ON THE TREATMENT OF ACHILLES TENDON RUPTURE

A prospective, randomised study of the results after surgical and non-surgical treatment

Michael Möller

Department of Orthopaedics
Institute of Surgical Sciences, Göteborg University
Göteborg, Sweden, 2001

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Michael Möller
Leg.Läkare

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Avhandlingen baseras på följande delarbeten:

I. **The test-retest reliability of concentric and eccentric muscle action during plantar flexion of the ankle joint in a closed kinetic chain**
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Abstract

Only two prospective, randomised studies have been published on the outcome after treatment for Achilles tendon rupture. The controversy regarding the optimal treatment continues. In the present study, 112 patients with acute Achilles tendon rupture were randomised and all of them were followed up for two years. Fifty-nine patients were treated surgically with end-to-end sutures followed by two weeks of plaster treatment and six weeks of treatment in a brace with increasing range of motion. Fifty-three patients were treated non-surgically with four weeks of plaster in equinus and four weeks in a neutral position.

The re-rupture rate was 20.8% in the non-surgical-treatment group and 1.7% in the surgical-treatment group (p=0.001). There were no major surgical complications. A new Achilles Tendon Rupture score including five objective and three subjective parameters did not reveal any significant difference between the treatment groups. The time of return to work and sports did not differ significantly between the treatment groups either.

Calf muscle strength was evaluated both for purposes of test-retest reliability in healthy volunteers and for outcome reasons in the clinical study. Isokinetic torque production in concentric and eccentric muscle action in plantar flexion and dorsiflexion at the ankle joint was studied on the right and left sides. Calf muscle endurance was evaluated using a standardised heel-raise test, until fatigue. The reliability test showed acceptable reproducibility for the isokinetic tests and the endurance tests. After treatment for ATR, we found calf muscle hypotrophy, thickening of the Achilles tendon, decreased calf muscle strength and reduced endurance on the injured side throughout the study period. There were, however, no significant differences between the treatment groups. Magnetic resonance imaging and ultrasonography detected the same amount of pathological findings during healing in both treatment groups. The correlation between the radiological findings and the clinical parameters was weak.

The non-surgical treatment of ATR, which produced treatment failure in every fifth patient, cannot be regarded as acceptable for healthy, active people under the age of 65 years. Surgical treatment followed by early functional rehabilitation is a safe method for the treatment of ATR with a low risk of complications. However, surgical and non-surgical treatments produced equally good medium-term results in the group of patients in whom no rerupture occurred.

Key words: Achilles tendon, rupture, score, prospective, randomised controlled trial, isokinetic, muscular endurance, magnetic resonance imaging, ultrasonography

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The whole problem with the world is that fools and fanatics are always so certain of themselves but wiser people so full of doubts

Bertrand Russell

Contents

List of papers

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Abbreviations

AT	Average torque
ATR	Achilles tendon rupture
Conc	Concentric
CV	Coefficient of variation
Ecc	Eccentric
FIL	Functional index for lower leg and ankle
HS	Huddinge University Hospital
ICC	Intra class correlation
MRI	Magnetic resonance imaging
Nm	Newtonmetre
PT	Peak torque
ROM	Range of motion
SD	Standard deviation
SS	Sahlgrenska University Hospital/Sahlgrenska
US	Ultrasonography
VAS	Visual analogue scale
ÖS	Sahlgrenska University Hospital/Östra

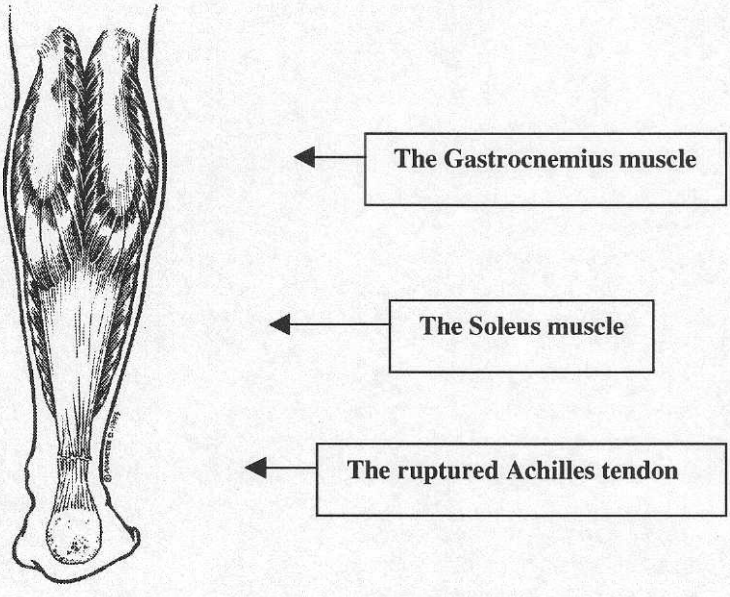
Introduction

Background

The conjoined tendon of the gastrocnemius and soleus muscles is the strongest tendon in the human body and the most commonly injured. The denomination "Achilles tendon" first appears in the medical literature in 1693, when it is used by the surgeon Philip Verheyen (Couch 1936). In Homer´s *Iliad*, Achilles is the outstanding warrior and hero. His mother Thetis made him invulnerable to physical injuries of all kinds by immersing him in the river Styx. The only part of Achilles´ body that remained vulnerable was the heel where he was held by his mother. Achilles led the Greek forces that destroyed Troy but was finally killed by Paris, the brother of the killed Troyjan prince, Hector. Paris fired a poisoned arrow into Achilles´ unprotected heel.

The legend of Achilles has fascinated people over the centuries and descriptions of injuries to the tendon that came to bear his name appeared early in the medical literature. Hippocrates concluded that "this tendon, if bruised or cut, causes the most acute fevers, induces choking, deranges the mind, and at length brings death". In modern western society, the Achilles Tendon Rupture (ATR) is looked upon in a somewhat different way, but, despite a large number of reports in the medical literature, especially during the past three decades, an ongoing controversy in terms of the optimal treatment continues.

Figure 1. The posterior aspect of the calf



Anatomy

The gastrocnemius muscle is a biarticular muscle that contributes to flexion of the knee joint and plantar flexion of the ankle joint. The gastrocnemius muscle has its origin above the knee joint, on the dorsal aspect of the distal femur. The two superficial muscle bellies, the medial and the lateral heads, give the calf its visible contour. Together with the uniarticulate soleus muscle, the largest tendon in the human body, the Achilles tendon, is formed (Figure 1). The soleus muscle originates below the knee joint, at the posterior aspect of the proximal tibia and fibula, and contributes to the plantar flexion motion of the ankle joint.

The muscle fibres of the gastrocnemius extend 11-26 cm above the calcaneus, whereas the muscle fibres of the soleus are situated more distally and extend 3-11 cm above the calcaneus (Cummins et al. 1946). The Achilles tendon is formed by the three broad and flat aponeuroses from the gastrocnemius and the soleus. In the midportion of the tendon, its shape is rounded and narrow and finally fans out at the insertion. During its course down to the insertion, the fibres of the Achilles tendon rotate up to 90°, which means that the soleus fibres insert posteromedially and the gastrocnemius fibres anterolaterally into the calcaneus (White 1943, Cummins et al. 1946).

The normal Achilles tendon is a whitish, smooth structure without any surrounding tendon sheath. The surrounding paratenon is a multi-layered non-synovial tissue that allows the tendon freedom of movement. The location of the Achilles tendon is in the posterior lower-leg compartment, surrounded by the superficial and deep crural fascia. The plantaris tendon lies in close proximity to the Achilles tendon and can be used for reinforcement purposes when repairing a ruptured Achilles tendon. However, the plantaris tendon is present in only 40% of the patients who sustain an ATR, whereas it is present in 90% of the population (Gruber 1879, Incavo et al. 1987).

Biomechanics

The Achilles tendon transmits the tension generated by the gastrocnemius and soleus muscles to the calcaneus. The muscles and their tendon in the triceps surae musculotendinous complex are active during standing, in postural control and during walking, running and jumping. During the gait cycle, the force in the Achilles tendon builds up before the heel strikes the ground and is thereafter suddenly released. Subsequently, the force builds up again to reach its peak at foot push-off (Komi et al. 1992). To do their work effectively, tendons must be capable of resisting high tensile forces with limited elongation (Best and Garrett 1994). The tendon is not only able to transmit forces from the contracting muscle to the bone but also has the capability to deforme and recover its original length.

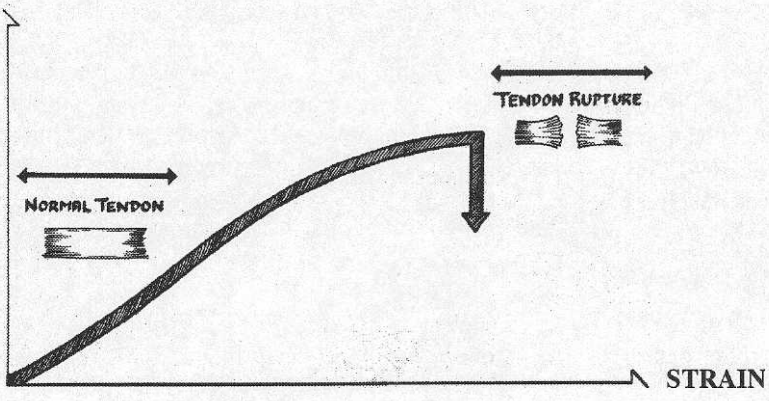
Tendon rotation plays an important role in Achilles tendon pathology. Collagen fibres which are twisted can produce high stress concentrations in the tendon (Curwin and Stanish 1984). In the Achilles tendon, this appears to happen mainly in the area 2-5 cm above the calcaneal insertion (Barfred 1973), which is the area where most complete ruptures occur. Load transmission is one of the important roles

of the tendon. In addition, the tendon has to be shock-absorbent to protect the muscle from damage (Best and Garrett 1994).

In-vitro tests for tensile forces are of limited value in in-vivo situations (Józsa and Kannus, 1997). For the Achilles tendon, however, in-vivo data are available. Komi and co-workers (1990, 1992) were the first to use a buckle transducer to study the in-vivo forces affecting the Achilles tendon in man, during different activities. The Achilles tendon is the strongest tendon in the human body. During cycling, power of less than 1,000N was produced, whereas during slow walking and running the corresponding power was 2,600N and 9,000N respectively. The power produced while running at six metres a second corresponds to more than 10 times the weight of the body.

In a resting state, the fibrils that build up the tendon are wavy and relaxed in their configuration. If the tendon is stretched more than 2%, this configuration disappears (Renström and Johnson 1985). If the subsequent continuous strain does not exceed approximately 4%, the tendon is able to return to its original length, i.e. the tendon is elastic. However, if the strain exceeds approximately 4%, the tendon fibres are damaged and, at a strain level of 8%, the tendon ultimately ruptures (Figure 2). Forces that put the tendon under the highest stress are the eccentrically generated muscle actions (Komi 1984). The work performed by the elongated muscle is an eccentric action. Typical heavy loading eccentric muscle actions involving the calf muscles and the Achilles tendon are the transition to fast push-off during running, fast running uphill or sudden dorsiflexion at the ankle joint when climbing or slipping.

Figure 2. Stress-strain diagram



Achilles tendon rupture

Diagnosis of the ATR

ATR usually occurs in middle-aged men during sports activities. If the possibility of a rupture of the Achilles tendon is kept in mind, the diagnosis should be simple and straightforward, soon after the rupture in particular. However, a number of ruptures are missed, either by the patient or by the physician. Older patients and patients who present late are more prone to recieve an incorrect diagnosis. Primarily, as many as 12-28% of ATRs are missed (Inglis et al. 1976, Nada 1985, Carden et al. 1987).

The history in most cases is typical. Only seldom is there a history of previous problems with the Achilles tendon. The patient suddenly feels a "pop" or "snap" in the calf and sometimes hears a sharp sound. Immediate pain that soon resolves is typical. Persistent weakness, poor balance and changed walking capabilities are common. On many occasions, the patient believes that he has been kicked by someone. A direct injury mechanism to the Achilles tendon is, however, very rare. ATR is a clinical diagnosis. In early cases (within 48 hours), a gap is palpable in the tendon at the site of the rupture. Later in the course, the gap is often filled with hematoma and fibrous tissue. Numerous diagnostic tests have been used, such as the needle test (O´Brien 1984), the sphygmomanometer test (Copeland 1990) and the hyperdorsiflexion sign (Matles 1975).

The calf squeeze test described by Simmonds (1957) and by Thompson and Doherty (1962) is simple, commonly used and reliable. With the patient prone, the calf muscles are squeezed from side to side. If there is a subsequent plantar flexion of the foot, the test is negative and the Achilles tendon is intact. If the plantar flexion movement is absent despite adequate calf squeezing, the test is positive and indicates a completely ruptured Achilles tendon. In addition, the patient is unable to raise his/her heel off the ground on the injured side. Different diagnostic tests were evaluated by Maffulli (1998) and the use of Thompson´s test and Matles´ test was encouraged. In combination, these two tests can be used to establish a certain diagnosis.

The diagnosis can be confirmed by ultrasonography (US) or MRI (Magnetic resonance imaging). The reliability of the US examination is, however, highly investigator dependent. The dynamic US evaluation can be useful to determine whether the torn ends of the tendon are lying in close proximity to oneanother. There is, however, a risk of missed diagnoses using US. The frayed tendon ends tend to overlap and might give the inexperienced ultrasonographer the false impression of a partial rupture.

Nomenclature of ATR

An Achilles tendon rupture may be partial or complete. The subject of this thesis is the complete rupture, which is an acute event. Sometimes ATR is called "subcutaneous" or "spontaneous". The rupture can be open or closed, and can be caused by a direct blow or an indirect force. The closed tendon rupture caused by indirect forces like a sudden foot push-off or an unexpected dorsiflexion of the ankle is the dominant etiological factor for ATR.

Re-rupture is the denomination given to a repeated rupture, often occurring soon after the treatment for the previous ATR is finished. Bilateral ruptures at the same time are very rare (Orava et al. 1996), whereas subsequent ruptures on one side after the other are relatively common, occurring in approximately 2% of patients. ATRs occur commonly in the mid-substance of the tendon, usually two to six cm proximal to the insertion into the calcaneus. Other types of more unusual location for ATR are the musculo-tendinous junction and the insertion into the calcaneus (avulsion rupture).

Etiology of ATR

The exact reason why the Achilles tendon ruptures is not known. Two main theories are advocated. According to the "degeneration theory", chronic degeneration of the tendon leads to a rupture without excessive loads being applied. Repetitive microtrauma and hypovascularity in part of the tendon are suspected as predisposing factors. This theory has been supported by angiographic (Carr and Norris 1989, Ahmed et al. 1998) and histological (Kannus and Józsa 1991) findings. According to the "mechanical theory", the Achilles tendon is ruptured due to malfunction of the normal inhibitory mechanism of the musculotendinous junction.

On the basis of experimental studies, Barfred (1973) suggested that an ATR can occur in a normal tendon if an excessive load is applied. Hoffmeyer and co-workers (1990) found lipid degeneration in the calf muscles of patients who had sustained ATR. These patients had been inactive for a period before they ruptured their Achilles tendons. In contrast, Maffulli and co-workers (1991) found no signs of degeneration among patients without previous symptoms who sustained their ATR during sports activities. Percutaneous biopses were used in this study. ATR can be associated with systemic diseases such as rheumatoid arthritis, SLE and gout. A correlation between local injections of corticosteroids and subsequent ATR has been debated. Numerous reports of anecdotal cases have been published; however, scientific evidence of the deleterious effect of corticosteroids on tendons is still lacking (Fredberg 1997).

Epidemiology of ATR

The incidence of ATR is increasing (Nillius et al. 1976, Kannus and Jozsa 1991, Möller et al. 1996, Leppilahti et al. 1996, Levi 1997, Houshian et al. 1998, Maffulli 1999, Maffulli et al. 1999, Nyyssönen and Lüthje 2000). Most ATRs are sustained during sports activities. This is in deep contrast to other tendon ruptures. In a retrospective study of 832 tendon ruptures by Józsa and co-workers (1989), 59% of ATRs were sustained during sports activities, whereas only 2% of other tendon injuries occurred during sports activities. The type of sport that dominates as the cause of ATR depends on the country where the study is performed. In Scandinavian countries, racquet sports dominate as the sports-related reason for sustaining ATR. Several studies on ATR and badminton have been published (Kaalund et al. 1989, Jörgensen and Winge 1990, Höy et al. 1994, Fahlström et al. 1998).

ATR is predominantly a male disease and the dominance of males is constant in all studies with male/female ratios of 2:1 to 12:1. One possible reason for the difference in male/female ratios could be the cultural differences in terms of female

participation in leisure sports activities. ATR can be a work-related injury, not only in professional athletes. ATR can also be sustained during activities of daily living, although this is rare. White-collar professionals are over-represented among the individuals who sustain ATR, in contrast to those who sustain other tendon injuries (Józsa 1989).

The mean age at injury is remarkably constant in the literature. In some studies, as in the present thesis, a lower age limit of 15-18 years is set, with an upper age limit of 65 years. In such studies, the mean age at ATR is usually 35-40 years. If the whole population is studied, a somewhat higher mean age is found, due to a second peak incidence that occurs at the age of 65-70 years (Leppilahti 1996).

Treatment of Achilles tendon rupture

The treatment of ATR can be either surgical or non-surgical (Figure 3). The parameters most frequently studied in modern outcome studies after ATR are complications to treatment, calf muscle strength, endurance, tendon configuration, patient satisfaction and the impact of the ATR on absence from work and sports participation.

In a review of publications in the English literature, Lo and co-workers (1997) found almost 800 articles on Achilles tendons. Eighty-two articles were found to deal with the treatment of Achilles tendon disorders. Nineteen articles fulfilled the review´s inclusion criteria of an injury not older than four weeks, treatment series without selection or randomised controlled trials, ability to extract data regarding treatment given, not experimental treatment and only original studies. Surgical treatment was studied in 12 articles (643 ruptures). Non-surgical treatment was studied in five articles (133 ruptures) and there were two randomised, controlled trials (Nistor 1981, Cetti et al. 1993) comprising 105 and 111 patients respectively.

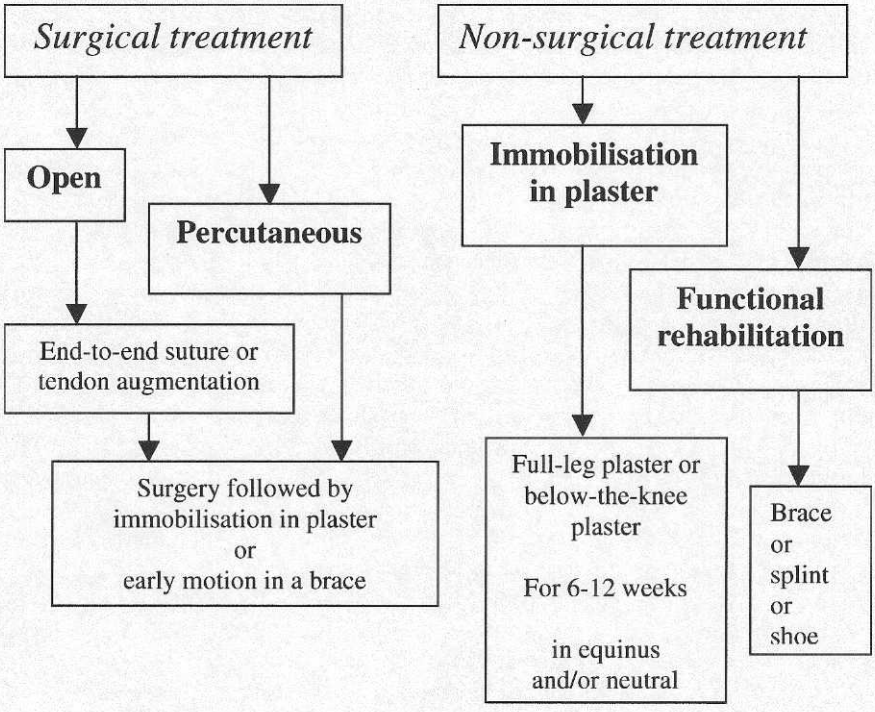
Surgical treatment

Open or percutaneous methods can be used for the surgical treatment of ATR. The open repairs can be divided into repairs with or without augmentation of the tendon. The primary goal of surgical intervention is the apposition of the torn ends of the tendon which can be accomplished by a simple end-to-end suture. The suture has to be placed at a distance from the frayed tendon ends at the rupture site. If augmentation of the repair is performed, it is usually the second step of the operation, adding extra strength to the end-to-end suture.

Comparisons between simple end-to-end sutures and augmentation techniques have been published (Jessing and Hansen 1975, Rantanen et al. 1993), but no significant differences were detected. A large number of studies, some of them comparative, of cadavers have been published dealing with the in-vitro strength of different repair techniques. Local or distant tissue can be used to reinforce the tendon repair. The local tissue available for tendon augmentation is the gastrocnemius fascia and other tendons in the calf. The gastrocnemius fascia can be used as a single turned-down strip (Christensen 1931, Bosworth 1956) or as a single, rotated and turned-down strip (Silfverskiöld 1941) or as two strips, rotated and turned down (Arner and Lindholm 1959). The gastrocnemius fascia can also be used

as a free flap to cover the repair site (Möller et al. 2001) or it can be attached through a drill hole in the calcaneus (Mahmoud 1992).

Figure 3. Different methods for the treatment of ATR



The plantaris tendon (Quickley and Scheller 1980), the peroneus tendons (Teuffer 1974, Turco and Spinella 1987, White and Kraynick 1959), the flexor digitorum longus tendon (Mann et al. 1991) or the flexor hallucis longus tendon (Wapner et al. 1993) can be used, either as simple reinforcements or in a tendon transfer procedure. The distant tissues that are available are the fascia lata as a free flap (Zadek 1940, Bugg and Boyd 1968) or the patella-tendon-bone strip for re-attachment of the Achilles tendons avulsed from the insertion to the calcaneus (Besse et al. 1995). Usually, the use of the more complex augmentation procedures is limited to the repair of late-presenting ruptures, neglected cases or re-ruptures. Artificial tendon implants such as Marlex mesh®, Dacron® and so on (Puddu et al. 1976, Ozaki et al. 1987, Giannini et al. 1994, Fujii et al. 1997) and carbon-fibre composite (Howard 1984, Parsons et al. 1989) have been used. Allografts have also been used (Nellas et al. 1996) for the treatment of neglected ruptures with a significant defect.

The ruptured tendon can be sutured end to end in a Kessler or Bunell (Arner and Lindholm 1954, Cetti et al. 1981, Anderssen and Hvass 1986, Sejberg et al. 1990, Soldatis et al. 1997) fashion. Other techniques which have been described are the three-bundle technique (Beskin et al. 1987), the suture weave (Cetti 1988), the Krackow suture (Krackow et al. 1986, Jaakokola et al. 2000), pull-out wires (DiStefano and Nixon 1972, Motohashi et al. 1996) and many others.

The open surgical repair of ATR has been performed under local anaesthesia, with a good outcome (Cetti 1981, Andersen and Hvass 1986, Keller and Bak 1989, Sejberg et al. 1990). Sejberg and coworkers (1990) showed that patients who were surgically treated for ATR can be treated as out-patients. Cetti et al. (1993) found that the hospitalisation period was seldom described in previous reports but found a mean hospitalisation period after surgical repair (in four studies) of 6.4 days (range 2-17 days). After the introduction of surgery under local anaesthesia, the hospitalisation period for surgically-treated patients is close to the time for non-surgically-treated patients, i.e. less than one day.

The placement of the skin incision has been much debated (Anderssen and Hvass 1986) due to complications to the surgical treatment such as wound breakdown, infections, adhesions and nerve injuries (Webb et al. 2000). Longitudinal skin incisions of varying length have been the most common. However, transverse skin incisions producing a good outcome have been described (Aldam 1989). The longitudinal straight or curved incision can be either medial or lateral to the AT or placed over the tendon. The incision to the superficial crural fascia can be placed underneath the skin incision or at a distance of one to two cm from the skin incision. There is no true paratenon surrounding the Achilles tendon, but the superficial and deep crural fascia surrounds the tendon and has to be carefully closed at the end of the operation. There has been a tendency towards shorter, more medially positioned skin incisions, because of reported sural nerve injuries with the lateral incision and wound complications with extensive incisions.

Ma and Griffith (1977) described a technique using six small insicions when repairing an ATR. Percutaneous techniques using multiple small incisions have since been advocated by several authors and many modifications of the percutaneous technique have been evaluated and presented (Rowley and Scotland 1982, Klein et al. 1991, FitzGibbons et al. 1993, Gorschewsky et al. 1999, Webb and Bannister

1999). Comparisons of the outcome in terms of open and percutaneous surgical treatment have been studied by Bradley and Tibone (1990), by Steele and co-workers (1993) and by Kakiuchi (1995). Using percutaneous techniques, there is an increased risk of sural nerve injury and the repair is usually weaker than when using open repairs (Aracil et al. 1992, Maffulli 1999).

Non-surgical treatment

Non-surgical treatment includes no treatment at all, immobilisation in plaster or functional rehabilitation with early mobilisation without previous surgical repair. Some of the historically-reported cases (Quenu and Stoianovich 1929) had virtually no treatment at all (Nistor 1981). Non-surgical treatment has consisted of immobilisation in various degrees of plantar flexion or a neutral position at the ankle joint, with plaster treatment being by far the most common. The plaster treatment is usually modified after three to five weeks to less plantar flexion. The time in plaster has varied from five to twelve weeks, with eight weeks of treatment as the most common (Cetti et al. 1993). Plaster treatment can either consist of a long-leg plaster, immobilising both the ankle and the knee joint, or a below-the-knee plaster, immobilising only the ankle joint. Some authors have used a long-leg plaster for several weeks before changing to a below-the-knee plaster. Various braces have also been described with limitation of dorsiflexion and increased heel height (Saleh et al. 1992, Thermann et al. 2000). Weight-bearing has varied, as has the use of a shoe raise after completion of the plaster treatment. Functional non-surgical treatment can also consist of a brace with a gradually decreasing heel height.

Timing of the treatment

The treatment of ATR can be early or delayed (more than one week) and, in many of the studies of ATR, the patient population is a mixture of early and delayed treatment. The outcome for early and late repairs has been compared (Carden et al. 1987). No differences in outcome were found. However, Boyden and co-workers (1995) found that there were advantages to late repair. In recent years, the approach has focused on early rehabilitation and an early return to work and sports activities. Early repair has therefore, been the obvious choice for most surgeons. In contrast, delayed treatment was favoured by Myerson (2001) for reasons of supposedly favourable tissue conditions. However, if non-surgical treatment is considered, the treatment should be started early, preferably within two days (Carden et al. 1987).

Rehabilitation

In many studies, the type of rehabilitation that is used has not been stated. Different protocols have been used, with or without formal physiotherapy. The main differences in terms of the early stages of the rehabilitation are immobilisation or early functional exercise. This applies to both surgical and non-surgical treatment. The main questions that have been under debate are as follows. Is it possible or even advisable to bear weight early after an ATR? Is immobilisation for safe healing necessary after ATR? Is a heel lift necessary in the early rehabilitation phase?

Beskin and co-workers (1987) demonstrated that six to eight weeks with a short-leg cast with early weight-bearing is sufficient after surgical repair. Early or late

repair did not appear to matter. Early range-of-motion exercises without weight-bearing after surgical treatment for ATR were described by Moberg and co-workers (1992). Many reports of good results after the surgical repair of ATR followed by early motion and/or early weight-bearing have been published during the past decade (Cetti 1988, Carter et al. 1992, Armbrecht et al. 1993, Saw et al. 1993, Troop et al. 1995, Mandelbaum et al. 1995, Fernandez and Gimeno 1997, Motta et al. 1997, Aoki et al. 1998, Speck and Klaue 1998).

Functional non-surgical treatment

During the past decade, there has been a tendency towards early functional rehabilitation following non-surgically-treated ATR. Immobilisation in plaster was compared with early functional rehabilitation for non-surgically-treated ATR by Saleh and co-workers (1992). The use of a dorsiflexion-limiting splint restored mobility more rapidly and was appreciated by the patients. Eames and co-workers (1997) presented non-surgical treatment with a combination of plaster treatment and brace treatment, producing good results. Reilmann and co-workers (1996) presented the results from 161 patients treated non-surgically with a special shoe (Variostabil®). The results were adjudged to be good, with a re-rupture rate of 5.3%. In a study by McComis and co-workers (1997), 15 patients were managed non-surgically and the results, after early weight-bearing and range-of-motion exercises, were good.

The history of outcome studies after ATR

1. Historical reports

The first case reports on the treatment of ATR in the medical literature were written by "the father of surgery", Ambroise Paré, in 1575 (Prost 1641), Jean Louis Petit in 1722 (Petit 1728) and Olof Acrel in Stockholm (1759). The first description of surgical treatment for ATR was written by Polaillon (1888). In a review by Quénu and Stoianovitch (1929), all the previously reported cases of ATR were described and discussed. In their study, 39 cases of non-surgically-treated patients and 29 surgically-treated patients were described. According to Nistor (1979), only two other cases treated before 1929 could be found.

2. Surgical treatment series

Since 1930, several large studies on the outcome after surgical treatment for ATR have been published. Many of these studies are heterogeneous. However, the first fairly homogeneous studies on the surgical treatment of ATR were published by Platt (1931), 11 patients, and Kager (1939), 38 patients. According to Toygar (1947), 86 patients with ATR were described between 1929 and 1947.

Silfverskiöld (1941) reported on a series of patients treated with a central rotation flap from the gastrocnemius fascia, while Christensen (1953) presented a series operated on with a gastrocnemius turn-down flap. Arner and Lindholm (1954) reported on 86 surgical repairs of ATR. They estimated the total number of described cases of ATR in 1954 to be 300-400. The authors recommended surgical repair, despite a 24% complication rate, including wound infections, wound

necrosis, deep venous thrombosis, pulmonary embolism and death. Lindholm (1959) presented a modification with two turn-down flaps.

Nistor (1979) reviewed 18 studies between 1953 and 1971, each consisting of at least 50 surgically-treated patients. Arndt (1976) found 5,299 cases of ATR, including studies from Eastern Europe. Even after non-surgical treatment was popularised in the early 1970s, there have been a large number of non-randomised, non-comparative reports on surgical treatment (Shields et al. 1978, Inglis and Sculco 1981, Kellam et al. 1985, Beskin et al. 1987, Bomler and Sturup 1989, Kruger-Franke et al. 1995, Soldatis et al. 1997, Leppilahti et al. 1998, Winter et al. 1998).

Lo and co-workers (1997) found 12 series of 545 surgically-treated patients published between 1971-1994 that met their study criteria. Eight of these 12 series were of Scandinavian origin.

3. Non-surgical treatment series

During the period 1930-1971, only 47 cases of ATR treated non-surgically were reported. Between 1968 and 1972, Lea and Smith (1968, 1972) and Gillies and Chalmers (1970) reported series of successful non-surgical treatment for ATR. These patients were treated with at least eight weeks of plaster immobilisation. Lo and co-workers (1997) found five series (Lilholdt and Munch-Jörgensen 1976, Nistor 1976, Persson and Wredmark 1979, Keller and Rasmussen 1984, Fruensgaard et al. 1992), including 106 patients between 1953 and 1997, that met their study criteria. All these series were of Scandinavian origin.

4. Non-randomised comparisons of surgical and non-surgical treatment

In retrospective studies, series of surgically-treated patients have been compared with series of non-surgically-treated patients. Gillis and Chalmers (1970) found favourable results for non-surgical treatment compared with surgical treatment, but in a very small cohort. Inglis and Sculco (1976) and Häggmark and co-workers (1986) favoured surgical treatment compared with non-surgical treatment. The same conclusion was drawn by Jacobs et al. (1978), who presented 58 cases treated surgically or non-surgically and concluded that surgical treatment produced better results. Thermansen and Damholt (1979) found equal results in a study of 66 patients. In a recent study (Nestorsson et al. 2000) the complication rate after both surgical and non-surgical treatment, in a group of patients over the age of 65 years, was found to be higher than usual in younger groups of patients.

5. Randomised studies of surgical versus non-surgical treatment

Encouraged by the good results of non-surgical treatment, Nistor (1981) carried out the first randomised trial comparing surgical and non-surgical treatment. Cetti and co-workers (1993) performed the only other randomised trial comparing surgical and non-surgical treatment for ATR that can be found in the English literature. Both studies have been criticised for methodological problems (Lo et al. 1997). In the study by Nistor, non-surgical treatment was favoured, due to the lower risk of complications and equal functional outcome. Cetti and co-workers (1993)

recommended surgical treatment, even though non-surgical treatment was claimed to be an acceptable alternative due to minor differences in outcome.

The re-rupture rate in the surgically-treated group was 4% and 5% in the studies by Nistor and Cetti and co-workers respectively. In the non-surgically-treated group the rerupture rate was 8% and 15% respectively and the differences between the treatment groups were not statistically significant.

In both studies, surgical treatment was combined with after-treatment in plaster for eight and six weeks respectively and the non-surgical treatment consisted of eight weeks in plaster.

6. Other prospective, randomised comparisons

Prospective studies during the past ten years have added valuable information about certain parts of the treatment for ATR. Thermann et al. (1995) found that functional non-surgical treatment in a special shoe (Variostabil®) was as good as surgical treatment, with less risk of complications and no re-ruptures. Early rehabilitation versus immobilisation after surgery for ATR has been compared in two prospective, randomised studies (Cetti et al. 1994, Mortensen et al. 1999). The results were good in both groups and recovery was faster in the group which was treated with early rehabilitation using a brace. Saleh and co-workers (1992) studied non-surgical treatment with a randomised comparison between plaster immobilisation for eight weeks and plaster immobilisation for three weeks combined with the subsequent use of a dorsiflexion-limiting splint. The short-term results were better in the splint group.

Evaluation of treatment for ATR

Complications

As ATR can be treated surgically as well as non-surgically, the complication rate has been the parameter of major interest in most of the available retrospective studies and the primary end-point in prospective studies. Complications can be rated as either major or minor on the basis of the impact they have on the patients during activities of daily living. Deep venous thrombosis, pulmonary embolism and re-rupture are the most severe complications and may affect patients regardless of treatment. Surgical complications of major importance are deep infection, wound breakdown and skin necrosis. Minor surgical complications are superficial infection, skin adhesions and disturbances in sensitivity due to sural nerve injury. One major complication correlated to non-surgical treatment is excessive lengthening of the tendon.

In a literature review of 4,083 patients (Cetti et al. 1993), the re-rupture rate following surgical treatment was 1.4% (range 0%-7.1%) and, if simple end-to-end suture was studied separately, the re-rupture rate was 0.7% (n=462). Following non-surgical treatment, the mean re-rupture rate was 13.4% (range 3.9%-50%). In their review of 19 articles, Lo and co-workers (1997) found a re-rupture rate of 2.8% in surgically-treated patients and 11.7% in non-surgically-treated patients.

According to Cetti and co-workers (1993), major complications following surgical treatment are rare in modern studies. Deep infection occurred in 1% of their

patients and skin necrosis occurred in 0.6%. In non-surgically-treated patients, 2.6% of the tendons were extremely lengthened. In the review by Lo and co-workers (1997), major complications, other than re-rupture, were seen in 3.0% of the surgically-treated patients and 2.8% of the non-surgically-treated patients.

Strength

An isokinetic calf muscle strength test can be performed using a dynamometer. The plantar flexion strength at the ankle joint is of major interest following ATR. In a large number of studies, no objective evaluation of muscle strength following ATR has been made. Peak torque in the concentric mode is the most commonly evaluated parameter. The most common test positions and angle velocities have been supine with a straight leg (Shields et al. 1978, Nistor 1981, Bradley and Tibone 1990, Carter et al. 1992, Leppilahti et al. 1996) or sitting with a flexed knee (Kreuger-Franke et al. 1995). Usually, the injured side has been compared with the non-injured side using angular velocities ranging from 30°/sec to 240°/sec.

The deficit on the injured side compared with the non-injured side has been 10-30% in most studies, with somewhat larger deficits following non-surgical treatment. In a review, Cetti at al. (1993) found that, in studies in which side-to-side comparisons had been made, the average strength on the injured side was 87% (range 75-101%) after surgical treatment and 78% (range 65-98%) after non-surgical treatment. In at least two studies (Carter et al. 1992, Mandelbaum et al. 1995), no significant plantar flexion deficits were detected two and one year respectively after surgery for ATR.

Endurance

The calf muscles are active in standing and locomotion. An evaluation of calf muscle work with endurance tests can be assumed to reflect the functional status of the calf muscles better than isokinetic peak torque measurements. Endurance tests using standardised heelraises have been published (Häggmark et al. 1986, Moberg et al. 1992, Mortensen et al. 1999). The ability to raise the heel above a certain level is evaluated and the number of times the patient can repeat the heelraises is compared between the injured and the non-injured sides.

Patient satisfaction

Satisfaction with the outcome of treatment and the time period when the treatment took place can be estimated in various ways, such as questionnaires and visual analogue scales. In the two randomised studies by Nistor (1981) and Cetti and co-workers (1993), no information other than anecdotal about the patients´ opinion of the treatment can be found. In some of the case series and comparative retrospective series, patient satisfaction is mentioned, but it is not documented or discussed in any further detail.

Tendon and calf muscle properties

It is a well-known fact that the Achilles tendon becomes thicker after rupture, regardless of the treatment that is given. The calf muscle hypotrophies, as measured by calf muscle circumference and cross-sectional area. Muscle hypotrophy and

tendon thickness have been studied in most articles dealing with the outcome after ATR. The significance of the findings is, however, not clear.

Time of return to work

One of the main goals for the treatment of ATR is the fast return of the patient to work. The other goal applicable to most patients sustaining an ATR is a return to sports at the same level as before the injury. These two parameters have been evaluated in many modern studies of the outcome after ATR. However, the type of sports activity has seldom been described in detail and the time of return to work has not been investigated as often as the time of return to sports.

Nistor (1981) found a mean time of return to work of 91 days among surgically-treated patients and 63 days among non-surgically-treated patients ($p<0.05$). In the study by Cetti and co-workers (1993), surgically-treated patients were absent from work for a mean of 43 days and non-surgically treated patients for 56 days (n.s.). In the randomised study by Mortensen and co-workers (1999), two groups of surgically-treated patients were compared. In the group that was managed with early rehabilitation, the mean period of sickleave was 43 days, whereas in the group managed with a postoperative cast for eight weeks, the mean sickleave was 68 days ($p<0.05$).

Time of return to sports

Varying times of a return to sports have been reported, as well as a varying number of patients who return to the same level of sports activity as before the injury. Cetti and co-workers (1993) found a significant difference between the treatment groups, as 57% of the surgically-treated patients and 29% of the non-surgically-treated patients returned to the same level of sports participation as before the tendon rupture. It was not reported when the patients returned to sports activity. Nistor (1981) found no significant differences between the groups. The patients returned to sports after an average of 11 months. In a non-randomised comparison by Kellam and co-workers (1985), 83% of the surgically-treated patients and 69% of non-surgically-treated patients returned to their preinjury level of activity. Keller and Bak (1989) found a 55% return to the same level of sports participation as before the injury among 105 surgically-treated patients. In the review by Lo and co-workers (1997) of 17 reported series, the rate of return to sports was 74% and 76% respectively, in the surgically-treated and the non-surgically-treated groups. Mandelbaum and co-workers (1995) treated 29 athletes with surgery and early rehabilitation and found a 100% return to the preinjury level for all patients after four months!

Imaging of the tendon

Imaging of the ruptured Achilles tendon can be performed using US and MRI. Historically, plain radiographs have been used to visualise the tendon indirectly, but this technique is of no value today. MRI and US can be used for diagnostic purposes, to estimate the position of the torn ends of the tendon before treatment, to monitor non-surgical treatment and for follow-up purposes when evaluating healing. The diagnosis of ATR is clinical and the use of US and MRI investigations to

establish a correct diagnosis is not necessary, provided that the patient presents early. In late-presenting cases, US can be of value if the radiologist is experienced. MRI can be used to establish the diagnosis, but it is not freely available in most parts of the world and is seldom necessary. If non-surgical treatment with early functional rehabilitation is used, US needs to be used to monitor the early process of healing (Thermann et al. 1995). The literature with regard to US and MRI and the outcome of ATR is relatively sparse.

Aims of the study

The aim of the studies in this thesis was to test the null hypothesis that surgical treatment followed by early functional rehabilitation in a brace and non-surgical treatment with immobilisation in a below-the-knee plaster produces equal outcomes after ATR.

The specific aims of the studies were:

To evaluate isokinetic strength measurements at the ankle joint in a closed kinetic chain

To analyse the reliability of leg muscle function tests with the focus on isokinetic strength measurements

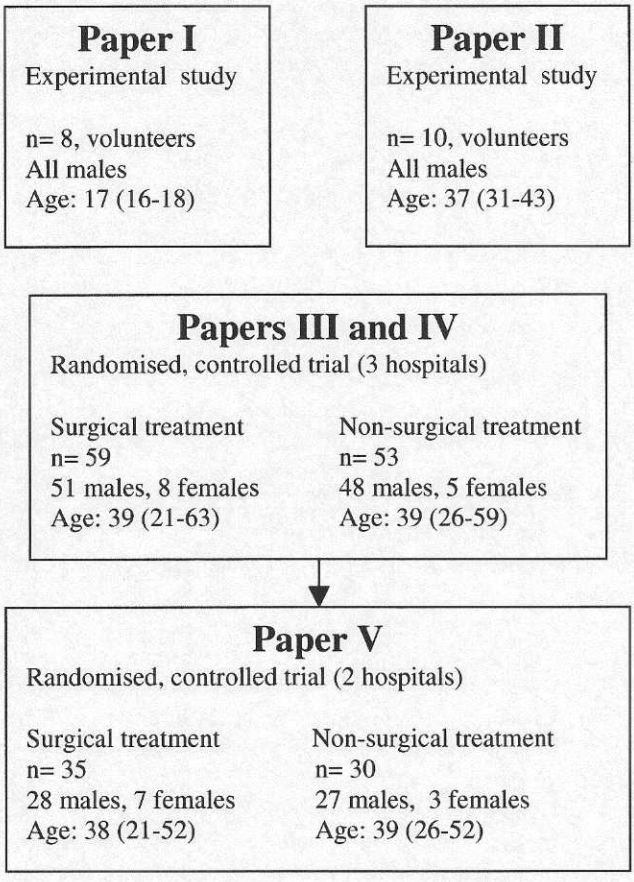
To study the outcome after treatment for ATR in a prospective and randomised manner with the complication rate as the primary end-point for the study and with objective and subjective functional parameters as secondary end-points

To evaluate the calf muscle function after ATR over time in the injured and non-injured leg and to compare the muscular strength and endurance between the treatment groups

To study the appearance of the ruptured Achilles tendon during healing and to compare the MRI and US findings between the treatment groups.

Material

Figure 4. Patients included in the respective papers



Patients

Experimental studies (Paper I and II)

In the two experimental studies (Papers I and II), healthy male volunteers participated. In Paper I, eight young males from a junior soccer team were studied. In Paper II, 10 healthy male recreational athletes, employed at two of the participating hospitals, volunteered to participate. All the volunteers in Papers I and II were righthanded and used their right foot for precision activities such as kicking a ball.

Clinical studies (Papers III and IV)

One hundred and twelve patients were included in a prospective, randomised multicentre study. The inclusion of patients in the study took place at the respective accident and emergency departments at the three participating hospitals between January 1995 and July 1997. Randomisation was performed using non-translucent envelopes in blocks.

The inclusion criteria were: age 16-65 years at the time of injury, closed injury in the tendon substance and injury not older than seven days. The exclusion criteria were previous ATR on the injured or the contralateral side, functional impairment due to illness or injury on the contralateral side or previously significant injury with persisting functional deficit, avulsion injury at the insertion of the Achilles tendon to the calcaneus, diabetes, neurological or vascular disease, serious immunological deficit or treatment with immunosuppressive therapy. Of the 112 randomised patients, three patients allocated to non-surgical treatment refused this treatment. They were subsequently operated on. They were analysed both as belonging to the surgical treatment group and, in the intention-to-treat analysis, as non-surgically treated as they were randomised to this group. All the patients who fulfilled the inclusion criteria but were not willing to participate in the randomised study were offered the standard non-surgical treatment at that time, as described in Paper III. A small number of patients were operated on and treated in the same way as the surgical-treatment group described in Paper III.

The total number of ATRs in January 1995-July 1997 was 219 (Table 1). According to the exclusion criteria, 25 patients were excluded. Of the remaining 194 patients, 82 did not wish to participate in the study. In this group of 82, ten patients did not want any follow-up examinations other than the routine clinical follow-up. Of the remaining 72 patients, 36 patients from Östra Hospital were offered the possibility to participate in a follow-up similar to the present study. From Huddinge Hospital 25 patients and from Sahlgrenska Hospital 11 patients were asked to complete a questionnaire after two years. One hundred and twelve patients were randomised.

Table 1. *Attendance at the follow-up examinations*

	Two-year follow-up	Two-year questionnaire	Unknown or other reason
Randomised study ÖS+HS+SS	n=86	n=25*	n=1**
Non-randomised ÖS	n=30	n=2	n=1+2***
Non-randomised HS+SS	n=0	n=34	n=2

* Fifteen patients completed the one-year follow-up.
** One patient with stroke, one-year follow-up completed.
*** Two patients completed the one year follow-up.

Table 2. *Demographics of the two study groups in Papers III and IV*

		Surgical treatment		Non-surgical treatment	
		n	%	n	%
Number of patients in the study		59	53	53	47
Sex	Male	51	86	48	91
	Female	8	14	5	9
Injured side	Left	34	57	30	57
	Right	25	43	23	43
Left-handed		2		2	
Right-handed		50	94*	43	96*
Both left- and right-handed		1		0	
Dominant leg** = injured leg		18	47***	18	53***
Participation in recreational sports		42	71	35	66
in competitive sports		5	8	3	6
not participating regularly in sports		12	21	15	28
Mechanism of injury	Sports activity	52	88	48	91
	Daily activity	5		2	
	At work	2		3	
Age at injury****		39.6 (9.0) 21-63		38.5 (7.3) 26-59	

* Information regarding handedness not available for all the patients.
** The dominant leg was defined as the leg preferred for kicking a ball.
*** Information regarding leg dominance not available for all the patients.
****Mean, standard deviation (SD) and ranges given

Re-rupture

In Papers III and IV, all the patients who sustained a re-rupture were subsequently excluded. This was because all the patients who sustained a re-rupture were operated on with a gastrocnemius fascia reinforcement and were not possible to analyse in the treatment groups to which they were allocated at randomisation. However, it is very important to obtain complete information about what happens if re-rupture occurs. Data about the 12 patients (in Papers III, IV and partly Paper V) who sustained a re-rupture are presented in Table 3.

The mean age of the non-surgically-treated patients who sustained a re-rupture was 38 years (median 40 years, range 28-50). The mean age of the non-surgically-treated patients who did not sustain a rerupture was 39 years (median 38 years, range 26-59).

Of the eleven patients in the non-surgical-treatment group who sustained a re-rupture, nine did so while walking. Two patients sustained a re-rupture while falling; one on stairs and the other on uneven ground. Eight patients used shoes with a heel lift, but three did not, against the instructions that were given. The re-ruptures occurred a mean of 12 weeks (range 8-18 weeks) after the ATR, four weeks after removal of the plaster. Ten of these eleven patients were athletes, nine at recreational level and one at competitive level.

The only surgically-treated patient who sustained a re-rupture was 28 years old. He was a recreational athlete who slipped and fell on a wet floor nine weeks after the ATR. He used shoes with a heel lift. The surgically-treated patients who did not sustain any re-rupture were a mean of 40 years old (median 39 years, range 21-63).

Table 3. *Patient characteristics/hospital in Papers III and IV*

Hospital	*ÖS*	*SS*	*HS*
Surgical treatment	26**	17	16
Non-surgical treatment	21	14	18*
Male	40	28	31
Female	7	3	3
Age	40 (21-53)	35 (26-56)	40 (23-63)
Re-rupture***	n=6 (13%)	n=3 (10%)	n=3 (9%)

*One non-surgically treated female patient at Huddinge sustained a rerupture.
**One surgically-treated male patient at Östra sustained a rerupture.
***The remaining 10 patients with re-ruptures were all non-surgically-treated males.

One female patient (8%) and eleven male patients (11%) sustained re-ruptures. The patients from Sahlgrenska and Östra Hospitals in Göteborg received the same information with regard to the risk of re-rupture and were treated by the same physiotherapists. The re-rupture rate in this group of 78 patients was 11.5%. The patients from Huddinge were treated by other surgeons and physiotherapists. The re-rupture rate in this group of 34 patients was 9%. Eight weeks after the ATR, all the patients were asked whether they were afraid of a re-rupture or whether they

expected a good functional outcome. The patient in the surgically-treated group who sustained a re-rupture was expecting a good result. Of the non-surgically-treated patients who sustained a re-rupture, 6/11(55%) feared a re-rupture and three expected a good result (27%). Of the non-surgically-treated patients who did not sustain a re-rupture, 14/42 (33%) feared a re-rupture and 18/42 (43%) expected a good result. No patient in the re-rupture group who sustained a re-rupture sustained a second re-rupture or any other major complication. Their mean Functional Index (FIL) (Andersson and Styf 2001) result after two years was 9.5, which is between the result for surgically-treated patients (7.7) and non-surgically-treated patients (12.1).

In the non-randomised group of 72 patients, 20 patients were treated surgically and 52 patients non-surgically. One surgically-treated patient sustained a re-rupture during the brace treatment period while bicycling and falling off the bike! This was the only re-rupture among the surgically-treated patients, producing a re-rupture rate of 5%. Three of the non-surgically-treated patients did not answer the questionnaire. Of the remaining 49 non-surgically-treated patients, seven sustained a re-rupture, producing a re-rupture rate of 14.3%. The difference between the treatment groups in this smaller, non-randomised cohort was not statistically significant (p=0.42).

Radiological study (Paper V)

In Paper V, a subgroup consisting of 65 consecutive patients from the two hospitals in Göteborg was studied. Of the 65 patients (55 men and 10 women), 35 underwent surgical treatment and 30 were treated non-surgically. Seven patients with a re-rupture were excluded. Six re-ruptures occurred in the non-surgically-treated group and one re-rupture occurred in the surgical-treatment group. As a result, 58 patients were included in this radiological follow-up; 34 surgically-treated patients and 24 non-surgically-treated patients. Their mean age was 38.6 (SD 8.3) years.

Methods

Treatment methods

Surgical treatment

Surgical treatment consisted of an end-to-end suture without augmentation, performed under local, spinal or general anaesthesia. Two No 1 sutures, either slowly resorbable (PDS®) or non-resorbable (Ti-cron®), were performed using a modified Kessler suture technique (Figure 5). A short skin incision (6-8 cm) was placed medially to the Achilles tendon, avoiding the sural nerve (Webb et al. 2000). The paratenon was carefully closed after the tendon repair was completed. The foot was placed in a below-the-knee plaster in the position achieved after surgery. Two single doses of antibiotics were used and two units (500 ml) of Dextran (Macrodex®) were used as prophylaxis against deep venous thrombosis (DVT). The plaster was removed 10-14 days after surgery and replaced by a brace (ROM-Walker, Don Joy®, Smith&Nephew, Vista, CA, USA, Figure 6). Weight-bearing as tolerated was allowed during the first two weeks. Full weight-bearing was encouraged during weeks three to eight. The brace was set to full plantar flexion and it allowed dorsiflexion up to -30°. Four weeks after surgery, the ROM was increased to -10°. Six weeks after surgery, the ROM was further increased to +10° dorsiflexion. The patients were encouraged to perform range of motion exercises.

Figure 5. The modified Kessler end-to-end suture

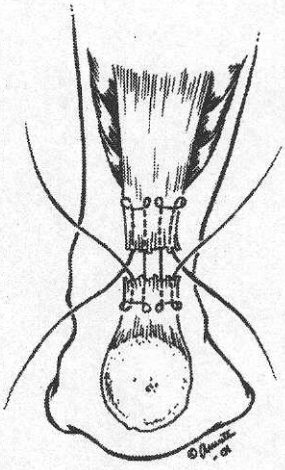
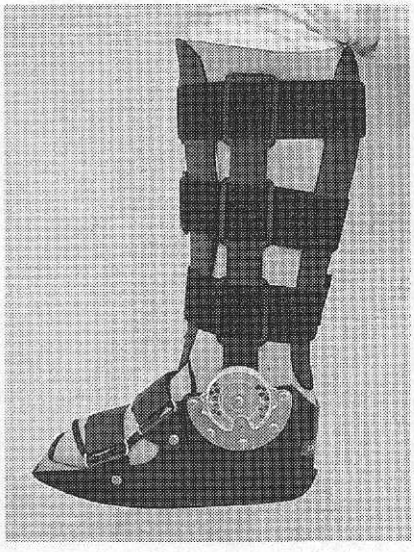


Figure 6. The ROM-Walker brace



Non-surgical treatment

Non-surgical treatment consisted of a below-the-knee plaster for eight weeks. During the first four weeks, the ankle was kept in a plaster in equinus and weight-bearing was allowed as tolerated. After four weeks, the plaster was changed and replaced by a below-the-knee plaster in a neutral position if possible and weight-bearing was encouraged. No prophylaxis against thromboembolic complications was used.

Rehabilitation

The rehabilitation protocol included a bilateral heellift of 15 mm. The heellift was mandatory during the first four weeks. The use of a heellift was recommended but was not mandatory for a further four weeks. Identical rehabilitation protocols were used in both groups and physiotherapy was started eight weeks after injury. Full weight-bearing without crutches was allowed at eight weeks. The rehabilitation protocol consisted of ROM exercises, balance training and strength and endurance exercises. Functional closed chain exercises were started at eight weeks and were followed by stationary cycling and water exercises including swimming during weeks nine to ten. The strength training for the calf muscles was gradually increased and specific eccentric training was added to the concentric/eccentric exercises in the 12^{th} week. During the 16^{th} week, running and sports-specific training were allowed, provided that adequate muscular strength and functional ability had been achieved.

Summary of the evaluation methods

Clinical follow-up

Papers III, IV, V

The follow-up examination was carried out prospectively at 8.0 (0.6) weeks, 12.1 (0.9) weeks, 6.7 (1.0) months, 12.5 (0.9) months and 25.2 (1.3) months. The evaluation after eight and 12 weeks was made by an orthopaedic surgeon and a physiotherapist separately. The six-, 12- and 24 month examinations were conducted by research physiotherapists.

Isokinetic strength measurement

Papers I, II, III, IV

A KINetic-COMmunicator (Kin-Com®) 500 H (Chattex Corp., Chattanooga, TN, USA) was used to measure isokinetic torque production in plantar- and dorsiflexion at the ankle joint. Three different positions were used in the studies. The measurements in the closed chain position were evaluated in Paper I. In Paper II, the seated position (Figure 7) was compared with the closed chain position (Figure 8) and the supine position (Figure 9). In Paper IV and briefly in Paper III, the three positions were used to evaluate calf muscle function after ATR. Concentric and eccentric muscle actions were performed at the angular velocities of 30°/sec and 180°/sec. Peak torque production and torque production at 5° of plantar flexion were analysed. Measurements of dorsiflexion and plantar flexion strength were made. The right and left sides were compared in Papers I and II and, in Papers III and IV, the injured side was compared with the non-injured side.

Figure 7. The seated position

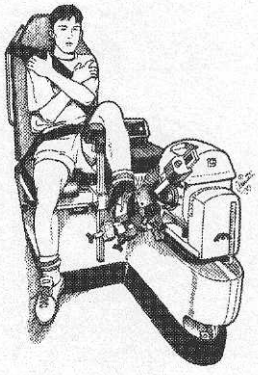


Figure 8. The seated closed-chain position

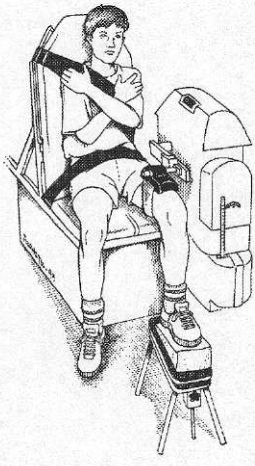


Figure 9. The supine position

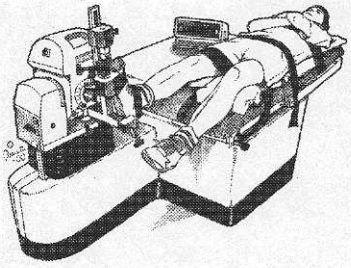
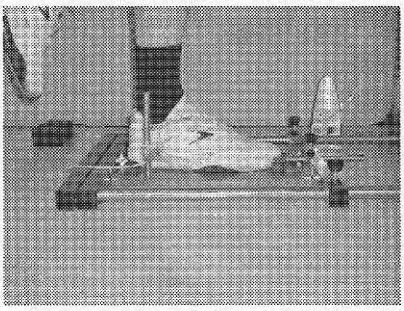


Figure 10. The heel-raise test



Heel-raise test

Papers II, III, IV, V

A standing heel-raise test (Figure 10), modified from Häggmark and co-workers (1986), was used to evaluate the endurance of the calf muscles. The number of standing unilateral heel raises, at a rate of 40/minute, above a level of five cm from the floor was counted. The addition of a block kept the ankle in a position on a level with the light beam. The test was stopped when the subject was unable to continue performing proper heel raises. Each test was performed twice and the average of the tests was used for analysis. Both the time taken and the number of heelraises were documented.

Ankle joint range of motion

Papers II, III

Active ankle ROM was measured in the supine position using a goniometer. Passive range of motion was measured in the identical way, but, with the patient standing.

Achilles tendon rupture score

Papers III, V

An overall outcome measurement after ATR was constructed as a modification of scores previously used (McComis et al. 1997, Leppilahti et al. 1998). The ATR score (Figure 11) includes five objective parameters (range of motion, calf muscle circumference, isokinetic strength, endurance, complications) and three subjective parameters (pain, opinion of treatment, functional index). A total score of 100 is possible and is the best achievable result. Not all patients were able to participate in every part of the examination on all occasions. If data were missing for one parameter, the total score was counted as a percentage of the possible total score excluding the missing parameter. For reasons of comparison all scores are therefore given as percentages.

Figure 11. Achilles tendon rupture score

Dorsiflexion and plantar flexion at the ankle joint on the injured side compared with the non-injured side. Difference in either direction		
	5° difference or less	10
	10° difference	5
	15° difference or more	0
Calf muscle hypotrophy measured as maximum calf circumference as a ratio between the injured and the non-injured side		
	97-100%	10
	93-96%	5
	< 93%	0
Isokinetic plantar flexion peak torque at 30°/sec supine, extended knee, expressed as a ratio between the injured and the non-injured side		
	95-100%	15
	85-94%	10
	75-84%	5
	< 75%	0
Endurance measured as number of heelraises, expressed as a ratio between the injured and the non-injured side		
	80-100% (or more)	15
	55-79%	10
	1-54%	5
	Impossible	0
Pain		
	None	10
	Moderate	5
	During walking	0
Complications (patients with rerupture excluded)		
	None	15
	One minor	10
	> one minor	5
	Major	0
Subjective assessment of results of treatment		
VAS		
	90-100	10
	75-89	5
	< 75	0
FIL		
	0-5	15
	6-10	10
	16-30	5
	> 30	0
	Total	***100***

Maximum calf circumference

Papers II, III, IV

Measurements of maximum calf circumference were made with the patient prone and relaxed. The injured side was compared with the non-injured side and the values are expressed as absolute figures in cm and as a ratio between the injured and non-injured sides.

Maximum Achilles tendon width

Papers II, III, IV

Maximum tendon width was measured with the patient prone, using a Vernier calipers and the values are expressed as absolute figures in mm and as a ratio between the sides. Manual palpation of the Achilles tendon was performed to evaluate homogeneity and tenderness.

Questionnaire

Paper III

Interviews were administered at eight weeks and at six, twelve and 24 months by the research physiotherapists. The patients filled in the questionnaire while in hospital for the clinical examination. If a patient did not attend a follow-up, the questionnaire was answered at home and returned by mail.

Analysis of complications to treatment

Paper III

Complications were registered prospectively. At all follow-ups protocols based on a check-list were filled in. All the patients´ file notes were thoroughly checked for additional information. The following complications or symptoms after ATR were checked for: disturbed sural nerve function, signs of deep venous thrombosis, edema, skin adhesions, skin or tendon necrosis, delayed wound healing, superficial or deep infection, scar formation and tenderness, calf muscle weakness, ankle joint mobility, pain while walking and after walking, re-ruptures and problems with shoe wear.

Visual Analogue Scales

Papers III, V

The Visual Analogue Scale (VAS) (Scott and Huskisson 1976, McCormack et al. 1988) was used at all follow-ups to evaluate the patients´ opinion of their treatment and the outcome following the rupture.

Functional index

Paper III

A recently developed functional index for lower leg and ankle (FIL, Figure 12) was used to evaluate functional performance (Andersson and Styf 2001). The overall results were divided by the number of VAS answers. At least nine of the 11 parameters had to be answered for the analysis to be used. The measurement from each VAS was expressed as a value between 0 and 100 and the overall result was divided by the number of VAS answers, rendering a mean result of between 0 and 100. Zero was the best possible result, indicating no problems at all while performing the actual activity, and 100 was the worst possible outcome, indicating that the activity was impossible to perform. This index was used at all the follow-ups after week 12.

Figure 12. **Functional index for lower leg and ankle**
(FIL)

How do you manage?

	Without difficulty	Not at all
1. Walking on uneven ground		
2. Walking upstairs		
3. Walking downstairs		
4. Running downhill		
5. Running on uneven ground		
6. Doing heavy work		
7. Doing your regular job		
8. Squatting		
9. Running uphill		
10. Driving a car		
11. Dancing		

Ultrasonographic examination

Paper V

US examinations were performed by one of two experienced radiologists at six, 12 and 24 months. Abnormal findings on US were graded according to a protocol consisting of six parameters; partial tendon defect, tendon homogeneity, tendon

edema, tendon thickening, peritendinous reaction and tendon glide function (Figure 13).

Figure 13. Grading of abnormal findings at MRI and US evaluations

Partial tendon defect		**Tendon homogeneity**		**Tendon edema**	
No	0	Homogeneous	0	No	0
< 5mm	1	Mild heterogeneity	1	Focal	1
> 5mm	2	Heterogeneous	2	Generalised	2
Tendon thickening		**Peritendinous reaction**		**Tendon glide function (only US)**	
No	0	No	0	Normal	0
Fusiform	1	Focal	1	Decreased	1
Generalised	2	Generalised	2		

Magnetic Resonance Imaging

Paper V

The MRI images were evaluated by one of two experienced radiologists. The examination was performed after one year and also after six months in a small number of patients. The number of MRI examinations was limited during the study for practical reasons and for reasons of availability. The same six parameters were evaluated as for US, apart from the dynamic tendon glide function (Figure 13).

Statistical methods

Figure 14. Statistical tests and descriptive methods used in the papers

Statistical tests	Paper I	Paper II	Paper III	Paper IV	Paper V
Comparisons within groups					
Wilcoxon´s signed rank test	x			x	x
Comparisons between groups					
Mann-Whitney U-test				x	x
Fisher´s non-parametric permutation test		x			
Chi-square test			x		
Student´s t-test			x		
Fischer´s exact test			x	x	x
Mantel-Haentzel´s test			x		x
Changes over time					
Wilcoxon´s signed rank test				x	x
Correlation analysis					
Spearman´s correlation coefficient				x	x
Descriptive statistics					
Mean and SD	x	x	x	x	x
Median and range	x		x	x	x
Limits of agreement		x			
Intra-individual SD		x			
Coefficient of variation		x			
Intra class correlation	x	x			

All the significance tests were two tailed and conducted at the 5% significance level.

Ethics

Informed consent was obtained from the patients and the volunteers. All the studies were approved by the Human Research Ethics Committees at the Faculty of Medicine, Göteborg University, and the Karolinska Institute, Stockholm.

Summary of the papers

Paper I: The test-retest reliability of concentric and eccentric muscle action during plantar flexion of the ankle joint in a closed kinetic chain

Introduction: The aim of this study was to evaluate the test-retest reliability of the closed kinetic chain position, for concentric and eccentric isokinetic measurements during plantar flexion of the ankle joint.

Material: Eight young (16-18 years) male, high-level, junior soccer players participated in the study. They were all right handed and preferred to use their right foot for precision activities such as kicking a ball.

Methods: A previously described but not reliability tested method for positioning the subjects was used. The Kin-Com® dynamometer was used with the pad of the actuator arm positioned proximal to the knee joint and the foot placed on a stool. Tests were performed twice with a 48-hour interval and measurements were made with an angular velocity of 30°/sec, which corresponds to approximately 75°/sec at the ankle joint. Peak torque output was measured for concentric and eccentric muscle action.

Results: The Intra class correlation was found to be high, with ICCs for concentric and eccentric measurements on the right side of 0.87 and 0.89 respectively. Corresponding values on the left side were 0.97 and 0.95. The maximum torque generation during concentric and eccentric muscle action showed no significant side difference.

Conclusions: The closed kinetic chain position was found to be a reliable method for measuring maximum isokinetic plantar flexion torque of the ankle joint.

Paper II: The reliability of measuring leg muscle function. Isokinetic testing at the ankle in three positions and a heel-raise test for endurance

Introduction: The aim of this study was to perform an evaluation of the test-retest reliability of isokinetic and endurance tests of calf muscle function.

Material: Ten healthy male (31-43 years) recreational athletes participated in the study. They were all right handed and they were right legged for precision activities.

Methods: The Kin-Com® dynamometer was used to measure isokinetic torque production, both peak torque and torque at 5° plantarflexion. Dorsiflexion and plantarflexion muscle action were recorded at two angular velocities, 30°/sec 180°/sec respectively. Tests were performed twice with a five- to seven-day interval. Concentric and eccentric muscle action were recorded on the right and left sides in three different positions (supine, seated and in a seated closed kinetic chain). In addition to the isokinetic tests, ankle joint range of motion, maximum calf muscle circumference, maximum tendon width and endurance were evaluated. Endurance was evaluated as the ability to perform single-leg heel raises and measured as the number of heel raises performed until fatigue.

Results: ICC was analysed for all tests. The results for dorsiflexion strength were ICCs of 0.61-0.95, except for the concentric mode in the supine position (ICC 0.00-0.49). Plantar flexion strength ICCs were 0.37-0.88. Torque production was lower at the higher angular velocity. Eccentric torque production was higher than concentric torque production. Plantar flexion strength was greater than dorsiflexion strength. There was no clear difference between strength on the right and left sides. In the seated position, plantar flexion strength was greater on the left side compared with the right side. In the other two positions, no such difference was detected. In dorsiflexion, the torque production was higher on the right side. The reliability of the endurance test, the calf circumference measurements, the tendon width and the range of motion were 0.71-0.98 (ICC). A significant side-to-side difference in endurance was detected, with the right side having better endurance.

Conclusions: All three test positions used for the isokinetic tests of plantar flexion at the ankle joint were found to be reliable. Low reliability was found in the supine position when evaluating dorsiflexion strength. The clinical measurements of calf muscle circumference, tendon width and range of motion at the ankle joint all produce highly reproducible results. The standing heel-raise test is as reliable as isokinetic tests for calf muscle function.

Paper III: Surgical treatment of Achilles tendon rupture followed by functional rehabilitation versus non-surgical treatment with immobilisation in plaster. A prospective, randomised study

Introduction: The aim of this prospective, randomised, multicentre study was to compare the outcome after surgical and non-surgical treatment for ATR in a large cohort.

Material: At the three participating hospitals, 112 patients were included in the study. There were 99 men and 13 women and the mean age was 39.1 years (SD 8.2). Fifty-nine patients were treated surgically and fifty-three patients were treated non-surgically.

Methods: Surgical treatment consisted of an end-to-end suture through a short, medial skin incision. Plaster in the position achieved at surgery was used for 10-14 days, followed by six weeks of brace treatment with gradually increasing range of motion and weight-bearing. Non-surgical treatment consisted of eight weeks of plaster treatment. A below-the-knee plaster in equinus was used for four weeks and was followed by four weeks in a neutral position. Weight-bearing was allowed. The outcome of treatment was studied with the re-rupture rate as the primary end-point.

The follow-up was performed by research physiotherapists on five occasions between eight weeks and two years. Five objective parameters and three subjective parameters were evaluated and these eight parameters consitute the Achilles Tendon Rupture score. Isokinetic plantar flexion strength was measured as peak torque at 30°/sec in the supine position, with comparisons between the injured and the non-injured sides. Endurance was measured as the number of single-leg heel raises, with comparisons between sides. The calf muscle circumference was measured and comparisons were made between the sides. Major and minor complications after each type of treatment were recorded and analysed.

The degree of pain experienced was analysed. A functional index (FIL) based on 11 Visual Analogue Scales was used to measure the degree of function in terms of activities that are demanding for the calf muscles. Visual Analogue Scales were also used to measure satisfaction with the treatment and the result of the treatment.

Results: All the patients were followed up after two years using either a clinical examination or, in a minority, with a questionnaire. The re-rupture rate was significantly (p=0.001) higher in the non-surgically-treated group (20.8%) compared with the surgically-treated group (1.7%). All the patients who sustained a re-rupture were subsequently operated on and were excluded from further follow-up in the study.

All the minor complications were found in the surgical group, but none of them produced any permanent functional impairment. On all occasions, the differences

between the two treatment groups were significant when analysing the patients´ opinion of the results of treatment and quality of life during the treatment.

The patients´ opinions of the treatment were categorised and evaluated. Eight weeks after injury, all the surgically-treated patients claimed that they would have chosen the same treatment on a possible second occasion. No significant differences were found between the treatment groups when analysing the functional index (FIL), the ATR score, the isokinetic strength, the endurance and the range of motion at the ankle.

Patients with light, mobile work had a significantly ($p=0.03$) shorter period of sick leave in the surgically-treated group, but the time of return to work in the surgical group as a whole was 54.9 (SD 47.9) days compared with 73.4 (SD 56.5) days in the non-surgical group (n.s.). In both groups, 54% of the patients had resumed sports at the same level as before the injury and approximately 30% had the ability, but not the ambition.

Conclusions: Surgical treatment followed by early functional rehabilitation is a safe method for the treatment of ATR. The risk of major complications can be minimised using surgical treatment. However, surgical and non-surgical treatment produced equally good long-term results in the group of patients in whom no re-rupture occurred. The non-surgical treatment of ATR, which produced treatment failure in every fifth patient, can, however, not be regarded as acceptable for healthy, active persons under the age of 65 years.

Paper IV: Calf muscle function after Achilles tendon rupture. A prospective, randomised study comparing surgical and non-surgical treatment

Introduction: The aim of this study was to compare calf muscle function after the surgical and non-surgical treatment of ATR.

Material: A group of 112 patients who were randomised between surgical and non-surgical treatment after ATR were followed prospectively. Fifty-nine patients were treated surgically and fifty-three non-surgically.

Methods: The surgical treatment consisted of an end-to-end suture, followed by functional rehabilitation, including plaster treatment for 10-14 days, and thereafter six weeks of brace treatment. The non-surgical treatment included four weeks of below-the-knee plaster in equinus, followed by four weeks in a neutral position.

The evaluation focused on isokinetic calf muscle strength, but an evaluation of endurance, tendon width and calf muscle circumference was also performed prospectively. Follow-up examinations were performed after six, 12 and 24 months. Isokinetic calf muscle strength was measured in the supine, seated and seated closed kinetic chain position. The angular velocities of 30°/sec and 180°/sec were chosen and both concentric and eccentric muscle action were analysed. Dorsiflexion and plantar flexion strength were evaluated and a side-to-side ratio was analysed. Peak torque and torque at 5° of plantar flexion were analysed.

Endurance was measured as standardised single-leg heel raises until fatigue. The number of heel raises performed on the injured side was compared with the number of heel raises on the non-injured side. Maximum calf circumference and maximum tendon width were measured and analysed, comparing the injured and non-injured sides.

Results: Re-rupture was regarded as treatment failure. Eleven patients (20.8%) in the non-surgical-treatment group and one patient (1.7%) in the surgical-treatment group sustained a re-rupture between weeks eight and 18 and were excluded from the follow-up. The functional outcome did not differ between competitive and recreational athletes. There were no significant differences in plantar flexion peak torque or torque at 5° of plantar flexion between the treatment groups on any occasion. A correlation was found between concentric and eccentric measurements in plantar flexion. A strength deficit in plantar flexion was found in both treatment groups on all occasions when the injured side was compared with the non-injured side. Eccentric torque production was higher than concentric torque production.

Dorsiflexion peak torque and torque at 5° of plantar flexion did not differ between the treatment groups. In the case of plantar flexion measurements, the eccentric mode produced higher torque than the concentric mode of muscle action. However, there were no strength deficits on the injured side in dorsiflexion compared with the non-injured side.

No significant difference was found between the treatment groups in terms of the heel-raise ability. The endurance was higher after twelve months than after six months in both treatment groups. In the surgically-treated group, this trend continued between one and two years but not in the non-surgically-treated group. The tendon width was greater on the injured side compared with the non-injured side in both treatment groups on all five occasions between eight weeks and two years. The calf muscle circumference on the injured side did not differ significantly between the treatment groups. There was a deficit in calf muscle circumference on the injured side compared with the non-injured side on all occasions in both treatment groups.

Conclusions: If re-ruptures are avoided, surgical treatment followed by early functional rehabilitation and non-surgical treatment appear to produce equally good results. The evaluation methods for muscle strength and endurance used in the present study were not able to detect any significant differences between the treatment groups, but they revealed a clear difference between the injured and non-injured sides. The standardised single-leg heel-raise test should be used as a measure of recovery of calf muscle endurance after ATR.

Paper V: The ultrasonographic appearance of the ruptured Achilles tendon during healing. A longitudinal evaluation of surgical and non-surgical treatment, with comparison to MRI appearance

Introduction: The aim of the study was to evaluate the healing characteristics of the ruptured Achilles tendon. Surgically- and non-surgically-treated patients were compared during healing.

Material: In a prospective, randomised study, surgical treatment was compared with non-surgical treatment for ATR. Sixty-five patients were randomised (55 men and 10 women) to surgical or non-surgical treatment. Thirty-five patients underwent surgical treatment and 30 patients were treated non-surgically. Seven patients were excluded due to re-rupture. Fifty-eight patients were included in the radiological follow-up.

Methods: Surgical treatment consisted of an end-to-end suture placed through a short medial skin incision. Postoperative plaster treatment for two weeks was followed by a brace for six weeks. Non-surgical treatment consisted of a below-the-knee plaster. For the first four weeks, a plaster in equinus was used, followed by four weeks in a neutral position.

The radiological evaluation was performed by one of two experienced radiologists, prospectively six, 12 and 24 months after the injury. Comparisons were made with clinical outcome parameters such as isokinetic strength, endurance, patient satisfaction and the ATR score.

Ultrasonography was performed using a real-time scanner with a 7.5 MHz linear array probe. The injured and non-injured sides were evaluated on all occasions. MR imaging was performed using a 1.0 T-scanner, using the quadrateure extremity transmit-receive coil, and both sides were evaluated and scanned separately. PD-weighted and T2-weighted images were obtained.

Results: No statistically significant differences in terms of the number of pathological findings were found using either US after six and 12 months or MRI after 12 months. After one year, the US findings included moderate heterogeneity, fusiform or generalised tendon thickening and reduced tendon glide function in both treatment groups. The MRI findings after one year included thickening of the tendon and moderate heterogeneity, while but only edema, tendon defects or peritendinous reactions were only found in a minority of the patients. The number of positive findings on US and MRI diminished over time during the follow-up. The correlation between pathological findings on US and MRI and the clinical parameters was not significant.

Conclusions: No significant differences in the number of pathological findings could be detected between the treatment groups, using US and MRI during healing

after ATR. No significant correlation between the clinical parameters and the number of pathological radiological findings was found. The result producing non-significant differences between the treatment groups is in accordance with previous findings relating to the clinical outcome after ATR in the population that does not sustain a re-rupture.

Discussion

Experimental studies (I-II)

Isokinetic tests

In Papers I and II, we studied the methods that are commonly used in research and clinical evaluations of calf muscle strength, especially plantar flexion strength at the ankle joint. Since its introduction in the 1960s, the use of the isokinetic dynamometer has evolved to become the accepted standard in muscle function testing (Cox 1995, Keating and Matyas 1996). Isokinetic dynamometers have thus enabled the quantification of many parameters of muscle function, but the routine use of many parameters is limited due to a lack of validity, reproducibility and clinical importance. Our concern when planning the prospective study on the treatment of ATR was whether the isokinetic methods currently in use were reliable enough for use in evaluations of muscle strength after ATR. This concern was also influenced by the fact that isokinetic evaluations at the ankle joint have been studied to a far smaller degree than, for example,at the knee joint (Cox 1995, Porter et al. 1996). Reliability measures for the Kin-Com® dynamometer are scarce in the literature and, due to study inconsistencies, the normative values from one study cannot easily be used for comparisons with other studied populations. The need for a reliability study was obvious in the field of calf muscle function.

Most previous studies have used young, healthy volunteers, predominantly males. In Paper I we evaluated a homogenous group of eight young males for the purpose of establishing whether the new and different method of measuring isokinetic torque production in a closed kinetic chain was reliable in the range of previously used positions.

In the subsequent Paper II, this method was compared with the established methods of measurement, in the supine position and seated in an open kinetic chain. In this study, a group of male recreational athletes with a mean age of 37 years was studied. The aim of using this group of volunteers was to study a population similar to the population of patients who usually sustain an ATR.

It is well known that subject factors and test procedure factors are difficult to control during isokinetic testing. It is doubtful whether information such as normative data can be compared with results from other studies due to the common inconsistencies in many parameters. Our purpose was to design experimental studies that fulfilled the criteria of high reproducibility. In addition, we wanted to extend the studies that have previously been performed in which a small number of parameters have generally been evaluated in each study (Holmbäck et al. 1999). The eccentric mode of muscle action is used in rehabilitation after ATR and should be included in any evaluation of treatment after ATR. We therefore needed to establish the normative data in the experimental studies and to know whether these methods were reliable.

In a review of more than 200 studies of dynamometric measurements, Keating and Matyas (1996) concluded that "in the majority of the publications, the authors failed to provide sufficient detail for accurate replication of test procedures or for

comparison with other studies". Studies of isokinetic strength testing of the ankle were reviewed by Cox (1995) and only three studies dealing with reliability measurements of plantarflexors or dorsiflexors at the ankle joint were found (Öberg et al. 1987, Karnofel et al. 1989, Wennerberg 1991). Recently, a study of plantar flexion and dorsiflexion measurements in both the concentric and eccentric mode was published (Poulis et al. 2000), making comparisons with previously reported normative data. The average normative data for plantarflexion ranged from 71 to 185 Nm in the eight studies reviewed. No reliability data were shown.

Many subject factors and test procedure factors influence the result (Keating and Matyas 1996, Holmbäck et al. 1999) of isokinetic measurements. The crucial factor appears to be whether the study protocol can control these factors. Age, sex, weight, athletic background, disability and limb dominance are all subject factors that have been found to affect dynamometric measurements in general (Keating and Matyas 1996). All these factors have been described in our studies. For example, if age is considered, previous studies have shown that higher age correlates to lower torque production (Gajdosik et al. 1996). Age should therefore be considered if different study populations are compared. However, when comparing measurements in the seated closed chain position in Papers I and II, no such age correlations were found. On the contrary, the group of middle-aged recreational athletes in Paper II produced higher torque values than the group of young competitive athletes in Paper I. One can only speculate whether this was due to psychological factors such as motivation or whether the ability to produce muscle torque really was higher in the older group of volunteers.

Test procedure factors can be analysed as pre-test-related factors, during-test-related factors and post-test-related factors. The pretest factors such as warm-up procedures, subject positioning, stabilisation, alignment of anatomical and dynamometeric axis, preload and gravity correction have all been considered and described in our studies. The during-test factors are angular velocity, rest intervals, feedback given, range of motion within which the test is performed, muscle action (concentric or eccentric) and mode (isokinetic, isometric, isotonic). The post-test factors include the type of data collected and the analyses performed. All the above have been described in our studies to enable reproduction of the methods for further tests. The data analysis was performed in accordance with the recommendations of Holmbäck et al. (1999) and was based on the Intra class correlation (ICC) analysis.

Despite efforts to control subject factors as well as test procedure factors, we did not obtain higher ICC figures than 0.37-0.95 for plantar flexion strength in Paper II. In the more homogeneous population in Paper I, the ICCs were 0.87-0.97. The corresponding values for the closed kinetic chain measurements in Paper II were 0.61-0.91. One possible explanation is the relatively small number of subjects which makes the study vulnerable to outliers. However, if the values for reliability are compared between studies, it has to be remembered that, in other studies, outliers have often been excluded (Andersen 1996), which was not the case in our studies.

All our measurements were performed on both limbs. This makes an evaluation of the limb dominance effect possible. No clear conclusions have, however, been drawn in terms of limb dominance. Further research focusing on limb dominance is needed in order to answer the very interesting question about the influence of side dominance on the strength values obtained.

In the end, the important question is whether the addition of new tests adds valuable information about calf muscle function. The question of the validity of the muscle function tests has not been explicitly investigated in our experimental studies and was not the primary purpose of the studies. To answer this question, it is better to compare an injured limb with a non-injured limb, which was the case in the clinical studies. We used the isokinetic method that is the accepted standard and expanded it. However, doubt can easily be felt about these tests. Do we really study muscle performance that resembles calf muscle function, which is important in activities of daily living, at work and in sports activities?

Other evaluation tests

The calf muscles are active during standing and walking, as well as during jumping and running. Both endurance and explosive muscle action are expected from the calf muscles. However, the focus has mostly been placed on peak performance rather than endurance. It was therefore important to establish the normative data for the standardised endurance test and to evaluate whether this test was as reliable as the isokinetic tests.

The standardised heel raise test has been described previously (Häggmark et al. 1986, Lunsford and Perry 1995, Svantesson et al. 1998) and normative data were given for healthy volunteers in the last two of these studies (27 and 25 heel raises on each side respectively). Our findings agree well with these data. In the present study (Paper II), the reliability measured with ICC was 0.78 and 0.84 respectively on the left and right sides. This was as good as the isokinetic tests on the same population. To our knowledge, the test-retest reliability has not previously been described for the standardised heel-raise test. The standardisation of the heel raise consisted of the addition of a block for the forefoot. As a result the tendency towards the forward movement of the foot against the wall is counteracted and the alignment of the malleoli to the light beam is thereby ensured. The factor most prone to variability in heel-raise testing is probably the estimation of when to stop the test. The test should be stopped when the heel raises are not done in the right way, i.e. with increasing flexion of the knee. The best thing is probably if only one investigator is involved in the heel-raise test, to reduce the influence of the subjective decision-making.

The Achilles tendon and calf muscle properties such as maximum tendon width, maximum calf circumference and the ankle joint range of motion are parameters which are often studied in clinical investigations after ATR. The reliability was found to be good or excellent (ICC 0.71-0.97) for these commonly used methods. The validity of the measurements, especially tendon width, can be debated and the correlation to functional performance questioned. However, the establishment of whether or not these methods are reliable is important because they are commonly used and will still be used as comparative data to which most functional tests can be correlated.

Clinical studies (III-IV)

Study design

The method of randomisation is of great importance in a randomised, controlled study. In an editorial (JBJS Am 1997), it was stated that "the process of selection itself is critical" and that "the drawing of envelopes or a similar method is the only appropriate way to randomise patients". The randomisation in our clinical study took place at the accident and emergency departments at the three hospitals involved. Because envelopes in blocks were used, there was no possible bias in the selection of patients. No exclusion of patients took place after randomisation. As ATR is becoming increasingly common, we believe there are good opportunities to perform strictly randomised studies. Non-randomised treatment reports are of limited scientific value. The literature about treatment after ATR contains a huge number of such reports, mostly on the surgical technique preferred by the author, producing excellent results.

Our prospective data are presented in two papers (III and IV), due to the large amount of data collected. The design was identical in both studies. Concerns have previously been raised about randomisation (Lo et al. 1997) in the study by Nistor (1981). In the study by Nistor, randomisation was performed according to which of the two orthopaedic departments was responsible for the care of the emergency cases. In the other randomised study by Cetti and co-workers (1993), the process of randomisation is not explained and a large number of patients (45/156) were excluded after randomisation. Another criticism against that study was the differences in the length of the period of treatment for the respective study groups. The follow-up period in the study by Cetti and co-workers (1993) was one year. In the other prospective study by Nistor (1981), the follow-up was one to five years (mean 2.5 years).

Complications

The re-rupture rate after surgical and non-surgical treatment for ATR has probably been reported in all studies. A complication like re-rupture signifies failure to treat. However, the decision-making is still difficult when taking account of the fact that the ATR can be treated non-surgically with good results, avoiding potentially serious surgical complications.

Complications are reported as minor, moderate and major (Lo et al 1997). We believe, however, that the most important issue is to weigh up the rate of re-rupture after non-surgical treatment against the rate of serious surgical complications such as deep infections, wound breakdown and tendon necrosis.

The re-rupture rate after non-surgical treatment was 8% in the study by Nistor (1981) and 15% in the study by Cetti and co-workers (1993). Our re-rupture rate of 21% is higher than the average re-rupture rates reported after non-surgical treatment. In the reviews by Kellam (1984) and Wills and Washburn (1986), the re-rupture rate was 18% and, in the reviews by Cetti and co-workers (1993) and Lo and co-workers (1997), it was 13% (range 4% -50%) and 12% respectively.

We have not found any circumstances that can explain the higher incidence of re-ruptures among the non-surgically-treated patients in our study. The type of

plaster treatment was the standard that has been used for more than 20 years and the same as that in the study by Nistor (1981). Information about the risk of re-rupture was given after eight weeks by an orthopaedic surgeon and a physiotherapist. Physiotherapy was offered to all patients and almost all attended (97%). Shoe-lifts were used and the pace of the rehabilitation was set by the patient after guidance from the physiotherapists. Our values, with relatively low rates of return to sports and relatively moderate ambitions in relation to a return to sports by six months, point to the fact that no patient was forced into rapid rehabilitation, thereby increasing the risk of re-rupture. In conclusion, we believe that our re-rupture rate is representative of the incidence of re-rupture in a group of patients strictly randomised and treated with a standardised non-surgical protocol.

In the present study, all the patients who sustained re-ruptures were excluded from the time they sustained the re-rupture. This was due to the fact that all twelve (11 non-surgically-treated and one surgically-treated) patients were operated on with augmentation tenoplasty. The results presented after week 12 only include the remaining 100 patients. When comparing the results of the present study and other previous studies, this fact must be borne in mind.

Patient satisfaction

The single most important goal after treatment for an injury, i.e. ATR, is that the patient is satisfied with the results of the treatment. The second most important goal is that the patient is satisfied with the quality of life during the treatment and rehabilitation period. In most cases, satisfaction with the outcome correlates with restored function and little or no permanent disability. However, explicit results in terms of patient satisfaction are scarce in the literature. In the study by Nistor (1981), only anecdotal information is given. Cetti and co-workers (1993) did not mention patient satisfaction at all in their randomised study.

We used questionnaires in combination with VAS and found a statistically significant difference on all occasions in favour of surgical treatment. Both the results of treatment and the quality of life during the treatment period were more appreciated in the surgically-treated group of patients. The VAS has gained widespread use not only for pain evaluation but also as single scales in questionnaires (McCormack et al. 1988) or as multiple scales evaluating function, (for example Salén et al. 1994). The FIL index used to describe function after ATR in our study has been found to be reliable (unpublished data) and valid (Andersson and Styf 2001).

One possible bias in favour of surgical treatment is the higher level of care for this group than the non-surgically-treated group. However, in the present study protocol, 12 contacts with surgeons and research physiotherapists were scheduled in the non-surgically-treated group and 14 in the surgically-treated group.

Return to sports and work

In the present study, 89% of the patients sustained their ATR during sports activities. Seventy-six per cent of the patients regularly participated in sports activities. Almost exclusively recreational athletes were treated in our study, which is in accordance with previous studies of ATR. However, the goal can be assumed to

be a return to sports participation at the preinjury level. We explicitly asked the patients at eight weeks if they wanted to return to sports participation. Sixty-one per cent answered the question "yes absolutely", 23% said "yes if possible" and 16% said they had no such ambitions. After one year, 54% of both treatment groups had returned to sports participation, 30% had the ability but not the ambition and 16% had not been able to return to sports. We believe that these values are representative of the population of mostly recreational athletes. All the data are based on the patients´ answers and not the doctors´ opinion. However, to make an analysis of true functional recovery and a return to the preinjury level of sports participation after ATR, far more detailed information is needed.

In the study by Cetti and co-workers (1993), a significant difference was found in favour of the surgical treatment. Sixty-two per cent of the sports active patients in the surgically-treated group returned to their preinjury level of sports participation, whereas the corresponding figure after non-surgical treatment was 34%. In the study by Nistor (1981), only anecdotal information in terms of return to sports is reported. In the present study, the majority of the patients were white-collar professionals, which is in accordance with previous studies (Józsa et al. 1989). The typical patient in our study was a 40-year-old, hardworking man who felt he had little or no opportunity to stay away from work for any long period of time. When comparing the return to work between treatment groups, it is important to define the groups of patients who can possibly benefit from the type of treatment given.

We believe that all patients with a truly sedentary job can return to work immediately after sustaining an ATR, irrespective of the treatment given. On the other hand, blue-collar workers with heavy, manual jobs cannot return to work before healing has occurred and successful rehabilitation has been completed. Surgically-treated patients with light and mobile jobs returned to work significantly faster than the non-surgically-treated ones in the present study.

In the study by Nistor (1981), non-surgically-treated patients returned to work significantly faster. Nistor presumed that the reason for this was that the non-surgically-treated group did not regard their injury as being as serious as the surgically-treated patients.

In the study by Cetti and co-workers (1993), there was a non-significant difference in the time of a return to work between the treatment groups. However, the patients who sustained re-ruptures were included in this study and their occupation was not mentioned.

In non-randomised studies of the treatment of ATR, the time of return to work is seldom interesting because only comparisons between groups can add any valuable information. Absolute values for return to work cannot be compared between studies because they probably reflect the conditions on the labour market in each country more than differences in outcome after ATR.

Calf muscle strength and endurance

Objective evaluations of calf muscle strength, with comparisons between the injured and the non-injured limb, are important after ATR. Sufficient calf muscle strength is necessary for normal balance, standing, gait, running, jumping and climbing.

Normal peak torque production, as well as normal endurance, are important features of restored calf muscle function after ATR.

Our experimental studies demonstrated good reliability. However, the validity of the isokinetic methods has been a matter of concern, because the function is evaluated over a limited period of time and under non-functional circumstances. We wanted to add the closed chain position to the traditionally used supine and seated open chain positions. Concentric peak torque has been the most commonly analysed parameter and we wanted to add eccentric measurements and analysis of torque at a fixed angle (5° plantar flexion). Torque deficit appears to be speed specific in isokinetic evaluations (Washburn et al. 1992, Leppilahti et al. 1996) and we wanted to use a slow (30°/sec) and a fast (180°/sec) angular velocity to cover a spectrum of calf muscle function. Endurance was evaluated in a more functional manner using heel raises instead of repeated, less functional ankle movements in the dynamometer.

Our data show that the addition of measurements in eccentric muscle action did not produce any valuable new information in terms of the function of the calf muscles after ATR. Measurements in all three positions of the dynamometer all failed to demonstrate any statistically significant difference between the treatment groups in terms of the torque production of the injured limb. There was, however, a non-significant tendency in almost all the evaluated parameters in the present study in favour of surgical treatment. It is possible that comparisons of strength and endurance between the treatment groups could result in significant differences if a larger number of patients were studied. The ratio between the injured and the non-injured limbs was analysed and a permanent deficit was shown during the study period. This finding is in accordance with most previous studies showing a permanent plantar flexion strength deficit after ATR (Gillies and Chalmers 1970, Inglis et al. 1976, Jacobs et al. 1978, Shields et al. 1978, Häggmark et al. 1986, Washburns et al. 1992, Cetti et al. 1994, Mortensen et al. 1999). Some reports on the functional outcome after ATR have, however, shown that the plantar flexion deficit has been less pronounced and not significantly different when compared with the non-injured side (Carter et al. 1992, McComis et al. 1997, Speck and Klaue 1998). These studies have mainly dealt with comparisons of groups of surgically-treated patients and different postoperative regimens.

The strength measured as torque production using the Kin-Com® dynamometer showed a weak correlation to function measured with the functional index (FIL), patient satisfaction measured with the VAS, the ATR score and endurance measured as heel-raise ability. Questioning the validity of the isokinetic measurements as a follow-up tool after ATR still appears to be justified. Endurance measurements also failed to show any significant differences between the treatment groups but showed a significant deficit between the injured and non-injured limbs, like the isokinetic evaluations.

In the study by Nistor (1981), isokinetic concentric torque measurements were performed in a Cybex dynamometer in the supine position at 30, 90 and 180°/sec and isometric measurements were made in four ankle positions. Peak torque was analysed and the highest score from three repetitions was used, as it was in the present study. Nistor (1981) found no significant concentric strength differences between the treatment groups, but found a permanent concentric strength deficit

compared with the non-injured limb. No muscular endurance tests were performed. Cetti and co-workers (1993) did not perform any strength or endurance measurements in their study.

It may be that our postoperative regimen with slowly and gradually increasing dorsiflexion range of motion was too defensive. A more aggressive rehabilitation protocol with more tension on the repaired tendon could be beneficial in terms of regaining strength. Wählby (1978) showed that tension on the tendon improves calf muscle strength. Postoperative immobilisation in the neutral position was compared with immobilisation in equinus by Rantanen and co-workers (1993), who did not find any increased risk of re-ruptures with immobilisation in the neutral position. In a recent cadaver study, Davis and co-workers (1999) showed that "positioning the hindfoot in 20° to 25° plantar flexion effectively eliminates tension in the Achilles tendon, regardless of knee position".

Achilles tendon properties

During healing after ATR, the tendon width increases, regardless of treatment. The thickened tendon appears never to return to normal, even though a reduction occurred in our study, between six months and two years after the injury. Our findings are in accordance with previous findings (Leppilahti et al. 1998). There was a significant difference between the treatment groups, where the tendon width increased more in the surgically-treated group at several of the follow-ups. However, this appears to have little or no functional significance. No problems with shoe wear were reported in the two treatment groups.

Maximum calf muscle circumference has been registered in many studies of ATR and comparisons have been made between the injured and non-injured limbs (Arner and Lindolm 1959, Nistor 1981, Mortensen et al. 1999). The value of the measurement of calf muscle circumference can be questioned because of the weak correlation to calf muscle function. In a recent study, Leppilahti and co-workers (2000) found a correlation (0.52-0.61) between isokinetic concentric peak torque measurements and the cross-sectional area of the calf muscles using computerized tomography (CT). There was a significant deficit when the injured limb was compared with the non-injured limb in the surgically-treated patients after ATR, using isokinetic tests as well as the CT measurements. CT scans were used by Häggmark and co-workers (1986) to measure calf muscle cross-sectional area and they found a significantly larger deficit in a non-surgically-treated group compared with a group of surgically-treated patients. The same was seen when evaluating muscular endurance using a heel-raise test, but the concentric isokinetic plantar flexion peak torque measurements were insensitive to differences between the groups.

In the present study, neither concentric or eccentric isokinetic strength nor muscular endurance correlated to calf muscle circumference. A permanent side-to-side difference is evident in this study, as in previous studies. In both treatment groups, 96-98% of the calf circumference on the non-injured side was restored on all occasions. However, the functional importance of these findings is less clear. In the study by Nistor (1981), no detailed information is given in terms of tendon width and calf circumference. Cetti and co-workers (1993) gave no information relating to

tendon width, but found significant differences for calf circumference after one year with less hypotrophy in the surgically-treated group.

In our study, we found a small increase in calf muscle circumference in both the injured and the non-injured limbs during the study period. This might be due to the rehabilitation programmes (Kannus 1992) and the consequence for the analysis is that the ratio between the injured and non-injured limbs remains the same, despite an increase in calf muscle mass on the injured side.

Achilles tendon rupture score

Obviously, no single parameter can be used to describe the outcome after ATR. Several different parameters have been evaluated in the randomised and non-randomised outcome studies available. There have been attempts to create a scoring system in order to summarise the outcome results after ATR. It appears, however, that no such system has gained widespread use. In the present study, we included five objective and three subjective parameters described in Papers III and IV for the ATR score. All these parameters are also presented separately. A score has the limitation of reducing the importance of specific significant findings if the rest of the parameters do not demonstrate significant differences between compared groups.

A scoring scale has a limited, yet specific value. A huge amount of information can be condensed into one numerical value. The present ATR score is a modification of recently presented scores which we found to be partly inadequate (Thermann et al. 1995, McComis et al. 1997, Leppilahti et al. 1998).

Radiological study (V)

Our purpose was to study the appearance of the Achilles tendon during healing after ATR in a large cohort. We designed a protocol including the six important tendon features that can be evaluated using US or MRI. This protocol was used prospectively to summarise findings and make comparisons possible over time and between the treatment groups. Like all such protocols, details tend to get lost, but we felt that the creation of a standardised protocol was an important improvement for study purposes in the present field of research.

US was carried out on two or three occasions, whereas MRI was only evaluated after one year for practical reasons. A longitudinal comparison is therefore possible for the US, but not for the MRI.

All re-ruptures occurred before the six-month radiological follow-up. These patients were therefore not evaluated using radiological methods because they were all subsequently operated on.

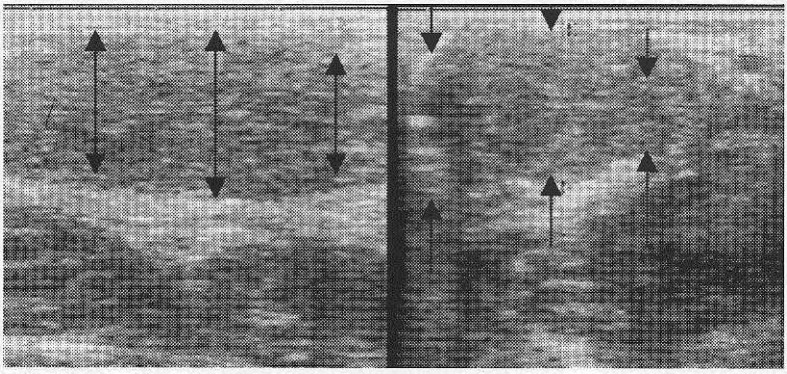
US

Our protocol includes six parameters which are combinations of morphological and echogenic assessments of the various aspects of the tendon itself, the peritendon and the surrounding area. Tendon edema, tendon homogeneity and partial tendon defects might be difficult to distinguish from one another. They can all easily be found soon after ATR and all three parameters become more or less normalised between six and twelve months after ATR (O'Reilly and Massouh 1993).

Tendon thickening is well known after ATR but the functional significance is small or limited. Because the maximum transverse width is the clinically measured thickness and the maximum sagittal width is the radiologically measured thickness, no comparisons can be made between these two methods when evaluating tendon thickening. The generalised thickening was predominant after six months, but after one year the majority of the tendons had thickened in a fusiform way (Figure 15). This fusiform thickening is in accordance with the findings of Karjalainen and co-workers (1996), who studied ATR one to three years postoperatively.

The peritendinous reaction was focal in approximately 40% of the patients and general in a small number of patients, after both six and twelve months. Comparisons with MRI using PD-weighted T2 sequences showed that the peritendinous reaction was detected at a much higher frequency in this study using US.

Figure 15. Fusiform thickening of the tendon on US; to the left a longitudinal view and, to the right an axial view.



US also offers an opportunity for dynamic evaluation. US, but not MRI was therefore used to study tendon glide. When performed by experienced radiologists, this gives US an advantage compared with MRI. The reduction in tendon glide function was the only parameter of all six of the parameters evaluated with US that was able to detect any significant difference between the treatment groups. However, the reduction in glide function only differed significantly between the treatment groups after one year. Thirty per cent of the surgically-treated patients had a reduced glide function after six months and the values increased to 57% after one year. It might be that the surgical trauma is more important when it comes to creating adhesions than early functional rehabilitation is in counteracting adhesion formation.

However, no correlations with decreased range of motion, strength and endurance at the ankle joint were found. It is also not clear why there were more patients with reduced tendon glide after one year in the surgically-treated group than after six months. The finding of reduced glide function after surgical repair is in accordance with the findings of Burchardt and co-workers (1991) and Rupp and co-workers (1995). In the study by Burchardt and co-workers (1991), the reduced tendon glide was correlated with poor clinical outcome. Rominger and co-workers (1998) demonstrated significant correlation between sonographic findings and clinical

outcome in 60 patients, following the surgical repair of ATR. The longstanding changes in the Achilles tendon after ATR and surgical repair were discussed by Rupp and co-workers (1995). After 11 years (2-19), the injured tendon still displayed US alterations in 56/60 patients. However, Rupp and co-workers (1995) found no correlation between the ultrasonographic findings, including reduced tendon glide, and clinical outcome, which is in accordance with our study and the findings of Merk and co-workers (1997) who evaluated 54 patients, who were treated surgically.

MRI

The tendon defects on MRI were areas with high signal intensity on both PD- and T2-weighted images in the tendon (Figure 16). Karjalainen and co-workers (1997) used PD- and T2-weighted MRI, as we did in the present study, but with different results regarding tendon defects. Also in contrast to Karjalainen and co-workers (1997) and Rominger and co-workers (1998), we were not able to detect any close relationship between clinical outcome and signal alterations on MRI. Our MRI evaluation was performed after one year, whereas the maximum follow-up period in the study by Karjalainen and co-workers (1997) was six months. Maffulli and co-workers (2001) evaluated 16 patients with surgically-treated ATRs, using MRI. Three years after surgery five patients were found to have small (< 25%) areas with abnormal signal, however they were asymptomatic.

T1-weighted images could be more sensitive to tendon pathology, at least in the case of chronic disorders. Movin and co-workers (1998) found that T1-weighted images following gadolinium contrast-medium enhancement were a better method for visualising intratendinous signal abnormality compared with PD-weighted T2 sequences in patients with achillodynia. In a recent study in which Shalabi and co-workers (2001) evaluated patients with Achilles tendinosis using MRI, signal changes of < 3 mm were regarded as non-significant. In our study protocol, we graded the partial defects as non-existent, < 5 mm or > 5 mm. Only a small number of patients displayed defects of < 5 mm. However, it is possible that small signal alterations will be overestimated as significant when a limit of < 5 mm is used.

Contradictory findings using US and MRI after ATR are obvious when studying the relatively sparse literature and comparing the results with those in the present study. The examiner dependence using US makes comparisons between studies even more difficult. Randomised studies could, however, produce interesting results if a small number of experienced radiologists performed standardised examinations. Further reliability tests for the evaluation of every single parameter in the protocol are, however, needed, together with validity tests of the parameters.

These findings might be the true ones in that no real differences exist between the treatment groups. This is in accordance with the findings relating to strength and endurance in Paper IV. However, as is the case for the isokinetic tests, the radiological methods can easily detect abnormalities on the injured side and describe the gradual restoration to normal or closer to normal over time.

Figure 16. Partial defect in the tendon in a surgically-treated patient on sagittal MR images; to the left, PD-weighted images and, to the right, T2-weighted images.

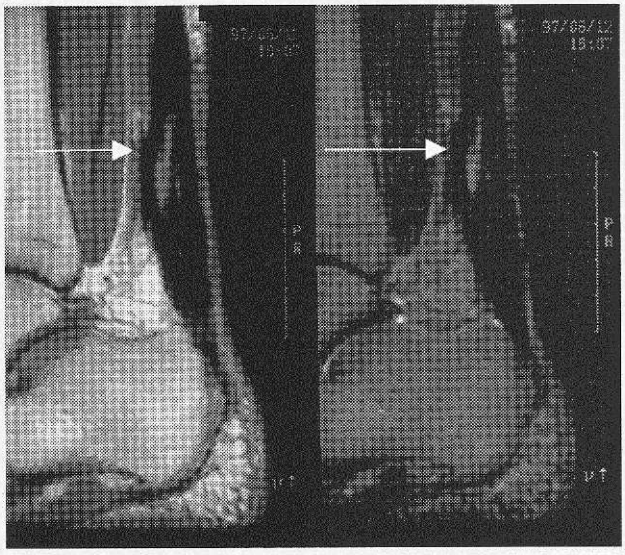


Table. 4 Summary of US and MRI findings after ATR

	US 6 months		US 12 months		MRI 12 months	
Positive findings	Surgical treatment	Non-surgical treatment	Surgical treatment	Non-surgical treatment	Surgical treatment	Non-surgical treatment
Mean (SD)	5.6 (1.7)	4.9 (1.2)	4.3 (1.6)	3.6 (1.0)	2.8 (1.3)	2.9 (1.3)
Median	6	5	4	3	3	3
Range	2-9	3-7	2-8	2-6	1-6	1-5
p-value	0.11		0.11		0.65	

A p-value of < 0.05 was considered statistically significant.

Conclusions

The measurement of isokinetic concentric and eccentric strength in a closed kinetic chain at the ankle joint is a reliable method.

The reliability is acceptable for the isokinetic strength measurement methods at the ankle joint. Isokinetic measurements in a seated, a supine and a seated closed kinetic chain position showed approximately the same reliability as the standardised heel-raise test.

Surgical treatment followed by early functional rehabilitation is a safe and reproducible method for the treatment of ATR. The non-surgical treatment of ATR, which produced treatment failure in every fifth patient, cannot be regarded as being acceptable for healthy, active persons under the age of 65 years.

If re-ruptures are avoided, surgical treatment followed by early functional rehabilitation and non-surgical treatment with a plaster appear to produce equally good results after ATR. The currently used evaluation methods for isokinetic concentric and eccentric muscle strength and muscular endurance were not able to detect any significant differences between the treatment groups, but they revealed a clear difference between the injured and non-injured sides.

No significant differences in the number of pathological findings could be detected between the treatment groups evaluated using US during the healing period after ATR. The MRI findings correlated well with the US findings, but no significant correlation was found between the clinical parameters and the number of pathological radiological findings.

The future

There is scientific evidence, based on previous prospective, randomised studies, to indicate that early functional rehabilitation is advantageous in comparison with immobilisation using plaster after surgical repair for ATR. We compared surgical treatment followed by early functional rehabilitation with immobilisation in plaster in the present study. Our conclusion was that surgical treatment followed by early functional rehabilitation was superior to non-surgical treatment, i.e. immobilisation in plaster. However, our surgical treatment method is a combination of two important parts; the surgical repair and the postoperative, early functional rehabilitation. It is not clear from the present study whether it was the surgical treatment or the early functional rehabilitation or the combination of the two that was the key to the successfull treatment.

During the past decade, there have been several studies, mainly from Germany, of functional non-surgical treatment for ATR. Good results have been reported, also in comparison with surgical treatment. However, according to a nationwide questionnaire in Germany in 1996 (Lill et al. 1996), 89% of all hospitals treating ATR still considered the surgical treatment to be the treatment of choice.

We believe that there is a need for a large, prospective and randomised study comparing surgical treatment followed by early functional rehabilitation with early functional rehabilitation without previous surgical repair for ATR. The evaluation should be further validated. Functional strength tests should be developed and might replace the non-optimal isokinetic tests in use today. The muscular endurance test can be refined and further standardised. Anthrophomorphic parameters such as tendon width and calf circumference can be replaced by other methods evaluating healing and hypotrophy, such as US and MRI. The radiological evaluation methods have to be further validated and refined. In the future, we hope we will have more objective evaluation methods that correlate to the subjective functional outcome after ATR.

Sammanfattning på svenska

Frågeställning

Behandling av akut hälseneruptur är kontroversiell. Det saknas moderna, prospektiva, randomiserade studier där kirurgisk behandling jämförs med icke-kirurgisk behandling och där risken för komplikationer vägs mot möjliga fördelar. I de föreliggande fem delarbetena belyses denna frågeställning och de använda behandlings- och utvärderingsmetodernas värde analyseras.

Metodik

Etthundratolv patienter randomiserades i en multicenterstudie till behandling med gips i åtta veckor eller operation med efterföljande kortvarig gipsbehandling följd av tidig rörlighetsträning med ortos. Samtliga patienter följdes prospektivt med undersökningar vid åtta och 12 veckor samt efter sex, 12 och 24 månader. Kliniska undersökningar av senbredd, fotledsrörlighet och vadomfång har kombinerats med omfattande intervjuer, Visuella Analog Skalor (VAS) för bedömning av resultat och tillfredsställelse med behandling och analys av återgång i arbete och idrott. Styrkemätningar med isokinetisk dynamometer har gjorts vid tre tillfällen liksom mätning av uthållighet genom tåhävningstester. Ett funktionsindex för subjektiv utvärdering av förmågan att utföra 11 olika för vadmusklerna krävande dagliga aktiviteter användes. Fortlöpande komplikationsregistrering har genomförts. En hälsenescore som värderade åtta ingående variabler, fem objektiva och tre subjektiva, användes.

En undergrupp av 58 patienter analyserades med Magnetkameraundersökning och Ultraljudsundersökning av läkningsförloppet efter hälseneruptur. I två delarbeten analyserades isokinetiska mätmetoder och tåhävningstester med hjälp av friska försökspersoner. En tidigare inte utvärderad position för isokinetisk mätning av plantarflexion i fotleden analyserades.

Resultat

Icke-kirurgisk behandling gav signifikant högre andel allvarliga komplikationer än kirurgisk behandling. Reruptur förekom hos 20.8% jämfört med 1.7%. Kirurgisk behandling gav inte i något fall sårproblem, djup infektion eller trombos. Den kirurgiska behandlingen var signifikant mer uppskattad av patienterna och sjukskrivningstiden var kortare bland patienter med lätt, rörligt arbete. I övriga undersökta parametrar inklusive styrka, uthållighet, återgång i idrott, hälsenescore och funktionsanalys noterades inga signifikanta skillnader mellan behandlingsgrupperna. De tolv patienter som ådrog sig en reruptur uteslöts ur studien och ingår inte i någon resultatanalys efter rerupturen. Styrkemätning utfördes i den kliniska studien vid tre tillfällen, i tre positioner, såväl plantarflexion som dorsalextension i fotleden, i vinkelhastigheterna 30 och 180°/s, både koncentriskt och excentriskt. Inte i någon parameter noterades skillnader mellan grupperna. Vid samtliga undersökningstillfällen noterades i båda grupperna en kvarstående skillnad i alla parametrar mellan skadat och friskt ben. Detsamma gällde uthållighetstesterna med tåhävningsmätningar. I den radiologiska studien förelåg god korrelation mellan fynd vid

Magnetkameraundersökning och Ultraljudsundersökning. Någon korrelation till kliniska fynd påvisades dock inte. Det normala läkningsförloppet kännetecknas av breddökning av senan, ökad heterogenicitet och med tiden minskande antal avvikelser jämfört med den oskadade sidan. Vid kirurgisk behandling befanns senans glidförmåga vara nedsatt i högre utsträckning än efter icke-kirurgisk behandling.

Styrkemätning i sluten kinetisk kedja gav reliabilitetsvärden mellan 0.87 - 0.97. Sidoskillnad förelåg ej bland friska försökspersoner. Reliabiliteten mätt i tre olika försökspositioner i en grupp av något äldre försökspersoner var 0.61-0.95. Reliabiliteten var högre vid excentriska mätningar än vid koncentriska. Vanliga kliniskt använda metoder för mätning av senbredd, vadomfång, rörlighet och uthållighet gav lika goda eller bättre reliabilitetsvärden än de isokinetiska testerna (0.71-0.98).

Slutsatser

Icke-kirurgisk behandling av akut hälseneruptur är icke acceptabel p.g.a den höga frekvensen reruptur. Kirurgisk behandling ger få komplikationer och uppskattas av patienterna. Kirurgisk och icke-kirurgisk behandling ger dock jämförbara resultat om inte reruptur inträffar. Vadmuskelstyrka och uthållighet skiljer sig inte åt mellan behandlingsgrupperna. Två år efter en hälseneruptur finns kvarstående nedsättning av styrka och uthållighet i vadmuskulaturen på den skadade sidan. Reliabla metoder finns för mätning av muskelstyrka och uthållighet, dock är inte de isokinetiska testerna mer reliabla än de kliniska metoderna och uthållighetstesterna.

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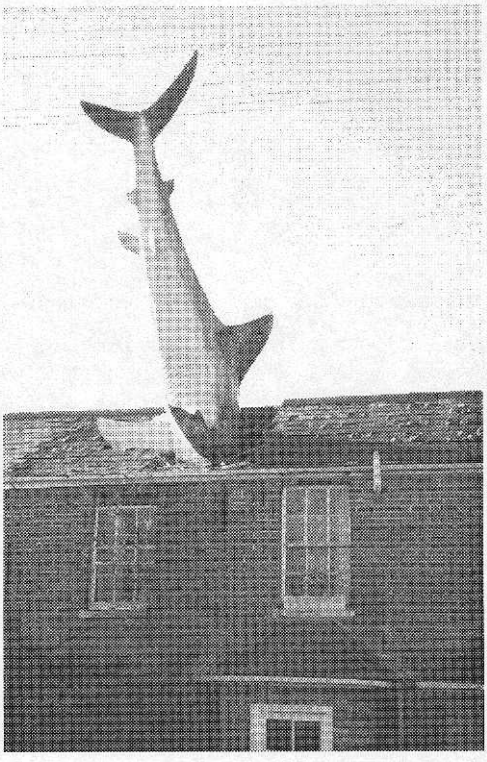

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