ORIGINAL RESEARCH

Pulley Injuries in Rock Climbers

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Objective.— The closed traumatic rupture of finger flexor tendon pulleys in rock climbers appeared as a new complex finger trauma in the mid 1980s. The objectives of this study are to characterize this injury and to describe diagnostic and therapeutic guidelines. A grading system for the severity of pulley injuries was developed and used to set therapeutic pathways.

Methods.— Six hundred four injured rock climbers were prospectively evaluated from January 1998 to December 2001 with a questionnaire and standard examination protocol. Diagnostic ultrasound was performed in all rock climbers with finger injuries; if necessary, an additional magnetic resonance imaging was done. All pulley injuries were graded according to an introduced pulley-injury score (grade 1–4).

Results.— Three of four of the most frequent injuries were related to the fingers: pulley injuries accounted for 20%, tendovaginitis for 7%, and joint capsular damage for 6.1%. One hundred twenty-two (20.2%) rock climbers presented an injury of the flexor tendon pulley system, 48 had pulley strains, and 74 had ruptures (a single rupture in 90.5% and multiple pulley ruptures in 9.5%). According to the pulley-injury score, 39% were grade 1, 25% were grade 2, 30% were grade 3, and 6% were grade 4 injuries.

Conclusions.— Pulley injuries were the most frequent injuries in rock climbers. Whereas grade 1–3 injuries respond well to conservative treatment, grade 4 injuries require surgical repair. We recommend the “loop and a half” technique of Widstrom and colleagues and, alternatively, the Weilby repair. We also recommend postoperative initial immobilization and early functional treatment under external pulley protection.

Key words: pulley rupture, sport climbing, rock climbing, flexor tendon

Introduction

Since Bollen^{1,2} and Tropet et al³ first reported in 1990 the closed traumatic rupture of a finger flexor tendon pulley in rock climbers, further reports have given various diagnostic and therapeutic recommendations. Although the open injury of the pulley system leads to a primary reconstruction,⁴ there are no clear guidelines for the procedure with a closed pulley rupture. Whereas the indication for a surgical repair was further spread in the early 1990s, now a nonsurgical approach, at least for a single rupture, is standard.^{5,6} This attitude is based on biomechanical analyses of the flexor tendon pulley system^{7–10} as well as the very good functional results of many rock climbers, who underwent only self therapy after pulley rupture. The objectives of this study are to

determine the frequency of this injury and to give diagnostic and therapeutic guidelines. A severity grading system that can be used to guide treatment of pulley injuries is presented.

Methods

We prospectively evaluated 604 injured rock climbers during a 4-year period (January 1, 1998–December 31, 2001). Four hundred nineteen (69.4%) athletes were seen during clinical work and were evaluated with a standard questionnaire and examination protocol. One hundred eighty-five (30.6%) athletes were seen during the sport medical care of national (National Championships) and international (World Cup, World Championships) climbing competitions. For evaluation of the climbing difficulty level, the Union Internationale des Associations d’Alpinisme (UIAA) scale was transferred

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Figure 1. Diagnostic and therapeutic algorithm in suspected pulley injury.

into the metric scale (eg, UIAA 9– = metric 8.7, UIAA 9 = metric 9.0, UIAA 9+ = metric 9.7). The UIAA scale, ranging from grade 1 to 11, is used for classification of the difficulty of a climb, with grade 1 being the easiest and grade 11 currently being the hardest climbing route. The UIAA scale has an open end. Within a grade, a minus applies to an easy climb for the grade, whereas a plus applies for a hard route for the grade. Climbing level was graded according to the hardest on sight (climber tries the route for the first time) and hardest redpoint route (climber knows the route and its special moves well and has trained on it) within the past 2 years. All rock climbers presenting with the suspicion of a pulley injury also received diagnostic ultrasound and optional magnetic resonance imaging (MRI). Ultrasound was performed in a water tube by using a 7.5-MHz linear ultrasound head. In suspected pulley injury, the pathway in Figure 1 was used.

We developed a grading score (Table 1) and used it in this study to aid scientific evaluation and to guide therapy. Grade 1 injuries are pulley strains with no dehiscence between bone and tendon in the MRI or ultrasound (<2 mm). The complete rupture of an A4 pulley has a very good prognosis, sometimes leading to a full recovery within 4 to 6 weeks. This has the same severity as a partial rupture of the more essential A2 or A3 pulley. These injuries are rated grade 2. The complete rupture of the A2 or A3 pulley, leading to a prolonged recovery, is rated grade 3. Grade 4 injuries include complex lesions with multiple pulley injuries or single pulley injuries combined with lumbricalis muscle damage or

Table 1. Pulley-injury score (closed injuries)

Grade	Injury
1	Pulley strain
2	Complete rupture of A4 or partial rupture of A2 or A3
3	Complete rupture A2 or A3
4	Multiple ruptures (as A2/A3, A2/A3/A4) or single rupture (as A2 or A3) combined with lumbricalis muscle or collateral ligament trauma

collateral ligament rupture. These lead to a functional deficit if not surgically repaired. Grade 1–3 injuries received conservative therapy, and grade 4 injuries received surgical repair. Table 2 shows the therapeutic procedure according to the grading.

Results

Six hundred four rock climbers with acute injuries or overuse syndromes were enrolled in a prospective study during January 1, 1998, to December 31, 2001. The types and extents of the injuries were determined in all athletes. In the 419 (60.4%) athletes seen in our clinic, demographic (age, sex) and sport specific data (climbing levels, years of climbing experience) were also gathered. In this group of 302 men (70.1%) and 117 women (27.9%), the average age was 28.3 years (13–52). The athletes had been sport climbing for an average of 7.3 years (2–35). The interval between the acute injury and medical consultation ranged from a few minutes to 1.5 years. Average redpoint climbing level was metric 8.63 (5.3–11.0) or UIAA 9–, representing US 5.12c. Average on-sight level was metric 8.09 (5.9–11.3) or UIAA 8, representing US 5.12a.

Of 604 injuries, 247 (41%) were related to fingers, 81 (13.4%) to forearms and elbows, 55 (9.1%) to feet, 47 (7.8%) to hands, 43 (7.1%) to trunks and spines, 42 (6.9%) to skin, 30 (5.0%) to shoulders, 22 (3.6%) to knees, and 37 (6.1%) to other regions. Injuries with a higher grade of severity (polytrauma) were rare (5 cases, 0.8%).

Of 247 finger injuries, pulley injuries were the most frequent ($n = 122$) followed by tendovaginitis ($n = 42$) and joint capsular damage ($n = 37$). Table 3 summarizes the finger injuries and overuse syndromes, and Table 4 summarizes the pulley injuries. According to the proposed grading system, 39% of the pulley injuries were grade 1, 25% were grade 2, 30% were grade 3, and 6% were grade 4 injuries (Figure 2). The 50 patients with

Table 2. Therapeutic guidelines

	<i>Grade 1</i>	<i>Grade 2</i>	<i>Grade 3</i>	<i>Grade 4</i>
Injury	Pulley strain	Complete rupture of A4 or partial rupture of A2 or A3	Complete rupture A2 or A3	Multiple ruptures, as A2/A3, A2/A3/A4 or single rupture (A2 or A3) combined with lumbricalis muscle or ligament damage
Therapy	Conservative	Conservative	Conservative	Surgical repair
Immobilisation	None	10 days	10–14 days	Postoperative 14 days
Functional therapy	2–4 wk	2–4 wk	4 wk	4 wk
Pulley protection	Tape	Tape	Thermoplastic or soft-cast ring	Thermoplastic or soft-cast ring
Easy sport-specific activities	After 4 wk	After 4 wk	After 6–8 wk	4 mo
Full sport-specific activities	6 wk	6–8 wk	3 mo	6 mo
Taping through climbing	3 mo	3 mo	6 mo	>12 mo

A2 ruptures included 17 partial and 33 complete ruptures.

THERAPY

Grade 1–3 injuries were treated conservatively with initial immobilization and early functional therapy under pulley protection. In grade 4 injuries, a surgical repair was performed by the “loop and a half” technique of Widstrom et al¹¹ or, alternatively, the Weilby repair.¹²

Table 3. Injuries and overuse syndromes of the fingers in climbers (247 climbers/271 diagnoses)

Pulley rupture	74
Pulley strain	48
Tendovaginitis	42
Joint capsular damage	37
Arthritis (acute)	13
Ganglion	11
Flexor tendon strain	7
Fracture	7
Arthritis (chronic)	7
Dupuytren contracture	5
Soft tissue injury, contusion	5
Flexor tendon partial tear	4
Collateral ligament injury	3
Osseous tear, fibrocartilago palmaris	2
Epiphyseal fracture	2
Lumbrical shift syndrome	2
Abscess	1
Finger amputation	1

Postoperatively, an initial immobilization was followed by functional therapy.

OUTCOME

Follow-up included 87 (71.3%) of all rock climbers with pulley injuries, including all grade 4 injuries. Of the 80 cases treated conservatively (grade 1–3 injuries), 7 (8%) athletes complained of persistent pain after 3 months, caused by posttraumatic tendovaginitis. After local cortisone injection and a prolonged resting period, they regained their initial sport activity level. The other 73 patients returned to full climbing level, with occasional minor pain. Only 6 reported a continuing need of taping the injured finger for longer than 12 months during climbing. All 7 grade 4 patients were re-evaluated: 1 presented a very good functional result, 5 presented a good functional result, and 1 presented a satisfying functional result. One reported a very good sport-specific result with climbing again in the top difficulty levels (UIAA 10, US 5.13d), 3 reported good sport-specific results, 2 reported a sufficient sport-specific result, and 1 reported a poor sport-specific result. Finger taping during climbing activity was necessary in all patients.

Discussion

As expected, we found a high number of finger injuries within our total group of rock climbers. This is consistent with data in the literature. Bollen,^{1,2} Rooks,¹³ and Largiadèr and Oelz¹⁴ reported that about 60% of all

Table 4. Pulley injuries from January 1998 to December 2001 ($n = 122$)*

	No.	M	F	Right	Left	D2	D3	D4	D5	A2	A3	A4	A2/A3	A2/A3/A4
Pulley strain	48	43	5	28	20	0	21	27	0	31	3	14	0	0
Pulley rupture	74	67	7	41	33	0	26	46	2	50	3	14	4	3

*M indicates male; F, female; D, Digit; A2, A2 pulley; A3, A3 pulley; A4, A4 pulley.

climbing injuries concentrated on the hand and fingers. Hochholzer et al¹⁵ reported a similar finding, with osteoarthritis being the most common and pulley ruptures being the second most common climbing injuries. Considering all finger injuries and overuse syndromes within our group, pulley injuries were the most common. This results from 2 main reasons. First, the Bamberg hospital is located within the Frankenjura, Germany's largest sport-climbing area, which is characterized by short, very steep climbs and requires maximum power moves by using the crimping technique (Figures 3 and 4). The crimping finger position seems especially responsible for pulley injuries.^{1,3,6,8,10} Second, our center is a major referral center for patients suspected of having this injury.

DIAGNOSIS

We propose an algorithm (Figure 1) that we use in diagnosing suspected pulley injuries. The clinical picture of pulley injuries and the history from the athletes were in accordance with other studies.^{1,2,3,6,7,10,16} Most rock climbers reported an acute onset while performing a hard move or slipping off a foothold. Sometimes a loud popping was mentioned. The fingers showed swelling at the level of the proximal or middle phalanx, sometimes accompanied by hematoma. A visible bowstring only occurred in high-grade injuries. When caused by the combined injury of the lumbricalis muscles, an extension deficit of the proximal interphalangeal joint could occur, leading to contraction. According to our algorithm as well as the reports of Gabl et al,¹⁶ we always obtain

radiographs to exclude fractures or osseous tears of the fibrocartilago palmaris as well as chronic overuse fractures in the epiphysis of adolescent rock climbers.

For further work-up, ultrasound examination and MRI are important. MRI has been demonstrated to be very sensitive in detecting pulley injuries in many studies^{4,7,15-17} and is widely accepted. Although MRI cannot directly detect the damaged pulley, the T1 sequences show dehiscence of tendon from bone, whereas T2 sequences help distinguish a tendovaginitis (Figure 5). Intratendonal lesions can be detected in addition to partial ruptures. MRI is limited by its high costs. Lately, ultrasound examination has been demonstrated to achieve nearly the same quality results, sometimes even being superior to MRI, allowing additional dynamic examination.¹⁶⁻¹⁸ We recommend use of ultrasound as the standard examination, with MRI added if the diagnosis remains unclear.

THERAPY

In 1990, Bollen¹ and Tropet et al³ first reported rock climbers with closed traumatic pulley ruptures. Both Bollen, with conservative treatment, and Tropet, with surgery, achieved good functional results. During the ensuing years, further reports about surgical and conservative treatment have appeared^{2,4,7,8,16} but without general guidelines. Whereas surgical repair was commonly used in early years, conservative, nonsurgical approaches are now standard, at least for single ruptures.^{5,6} This attitude is based on biomechanical analyses of the flexor tendon pulley system⁷⁻¹⁰ and the very good functional results of many rock climbers, who underwent only self therapy after pulley rupture. An initial strength deficit disappears after 3 to 6 months. Bollen^{1,2} reported a survey held at the British National Climbing Championships in 1989, where 18 rock climbers showed an increase of "bowstring phenomenon" in their fingers. None of these athletes underwent any kind of previous therapy, but at the time of the competition all had good functionality and few complaints. Gabl et al¹⁶ used the MRI and the visible bowstring for indication of conservative or surgical therapy. They applied surgery if the bowstring on the MRI extended proximal to the base of

Figure 2. Grading of 122 pulley injuries.

Figure 3. The hanging finger position.

the proximal phalanx of the involved finger. MRI is essential in this approach. Although conservative treatment of single pulley injuries became standard, there was no distinction among the different pulleys themselves. An A2-pulley tear has a prolonged recovery in comparison with an A4 tear. For further scientific evaluation, as well as therapeutic decision making, we developed a grading score (Table 1).

CONSERVATIVE THERAPY

Mainly on the basis of biomechanical analyses of Bollen,² a nonsurgical procedure is becoming standard for single ruptures. Bollen described a tearing force of 500 N of a 1.5-cm wide tape above the A2 pulley, which allows good protection of the pulley. Although Warne and Brooks¹⁹ could not find any difference in pulley tearing force with or without taping, conservative therapy has shown very good functional results.^{1,2,7,8,20} Depending on the interval between trauma and consultation as well as local swelling, we recommend an initial immobilization of 10 to 14 days with a palmar splint combined with anti-inflammatory agents and elevation. Thereafter, treatment consists of early functional therapy with pulley protection by using tape or thermoplastic/soft-cast ring, finger gymnastics, or a Thera-Band Hand Exerciser (Thera-Band, Akron, OH). Easy sport-specific activities are allowed for grade 3 injuries after 6 to 8 weeks under pulley protection (tape). Full sport activities can be done after 3 months, with continued taping for at least 6 months. Grade 2 injuries can be treated in a similar but more rapid fashion (Table 2). Initial strength deficit will resolve after 3 to 6 months, and bone-to-tendon dehiscence is stable on ultrasound follow-ups.

Figure 4. The crimping finger position.

SURGICAL REPAIR

Grade 4 injuries require surgical repair to prevent functional deficits. Clinically, there is reduced flexion in the distal interphalangeal joint, and sometimes there is an extension deficit of the proximal interphalangeal joint.^{4,6,7,16,20} Surgical repair is based on the biomechanical analyses of Lin et al²¹ as well as the comparison of surgical repairs done by Widstrom et al.^{11,22} A single stitching of the remaining incomplete rims of the pulleys is insufficient; a plastic repair is essential. The following various methods have been described: the Kleinert and Bennet¹² repair based on Weilby's idea, the "belt-loop" technique of Karev et al,²³ the "single-loop" technique according to Bunnel,²⁴ the Lister²⁵ repair with retinaculum flexorum, the palmaris longus tendon transplantation through the volar plate according to Doyle,¹¹ the "loop and a half" technique of Widstrom et al,¹¹ and the "triple loop" technique by Okutsu et al.²⁶ Considering the biomechanical analyses of Widstrom et al^{11,22} and the reports of Hahn and Lanz,⁴ we favor the loop-and-a-half technique of Widstrom et al with a free transplant of the palmaris longus tendon. Although the Weil-

Figure 5. A2 pulley rupture.

by repair¹² was reported as having the best functional results, sport climbers often need a higher tearing force after reconstruction. This is provided by the loop-and-a-half technique. Nevertheless, the final decision is made during the operation according to the anatomical situation. For reconstruction of the A3 pulley, the loop-and-a-half technique sometimes is not the ideal solution, as the loop can cause irritation on the extensor tendon at the proximal interphalangeal joint. Postoperatively, we apply an initial immobilization for 2 weeks, followed by an early functional treatment with pulley protection with thermoplastic or a soft-cast ring for 4 weeks and further taping during sport activities. The overall results are good, with nearly full recovery of function.

Conclusion

Closed traumatic pulley rupture was described as a new injury mechanism in the 1980s, and early diagnostic and therapeutic approaches varied. Today's approach should include the exclusion of a fracture or joint capsular/collateral ligament lesion, followed by ultrasound differentiation of pulley strains and partial, complete, or multiple pulley ruptures. If the ultrasound fails to give an exact diagnosis, an MRI should be performed. Injuries can be graded according to our proposed grading system to guide therapeutic approach. Grade 1–3 injuries (strains and partial or single ruptures) are treated conservatively, with initial immobilization and early functional therapy under pulley protection (Table 2). Grade 4 injuries (multiple ruptures) require surgical repair. The loop-and-a-half technique of Widstrom et al¹¹ is favored, with the Weilby repair¹² being an alternate approach. Postoperatively, initial immobilization is used, followed by physical therapy. Although closed pulley ruptures were initially seen only in rock climbers, who are subject to high impact on the fingers, these injuries may also occur in nonclimbers. We have seen 4 cases of closed pulley ruptures in nonclimbers within the past 3 years. The trauma mechanism in these involved primarily lifting heavy items with crimped fingers.

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