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Hans汉斯

静脉内射频消融与微波消融治疗小隐静脉曲张的临床研究进展

谢雨芊[1]，何春水[2*]

[1]成都中医药大学临床医学院，四川 成都
[2]成都中医药大学附属医院血管外科，四川 成都

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摘 要

外科干预仍是下肢静脉曲张(Lower Extremity Varicose Veins, LEVV)的主要治疗方式，其中，小隐静脉曲张(Small Saphenous Varicose Veins, SSV)因进展风险及对生活质量的影响需早期干预。射频消融(Radiofrequency Ablation, RFA)与微波消融(Microwave Ablation, MWA)作为主流腔内热消融技术，其技术机制及临床应用存在差异。RFA通过高频交流电产热(50~90℃)使静脉壁纤维化闭合，依赖电阻加热与传导加热；MWA则利用微波(915 MHz或2.45 GHz)激发极性分子摩擦产热，穿透更深且消融范围更广。本文通过文献阅读对两种热消融方式进行综述与总结，以期给不同下肢静脉曲张的患者在选择合适的微创治疗方式上提供参考方向。

关键词

下肢静脉曲张，小隐静脉曲张，静脉腔内热消融术(EVTA)，射频消融术(RFA)，微波消融术(MWA)

Clinical Research Progress of Intravenous Radiofrequency Ablation and Microwave Ablation in the Treatment of Small Saphenous Varicose Veins

Yuqian Xie[1], Chunshui He[2*]

[1]Clinical College of Medicine, Chengdu University of Traditional Chinese Medicine, Chengdu Sichuan
[2]Department of Vascular Surgery, Affiliated Hospital of Chengdu University of Traditional Chinese Medicine, Chengdu Sichuan

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*通讯作者。

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Abstract

Surgical intervention remains the primary treatment for lower extremity varicose veins (Lower extremity varicose veins, LEVV). Among these, small saphenous vein varicose (Small Saphenous Varicose Veins, SSV) requires early intervention due to its progression risk and impact on quality of life. Radiofrequency ablation (Radiofrequency Ablation, RFA) and microwave ablation (Microwave Ablation, MWA), as mainstream intracavitary thermal ablation techniques, differ in their mechanisms and clinical applications. RFA generates heat through high-frequency alternating current (50~90˚C), causing fibrosis and closure of the venous wall, relying on resistance heating and conduction heating; MWA uses microwaves (915 MHz or 2.45 GHz) to excite polar molecules for frictional heat generation, providing deeper penetration and a wider ablation range. This article reviews and summarizes both thermal ablation methods through literature review, aiming to provide reference guidance for patients with different types of lower extremity varicose veins in selecting appropriate minimally invasive treatments.

Keywords

Lower Extremity Varicose Veins, Small Saphenous Varicose Veins, Intravascular Thermal Ablation (EVTA), Radiofrequency Ablation (RFA), Microwave Ablation (MWA)

1. 引言

LEVV 是临床常见的血管外科疾病，全球患病率较高，约影响 13.3%的成年人群，而慢性静脉功能不全(Chronic Venous Insufficiency, CVI)的患病率可达 40.8% [1]。在西方国家，静脉曲张总体影响约三分之一的人口[2]。患病率随年龄增长显著增加，女性发病率高于男性[1] [2]。据统计，我国男女患病率分别为 10%~15%、20%~25%每年新发病率为 0.5%~3% [3] [4]。SSV 作为下肢浅静脉曲张的重要类型，具有显著的临床重要性，并对患者生活质量产生多方面影响。早期表现：下肢肿胀、疼痛、沉重感及皮肤色素沉着 34。进展期风险：可能发展为 CVI，伴随脂性硬皮病、湿疹甚至静脉溃疡[5] [6]。血栓风险：曲张静脉内血流淤滞可能增加血栓形成概率[7] [8]。小隐静脉曲张不仅是局部血管病变，更是需多维度干预的慢性疾病。早期干预可显著提升生活质量，传统手术仍是治疗下肢静脉曲张的有效手段，但是传统手术治疗存在创伤大、风险高、恢复周期长、复发率高等缺点，微创技术的进步为患者提供了更多的治疗参考方向[9] [10]。

腔内热消融技术因其微创性和有效性成为重要选择，如 RFA、MWA，作为隐静脉反流的推荐治疗，因创伤小、恢复快等优势被广泛采用[11] [12]。本文针对目前临床上常用的微创治疗方法进行综述与总结，本文从技术机制、临床疗效、生活质量及并发症等方向对比，期以给不同下肢静脉曲张患者提供个体化治疗路径选择。

2. RFA 与 MWA 的技术机制比较

2.1. 射频消融(RFA)

RFA 的技术原理是通过高频交流电产生的热能选择性破坏目标组织，从而实现对静脉功能异常的干预。导管电极释放高频(通常为 350~500 kHz)交流电，电流通过组织时因电阻产生热量[13] [14]。这种热

能通过两种机制传递：(1) 电阻加热：直接接触电极的组织因电阻作用快速升温(通常达 50~90℃)，导致细胞蛋白质变性和凝固性坏死。(2) 传导加热：热量从高温区域向周围组织扩散，形成更广泛的消融区域[14] [15]。对于静脉治疗，热能主要作用于静脉壁的内膜和中膜，使胶原收缩、内皮细胞坏死，最终导致静脉纤维化闭合[16]。现代射频消融导管常配备温度反馈或接触力传感系统，以实时调整能量输出，确保消融深度和均匀性[17] [18]。静脉内射频消融通过可控的热能释放实现目标组织的选择性破坏，其技术核心在于能量传递的精确调控和病灶形成的生物学效应。

2.2. 微波消融(MWA)

MWA 是一种通过电磁波能量产生热效应以灭活目标组织的技术。电磁波产热机制：微波消融利用高频电磁波(通常为 915 MHz 或 2.45 GHz)作用于组织中的极性分子(如水分子)和离子，使其高速振动摩擦，从而产生热能。这种产热方式不依赖组织导电性，因此具有更广泛的适用性[19] [20]。微波的穿透深度更大，且能通过多电极同步作用扩大消融范围。

3. 临床疗效与安全性对比

关于静脉曲张治疗，多数针对大隐静脉(Great Saphenous Vein, GSV)，直接比较 RFA 和 MWA 治疗小隐静脉曲张的文献较少，本文结合 GSV 领域的研究结果进行综合分析，评估不同消融技术在小隐静脉曲张的临床疗效。

3.1. 消融效率与闭合率

RFA 作为浅静脉功能不全的经典热消融方法，在 GSV 治疗中表现出高闭合率(96.8%~98.4%) [21]，且长期随访(72 个月)显示静脉闭合率稳定[22]。MWA 通过微波辐射产生更大且均匀的消融区域，消融时间更短[23] [24]。在肝肿瘤中，MWA 的消融体积优于 RFA [25] [26]，推测在静脉曲张治疗中可能减少因血流散热导致的复发风险。但尚无 SSV 相关闭合率数据，需进一步验证。

3.2. 安全性对比

术中疼痛与麻醉需求：RFA 需肿胀麻醉以减少热损伤，一定程度上增加患者不适[27] [28]。MWA 的热效应受血流影响较小，理论上可减少麻醉需求，但目前静脉消融中仍需类似操作，尚无明确优势证据。并发症类型：RFA 常见并发症包括皮肤灼伤、血栓性静脉炎和感觉异常，发生率较低(<5%) [16] [27]。MWA 在肿瘤消融中因高温可能增加周围组织热损伤风险[20] [26]，但在静脉治疗中尚未见显著差异。一项甲状腺结节研究显示，MWA 与 RFA 的并发症发生率相当(如血肿、声音嘶哑) [29]。

4. 生活质量改善

4.1. RFA

RFA 在治疗后显著降低 VCSS 评分。例如，一项研究显示，RFA 治疗后 VCSS 评分平均降低 3.25 分(95% CI −3.90 至−2.60) [5]。在长期疗效维持方面：在 10 年随访中，接受 RFA 的患者 VCSS 评分持续改善，且临床复发率低于传统手术组(37% vs. 59%) [9]。对健康相关生活质量的提升：使用标准化问卷(如 Aberdeen 静脉曲张问卷 AVVQ、EQ-5D-3L 和 SF-36)的研究表明，射频消融治疗后患者疼痛、日常活动能力和整体生活质量显著改善[30] [31]。

4.2. MWA

MWA 治疗 SSV 同样显著提高患者生活质量，Junjie Tan 等人研究表明，对于 1 年内使用微波消融联

合泡沫硬化剂治疗原发性小隐静脉功能不全的患者，VCSS 和 AVVQ 显著下降，与大多数热消融或微创腔内技术研究相似[32]。

5. 与其他治疗方式的联合应用

5.1. 联合泡沫硬化疗法(UGFS)

UGFS 通过超声引导将泡沫硬化剂(如聚多卡醇、聚桂醇)注射至病变静脉，其原理在于利用硬化剂药物诱导血小板活化、血栓形成及促炎状态，这一过程导致血管内促凝活性增加，纤维蛋白凝固，从而促进血管的闭塞和硬化，同时联合热消融以增强闭合效果。研究显示，UGFS 的静脉闭合率在短期(1 年)内较高(约 86%~96%)，可显著降低静脉临床严重程度评分(VCSS)和疼痛评分[33]。UGFS 的并发症与风险：(1) 血栓事件：泡沫硬化治疗后，浅表静脉血栓(SVT)和深静脉血栓(DVT)是常见并发症。研究发现，小腿肌肉静脉血栓(MVT)发生率较高(约 23/47 例)，尤其在体型消瘦或小腿背侧注射的患者中风险更高[34]。(2) 皮肤色素沉着：使用聚多卡醇后，色素沉着发生率随浓度升高而增加(0.25%浓度时为 2%~25%，1%浓度时为 13%~73%) [35]。(3) 其他副作用：局部疼痛和静脉炎。

5.2. 联合点式剥脱

点式剥脱其原理是通过小切口分段剥脱病变静脉，减少组织损伤。研究显示：与单纯高位结扎相比：联合点式剥脱可显著降低术后复发率。例如，一项研究对比了股静脉外瓣膜成形术联合高位结扎 + 剥脱与单纯高位结扎的效果，发现联合治疗组 3 年随访时下肢沉重感和疼痛完全缓解率更高(36/40 vs. 22/40) [36]。该术式仍存在隐神经损伤等周围神经并发症风险。此外，对深静脉功能不全患者效果有限。

6. 并发症

6.1. 热损伤并发症

由于腔内热消融闭合术(Endovenous Thermal Ablation, EVTA)通过热能的方式进行血管闭合，故会产生一些特有的热损伤并发症，如皮肤灼伤、热能诱导的血栓形成(Endothermal Heat Induced Thrombosis, EHIT)等。EHIT 由 EVTA 产生的浅静脉血栓及由浅静脉向深静脉蔓延的血栓形成，其发病率达 1%~8% [37]-[39]。肿胀麻醉液的使用亦是减少多种热损伤并发症的有效方式，通过肿胀液(生理盐水、利多卡因及肾上腺素混合液)形成的物理屏障直接吸收并分散热能，增加血管与导管的距离，减少热传导；同时，肾上腺素诱导的血管收缩显著减少局部血流，一方面削弱血液对热量的扩散作用，限制热损伤范围，另一方面使目标区域热量更集中于病变血管，提升消融效率，同时促进治疗段静脉血排空以减少 EHIT 的发生[40]。此外，肿胀液的导电性或光学特性可优化射频或微波能量的空间分布，减少侧向扩散；机械性压迫则确保消融导管与组织紧密贴合，避免因接触不良导致的重复能量释放。

6.2. 常见并发症

皮下淤血、色素沉着、局部疼痛、血栓性浅静脉和感觉异常等是 EVTA 的常见并发症。尤其在热消融中比非热消融更显著，可能与热能量对周围组织的刺激有关，也可能是手术过程中导管突破血管壁或是联合静脉剥脱手术等产生的物理损伤，如疼痛、隐神经损伤、皮下淤血等[41]。

6.3. RFA 与 MWA 并发症对比

虽然 RFA 和 MWA 设备均通过热能闭合血管以达到治疗曲张静脉的目的，但不同 EVTA 设备的产热方式及导管特性各不相同，导致其并发症发生率和作用场景均有所差别。杨晓玉等[42]研究显示，MWA

(54 例)与 RFA (52 例)术后闭合率及并发症相当，但 MWA 组手术时间及费用更低。Zhao 等[43]发现 EMA (65 例)与 RFA (46 例)术后 48 小时并发症无差异，RFA 组 4 周色素沉着率(13.04%)低于 EMA 组(32.31%)，但 1 年后均消退。高晔等[44]对比 EMA 与 RFA 治疗 168 例患者(均联合泡沫硬化剂)，均未发生严重并发症，RFA 与 EMA 并发症发生率分别为 5.9%和 6.1%，无统计学差异。对比不同 EVTA 术式，EMA 与 RFA 总体安全性相近。

7. 小结与展望

MWA 与 RFA 作为治疗静脉曲张的主流腔内热消融技术，其短期疗效(1~5 年)已得到较多研究支持，但长期疗效仍存在证据缺口，例如随访至 10 年以上以明确两者远期静脉闭合率差异、疾病复发或进展风险(如新生血管生成、深静脉代偿功能变化)以及并发症(血栓性浅静脉炎、皮肤色素沉着等)的长期演变规律。因此，需要长期随访研究和大规模随机对照试验以获得高质量的证据，尽管治疗小隐静脉功能不全的金标准仍不清楚，但静脉内消融术仍然是推荐的方法[45]。临床应用中，需结合患者解剖特征与需求制定个体化方案：例如针对 MWA 穿透深度更大的特性，可能更适合需要大范围消融的患者；RFA 热扩散均匀，可优先用于浅表静脉或需精准控温的场景。未来技术发展需聚焦精准控温与能量智能调控，结合实时温度监测优化治疗安全性，同时改进导管设计以匹配复杂静脉解剖结构，并探索联合泡沫硬化剂等技术以提升疗效。

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