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Achilles tendon injuries

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Abstract
Purpose of review The purpose of this study is to review the current literature of Achilles tendon injuries, specifically chronic tendinopathy and acute ruptures in regard to etiology, diagnosis, treatment options, and outcomes.
Recent findings The incidence of Achilles tendon injuries is increasing, but the necessity for surgical intervention is decreasing due to improved conservative therapies, which may provide comparable outcomes without the implied surgical risk. If surgery is undertaken, no difference has been noted between open and minimally invasive techniques. The majority of patients are able to return to pre-injury level of activity, with the elite athlete as an unfortunate exception.
Summary Achilles injuries can be devastating injuries, but if addressed early and appropriately, most patients have good self-reported long-term outcomes regardless of the treatment modality implemented. Further research is needed into the etiology, potential preventative measures, and longer-term outcomes of the different treatment options for wide range of Achilles pathology.

Keywords Chronic Achilles tendinopathy · Acute Achilles rupture

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Introduction

The Achilles tendon is one of the most important and multifunctional tendons in the body. A conjoining of the gastrocnemius and soleus muscles, the tendon spans three different joints and is integral in knee flexion, foot plantar flexion, and hindfoot inversion. Given the broad array of critical functions that it helps to provide, injury to the Achilles tendon can be devastating. Pathology of the Achilles tendon can be acute or chronic, ranging from tendinosis to frank tears, and can broadly affect athletes and non-athletes alike.

Etiology

Injury to the Achilles tendon is often multifactorial, with both intrinsic and extrinsic forces recognized. Individual patient characteristics such as increasing age, male sex, and obesity have been shown to have positive correlation with Achilles tendon pathology [1]. Extrinsic factors such as the use of fluoroquinolones and corticosteroids (both oral and intrasubstance) have also been shown to lead to weakening of the Achilles, with associated tendinitis and an increased risk of rupture [2, 3]. The risk for development of Achilles pathology with these drugs is even higher in patients greater than 60 years old [4–6].

The true etiology of Achilles tendon injuries is still unknown, but two major theories have been proposed. The degenerative theory postulates that chronic degeneration of the tendon leads to a rupture without the need for excessive loads to be applied [7]. This theory was first postulated after Arner et al. [8] found degenerative changes in all 74 of their patients with acute Achilles ruptures. These degenerative changes have been seen in multiple other studies, including in tendons operated on within 24 h of rupture, indicating preceding

chronic changes [9–11]. The exact mechanistic cause is unknown, but it is hypothesized that impaired blood flow to the tendon with resultant hypoxia and altered metabolism could play a major role [12].

Experimental findings of ruptures occurring in healthy tendons lead to development of the mechanical theory, which states that different movements and forces exerted on the tendon can lead to failure. In a biomechanical study of rat models, Barfred et al. [13] noted that a tendon was at greatest risk of rupture when obliquely loaded at a short initial length with maximum muscle contraction, a very common occurrence in any push-off-type activity. This risk is exacerbated when there is a dysfunction in the body's ability to limit excessive and uncoordinated muscle contractions [14]. This asynchrony is more common in athletes who train less consistently, a major reason why Achilles ruptures are often seen in the "weekend warrior" population.

Chronic Achilles tendinopathy

Chronic Achilles tendinopathies are painful conditions often found in athletes, particularly middle-aged male runners, though it can affect the sedentary population as well. Chronic tendinopathies are most commonly thought to be a result of repetitive overuse injuries, which explains a tenfold increase in Achilles tendon injuries in runners compared to age-matched controls [15]. However, Rolf et al. [16] did show that 31% of patients reviewed with Achilles tendinopathy did not participate in vigorous physical activity. This finding indicates that other etiologic factors, most likely related to metabolic or vascular imbalances, must also influence the development of these conditions. Histological studies of Achilles tendinopathies have shown a disorganized collagen structure that this is indicative of this process being a primarily degenerative, non-inflammatory condition [17]. Achilles tendinopathy can be divided mainly into disease of the midportion of the tendon (55–65% of injuries) and the insertion of the tendon (20–25%) [18].

Non-insertional Achilles tendinopathy

Non-insertional Achilles tendinopathy in the acute phase is due to an inflammatory cellular reaction in the tendon with circulatory impairment and edema, which can progress to fibrinous exudates and adhesions in a more chronic condition [19]. The main presenting symptom is pain, often occurring at the beginning of exercise and shortly after completion. Clinical exam can elicit pain on palpation (sensitivity 84%), and pain is often located on average 2–6 cm above the insertion site (sensitivity 78%) [20]. Though mainly a clinical diagnosis, ultrasound or MRI can be utilized, with tendinopathy defined as the presence of a hypoechogenic area within the substance of the tendon [21].

Conservative management is the first line of treatment for chronic Achilles tendinopathies. The most common modalities utilized are activity modification, eccentric exercises, NSAIDs, injections, and shock wave therapy. Non-insertional Achilles tendinopathies often respond quite well to these therapies, with Paavola et al. [22] showing only 29% of patients not returning to previous activities in an 8-year follow-up. Moreover, there is an overall low rate of rupture once an individual has advanced to the stage of a thickened midsubstance tendinopathy.

Though the mechanism of action is poorly understood, eccentric exercises have been shown in multiple studies to help in the early treatment of non-insertional Achilles tendinopathy. Ohberg et al. [23] showed that after a 12-week course of eccentric calf muscle exercises, 36/41 patients had no further tendon pain with activity, with the majority having a more normalized tendon structure (34/36) and elimination of neovascularity (32/36) at 2-year follow-up. All five patients who still reported a poor clinical outcome were found to have remaining tendon neovascularity. In a randomized comparison study, Alfredson et al. [24] found that 82% of patients were able to return to normal activities after 12 weeks of eccentric exercises compared with only 36% who performed concentric exercises. This difference was thought to be to due to the increased load with eccentric exercises leading to structural tendon change; however, Drew et al. [25] in a recent review have shown that the literature does not support this theory. The authors thus propose the need for future research focusing on neural, biochemical, and myogenic changes as potential explanations for the therapeutic response of eccentric exercise.

Injections are utilized to produce local mechanical effects to alter the increased neovascularity seen in tendinosis and provide pain relief through destruction of the surrounding sensory nerves [26]. Injections have been effective with both local anesthetic and corticosteroids but need to be done under ultrasound guidance to ensure avoidance of potentially deleterious intratendinous placement [27]. Even with ultrasound guidance, there is still an inherent risk of rupture when injecting around the Achilles, and it is the belief of the authors to advise against injection of corticosteroids. The use of injections of platelet-rich plasma has yet to consistently demonstrate any greater improvement in pain or activity compared to placebo [28]. The majority of patients, particularly those with insertional tendinopathies, respond to conservative management [19]. However, about 20% of patients continue to have symptoms, and after 6 months without improvement, potential surgical options should be evaluated [29].

Surgical intervention should address both the intratendinous lesions and the pain transmitting neurogenic structures outside of the tendon itself. Through either open or minimally invasive techniques, debridement and excision of the adhesions and

central tendinosis are performed with the goal of denervating and devascularizing the paratenon while promoting a scarring repair response within the tendon [30]. Lohrer et al. [31] in a systematic review determined that there was no statistical difference between the two techniques in regard to success rates (78.9 vs. 83.6%) or patient satisfaction (78.1 vs. 78.5%) but did note a slightly higher complication rate (10.5 vs. 5.3%) with open surgery. A majority of those patients who fail conservative management do well after surgery, but the authors caution that due to the paucity of well-done research in this field, these success rates may be falsely elevated and recommend discussing with patients the potential prolonged recovery time and not insignificant rate of failure of these procedures.

A relatively novel surgical technique for Achilles tendinopathy is a gastrocnemius recession, in which the gastrocnemius tendon and soleus fascia are cut transversely and the soleus muscle is stretched by dorsiflexing the ankle to alleviate gastrocnemius-soleus tightness that might be contributing to Achilles pain. Often, this is done in combination with debridement, but Labrode et al. [32] examined the results of this procedure alone for patients with Achilles tendon pain. In this study, 18/24 patients were available for follow-up, and all noted a marked improvement in their pain with no wound complications. Nawoczenski et al. [33] compared 13 patients undergoing gastrocnemius recession for Achilles tendinopathy compared to healthy controls and noted significant and sustained pain relief with good function for activities of daily living, but more limitations with power and endurance activities. These studies thus suggest that gastrocnemius recession may be used as an alternative for Achilles surgery in non-athletic, high-risk patients.

Insertional Achilles tendinopathy

Insertional tendinopathy is due to degeneration of the Achilles tendon fibers at the insertion on the calcaneus and is often associated with older age, steroid use, obesity, diabetes, and inflammatory arthropathies [34]. The pain is usually located at the midpoint of the calcaneus is worse in the morning and causes severe pain the day after exercising [35•]. It is often associated with a prominent calcaneal tuberosity (Haglund's deformity) and evidence of calcification at the insertion site on radiographs [36] (Fig. 1).

Non-operative management is also the initial treatment for insertional tendinopathies. Activity modification, particularly walking uphill, or other activities which place stress on the Achilles insertion should be avoided. Shoe lifts or a walker boot may be utilized to avoid pressure on the posterior heel. Physical therapy must be used cautiously, as typical eccentric exercises utilized for non-insertional tendinopathies can often aggravate and worsen insertional pathology [36]. Most patients respond to conservative management, but 10–30% of patients fail and require surgical intervention. Most

Fig. 1 X-ray of a 56-year-old male with chronic posterior heel pain, calcifications at insertion site indicative of chronic insertional tendinopathy

commonly, a posterior central tendon approach for debridement of the tendon along with removal of the prominent calcaneal projection is utilized [37]. Augmentation of the tendon repair with flexor hallucis longus may be required for older patients or revision cases in which greater than 50% of the tendon must be debrided. The augmentation with flexor hallucis longus (FHL) was shown by Hunt et al. [38] to have little compromise in function or patient satisfaction compared to debridement alone. Hamstring tendon autograft can also be utilized to augment large defects with similar satisfactory postoperative results [39, 40].

Acute Achilles tendon ruptures

Despite being the strongest and thickest tendon in the body, the Achilles tendon is the most common to rupture. Achilles tendon ruptures most commonly occur in a healthy, active, young- to middle-aged population, with a reported mean age of patients from 37 to 43.5 years old [35•]. There is a male predilection for this injury with a M/F ratio in the literature ranging from 5.5:1 to 30:1 [7, 41, 42]. The most common ruptures are of the midsubstance Achilles, often occurring in a vascular watershed area 3–6 cm proximal to the insertion site on the calcaneus [43]. Most patients with midsubstance tears had no Achilles pain prior to rupture with ruptures occurring in sports with abrupt repetitive jumping and sprinting activities, which require a pushing-off type of force [44]. In contrast, those with insertional ruptures often did have preceding Achilles pain from insertional tendinopathies which ruptured at the site of chronic degeneration while performing activities of daily living [12].

Incidence

The incidence of Achilles tendon ruptures has continuously increased in the last four decades. Leppilahti et al. [41] noted an increase in a Finnish population from an annual incidence of 2 (all numbers per 100,00) in 1979–1986 to 12 in 1987–1994, with a peak incidence of 18 in 1994. Houshian et al. [45] found a similar increase in Denmark with an annual incidence increase from 18.2 in 1984 to 37.3 in 1996. In more recent literature, Lantto et al. [46] investigated the epidemiology of ruptures in Finland from 1979 to 2011. The overall annual incidence increased from 2.1 in 1979 to 21.5 in 2011, with the largest increase occurring in the 30–39-year-old age range. In reviewing the Swedish national registry for acute Achilles tendon ruptures between 2001 and 2012, Huttunen et al. [47] found that in 2001, the sex-specific incidence of acute Achilles tendon ruptures was 47 for males and 12 for females with it rising to 55.2 in men and 14.7 in females in 2012, a 17 and 22% increase, respectively. Similar trends were noted by Ganestam et al. [48] in Denmark with a particularly significant increase in those over 50 years old. These recent studies indicate that the incidence of acute Achilles ruptures continues to rise in the last decade, which has been theorized to be likely due to an increase in the number of older adults still participating in high-demand activities.

Diagnosis

The diagnosis of an acute Achilles tendon rupture is largely reliant on history and physical exam. Patients usually complain of a popping or giving way sensation in their posterior heel after pushing off. Immediate pain is present but gradually dissipates, leaving a patient to complain of difficulty with plantar flexion, weight bearing, or a limp [49]. The American Academy of Orthopaedic Surgeons (AAOS) Clinical Practice Guidelines note that a diagnosis can be made when two or more of the following exam findings are noted: a positive Thompson test (when compression of calf in supine position does not elicit passive plantar flexion), decreased plantar flexion strength, palpable defect distal to insertion site, or increased passive ankle dorsiflexion at rest (Matles test) [48]. Maffuli et al. [18] evaluated the accuracy of these diagnostic tests in both awake and anesthetized patients and found that the Thompson (96%) and Matles (88%) tests were the two most sensitive, with all four tests having a high positive predictive value.

Imaging

While clinical exam is the primary component of diagnosis, imaging studies such as MRI and ultrasound are often utilized to confirm physical exam findings. The AAOS Clinical Practice Guideline recommendations were inconclusive regarding the routine use of MRI due to a lack of supporting literature [50]. Garras et al. [51] sought to determine the necessity of MRI utilization in routine diagnosis of Achilles tendon ruptures. The study compared the sensitivity of physical exam with that of MRI and found that in patients with a positive Thompson's test, palpable defect, and decreased resting ankle tension, the sensitivity was 100% for predicting a complete tear. When MRI was utilized, the sensitivity was noted to be 90.9% for the interpretation of a complete tear compared to what was seen intraoperatively. It was also found that those undergoing MRI were delayed in their initial evaluation by a surgeon (5.1 vs. 2.5 days) and time to operative intervention (12.4 vs. 5.6 days) and required additional procedures at the time of index repair (19/66 vs. 0/66), including 17 FHL transfers and 6 V-Y advancements (Fig. 2). Thus, the authors recommended MRI not be routinely utilized but reserved for those patients with inconclusive clinical exam findings and subacute or chronic tears occurring more than 4 weeks prior to presentation and patients with prior tears with concern for scar tissue in order to develop an appropriate surgical plan.

Ultrasound remains a cheaper and more readily available alternative to MRI. Margetic et al. [52] showed a high correlation between the size of the rupture noted on ultrasound and that found in surgery. Kotnis et al. [53] recommended dynamic ultrasound as a useful diagnostic tool, noting that if a >5-mm gap is noted between tendon edges, that surgical intervention is indicated. Ultrasound, however, does struggle with diagnosis of partial ruptures, particularly at the intratendinous junction with a sensitivity of only 50% [54]. Again, it is in these ambiguous cases that MRI is the most effective imaging modality.

Non-operative treatment

The two main options for non-operative management are cast immobilization and functional bracing with early rehab. Non-

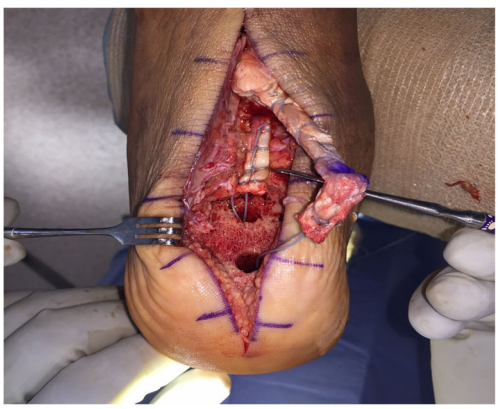

Fig. 2 Repair of insertional Achilles rupture utilizing FHL tendon augmentation

weight-bearing cast immobilization for 4 weeks with transition to a walking cast for another 4 weeks was historically the method of treatment. Wallace et al. [55] assessed the results of 140 patients treated with cast immobilization and found that 86% of patients had an excellent or good result.

In the functional rehab protocol, patients are placed into a boot with wedges with gradual reduction of plantar flexion to neutral over 6 weeks, after which formal physical therapy is started [49]. Functional bracing has been found to be preferred by patients to cast immobilization and is associated with increased dorsiflexion and an earlier return to activities [56]. Functional bracing and earlier rehab are also associated with lower rerupture rates. These patients can be weight bearing as tolerated immediately as there was no difference in outcome scores or functional ability but was an increase in health-related quality of life at 1 year compared to prior protocol of non-weight bearing for 6 weeks [57]. Porter et al. [58] found that an accelerated functional rehab program, where patients were encouraged to begin active range of motion as soon as possible instead of at 10 days, was also associated with less tendon lengthening and a more rapid return to running.

Surgical management

Acute Achilles tendon ruptures can be treated surgically utilizing either an open, a mini open, or a minimally invasive approach. Several randomized control clinical trials comparing these methods have been performed with conflicting results regarding superiority and complications [59–61]. In a systematic review of four meta-analyses, Li et al. [62] deemed the review by McMahon et al. [63] as the best available evidence, demonstrating that minimally invasive surgery (MIS) and open repair had no difference in regard to rate of rerupture, deep infection, deep vein thrombosis, adhesions, or sural nerve injury. The major difference occurred in MIS being superior in regard to lower rate of superficial infection (risk difference = 0.17) and patients being nearly three times more likely to report a good or excellent outcome. From a biomechanical standpoint, Clanton et al. [64] compared open repair versus three different percutaneous repair methods on cadaver tendons, which were then subjected to cyclic loading protocols indicative of progressive rehab. When compared to open repairs, minimally invasive techniques demonstrated a greater susceptibility to early repair elongation, but the ultimate strength of all four repairs in terms of cycles to failure was comparable. The authors concluded that MIS techniques can provide a biomechanically acceptable alternative but, due to early elongation, may require a longer protected period postoperatively.

Insertional ruptures occurring in patients with prior symptomatic Achilles tendinopathies can present a unique surgical challenge. Often, an extensive debridement of the diseased tissue is required, which can leave a substantial defect making primary repair difficult. In these cases, the reconstruction may require an augmentation with a flexor hallucis longus transfer. Wong et al. [65] examined this technique in elderly patients with insertional ruptures and found good pain relief and functional recovery without any major surgical complications or reruptures at 2 years.

Given the tenuous tissue envelope surrounding the Achilles tendon, choosing the correct patient population on which to operate is paramount. Currently, the AAOS provides a consensus opinion that surgical intervention should be approached cautiously in patients who are diabetics, smokers, older than 65 years old, sedentary, obese, and neuropathic or those with concern for wound healing [50].

Non-operative versus surgical management

For decades, open surgical intervention was considered the gold standard for acute Achilles ruptures due to a concern for an unacceptable rate of rerupture with conservative treatment. Khan et al. [66], in a meta-analysis of the literature prior to 2002, noted a pooled rate of rerupture of 12.6% in the conservatively treated group compared to 3.5% in the operative group. Over the last 15 years though, the incidence of surgical intervention has decreased despite the overall incidence of ruptures increasing [47]. The paradigm shift to increased non-operative management is concurrent with multiple well-designed randomized controlled trials comparing operative and non-operative treatments of acute Achilles ruptures with comparable results.

In a more recent meta-analysis of ten studies comparing surgical and conservative treatments, Soroceanu et al. [67] similarly found that surgery reduced the risk of rerupture by 8.8% when compared against non-operative treatment without functional rehab. However, if a functional rehab protocol with early range of motion was implemented as part of the conservative treatment, the rates of rerupture were equivalent to those undergoing surgical intervention. There was also found to be a 15.8% risk reduction of other complications like infection, adhesion formation, and sural nerve injury in the non-operative group. Surgical patients were able to return to work 19.6 days earlier, but there was no difference noted in any functional outcome measures reported. These results were echoed by Erikson et al. [68•] in a broader 2015 review of nine meta-analyses comparing the two treatment options. In a recent prospective randomized trial comparing surgical and nonsurgical treatment of acute ruptures, Lantto et al. [69] found similar results between the two options in Achilles tendon performance scores but found surgery restores calf muscle strength earlier with maintained increased strength at 18 months. The authors suggest that this should be taken into account particularly when treating physically active and demanding patients.

Previously, non-surgical treatment for acute ruptures was mainly utilized in those patients who were poor surgical candidates. Recent literature though has consistently shown non-surgical treatment with early functional rehab to result in acceptable outcomes and thus is a reasonable treatment option in those centers equipped to provide it.

Outcomes

Most athletes who suffer an Achilles rupture were participating in sports recreationally and mainly desire to return to this same level of activity [70]. In a systematic review of 108 studies, Zellers et al. [71] found that 80% of patients returned to play after an acute Achilles tendon rupture (range 18.6–100%). The mean time to return to play was found to be 6.0 months, but this range was also quite varied (2.9 to 10.4 months). This review noted numerous validated questionnaires measuring various aspects of return to play, but the authors believed that none comprehensively captures return to play in the Achilles tendon rupture population and suggested the development of an improved questionnaire that more thoroughly, consistently, and accurately assesses this metric [72–75].

One of most commonly utilized current outcome questionnaires is the Achilles Tendon Total Rupture Score (ATRS). The ATRS is a patient-reported instrument developed by Nilsson-Helander et al. [74] which asks patients to numerically quantify their limitations with different activities after treatment for an acute Achilles rupture. Olsson et al. [76•] utilized the ATRS as a predictive model and noted that a ten-point increase in ATRS at 3 months predicted a 2% higher heel rise at 6 and 12 months, where heel rise at 6 months was independently found to predict the degree of symptoms at 1 year. Hansen et al. [77] found that an increased ATRS at 3 months correlated with a significantly increased chance of return to sport at 1 year after injury. Thus, utilizing the simple ATRS may help to identify patients not responding adequately to treatment within a time period where outcomes can still be altered.

Olsson et al. [76•] also attempted to identify potential predictors of clinical outcomes after an acute Achilles tendon rupture. Increasing age and higher BMI were found to be strong and significant predictors of decreased function and having a greater degree of symptoms respectively at 1 year.

While a majority of patients are found to ultimately return to play, Olsson et al. [78] noted that major functional deficits and decreased physical activity level persist for 2 years after acute Achilles rupture regardless of surgical or non-surgical treatment. The study also noted only minor improvements in function, symptoms, and activity level between the 1- and 2-year evaluations, indicating that the vital stages for improvement occur mainly in the first year of recovery. Despite these persistent limitations though, patient-reported outcomes were still relatively high, suggesting that most patients have adjusted to their deficits.

Horstmann et al. [79] found that even at 10 years after surgical repair for Achilles tendon rupture, long-term changes were still noted compared to the contralateral leg. Ankle range of motion and calf circumference were noted to be less on the injured leg, while gastrocnemius muscle activity was found to be greater, with the authors hypothesizing the increased activation served as a compensatory mechanism to protect the repaired Achilles tendon during plantar flexion movements. While these differences can be measured objectively, it is again seen that patients have adapted as most patients reported no reduction in subjective ankle range of motion, pain, or functional limitations in daily or physical activities.

While the majority of recreational athletes are able to return to their prior level of sporting activity, the impact of an acute Achilles rupture on a professional athlete can be much more devastating. In a study of NFL players suffering Achilles tendon ruptures from 1997 to 2002 (n = 31), Parekh et al. [80] found that nearly 32% of players with this injury were never able to return to play in the NFL, while those who did return had a greater than 50% reduction in performance. In a similar study in NBA players, Amin et al. [81] found that 7/18 players (39%) who suffered an Achilles rupture and underwent surgical repair from 1988 to 2011 never returned to play in the NBA. Those who did return to play were also found to have a significant decrease in both playing time and performance.

Conclusions

Achilles tendon pathology is a very common ailment affecting a wide variety of the population. Given its vital role in ambulation and activity, injury to the Achilles tendon can be quite debilitating. Chronic tendinosis is most often due to overuse and typically responds to conservative management. If no improvement is seen after 6 months though, surgical debridement should be considered. The incidence of acute ruptures of the Achilles continues to increase as the older population continues to stay more active than past generations. The diagnosis is mainly clinical, but ambiguous presentations may require advanced imaging. The development of functional bracing and early rehabilitation has provided another equal and potentially superior alternative to surgical fixation. Overall, regardless of the method of fixation, most patients ultimately return to their prior level of activity despite slight persistent objective limitations. While the understanding of Achilles tendon pathology has grown exponentially, much more research is still required to more fully understand the multifaceted etiology, optimal treatment modalities, and long-term outcomes of this common and complex set of problems.

Compliance with ethical standards

Conflict of interest Anthony C. Egger and Mark J. Berkowitz declare that they have no conflict of interest.

Human and animal rights and informed consent This article does not contain any studies with animal subjects performed by any of the authors. With regard to the authors' research cited in this paper, all procedures were followed in accordance with the ethical standards of the responsible committee on human experimentation and with the Helsinki Declaration of 1975, as revised in 2000 and 2008.

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