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· 专家论坛 ·

慢性肾功能不全患者腹主动脉腔内修复术的策略和技术要点

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摘要

随着人口老龄化加速, 腹主动脉瘤 (AAA) 合并慢性肾功能不全 (CRI) 的患者比例逐年升高。两种疾病并存显著增加围术期管理难度并对患者预后造成不利影响。腹主动脉腔内修复术 (EVAR) 作为 AAA 的主要微创治疗方式, 其术前增强 CT 及术中造影剂的应用对 CRI 患者存在明确的肾毒性风险, 可诱发对比剂肾病及急性肾损伤, 进而增加心力衰竭和死亡风险。针对上述临床难点, 本文提出“ACIER”肾保护策略, 围绕术前评估肾功能、控制肾高危因素、增加肾储备, 术中减少肾损害及术后尽早肾挽救五个关键环节, 构建覆盖“术前-术中-术后”全过程的系统化、个体化管理路径。该策略整合精细化风险评估、优化对比剂使用、替代造影技术及围术期肾功能监测等措施, 旨在最大限度降低 EVAR 相关肾损伤风险、改善高危患者预后, 为 AAA 合并 CRI 患者的安全治疗提供可操作的临床参考。

关键词

主动脉瘤, 腹; 肾功能不全, 慢性; 造影剂; 急性肾损伤
中图分类号: R543.1

Strategies and technical considerations for endovascular aortic repair in patients with chronic renal insufficiency

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Abstract

With the accelerating aging of the population, the coexistence of abdominal aortic aneurysm (AAA) and chronic renal insufficiency (CRI) has become increasingly common, posing substantial challenges to perioperative management and adversely affecting patient outcomes. Although endovascular aortic repair (EVAR) is the standard minimally invasive treatment for AAA, the routine use of contrast-enhanced computed tomography and intraoperative angiography carries a significant risk of nephrotoxicity in CRI patients, potentially leading to contrast-induced nephropathy and acute kidney injury, and consequently increasing the risks of heart failure and mortality. To address these challenges, we propose the "ACIER" renal protection strategy, a structured perioperative management framework encompassing five key components: assessment of renal function, control of renal high-risk factors, enhancement of renal reserve, intraoperative reduction of renal injury, and early postoperative renal salvage. This strategy

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integrates refined risk stratification, contrast-sparing techniques, alternative imaging modalities, and dynamic postoperative renal monitoring, aiming to minimize contrast-related renal injury and improve outcomes in high-risk patients undergoing EVAR. The ACIER strategy provides a practical and individualized approach for the safe application of EVAR in patients with AAA complicated by CRI.

Key words

Aortic Aneurysm, Abdominal; Renal Insufficiency, Chronic; Contrast Media; Acute Kidney Injury

CLC number: R543.1

腹主动脉瘤 (abdominal aortic aneurysm, AAA) 与慢性肾功能不全 (chronic renal insufficiency, CRI) 在老龄化社会中常合并存在, 术前合并率高达约 28%^[1-2]。两者共存时, 患者预后显著恶化, 治疗难度增加。随着微创技术的发展, 腹主动脉腔内修复术 (endovascular abdominal aortic repair, EVAR) 因创伤小、恢复快, 已成为 AAA 的主要外科治疗手段。然而, EVAR 术前 CT 增强检查与术中使用的造影剂对 CRI 患者具有潜在肾毒性可能, 增加对比剂肾病 (contrast-induced nephropathy, CIN) 及急性肾损伤 (acute kidney injury, AKI) 风险, 进而提升心力衰竭发生率与病死率^[3-4]。研究^[5-6]表明, CRI 是 EVAR 术后短期与长期死亡率的独立预测因子, 其风险甚至超过传统的查尔森合并症指数 (Charlson comorbidity index, CCI)。为应对该临床挑战, 笔者结合最新文献与临床经验, 提出“ACIER”策略, 旨在通过术前评估肾功能 (A-assess renal function)、控制肾高危 (C-control renal high risk)、增加肾储备 (I-increase renal reserve)、术中减少肾损害 (R-reduce renal damage) 及术后尽早肾挽救 (E-early renal salvage) 五个关键环节, 为肾功能不全患者实施安全有效的 EVAR 提供系统化、个体化的肾保护策略。该策略的提出, 有助于规范高危患者的临床管理, 推动 EVAR 在 AAA 合并 CRI 患者中安全应用。

1 CRI 患者 EVAR 的风险分析

1.1 CRI 是 CIN 的独立危险因素

CIN 通常定义为患者在接受含碘对比剂后 48~72 h 内, 血清肌酐较基线水平急剧上升 25% 或绝对值增加 ≥ 0.5 mg/dL 的肾功能急剧下降现象^[7]。CRI 被认为是 CIN 重要且独立的危险因素。其发病率在肾功能正常者中较低, 约为 1%~5%, 但在已有 CRI 患者中显著升高, 发病率可高达 20%~30% 甚至更

高, 这种差异主要源于 CRI 患者肾脏本身已有的功能障碍和对肾脏损伤的易感性明显增加^[8-9]。CIN 的发病机制源于对比剂诱发的肾髓质缺血, 进而产生直接的肾小管毒性, 并加剧氧化应激, 多重损伤相互叠加形成恶性循环, 最终导致肾功能急剧下降。糖尿病肾病等基础疾病还会通过高血糖状态促进氧化应激和免疫炎症反应, 加重肾损伤的程度, 进一步提升 CIN 风险^[10-12]。临床研究明确指出, CRI 患者在接受含碘对比剂检查或介入治疗时, CIN 的发生率明显高于肾功能正常者; 在急诊接受静脉注射对比增强 CT 扫描的患者中, 肾功能不全患者的血清肌酐升高发生率显著高于无肾功能障碍患者, 且绝大多数血清肌酐升高患者均有慢性肾病、糖尿病、高血压等潜在肾功能损害风险因素^[13]。这提示通过病史和临床评估能够有效识别高风险患者, 采取针对性预防措施对于减少 CIN 发生至关重要。此外, CRI 患者的肾动脉钙化也被认为是 CIN 发生的独立相关因素, 提示血管病变对肾血流灌注的影响在 CIN 发病机制中不可忽视^[8,14]。可见, CRI 患者行 EVAR 时, 须重视风险评估、优化对比剂使用并严密监测肾功能, 以显著降低 CIN 风险。

1.2 CIN 对患者预后的严重影响

CIN 作为介入性治疗中常见的并发症, 尤其在肾功能不全患者中表现出显著的预后影响^[15]。首先, CIN 不仅可引起短期的 AKI, 而且还会增加长期肾功能恶化的风险。其次, CIN 的发生与需肾脏替代治疗 (如透析) 的比例密切相关。研究显示, 约有 6% 的 CIN 患者最终需要接受透析治疗, 这一比例在肾功能不全的患者群体中更高。最后, CIN 还与全身多器官功能障碍密切相关, 尤其是心力衰竭和感染等严重并发症, 肾功能的急剧下降会导致体内代谢产物和毒素的积累, 诱发系统性炎症反应综合征, 导致心力衰竭风险显著提升^[16]。同时, 肾功能障碍还会抑制免疫系统, 增加感染

的发生率,尤其是在接受腔内修复术后的免疫抑制状态中更为明显^[17]。多器官功能障碍和感染的叠加效应显著提高了患者的病死率,使CIN成为影响患者短期及长期预后的关键因素。

2 “ACIER”策略系统化介绍

为应对AAA合并CRI患者行EVAR时面临的高危CIN风险与复杂的围术期管理,笔者系统性地提出“ACIER”肾保护原则。该原则旨在通过一个结构化框架,将零散的防护措施整合为连贯的临床路径,实现涵盖“术前-术中-术后”的全程化、精细化肾脏管理。“ACIER”一词在法语中意为“钢”,寓意为患者肾功能构筑如钢铁般坚固的防护体系。

2.1 评估肾功能(A-assess renal function)

术前评估不仅要关注AAA本身,还需系统评估患者全身血管状况及合并症,因为合并的心血管疾病、糖尿病、慢性肾病等均显著影响术后肾功能及全身预后^[18-19]。肾功能的精细化评估应采用适合中国人群的估算公式,如基于中国人群特异性的肾脏病饮食改良研究公式计算的估算的肾小球滤过率(estimated glomerular filtration rate, eGFR),较单纯血清肌酐指标更准确反映肾功能状态。此外,尿液中尿钙结合蛋白水平的降低也被发现是术前预测AKI的独立指标,提示肾小管储备受损患者术后肾功能下降风险较高^[20]。关于CRI患者行EVAR的风险评估,可选择基于Mehran风险评估系统的方法,以量化个体风险:评分 ≤ 5 时,CIN为低风险(约为7.5%);评分6~10时,CIN中低风险(约为14%);评分11~16时,CIN中高风险(约为26.1%);评分 ≥ 16 时,CIN高风险(约为57.3%)。此外,造影剂体积(contrast media volume, CMV)与eGFR的比值(CMV/eGFR)被证明是预测术后肾功能减退的重要指标,CMV/eGFR比例 >2 时,患者术后发生肾功能减退的风险显著增加^[21]。此外,术前低碱剩余和无乳酸碱剩余水平也与术后肾功能恶化相关,提示酸碱平衡状态在肾脏保护中具有潜在意义^[22]。

综上,全面评估肾功能需结合患者的基础疾病、肾功能动态指标及个体化风险评分,合理调整造影剂使用量和术前准备,最大限度降低术后肾功能恶化风险。

2.2 控制肾高危(C-control renal high risk)

术前应积极管理高血压、心力衰竭、糖尿病及贫血等并存疾病,以减轻肾脏负担与结构损伤^[23-24]。同时需合理调整用药方案,暂停或替换非甾体抗炎药、氨基糖苷类抗生素等肾毒性药物,并谨慎使用利尿剂,必要时根据肾功能调整抗反转录病毒药物剂量^[25-26]。在对比剂使用方面,应避免短期内重复造影检查,优先选择无创影像技术或等渗对比剂,并充分补液以降低对比剂相关肾病风险^[27]。此外,术中须严密监测血流动力学,维持平均动脉压不低于65 mmHg(1 mmHg=0.133 kPa),防止低灌注引起的AKI^[28]。通过系统化控制上述因素,可有效降低术后肾功能恶化风险。

2.3 增加肾储备(I-increase renal reserve)

包括规范化的水化与碱化以及合理的药物预防。水化与碱化是经济有效的基础肾保护措施,强调对输注时机、液体种类、速度及目标尿量的精细管理。术前数小时应开始输注液体,首选生理盐水或具有碱化尿液作用的碳酸氢盐液,后者能够有效减少造影剂诱导的氧化应激与细胞损伤。输注速度需根据患者心肾功能个体化调整,避免容量过负荷,目标尿量一般设定为100~150 mL/h,以保障充分的肾脏灌注与排泄。该方案因安全、有效且操作简便,已被多项指南推荐为标准化预防措施^[29-30]。在药物辅助方面,他汀类、N-乙酰半胱氨酸及茶碱是常用药物,他汀通过抗炎、抗氧化及改善内皮功能发挥潜在保护作用^[31],N-乙酰半胱氨酸作为抗氧化剂曾被广泛研究,而茶碱则通过扩张肾血管、改善肾血流被关注^[32]。然而,这些药物的肾脏保护效果在不同临床研究中结论不一,目前尚无指南将其列为常规推荐,故建议在充分评估患者具体情况并权衡利弊后个体化应用,且必须与水化/碱化等基础措施联合实施^[33]。

2.4 减少肾损害(R-reduce renal damage)

术中操作中,减少对对比剂用量是保护肾功能、改善预后的核心^[34]。遵循“能不则不、能少则少、能替则替”原则具体实施。“能不则不”强调术前充分利用CT血管成像影像与骨性标志进行精准定位,并借助融合影像技术,尽量不用对比剂^[35];“能少则少”通过对比剂稀释方案(高压造影1:1稀释、手推路图2:8稀释)及严格控制造影剂量,在保证影像质量基础上降低肾毒性风险^[36],争取少用对比剂;“能替则替”优先选用等渗对比剂

(如碘克沙醇)以降低AKI发生率,对重度肾功能受损者可采用CO₂造影或超声引导实现无碘操作^[37-38],必要时替换对比剂。此外,未来可应用人工智能辅助系统为精准控量提供技术支撑^[39-40]。系统化实施上述措施可有效降低EVAR术中肾损伤风险,改善患者预后。

2.5 尽早肾挽救(E-early salvage)

术后管理上,注意涵盖以下三个层面:(1)应严密动态监测血清肌酐水平及尿量变化,以实现AKI的早期识别与干预,主要标准是48~72 h内,血清肌酐升高 ≥ 0.3 mg/dL或 \geq 基线值的1.5倍,辅助标准是尿量 < 0.5 mL/kg/h持续6 h以上。研究表明AKI的发生与手术方式、肾脏灌注状态及基础肾功能密切相关,早期监测可显著改善预后^[41]。(2)需延续实施综合性保护措施,包括个体化水化治疗以维持肾脏灌注压、合理应用具有肾脏保护潜力的药物(如抗氧化剂),同时严格避免肾毒性药物并控制血流动力学波动^[42]。(3)一旦患者出现CIN或AKI进展的迹象,应及时启动肾脏替代治疗,如血液透析,以防止肾功能持续恶化及多器官功能衰竭的发生,早期积极干预可显著降低终末期肾病风险及相关死亡率^[43]。

3 CRI患者行EVAR的技术要点

系统性减少碘对比剂相关的肾脏负担,是CRI患者EVAR术中技术操作的核心目标。在EVAR术中操作中通过两方面实现:减少造影次数与控制单次对比剂用量^[44]。

3.1 减少造影次数

通过优化影像引导策略,可在不牺牲手术安全性的前提下显著减少术中造影次数^[45-46]:(1)骨性标志定位:在导丝、导管及支架输送过程中,充分利用脊柱、骨盆等固定的骨性解剖标志进行初步定位,可有效避免不必要的路图造影,从而降低对比剂使用总量^[47];(2)导丝、导管定位:在肾动脉、肠系膜动脉等关键分支血管内预先留置导丝或标记导管,可作为可靠的解剖参考,其定位稳定性优于反复造影确认^[48];(3)标记猪尾导管的应用:使用具有放射性标记的猪尾导管,可在无需造影的情况下精确测量病变长度和支架锚定区,进一步减少诊断性造影次数。

3.2 减少单次对比剂用量

通过优化对比剂注射方案,可在满足影像需求的同时显著降低总碘负荷^[49]:(1)高压注射器造影时,采用对比剂与生理盐水1:1稀释方案,并将单次注射剂量减半,可在保证主动脉主干显影的同时降低肾毒性;(2)手推造影或路图采集时,推荐使用更高稀释比例(如对比剂与生理盐水2:8稀释)。所有造影操作应以满足器械定位和路径指引为度,避免过度追求血管影像的解剖细节而增加对比剂用量。研究表明,严格遵循低剂量对比剂方案,可将EVAR术中总对比剂用量控制在30 mL以下,显著降低术后AKI发生率。

3.3 技术整合与展望

将上述技术要点系统整合,结合等渗对比剂的选择及CO₂造影等替代技术^[37],可构建个体化的肾保护方案。随着融合成像、三维导航及人工智能辅助技术(如AngiSight)的发展,未来有望在零对比剂条件下完成部分EVAR手术,为CRI患者提供更安全的手术选择^[39]。

4 小结与展望

AAA合并CRI患者行EVAR治疗时,面临着CIN这一严峻挑战,其发生风险高、预后影响深远,对围术期管理提出了极高要求^[50]。本文系统提出的“ACIER”肾保护策略,通过将评估、控制、增加储备、减少损害和早期挽救五个环节有机整合,构建贯穿“术前-术中-术后”的全程化、系统性管理框架。该策略框架不仅涵盖了风险评估、并存病优化、水化/碱化等基础措施,更重点突出了基于“能不则不、能少则少、能替则替”原则的精细化术中操作技术,以及以严密监测和及时干预为核心的术后管理方案。本中心临床实践表明,遵循这一策略能显著减少对比剂相关肾损伤的发生,有效保护肾功能,为高危患者安全接受EVAR治疗提供了关键保障。未来,随着等渗对比剂的普及、CO₂造影技术的成熟以及人工智能辅助手术规划系统的应用,肾功能不全患者的EVAR治疗将更加安全、精准。通过多学科团队的协同合作与个体化方案的深入优化,“ACIER”策略有望进一步改善患者预后,推动血管外科在合并复杂基础疾病患者中的技术进步与疗效提升。

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