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# Research Progress of Intravascular Ultrasound

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## Abstract

**Intravascular ultrasound (Intravascular unltrasound, IVUS) as a tool in recent years, the rapid development of imaging, with its excellent image quality and spatial resolution, has become the atherosclerotic process in the diagnosis and treatment of coronary heart disease of important auxiliary means. It is mainly used for quantitative and qualitative analysis of Intravascular plaque and optimization of stent implantation. In addition, IVUS is widely used in the diagnosis and treatment of peripheral vascular diseases. This review mainly introduces the achievements of IVUS in the recognition of plaques, the optimization of stent implantation and the application of peripheral vascular system in recent years.**

## Keywords

**Intravascular Unltrasound, Plaque, Percutaneous Coronary Intervention, Aortic Dissection**

# 血管内超声的研究进展

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## 摘　要

**血管内超声(Intravascular unltrasound, IVUS)作为近几年来飞速发展的成像手段，凭借其优异的成像质量和空间分辨率，已成为诊断和治疗冠状动脉粥样硬化性心脏病的重要辅助手段，主要用于定量、定性的分析冠脉内斑块及优化支架的植入。另外，IVUS还广泛的运用于外周血管系统疾病的诊断及治疗。本**

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综述主要介绍近几年来IVUS在对斑块的识别、优化支架植入及外周血管系统中的运用所取得的成就。

## 关键词

**血管内超声，斑块，经皮冠脉介入，主动脉夹层**



## 1. 引言

冠脉造影术是一项传统而又广泛应用于临床的成像手段，然而冠脉造影有其局限性，在实际应用中不能准确反映血管解剖结构，往往低估病变严重程度。IVUS 为冠脉造影提供了关于血管管腔大小、斑块形态和性质以及动脉重构的补充诊断信息，已成为冠脉造影术重要的辅助手段。近几年来由于病理学的发展，对冠脉血管内斑块的认识越来越深，不同类型的斑块与心血管事件的相关性的研究也离不开 IVUS 的支持，然而由于斑块的成分十分复杂，IVUS 图像的解读难度较大，常常需要多位经验丰富的工作人员共同分析，因此，在临床实际应用中，IVUS 主要应用于优化支架的植入。另外，在外周血管系统疾病的诊断及治疗中，IVUS 通过呈现从血管内部到相邻血管外结构的血管系统的实时横断面成像，不仅同样可以精确测量血管的横截面积、确定斑块的性质及评估支架植入后的贴壁程度，相较于数字减影血管造影(Digital subtraction angiography, DSA)还能减少碘对比剂的剂量、减少暴露时间。

## 2. 血管内超声对斑块的识别

动脉粥样硬化斑块破裂和随之而来的急性心血管并发症是全世界急性冠脉综合症发病和死亡的主要原因[1]，容易破裂的斑块被称为“易损斑块”。既往研究表明易损斑块的组织学标志是薄帽纤维动脉粥样瘤(Thin cap fibrous atherosclerosisTCFA)，其由富含脂质的坏死核心和覆盖在上面的富含巨噬细胞的薄帽组成，并且纤维帽的厚度与斑块破裂的风险相关[2] [3]。因此尽早识别 TCFA 有助于早期对斑块破裂进行干预[4]。Narula 等人运用 IVUS 研究了 295 块冠状动脉粥样硬化斑块，其中包括稳定性斑块(105)、易损性斑块(88)和破裂性斑块(102)，用递归分割分析评估管腔狭窄百分比、纤维帽厚度、钙化斑块面积、巨噬细胞面积和坏死核心面积的等级重要性，结果表示纤维帽厚度是斑块类型的最佳判别指标[5]。

研究者们在运用 IVUS 分析冠脉斑块时，发现有回声衰减信号的斑块与心血管高风险事件有关。Jun Pu [6]等人为了解这种信号斑块背后的确切机制、病理相关性及心血管事件风险性，分析了 151 个冠状动脉标本的 2294 个血管节段，表明有 91.4%的回声衰减斑块内有含有坏死核心的纤维动脉粥样瘤或伴有脂质池的病理性内膜增厚，并且与深度回声衰减的斑块相比，浅表回声衰减的斑块更常与纤维动脉粥样硬化瘤相伴，这提示回声衰减，尤其是浅表回声衰减，是识别高危斑块较为可靠的 IVUS 信号。

不仅如此，回声衰减斑块还与 ACS 患者经皮冠状动脉介入治疗术(Percutaneous coronary intervention, PCI)中慢复流甚至无复流现象[7] [8]及术后的不良事件相关。Shigeki Kimura [9]等人运用 IVUS 研究了 609 例患者的冠脉斑块，其中包括 STEMI 患者 168 个，NSTEMI 患者 40 个，不稳定型心绞痛(Unsatble angina-pectoris, UAP)患者 26 个和 375 个稳定性心绞痛(Stable angina pectoris, SAP)患者，发现回声衰减斑块在 ACS 患者中比 SAP 患者更常见(44.0% vs 25.1%)，并且与 ACS 患者的回声衰减斑块相比，SAP 患者中回

声衰减斑块的纤维帽更厚(157 ± 97 μm vs 100 ± 58 μm)、脂质弧度更小(208˚ ± 76˚ vs 266˚ ± 99˚)、斑块负荷更小(83.0 ± 6.1% vs 86.5 ± 4.1%)，这表明 SAP 患者的回声衰减斑块易损性更低。

## 3. 在优化支架植入方面的作用

与传统裸金属支架相比，经皮植入药物洗脱支架(Drug eluting stent DSE)显著降低了支架再狭窄(In-stent restenosis ISR)发生率及支架内血栓形成率。Meta 分析[10] [11] [12]表明，与单纯血管造影术相比，如果在 IVUS 的指导下植入 DSE，则能进一步降低 ISR 的发生率及支架内血栓的形成率，特别是在复杂病变下，还能降低不良心脏事件的发生率。

张俊杰等人[13]选取了 1448 例需行 DSE 植入术的患者，随机分为 IVUS 指导组(724 例)及单纯冠脉造影指导组(724 例)，术后 12 月随访发现有 60 例(4.2%)患者发生了靶血管衰竭，包括靶血管心肌梗死、心源性死亡及临床驱动的靶血管再血管化，其中 IVUS 指导组中有 21 例，单纯冠脉造影指导组有 39 例(2.9% vs 5.4%；$P = 0.019$)。该研究中 IVUS 指导组中发生临床驱动的靶血管再血管化及支架内血栓形成的风险较单纯冠脉造影组显著减少。

Byeong-keuk Kim [14]等人在治疗 402 例冠脉慢性完全闭塞(Chronic total occlusion, CTO)患者时，分别使用 IVUS 及单纯冠脉造影指导药物洗脱支架(DSE)植入，IVUS 指导组术后最小管腔直径明显大于单纯血管造影指导组(2.64 mm ± 0.35 mm vs 2.56 mm ± 0.41 mm; $P = 0.025$)。随访 12 月后发现 IVUS 指导组患者术后心脏不良事件发生率明显低于单纯血管造影指导组(2.6% vs 7.1%; $P = 0.035$)，IVUS 组患者心源性死亡或心肌梗死的发生率明显低于单纯冠脉造影组(0% vs 2.0%; $P = 0.045$)。Nai-Liang Tian [15]等人还发现 IVUS 引导的 CTO 支架植入术后支架内管腔丢失率低于单纯冠脉造影($P = 0.025$)，支架再狭窄率也低于单纯冠脉造影(3.9% vs 13.7%; $P = 0.021$)。IVUS 引导的支架适度扩张还能降低支架植入术后慢血流的风险[16] [17] [18]。在对支架植入术后支架内再发血栓的治疗中，IVUS 指导的球囊血管成形术相较于再次支架植入有更好的预后，能更大程度的减少支架扩张不足[19]。IVUS 对支架尺寸选择的优化及辅助支架植入时精确对位可以尽量避免支架贴壁不良的发生[20] [21]。虽然 IVUS 的价格昂贵，但是可以为高风险患者(如合并糖尿病、肾功能不全患者)带来更高的经济效益[22]。

## 4. 血管内超声在外周血管系统中的运用

### 4.1. 在外周血管狭窄中的诊断及治疗

外周血管狭窄通常继发于动脉粥样硬化的下肢供血动脉阻塞所致[23]，发病率较高，常导致肢体功能下降甚至有截肢风险，常见治疗方案为经皮腔内血管成型术或支架植入术。既往的诊断及治疗离不开 DSA，然而 DSA 因其局限性往往低估或错估了血管的狭窄程度、血栓的存在、钙化的严重程度[24]，IVUS 可以实时提供更多的解剖信息弥补了这一局限性。Shinichi Nakamura [25]等人在治疗股浅动脉长段慢性完全闭塞时(CTO)通过运用 IVUS 创造了一种新的治疗方案 GIP (IVUS 指导下 Gogo 导管股动脉穿刺)，可减少造影剂的剂量及辐射暴露时间。Yasuhiro Takahashi [26]等人运用 IVUS 指导血管内治疗 44 例患者(50 条肢体)下肢动脉 CTO，1 年后随访发现 48 条(96%)肢体血管成功再通。IVUS 不仅能显示血管内闭塞情况，增加导丝顺行穿越的成功率，优化 CTO 中导丝的操作，还可以降低内膜下球囊扩张或支架植入引起的动脉穿孔的风险。

足深静脉动脉化是治疗严重肢体缺血患者的一种重要方案[27]，术者通常在胫骨水平实现动静脉瘘，此术的关键是找到合适的手术区域－动脉钙化较少且静脉直径足够，IVUS 不仅可以帮助术者找到合适的手术区域，还能评估动脉和静脉之间的正确距离，可明显增加手术成功率。

### 4.2. 在主动脉介入治疗方面的作用

主动脉夹层在临床中是一类发展迅猛、致死率高的疾病，Stanford B 型较为多见，目前常采取胸主动脉腔内修复术(Thoracic endovascular aortic repair, TEVAR)，特别是对于复杂型急性 B 型主动脉夹层，可显著降低患者 30 天及 1 年的死亡率[28]。该术使用覆膜支架封闭主动脉破口、重塑主动脉，能够明显减少患者主动脉破裂发生率，术中真假腔的鉴别以及所选取支架的精确度[29] [30]直接影响到手术效果和患者预后。由于 CT 通常在疾病诊断时进行，与 TEVAR 之间存在难以避免的时间延迟，而且血流动力学和容量充盈的变化会导致术前测量的直径与术中操作时的实际直径有差异，并且 CT 图像常常缺乏可靠的成像质量，这些都对支架的合理选择产生了极大的挑战，IVUS 通过实时描述病变的相关直径可以弥补这些不足[31] [32] [33]。一项单中心回顾性研究[34]表明了 IVUS 对 TEVAR 支架的选择有积极作用。研究选取了行 TEVAR 的 45 名 Stanford B 型主动脉夹层的患者，其中 20 名患者接受基于 IVUS 测量的支架移植，25 名患者接受基于 CT 的支架移植。术后随访表明，与 CT 辅助支架植入相比，IVUS 辅助支架植入术后产生了更大的真腔(30.4 mm ± 6.2 mm vs 25.6 mm ± 5.3 mm; $p = 0.008$)，减少了假腔的直径(14.4 mm ± 8.5 mm vs 23.9 mm ± 9.3 mm; $p = 0.001$)，这些都对患者预后产生了积极的作用。此外，IVUS 可以实时评估主动脉的直径和分支的起源，可帮助评估多通道主动脉夹层的复杂血液动力学[35]。

慢性 B 型主动脉夹层行 TEVAR 术后的主动脉重塑还与内膜瓣活动度相关，Julia Lortz [36]等人的研究表明高内膜瓣活动度的患者术后真腔的扩张度大于低内膜瓣活动度的患者，且术后再干预率也低于低内膜瓣活动度患者。IVUS 对慢性 B 型主动脉夹层内膜瓣活动度的评估可能有助于建立个性化的治疗策略。Giulio Illuminati [37]等人通过对比 IVUS 和 DSA 辅助血管内修复术，表明 IVUS 可显著降低造影剂使用剂量(60 ml ± 20 ml vs 120 ml ± 40 ml; $P < 0.01$)及曝光时间(24 ± 15 min vs 40 ± 30 min; $P < 0.01$) [30]。

综上，IVUS 的飞速发展使其已成为冠脉介入中的重要工具，特别是在左主干、分叉、CTO、支架再狭窄等复杂病变中。虽然其价格高昂，但对于高风险病人(如合并糖尿病、肾功能不全患者)可带来一定的经济效益。不同信号的斑块对应不同的心血管事件，对斑块的认识离不开 IVUS。此外，IVUS 在外周血管系统的运用带来了许多创新技术。然而 IVUS 对组织的判断基于相邻组织间的声阻抗差别，图像的重建来源是组织的声反射，而非真正的组织，因此分辨率尚有不足。各种高频 IVUS 的开发可以带来更高的分辨率，而其他成像方式，比如红外线光谱，已经开始与 IVUS 结合使用。未来，具有多种成像方式的导管可能会被整合在一起，为动脉粥样硬化的研究提供了一个独特的机会，先进的数据融合方法使快速冠状动脉重建和准确评估血管几何形状和斑块性质及分布成为可能。

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