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成人非心脏胸外科手术围术期区域镇痛技术研究进展

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摘　要

术后疼痛是影响成人非心脏胸外科手术患者康复的重要因素。完善的围术期镇痛不仅可减轻术后疼痛强度、减少阿片类药物用量，还能降低术后肺部并发症发生率并加速患者康复。目前，临床上常用的围术期区域镇痛技术包括胸段硬膜外阻滞(thoracic epidural analgesia, TEA)、胸椎旁神经阻滞(thoracic paravertebral block, TPVB)、竖脊肌平面阻滞(erector spinae plane block, ESPB)、前锯肌平面阻滞(serratus anterior plane block, SAPB)、椎板后阻滞(retrolaminar block, RLB)及肋间神经阻滞(intercostal nerve block, ICNB)。其中，TEA镇痛效果确切，曾被视为胸科手术镇痛的“金标准”，但穿刺操作难度较大、并发症相对较多；TPVB镇痛效果与TEA相当且安全性更高，已成为胸腔镜手术围术期镇痛的一线方案；ESPB与SAPB操作简单、超声下解剖结构易于辨认、安全性良好，临床应用日益广泛；RLB及ICNB实施便捷，可作为辅助或替代镇痛手段。本文围绕上述各类区域镇痛技术的解剖学基础、作用机制及临床研究现状进行综述，以期为临床制定合理、安全的围术期镇痛方案提供参考。

关键词

胸外科手术，围术期镇痛，区域阻滞，胸段硬膜外阻滞，胸椎旁神经阻滞，筋膜平面阻滞，肋间神经阻滞

Advances in Regional Analgesia for Perioperative Adult Non-Cardiac Thoracic Surgery

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Abstract

Postoperative pain is a key factor hindering the rehabilitation of adult patients undergoing non-cardiac thoracic surgery. Optimal perioperative analgesia can not only alleviate postoperative pain intensity and reduce opioid consumption, but also lower the incidence of postoperative pulmonary complications and accelerate patient recovery. Currently, commonly used clinical perioperative regional analgesia techniques include thoracic epidural analgesia (TEA), thoracic paravertebral block (TPVB), erector spinae plane block (ESPB), serratus anterior plane block (SAPB), retrolaminar block (RLB) and intercostal nerve block (ICNB). Among them, TEA delivers definite analgesic efficacy and has been once regarded as the gold standard for thoracic surgical analgesia, yet it features difficult puncture operation and relatively high complication risks. TPVB achieves analgesic effects comparable to TEA with superior safety, and has become the first-line perioperative analgesia strategy for thoracoscopic surgery. ESPB and SAPB are characterized by simple operation, easily identifiable anatomical structures under ultrasound and favorable safety, thus gaining increasingly wide clinical application. RLB and ICNB are convenient to perform and can be used as adjuvant or alternative analgesic methods. This article reviews the anatomical basis, mechanism of action and current clinical research status of the above regional analgesia techniques, aiming to provide references for formulating rational and safe perioperative analgesia regimens in clinical practice.

Keywords

Thoracic Surgery, Perioperative Analgesia, Regional Block, Thoracic Epidural Analgesia, Thoracic Paravertebral Block, Fascial Plane Block, Intercostal Nerve Block

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1. 引言

2020 年，国际疼痛研究协会(International Association for the Study of Pain, IASP)将疼痛重新定义为“与实际或潜在的组织损伤相关的不愉快感觉和情绪情感体验”[1]。胸科手术术后疼痛发生率较高，尽管疼痛本质上是机体对有害刺激的保护性防御反应，但术后疼痛管理不当仍会对生理功能恢复及远期预后产生不良影响。一方面，术后剧烈疼痛可增加肺部并发症及血栓形成风险[2]-[4]；另一方面，急性期疼痛控制不佳亦是慢性术后疼痛发生的主要危险因素之一。因此，优化围术期疼痛管理策略对促进患者快速康复、改善远期预后具有重要临床意义。

传统阿片类药物镇痛虽可在一定程度上缓解术后疼痛，但常伴随恶心、呕吐、头晕及呼吸抑制等不良反应，其广泛应用受到限制[5] [6]。区域镇痛技术通过将局麻药物精准作用于外周神经或筋膜间隙，选择性地阻断痛觉信号的产生与传导，已成为胸外科手术围术期多模式镇痛的核心组成部分，有助于减少阿片类药物用量及其相关不良反应。

目前，成人非心脏胸外科手术中应用较多的区域镇痛技术主要包括 TEA、TPVB、ESPB、SAPB、RLB

及 ICNB。上述技术基于不同的解剖学基础与药物扩散路径，在镇痛范围、操作难度、安全性、适用场景及临床局限性方面各具特点。随着胸腔镜手术的广泛普及以及加速康复外科理念的深入推广，围术期区域镇痛策略正逐步从传统神经轴镇痛向创伤更小、操作更简便、安全性更高的外周神经阻滞和筋膜平面阻滞方向发展。本文拟对上述各类区域镇痛技术的作用机制及研究进展进行综述，以期为临床麻醉医师合理选择镇痛策略、优化围术期疼痛管理提供参考。

2. 胸段硬膜外阻滞

TEA 是成人胸外科围术期镇痛中应用历史最久、范围最广的经典技术。其通过向胸段硬膜外腔注射局麻药物和/或阿片类药物，阻滞相应节段的脊神经根及交感神经，实现覆盖广泛的胸壁及胸膜镇痛。在机制层面，TEA 既可直接阻断痛觉信号向中枢的传导，又能抑制相应节段的交感神经活动，从而改善术后肺功能指标并维持血流动力学稳定性[7]-[9]。

在开胸手术中，TEA 的镇痛优势尤为突出。Acil 等在一项纳入 140 例开胸患者的随机对照研究(randomized controlled trial, RCT)中发现，与 ESPB 相比，经硬膜外腔使用低剂量吗啡的 TEA 组术后各时间点视觉模拟评分(VAS)更低，阿片类药物消耗量显著减少，且肺功能改善更为明显[10]。Babu 等研究亦表明，TEA 可降低开胸术中全身麻醉药物需求，但低血压及尿潴留发生率高于 TPVB，提示临床应用 TEA 时需结合患者血流动力学状态进行审慎选择[7]。一项系统综述指出，TEA 在术后即刻镇痛方面优于 TPVB，尤其是在连续输注联合阿片类药物时优势更为显著；但 TPVB 在血流动力学稳定性方面表现更优，低血压发生率较低[11]。

在胸腔镜手术中，TEA 的应用则更加趋向选择性。Holm 等的一项 RCT 显示，TEA 可降低患者术后不可接受疼痛的发生率并减少阿片类药物使用，但补救性阿片用量的组间差异虽有统计学意义，其临床意义却较为有限[8]。Jiang 等发现，相较于患者自控静脉镇痛，TEA 可降低胸腔镜术后 24 小时急性疼痛发生率及术后 3 个月、6 个月慢性疼痛发生率[9]。Wu 等研究表明，在胸腔镜术后静息和咳嗽疼痛方面，TPVB 可提供与 TEA 相当的镇痛效果，而不良反应发生率更低[12]。一项多中心非劣效研究进一步显示，在胸腔镜解剖性肺切除术中，ICNB 的镇痛效果不劣于 TEA [13]。Broek 等研究发现，连续 ESPB 在胸腔镜术后恢复质量方面亦不劣于 TEA，提示浅层筋膜平面阻滞在部分微创胸科手术中可作为安全、简便的替代方案[14]。荟萃分析亦表明，TEA、TPVB、ESPB 和 ICNB 在胸腔镜手术中均可显著降低术后疼痛评分，但 TEA 并未在所有结局指标上显示出绝对优势[15] [16]。

现有研究关于 TEA 在胸腔镜手术中的价值存在明显分歧，核心原因包括以下几点：1. 研究人群异质性：部分研究纳入高龄、合并心肺基础病高危患者，TEA 血流动力学副作用被放大；而低危患者中组间差异不显著。2. 给药方案不统一：单次推注、持续输注、是否复合阿片药物，直接影响镇痛强度与不良反应发生率。3. 手术创伤差异：多孔胸腔镜、单孔胸腔镜、复杂肺段切除创伤梯度不同，对 TEA 依赖度不一致。4. 加速康复外科方案混杂因素：多模式镇痛背景下，非甾体药物、辅助镇静等干预会弱化 TEA 组间效应。

综合而言，TEA 仍是开胸手术及高疼痛风险胸科患者的重要镇痛方式，其优势在于镇痛效果确切、覆盖范围广泛。然而，临床应用需权衡低血压、尿潴留、瘙痒、运动阻滞、硬膜外血肿及感染等风险，同时考虑凝血功能异常、穿刺部位感染及心血管功能状态等禁忌证。在微创胸科手术及加速康复外科背景下，TEA 的应用应更加具有选择性，并与其他镇痛技术结合患者个体情况进行综合权衡。

3. 胸椎旁神经阻滞

TPVB 是成人胸外科围术期常用的单侧区域镇痛技术，其通过在椎旁间隙注射局麻药物，阻滞相应

节段的脊神经根及交感神经，实现胸壁单侧镇痛。与 TEA 相比，TPVB 的镇痛范围略为局限，但因不产生双侧交感神经阻滞，其血流动力学稳定性更优，低血压及尿潴留发生率明显低于 TEA [12] [13]。

在一项针对我国患者的研究中，TPVB 在老年与非老年患者中的镇痛效果无显著差异，证实了其在老年人群中应用的安全性[17]。阻滞节段数和注射节段直接影响镇痛效果，多节段注射可扩大覆盖范围并降低术后疼痛评分[7] [11]。鉴于单次 TPVB 的镇痛时效有限，可通过留置导管进行连续输注以实现长效镇痛。Thanh Trung 等比较了连续 TPVB 与连续 TEA 在肺手术患者中的镇痛效果，结果显示二者镇痛作用相当，但连续 TPVB 组循环系统和呼吸系统不良反应发生率低于连续 TEA 组，提示连续 TPVB 可在保证镇痛效果的同时改善血流动力学和呼吸安全性[18]。Yang 等进一步探讨了连续 TPVB 的给药模式，发现程序化间断推注联合连续输注较两种模式单独使用镇痛效果更佳，可通过优化给药模式进一步提升术后疼痛管理满意度[19]。此外，延长 TPVB 时效还可借助新型长效局麻药物(如布比卡因脂质体)或在局麻药物中加入佐剂(如地塞米松)来实现[20] [21]。除镇痛作用外，TPVB 还可改善术后胃肠功能和整体恢复质量[22]。

在操作层面，TPVB 存在气胸和局麻药物误入血管等潜在风险。随着超声可视化技术的广泛应用，TPVB 已不再依赖盲探操作，其穿刺精准性和安全性均得到显著提升。尽管 TPVB 操作难度较 TEA 小，仍需注意患者个体解剖差异及术前状况对阻滞效果的影响。例如，术前存在胸腔积液的患者在超声或压力引导下进行 TPVB 时，阻滞成功率下降，导管置入难度增加[23]，这为操作更为简便的筋膜平面阻滞提供了发展空间。

目前关于 TPVB 与其他区域镇痛技术的优劣结论不一，可以从以下几点进行考虑：局麻药容量、浓度、节段选择不统一，直接影响扩散范围与阻滞平面；部分研究为单次阻滞，部分为连续置管，结局无可比性；肥胖、脊柱侧弯、胸腔积液等解剖变异人群，TPVB 成功率个体差异大；结局指标侧重不同(疼痛评分、阿片类药物消耗、慢性疼痛)，易出现结论分歧。

总体而言，TPVB 是胸外科围术期安全、有效的单侧区域镇痛技术，具有血流动力学稳定、术后镇痛明确等优势。其局限性包括覆盖范围有限、多节段阻滞可能增加局麻药全身吸收风险，以及需要经验丰富或超声引导下操作。TPVB 可作为 TEA 的选择性替代方案，尤其适用于微创手术、血流动力学不稳定或存在 TEA 禁忌证的患者，在多模式镇痛体系中发挥着重要作用。

4. 竖脊肌平面阻滞

ESPB 是近年来快速发展的新兴筋膜间隙阻滞技术，操作简便、安全性高，已广泛应用于胸科手术围术期镇痛。其操作原理为将局麻药注射至竖脊肌深面与胸椎横突之间的筋膜间隙，药物可沿筋膜间隙向头尾端扩散，间接作用于脊神经后支、前支及交通支，实现胸壁多节段镇痛。

尽管 ESPB 已在胸科手术中显示出良好的镇痛效果，但在与 TEA 及 TPVB 对比时，既往研究结果存在一定分歧。部分研究显示，ESPB 镇痛效果弱于 TEA 和 TPVB，对剧烈疼痛的控制能力相对有限[10] [24]-[27]。然而，另一项关于单孔胸腔镜手术的研究指出，ESPB 可提供不劣于 TPVB 的镇痛效果[28]。在连续阻滞模式下，ESPB 显示出一定优势：一项针对老年患者胸腔镜肺叶切除的研究表明，连续 ESPB 和连续 TPVB 均可有效缓解术后疼痛，且 ESPB 组置管时间更短、并发症更少、术后恢复更快[29]。对输注模式的进一步探索发现，程序化间断推注与连续输注在镇痛效果和术后恢复质量方面并无差异，提示输注模式对 ESPB 效果的影响可能弱于局麻药物的容量和剂量[28]。目前，关于 ESPB 的最佳给药剂量、浓度及输注方式仍需大样本临床研究进一步明确。

既往研究结果出现分歧可能与以下原因有关，ESPB 为间接扩散阻滞，药液弥散受筋膜疏密、体型、体位影响较大；不同研究给药容量差异大，阻滞节段覆盖不全易导致镇痛偏弱。

综合来看，ESPB 是胸科手术安全、可行且有效的区域阻滞方式，适合单侧胸壁镇痛。其操作简便、并发症少、血流动力学影响小，可置管实现连续输注从而延长镇痛持续时间并提升镇痛质量，为胸科手术患者提供可靠的围术期镇痛和早期康复支持。

5. 前锯肌平面阻滞

SAPB 是一种胸壁外侧区域阻滞技术，药物可注射于前锯肌浅面或深面，通过阻滞肋间神经外侧皮支和胸长神经，实现胸壁前外侧区域的镇痛。SAPB 一般于腋中线处实施，分为浅层 SAPB (药物注射于背阔肌与前锯肌之间的筋膜层)和深层 SAPB (药物注射于前锯肌与肋骨或肋间外肌之间)。该技术超声下解剖结构易于辨认，且注射部位远离重要器官和大血管，安全性较高。

一项较早的荟萃分析显示，全身麻醉联合 SAPB 较单纯全身麻醉可显著减轻胸腔镜患者术后疼痛、减少阿片类药物用量，且不增加低血压风险，证实了 SAPB 的镇痛有效性[30]。Abd Ellatif 等对传统 SAPB 进行了改良，将超声探头置于更靠近腋后线的位置以额外阻滞胸背神经，可延长镇痛时间[31]。多项研究指出，无论在开胸手术还是胸腔镜手术中，SAPB 的镇痛效果均弱于 ESPB [32]-[34]。然而，Zengin 等发现，深层 SAPB 联合浅层 SAPB 可提供与 ESPB 相当的镇痛效果，且未延长操作时间，提示多点 SAPB 可有效替代 ESPB [35]。

总体而言，SAPB 操作简便、并发症少，是胸科手术围术期疼痛管理的有效选择，并可通过连续输注和多部位注射进一步提升镇痛效果。

6. 椎板后阻滞

RLB 通过向椎板浅层注射局麻药物，实现对相邻脊神经前后支以及交感神经支的阻滞。RLB 的具体镇痛机制尚不完全清楚，推测局麻药物可能通过上肋横韧带扩散至椎旁间隙而发挥作用。与 TPVB 直接将药物注入胸椎旁间隙相比，从机制上推测 TPVB 可能带来更优的镇痛效果。此外，RLB 因在解剖学上避开了胸膜和血管结构且穿刺位置较为表浅，操作简便、安全性较高。

目前，RLB 应用于胸科手术的研究仍相对有限。在微创胸腔镜手术中，Nobukuni 等的回顾性研究显示连续 RLB 的镇痛效果与 TEA 相当[36]。然而，Sugiyama 等在一项随机非劣效对照研究中发现，在胸腔镜手术和限制性开胸手术中，RLB 的镇痛效果弱于 TPVB，但因两种区域阻滞使用的局麻药物浓度不同，该结论的外推性受到一定限制[37]。在限定手术类型为单孔胸腔镜手术并统一局麻药物浓度的前提下，Wang 等发现 TPVB 降低术后动态和静息疼痛的程度均大于 RLB [38]。而相同手术类型下，Zhu 等的后续研究则发现 RLB 可提供不劣于 TPVB 的镇痛效果[28]。上述两项研究结果之间存在一定矛盾，由于研究设计并非完全相同，尚不能进行完全同质化比较。此外，RLB 药物扩散路径尚未完全明确，个体筋膜差异极大。

总体而言，RLB 的临床应用仍较为有限，存在诸多亟待解决的问题：局麻药扩散规律及最佳给药剂量与浓度尚未明确，镇痛效果存在个体差异；其在胸科手术中的镇痛效能仍需更多大样本、高质量临床研究加以验证。

7. 肋间神经阻滞

ICNB 通过对切口相关肋间神经进行单点或多点阻滞，直接阻断肋间神经的痛觉信号传导，可快速缓解疼痛。该操作较 TEA 和 TPVB 更为简单、快速，不良反应发生率低，适用范围更广。

ICNB 可由麻醉医生在超声引导下实施，亦可由外科医生在胸腔镜直视下完成。Li 等的研究表明两种方式镇痛效果相当，且胸腔镜直视下行 ICNB 更为简便、成功率更高[39]。一项荟萃分析结果显示，

ICNB 在胸科手术中可提供不劣于 TEA 和 TPVB 的镇痛效果[40]。然而，后续 RCT 提出 TPVB 的镇痛效果优于 ICNB [41] [42]。上述矛盾结果的出现可能与以下因素有关：TPVB 可实现多节段阻滞，而 ICNB 单点操作仅能阻滞单个节段，因此需通过多点阻滞实现更为充分的镇痛覆盖。在与 ESPB 对比的研究中，ICNB 在镇痛效果和镇痛持续时间方面均优于 ESPB [43]-[45]，而与 SAPB 的镇痛效果相当[46]。

总之，ICNB 镇痛作用时间短、阻滞范围局限，需对多个肋间神经进行多点注射。在 TEA 和 TPVB 存在使用禁忌时，ICNB 可作为有效的替代方案。

8. 小结与展望

成人非心脏胸外科手术围术期区域镇痛技术已形成以 TEA 和 TPVB 为核心，ESPB、SAPB、RLB 及 ICNB 等多种技术为补充的体系。各类区域阻滞技术的镇痛效果不仅受其自身作用机制影响，还受手术类型、局麻药物的种类、浓度、容量及联合佐剂的使用、给药方式(单次注射或连续输注)、患者个体差异以及操作者经验等多重因素的综合调控。

从临床选择角度看，TEA 因其镇痛效果确切、覆盖范围广泛，仍是开胸手术及高疼痛风险患者的首选方案，但需关注其血流动力学影响及操作相关风险。TPVB 凭借与 TEA 相当的镇痛效能和更优的安全性，已成为胸腔镜手术围术期镇痛的一线选择。ESPB 和 SAPB 作为新兴的筋膜平面阻滞技术，以操作简便、安全性高为主要优势，特别适用于微创胸科手术或存在神经轴阻滞禁忌的患者。RLB 和 ICNB 操作便捷、安全性良好，可作为辅助或替代镇痛手段应用于特定临床场景。

值得注意的是，不同区域阻滞技术并非相互排斥，联合应用可实现优势互补、进一步优化镇痛效果。例如，在临床实践中可将 ESPB 或 SAPB 与 ICNB 联合使用，以弥补单一技术覆盖范围的不足。

未来研究方向应聚焦于以下几个方面：一是开展更多高质量、大样本、多中心的头对头 RCT，为不同技术的镇痛效能比较提供更可靠的循证依据；二是探索各技术的最佳给药方案(包括局麻药物种类、浓度、容量及佐剂的优化组合)；三是建立基于患者个体特征(年龄、合并症、手术方式、疼痛风险评估等)的精准镇痛决策体系；四是借助人工智能和影像学技术进一步提升阻滞操作的精准性和安全性以及明确新兴筋膜阻滞的药物扩散规律。

综上所述，在临床实践中，麻醉医师应充分权衡各类区域阻滞技术的风险与获益，结合患者个体情况和手术需求，制定个体化、多模式的围术期镇痛方案，以最大程度减轻术后疼痛、减少阿片类药物暴露、降低并发症发生率并加速患者康复。

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