Acute and old ruptures of the extensor apparatus of the knee in adults (excluding knee replacement)

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Accepted: 24 November 2012

Summary Rupture of the extensor apparatus of the knee in adults is infrequent and dominated by patellar fracture, which in our experience is six times as frequent as quadriceps or patellar tendon tear. Patellar fracture poses few diagnostic problems and treatment is now well codified. Tension-band osteosynthesis is generally used, involving two longitudinal K-wires and wire in a figure-of-eight pattern looped over the anterior patella; sometimes, for more complex fractures, cerclage wiring is added to the tension band. Non-union is rare and generally well tolerated. Quadriceps tendon tear mainly affects patients over 40 years of age, in a context of systemic disease. Diagnosis is easily suggested by inability to actively extend the knee, but is unfortunately still often overlooked in emergency. In most cases, early surgical management is needed to reinsert the tendon at the proximal pole of the patella by bone suture. For chronic lesions, it is often necessary to lengthen the quadriceps tendon by V-Y plasty or the Codivilla technique. Patellar tendon tear, on the other hand, typically occurs in patients under 40 years of age, often involved in sports. Diagnosis is again clinically straightforward, but again may be missed in emergency, especially in case of incomplete tear. Surgery is mandatory in all cases. The procedure depends on the type of lesion: either end-to-end suture or transosseous reinsertion. In most cases repair is protected by tendon augmentation. Old lesions often require tendon graft or a tendon-bone-tendon-bone graft taken from the opposite side.

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Introduction

The knee-extensor apparatus comprises the quadriceps, patella and patellar ligament. Rupture may involve any of these, and usually results in failure of active extension of the knee, with highly disabling functional consequences. Frequency varies according to reports, but is generally considered low, especially for quadriceps tendon and patellar ligament tear. The 21-year experience of our department totals 102 quadriceps tendon avulsions, 98 patellar ligament tears and 600 patellar fractures. Quadriceps lesions classically involve rectus femoris lesions at the proximal insertion onto the antero-inferior iliac spine and distal...
insertion onto the vastus intermedius aponeurosis; as they have little impact on knee extension, they will not be dealt with in this update.

**Knee-extensor apparatus anatomy and biomechanics**

The quadriceps or femoral muscle is the extensor of the knee. When the knee is in hyperextension, the quadriceps is not required to maintain upright posture, but acts strongly to prevent falling as of the first degrees of flexion.

The quadriceps comprises four muscles, ending in a common tendon on the anterior tibial tuberosity [1]: three single-joint muscles — vastus intermedius, lateralis and medialis, which are purely extensors — and one double-joint muscle, the rectus femoris, which contributes only one-fifth of the total quadriceps force, so that tearing has little impact on knee extension force.

The patella is a sesamoid bone, part of the knee-extensor apparatus (Fig. 1). The quadriceps tendon, terminating the three vasti and the rectus femoris, is inserted onto its proximal side, and the patellar ligament, stretched between the anterior side of the patella and the anterior tibial tuberosity, is inserted at its distal pole. It enhances quadriceps action, shifting traction force forward. Expansion of the vasti and fascia lata passes forward of the patella, forming the classic fibrous pre-patellar fascia, which is involved in knee extension (Fig. 1). The patellar wings contribute to its mediolateral stability. The superior three-quarters of the posterior side is covered by very thick cartilage and has two facets, medial and lateral, separated by a blunt vertical crest; 2 to 3% of the population have an accessory ossification node at the craniolateral angle, not integrated at end of growth, known as patella bipartita (Fig. 2).

**Patellar fractures**

**Mechanism**

Fracture may be caused by direct or indirect trauma. Direct trauma is a shock to the anterior side of the knee in falling; it involves patellar compression, resulting in comminutive or stellate fracture. Although frequently without displacement, there may be major associated cartilage damage [2].

Indirect trauma involves knee-extensor apparatus tension, which may fracture the patella if it exceeds bone resistance [3].

**Classification**

Classification should consider on the one hand fracture displacement and on the other the location of the fracture line or lines. A fracture may be said to be displaced if there is a step and/or inter-fragment space exceeding 2 or 3 mm. In terms of fracture-line (Fig. 3), fractures interrupting extensor apparatus continuity (transverse [Fig. 4], comminutive [Fig. 5], superior and inferior pole fracture-avulsion [4]) and those which do not hinder extension (sagittal and fragmented fracture) are to be distinguished.

Duparc’s classification, referred to by Neyret [5], distinguishes three types of fracture: type 1, with a simple transverse line usually at the junction between the proximal two-thirds and distal third, without posterior joint-surface compaction and with variable displacement; type 2, with a type-1 transverse line associated with compaction or comminution of the distal fragment with the proximal fragment intact or at worst with a non-displaced fracture line; type 3, with compaction of the entire joint surface, stellate (comminutive) fracture and osteochondral fragments molded onto the femoral trochlea.
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Diagnosis

Patients usually present with a swollen knee, total functional impotence and active knee extension failure. Palpation confirms fracture site detachment.

In some cases, the presenting symptom is simply anterior knee pain with moderate edema and partial loss of function without active extension defect.

Clinical examination finishes with exploration for associated lesions, which are quite frequent in high-energy fracture.

AP and lateral X-ray easily confirms transverse fracture and proximal or distal patellar pole fracture-avulsion. Sagittal and fragmented fracture is better seen on skyline view. If patella bipartita is suspected, contralateral views will help diagnosis. Fragmented fractures are often associated with traumatic patellar dislocation, sometimes showing spontaneous reduction, and tend to occur on the medial side of the patella or on the posterior side as an osteochondral fracture (Fig. 6).

Treatment

Conservative treatment

Conservative treatment consists in 30–45 days’ strict immobilization in a trochanter-malleolar cast. Some authors [5,6] recommend earlier resumption of knee movement with a moveable splint for walking, which is removed for passive rehabilitation on a motorized splint not exceeding 90° flexion up to day 45 [5].

Conservative treatment should be reserved for non-displaced sagittal fracture (which in fact we manage functionally, with no immobilization), transverse or stellate fracture with little or no displacement (Fig. 7a, b), without interrupting the fibrous prepatellar fascia, partial fracture and extra-articular fracture of the distal pole of the patella.

Braun et al. [6] and Boström [2] reported very satisfactory results for conservative management of fractures with little displacement not interrupting extensor apparatus continuity.
Surgical treatment
Extensor apparatus failure is the main indication for surgical management. Surgery may also be indicated in some cases despite conserved active extension, to correct a step and/or inter-fragment space exceeding 2 or 3 mm.

Open reduction internal fixation (ORIF) is the treatment of choice for displaced patellar fracture. Several skin incisions have been described as approaches. The classic horizontal approach should be avoided, as it compromises possible future intervention on the knee. A vertical median incision centered on the patella is preferable, and can easily be extended upward or downward. Parapatellar arthroscopy is often useful to control reduction. Tension-band osteosynthesis is the most commonly employed technique [7]; in transverse fracture, it comprises reduction using pointed bone-holding forceps then positioning two parallel K-wires as close as possible to the cartilage surface, and looping a figure-of-eight in front of the patella; this is the most effective method of osteosynthesis (Fig. 8). When there are several fracture lines, and notably in stellate or comminutive fracture, assembly should be completed with one or two complementary horizontal tension-bands (Fig. 9) or 1 or 2 wire cerclages. The metal tension-band should be flush with the bone when it passes behind the K-wires, and the ends of the K-wires should be curved and turned 180° to enter the tendon. Some authors [8] have adopted woven polyester sutures, with results similar to those with metal wires. To avoid K-wire-related complications, Berg [9] recommended passing wires through cannulated screws to form the figure-of-eight tension-band (Fig. 10). We ourselves have been using wire-stopper balls for several years, minimizing the risk of skin perforation when the K-wires are turned (Fig. 9).

Isolated screwing is rarely recommended, except for certain displaced sagittal fractures.

Minimally-invasive techniques were recently recommended by Luna-Pizzaro et al. [10] and El-Sayed and Ragab [11]. Results seem promising, but it is difficult for the technique to become widespread, because it is quite demanding and the patellar wings cannot be properly sutured.

Partial patellectomy of the distal pole is an interesting alternative when it is too comminutive for stable and solid osteosynthesis, but leads to patella baja. Reinsertion is generally protected by frame-shaped reinforcement between the patella and the proximal extremity of the tibia, using either wire, hamstring tendon or a synthetic band. In some lateral sagittal patellar fractures with lateral fragment comminution, sagittal patellectomy may have much less negative impact. Saltzman et al. [12], in a series of 40 partial patellectomies with a mean 8.4 years’ follow-up, reported 78% good and very good results, with 85% quadriceps efficacy as compared with the contralateral side. One

Figure 7  a: AP view: non-displaced stellate patella fracture, managed conservatively; b: lateral view: non-displaced stellate patella fracture, managed conservatively.

Figure 8 Transverse patella fracture, managed by osteosynthesis using a tension band supported by two parallel K-wires.
of the most modern techniques is Kastelec and Veselko’s basket plate [13], enabling the distal pole of the patella to be osteosynthesized rather than resected. Total patellectomy should be reserved for exceptional cases where no satisfactory reconstruction is feasible: highly comminutive fracture or open fracture with bone loss.

Postoperative course and rehabilitation
Once solid and stable osteosynthesis has been achieved, rehabilitation can be initiated quickly, to recover satisfactory range of motion. Walking with full weight-bearing can be authorized as of the day after surgery, as long as a moveable splint and crutches are used. In the first postoperative days, it is important to combat flexion contracture and to “awaken” the quadriceps. Passive flexion on a motorized splint helps remodel the patellar cartilage. Flexion exercises, in prone position, are an excellent means of recovering good knee flexion without putting strain on the osteosynthesis. Concentric quadriceps exercises may, generally, be initiated as of postoperative day 45.

Complications
Intolerance of material is a frequent complication, due partly to the subcutaneous position of the patella and partly to the K-wires turning or migrating and to the metal twist. It may hinder rehabilitation. Skin perforation may require early removal of material, which may generally be removed as of the 6th postoperative month.

Non-union is rare, at least in closed fracture, with a rate of less than 1% in most reports, but of 7% in open fracture [3,14]. Non-union discovered late after unreported trauma, which is exceptional, may be well tolerated; if not, symptomatology associates pain, instability due to quadriceps insufficiency, active extension defect of varying severity, loss of muscle force and depression of the anterior side of the patella. Diagnosis is confirmed on X-ray. Surgical treatment is tricky, and uses three techniques. The first is to freshen the fracture site ahead of tension-band osteosynthesis using two K-wires [15]; there is a risk of disassembly due to quadriceps retraction. The second uses a composite tendon-bone-tendon-bone graft from the contralateral extensor apparatus [5], grafting the non-union with the patellar bone block. The third comprises total patellectomy using the De La Caffinière and Theis technique [16], which conserves extensor apparatus continuity, thereby allowing immediate initiation of rehabilitation (Fig. 11).

Deep infection is also rare, at least in closed fracture, where it is estimated at 0–5%, and 11% in open fracture [17].
Knee stiffness is a frequent complication, and is multifactorial. The most frequent causes are insufficient rehabilitation due to fragile osteosynthesis, patella baja, complex regional pain syndrome and abnormal soft-tissue fibrosis.

Recent reports rarely mention arthritic complications. In 1972, Boström [2] reported lower rates of osteoarthritis after conservative than surgical management at 9 years’ follow-up (16% versus 35%). Saltzmann et al. [12] reported a 53% osteoarthritis rate after partial patellectomy, at a mean 8.4 years’ follow-up.

Quadriceps tendon tear

Recent tear

Recent quadriceps tendon tear is most often found in over 40-year-olds [18] following usually indirect trauma by sudden quadriceps contraction. Tearing is usually associated with systemic disease (renal insufficiency, diabetes, rheumatoid polyarthritis, gout, hyperparathyroidism, disseminated erythematous lupus, or obesity) or long-course corticotherapy, which weakens the tendon due to fatty infiltration [18] or fluoroquinolone therapy [19]. Bilateral tears are not exceptional, at 12% in Vidil et al.’s series [18].

Diagnosis

Diagnosis is founded on the triad of sudden-onset intense syncopal pain at the moment of tearing, sometimes accompanied by a cracking sensation, failure of active knee extension, and palpable suprapatellar depression. Active knee flexion is unaffected, and quadriceps contraction induces no mobilization of the patella. Despite such fairly typical signs, diagnosis may be missed in emergency — in up to 50% of cases, according to some reports.

AP and lateral X-ray views are sufficient in normal forms, showing: a suprapatellar mass, indicating proximal retraction of the torn tendon; suprapatellar calcification, corresponding to patellar bone fragment avulsion, or dystrophic calcification within the quadriceps tendon; patella baja; and forward shift of the proximal pole of the patella, detached from the femoral trochlea (Fig. 12).

MRI should not be systematic, but is recommended when radio-clinical correlation leaves a doubt. We prefer MRI to ultrasound, as interpretation is easier for a surgeon who did not make the examination. It confirms diagnosis and specifies lesion type: complete or incomplete tear, avulsion or intratendon tear [20].

Treatment

Partial tear is managed conservatively by trochanter-malleolar cast immobilization with the knee in extension, for at least 6 weeks. The cast is then replaced by a movable splint until active extension without pain or deficit becomes possible.

Total tear is managed surgically, as early as possible (within the week following trauma), to avoid quadriceps retraction. A vertical median approach is used, centered on the proximal pole of the patella. The patellar wings are usually torn transversely and have to be sutured after tendon reinsertion. The quadriceps tendon is laced with two or three thick and preferably non-resorbable sutures. Reinsertion may use bone suture through two parallel craniocaudal tunnels drilled through the patellar body. Some authors recently suggested using anchors to reinsert the tendon, but this technique provides no benefit in terms of solidity or functional recovery [21]. Intratendon tear is relatively rare and is managed by end-to-end suture, sometimes reinforced by a reverse quadriceps tendon flap as described by Scuderi (Fig. 13) [22].

Postoperative course

The knee is immobilized in a trochanter-malleolar walking cast for at least 6 weeks. The cast is then replaced by a movable splint until active extension without pain or extension deficit becomes possible (i.e., a further 2 weeks to 1 month). Some authors recommend early rehabilitation; Rougraff et al. [23], however, found no difference in results between rehabilitation and immobilization, while there is a non-negligible risk of iterative tear if the patient is careless or falls, as is always possible, during rehabilitation itself.

Results

The series in the literature report good or very good functional results after surgical treatment of quadriceps tendon tear. Rougraff et al. [23] reported a mean satisfaction score of 8.5 out of 10 and a pain score of 8.6/10 (where 10 equals complete absence of pain). These subjective results were in line with satisfactory clinical recovery: mean knee flexion of 123° and mean active extension deficit of 2°.

Vidil et al. [18] reported 89.5% satisfaction, with very good (53.5%) or good (36%) functional results. Clinical recovery was likewise satisfactory, with mean flexion of 129°, active extension deficit of 2° and mean quadriceps force of 4.8. In 78% of cases, active extension was complete and quadriceps force was normal.
Old tear

Reconstruction of overlooked or chronic quadriceps tear is difficult; the literature generally reports poorer surgical results than in recent tear [23]. If the extremities of the tendon can be approximated, repair is relatively easy and similar to the above technique for recent tear. The interval between the extremities may, however, be too large for this, in which case the quadriceps has to be detached from the anterior, medial and lateral sides of the femur, to bring the tendon down to the patella. If the extremities still cannot be approximated, the tendon has to be lengthened, either by V-Y plasty or by Codivilla’s technique [22]. The base of the inverted V should be 1.5 to 2 cm from the proximal edge of the tear; the edges are then sutured with several stitches of thick non-resorbable
suture, and the triangular tendon flap is pulled back distally as reinforcement, with the open sides sutured edge to edge (Fig. 14).

Postoperative management is the same as for suture of recent tear.

**Patellar tendon tear**

Unlike quadriceps tendon tear, patella tendon tear more often occurs in active under 40-year-olds, usually after indirect trauma due to sudden quadriceps contraction with the knee in slight flexion (sudden impulsion, sprint, avoiding a fall, etc.). It is generally agreed that a healthy patellar tendon will not tear, and that tearing usually involves a tendon weakened by iterative microtrauma [24] or local corticoid injections.

**Diagnosis**

There has usually been sudden quadriceps contraction during a sudden impulsion, landing from a jump or stumbling on stairs, with intense pain and immediate functional impotence preventing unaided standing.

Active knee extension is impossible, except in certain cases in which the patellar wings remain intact, enabling extension with greatly reduced force. Palpation finds a sub-patellar "hole" in which the index finger can be inserted without resistance (Fig. 15).

AP and lateral X-ray confirms diagnosis, showing a patella alta (Fig. 16) in comparison to the contralateral knee. There may be bone fragment avulsion from the tip of the patella or, much more rarely, from the anterior tibial tuberosity.

Ultrasound is not very contributive in recent patellar tendon tear, but may be indicated in some chronic cases.

Likewise, MRI is not very contributive in recent tear except in case of doubt (which is exceptional). It is, on the other hand, very useful in chronic cases or in case of suspected associated intra-articular lesion, where it provides preoperative lesion location: avulsion of the patella tip or anterior tibial tuberosity or full-body tear with or without tendon laceration.

**Treatment**

Surgery is mandatory, regardless of age and physical activity, and should be as early as possible.
Repair of recent tear
Either end-to-end suture or tibial or patellar transosseous tunnel reininsertion is performed. A frame-shaped reinforcement is often added between the patella and tibial tuberosity, using either wire or, preferably, a semitendinosus band as wires tend to break, often requiring ablation.

In full-body tear, end-to-end suture is performed using thick resorbable suture; non-resorbable suture should be avoided, as it often becomes visible under the skin once the edema has resolved. It is important to check that the patella is not lowered during suturing, comparing the patella on fluoroscopy with the contralateral patella on X-ray of the knee in 45° flexion. It is in these cases that a semi-tendinosus tension band is especially useful (Fig. 17).

In proximal avulsion, the tendon is anchored to the bone by two thick non-resorbable sutures through two parallel bone tunnels to the proximal pole of the patella.

Distal avulsion is very rare in adults, but can be managed by one or two notched staples or using anchors.

Repair of old tear
End-to-end suturing is often difficult beyond 45 days after tearing [25]; the longer the time to repair, the more difficult it is to descend the patella, which has risen under quadriceps traction. Some authors recommend transpatellar traction for a maximum 2 weeks [26] to descend the patella ahead of tendon reconstruction.

Repair usefully associates tendon reinforcement such as a fascia lata [26] or semitendinosus band [25], or synthetic reinforcement such as Dacron® [27] or resorbable material such as PDS® [28].

Autograft using the contralateral patellar tendon was suggested by Dejour et al. in 1992 [29]; this is a tendon-bone-tendon-bone graft (Fig. 18) able to manage a tendon defect with a solid bone anchorage.

Other authors [30] recommended Achilles or patellar tendon allograft in some extreme situations.

Postoperative course
Care must be taken postoperatively in both recent and old tear. The quadriceps is a very powerful muscle, and sutures may break under sudden contraction, as, for example, to stop oneself falling or stumbling. Strict immobilization of the knee in a walking cast is recommended for at least 1 month, followed by a moveable splint until rehabilitation begins to restore passive flexion on a motorized splint, followed by eccentric quadriceps exercises in prone position and finally concentric exercises. The motorized splint is removed once active extension is complete, with good quadriceps contraction (often, by 2 or 3 weeks). Four to 6 months are usually needed to recover normal knee function.

Results
The vast majority of recent lesions recover good mobility and quadriceps force, despite slight residual quadriceps atrophy [26]. There would seem to be no correlation between type of tear, type of repair and clinical results; only the trauma-to-surgery interval seems to have a negative impact, with poorer results after 1 week [26].

There are no reports of large series of chronic tear, but only isolated cases using a variety of techniques. Dejour, in his original article [29], reported good knee extension in 10 out of 13 cases, with resolution of active flexion contracture. Results, however, are bound to be poorer in case of quadriceps retraction with large loss of tendon substance requiring temporary preoperative traction.

Conclusion
Knee-extensor apparatus rupture in adults is relatively rare, mainly comprising patella fracture, which, in our experience, is six times frequent as quadricipital or patellar tendon tear. In case of loss of active knee extension, surgery is mandatory, to restore quadriceps force fully. Neglected patella fracture is exceptional, whereas quadricipital or
Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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