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Rupture of the pectoralis major: a meta-analysis of 112 cases

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Abstract Of about 150 cases reported in the literature on pectoralis major ruptures, 108 were selected as presenting enough data to be analyzed for cause, rupture site, injury mechanism, and treatment outcome. We added data on four of our own cases reported here. All patients yet reported have been men. Rupture of the PM occurs most commonly in sports during weight training, weight lifting, or wrestling when the arm is externally rotated and abducted. Most reported ruptures are complete and are located at the insertion to the humerus. Work-related injuries occur more often at the musculo-tendinous junction. The prognosis is related neither to the age of the patient nor to the location of the rupture. Surgical treatment, preferably within the first 8 weeks after the injury, has a significantly better outcome than conservative treatment or delayed repair.

Key words Pectoralis major · Treatment · Meta-analysis

Introduction

The pectoralis major (PM) muscle is a powerful internal rotator, flexor and adductor of the arm. The origin is extensive and ranges from the anterior thorax to the clavicle. The fibers converge as a fan into three laminae that twist upon each other 90° before coalescing into a single tendon of insertion [46]. The upper portion originates from the medial end of the clavicle and upper end of the sternum and inserts at the lateral lip of the bicipital groove. The lower portion arises from the end of the sternum, the aponeurosis of the external oblique muscle and the cartilage of the first six ribs [46]. The lower portion attaches to the humerus on the superior part of the lateral lip of the bicipital groove. The tendons of the two parts of the muscle twist around each other, so that the lower (sternal) portion inserts more proximally on the humerus [46].

Until the early 1970s ruptures of the PM were reported only sporadically and were believed to be very rare [24, 25]. Over the past two decades an increasing number of cases have been added to the literature, and to date about 150 cases can be found. Whereas work-related injuries dominated in earlier reports, and patients tended to be in their 30s or older, recent reports on PM rupture are more common in athletes, and the patients are younger. Due to the rarity of the lesion it is difficult from single case reports to extract general knowledge concerning causes, epidemiology and strategies for treating the lesion. Kretzler and Richardson [17] reported the hitherto largest series in 1989, with 19 cases, and Wolfe et al. [46] reported 14 ruptures in 12 patients in association with an anatomical study.

The aim of the present study was to evaluate the causes of the injury and to determine a possible relationship of age to rupture type and location. In addition, outcome of treatment was evaluated with respect to the type of treatment and the site of the rupture.

Material and methods

A thorough review of the existing literature on rupture of the PM was carried out. We included papers reporting the following data: age and sex of the patient, injury mechanism, injury environment, rupture type and location, treatment, and description of the outcome. In patients undergoing surgery, the period from injury to op-

eration was required. These criteria produced 69 individual cases reported in the literature from 1941 to the end of 1998 [1–11, 13–16, 18–39, 41, 43–45, 47], and four of our own cases were added. Pavlik et al. [32] recently reported seven cases of PM rupture, giving specific data on one case and overall results for the whole group. After personal communication (A. Pavlik, personal communication, 1998) we received individual data on the remaining six, resulting in a total of individually reported cases. In addition, 33 cases from the three series by Kretzler and Richardson [17] (19 cases) and Wolfe et al. [46] (14 cases) were included in an overall analysis of rupture type, mechanism, location, and treatment outcome, making a total study population of 112.

The type of injury was grouped using a modification of Tietjens classification [42]: type I is a simple contusion, type II is an incomplete rupture, and type III is a complete rupture. The subcategories A–D are based on the anatomical site of the lesion: category A is a rupture of the muscle origin, category B a rupture of the muscle belly, category C, a rupture at the musculo-tendinous junction, and category D is tendon avulsion off the humerus. We added categories E and F to describe bony avulsion from the insertional site (E) and tendon substance rupture (F).

The outcome of the treatment was classified as *excellent* if the patient was pain free, had a full range of motion, no cosmetic complaints, had symmetrical manual adduction strength assessment or less than 10% isokinetic strength loss, and had returned to previous activities without restrictions; *good* if the patient had only slight functional impairment with only slight restrictions in movement or strength, and without cosmetic complaints, with symmetrical manual adduction strength, or less than 20% isokinetic deficit; *fair*, if there was an impairment of function which affected return to desired activity, that is, pain or weakness on activity, or if the cosmetic result was unsatisfactory; and *poor* in cases of treatment failure, that is, for non-surgical treatment if an operation was required after a minimum of 16 weeks after the injury, and in surgical cases if significant complications occurred, if pain or restricted range of motion persisted, or if there was significant cosmetic complaints from scarring or an inadequate repair.

Data were stored and analyzed with the Epi-Info database, version 6.01. Analysis of correlation of age, injury type, injury location and outcome of treatment was performed using Fisher's exact test for between-group comparisons, and the Mann-Whitney test for analysis of variance in non-parametric data.

Case reports

Case no. 1

A 16-year, 8-month-old male felt a twitch in his left shoulder half way through the second set of flat flies with 85-lb dumbbells. The arm gave way, dropping the weight. The next day massive swelling and ecchymosis appeared over the medial aspect of his left upper arm. The patient was treated with ice, rest and gradual return to activity, assuming a sprain. Four weeks after the accident the patient resumed strength training, but the function of the left arm remained unsatisfactory despite additional physiotherapy. The patient felt a hard lump in the left axilla, and he was unhappy with the cosmetic appearance. Medical advice was sought 10 months after the injury. Ultrasound diagnosed a bony avulsion of the PM tendon with the fragment adherent to the axillary fold. Eleven months after the injury surgical exploration was carried out. Through an axillary incision and deltopectoral approach the avulsed PM tendon was exposed and mobilized. A 5×25 mm bone block was attached to the tendon. The bone block was reattached to the humerus into a bony trough made on the lateral lip of the bicipital groove requiring rotation to restore normal insertion anatomy. The arm was placed in a sling for 3 weeks, allowing immediate passive exercises. The recovery was initially slow, but after 5 months the range of motion was symmetrical, and after 8 months strength was clinical symmetrical. At the last follow-up 17 months after surgery the patient was very satisfied with the cosmetic and the functional result. He had returned to bodybuilding at preinjury level. He complained of a slight ache while performing biceps curls. On inspection the PM and anterior axillary fold looked normal throughout the range of motion and when posing. A Cybex isokinetic strength assessment showed a 43% deficit in adduction torque to the contralateral arm at 60°/s. The result of the non-surgical treatment was classified as poor, and the result of the surgical treatment as fair.

Case no. 2

A 28-year-old self-employed male bricklayer lost balance on a tight-curve while water-skiing. On falling he dug his right dominant arm into the water and immediately felt a sharp pain. The arm rapidly swelled and turned blue. After having rested the arm for a few days and receiving a few sessions of electrotherapy, he returned to work. Due to continuing pain and weakness during work he sought medical advice 4 months after the injury. Clinically there was weakness of adduction, and the situation was cosmetically unsatisfactory. At surgery the muscle was seen to be torn at the musculo-tendinous junction and adhered to the subcutaneous tissue. There was massive scarring of the tendon which required extensive mobilization. The scarred borders were resutured over the bicipital groove. Immobilization and rehabilitation was as in the above case. Five months after the operation the patient felt equally strong in his right and his left arm, and he was using the arm normally. Fifteen months after the operation he was fully satisfied with the functional result. He played squash and performed full work duties. Manual strength testing revealed no side-to-side difference, and the range of movement was normal. Cybex isokinetic assessment showed a 6% deficit in adduction torque at 60°/s, and 13% at 120°/s. The result of the non-surgical treatment was classified as poor, while the result of the surgical treatment was rated excellent.

Case no. 3

A 41-year-old male general manager and amateur bodybuilder felt a snap in his right dominant shoulder while performing bench press. The same day he saw a sports physician who referred him immediately, having established the diagnosis of a PM rupture. At surgery the next day a clean avulsion of the PM tendon off the humerus was seen. The tendon was reinserted as described above, and the postoperative regime was as in the above cases. After 3 months he resumed weight training, and he was satisfied with the functional result. The patient chose not to have his shoulder function evaluated by Cybex assessments. His result was rated excellent.

Case no. 4

A 38-year-old man sustained a rupture of his left (dominant) PM in an attempt to perform a hand stand on a parking meter. While falling his arm was in abduction and external rotation, and he immediately became aware of pain and a disruptive sensation in the left arm. He attended physiotherapy for 3 months without any improvement. Eight months after the injury he was seen in the clinic, with difficulties managing his work as a lead lighter, lifting heavy windows. He also complained of problems riding a bike and performing sports activities. Apart form discomfort and weakness, he was unsatisfied with the deformity of the anterior axilla. Ultrasound performed prior to clinical investigation showed evidence of an avulsed PM tendon. The diagnosis was confirmed clinically. He chose to postpone surgery 2 months, until 10 months after the in-

Table 1 Injury event

Sport	Total	This review	Kretzler and Richardson [17]	Wolfe et al. [46]
Weight training	25	13	12	0
Weight lifting	22	13	0	9
Wrestling	10	8	1	1
Bodybuilding	7	7	0	0
Water skiing	6	2	2	2
Football	3	3	0	0
Skiing	2	1	1	0
Rugby	2	1	0	1
Sailboarding	2	1	0	1
Handball	2	2	0	0
Icehockey	2	2	0	0
Basketball	1	0	1	0
Parachuting	1	1	0	0
Mountain climbing	1	1	0	0
Rodeo	1	1	0	0
Sport total	87	56	17	14
Unspecified activity	8	6	2	0
Work	17	17	0	0
Total	112	79	19	14

Table 2 Injury mechanism

	Total	This review	Kretzler and Richardson [17]	Wolfe et al. [46]
Indirect	83	61	13	9
Bench pressing	29	20	9	0
Non-specified lifting	20	11	0	9
Abduction-external rotation injury	16	14	2	0
Resisting a force	11	9	2	0
Extension-adduction	4	4	0	0
Throwing	2	2	0	0
Direct	11	9	2	0
Fall	4	3	1	0
Blow or tackle	7	6	1	0
Unspecified	18	9	4	5

jury. Significant scarring was found. The tendon was seen avulsed from the insertion to the humerus, and after mobilization reinsertion as described above was carried out. Six months after surgery he was very satisfied with the result. He had no limitations and no discomfort on heavy working. He had a normal range of movement and symmetrical manual adduction strength. Two years after surgery he was still satisfied with the result. He had slight restrictions during heavy lifting but otherwise no complaints of weakness or fatigue. The result of the non-surgical treatment was classified as poor, and the result of the surgical treatment as good.

Results

Etiology

Together with the four cases reported above, a total of 112 ruptures of the PM muscle have been reported, all in males. The patients' median age at the time of rupture was 28 years (range 16–67). The injury was most commonly reported during sports activity (n = 87), followed by work (n = 17; Table 1). Work injuries constituted the majority of PM ruptures reported until 1972, after which almost all reported cases have been sports injuries, the first sports injury having been reported in 1961. PM rupture was most commonly reported in non-specified weight training (n = 25), followed by competitive weight lifting (n = 22), wrestling (n = 10) and bodybuilding (n = 7; Table 1).

Dominance was not recorded in all the papers reviewed. In 49 cases the right (n = 28) or left side (n = 21) was noted, and in 21 cases in which dominance was noted 17 were dominant and 4 non-dominant. In the remaining 9 cases nothing was mentioned about side or dominance. Wolfe et al. [46] did not record dominance; two of their cases were bilateral. Kretzler and Richardson [17] reported 11 non-dominant arms involved and 8 dominant, making a total of 40 cases in which dominance was reported, 25 ruptures the dominant arm, and 15 non-dominant.

The injury mechanism was most commonly indirect (n = 83; Table 2). The rupture tends to occur at low speed after repetitive training, preventing a weight or a heavy object from falling, with the arms abducted and externally rotated, such as during lifting and bench pressing (Table

Table 3 Classification of ruptures in 86 surgically verified cases

	Muscle belly	Musculo-tendinous junction	At the insertion	Bony avulsion	Tendon substance
Type II (incomplete)	1	0	5	0	2
Wolfe et al. [46]	0	0	0	0	0
Kretzler and Richardson [17]	0	0	1	0	0
This study	1	0	4	0	2
Type III (complete)	1	21	51	4	1
Wolfe et al. [46]	0	4	7	0	0
Kretzler and Richardson [17]	0	0	16	0	0
This study	1	17	28	4	1

2). Eleven injuries occurred during high speed, direct blows, or falls as during work (n = 7), skiing (n = 3) or contact sports (football; n = 1). Four of these injuries were recorded to occur with the arm extended and abducted.

Rupture type and location

Table 3 shows the distribution of ruptures using the modified Tietjen's classification [40]. The most common rupture site in the 86 surgically verified cases was avulsion of the tendon at the site of insertion (types IID and IIID, n = 56), followed by rupture at the musculo-tendinous junction (types IIC and IIIC, n = 21). Bony avulsion was seen in four, ruptures in the tendon substance in three, and ruptures in the muscle belly in two. There was a tendency for bony avulsions to occur in younger individuals (mean age 26 ± 13.1) than tendon avulsions (mean age 34.0 ± 10.8, P = 0.23) and ruptures at the musculo-tendinous junction (mean age 32 ± 11.1, P = 0.33). Rupture at the musculo-tendinous junction was more commonly related to work (41%) than to sport (31%; P = 0.42). Of 51 cases with consistent information in which the speed of the injury could be linked to the location of the rupture, 33 occurred during high-speed (water skiing, falls, violent trauma), and 18 during low-speed maneouvres (weight training, bench pressing etc.). There was a tendency for ruptures at the insertion to occur during low-speed injuries (74%) and ruptures at the musculo-tendinous junction to occur at high speed (44%); however, the differences were not statistically significant.

Treatment and timing of surgery

There were data on treatment and outcome in 72 patients (Table 4). Treatment was either reinsertion or repair in 57 and conservative in 15. The outcome of surgical treatment was substantially better, than in conservatively treated cases (excellent or good: 88% vs. 27%, P = 0.003). Nine of the surgical cases with treatment delay of more than 16 weeks had initially been treated conservatively, with a poor result. When corrected for this, the outcome of surgical treatment is even more superior, 90% being excellent or good compared to 17% in conservatively treated cases (P < 0.00000001; Table 4). The delay to surgery was least in cases with excellent (mean 2.3 ± 4.3 weeks) or good result (mean 10.5 ± 15.7 weeks; P = 0.14) while patients with a fair result had had their surgery after 13.4 ± 20.6 weeks (P = 0.28). There were significantly more cases with an excellent outcome of surgery performed within 8 weeks of the injury than with delayed surgery (Table 4; P = 0.01). Patients with an excellent outcome (mean age 27.2 ± 6.3 years) were younger than those with good (35.9 ± 12.5, P = 0.08) or fair outcome (32.0 ± 9.9, P = 0.07). There was no difference in outcome between the different sites of rupture.

Table 4 Outcome in relation to total treatment, primary treatment (< 16 weeks after the injury) and delay in surgical treatment

	Excellent	Good	Fair	Poor
Total treatment (n = 72)				
Surgical (n = 57)	28	22	5	0
Conservative (n = 15)	0	4	11	0
Primary treatment (n = 72)				
Surgery (n = 48)	27	16	5	0
Conservative (n = 24)	0	4	11	9
Delay in surgical treatment (n = 57)				
0–8 weeks (n = 45)	26	14	5	0
9–52 weeks (n = 12)	2	8	2	0

Discussion

In 1950 Hayes [11] reported 22 cases of PM rupture in literature from 1822 until 1946, including two of his own. Twenty of the cases in this review are not reported here, as the cause and the treatment options are mainly of historical interest. Most PM ruptures reported in the nineteenth century were related to horse accidents, and the first case described by Patissier in his thesis in 1822 had a rather dramatic outcome [11, 31]. The patient, "a very strong butcher boy" died shortly after the incident, possibly due to an infected hematoma [31].

Rupture of the PM has been reported exclusively in males, the youngest so far has been our patient (case no. 1) aged 16 years. Weinlechner [45] reported two infants with possible ruptures occurring during delivery, but it is possible that one or infants had congenital absence of the PM muscle [11], as later described by Gudmundsson [10].

Rupture of the PM is most commonly reported in weight lifters, bodybuilders, wrestlers and individuals performing weight training. The injury has been incorrectly reported by some authors as occurring during swimming and boxing. In the first case the injury occurred during a push-up maneouvre from the pool [28], and both boxers reported the rupture occurred during weight training [1, 47]. The bench press is the most commonly reported activity leading to injury. During the bench press the arms are abducted and externally rotated, and the PM muscle is under tension and contracts during the lift. When the weight is taken down, the PM helps during the braking motion, preventing the weight from falling down on the chest. If this motion is uncoordinated due to fatigue or weakness, most individuals try to avoid the impact of the weight by letting it slip to one side. This produces a sudden contraction in the PM a muscle while under tension, and this might lead to rupture [35]. Wolfe et al. [46], in a cadaver study with an experimental set-up mimicking a

bench press, showed that the short, inferior fibers respond disproportionately during the final 30° of humeral extension, making them susceptible to injury.

Kretzler and Richardson [17] reported the rupture to be more common in the non-dominant arm, but we found no preference of the injury to the dominant arm. The majority of activities at which the rupture has been reported are ambidextrous activities in which both arms are used equally. The rupture type and site is influenced by the large number of surgically reported cases. The type and rupture site of the cases treated conservatively may be less precise than the surgically verified cases, and insertional site ruptures are common among surgically verified cases, as this rupture probably is clinically more obvious and also accounts for a larger amount of disability. The most frequent site of rupture of the PM tendon is at the insertion on the humerus, accounting for 58% of those confirmed at surgery, while ruptures at the musculo-tendinous junction are reported in 31%. This is in contrast to the experimental data reported by Wolfe et al. [46], who found that in cadavers the most frequent site was at the musculotendinous junction. This discrepancy can be explained by the age of the cadavers (58–63 years), and that it is difficult to mimic reality because ruptures in living humans probably occur in weakened and fatigued tissue. In the clinical series of Wolfe et al. four ruptures were seen at the musculo-tendinous junction, compared to 3 at the insertion [46]. In 1970 Park and Espinella [30] reported that no total ruptures occurred at the junction, but that 6 of 19 partial ruptures had occurred at this junction. We found that rupture at the musculo-tendinous junction was more common with work-related accidents, and that most insertional ruptures were related to sport, but the difference was not statistically significant. The speed of the force producing the rupture may influence the rupture site. Work injuries are often associated with high speed, with ruptures at the musculo-tendinous junction being more common. Most reported PM tears in sports, as during wrestling, weight training or bodybuilding, occur at low speed, and are located at the insertion.

Four individuals in the study of Wolfe et al. [46] admitted previous use of anabolic steroids. In association with vigorous strength training intake of anabolic steroids may increase muscle strength disproportionate to the strength of the tendon, of the musculo-tendinous junction, and of the insertional site, making these tendons more susceptible to injury. A biomechanical and biochemical analysis of the effects of anabolic steroids on rat tendons showed that anabolic steroids produce a stiffer tendon that absorbs lesser energy, and fails with lesser elongation [12]. The tendon strength was unaffected, and the ultrastructural effects were entirely reversible on discontinuation of the steroids [12].

There are some limitations involved in a meta-analysis based on a literature review. One is that the distinction between incomplete and complete ruptures cannot be made if the diagnosis is based purely on a standard clinical examination. In particular, ruptures at the musculo-tendinous junction might extend into the insertional area, as in our case no. 2. Diagnosis may be difficult. Often the disability is not obvious after the acute stage has passed. In the acute stage ecchymosis and swelling is present, together with pain with movement. Radiographs may show a bony avulsion, but this is rare [22, 26, 28, 44]. Absence or a change in the shadow on radiographs of the PM muscle may raise the suspicion of a rupture [7, 8, 23, 24]. Ultrasound was helpful in our case no. 1, and as reported earlier [21]. Magnetic resonance imaging (MRI) has been reported to be valuable [2, 26, 27], but the rupture may not always be visible with this examination [1]. Ohashi et al. [27] reported four patients, of whom three had MRI, and one computed tomography. Only one patient had surgery to confirm the MRI findings [27]. No studies have yet demonstrated the ability of MRI to distinguish between complete and incomplete ruptures, which might be helpful in the treatment strategy.

Associated injuries are rare. Arciero et al. [2] reported a PM rupture with simultaneous anterior dislocation of the glenohumeral joint, and in one case of a rerupture of the PM after surgical repair the prognosis was affected in the last instance by an associated rotator cuff injury.

Some 20 years ago the treatment strategy of the PM rupture was still a controversial issue. Most authors now recommend surgery for all complete tears in order to restore full strength and function and to resume athletic activity in individuals who require full use of their upper extremity [1, 4, 5, 17, 21, 25, 32, 36]. Our study confirms that, independently of the patient's age and the type of rupture, reinsertion or repair before 8 weeks results in a significantly better outcome than delayed surgery or conservative treatment. When discussing surgical versus conservative treatment for this lesion, it is important to remember that a vast number of cases in the literature undergoing delayed surgery are actually failures of conservative treatment. When outcome was corrected for failed "unreported" non-surgically treatment cases, the difference in outcome between surgical and conservative treatment was even more obvious.

If the cases reported in the literature over the past 20 years are representative of the typical PM rupture, there seems to be no indication for non-surgical management of this lesion. PM rupture is reported to occur mostly in weight lifters, wrestlers and bodybuilders, and these all require normal function and cosmetic appearance of their PM muscle. Conservative treatment, however, might be satisfactory in elderly and inactive persons [46]. Reports concluding that conservative treatment is an option note that patients regain nearly full adduction strength, but most studies evaluating the results with isokinetic strength testing show a significant loss of torque with conservative treatment [25, 40]. Liu et al. [21], Pavlik et al. [32] and Kretzler and Richardson [17] reported significant im-

provement in isokinetic torque and work from preoperative to follow-up assessment after surgical repair. In two of three cases of conservatively treated incomplete ruptures Roi et al. [37] showed statistically significant lower isokinetic adduction strength to the healthy arm.

Bias may exist in the reported cases for both surgical and conservative treatment options, as it is more likely that successfully treated cases are reported than failures. Complications after surgical repair have not been reported. Most authors use an axillary approach or a distally extended anterior deltopectoral approach. In many instances a large hematoma is found. When surgery is delayed more than 8 weeks from the time of injury, the risk of complications increases as a result of increased surgical exposure due to significant scarring and retraction of the muscle. A variety of methods and fixation devices have been described to reinsert the tendon into the humerus. The most frequent method is suturing the tendon into a trough lateral to the bicipital groove [17]. Screw and washer fixation [15], barbed staples [9], and suture anchors [26] have proven effective. Ruptures at the musculo-tendinous junction are adapted with mattress sutures. McEntire et al. [25] reported of a case of a rerupture at the insertion 3 years after reinsertion, with pull-out wire after a new injury [25].

In primarily conservatively treated cases, a large hematoma may give rise to rare but serious complications. Apart from the original report of Patisserie in 1822 [31] another two cases of an infected hematoma following conservative treatment of PM rupture have been reported [29, 30]. One patient died of the infection [30], and the other recovered completely after surgical revision and antibiotic treatment [29]. Purnell [34] reported myositis ossificans as a complication of PM rupture. The patient presented 4 months after the injury with a tender lump in his left shoulder measuring 5 cm. After surgical resection the symptoms were completely relieved [34]. As a rarity, Smith [41] reported the development of a rhabdomyosarcoma in a 10-year-old PM rupture.

In conclusion, ruptures of the PM are reported mainly in individuals engaged in weight training activities. Diagnosis should be made within the first weeks to initiate treatment. MRI does not seems superior to clinical or ultrasound assessment. Surgical treatment, preferably within the first 4–8 weeks, is associated with a better outcome than conservative management. Adduction and internal rotation strength can be regained, vigorous upper extremity demanding activities at high level can be resumed, and a satisfactory cosmetic result is more likely.

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