Pectoralis major tendon rupture. Surgical procedures review.

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Summary

Pectoralis major (PM) muscle is the powerful dynamic stabiliser of the shoulder that acts as a flexor, adductor and internal rotator. The rupture of the PM tendon is a relatively rare injury that was firstly described in a French boy by Patissier in 1822 and later, in 1861, by Letenneur who reported another similiar case. To date, over 200 cases have been published. In this article we describe the clinical anatomy and the mechanism of injuries of PM and we review the surgical procedures for acute and chronic ruptures.

Key words: pectoralis major, rupture, surgical procedure.

Introduction

Pectoralis major (PM) muscle is the powerful dynamic stabiliser of the shoulder that acts as a flexor, adductor and internal rotator[1]. The rupture of the PM tendon is a relatively rare injury that was firstly described by Patissier in 1822 in a French boy who tore his tendon while he was lifting an heavy piece of beef from a hook[2]; later in 1861, Letenneur reported another similiar case[3]. To date, over 200 cases have been published[4,5]. Historical perspective of non-operative treatment in older subjects or for those with incomplete tears is prognostically unfavorable[4,6,7] due to the loss of peak torque and work deficit in shoulder adduction[8]. In this review we describe the surgical procedures used to repair the PM tendon injuries preceded by the decription of the anatomy of the pectoralis region, mechanism of injury and examination.

Clinical anatomy

PM is a pennate muscle, whose belly form the anterior wall and the fold of the axilla profile, contributing to the aesthetic appearence of the chest. The muscle can be divided in a clavicular portion (CP) and sternal portion (SP) that are morphologically different (Fig.1)[9]. Fung et al.[10] in a three-dimensional study model of PM muscle and tendon architecture, found that CP was a uniform region without further segmentations, while the SP could be divided along fascial planes into 7 muscular segments in 8 specimens and 6 segments

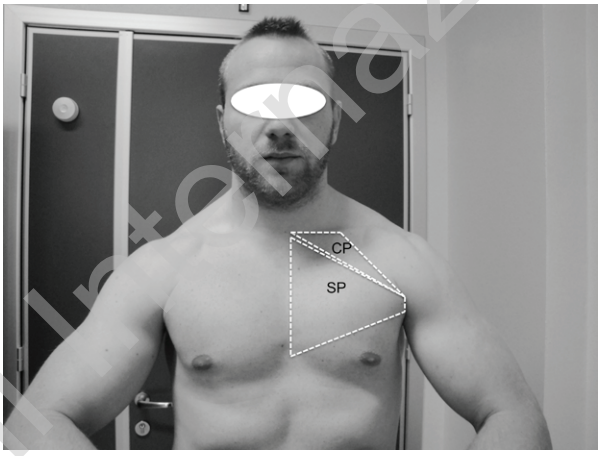

Figure 1. Schematic drawing with the two heads of the PM muscle. CP: clavicular portion, SP: sternal portion.

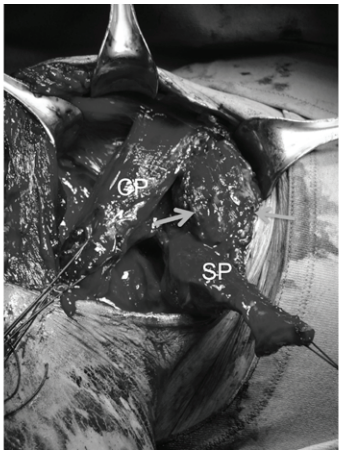

Figure 2. PM anatomy of the right shoulder. CP: clavicular portion, SP: sternal portion. The gray arrows highlights the medial muscle belly attacking to the ribs and sternum.

in 3 specimens and those segments represented about the 80% of the muscle volume. These segments were numbered from superior to inferior and attached medially from the first to the sixth rib and to the sternum (Fig.2)[10]. The morphology of the tendon has been described as bilaminar[10-12] except for Wolfe et al.[8] who found a trilaminar architecture. The anterior and posterior layers of the bilaminar model are

continuous inferiorly[10-13] as supported by embriologic findings that showed how the posterior layer arised from the inferior edge of the anterior layer[12]. Several studies excluded a twisting of the bilaminar tendon[10,12], while Wolfe et al.[8] reported twist of the trilaminar tendon, where the three layers of the tendon twist upon each other 90° before coalescing into a single tendon of insertion. The mean PM muscle volume was 283 $\pm$ 64 cm^3 with a mean volume of 55 $\pm$ 8 cm^3 (about 20% of total volume) in the CP and 228 $\pm$ 61 cm^3 (about 80% of total volume) in the SP. Proceeding towards the musculotendinous junction, the CP attached most laterally to the anterior layer of the tendon, overlapping all the segments of the SP deeply[10]. The underlying SP segments overlapped each other with the superiorly originating segments lying more superficially and attaching more laterally at the musculotendinous junction; the SP segments joining the posterior layer of the tendon partially overlapped each other at the musculotendinous junction with the more superior segments lying anterior to the inferior segments. Following the SP segments attaching the posterior tendon you can found that the most superior segment that attached medially to the inferior body of the sternum, attached to the posterior-superior part of the tendon, while the most inferior segment that blended medially with the external oblique aponeurosis attached to the posterior-inferior part of the tendon[10]. Medially, the most inferior SP segment (S7) form a fold with the adjacent superior segment, resulting in a "J" shape of half the muscle belly in cross-section. PM bloody supply derives from the thoracoacromial artery and internal mammary for 80% [14].The clavicular branch of the thoracoacromial supplies the CP of the muscle while a branch of the lateral thoracic artery provide to supply the inferior one fifth of the muscle[15]. Among these branches there are numerous anostomoses. PM receive innervation by lateral pectoral nerve (LPN) and medial pectoral nerve (MPN). LPN originates by the C5-6 roots, from the lateral cord of the brachial plexus or from the anterior divisions of the superior and middle trunks, moves inferolaterally through the clavipectoral fascia distal to the clavicle and close to the coracoid process, supplying the clavicular portion of the muscle. The MPN arises form C8-T1, from the medial cord of the brachial plexus, although its origin is more lateral in position, with respect to the thoracic wall, than that of the LPN. It course posterior to the subclavian artery, making an upward right angle around the lateral thoracic artery. A communicating branch, called "ansa pectoralis" (AP) has been described as a loop connecting the MPN and LPN giving off branches wich supply both pectoralis major and minor muscle[16].

Mechanism of injury and examination

PM injuries are male dominant and occur in patients during their second to fourth decade of life[17]; SP is the most commonly involved[8,18], CP being hit so rarely to make these lesions sometimes misdiagnosed as a muscle sprain[19-21]. PM injuries are classified on the degree as muscle sprain (type I), partial tear (type II), complete tear (type III); complete tear are further subdivided according to location in: type IIIA (muscle origin), type IIIB (muscle belly), type IIIC (myotendinous junction) and type IIID (tendinous) (Fig. 3)[18,22]. A recent subclassification introduced a bony avulsion from the

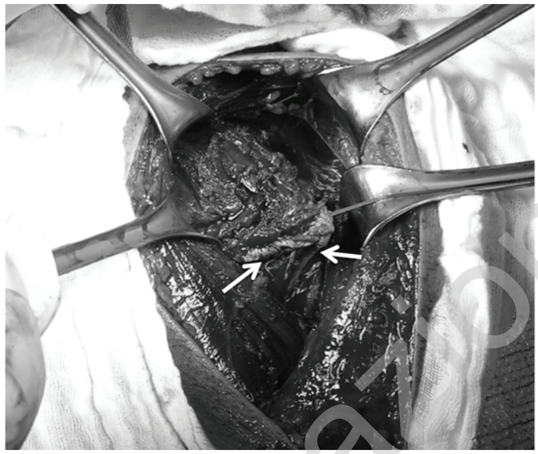

Figure 3. Acute ruptures of the SP of the PM muscle (Type IIID). The white arrows show the tendon left exposed and pulled with a suture marker.

insertion (type IIIE) and a muscle tendon substance rupture (IIIF) [5].

Type IIID is the most frequent with a rate of 65% folllowed by the type IIIC that occurs with a frequency of 27% [5].

PM ruptures have been described almost exclusively in young men weight lifters and high-performance athletes (boxing, football, water skiing, wrestling, rugby) as results of eccentric contraction of the musculotendinous unit[8,23,24]. Rare cases occurred when resisted forces are applied to the extended and abducted arm[20,25,26]. From patient's history arise that he felt in his shoulder a sound like a "pop" and moderate pain during a maximal effort, followed by ecchimosys and mild swelling over the anterior lateral chest wall and in the proximal arm (Fig. 4) [27-30]. Physical examination shows loss of the anterior axillary fold and pectoralis contour and performing the test in "prayer position" asking the patients to press the hands together with the arm adducted, the chest wall reveals to be asymmetryic [(31)], particularly evident when the chest wall moves medially. Loss of strength is notable to internal rotation of the arm when tested at neutral. Conventional X-ray is limited as diagnostic tool[25,32] while ultrasound is effective and less expensive to identify and locate PM rupture[33,34], however, MRI remains the method of choice to identify partial and complete tears[35,36] and to assess the amount of muscle retraction (Fig. 5) [36].

Surgical procedures

Conservative management is indicated in elderly patients[34,37], partial tendon tears and muscle belly ruptures[5,6]; furthermore, lower demands subjects could be cadidated for nonoperative treatment. Surgical approach is required in young active patients with acute ruptures[38], despite the chronicity does not represent a limit for tendon reattachment[5,23,28]. Tendon repair is performed on the patient in beach chair position[38,39], though supine position have been described to effectively repair PM rupture[23]. General anesthesia is recommended to have a complete muscle relaxation that facilitate the mobilization of the torn muscle in chronic tears. Deltopectoral approach and axillary approach are the most commonly used[23-25, 27, 38, 40-42], but in our[38] and

Figure 4. Ecchimosys and loss of the anterior axillary fold in a body builder with acute (2 days) PM tendon rupture.

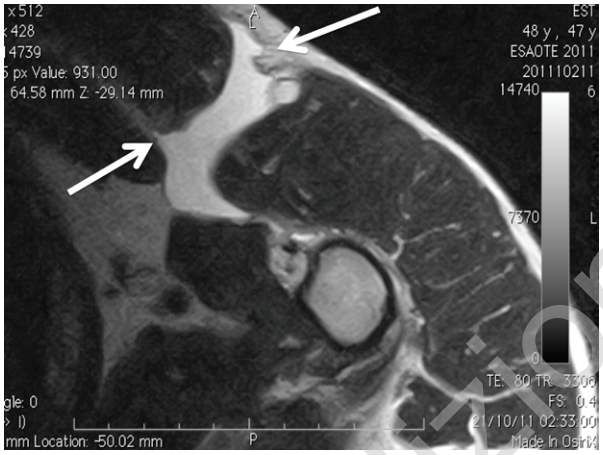

Figure 5. T2-weighted axial MRI image of complete PM tendon tear with severe tendon retraction (white arrow).

other author's[23-25,40-44] experience deltopectoral approach is preferred, with the proximal extent of the incision slightly medial to make easier access to the retracted tendon, while the distal incision should be more lateral for a better exposure of the pectoralis insertion[1].

Acute ruptures

The clavicular fibes are usually preserved and often a connection ("cord") between the medial brachial and antebrachial septum is found simulating an intact tendon[1]. In acute ruptures (< 6 weeks) the terminal end of the tendons are identified and fixed with non absorbable sutures (# 5) that are used to pull on the muscle belly. The PM insertion is checked lateral to the long head of the biceps where a residual of tendon fibers are frequently used to determine the insertion site during the reconstruction. In order to the type and the size of the suture we have to give the right tension that should not be too high and in case the tendon cannot be mobilized a partial release of the infero-medial portion of the muscle can be considered[24]. Several techniques have been described to fix the PM muscle and its tendon to the humerus[4,8,19,24,25,38,41,42,44-49]. The sutures used to reattack the tendon include size No.1 to No.5 [8,24,25,45] of both types, absorbable[8,50] and nonabsorbable[27,45]. Mason-Allen and Krachow stitches have been described to guarantee adequate strength to the knot[51], while a modified Kessler stitches in multiples layers should be preferred to repair intramuscular tears[1,45].

Techniques for tendon fixation

PM can be fixed to the humerus with suture anchors[38], bone tunnels[52] or bone trough[1].

Suture anchors

When we choose to use suture anchors, PM tendon footprint is prepared with a burr or a chisel to create an area of bleeding of about 3 cm^2, taking care not to over-decorticate that would weaken the site of insertion of the anchor (Fig. 6). Two to five suture anchors with braided No.5 non absorbable sutures are placed and the first one stich (Krackow or Kessler suture technique) is sutured through the tendon with a single limb of suture[1,38], while the second limb of the suture is brought through the tendon with a single throw and used as the post to tension and advance the tendon as the suture slides through the anchor. Alternatively, using a Mason-Allen configuration, one limb of each suture from the anchor is passed into the tendon using the three steps of the Mason-Allen configuration (1, "bottom to top"; 2, "top to bottom"; 3, "bottom to top"), and after all sutures from the anchors are passed, the free end through the anchor is pulled to tighten the tendon to its insertion[38,52] keeping the arm in neutral rotation (Fig. 7). A polypropylene net (Marlex®) can be used to reinforce the musculotendinous junction (Fig. 8). The LHB lies medial to PM foot print and therefore must be protect to avoid injury when the tendon is tied. Sutures anchors are preferred in acute tears in patient with good bone quality and little muscle tension (Fig. 9)[1]. Good to excellent results have been described in case series studies using suture anchors for tendon reattachment[1,23,38].

Bone tunnels

Bone tunnels technique begin drilling the bone tunnels in

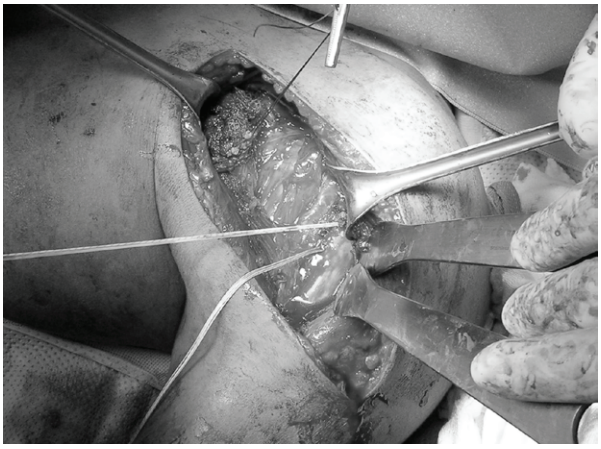

Figure 6. Left shoulder. Suture anchors are placed in the humerus insertion of PM.

Figure 7. Left shoulder. The suture limbs of the anchors are brought through the tendon using a Mason-Allen conficuration. Note the musculotendinos juncton augmentation with fascia lata allograft.

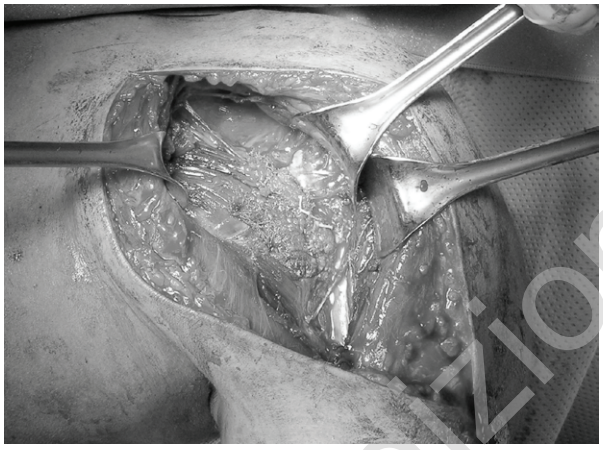

Figure 8. Left shoulder. Polypropilene (Marlex®) has been used to reinforce the musculotendinous junction.

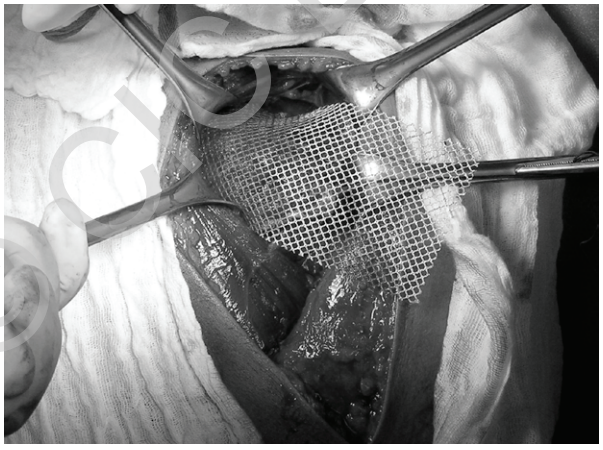

Figure 9. Left shoulder. PM tendon fixation with suture anchors in a case with acute rupture (3 weeks).

the humerus, protecting the LHB pulling it medially to the PM insertion until to obtain 2 row of 4 drill holes 2 mm in diameter, then, the strength sutures (No. 5 braided or No. 2 high strength) are passed through each of the bone tunnels and through the distal pectoralis tendon using one of the above described stitch configurations.
As for suture anchors, bone tunnels guarantee excellent outcomes for strength recovery and return to sports activity[1,23,51].

Bone trough
In the bone trough technique, we create a 3-cm bony trough with a burr at the tendon insertion site. The superior portion of the trough is under-cut with the burr. A 2-mm drill bit is used to create three to five equally spaced drill holes 1 cm distal to the trough edge. A strong No. 2 braided nonabsorbable suture is woven through the tendon, similar to the suture anchor technique. Three or four of these sutures are placed and passed through the drill holes using a suture passer[1]. Optimal tendon fixation with satisfactory subjective and objective outcomes have been reported using bone through technique[45].
Other authors, in order to strengthen the initial fixation, suggested to insert endobuttons at the end of the non-absorbable sutures and introduce the tendon stump into the trough to be transfix on the other side of the cortex using endobuttons and sutures[53]. Alternative methods described to fix acute torned tendon include the use of two 4.5 mm cancellous screws with spiked plastic washers[39] and barbed staples[47].

Chronic ruptures
In cases of chronic ruptures in which direct tendon attachment is not feasible (Fig. 10), PM can be reconstruct using tendon autograft or allograft. Zafra et al. described the use of a bone patellar autograft procured from the knee, sutured to the musculotendinous junction with the bone fragment inserted into the humerus by means of a 4.5 mm cortical screw with a washer[54]. Schachter et al. reported the use of autologus gracilis and semitendinous tendon harvested from the knee in a standard fashion and looped to form a

Figure 10. Left shoulder. Chronic rupture with completely retracted PM tendon.

standard 4-strand graft. The looped portion was stitched together with No. 2 non absorbable suture (FiberWire) and the 4-strand end left free. The sutures of the looped end of the graft were then passed through the drill holes and tied over the bone bridge[55]. Achilles tendon allograft has been described in delayed repair of PM rupture including both, sternal and clavicular portion; the graft was tubularized and sewn into the stump circumferentially beginning at the musculotendinous junction to provide approximately 3-4 cm of additional length followed by direct repair to the humerus using metal suture anchors[40]. In our study which is still in progress we found encouraging results using the fascia lata allograft for tendon augmentation (Fig. 7; Figs. 11-12) (Merolla G et al. unpublished data).

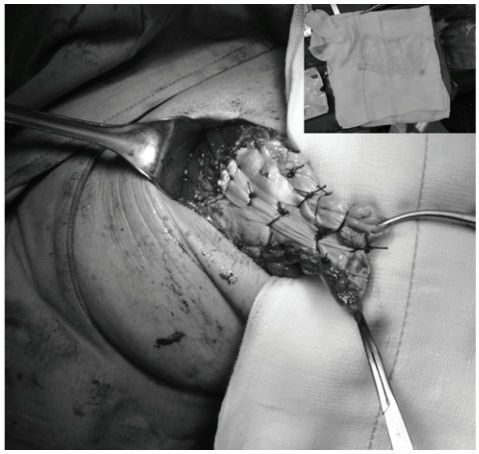

Figure 11. Left shoulder. Fascia lata allograft (box at the top right) used for PM tendon augmentation and reinforcement in a case with chronic tear.

Figure 12. Left shoulder. PM reattached to the humerus after restoration of adequate lenght using fascia lata allograft.

Postoperative care

The arm is protected in a sling for 6 weeks in both, acute and chronic repair. The patient is instructed to avoid active abduction, forward elevation, and external rotation. At 6 weeks begin gentle passive mobilization for ROM recovery. A gentle periscapular strengthening program is also added at 6 weeks. Additionally, isometric strengthening exercises are begun, although the patient should avoid shoulder adduction, internal rotation, and horizontal adduction.

Discussion

The peculiar anatomy of PM muscle make its injuries relatively rare and localized to the SP, perhaps due to the uniform architecture of the clavicular region compared with the segmentations of the SP[10]. Therefore, a meticulous analysis of the PM muscle and tendon helps in understanding the typical appearence of these lesions. The bilaminar or trilaminar morphology of the tendon, deriving mainly from the SP whose fibers attach laterally at the musculotendinous junction, accounts for the high incidence of the type IIID and IIIC injuries which also contributes the considerable volume of the sternal component representing about the 80% of the total muscle volume. The inferior fibers have been shown to be most at risk for failure owing to a mechanically disadvantageous position during forced adduction, internal rotation and flexion[8]. The CP overlap the segments of the SP deeply and this could explain the exact location of the CP ruptures at this level when they are associated with the SP detachment. Although PM injuries have been described almost exclusvely in men between 20 and 40 years of age, two reports[56,57] described this kind of injuries in the skeletally immature population. Only one case of this injury has been found in women[18] and the reason for this discrepancy remains unclear[18,45]. Simultaneous bilateral rupture of the PM is very rare with only two cases reported in the world literature[58,59].

Anabolic steroids could be implicated in tendon ruptures because of the fast build-up of muscular tissue and strength that exceeds the adaptive capacity of tendons, leaving them susceptible to injury[60,61]. Evidence of steroid doping has been reported in 12 cases of pectoralis tendon ruptures[23]. Complete PM ruptures require surgical approach as arised by several studies comparing operative vs conservative treatment[5,62,63] that all showed advantageuos functional outcomes of surgical treatment. Acute repair of tendon tears should be performed within 6 weeks to achieve an optimum mobilization of the muscle belly and reattach the tendon to its anatomic origin on the humeral shaft. The mobilization of the musculotendinous junction is more difficult in case of chronic ruptures due to the surface and deep adhesions of the chest wall; furthermore, it is important to proceed with a blunt dissection taking care not to go too deep to avoid damage of the medial and lateral pectoral nerves. Bak et al.[5] in a meta-analysis of 112 cases of PMM rupture reported that surgical outcomes of tendon reinsertion or repair were better than in conservatively treated cases and there were significantly more cases with an excellent outcome when surgery was performed within 8 weeks of injury than with delayed surgery. Additonal authors[62,63] confirmed the best results of surgical procedures compared with nonsurgical treatment in patients with complete tears. The largest case series of surgically treated patients was reported by Äärimaa et al.[23] who showed how early surgical approach was

associated with better outcome than delayed treatment. Recent research findings[38,64,65] emphasize the relevance of operative treatment of acute ruptures of the PMM in active people and athletes to obtain better outcomes in term of restoration of strength than does conservative or delayed treatment. Conversely, in a retrospective study of 17 cases with literature review, Schepsis et al.[66] found no significant subjective or objective differences in the outcome between the patients treated operatively for acute or chronic injuries, but all these patients achieved better results than patients treated nonoperatively. Antosh et al.[67] reporting the results of PM repairs in fourteen active-duty soldiers found an acceptable overall outcomes after both immediate and delayed treatment, but there was a statistically significant difference between outcomes for the immediate and delayed-treatment groups, with the immediate-treatment group having better overall DASH and Work Module scores. The method for tendon fixation remains a choice of the surgeon based on his experience and his preference for one or the other of the procedures above described. Hart et al.[68]_biomechanically tested tendon avulsion repair comparing transosseus and suture anchor repair in twelve fresh-frozen shoulder specimens. The ultimate failure load (N) was recorded for all specimens and stiffness (N/mm) was calculated from the slope of the linear portion of the force-displacement curve. They found that the mean ultimate failure load of the transosseous repairs was 611 N (SD 102) and that of the suture anchor repair was 620 N (SD 111), showing that the biomechanical characteristics of these two common repair techniques were similar. Some authors[64] suggested that the use of suture anchors aiming for intraosseous fixation helps to avoid intraoperative complications and leads to a stable condition with nearly full restoration of strength; these considerations are consistent with the results reported by Merolla et al.[38]. Among the potential complications following PM tendon repair, postoperative infection remain the most concerning issue[1,65,69,70]. A careful skin and soft tissue protection and an adequate closure in layers should minimize the potential risk of wound infection. Tendon rerupture[42,65], postoperative hematoma requiring evacuation[65], heterotopic ossifications[71] and proximal humerus fractures after PM tendon repair[72] have also been described. Although there is no description of nerve injuries following PM tendon repair, the medial and lateral pectoral nerves are the structures at risk during shoulder exposure, especially in chronic tears when the retracted tendon need to be mobilized or when the dissection proceed medial and deep to the coracoid.

Essentially, PM ruptures are rare injuries requiring immediate diagnosis to set the most appropriate treatment which is identified with surgical reattachment in case of complete tendon tears, both acute and chronic. Since no significant biomechanical difference have been demonstrated among suture anchors and transosseous repair[68] our final message is to prefer the surgical technique that “give the best in your hands” according to your experience and your knowledge.

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