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Management of Isolated Anterior Tibial Tendon Rupture: A Systematic Review and Meta-Analysis

Anthony Tickner, DPM[1], Seiha Thorng, DPM, AACFAS[2], Mary Martin, DPM, PGY-2[3], Valerie Marmolejo, DPM[4]

[1] Podiatric Surgical Attending, Saint Vincent Hospital/Worcester Medical Center PM&S 36 Surgical Residency Program, Worcester, MA
[2] Staff Podiatrist, Sutter Gould Medical Group, Stockton, CA
[3] Resident, Saint Vincent Hospital/Worcester Medical Center PM&S 36 Surgical Residency Program, Worcester, MA
[4] Medical Writer, Scriptum Medica, University Place, WA

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ABSTRACT

Rupture of the tibialis anterior tendon is a rare condition reported to occur most often spontaneously in patients >45 years of age. Diagnosis is often delayed due to transient pain at the time of rupture and the ability of the long extensors to compensate for the lost action of the tibialis anterior. Treatment has been proposed to be based on the activity level of the individual; however, no consensus has been reached on the optimal treatment modality for this rare condition. A systematic review and meta-analysis were performed to determine outcomes obtained with conservative and surgical management. Twenty-four references (155 cases) were identified. Conservative management (21 cases, 13.55%) was associated with poorer outcomes (odds ratio [OR] 0.68; $I^2 = 61\%$) because of pain and functional limitations related to ankle dorsiflexory weakness. Surgical intervention (134 cases, 86.45%) had a better chance for good outcome (OR 8.40; $I^2 = 63\%$). Use of an ipsilateral split/turn-down ipsilateral tibialis anterior tendon graft (OR 32.15; $I^2 = 0\%$) semitendinous autograft (OR 15.25; $I^2 = 44\%$), or direct repair (OR 12.57; $I^2 = 0\%$) provided the best postoperative outcomes, whereas extensor hallucis longus autograft was associated with the worst (OR 0.27, $I^2 = 34\%$). The most common postoperative finding was objective mild dorsiflexory weakness (4/5 muscle strength), which did not translate to subjective functional limitation. Good functional results were found to occur regardless of patient age at the time of intervention. Results of this systematic review and meta-analysis suggests that surgical intervention provides better functional outcomes than conservative management. Use of an extensor hallucis longus autograft is not recommended if surgical intervention is performed.

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Closed rupture of the tibialis anterior tendon is rare (1–36). Bruning published the first case report in 1905 (2,4,6,7,11,22,37,38). The first case report to appear in the American literature was almost 3 decades later (13). Sudden plantarflexion and eversion of the foot against a contracting tibialis anterior is the most common mechanism of injury. Rupture can be acute following a traumatic event, which is most often minor, or can be spontaneous in nature (1–6,8,10,14,16,19,20,22,29,33,34,36,39–52). Diagnosis of an atraumatic rupture is often delayed because of transient pain at the time of the event and the ability of the long extensors of the ankle to substitute for the lost function of the tibialis anterior (1–7,9,10,12,14,16,20,21,25,27,28,30–34,39,40,46,48,56,51,53–58). The most common chief complaint following rupture is frequent tripping and foot "slapping" during ambulation accompanied by functional limitations secondary to reduced ankle dorsiflexory strength (1,2,4–6,8,21–24,33,38,39,40,42,44,46,48,50,51,53,56,57). Clinical presentation is typically unilateral and consists of the classic triad of pseudotumor of the proximal ruptured end of the tendon at the anterior medial ankle joint, loss of normal tendon contour from ankle joint to insertion, and ankle dorsiflexory weakness (2,4–6,17,18,22,25,39,40,42,53,56). Late sequelae include progressive flatfoot deformity and digital deformities, often enhanced on gait examination resulting from extensor substitution (6). Isolated muscle testing and/or electromyography can rule out drop foot from peroneal nerve palsy or L4-L5 radiculopathy (6,14,17–19,21,24,28–30,43,47,49,55,59). Radiographs are typically of no benefit in confirming the diagnosis. Ultrasound provides rapid diagnosis confirmation; however, magnetic resonance imaging is the most beneficial in confirming the diagnosis, distinguishing between partial and complete rupture, and assistance in surgical planning through estimation of the length of the tendon gap present and identification of adjacent tendons that could be used for reconstruction (4,5,12,16–19,36,47,58,60,61). No consensus currently

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Address correspondence to: Anthony Tickner, DPM, Associated Foot Specialists, P.C., 439 Main Street, Hudson, MA 01749.
E-mail address: a_tickner@hotmail.com (A. Tickner), vlsdpm@gmail.com (V. Marmolejo).

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exists on the optimal modality of treatment, although surgical intervention is often recommended for better functional results and avoidance of late sequelae (4,56,60). This systematic review and meta-analysis was performed to determine outcomes obtained with surgical and conservative management of isolated complete rupture of the tibialis anterior tendon.

Materials and Methods

Search Strategy

The systematic review and meta-analysis were performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines (62). A systematic review of PubMed (National Institutes of Health, National Library of Medicine, Bethesda, MD; https://www.ncbi.nlm.nih.gov/pubmed/) with an inclusive query of "tibialis" OR "tibial" AND "anterior" AND "tendon" AND "rupture" NOT "cruciate," in which all-capitalized words represent the Boolean operators used, was performed from date of inception through July 2018. All titles and abstracts were screened for potentially eligible studies. Each publication identified was manually searched for pertinent data and additional references. All studies were reviewed by each author and complete agreement was used for final inclusion, with V.L.M. as the moderator.

Inclusion and Exclusion Criteria

Criteria for inclusion were peer-reviewed publications in the English language in which the results of conservative or surgical management of more than one case of isolated complete rupture of the tibialis anterior tendon were reported. Exclusion criteria included: non-peer-reviewed publications, non-English language publications, case reports, partial rupture of the tibialis anterior tendon, nonisolated rupture of the tibialis anterior tendon, and nonpublished data to include poster presentations that did not appear to have an associated English language peer-reviewed publication of the same data presented.

Data Extraction and Quality Assessment

Data extracted from the studies were: subject age and gender, laterality, mechanism of injury, predisposing comorbidities, time from injury to treatment, treatment performed, length of tendon gap, follow-up time, and outcome. Results were grouped by conservative and surgical management. For consistency of reporting, outcomes were defined as: good (improved function without pain or limitations); fair (improved function with muscle strength of 4/5 or occasional pain); poor (muscle strength 3/5, type I complex regional pain syndrome, postoperative infection, or limited walking ability).

Quality assessment was performed using the modified Coleman methodology score (63), which is a 100-point scale that assesses methodology based on study size, subject selection process, follow-up time, the number of subjects with follow-up, the type of study performed, the certainty of diagnosis, description of surgical technique and postoperative rehabilitation, and outcome assessment. A score <70 is considered consistent with poor methodology.

Statistical Analysis

Continuous variables were pooled, weighted, and reported descriptively. Weighted data were obtained as follows: the median of the respective numeric results (i.e., patient age) for a single study was obtained and multiplied by the number of subjects in the study. This was done for all studies. The total number obtained was then divided by the total number of patients from all studies. Continuous variables reported were patient age, time to treatment, follow-up time, and length of tendon gap.

Outcome of treatment was designated as a dichotomous variable of good versus fair or poor. Dichotomous variables were reported as an odds ratio (OR) with a 95% confidence interval. Heterogeneity across the pooled data was formally tested using the Cochrane χ^2 test and quantified using the I^2 test. A fixed effects model was used if I^2 was $<50\%$. A random effects model was used if the I^2 was $>50\%$, signifying significant heterogeneity. Differences were considered significant if $p < .5$. Statistical analysis was performed using Review Manager software, version 5.3.5 (RevMan 5, Cochrane Community, London, UK).

Results

Systematic Review

Systematic review of the literature yielded a total of 84 references. Fifty (59.52%) case reports, 6 (7.14%) reported no treatment and outcome, 2 (2.38%) reported the outcome of treatment of nonisolated tibialis anterior rupture, 1 (1.19%) reported the outcome of treatment of a partial rupture, and 1 (1.19%) was a prior systematic review, leaving 24 (28.57%) references that met all criteria (Fig. 1). These 24 references

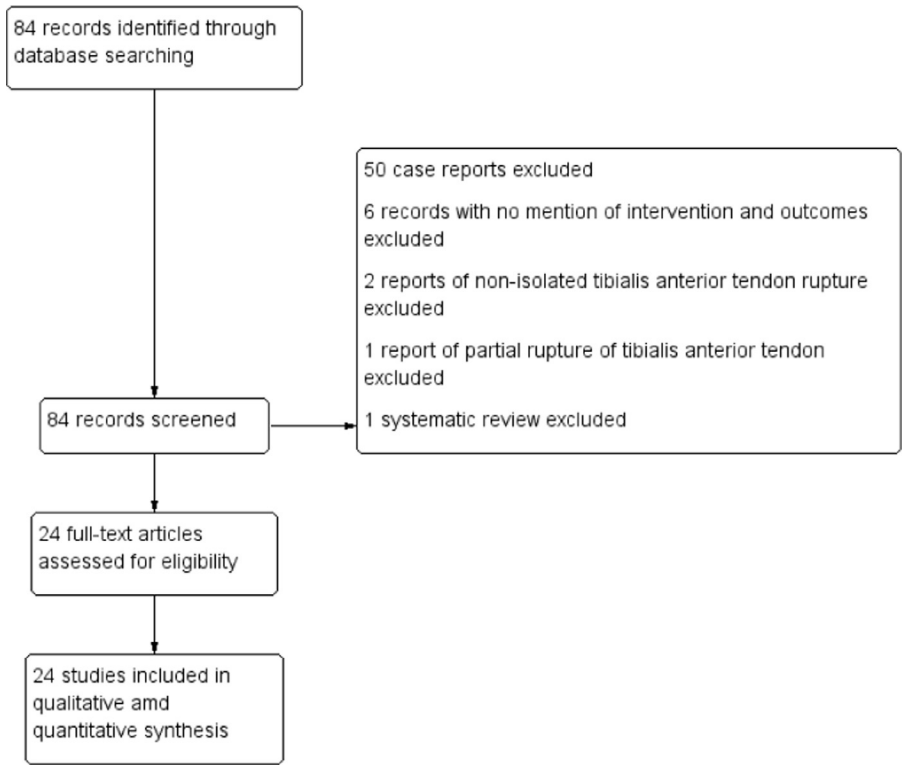

Fig. 1. Schematic of citation selection for systematic review.

Table
Systematic review and meta-analysis results (N = 118 limbs)

	Conservative Management	Surgical Management
No. included studies	8	23
No. cases	21	134
Weighted mean age (years)	70.0 (46–83)	59.1 (14.5–81)
Weighted mean time to treatment (months)	10.7 (0.17 97.33)	1.7 (0–22.40)
Weighted mean follow-up (months)	26.4 (8–84)	27.05 (0.7–360)

reported on 154 patients (95 male, 56 female, 3 gender not stated; 155 extremities: 40 left, 48 right, 67 laterality not stated) (1,2,4-6,8,16,22,27,31,35,38,42,46,48,49,51,54,56,60,64-67). Treatment of only 1 (0.69%) bilateral case was reported (16). Twenty-one (13.55%) cases were managed conservatively and 134 (86.45%) were managed surgically. The mean modified Coleman methodology score of the included studies was 28 (range 8 to 40) (Table).

Conservative management

Eight references (21 patients; 21 limbs) reported outcomes on patients managed conservatively with orthotics, ankle-foot orthosis use, and/or activity limitation (1,2,5,16,46,49,51,54). The weighted mean age was 70.0 years (range 46 to 83). The majority of ruptures occurred spontaneously (14/21; 59.14%). Only 3 (14.29%) were due to a traumatic event. The etiology of rupture was not reported in 4 cases (4/21; 19.05%). The presence of a potentially predisposing condition to rupture was reported for 1 patient (4.76%, diabetes). No ruptures were reported to occur after local steroid injection or oral steroid use. The weighted mean time from diagnosis to treatment was 10.7 months (range 0.17 to 97.33). The weighted mean time of follow up was 26.4 months (range 8 to 884). Meta-analysis of conservative management revealed a reduced potential for good outcome, although heterogeneity existed across the studies (OR = 0.68; $I^2 = 61\%$). Fair or poor outcome was mostly related to functional limitations and pain with walking due to weak ankle dorsiflexory strength (Fig. 2).

Surgical management

Twenty-three (134 patients; 134 limbs) reported outcomes on patients treated surgically (1,2,4-6,8,16,22,27,31,35,38,46,48,51,54,56,60,64-67). The weighted mean age was 59.1 years (range, 14.5 to 81.0). The mechanism of rupture was spontaneous or not recalled in 58 (43.28%) cases, acute due to trauma in 28 (20.90%) of cases, and unknown in 46 (34.33%) cases. One (0.75%) case each was due to failed primary pair and repair of iatrogenic laceration sustained during a first metatarsocuneiform joint arthrodesis procedure. The presence of potentially predisposing conditions to rupture was reported to a greater extent in this group, although the numbers were still nominal: diabetes (9, 6.72% cases), local cortisone injection (6, 4.48%), oral prednisone use (4, 2.99%), and gout (1, 0.75%). The weighted mean time from diagnosis to surgery was 1.7 months (range 0 to 22.40). Tendon gap length was reported in only 3 publications (8,38,66) with a weighted mean length of 8.98 cm (range 4 to 13). The weighted mean time to follow-up was 27.05 months (0.70 to 360.00). (Fig. 3)

Meta-analysis of surgical management irrespective of the procedure performed favored good outcome all heterogeneity was present (OR 8.40; $I^2 = 63\%$). Subgroup analysis was performed for procedure in which the outcome for >1 case was reported (Fig. 4). Good outcome with no heterogeneity was found to occur with use of an ipsilateral split/turn-down tibialis anterior tendon autograft (OR 32.15; $I^2 = 0\%$) and direct repair (OR 12.57; $I^2 = 0\%$). Good outcome with some heterogeneity was reported with use of a semitendinous autograft (OR 15.25; $I^2 = 44\%$). The poorest outcomes were found to occur with use of an extensor hallucis longus autograft OR 0.27; $I^2 = 34\%$).

Discussion

Lack of consensus on the optimal treatment for the rare condition of treatment of isolated tibialis anterior tendon rupture prompted the undertaking of this systematic review and meta-analysis (21,22,39,67). Results of this study found that isolated tibialis anterior tendon rupture most often affects males in the sixth decade of life. Closed, spontaneous rupture was the most common mechanism of injury identified. Acute, traumatic rupture accounted for 20% of the reported cases. Average length of delay in diagnosis reported in the literature is 7 months (3,7,10,68). Mean time to diagnosis, with removal of the 1 outlier treated conservatively 8 years after rupture, was 4.5 months for cases managed conservatively and <2 months for cases treated surgically. Conservative management was performed more often in patients of older age compared with those who underwent surgical intervention (70.0 vs 59.1 years). Conservative management was associated with a greater risk of fair or poor outcome with the primary complaint reported being functional limitation and pain resulting from loss of ankle dorsiflexory strength (46,49,51). Surgical management favored good outcomes overall. Subgroup analysis suggests that an ipsilateral split/turn-down autograft of the tibialis anterior tendon, semitendinous

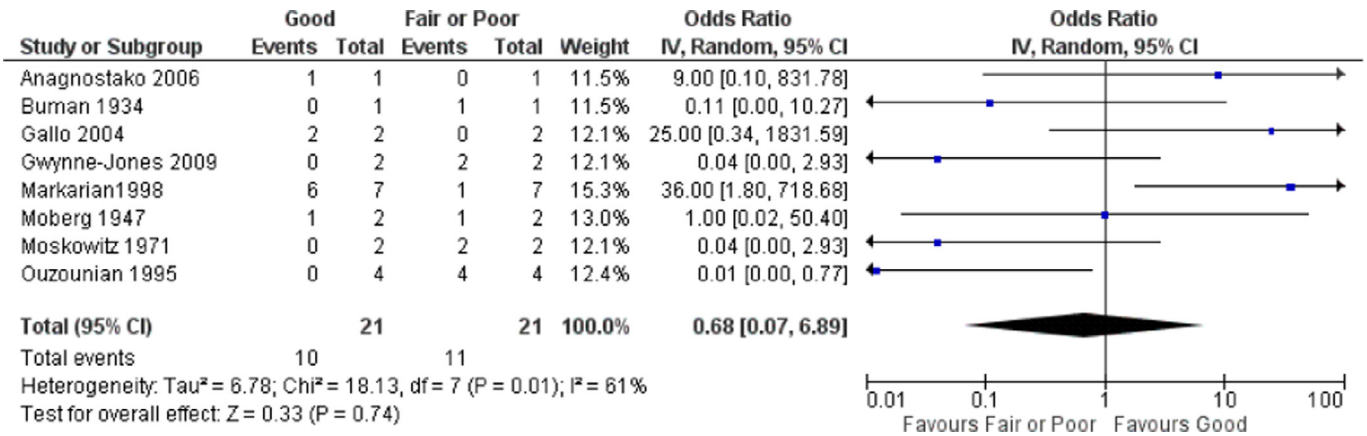

Fig. 2. Meta-analysis results of conservative management outcome. CI, confidence interval.

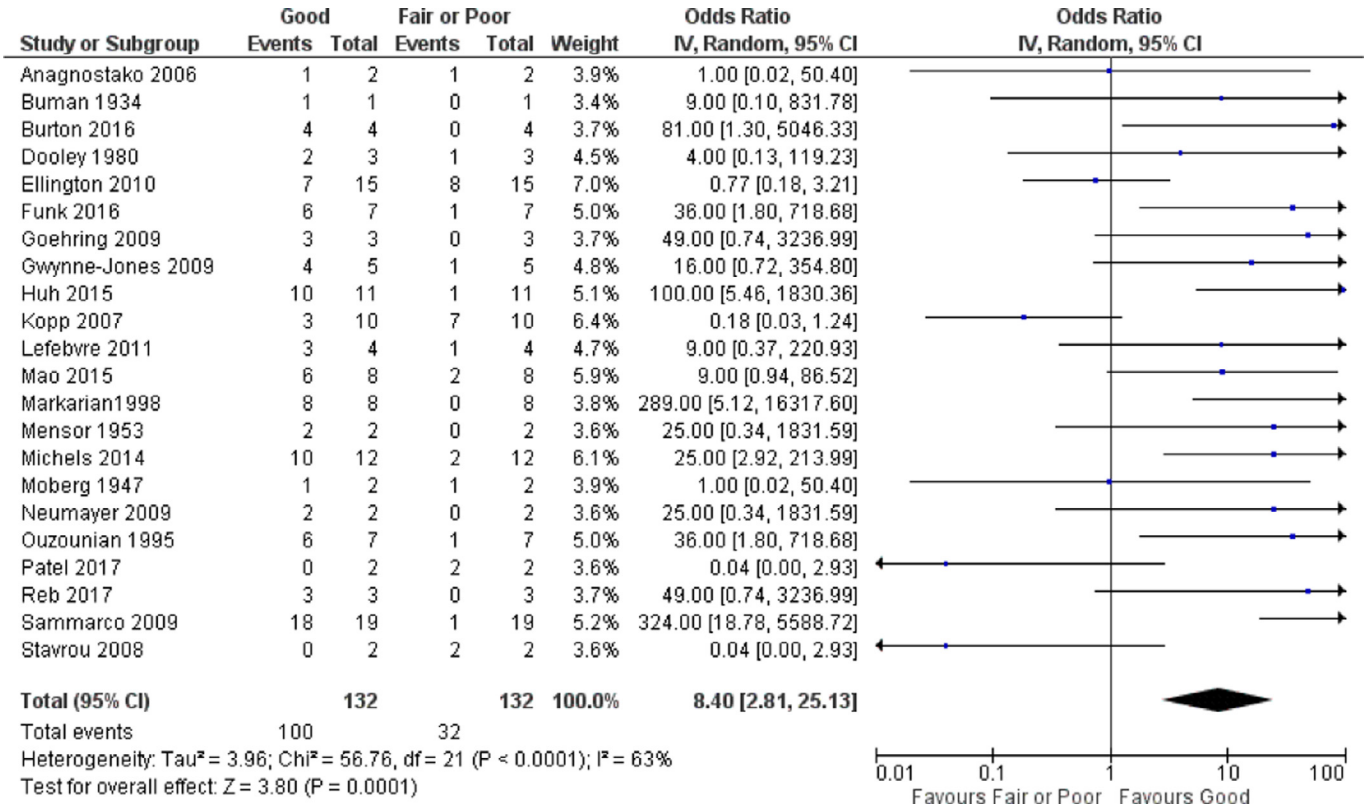

Fig. 3. Meta-analysis results of surgical management outcome regardless of procedure performed. CI, confidence interval.

autograft, or direct repair provided the best potential for good outcome over reconstruction with other tendon autografts. Use of the extensor hallucis longus tendon had the worse outcome potential and is likely from loss of ankle dorsiflexory strength resulting from reconstruction of the ruptured tibialis anterior tendon with another primary dorsiflexor of the ankle. A greater potential for poor outcomes was also noted with gracilis autograft. Three studies (8,27,38) reported the results of 7 patients. Two of these studies (8,38) focused solely on reconstruction with a gracilis autograft. One study (38) reported good outcomes for all four patients treated and reported the largest tendon gap lengths of all the included studies (mean 11.5 cm; range 10 to 13 cm).

Although surgical reconstruction has been reported to be associated with a higher incidence of postoperative complications, this was not supported by the results of this systematic review and meta-analysis. Even though objective mild dorsiflexory weakness was noted on clinical examination following surgical intervention, patients had no subjective complaints of functional limitations or pain (3,4,27,29,45,54,62,69). One study (67) used a standardized scoring system, the American Orthopedic Foot and Ankle Society ankle-hindfoot score, both preoperatively and postoperatively. Although 2 cases from this study were defined as having a fair outcome in this review because of superficial peroneal nerve pain requiring reoperation and mild dorsiflexory weakness, their postoperative scores were both increased, 46 preoperative to 96 postoperative and 51 postoperative to 90 postoperative, respectively. Although this scoring system is not validated, the results speak to lack of subjective functional complaints despite objective dorsiflexory weakness on clinical examination.

Controversy continues to exist as to what are potential contributing factors to rupture of the tibialis anterior tendon. As rupture occurs most often 0.5 to 3.0 cm proximal to the insertion, decreased vascularity and anatomic constraint by the extensor retinaculum have been implicated (4,5,7,11,16,20,22,29,31,36,39–41,47,48,52,70). Geppert et al. performed an injection study on 12 cadaveric limbs to determine if a zone of avascularity within the tibialis anterior tendon existed. The tendon was sectioned into 3 zones: zone A, the musculotendinous junction to the superior border of the inferior arm of the inferior extensor retinaculum; zone B, beneath the inferior extensor retinaculum; and zone C, distal to the inferior extensor retinaculum (11). Vascular supply of the tendon was noted to enter on the undersurface from muscular branches of the anterior tibial artery proximally and branches of the medial tarsal arteries from the dorsalis pedis artery distally. No zone of avascularity was noted. Petersen et al. repeated this study with the addition of immunohistochemical testing for the presence of lamin, a reliable method for detecting blood vessels in dense connective tissue; injection studies have the potential to be interpreted incorrectly (71). Results from this study confirmed the proximal and distal origins and undersurface entry of the vascular supply; however, although the deep half of the tendon was found to have a complete vascular network, the superficial portion of the tendon was noted to be avascular an average of 10.1 mm (range 5 to 16) from the point of insertion. This avascular zone averaged 56.6 mm (range 45 to 67) in length. A well-vascularized peritenon was also noted to be lacking in this location. This location of avascularity resides beneath the anatomic constraint of the extensor retinaculum (1,5,11,16,41,74). Decreased tendon elasticity, prolonged muscle reaction time, and decreased muscular contraction seen in older patients are also believed to contribute to the potential for rupture to occur (10,11,14,16). Although the presence of diabetes, gout, and a history of local corticosteroid injection and oral prednisone use has been documented to predispose to Achilles tendon rupture, these predisposing factors were not reported to a great extent in the literature specific to tibialis anterior tendon rupture (4,8,12,14,16,18–22,25,26,28–30,34,36,39,45,47,48,52,55,57,60,69,72,73).

Limitations of this systematic review and meta-analysis stem primarily from the paucity and the poor methodology of the literature

available discussing the management of isolated tibialis anterior tendon rupture. Weaknesses in the included studies determined by the modified Coleman methodology scale included the retrospective nature of the studies, the small size study, varying interventions performed in studies, and the lack of use of reliable outcome measures. Lack of reliable outcomes measures prompted the need of the authors to defined good, fair, and poor to perform the systematic review and meta-analysis. Although this is not optimal compared with use of validated measures of preoperative and postoperative outcomes, it was necessary and grouped accordingly for this study. Case reports were excluded in attempts to strengthen the results of this study. Restriction to the English language may limit potential inclusion of references, but those identified were limited and likely did not add significantly to the results of this review. Several poster presentations on tibialis anterior tendon rupture were also identified (23,74,75); however, these have not gone through the rigors of peer review and have yet to be published. Combination of the results of treatment for acute and spontaneous isolated tibialis anterior rupture may also confound the results obtained. However, the results are unlikely to change to a considerable degree as only 20% of cases reported were attributed to acute isolated rupture.

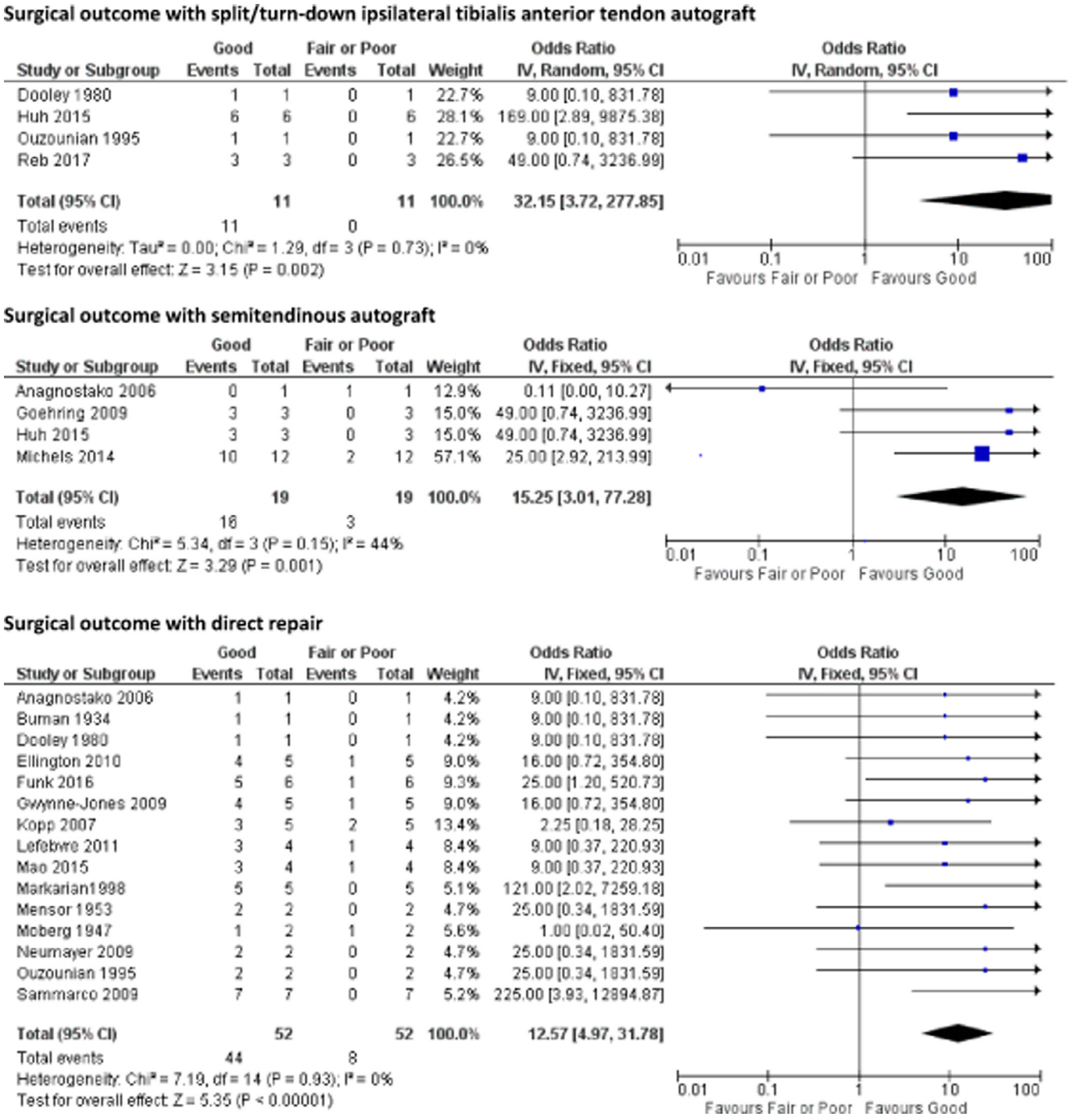

Fig. 4. Meta-analysis results of subgroup analysis for outcomes of surgical procedures performed in more than one case. CI, confidence interval.

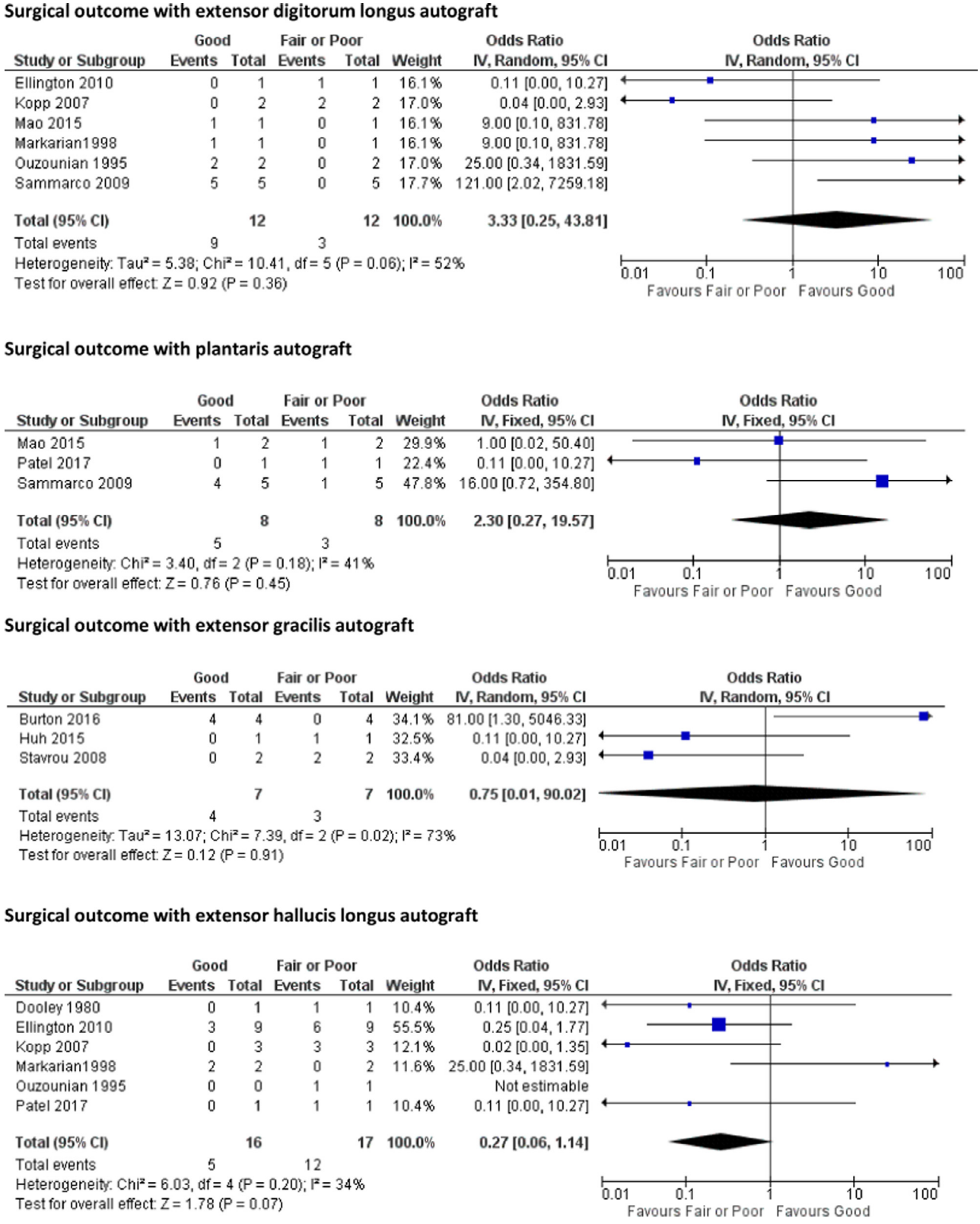

Fig. 4. Continued.

In conclusion, a systematic review and meta-analysis of English language, peer-reviewed publication on the conservative and surgical management of isolated complete rupture of the tibialis anterior tendon were performed. Results of this study confirmed that isolated complete rupture of the tibialis anterior tendon is most often closed and spontaneous, occurring more often in males in the sixth decade of life. Predisposing factors to rupture remain unknown, although a zone of avascularity, limited motion beneath the extensor retinaculum,

decreased tendon elasticity, prolonged muscle reaction time, and decreased muscular contraction may play roles. The presence of potentially predisposing comorbidities and the association with local or systemic steroid use were not reported to a great extent. The paucity and low methodology of the literature available did not allow for any definitive recommendation to be made, although surgical management appears to provide better outcomes than conservative management. Use of an ipsilateral split/turn-down ipsilateral tibialis anterior tendon autograft, semitendinous autograft, or direct repair appears to provide the best potential for good outcome while extensor hallucis longus autograft was associated with the poorest outcomes. Although dorsiflexory weakness may be noted on clinical examination postoperatively, it does not appear to hinder daily function. Further prospective studies with larger numbers of patients and utilization of validated scoring systems before and following treatment would assist in providing further guidance on optimum management of this rare condition.

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