

急性闭合性跟腱断裂非手术治疗的研究进展

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摘要

跟腱作为人体最强健的肌腱, 跟腱在运动功能中承担着核心力学负荷, 却因其独特的解剖特性成为高发断裂部位。尽管其损伤机制尚未完全阐明, 但现有证据支持“暴力牵拉 - 退行性变 - 累积微损伤”三联作用假说。近年来, 全球范围内跟腱断裂发病率持续攀升, 但其最佳治疗策略仍存争议。传统观念(2005年前)因非手术治疗再断裂率较高及康复周期漫长, 多推荐手术修复以降低再断裂风险。然而, 随着早期功能康复体系的革新, 现代保守治疗通过动态支具联合渐进性负重训练, 将再断裂率显著下降, 且治疗后1年的总跟腱断裂评分与手术组无统计学差异($P > 0.05$)。同时, 手术相关并发症风险促使临床决策向非手术方案倾斜, 尤其适用于老年患者或合并代谢性疾病人群。本综述系统梳理非手术治疗的最新循证证据, 旨在为临床医生优化治疗方案提供科学依据。

关键词

急性跟腱断裂, 手术治疗, 非手术治疗, 文献综述

Research Advances in Nonoperative Treatment of Acute Closed Achilles Tendon Rupture

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Abstract

The Achilles tendon, the strongest tendon in the human body, plays a central biomechanical role in

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locomotion but is prone to rupture due to its unique anatomical characteristics. Although its injury mechanisms remain incompletely understood, existing evidence supports the triple mechanism hypothesis of “violent traction-degenerative changes-cumulative microtrauma”. Despite the rising global incidence of Achilles tendon ruptures in recent years, the optimal treatment strategy remains controversial. The traditional paradigm (before 2005) favored surgical repair to mitigate re-rupture risks associated with higher re-rupture rates and prolonged recovery in nonoperative approaches. However, with the innovation in early functional rehabilitation protocols, modern conservative treatment with dynamic bracing combined with progressive weight-bearing training has significantly reduced re-rupture rates. At 1-year follow-up, nonoperative treatment demonstrates no significant difference in the Achilles tendon total rupture score compared to operative groups ($P > 0.05$). Furthermore, surgical complication risks have prompted clinical decision-making toward nonoperative strategies, especially for elderly patients or those with metabolic comorbidities. This review synthesizes the latest evidence on nonoperative management to provide clinicians with evidence-based insights for optimizing therapeutic decision-making.

Keywords

Acute Achilles Tendon Rupture, Operative Treatment, Nonoperative Treatment, Literature Review

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1. 引言

急性跟腱断裂(acute Achilles tendon rupture, AATR)是常见的运动损伤之一,年发病率可达18例~29.3例/10万人,且呈上升趋势[1]。发病人群中男性是女性的3.5倍,高发年龄为20~40岁[2]。由于人口老龄化、肥胖率的上升以及参加体育运动的增多使得闭合性跟腱断裂的发生率不断上升[3]~[6]。目前发表了10,000多篇关于该主题的参考文献和200多篇系统评价,关于最佳治疗策略和康复方案的争论仍然存在。在过去,特别是2005年以前,基于早期研究表明非手术治疗与高复发率相关且恢复时间长的特性,积极的手术干预比非手术治疗更被推荐[7]~[9]。这些研究为急性跟腱断裂的手术治疗提供了理论依据,尽管手术存在诸如伤口感染、腓肠神经损伤等并发症的风险。然而,最近的研究表明[10]~[12],使用早期功能康复的非手术治疗效果良好。在这些研究中,功能康复在降低再破裂率方面比长期石膏固定更有效,非手术治疗后的功能改善与手术修复后的功能改善相当。因此,本综述旨在通过急性跟腱断裂非手术治疗文献进行了全面回顾,并讨论了适当的治疗方案。

2. 跟腱解剖学

跟腱是小腿后侧的重要结构,起始于小腿中部附近,由腓肠肌和比目鱼肌的肌腱联合形成[13]。其血液供应主要来自三个部位:肌腱交界处、周围结缔组织血管和骨髓交界处[13]。尸体血管造影研究进一步证实了跟腱的三个血管来源[14]~[15]。从解剖学分布来看,跟腱的血管供应可分为三个区域:中段由腓动脉供血,近端和远端则由胫后动脉供血。值得注意的是,由于中段血管分布相对稀疏,这一区域形成了血供薄弱区,这也解释了为什么大多数急性跟腱断裂都发生在肌腱的中部位置。

3. 急性跟腱断裂流行病学

跟腱(Achilles tendon, AT)作为人体最强健的肌腱,在生物力学传递中承担关键作用,却同时成为

临床最常见的肌腱断裂部位[13]。近年来,全球多国(美国、瑞典、新西兰、丹麦、芬兰及中国等)[14][16]-[18]的流行病学研究均显示,急性跟腱断裂发病率呈显著上升趋势,且超过 70%的病例与运动损伤直接相关。

目前学界将急性跟腱断裂的致伤机制归纳为以下三类:1)爆发性牵拉损伤:前足蹬地时膝关节处于伸直位,跟腱承受突发性高张力负荷;2)被动过度牵张:踝关节意外背屈导致跟腱超出弹性形变阈值;3)拮抗性应力失衡:足部在跖屈状态下遭受剧烈背屈外力[19]。

值得注意的是,急性跟腱断裂呈现特征性年龄双峰分布:第一高峰(25~40岁):以运动相关高能量损伤为主,常见于篮球、足球等爆发性运动;第二高峰(≥ 60 岁):多由低能量日常活动诱发,与年龄相关的肌腱退行性病变密切相关[20]。第一高峰的发生大多是因为高能量的急性爆裂损伤,而第二高峰的发生原因大多与低能量的退行性病变有关[20]。而年龄因素通过多重机制加剧跟腱脆弱性:1)微循环退化:AT中下段血管密度随年龄的增长显著下降,血供减少削弱肌腱代谢修复能力[13];2)累积性微损伤:退行性病变导致胶原纤维排列紊乱,弹性蛋白比例失调,使肌腱更易在低应力下断裂[21]。

4. 急性跟腱断裂的诊断

急性跟腱断裂的诊断以病史采集与系统性体格检查为基石。典型病例多见于 30~50 岁活跃人群(双峰年龄分布的第一阶段),患者常主诉运动中突发踝后部剧痛伴“爆裂声”或“被击打感”,随即出现行走功能障碍[12]。值得注意的是,尽管疼痛起病急骤,但部分患者疼痛迅速缓解可能掩盖病情[22]。

4.1. 诊断标准

美国骨科医师学会(AAOS)临床实践指南[23]强调,符合以下四项体征中任意两项即可确立诊断:1)汤普森试验阳性(挤压腓肠肌无踝跖屈);2)跖屈肌力显著下降;3)跟腱连续性可触及缺损;4)被动背屈活动度异常增加。

4.2. 误诊漏诊的高危因素

临床误诊率可达 25%,常见于两类群体:

运动创伤误判:低能量损伤(如日常跌倒)易被误诊为踝关节扭伤;

老年群体漏诊:60 岁以上患者因退行性肌腱病变、痛觉敏感性下降、基层医疗机构查体不规范(如未行汤普森试验)、合并下肢软组织感染(如丹毒)等复杂因素,漏诊风险显著升高[4]-[6]。

4.3. 影像学检查

X 线:可排除骨折,但其对软组织分辨率不足导致漏诊率高达 40%。

超声检查(7.5~15 MHz 高频探头):作为一种影像学手段,具有实时动态评估、经济便捷(床旁可操作)、无辐射等优势。研究证实其诊断灵敏度达 95%~98%,可精准识别断裂类型(完全/部分)、断端间隙及血肿范围,并为个性化康复方案提供形态学依据[21]。

MRI 检查:适用于复杂病例或术前规划,可多平面显示肌腱退变程度及周围软组织损伤。

CT 检查:临床价值有限,仅用于合并骨性结构异常的鉴别诊断。

5. 急性跟腱断裂的非手术治疗

急性跟腱断裂的治疗需围绕三大核心目标展开:①重建肌腱正常张力关系,②最大限度保留肌肉功能,③促进运动功能恢复,同时需动态权衡不同治疗方式的并发症风险。临床决策本质上是医患共同

参与的个体化选择过程，需综合考量患者年龄、活动需求、全身状况及医疗资源可及性。

5.1. 功能支具：非手术治疗的优势革新

1) 传统非手术治疗(如石膏固定 6~8 周)虽能保护愈合中的跟腱，但长期制动可能导致小腿肌肉萎缩、踝关节僵硬及血栓风险[24] [25]。为克服这些缺陷，功能性支具(如可拆卸步行靴联合渐进式足跟楔形垫)被广泛采用。其设计特点包括：

渐进负重：通过调节楔形垫高度逐步过渡至全负重，减少跟腱牵张力。

可控活动：允许每日定时拆除支具进行踝关节背屈-跖屈训练，防止关节僵硬[26]。

2) 早期负重的生物学效应：

Valkering 等[27]的随机对照试验(单盲)表明，损伤后 2 周内启动功能性负重活动可显著提升早期愈合质量。MRI 显示，干预组在 6 周时跟腱断端胶原纤维排列有序性提高 25%，且血管生成标志物(VEGF)表达量较对照组增加 40%。

Kastoft 等[28]的随机对照试验(双盲)则指出，尽管早期负重组在 3 个月时的跟腱强度优于传统固定组(极限抗拉强度：12.3 MPa vs 10.1 MPa, $P < 0.05$)，但两组在 12 个月时的功能评分(ATRS)与重返运动率无显著差异(85.2 vs 83.7, $P = 0.42$)。上述证据提示，早期负重虽加速早期组织修复，但对中长期功能恢复的贡献需结合系统化康复计划。Costa 等人的多中心 RCT(纳入 540 例患者)进一步证实，功能支具组的再破裂率为 4.7%，与传统石膏组(5.1%)无显著差异，但并发症发生率降低 35% (如皮肤溃疡、血栓等)，且平均康复周期缩短 2 周[26]。

5.2. 手术 vs 非手术

1) 功能康复下的疗效趋同

多项高质量研究指出，在系统化功能康复方案下，非手术与手术治疗的疗效差异显著缩小。

功能评分一致性：Myhrvold 等的多中心 RCT(纳入 554 例患者，非手术组 175 例 vs 开放修复组 183 例 vs 微创手术组 196 例)显示，非手术治疗组 12 个月时的患者总跟腱断裂评分(定义为“恢复至伤前活动水平”)为 71.4%，与开放修复组(73.2%)和微创手术组(74.5%)无统计学差异($*P = 0.68$) [11]。Cramer 等[29]通过研究得出与 Myhrvold 等人相似的结果。

再破裂率与并发症对比：非手术组再破裂率为 6.3% (11/175)，显著高于微创手术组(2.0%, 4/196, $P = 0.03$)，但与开放修复组(4.9%, 9/183)无显著差异($P = 0.43$)。

非手术组症状性神经损伤发生率为 1.1% (2/175)，显著低于微创手术组(8.2%, 16/196, $P < 0.001$)；

深静脉血栓发生率在三组间无差异(均 $<2\%$) [11]。

值得注意的是，Soroceanu 等的荟萃分析强调，功能康复的规范性是疗效趋同的关键：若无早期活动干预，非手术治疗的再破裂率将升至 12%~15%，显著高于手术组(4%~6%) [30]。

5.3. 机械负荷的生物学机制

深入研究表明，机械负荷对肌腱修复过程影响重大[31] [32]。Hammerman 等[31]发现，大鼠跟腱愈合时，轻、重度负荷激活机制不同；Khayyeri 等[32]指出，负荷影响随时间减弱。同时，负荷还影响愈合肌腱内生长因子的产生，Hammerman 等[33]的研究表明，大鼠跟腱愈合早晚期，负荷引发基因响应不同。因此，可得出早期适当负重对生物力学的影响是有益的。

5.4. 治疗时机及临床决策关键点

1) 治疗时机：目前没有针对急性跟腱断裂非手术治疗的统一标准，但文献提到非手术治疗需在损伤

后 14 天内启动, 避免瘢痕导致跟腱延长[34] [35]。

2) 断端评估: 超声动态检查(轻轻的屈屈足部或通过小腿挤压试验)可量化断端间隙, 若间隙 $< 5\text{ mm}$, 且应力下对合良好, 则非手术成功率较高[12]。

3) 首选方案推荐

功能康复可行时: 非手术治疗为首选, 尤其适用于低活动需求或合并手术禁忌症患者[30] [36]。Garrick [37]通过随访 144 名患者 2 年发现, 非手术治疗患者伤后立即予以患肢足背部夹板固定, 足跖屈 20° 方式固定 2 周, 期间允许患者拄拐行走。2 周后移除夹板, 改用穿鞋跟约 30 mm 高的鞋。伤后约 6 周时, 逐渐开始加速功能康复计划, 包括渐进式阻力、健身和日常活动范围锻炼。12 周后则开始进行针对性的运动锻炼。通过这样的方式早期功能锻炼可以减少跟腱再发破裂风险, 其破裂风险与手术治疗患者相差不多。

功能康复不可行时: 微创手术(如经皮缝合)可降低再破裂风险, 但需权衡神经损伤可能性[11]。

5.5. 长期结局: 生物力学恢复一致性

术后 26 个月的 MRI 显示, 手术与非手术组的跟腱长度(静息/应力状态)与健侧无差异, 提示长期功能恢复趋同[38]。

5.6. PRP 治疗急性跟腱断裂的循证争议

Alviti 等[39]的生物力学研究表明, 手术缝合联合富血小板纤维蛋白(PRF)可显著提升跟腱抗张强度(较传统修复组提高 $18\%\sim 22\%$), 提示其改善组织愈合质量的潜力。高超等[40]通过对照试验发现, PRP 联合 Kessler 缝合组在术后 3~9 个月的关键功能指标(踝关节活动度、VAS 疼痛评分、VISA-Achilles 及 AOFAS 评分)均优于单纯缝合组, 支持 PRP 对早期功能恢复的促进作用。然而, 2021 年, 由 Daley 等[41]对 8 项 RCT 的系统分析(2021)显示, 仅 1 项研究证实 PRP 显著改善愈合结局, 其余 7 项(包括 3 项双盲试验)在术后 6~12 个月的长期随访中未发现统计学差异。当前证据表明, PRP 可能通过局部生长因子释放加速急性期愈合, 但其长期疗效(>1 年)尚未形成共识。

6. 结论

急性跟腱断裂的非手术治疗已进入以功能康复为核心的个体化精准时代。研究表明, 系统性功能康复方案(如动态支具固定、渐进性负重训练)是手术与非手术治疗取得良好功能结局的共同基石: 其将非手术治疗的再破裂率从传统石膏固定的 $8\%\sim 15\%$ 降至 $4\%\sim 6\%$, 与手术修复($2\%\sim 5\%$)无统计学差异($P > 0.05$), 同时完全规避了手术相关并发症(如切口感染、神经损伤、深静脉血栓等)。目前共识主张优先推荐非手术治疗(尤其适合老年或合并症患者), 而年轻运动员(<40 岁)或断端分离 $> 2\text{ cm}$ 者仍优选微创手术联合早期康复。然而, 不管是手术治疗还是非手术治疗, 功能康复已成为所有治疗策略的核心支柱。

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