Surgical Anatomy in ACL Tears

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In the previous chapters, we carefully described the anatomy and biomechanics of the anterolateral complex of the knee, particularly focusing on the anatomy and the role of the anterolateral ligament in the pathogenesis of anterolateral rotatory instability (ALRI) and the pivot shift phenomenon.

Another crucial aspect worthy of being thoroughly investigated and analysed in this chapter is the real involvement of the anterolateral complex in ACL tears and how often its injuries occur in current clinical practice.

To carefully investigate this issue, when studying the actual involvement of the anterolateral complex in the framework of ACL injuries, the most reliable sample is represented by acute injuries. At this stage, not only are the injuries easily detectable during surgery, but they are also likely linked to the initial trauma; all other tears or injuries that possibly occurred as a result of new giving-way episodes, joint instability, progressive stretching or any functional overload associated with ACL insufficiency can be reasonably excluded.

In the past, at the beginning of the modern era of knee surgery and until the late eighties, when knee surgery was still carried out through open techniques without the aid of an arthroscope and femoral tunnelling was inevitably made through an outside-in technique, exploring the external compartment was a standard practice [1]. Furthermore, according to the rules at that time, surgery at the acute stage of the injury was recommended on a large scale, as the repair and reconstruction of peripheral structures and of the ACL itself was technically easier only when an early operation was performed within a few days or weeks of the initial injury.

Moreover, early surgery was strongly encouraged, as it would result in a higher rate of repairable meniscal tears and a lower prevalence of cartilage and meniscal

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tears, resulting in a lower risk of late degenerative osteoarthrosis (DOA) [2]. With the rise of arthroscopy and the spread of arthroscopic-assisted ACL reconstructions with minimally invasive techniques, surgeons have progressively focused increasingly on the ACL. Other structures, including the anterolateral capsule and ligaments, that were not visible with an arthroscope soon became neglected and disappeared from a comprehensive description of the surgical anatomy of ACL tears. As a result, the most popular technique soon became single-incision arthroscopy-assisted ACL reconstruction with the patellar tendon, performed through inside-out femoral tunnelling in a nonanatomical vertical position (Rosenberg's technique) [3]. It took decades to realize how irrational the method was, based on inappropriate use of an incredibly useful tool, i.e. the arthroscope; in actual fact arthroscopy itself, like other revolutionary discoveries, caused some collateral damage. Moreover, due to the high risk of postoperative stiffness and arthrofibrosis observed as a result of BPTB ACL reconstruction performed soon after injury (acute phase), most surgeons suggested that a delayed operation be performed once the early posttraumatic inflammatory phase was resolved, and a full range of motion was regained [4]. As a result, acute ACL reconstruction became very unusual, and an entire generation of young surgeons lost any chances to comprehensively understand the actual surgical anatomy of ACL tears.

In contrast, since we moved to the new hospital, the entire emergency department was organized to recognize and treat all acute ACL tears requiring surgery early. Thanks to our original approach to acute ACL injuries, a prospective study on the surgical findings of ACL tears was started, allowing us to develop one of the largest worldwide experiences of ACL reconstructions performed within two weeks of the first injury. Furthermore, as our preferred technique still included a second incision on the lateral side for either outside-in femoral drilling or the inspection of the anterolateral compartment, the anterolateral complex was actually inspected in most cases.

Our first study on the surgical anatomy of ACL tears dates back to 2017, when, after a long pathway of submissions, reviews, resubmissions and a final rejection by the KSSTA, followed by lively controversy with the editor, other members of the editorial board, and reviewers, it was finally published in "Arthroscopy". In this paper [5], we presented our first consecutive series of acute ACL injuries with regular exploration of the anterolateral complex and an accurate description of the surgical anatomy. Nonetheless, at the end of the year, our study was the most quoted study in this prestigious scientific journal.

In a series of sixty cases of ACL injuries, which supposedly appeared to be isolated, with positive Lachman and Pivot Shift tests carried out under anaesthesia in the operating room, exploration of the external compartment made it possible to detect the presence of a macroscopically visible injury in the anterolateral capsular complex just beneath the fascia lata in 54 cases (90%). The fascia lata itself appeared as normal, just slightly stretched or mildly haemorrhagic but perfectly inserted to the Gerdy's tubercle in all cases (Fig. 4.1).

The patterns of ALL and capsular injuries were also classified into the following 4 types [5] (Fig. 4.2):

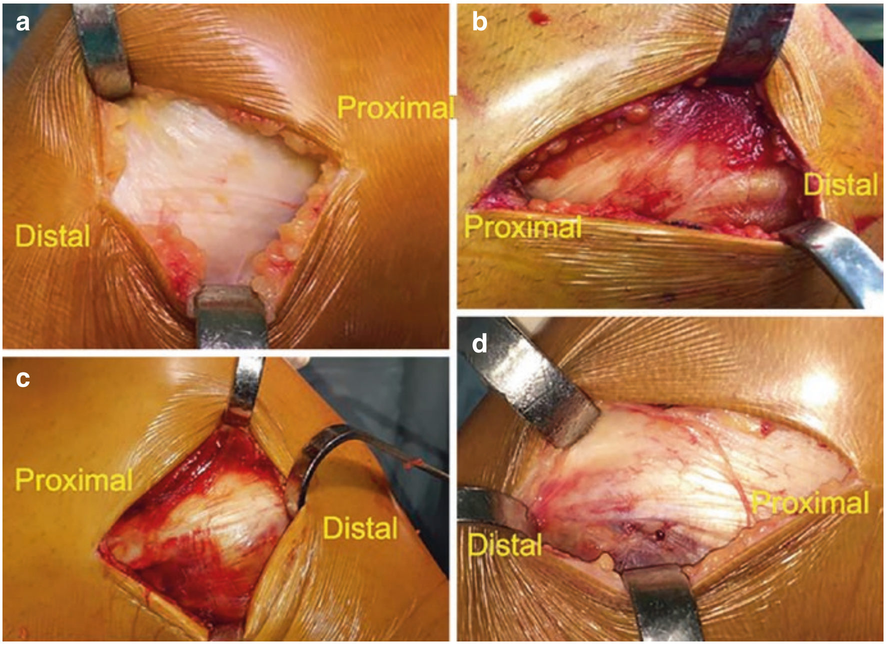

Fig. 4.1 The fascia lata as it can appear in anterolateral complex injuries: (**a**) Normal; (**b**, **c**) Mildly stretched and haemorrhagic; (**d**) Moderately stretched and haemorrhagic. In all cases, the iliotibial tract is normally attached to Gerdy's tubercle

– Type I (19 cases, 31.7%): injury characterized by visible lengthening with haemorrhagic infiltration located on the distal and anterior portions of the ALL (incomplete injury) (Fig. 4.3a1–3)
– Type II (16 cases, 26.7%): injury comparable to type 1 but more extended. The injury included the anterolateral capsule, the proximal portion of the ligament and the posterolateral capsule (incomplete injury) (Fig. 4.3b1–3)
– Type III (13 cases, 21.6%): complete ALL injury, generally located on the distal portion of the ALL, below the lateral meniscus and just above the tibial plateau (Fig. 4.3c1–3)
– Type IV (6 cases, 10%) injury characterized by insertional detachment (avulsion) with a bone fragment at the level of the margin of lateral tibial plateau (Segond's fracture)

To find comparable data, we had to refer to studies in the seventies when similar findings were reported by several authors. Hughston et al. [6], in a series of six cases of acute ALRI, reported injury of the middle third of the lateral capsular ligament in five cases. Mueller [7], in addition to recognizing the role of the anterolateral femoral ligament as the first structure involved in ALRI, described how its injuries were mostly confined to the posterior inner aspect, being either a visible avulsion from the femur or the overstretching of its femorotibial fibres. Similarly, Terry et al. [8], in a series of eighty-two cases of knee ligament injuries classified as anteromedial-anterolateral rotatory instability, reported that injuries of deep and superficial layers of the iliotibial tract occurred in 93% of the cases. Later, Puddu [9] stated that in ALRI, injuries to the anterolateral capsule occur in all cases, along with ACL tears.

After many decades, our abovementioned study brought surgeons' attention back to a long-hidden aspect (ever since the introduction of arthroscopy). Although the results were not essentially different from those reported in the seventies and eighties, this study aroused interest in the scientific community, as it reaffirmed the fact that an isolated ACL injury is an extremely rare event.

In the following years, the collection of data concerning surgical findings in acute ACL injuries has been ongoing, and recently, the results of a consecutive series of 200 cases were reported [10]. This probably represents the most conspicuous case history ever published on this kind of injury. In this study, all injuries associated with ACL tears were reported. Moreover, even the bone structure of the

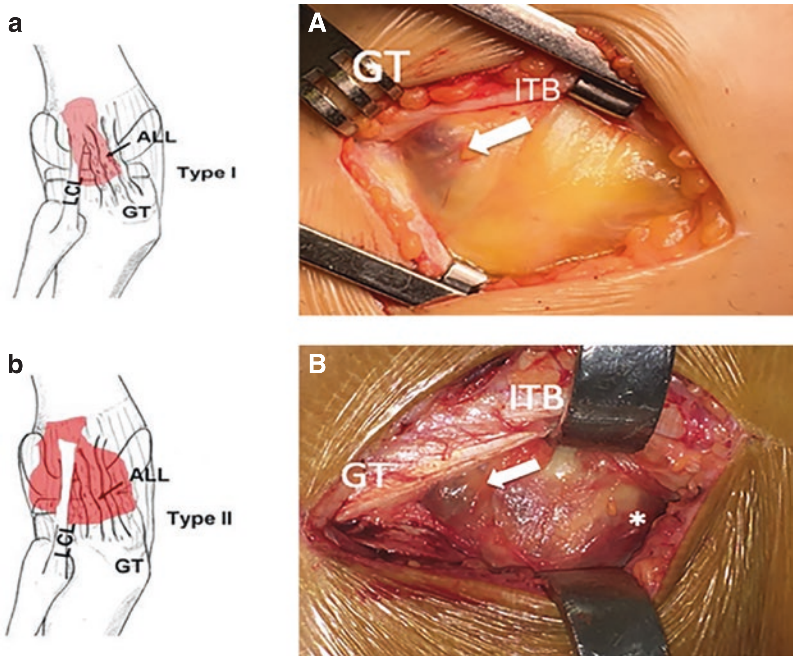

Fig. 4.2 Pattern of injuries of the anterolateral capsule in acute ACL tears. (**a**) Type I lesion: multilevel rupture in which individual layers are torn at different levels with macroscopic haemorrhage involving the area of the anterolateral ligament (ALL) and extended to the anterolateral capsule only (white arrow). (**b**) Type II lesion: multilevel rupture in which individual layers are torn at different levels with macroscopic haemorrhage extended from the area of the ALL and capsule (white arrow) to the posterolateral capsule (*). (**c**) Type III lesion: complete transverse tear involving the area of the ALL near its insertion to the lateral tibial plateau, always distal to the lateral meniscus. (**d**) Type IV lesion: bony avulsion (Segond's fracture). (Drawings courtesy of Angelo de Carli). *ALL* anterolateral ligament, *GT* Gerdy's tubercle, *LCL* lateral collateral ligament, *SF* Segond's fracture

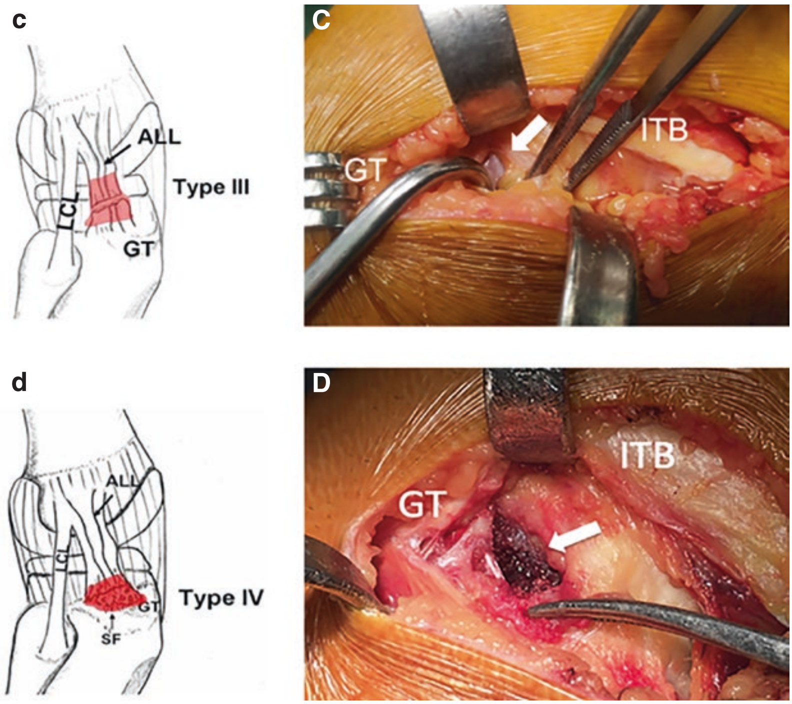

Fig. 4.2 (continued)

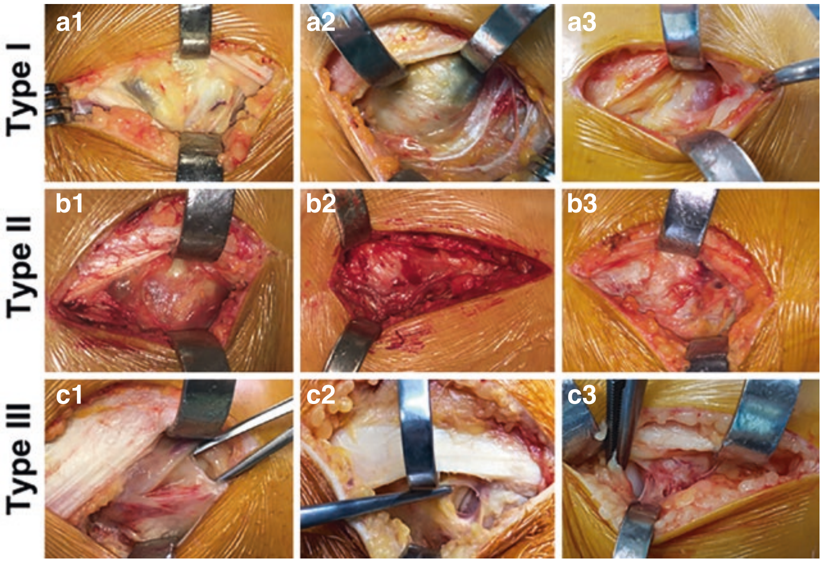

Fig. 4.3 (**a**, **b**, **c**) The different types of lesions are described. Segond's fracture (Type IV) will be better described in the next chapter. (**a2**, **a3**, **b3**, **c1**, **c2** Right Knee. **a1**, **b1**, **b2**, **c3** Left Knee)

joint was analysed to investigate its possible effect on the pivot shift phenomenon; the tibial slope, meniscal slope, and femoral condylar morphology were evaluated with MRI.

In addition to confirming the high prevalence of ALL injuries (90%) with eight percent of Segond's fractures, in this study a high prevalence of injuries of either the lateral and medial meniscus or both were reported (Table 4.1).

As a result of a particularly accurate statistical analysis, the most interesting aspect of this study was that, among all the variables (associated ligamentous injuries, meniscal injuries, skeletal structure), the only factor that could cause an explosive pivot shift was the presence of an ALL injury.

Table 4.1 Rate of identified associated injuries, stratified by explosive (grade 3) and nonexplosive (grades 1–2) pivot shift

		Total (%)	**PS grade 1-2 (%)**	**PS grade 3 (%)**
AL lesion	*n* No lesion Incomplete tear of the AL capsule Incomplete tear of the AL and PL capsule Complete tear Segond's fracture	200 26 (13.0) 34 (17.0) 66 (33.0) 58 (29.0) 16 (8.0)	165 26 (15.8) 32 (19.4) 45 (27.3) 50 (30.3) 12 (7.3)	35 2 (5.7) 21 (60.0) 8 (22.9) 4 (11.4)
AL lesion (Y/N)	*n* Yes No	200 174 (87.0) 26 (13.0)	165 139 (84.2) 26 (15.8)	35 35 (100)
MCL	*n* 0 mm 0–5 mm 5–10 mm >10 mm	200 174 (87.0) 16 (8.0) 7 (3.5) 3 (1.5)	165 146 (88.5) 11 (6.7) 6 (3.6) 2 (1.2)	35 28 (80.0) 5 (14.3) 1 (2.9) 1 (2.9)
MCL (Y/N)	*n* Yes No	200 26 (13.0) 174 (87.0)	165 19 (11.5) 146 (88.5)	35 7 (20.0) 28 (80.0)
Outerbridge	*n* 0 Grade 1 MFC Grade 2 MFC Grade 2 LFC	200 191 (95.5) 7 (3.5) 1 (0.5) 1 (0.5)	165 157 (95.2) 6 (3.6) 1 (0.6) 1 (0.6)	35 34 (97.1) 1(2.9)
Outer bridge (Y/N)	*n* Yes No	200 9 (4.5) 191 (95.5)	165 8 (4.8) 157 (95.2)	35 1 (2.9) 34 (97.1)

Table 4.1 (continued)

		Total (%)	**PS grade 1–2 (%)**	**PS grade 3 (%)**
Medial meniscal tears				
	n No Lesion Bucket handle Longitudinal anterior horn Longitudinal posterior horn Radial body lesion Ramp lesion	200 147 (73.5) 3 (1.5) 5 (2.5) 21 (10.5) 5 (2.5) 19 (9.5)	165 119 (72.1) 3 (1.8) 4 (2.4) 16 (9.7) 4 (2.4) 19 (11.5)	35 28 (80.0) 1 (2.9) 5 (14.3) 1 (2.9)
Medial meniscal tears (y/n)	*n* Yes No	200 53 (26.5) 147 (73.5)	165 46 (27.9) 119 (72.1)	35 7 (20.0) 28 (80.0)
Lateral meniscal tears	*n* No Lesion Flap handle Longitudinal anterior horn Longitudinal posterior horn Radial body lesion Root lesion	200 140 (70.0) 3 (1.5) 15 (7.5) 4 (2.0) 24 (12.0) 14 (7.0)	165 115 (69.7) 2 (1.2) 12 (7.3) 2 (1.2) 21(12.7) 13(7.9)	35 25 (71.4) 1 (2.9) 3 (8.6) 2 (5.7) 3 (8.6) 1 (2.9)
Lateral meniscal tears (y/n)	*n* Yes No	200 60 (30.0) 140 (70.0)	165 50 (30.3) 115 (69.7)	35 10 (28.6) 25 (71.4)
Medial and lateral meniscal tears (y/n)	*n* Yes No	200 5 (2.5) 195 (97.5)	165 5 (3.0) 160 (97.0)	35 35 (100.0)

AL anterolateral, *MCL* medial collateral ligament, *MFC* medial femoral condyle, *LFC* lateral femoral condyle, *PL* posterolateral, *PS* pivot shift

This aspect has also been confirmed by a previous study [11], in which a significant reduction in the pivot shift can be achieved, in acute cases, as a result of ALL repair only, despite a concomitant ACL tear.

This long-lasting effort of data analysis and collection regarding a unique case series firmly confirmed the crucial role of secondary restraint injuries in the pathogenesis of anterolateral rotatory laxity and the pivot shift phenomenon.

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