·论著·皮瓣移植创面修复·

本文亮点：

(1) 证实垂直褥式缝合联合水滴形动脉端侧吻合技术可安全有效地实现动脉内膜外翻对合，减少动脉吻合口形成夹层、狭窄风险，显著提高吻合口通畅率。

(2) 证实在游离皮瓣移植修复四肢创面术中，采用垂直褥式缝合联合水滴形动脉端侧吻合技术，术后皮瓣存活率高，患者对供受区外观及患肢功能恢复均表示满意。

Highlights:

(1) It was confirmed that the technique of vertical mattress suture combined with teardrop-shaped end-to-side arterial anastomosis could safely and effectively achieve the eversion and apposition of the arterial intima, reduced the risk of dissection and stenosis at the arterial anastomosis site, and improved the patency rate of the anastomosis site.

(2) It was confirmed that the technique of vertical mattress suture combined with teardrop-shaped end-to-side arterial anastomos applied in free flap transplantation for repairing limb wounds achieved high survival rate of flaps after surgery, and patients were satisfied with the appearance of the donor and recipient sites and the function of affeted limbs.

垂直褥式缝合联合水滴形动脉端侧吻合技术在游离皮瓣移植修复四肢创面中的临床应用效果

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【摘要】　目的　探讨垂直褥式缝合联合水滴形动脉端侧吻合技术在游离皮瓣移植修复四肢皮肤软组织缺损创面中的临床应用可行性、安全性及效果。　**方法**　该研究为回顾性病例系列研究。遵义医科大学附属医院烧伤整形外科 2023 年 3 月—2024 年 12 月收治 41 例符合入选标准的四肢皮肤软组织缺损创面患者，其中男 29 例、女 12 例，年龄 39~74 岁。清创后创面面积为 5.8 cm×3.5 cm~17.5 cm×6.6 cm，采用游离股前外侧穿支皮瓣、胸背动脉穿支皮瓣、背阔肌肌皮瓣、腓肠内侧动脉穿支皮瓣修复，皮瓣面积为 8.0 cm×4.0 cm~19.5 cm×7.0 cm。因受区动脉出现粥样硬化，甚至动脉内膜分层或供受区动脉直径显著不匹配，采用垂直褥式缝合联合水滴形动脉端侧吻合技术行供受区动脉吻合。供区创面经减张后直接闭合。术中观察受区动脉粥样硬化，甚至动脉内膜分层或与供受区动脉直径显著不匹配的情况。术后观察皮瓣完全存活情况，并计算皮瓣完全存活率。统计术后并发症发生情况。术后随访时，观察存活皮瓣的色泽、质地和臃肿情况，以及供区瘢痕增生情况。术前及末次随访时，分

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别采用上肢功能指数(UEFI)及足部功能指数(FFI)评定上下肢创面患者患肢功能恢复情况。末次随访时,统计患者对供受区外观及患肢功能恢复的满意度。 **结果** 术中观察到23例患者受区动脉吻合口区域动脉存在粥样硬化,甚至动脉内膜分层;18例患者皮瓣动脉直径与受区动脉直径存在显著差异,两者之比为1.0∶1.5~1.0∶3.3,平均为1.0∶2.4。术后40例患者皮瓣完全存活,皮瓣完全存活率为97.6%(40/41)。术后,5例感染性创面患者缝合口延迟愈合,经换药后愈合。所有患者术后住院期间未发生动脉危象。术后随访6~18个月,存活皮瓣色泽及质地与受区皮肤相似,外形饱满不臃肿。供区仅存在线性瘢痕,未见明显增生性瘢痕形成。术前,上肢UEFI为29~54分,平均41分;末次随访时,上肢UEFI为59~72分,平均65分。术前,下肢FFI为43~87分,平均73分;末次随访时,下肢FFI总分为15~42分,平均29分。末次随访时,28例下肢创面患者中24例可在无辅助工具帮助下行走,患者对供受区外观及患肢功能恢复均表示满意。 **结论** 垂直褥式缝合联合水滴形动脉端侧吻合技术,可有效实现动脉内膜外翻对合,减少动脉吻合口形成夹层、狭窄风险,显著提高吻合口通畅率。该技术应用于游离皮瓣移植修复四肢创面术中能有效预防动脉危象,术后皮瓣存活率高,患者满意度高,在临床中具有一定的应用价值。

【关键词】 显微外科手术; 外科皮瓣; 四肢; 端侧吻合术; 动脉粥样硬化; 创面修复

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Clinical application effects of vertical mattress suture combined with teardrop-shaped end-to-side arterial anastomosis technique in free flap transplantation for repairing limb wounds

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【Abstract】 **Objective** To explore the clinical feasibility, safety, and effects of vertical mattress suture combined with teardrop-shaped end-to-side arterial anastomosis technique applied in free flap transplantation for repairing limb wounds. **Methods** This study was a case series study. From March 2023 to December 2024, 41 patients with skin and soft tissue defect wounds in limbs who met the inclusion criteria were admitted to the Department of Burn and Plastic Surgery of the Affiliated Hospital of Zunyi Medical University. Among them, there were 29 males and 12 females, aged from 39 to 74 years. After debridement, the wound areas ranged from 5.8 cm×3.5 cm to 17.5 cm×6.6 cm. The wounds were repaired with free anterolateral femoral perforator flaps, thoracodorsal artery perforator flaps, latissimus dorsi myocutaneous flaps, and medial sural artery perforator flaps, with flap areas of 8.0 cm×4.0 cm to 19.5 cm×7.0 cm. Due to atherosclerosis or even intimal delamination of recipient arteries, or significant mismatch in arterial diameters between the donor and recipient sites, the vertical mattress suture combined with teardrop-shaped end-to-side arterial anastomosis technique was used for arterial anastomosis of in the donor and recipient sites. The wounds in the donor site were directly closed after reducing tension. During the operation, the situation of atherosclerosis, intimal delamination, or significant mismatch in arterial diameters between the donor and recipient sites was observed. After surgery, the complete survival of the flaps was observed, and the complete flap survival rate was calculated. The occurrence of postoperative complications was recorded. During the follow-up after surgery, the color, texture, and hypertrophy of the surviving flaps, as well as scar hyperplasia in the donor site were observed. Before surgery and at the final follow-up, the functional recoveries of the affected limbs were assessed in patients with wounds in upper and lower limbs using the upper limb function index (UEFI) and foot function index (FFI), respectively. At the final follow-up, the satisfaction of patients with the appearance of the donor and recipient sites and the function of the affected limbs were recorded. **Results** During the operation, it was observed that 23 patients had atherosclerosis in the recipient artery anastomosis area, even with intimal delamination; in 18 patients, there was a significant difference in the diameter of the flap artery and the recipient artery, with the ratio ranging from 1.0:1.5 to 1.0:3.3, with an average of 1.0:2.4. After surgery, 40 patients had complete flap survival, with a complete flap survival rate of 97.6% (40/41). After surgery, five patients with infectious wounds had delayed

suture healing, which healed after dressing changes. No arterial crisis occurred in all patients during hospitalization after surgery. During follow-up of 6 to 18 months after surgery, the surviving flaps had similar color and texture to the recipient skin, with a full appearance but not bloated. Only linear scars occurred in the donor site, with no obvious hypertrophic scar. Before surgery, the UEFI of upper limbs ranged from 29 to 54, with an average of 41; at the final follow-up, the UEFI of upper limbs ranged from 59 to 72, with an average of 73. Before surgery, the FFI of lower limbs ranged from 43 to 87, with an avarage of 73; at the final follow-up, the FFI of lower limbs ranged from 15 to 42, with an average of 29. At the final follow-up, 24 out of 28 patients with wounds in lower limbs were able to walk without the assistance of auxiliary tools; patients were satisfied with the appearance of the donor and recipient sites, as well as the functional recovery of the affected limbs. **Conclusions** The vertical mattress suture combined with teardrop-shaped end-to-side arterial anastomosis technique effectively achieves the eversion and apposition of the arterial intima, reduces the risk of dissection and stenosis at the arterial anastomosis site, and significantly improves the patency rate of the anastomosis site. This technique applied in free flap transplantation for repairing limb wounds can prevent arterial crisis, with high flap survival rate and satisfaction of patients after surgery, thus having application value in clinical practice.

【**Key words**】 Microsurgery; Surgical flaps; Extremities; End-to-side anastomosis; Atherosclerosis; Wound repaiar

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随着交通伤等高能量创伤及糖尿病足等慢性创面日益增多，四肢复杂急慢性创面的修复已成为创面修复医师面临的严峻挑战[1-2]。尤其当四肢皮肤软组织缺损伴骨、肌腱、关节等外露时，游离皮瓣凭借切取灵活且携带充足组织量及能提供可靠血供的优势，可修复创面并重建肢体功能。在显微技术熟练的医疗中心，游离皮瓣手术的成功率已很稳定[3-4]。采用游离皮瓣修复四肢皮肤软组织缺损创面时，当受区肢体主要血供来源单一或侧支循环不良时，供受区动脉行端端吻合有导致肢体远端坏死的风险，而行端侧吻合既能为皮瓣供血又可保持肢体远端血流灌注，成为更安全且符合原有受区动脉生理特点的血管吻合方式[5]。目前常规动脉端侧吻合技术在应用中面临 2 个重要挑战：第一，动脉粥样硬化的患者动脉内膜比较脆弱，在常规吻合过程中动脉内膜极易分层、剥离脱落，进而导致动脉分层、内膜碎片堵塞管腔或诱发血栓形成，是导致动脉吻合质量降低的高危因素[6]。目前仍缺乏能确保缝合稳定，避免内膜撕裂和吻合口狭窄，以及减少湍流的标准化端侧吻合方案。第二，当受区动脉与皮瓣动脉直径存在显著差异（如动脉直径相差 3 倍）时，传统动脉端侧吻合的操作难度增加。尽管已有学者提出通过调整吻合角度或扩大受区动脉开口等改良方法来应对供受区动脉直径差异，但效果仍不尽理想[7-8]。

本研究在游离皮瓣移植修复四肢皮肤软组织缺损创面中，创新采用垂直褥式缝合联合水滴形动脉端侧吻合技术行供受区动脉吻合，优化了动脉缝合方式及采用了模拟动脉分支生理形态的水滴形吻合口设计。本研究旨在探讨该吻合技术在临应用中的有效性与安全性。

1　对象与方法

本回顾性病例系列研究严格遵循《赫尔辛基宣言》的基本原则，根据遵义医科大学附属医院伦理委员会的相关规定，可在不泄露患者信息的情况下，对其相关临床资料进行分析研究。

1.1　入选标准

纳入标准：（1）伴骨、肌腱、关节等外露的四肢皮肤软组织缺损创面，采用游离皮瓣修复；（2）受区动脉粥样硬化，甚至动脉内膜分层或与皮瓣动脉直径显著不匹配，采用垂直褥式缝合联合水滴形动脉端侧吻合技术行供受区动脉吻合；（3）性别不限，年龄 18~80 岁。排除标准：临床资料或随访资料不完整。

1.2　临床资料

2023 年 3 月—2024 年 12 月，遵义医科大学附属医院烧伤整形外科收治 41 例符合入选标准的四肢皮肤软组织缺损伴骨、肌腱、关节等外露的患者，其中男 29 例、女 12 例；年龄 39~74 岁，平均 53.6 岁。

创面位于前臂下段及手腕部者 13 例，位于踝周及足部者 28 例。创面形成原因：创伤者 14 例，糖尿病足溃疡或感染性创面者 22 例，高压电烧伤者 3 例，热压伤者 2 例。

1.3　手术方法

1.3.1　术前皮瓣设计　所有患者在完善术前检查，排除手术禁忌后于全身麻醉下进行游离皮瓣手术。结合创面部位、大小、形状及所需软组织特性，灵活设计游离股前外侧穿支皮瓣、胸背动脉穿支皮瓣、背阔肌肌皮瓣、腓肠内侧动脉穿支皮瓣修复创面。

1.3.2　受区创面处理与血管准备　麻醉生效后，一组医师对受区创面行彻底清创处理，切除所有失活组织及感染病灶，直至创面基底可见点状活跃渗血。清创完成后，皮肤软组织缺损面积为 5.8 cm×3.5 cm~17.5 cm×6.6 cm。随后，根据受区血管的走行，在创面近端或侧方的健康皮肤做延长切口，或分离皮下隧道，在拟吻合血管的部位，充分显露并游离长度 3~5 cm 的受区目标吻合动脉，同时游离其伴行静脉或附近浅静脉。仔细探查受区动脉管壁状况，重点评估动脉粥样硬化情况，并使用显微血管测量尺，精确测量受区动脉的直径。

1.3.3　游离皮瓣切取与血管蒂准备　术中另一组医师依据术前设计及创面缺损大小切取创面修复所需大小及类型的游离皮瓣，其中切取股前外侧穿支皮瓣者 36 例、胸背动脉穿支皮瓣者 3 例、背阔肌肌皮瓣者 1 例、腓肠内侧动脉穿支皮瓣者 1 例，切取皮瓣大小为 8.0 cm×4.0 cm~19.5 cm×7.0 cm。皮瓣完全游离后，用温生理盐水冲洗后见皮瓣血运良好，用显微血管测量尺精确测量皮瓣动脉的直径，用直尺量取合适血管蒂长度后离断血管蒂，移植皮瓣修复创面[9-15]。

1.3.4　垂直褥式缝合联合水滴形动脉端侧吻合技术及皮瓣血运构建　所有吻合操作均在手术显微镜下进行。首先进行受区动脉端侧吻合口的开口和塑形：避开受区动脉粥样硬化明显点，用血管夹夹闭需开吻合口的受区动脉两端，使用 11 号手术刀反挑切开受区动脉上壁（图 1A）；根据皮瓣动脉直径，用显微剪刀将受区动脉上壁吻合口修剪为水滴形，吻合口大小略大于皮瓣动脉直径（图 1B）；以倾斜 45°左右的角度，将皮瓣动脉断端修剪成适配受区动脉吻合口的水滴形（图 1C）。根据血管直径选择合适粗细的无损伤尼龙线或非吸收聚丙烯等血管缝线。从皮瓣动脉水滴形吻合口顶点外垂直进第 1 针，于皮瓣动脉内膜下水平穿出；随即于第 1 进针点对称位置的受区动脉水滴形吻合口顶点的内膜进针，于受区动脉外穿出，完成第 2 次进针；再于平行第 2 进针点距吻合口更近的受区动脉外垂直进针，于受区动脉内膜下顺血管长轴穿出，完成第 3 次进针；最后于第 3 进针点对称位置的皮瓣动脉的内膜进针，于皮瓣动脉外穿出（图 1D）。也可同此法从受区动脉进第 1 针。缝线打结，完成 1 次垂直褥式外翻缝合。同前于水滴形吻合口底部（远端）行垂直褥式外翻缝合，完成动脉吻合口两点定位，使皮瓣动脉与受区动脉吻合口对合（图 1E）。最后完成动脉吻合口前、后壁的缝合（图 1F）。对于受区动脉与皮瓣动脉直径显著不匹配的情况，也可采用垂直褥式缝合联合水滴形动脉端侧吻合技术（图 2）。

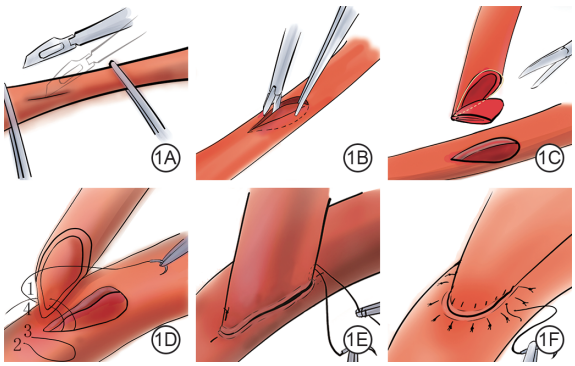

图 1　垂直褥式缝合联合水滴形动脉端侧吻合技术示意图。1A. 用 11 号手术刀反挑切开受区动脉上壁；1B. 用显微剪刀将受区动脉上壁吻合口修剪为水滴形；1C. 以倾斜 45°左右的角度，将皮瓣动脉断端修剪成适配受区动脉吻合口的水滴形；1D. 第 1 次垂直褥式外翻缝合吻合供受区动脉进针顺序；1E. 于水滴形吻合口底部行垂直褥式外翻缝合的第 2 定位针；1F. 采用垂直褥式外翻缝合完成吻合口前、后壁的缝合

Figure 1　Schematic diagram of vertical mattress suture combined with teardrop-shaped end-to-side arterial anastomosis technique

根据受区静脉的数量及管径情况，选择切取游离皮瓣动脉的伴行静脉或皮下静脉，对供受区静脉行端端吻合。观察皮瓣颜色迅速转为红润，边缘出现活跃渗血，游离皮瓣毛细血管充盈时间 1~2 s，确认血运重建成功后，将皮瓣稳妥缝合固定于受区创面，皮下放置引流皮片引流。皮瓣供区创面经减张后直接闭合。

1.4　术后处理

术后予补充血容量，静脉输注抗生素 3 d 预防感染，皮下注射肝素抗凝，静脉输注或肌内注射罂

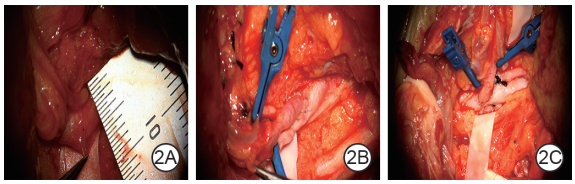

图 2　垂直褥式缝合联合水滴形动脉端侧吻合技术的临床应用。2A. 术中显示受区动脉与皮瓣动脉直径存在显著差异；2B. 受区动脉与皮瓣动脉行端侧吻合后即刻；2C. 垂直褥式缝合联合水滴形动脉端侧吻合后

Figure 2　Clinical application of vertical mattress suture combined with teardrop-shaped end-to-side arterial anastomosis technique

粟碱抗血管痉挛治疗 5 d。抬高患肢并制动促进皮瓣静脉回流，减轻皮瓣肿胀，于距离游离皮瓣 30 cm 处使用烤灯照射保暖，密切动态观测患者游离皮瓣颜色、温度和张力变化及毛细血管充盈时间[1,16-20]。

1.5　观测指标

术中观察受区动脉粥样硬化，甚至动脉内膜分层或供受区动脉直径显著不匹配的情况。术后观察皮瓣完全存活情况，并计算皮瓣完全存活率；统计术后并发症发生情况。术后随访时，观察存活皮瓣的色泽、质地和臃肿情况，以及供区瘢痕增生情况。对于 13 例上肢创面患者，采用涵盖上肢基本动作、精细动作、力量和耐力等方面的上肢功能指数（upper extremity function index，UEFI）评定术前及末次随访时患肢功能恢复情况。UEFI 总分为 80 分，得分越高，表明上肢功能越好。对于 28 例下肢创面患者，采用足部功能指数（foot function index，FFI）评定术前及末次随访时患肢功能恢复情况。FFI 包括疼痛、功能活动受限程度及日常活动能力等方面，FFI 越高表示足踝功能障碍越严重[21-24]。统计末次随访时患者对供受区外观及患肢功能的满意度。

2　结果

2.1　一般结果

术中观察到 23 例患者受区动脉吻合口区域动脉存在粥样硬化，甚至动脉内膜分层；18 例患者皮瓣动脉直径与受区动脉直径存在显著差异。皮瓣动脉直径与受区动脉直径比为 1.0∶1.5~1.0∶3.3，平均为 1.0∶2.4。2 例患者术后发生静脉危象，经急诊探查取栓后皮瓣存活；1 例患者因慢性创面严重炎症反应导致游离皮瓣术后 1 周感染坏死，接受二次手术修复。术后 40 例患者皮瓣完全存活，皮瓣完全存活率为 97.6%（40/41）。术后，5 例感染性创面患者缝合口延迟愈合，经换药后愈合。所有患者（包括存在动脉粥样硬化及内膜分层的患者）术后住院期间未发生动脉危象。术后随访 6~18 个月，存活皮瓣色泽及质地与受区皮肤相似，外形饱满不臃肿。供区仅存在线性瘢痕，未见明显增生性瘢痕形成。13 例上肢创面患者术前上肢功能均遭受严重损伤，大多数基本生活活动无法独立完成，术前上肢 UEFI 为 29~54 分，平均 41 分；末次随访时，UEFI 为 59~72 分，平均 65 分。28 例下肢创面患者术前下肢 FFI 为 43~87 分，平均 73 分；末次随访时，FFI 为 15~42 分，平均 29 分。末次随访时，28 例踝周及足部损伤患者中 24 例可在无辅助工具帮助下行走，患者对供受区外观及患肢功能恢复均表示满意。

2.2　典型病例

患者男，58 岁，因感染导致左外踝周围出现面积约 6.5 cm×4.0 cm 的皮肤软组织缺损创面，伴肌腱外露，创周及基底可见少量分泌物附着（图 3A）。行创面清创术并切除慢性炎性组织，清创后创面面积约 7.0 cm×4.2 cm。一组医师按清创术后缺损创面形状和大小设计并切取面积约 7.5 cm×4.5 cm 的右侧以旋股外侧动脉降支为蒂的游离股前外侧穿支皮瓣（图 3B）。测量切取的旋股外侧动脉降支吻合端直径为 0.9 mm，受区拟吻合的胫前动脉直径约 1.9 mm，皮瓣动脉与受区胫前动脉直径比约为 1.0∶2.1，存在供受区动脉直径不匹配情况。探查见受区胫前动脉吻合位置管壁弹性稍差，内膜质地脆，局部内膜分层形成。对皮瓣动脉和受区胫前动脉行垂直褥式缝合联合水滴形动脉端侧吻合（图 3C），对旋股外侧动脉降支伴行静脉与受区静脉行常规端端吻合。血管吻合后皮瓣血运良好、皮瓣外形饱满，毛细血管充盈时间 1~2 s（图 3D）。皮瓣供区创面经适当游离减张缝合后直接关闭。术后皮瓣血运良好，顺利成活，住院期间未发生动脉危象。术后 18 个月随访见皮瓣外形平坦，色泽、质地与小腿周围正常皮肤接近，无明显臃肿（图 3E）；供瓣区仅存在线性瘢痕，未见明显瘢痕增生（图 3F）；患肢创面愈合，可在无辅助工具帮助下行走，患肢 FFI 由术前的 53 分下降至 15 分，患者对供受区外观及患肢功能恢复均表示满意。

3　讨论

游离皮瓣移植既可修复创面又能重建肢体功能，因此近年在临床上得到广泛应用。股前外侧穿支皮瓣穿支位置相对恒定、血管蒂长且可切取面积

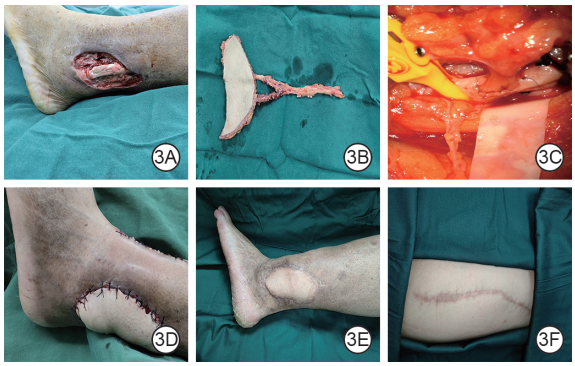

图 3　垂直褥式缝合联合水滴形动脉端侧吻合技术在游离股前外侧穿支皮瓣移植修复左外踝创面中应用的效果。3A. 术前见左外踝周围创面伴肌腱外露；3B. 术中游离股前外侧穿支皮瓣切取后；3C. 供受区动脉行垂直褥式缝合联合水滴形动脉端侧吻合后即刻；3D. 术中移植游离股前外侧穿支皮瓣修复左外踝周围创面即刻；3E. 术后 18 个月随访时，左外踝周围皮瓣外形不臃肿，色泽接近正常皮肤；3F. 术后 18 个月随访时，右大腿供区未见明显瘢痕增生

Figure 3　The effect of vertical mattress suture combined with teardrop-shaped end-to-side arterial anastomosis technique in transplantation of free anterolateral femoral perforator flap for repairing the left lateral malleolus wound

大等，是经典“万能皮瓣”，被广泛应用于临床四肢创面的修复重建[9-11,25-27]，这也是本组患者应用的主要皮瓣。胸背动脉穿支皮瓣由传统的背阔肌肌皮瓣发展演变而来，二者均可用于四肢复杂创面的修复重建，均可携带肌肉填塞死腔以增加抗感染能力，且二者的供区并发症发病率低，是修复四肢创面的理想皮瓣[28-33]。本研究中切取胸背动脉穿支皮瓣和背阔肌肌皮瓣，主要用于修复感染性创面及有腔隙形成的创面。腓肠内侧动脉穿支皮瓣是一种薄而柔韧的多功能皮瓣，且血管蒂长、不破坏主干血管，适用于四肢，尤其手部创面的修复重建[20,34-39]，本研究中主要将其用于手背创面的修复。

在采用游离皮瓣修复四肢创面术中，动脉端侧吻合因能保留受区动脉连续性，避免牺牲主干血供而常作为供受区动脉吻合的优选方案[5]。然而，当受区动脉存在粥样硬化、内膜分层或受区动脉与皮瓣动脉直径存在显著差异时，会造成供受区动脉吻合困难。本团队在游离皮瓣修复四肢创面术中创新采用垂直褥式缝合联合水滴形动脉端侧吻合技术，解决端侧动脉吻合困难的难题。该技术的核心在于两点：一是结构塑形，即通过将受区动脉吻合口修剪为立体的水滴形，构建了一个从大口径受区动脉向小口径皮瓣动脉平缓过渡且符合动脉分支构造的吻合通道，从生理形态上优化了血流动力学，有效减少了涡流与剪切力的产生。二是缝合加固，即在关键的吻合口采用垂直褥式缝合，既能确保血管内膜尤其是分层的血管内膜的铆定并整齐贴合中膜，又能通过血管内膜外翻显著增强吻合口的抗血流冲击强度，从根本上预防因血流冲击或反复操作牵拉导致的动脉内膜夹层、吻合口狭窄。本研究中，41 例动脉危象高风险患者术后均未发生动脉危象，皮瓣完全存活率高达 97.6%，充分证明了该技术在保障动脉通畅性方面的安全、可靠性。

本研究结果显示，13 例上肢创面患者 UEFI 平均分由术前的 41 分提高到末次随访时的 65 分；28 例下肢创面患者 FFI 平均分由术前的 73 分下降至末次随访时的 29 分，且末次随访时，24 例患者可在无辅助工具帮助下行走。本组患者术后良好的功能恢复效果与技术优势和术中严谨细心操作密不可分。在垂直褥式缝合时必须精准垂直穿过血管壁全层，尤其当动脉内膜分层时，需确保缝线将分离的内膜稳固铆钉对合且实现吻合口动脉内膜确切外翻等尤为重要。这些操作能在受区动脉存在粥样硬化，甚至动脉内膜分层或与供受区动脉直径显著不匹配的情况下，仍能实现动脉内膜外翻对合，减少动脉吻合口形成夹层、狭窄风险，显著提高吻合口通畅率及皮瓣存活率。创面愈合后的早期康复锻炼能显著增加上、下肢的功能恢复，使患者能完成大部分日常活动，提高患者满意度[40]。

本术式操作遵循经典的显微血管吻合原则，学习曲线相对平缓，具有良好的临床可重复性与推广潜力。但在临床应用本技术时，必须高度重视以下几个关键环节。(1)严谨细致的术中直视下血管评估是手术成功的前提，必须精确判断受区动脉粥样硬化程度或测量血管直径，选择合适的吻合部位。(2)术中精细定位与轻柔操作至关重要。依据皮瓣动脉直径精准设计水滴形吻合口，对动脉粥样硬化血管的操作需避免内膜损伤。垂直褥式缝合的首针十分关键，须确保垂直贯穿血管全层并使动脉内膜稳固铆钉及外翻缝合。在处理动脉内膜分层时，需有意识地将缝线作为复位与固定分层内膜的工具，且打结张力需恰到好处。(3)确保血管蒂部无扭转、张力或受压。

本研究存在一些不足之处。(1)属于单中心回顾性病例系列研究，受限于样本量等，研究过程中难免会出现选择偏倚，可能对研究结果的客观性产生一定影响。(2)目前尚无传统端侧吻合技术或其

他改良血管吻合技术对皮瓣完全存活率影响的对照研究，本研究的结论仍需更高级别的循证医学证据予以验证。基于此，在后续的研究工作中，本团队计划开展多中心、前瞻性对照研究，在更大规模的样本群体中，进一步验证该吻合技术的远期血管通畅率以及临床普适性，同时深入探索其改善血流动力学的具体生物力学机制，为该技术的临床推广应用提供更坚实的理论与实践支撑。

综上所述，通过水滴形动脉端侧吻合，本研究构建的吻合口能够高度模拟动脉分支的生理形态，同时依托垂直褥式缝合使血管内膜被铆钉并外翻对合的独特优势，在受区动脉存在粥样硬化，甚至动脉内膜分层或供受区动脉直径显著不匹配的情况下，可减少动脉吻合口形成夹层、狭窄风险。该技术是游离皮瓣修复四肢创面术中安全、可靠的动脉吻合方案，在临床中具有一定应用价值。

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作者贡献声明　陈涛：参与手术、研究设计、论文撰写、图片制作、经费支持；邓呈亮：手术指导、论文修改；高绍莹：文献查找、论文修改、经费支持；周健、张天华：参与手术、经费支持

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