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糖尿病足血管病变的治疗进展

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摘　要

糖尿病足溃疡是长期且管理不佳的糖尿病所常见的结果，足部溃疡的后果包括功能状态下降、感染、住院、下肢截肢和死亡，严重影响了糖尿病患者的生活质量及经济负担。外周血管系统的血运重建也是溃疡管理的关键组成部分。本文主要针对糖尿病足血管病变已成熟的技术(普通球囊血管成形术、裸金属支架、覆膜支架、自体静脉搭桥手术、开放式深静脉动脉化)与新技术(药物涂层球囊、药物洗脱支架、血栓动脉内膜切除术、改良球囊、经皮斑块切除术、血管内碎石术、经皮深静脉动脉化、生物可吸收支架)进行介绍，同时探求新的治疗方式，明确各个治疗方式之间的优越性及优缺点。

关键词

糖尿病足血管病变，介入治疗，手术治疗

Progress in the Treatment of Diabetic Foot Vascular Disease

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Abstract

Diabetic foot ulcer is a common result of long-term and poorly managed diabetes. The consequences of foot ulcer include decreased functional status, infection, hospitalization, lower limb amputation, and death, which seriously affect the quality of life and economic burden of patients with diabetes. Revascularization of the peripheral vascular system is also a key component of ulc-

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er management. This article mainly focuses on the mature technologies (standard balloon angioplasty, bare metal stents, covered stents, autologous vein bypass surgery, open deep vein arterialization) and new technologies (drug-coated balloon, drug-eluting stents, thrombotic endarterectomy, modified balloon, percutaneous atherectomy, Intravascular lithotripsy, percutaneous deep vein arterialization, and angioplasty) of diabetic foot vascular disease. At the same time, new treatment methods are explored, and the advantages and disadvantages of each treatment method are clarified.

Keywords

Diabetic Foot Vascular Disease, Interventional Therapy, Surgical Treatment

1. 引言

糖尿病足溃疡(diabetic foot ulcer, DFU)是长期且管理不佳的糖尿病所常见的结果。足部溃疡的后果包括功能状态下降、感染、住院、下肢截肢和死亡。足部溃疡的终生风险为19%至34%。溃疡后3~5年复发率为65%，终生下肢截肢发生率为20%，5年死亡率为50%~70%，严重影响了糖尿病患者的生活质量及经济负担[1]。外周血管系统的血运重建也是溃疡管理的关键组成部分[2]。糖尿病足的外周动脉疾病(Peripheral artery disease, PAD)常表现为血管受累极为弥漫，累及多条动脉，在小腿段动脉中尤其严重，闭塞时间长，闭塞长度长(50%的患者闭塞长度 > 10 cm)，血管侧支形成能力差[3]。膝下动脉组织病理学常提示血栓性管腔闭塞，动脉粥样硬化不明显，主要表现为动脉中层钙化[4]。相关研究指出以血管体(Angiosomes)的概念进行糖尿病足的血运重建，其被定义为由目标动脉供养的深层组织和皮肤的三维单位[5]。可通过介入手术行直接血运重建(Direct revascularization, DR)及间接血运重建(indirect revascularisation, IR)为血管体提供血运，虽然相关系统评价指出与IR相比，接受DR的受试者愈合的比例更高，并且带侧支的IR在伤口愈合方面可能与DR具有相似的结局[6]。但Chuter V等人指出[7]，DR的血管介入手术方式有效性暂无定论，相关证据质量低。一项回顾性研究也指出，在12个月时，DR和IR在无截肢生存期(73.2% vs 71.6%; p = 0.841)、无主要不良肢体事件(71.7% vs 66.1%; p = 0.617)和治愈率(72.7% vs 72.0%; p = 1.000)方面没有显著差异[8]。针对糖尿病足的血运重建，我们希望做到最佳的是恢复足部的血供，Settembre N等人的竞争性风险分析也表明[9]，足背动脉及足底动脉弓开放对截肢率降低有显著影响，可能对血管体靶向血运重建获益最好。对于前脚掌的广泛组织损失(WIfI临床的分级4级)或难以愈合的区域，足背和足底动脉的再通及其吻合可最大程度上改善血流供应[10]，间接说明了在糖尿病足溃疡，尤其是足部远端的溃疡，足背动脉及足底动脉弓的开放是至关重要的。本文主要针对糖尿病足血管病变已成熟的技术与新技术进行介绍，同时探求新的治疗方式，明确各个治疗方式之间的优越性及优缺点。

2. 传统治疗方式

2.1. 普通球囊血管成形术(Plain Old Balloon Angioplasty, POBA)

POBA会压碎动脉粥样硬化斑块并增加管腔直径，但再狭窄率很高，1年时长病变的再狭窄率为40%至70%，术中出现弹性反冲或限流夹层的概率大，后期可能出现重塑部位管腔狭窄率高于未处理段血管

可能性[11]，因为以上种种缺点，POBA 在实际临床引用中常结合其他手术治疗方式，但不可否认其价格低廉的优点。

2.2. 裸金属支架(Bare-Metal Stents, BMS)及覆膜支架(Covered Stent)

作为 POBA 的补充治疗方式，下肢动脉内支架置入已在临床中应用多年。但相关随机对照实验结果显示，BMS 不能预防新生内膜增生，支架内再狭窄和支架骨折的风险随着病变长度的增加而增加。进而提出覆膜支架在下肢血管介入中的应用，覆盖在支架上的膨胀聚四氟乙烯(ePTFE)可防止新生内膜组织的向内生长，使通畅性不太依赖于病变长度[12]。对不同类型覆膜支架治疗主髂动脉闭塞性疾病的系统评价表示其在 12 个月时技术成功率和通畅率高，对于复杂的主髂动脉病变，5 年随访表示覆膜支架优于 BMS [13]。VIABAHN 肝素结合覆膜支架长期随访安全有效，无靶病变血运重建率(freedom from target lesion revascularization, fTLR)为 79.1%，5 年内未发生截肢、急性肢体缺血或支架骨折[14]。然而，覆膜支架可能增加支架血栓形成的风险以及近端和远端边缘再狭窄的风险，在 3 年终点，裸镍钛合金支架在初级辅助通畅方面表现出优于 VIABAHN 的统计学优势(88.8%; 95% CI，78.0%~94.5% BMS vs 69.8%; 95% CI，53.5%~81.3% VIABAHN 覆膜支架；$p = 0.04$) [15]，急性肢体缺血(acute limb ischemia, ALI)风险较高，但原发性大截肢风险不高。血栓性支架移植物再干预后的临床结局并不理想[16]。同时针对球囊扩张支架(balloon-expandable stent, BE)或自膨胀支架(self-expanding stent, SE)进行随机 ICE 试验发现，SE 与 BE 相比，治疗髂动脉闭塞性疾病 12 个月再狭窄率较低，靶病变血运重建(target lesion revascularization, TLR)率显著降低。两组均未出现安全问题[17]。

2.3. 自体静脉搭桥手术

2016 年 AHA/ACC 关于下肢外周动脉疾病患者管理指南中指出：许多大型随机对照试验已证明膝上搭桥可选用自体静脉逆转或原位静脉搭桥[18]。对于预计寿命超过 2 年的患者通常应首先接受搭桥手术，尤其是在静脉可作为导管的情况下[19]。后针对下肢静脉搭桥手术相关系统评价及 Meta 分析结果也相继发表，Almasri J 的文章指出，与所有其他干预措施相比，大隐静脉搭桥术的通畅率最高，而移植到膝关节目标以下的通畅率和保肢率明显较差[20]。有随机对照试验指出，在具有足够大隐静脉进行手术血运重建的慢性肢体威胁性缺血(chronic limb-threatening ischemia, CLTI)患者中，手术组发生重大肢体不良事件或死亡的发生率显著低于血管内组[21]。而后续针对腘下的 CLTI 患者的随机对照研究发现，建议采用最佳的血管内治疗第一血运重建策略[22]。但 Peters F 等人研究指出，外周血管内介入手术后更有利的结局完全归因于患者特征的差异，而不是手术类型。所有手术方法在现实世界中的表现都相似[23]。

如果患者同侧大隐静脉已被使用的情况下，对侧大隐静脉、小隐静脉或手臂静脉是可能的替代方案，且在结局参数方面都是相等的，但显而易见的是，大隐静脉的通畅性和肢体挽救率优于非自体静脉和异位静脉导管[24]。虽然该手术通畅率较其他手术明显升高，但局限在须有可使用的大隐静脉，同侧大隐静脉无法使用的患者对侧大隐静脉的可用率 $< 50\%$，限制了手术的应用，同时手术创伤大，术后恢复时间长也是该手术的不良方面。

2.4. 开放式深静脉动脉化(Deep Venous Arterializations, DVA)

对于没有流出道远端靶点的患者，DVA 在近端动脉流入和远端静脉流出之间建立连接，同时破坏足部静脉瓣膜。这使得血液流到足部，并可能解决静息痛或帮助慢性伤口愈合。在早期开放式深静脉动脉化手术中，导管静脉可以在吻合术前采集、逆转和直接隧道处理。或者破坏瓣膜，静脉保持在原位以执行旁路。其手术必须进行远端静脉靶血管的瓣膜切开术；技术包括使用逆行球囊导管、瓣膜切开器、扩

张器、直接瓣膜切除术和切割球囊以破坏瓣膜[25]。在一项针对严重肢体缺血患者队列中静脉动脉化和足部搭桥术的比较研究显示，静脉动脉化组中，早期闭塞率为 15%，1 年通畅率为 71%，保肢率为 53% [26]。另一项系统评价提示 12 个月时保肢的汇总比例为 75%。静脉动脉化可能是面临患肢截肢患者的宝贵治疗选择；然而目前的证据质量低[27]。

3. 新型治疗方式

3.1. 药物涂层球囊

因 POBA 再狭窄率高、即刻弹性反冲或限流夹层和晚期负重塑等不良表现，支架植入逐渐引用起来。然而，永久性金属植入物会导致内膜增生，并且随着病变段长度增加，支架断裂的风险随之上升。为了减少内膜增生，提出通过药物涂层球囊(drug-coated balloons, DCB)或药物涂层支架进行局部给药[28]。因此近年来 DCB 的相关研究较为火热，相关药物主要集中于紫杉醇及西罗莫司等抗内膜增殖药物。然而，在 2018 年，Katsanos 等人发表了一项系统评价和荟萃分析，基于 28 项关于紫杉醇涂层设备与标准护理的随机对照试验(randomized clinical trial, RCT)，并报告了与使用紫杉醇涂层设备相关的迟发死亡率增加[29]。后续针对药物涂层装置在下肢应用中的有效性和安全性，完善相关 RCT 后提示该文失访率较高可能是一个问题，并且对紫杉醇涂层装置死亡率升高提出质疑。尚未确定对死亡率升高的合理机制解释[30]。因以上问题而停止入组的大型随机对照试验重新进行，BASIL-3 试验已接近完成入组阶段。SWEDEPAD 和 BASIL-3 试验可能最终解决这一临床困境，如果最终观察到的死亡率上升问题在数据集中得到证实，那么对西罗莫司涂层装置的持续评估[31]以及先进血管成像的新兴改进提供了替代解决方案。

3.1.1. 药物涂层球囊在膝上动脉的应用

针对 DCB 治疗股腘动脉疾病的 Meta 分析中，糖尿病患者亚组相较于非糖尿病患者原发性通畅率显着降低，这与冠状动脉介入治疗中观察到的结果一致[32]。同时也指出糖尿病和非糖尿病患者在 DCB 血管成形术后的 5 年再干预率相似，但糖尿病患者的死亡率预计更高[33]。尽管如此，Acotec 中对糖尿病患者的亚组分析研究显示，与 POBA 相比，DCB 组的 6 个月晚期管腔丢失显着降低，这表明 DCB 即使在糖尿病患者中也有效[34]。也有相关 RCT 研究使得紫杉醇药物球囊安全性和有效性得到证实，大截肢率和靶病变血运重建率低[35] [36]，初期通畅率显著提高[37] [38]。紫杉醇血浆水平在 1 小时内降至较低水平[39]。相比于裸金属支架，DCB 表现出显著更高的通畅性、更低的血运重建率和主要不良事件发生率，并且死亡率、截肢或血栓形成与 BMS 相比没有统计学意义差异[40]。

3.1.2. 药物涂层球囊在膝下动脉的应用

IN.PACT DEEP 随机对照试验 5 年随访数据指出(实验组、对照组糖尿病患病率分别为 75.7%、68.9%)，使用 DCB 血管成形术的 CLTI 患者进行胫动脉血运重建术的长期安全性和有效性与 POBA 相当。紫杉醇暴露与 5 年随访时截肢风险增加或全因死亡率无关[41]。而一项专门针对严重肢体缺血的糖尿病患者膝下血管成形术随机对照试验指出，与 POBA 相比，药物洗脱球囊在糖尿病重度肢体缺血患者膝下病变治疗中可显著减少 1 年再狭窄、靶病变血运重建和靶血管闭塞[42]。相同的，Acotec™ 药物洗脱球囊的随机对照试验也指出在膝下血管成形术中，与 POBA 相比，Litos™ DCB 显著减少了晚期管腔丢失、血管再闭塞和临床驱动的靶病变血运重建[43]。然而 Ipema J 等人的 Meta 分析却指出膝下动脉中 DCB 血管成形术与标准 PTA 比较，在保肢率、生存率、无截肢生存期、再狭窄和 TLR 方面无统计学意义差异[44]。有一项针对亚洲人群的随机对照试验甚至指出 DCB 组和 POBA 组在膝下动脉治疗后 6 个月初级通畅率相似。POBA 组 12 个月的无截肢生存率更高[45]。因此需要更多的 RCT 试验及系统综述针对亚洲人群的膝下动脉 DCB 应用的支持。

DCB 的开发是为了解决以前方法的一些局限性。它们能够将抗增殖药物输送到血管壁中，同时“不留下任何东西”。与药物洗脱支架和其他现有治疗方法相比，DCB 具有许多潜在的优势，包括持久的抗再狭窄疗效，广泛的表面接触，均匀的药物分布，没有支架足迹或聚合物残留物[46]。此外，DCB 可用于治疗支架无法有效覆盖的血管病变，例如高机械应力区域(曲折动脉)，微小血管，广泛病变和分叉病变。然而成本是一个重大障碍，缺乏可靠的成本效益研究是一个严重的问题。尽管如此，DCB 表现出球囊血管成形术固有的机械限制，最明显的是缺乏支架和机械支撑，这限制了它们的独立适用性。因此，如果最初使用 DCB 的结果不令人满意(即夹层，反冲，无效扩张)，则始终需要补救支架置入术，从而破坏其主要应用目的。另一个可能的制约因素是需要血管损伤才能获得最佳药物分布。具有严重血管损伤的气压伤是由球囊血管成形术引起的。斑块压迫不是管腔扩张的重要原因，管腔增大的主要原因是斑块破裂伴动脉夹层和整个动脉壁过度拉伸。此外，血管微切割本身被认为可以促进药物转移并在组织中产生适当的药物生物利用度，因此需要在正确的球囊尺寸和血管损伤程度之间取得微妙的平衡[47]。

3.2. 药物洗脱支架

为了降低再狭窄率(任何血管内干预后最常见的失败原因)，开发了药物洗脱支架(drug-eluting stents, DES)。尽管 DCB 在钙化程度较低的短病变中显示出有希望的结果，但其在治疗复杂疾病中的疗效仍不明确。当 DCB 用于治疗慢性完全闭塞(Chronic total occlusion, CTO)或长病变时，经常需要支架，而钙化的存在导致血管扩张减低，延迟血管阻力和减少血管壁中的药物摄取[48]。DES 在冠状动脉介入方面的成功导致了下肢动脉中 DES 的研究，希望为患有跛行或严重肢体缺血的患者提供安全持久的微创治疗选择。

3.2.1. 药物洗脱支架在膝上动脉的应用

不含聚合物的紫杉醇洗脱 Zilver PTX^{TM} 支架是第一个在治疗跛行患者短股腘动脉病变方面显示出良好 5 年效果的 DES。与 POBA 及 BMS 相比，Zilver PTX 药物洗脱支架的 RCT 试验指出整个 DES 组的临床获益、通畅性和 TLR 优于 POBA。同时，临时 DES 的临床获益、通畅性和 TLR 均优于临时 BMS [49]。同时一项随机对照试验指出 DCB 在治疗高危人群的复杂股腘动脉病变方面并不优于 DES，其再狭窄率和临床驱动的靶病变血运重建率相似[50]。DES 与 DCB 加补救支架置入术在股腘段介入治疗中的有效性和安全性相当；在长达 36 个月的时间里观察到有利于 DES 的趋势[51]。一项回顾性研究指出，Zilver PTX 支架的初次通畅率低于 Viabahn 肝素覆膜支架，但支架血栓形成率较低[52]。另一项回顾性研究指出与交织镍钛诺支架相比(INS^{TM}，Supera)，两种支架(INS 和 DES)在股腘病变中的临床驱动的靶病变血运重建(clinically driven target lesion revascularization, CD-TLR)结果相当，因此即使对于钙化或腘动脉病变，两者没有差异[53]。Eluvia^{TM} 是一种含氟聚合物紫杉醇洗脱血管支架，其具有更长的药物释放时间[54]。一项回顾性研究证明了其在严重钙化、长股腘动脉病变中较好的 1 年支架通畅性、安全性和有效性[55]，2 年结局有相似的结果[56]。另一项回顾性研究(糖尿病患病率在 60.1%~66.9%)指出，与 VIABAHN 肝素覆膜支架相比，接受 Eluvia DES 治疗的股腘动脉闭塞性疾病病变在≤15 cm 的病变中具有统计学上显著较高的初级通畅率，并且 CD-TLR 和伴随通畅性丧失的 ALI 的风险减低[57]。与 BMS 的随机对照试验表达了优良的 1 年初级通畅性[58]。Eluvia 组与 Zilver PTX 组相比，股腘病变一年时晚期管腔丢失(late lumen loss, LLL)显著降低[59]，支架血栓形成或 CD-TLR 风险降低，12 个月时初级通畅性高，并且具有相似的安全性[60]。一项涵盖了 Zilver PTX^{TM} DES (Cook Medical)和 Eluvia^{TM} DES (Boston Scientific)，PACT Admiral^{TM} DCB (美敦力公司)，LUTONIX^{TM} DCB (巴德)和 Ranger^{TM} DCB (波士顿科学)等多款药涂球囊及支架的多中心回顾研究指出 DES 组 1 年和 2 年的初级通畅性明显高于 DCB 组。然而，DES 与通畅性丧失时的临

床症状加重和复杂的病变特征有关[61]。ILLUMINA 研究显示，使用两性药物制剂的西罗莫司 NiTiDES 支架系统治疗有症状的股腘部病变，在 24 个月内具有良好的初级通畅性和安全性[62]。

3.2.2. 药物洗脱支架在膝下动脉的应用

针对紫杉醇药物洗脱支架在膝下动脉的相关应用，一项随机对照试验针对经皮腔内血管成形术联合裸金属支架补救(PTA-BMS)与 DES 治疗严重肢体缺血腘下病变的 5 年随访结果发现，与 PTA-BMS 相比，DES 治疗严重肢体缺血患者腘下病变后的截肢率和无事件生存率结果均有所改善[63] [64]。后续有西莫罗司洗脱支架相关随机对照试验指出，在膝下长段病变中，与紫杉醇 DCB 相比，DES 与显著较低的术后即刻残余狭窄相关，并在 6 个月时显著减少血管再狭窄[65]，一年的随机对照试验 ACHILLES 表现出了相同的结果[66]。与裸金属支架相比，西罗莫司洗脱支架则表现出较高的中期通畅率[67] [68]。虽然其相较于 BMS 表现出不错的有效性和安全性[69]，降低了再干预和截肢的风险，但对 1 年随访时死亡率和卢瑟福分级改善没有明显差异[70]。同时一项针对 DES 治疗后长期临床影响的荟萃分析中指出：腘下 DES 治疗在 3 年时不优于对照治疗(BMS/PTA)，尽管 DES 治疗后 12 个月的短期获益明显[71]，但需要进一步进行随访时间更长的随机试验[72]。

3.3. 斑块、钙化处理

3.3.1. 血栓动脉内膜切除术(Thromboendarterectomy, TEA)

标准的血管内治疗，如 POBA 和支架植入术，对严重钙化病变的效果有限。特别是环形钙化的病变导致球囊和支架扩张不足，因此长期通畅性差。必须进行血管准备以获得管腔和去钙化，从而促进更好的支架部署和药物沉积到血管壁中。针对内膜下斑块行 TEA 是股总动脉段金标准治疗方法。随着相关药涂球囊与药涂支架的发展，为明确血管内治疗(endovascular therapy, EVT)或开放手术优越性，有相关随机对照试验进行了研究。Nakama T 等人在一项日本多中心研究中指出，与 POBA 相比，TEA 显示出更好的 1 年通畅性。术后长期卧床削减了 TEA 的优越性，但应对结节性钙化显示其优越性[73]。一项回顾性研究也显示出较好的初期通畅率，短期随访中围手术期并发症和发病率没有显著增加，其相对于介入手术的安全性也得到了保障。在不适合动脉内膜切除术的患者中(无法耐受全麻手术的患者)，DCB 血管成形术提供了相似的二次通畅率，可以被认为是一种替代疗法[74]。

3.3.2. 改良球囊(Modified Balloons)

使用专门的球囊有助于限制夹层和应急支架的置入率，并可增加 DCB 扩张后药物进入血管壁的摄取。常用的改良球囊包括三类：切割球囊、刻痕球囊和最小创伤球囊。切割球囊的表面包括非常锋利的金属刀片，这对于切割特定位置的动脉粥样硬化斑块非常有用。刻痕球囊上有电线或聚合物，可以显著增加与斑块精确破裂相关的特定点的压力。最后，最小创伤气球对应于巧克力 PTA 球囊(美敦力公司，Santa Rosa，CA，USA)。这种半顺应性的气球被包裹在镍钛合金笼中，形成一系列凹槽和枕头，以限制夹层向血管壁的传播。在球囊扩张过程中，融合器能够使球囊以可控的方式扩张，减少过度膨胀和扭转[75]。虽然有不少前瞻性研究显示其较为可靠的有效性和安全性[76] [77] [78]，但是在用作支架置入准备的辅助药物和独立治疗时较 DCB 均未显著改善血管通畅性[78]，在 Chocolate Touch DCB 与 Lutonix DCB 随机对照试验糖尿病亚组中也有类似表达结果[79]。针对下肢动脉的相关随机对照试验较少，但在针对严重钙化性冠状动脉中的系统评价指出，与对照治疗 POBA 相比，支架置入前使用改良球囊进行病灶准备策略不能改善临床或影像学结局[80]，可能需要进一步的随机对照试验乃至荟萃分析评估其优越性。

3.3.3. 管腔减容

当由于突入管腔的钙化而需要进行管腔减容时，经皮斑块切除术是一种获得管腔并限制夹层和临时

支架置入术的选择。根据所选设备，斑块切除术可以是定向的(SilverHawk™、TurboHawk™、Hawkone™、Pantheris™)、混合的(Phoenix™)、旋转的(Jetstream™)或全程的(Diamondback360®外周轨道斑块切除术)，或者可以使用激光技术进行消融(Turbo-Elite™激光斑块切除术导管) [75]。相关前瞻性研究明确斑块切除术在治疗复杂钙化外周病变患者方面极好的安全性，较低的补救支架置入率和临床可接受的低 TLR 率[81]。同时在治疗糖尿病患者 PAD 方面并不劣效[82]。增加了中度或重度钙化股腘病变的管腔尺寸[83]。但也有随机对照试验指出定向斑块旋切术 + DCB 治疗长腘下动脉病变与单独治疗 DCB 相比，在 6 个月和 1 年时临床和技术结果相当[84]。

3.3.4. 血管内碎石术(Intravascular Lithotripsy, IVL)

血管内碎石术是一种用于修饰钙化斑块的新技术，它部署了嵌入碎石发射器的一次性球囊导管。它采用类似于用于肾结石的冲击波碎石术的概念，产生脉动声压波以安全地破坏钙化。荟萃分析支持 IVL 作为下肢 PAD 钙化斑块修饰的有效且安全的方法，可减少 59.3% (95% CI 53.30%~65.31%)的管腔狭窄，且血管并发症最少[85]。随机对照试验比较股腘动脉钙化患者接受 IVL 或 POBA 的短期结局，然后再进行 DCB 治疗有症状的外周动脉疾病的结果显示，IVL 组的手术成功率更高(65.8% vs. 50.4%; p = 0.01)，IVL 组残留狭窄病变 ≤ 30%的占比更多，而 PTA 组的限流夹层更常见。PTA 组的后扩张和支架置入也更高。30 天时主要不良事件发生率和 CD-TLR 在两组之间具有可比性。IVL 是一种有效的血管准备策略，有助于外周动脉疾病患者钙化股腘动脉的根治性血管内治疗[86]。

3.4. 经皮深静脉动脉化(Percutaneous Deep Venous Arterializations, pDVA)

LimFlow (LimFlow SA，法国巴黎)是一种血管内 DVA 系统，尚未在美国获得批准。该系统由顺行 7F 动脉导管和逆行 5F 静脉通路导管组成。插入导管，进行初始动脉造影和静脉造影以确定血管之间的最短距离[25]。一项前瞻性、多中心、单臂、早期可行性研究 PROMISE I 对 LimFlow 支架移植系统的可行性、安全性和有效性进行评估，30 天、6 个月和 12 个月的无截肢生存率分别为 91%、74%和 70%。6 个月时伤口完全愈合为 67%，12 个月时为 75%。对 16 例患者(52%)进行了再干预，其中 14 例(88%)发生在前 3 个月内。大多数再干预(n = 12; 75%)涉及支架内 LimFlow 回路近端的动脉流入道，并且没有因为支架内狭窄被再干预[87]。另一项回顾性研究也指出在 6、12 和 24 个月时，无截肢生存率的估计值分别为 83.9%、71.0%和 67.2%，保肢的估计值分别为 86.8%、79.8%和 79.8%，伤口完全愈合的估计值分别为 36.6%、68.2%和 72.7%。伤口完全愈合的中位时间为 4.9 个月(范围 0.5~15)。21 例患者随访期间 DVA 回路闭塞；闭塞的中位时间为 2.6 个月。对 17 例患者进行了闭塞再干预：16 例因伤口未愈合，1 例因新发溃疡[88]。一项前瞻性、单组、多中心研究指出 LimFlow 6 个月时无截肢生存期为 66.1%，76.0%的患者实现了保肢，63 例患者中的 16 例(25%)的伤口完全愈合，32 例(51%)的伤口正在愈合过程中[89]。LimFlow pDVA 系统用于治疗无选择性 CLTI 患者。观察到很高的技术成功率，很大比例的患者在 12 个月时没有大截肢而存活。这些结果表明了早期安全性，并且可以在慢性威胁肢体缺血且没有常规手术或血管内血运重建治疗选择的患者中成功进行。

3.5. 生物可吸收支架

生物可吸收或可生物降解支架由可在体内溶解或吸收的材料制成，支架生物可吸收性的想法被认为是革命性的(第三代支架) [90]。Absorb 生物可吸收血管支架(BVS) (Abbott Vascular, Santa Clara, California)具有与当前一代 DES 相似的机械支架和抗增殖特性。然而，在血运重建和血管壁稳定后，它通过惰性水解过程被人体吸收。该装置的可吸收性使其具有巨大的潜力，可以进行积极的血管壁重塑、稳定动脉粥样硬化斑块和恢复收缩功能。Varcoe RL 等人进行的一项前瞻性研究指出在 38 例接受治疗的肢体中，30

例(79%)出现临床改善。在 50 个支架中有 3 个(6%)检测到再狭窄，12 个月和 24 个月时的初次通畅率分别为 96%和 84.6%，12 个月和 24 个月时免于临床驱动的靶病变血运重建率分别为 96%和 96%。在接受组织丢失治疗的患者中，64%的伤口完全愈合，没有大截肢，保肢率为 100% [91]。12 个月的随访表明，使用膝以下的 Absorb 生物可吸收血管支架具有出色的安全性、通畅性和无靶病变血运重建。

4. 结论

对于血管病变的治疗各国学者在不同的治疗方式上面推陈出新，完善了大量的随机对照试验证明其优越性，但目前我国国内的相关研究仍较少，相关结果能否应用于我国人群仍未可知。目前针对糖尿病足血管病变的临床研究仍多以下肢动脉硬化闭塞症及慢性肢体缺血的设计标准作为研究方式，部分实验结果因纳入患者中糖尿病占比较少使得参考意义不明确，鲜有针对糖尿病患者的相关子集研究，后续有必要针对下肢血管病变中具有糖尿病的患者进行更为细致的研究以明确其特异性，为糖尿病足血管病变的治疗提供更有力的证据。

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