42, 46, 48, 55, 60, 71, 72, 78, 92].

HISTORY

Petit [65], in 1723, was the first to mention the possibility of a fracture of the glenoid rim associated with dislocation of the humeral head. During 19th century, almost all types of glenoid fractures were described and accompanied by drawings, based on autopsy findings (**Fig. 14-1**). The only exceptions were fractures of the posterior rim of the glenoid fossa [8].

The first description of fracture of the anterior rim of the glenoid, associated with dislocation of the shoulder joint, was published by Flaubert [23] in 1827, followed a year later by Gibson [26], including a drawing. Malgaigne's atlas of 1855 [52] contains a drawing of a complex intraarticular fracture of the scapula, although without any detailed description. Neil [59], in 1858, demonstrated a specimen of a scapula with a fracture of the glenoid fossa, and a transverse fracture line separating the coracoid base, the scapular spine and the superior border of the scapula. A drawing showing a comminuted fracture of the entire glenoid was published by Gross [31] in 1859. A fracture of the inferior glenoid was described by Spence and Steell [74] in 1863, the illustration documenting their case was published by Gurtl [32] in 1864. A fracture of the superior glenoid was noted as a secondary autopsy finding by Braun [16] in 1891.

The first radiograph of a glenoid fracture, including a description of the case and the outcome of non-operative treatment, was published by Struthers [76] in 1910. In view of severity of glenoid fossa fractures, it is surprising that the first internal fixation of a glenoid fracture was probably performed and described by Reggio [70] as late as in 1938. The first pre- and postoperative radiographs of a glenoid fracture were published by Fisher [22] in 1939. Significant studies dealing with operative treatment of intraarticular scapular fractures, however, began to emerge as late as in the last two decades of 20th century [7, 8, 33, 42, 47].

EPIDEMIOLOGY

The data on incidence of glenoid fractures reported by individual authors vary [12, 39, 40, 56, 81, 82]. The lowest number, 4%, was noted by Imatani [40] in a series of 62 patients with

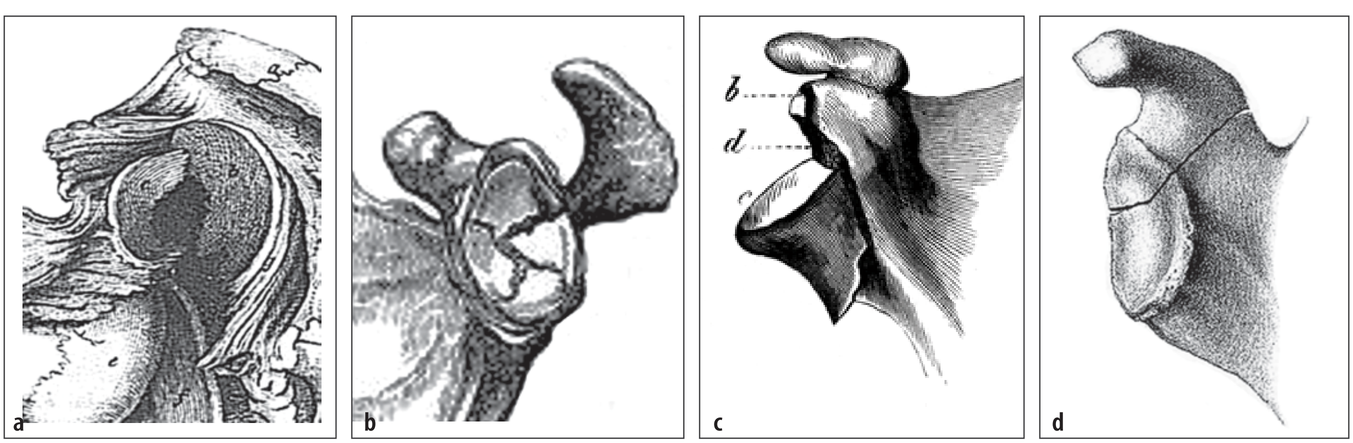

Fig. 14-1 Historical drawings of glenoid fractures: **a)** a fracture-dislocation of the anterior glenoid, Gibson, 1828 [26]; **b)** a comminuted fracture of the entire glenoid, Gross, 1859 [31]; **c)** a fracture of the inferior glenoid, Spence and Steell, 1863 [74] and its drawing published by Gurtl, 1864 [32]; **d)** a fracture of the superior glenoid, Braun, 1891 [16].

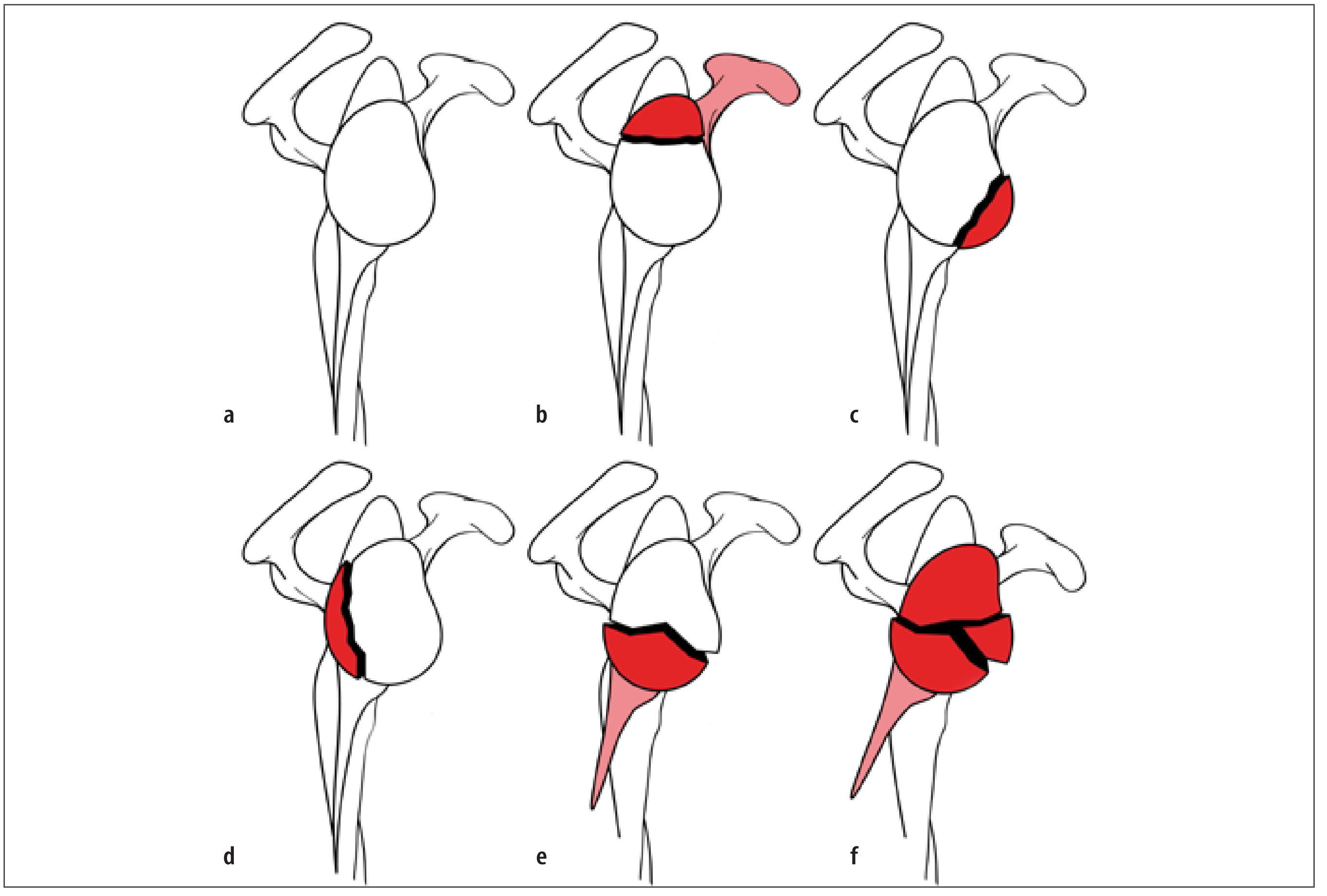

Fig. 14-4 Basic patterns of glenoid fractures: **a)** intact glenoid; **b)** a fracture of the superior glenoid; **c)** a fracture of the anterior glenoid; **d)** a fracture of the posterior glenoid; **e)** a fracture of the inferior glenoid; **f)** a fracture of the entire glenoid.

classification, presented in detail in Chapter 8. The basic criteria comprised the anatomical shape of the fragment, propagation of fracture line(s) into other parts of the scapula, the size of the separated articular surface, and the number of fragments. We also evaluated associated injuries to other parts of the scapula, the clavicle, the AC joint and the proximal humerus. Complex intraarticular scapular fractures that constitute a separate group of injuries, were excluded.

We have identified five basic types of glenoid fossa fractures, each with a typical anatomy, injury mechanism and severity (Fig. 14-4), (Table 14-1) [10]. Except for fractures of the posterior rim of the glenoid, all these types were identified on the basis of autopsy as early as in 19th century [8].

Anterior glenoid fractures

Fractures of the anteroinferior part of the articular surface are one of the most frequent injuries to the glenoid and, but for a few exceptions, they are associated with anterior dislocation of the humeral head. Despite the high variability of the shape

Fracture type	N	%	M/F	Age total	Age males	Age females	R/L	Treatment Non/Op (N)	Treatment Non/Op (%)
AG	41	32	30/11	52	48	62	24/17	28/13	68/32
PG	5	4	3/2	48	39	60	3/2	5/0	100/0
SG	22	17	16/6	43	42	47	6/16	16/6	73/27
IG	50	39	44/6	48	49	45	21/29	16/34	32/68
TG	10	8	6/4	45	39	53	8/2	4/6	40/60
Total	**128**	**100**	**99/29**	**48**	**46**	**55**	**62/66**	**69/59**	**54/46**

Table 14-1 Overview of our series of glenoid fractures. **AG** – anterior glenoid, **IG** – inferior glenoid, **M/F** – males/females, **Non/Op** – non-operative/operative, **PG** – posterior glenoid, **R/L** – right/left side, **SG** – superior glenoid, **TG** – total glenoid,

of the separated part, these fractures may be divided into three basic anatomical types, continuous with each other. *In the Goss' scheme this pattern is classified as type Ia.*

We have recorded a total of 41 such fractures (32%), 30 in men and 11 in women (**Table 14-2**). The mean age of the patients was 52 years (range, 23-82). In 38 cases the fracture resulted from a simple fall, or anterior dislocation of the shoulder joint; in only 3 cases from a high-energy mechanism. Two cases were combined with a fracture of the clavicle and 4 cases with a fracture of the proximal humerus. A total of 13 (32%) patients were treated operatively, always via the deltopectoral approach. According to the size and shape of the separated articular surface, the course of the fracture line and the overall size of the fragment, we have divided anterior glenoid fractures into three subtypes (**Fig. 14-5**).

Circumferential fracture of the glenoid rim is an avulsion of the labrum (Bankart lesion), with a thin sliver of attached bone, localized in case of the right glenoid between two o'clock and six o'clock, using the clock-face analogy. We diagnosed this type in 10 patients with a mean age of 56 years.

Fracture of the anteroinferior part of the glenoid may be divided into two subtypes according to the course of the fracture line, i.e., vertical, or oblique (**Fig. 14-6**). A vertical line passing in case of the right glenoid between two o'clock and five o'clock, separates the anterior part of the glenoid cavity. An oblique fracture line passing between three o'clock and seven o'clock, separates the anteroinferior quadrant of the glenoid fossa, i.e., that part of the fossa overhanging the scapular neck more markedly than the other parts. Sometimes, the fragment has multiple parts. It usually involves 1/5 to 1/4 of the articular surface. We diagnosed this type in 28 patients, with a mean age of 54 years.

A split fracture of the anterior glenoid differs from the above-mentioned subtypes. It results from a direct impact of the humeral head, i.e., from a higher-energy trauma. It typically occurs in younger patients. The vertical fracture line separates the anterior third to one half of the glenoid fossa. In our 3 cases, with a mean age of 30 years, 2 patients sustained an associated avulsion of the tip of the coracoid and 1 patient a split fracture of the humeral head and a transverse fracture of the infraspinous part of the scapular body.

Posterior glenoid fractures

These fractures are very rare. They are caused by posterior dislocation of the humeral head, i.e., by a low-energy mechanism. In the case of a right glenoid fossa, and again using the clock-face analogy, the fracture involves the circumference between six o'clock and eleven o'clock. The avulsed fragment may be solitary, or split into smaller pieces (**Fig. 14-7**). *In the Goss' scheme, this pattern is classified as type Ib.*

Type	N	M/F	Age total	Age males	Age females	Body fxs	Co fxs	Cla fxs	PH fxs	Treatment Non/Op
I	10	6/4	56	51	64	0	0	0	1	7/3
II	28	21/7	54	52	60	0	0	2	2	21/7
III	3	3/0	30	30	0	1	2	0	1	0/3
Total	41	30/11	52	48	62	1	2	2	4	28/13

Table 14-2 Anterior glenoid fractures. **Cla** – clavicle, **Co** – coracoid, **fxs** – fractures, **M/F** – males/females, **Non/Op** – non-operative/operative, **PH** – proximal humerus.

Fig. 14-5 Types of fractures of the anterior glenoid: **a)** a circumferential fracture; **b)** a fracture of the anteroinferior part (overhang); **c)** a split fracture of the anterior half of the glenoid fossa.

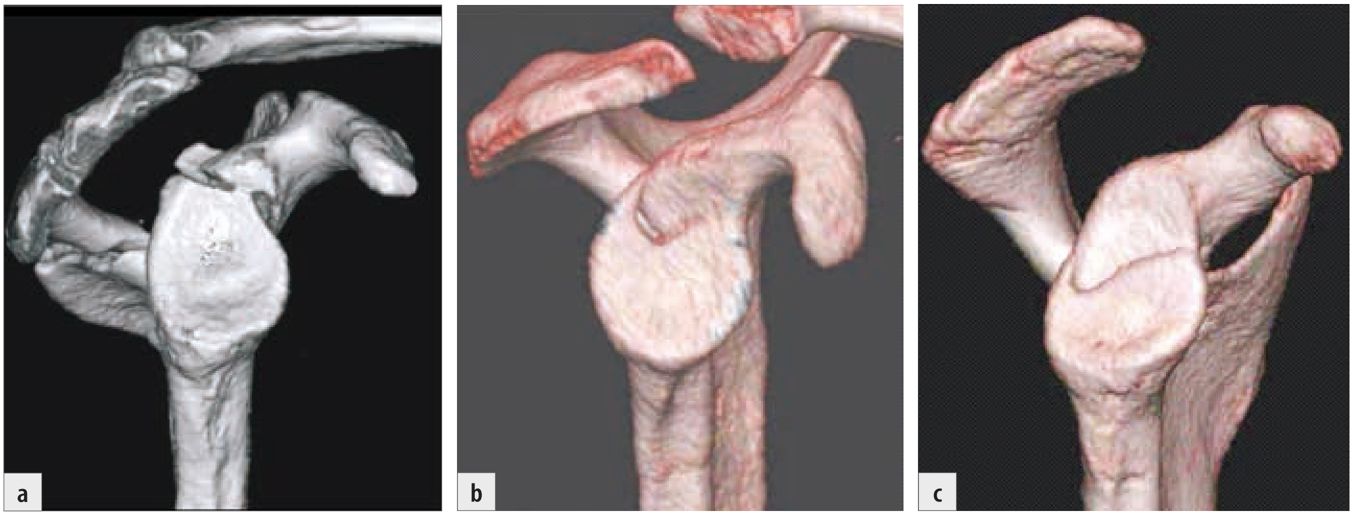

Fig. 14-8 Types of superior glenoid fractures according to the size of the separated articular surface: a) the superior quarter; b) the superior third; c) the superior half.

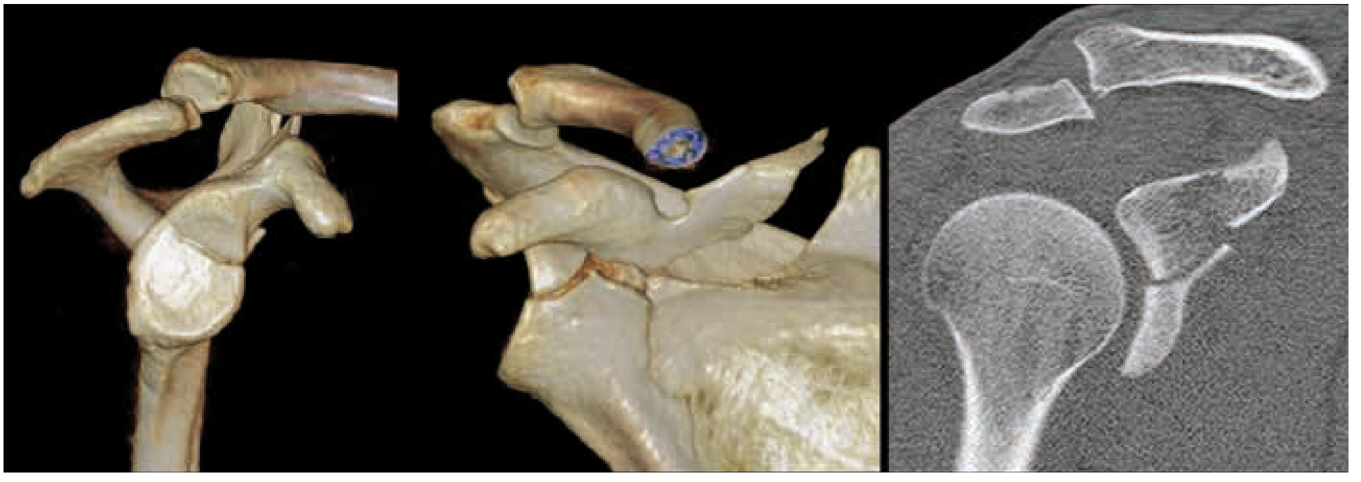

Fig. 14-9 CT scan of the superior glenoid. The fracture line extends superior to the spinal pillar. The separated fragment is displaced medially, tilted into slight varus and rotated medially; the AC joint is subluxed.

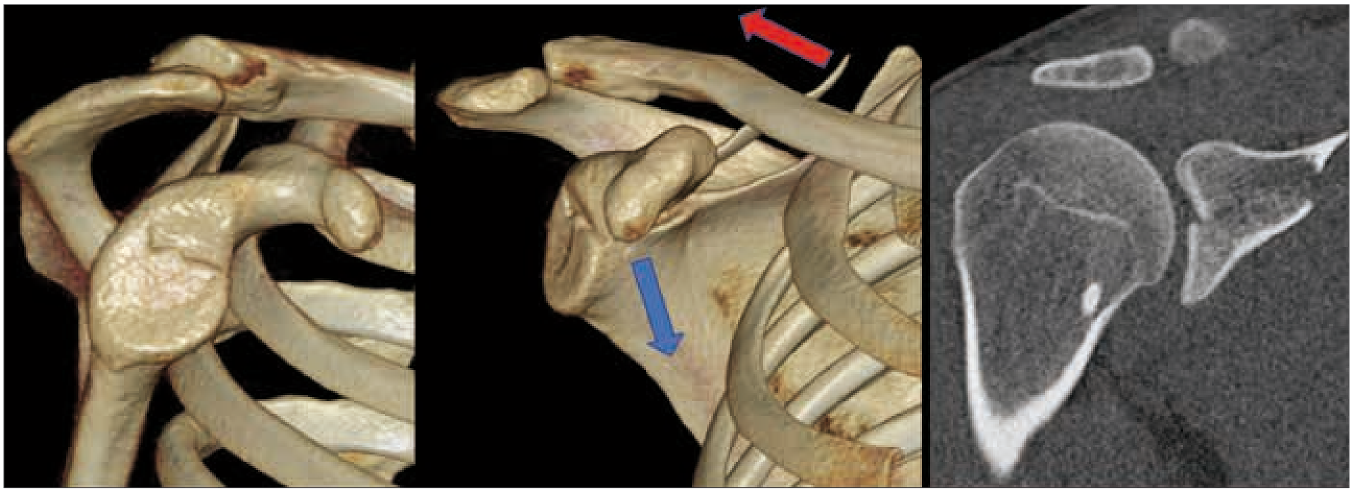

Fig. 14-10 A typical displacement of a superior glenoid fracture, with the separated fragment rotated medially (the blue arrow shows rotation of the coracoid medially, the red arrow lateral rotation of the superior border of the scapular body), tilted distally (into varus) and displaced medially in relation to the intact part of the articular surface.