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Advance in ultrasound-guided adductor canal block with different approaches for postoperative analgesia in total knee arthroplasty

LIU Qian*, YANG Changming

**Department of Anesthesiology, Joint Postgraduate Training Base of Wuhan University of Science and Technology, Jingmen Central Hospital, Jingmen, Hubei 438000, China*

Corresponding author: YANG Changming, E-mail: hbjmyangcm@163.com

Abstract: Pain management after total knee arthroplasty (TKA) is pivotal for optimizing patient recovery. Approximately 80% of patients experience moderate-to-severe acute postoperative pain, with 30% progressing to chronic pain. While the traditional femoral nerve block provides effective analgesia, it compromises quadriceps muscle strength, thereby impeding early rehabilitation. The adductor canal block (ACB), an emerging regional analgesic technique, can offer favorable pain relief while preserving motor function, though debate persists regarding its optimal approach. This review evaluates the safety and efficacy of distinct ACB approaches, focusing on their impacts on postoperative pain control and early functional recovery, aims to provide evidence- based guidance for clinical decision-making in TKA pain management.

Keywords: Total knee arthroplasty; Ultrasound-guidance; Adductor canal block; Pain management; Motor function; Approach; Enhanced recovery after surgery

With the aging of the population and the rising prevalence of obesity, the incidence of knee osteoarthritis has increased year by year. Total knee arthroplasty (TKA) has become an important surgical approach to improve the quality of life of patients [1]. However, intraoperative stimulation of the joint capsule, synovial tissue, and free nerve endings in the infrapatellar fat pad during TKA [2] can lead to severe postoperative pain within 24–48 hours. An ideal analgesic regimen should provide adequate pain relief while preserving muscle function. Currently, multimodal analgesia has become the mainstream strategy for postoperative analgesia after TKA, among which ultrasound-guided regional block is widely adopted due to its accuracy and safety. Although femoral nerve block (FNB) was once the gold standard for postoperative analgesia after TKA, its adverse effect on quadriceps muscle strength limits the early rehabilitation of patients [2-3]. Adductor canal block (ACB) selectively blocks the saphenous nerve [4-5] and reduces motor nerve block [6], thus emerging as an alternative to FNB. However, the optimal approach for ACB (proximal, mid, or distal) remains controversial. Based on recent studies, this article discusses the anatomical basis, operative techniques, and clinical efficacy of ACB with different approaches, aiming to provide evidence for optimizing postoperative analgesia after TKA.

1 Anatomical Characteristics of the Adductor Canal

1.1 Macroanatomical Structure of the Adductor Canal

The adductor canal, also known as the subsartorial canal or Hunter's canal, is a conical aponeurotic tunnel [7-8]. It traverses the distal third of the medial thigh and serves as a pathway for neurovascular structures from the femoral triangle to the adductor hiatus [9]. Its length ranges from 8.5 to 11.5 cm (longer in males and shorter in females [10]). The anterior wall consists of the vastus medialis and sartorius muscles; the posterior wall is formed by the adductor longus and adductor magnus muscles; and the medial wall is the gracilis muscle. The adductor canal contains the femoral artery, femoral vein, and saphenous nerve, all of which are enveloped by the dense vastoadductor membrane (VAM).

1.2 Regional Boundaries of the Adductor Canal

The proximal boundary of the adductor canal is marked by the junction of the medial margins of the sartorius and adductor longus muscles. Anatomical studies have confirmed that the roof of the adductor canal is formed by the VAM, which is covered superficially by the sartorius muscle [11]. This unique anatomical structure provides a clear imaging landmark for ultrasound-guided proximal localization. When performing the block at this level, local anesthetics can simultaneously infiltrate the saphenous nerve, posteromedial branch of the femoral medial nerve, medial superior genicular nerve, and genicular branch of the obturator nerve [12].

The distal end of the adductor canal terminates at the adductor hiatus (also called Hunter's hiatus), a fibro-osseous canal formed by the gap between the two tendinous bundles of the adductor magnus muscle inserting into the lower medial lip of the linea aspera and the adductor tubercle, together with the femur [13]. Notably, the femoral artery continues as the popliteal artery through this hiatus, and this vascular landmark is of great value in ultrasound localization. When a distal approach is selected for the block, local anesthetics can spread distally through the adductor canal to the popliteal fossa via the adductor hiatus, blocking the popliteal plexus and the genicular branches of the posterior obturator nerve [14].

2 Technical Features and Clinical Application of Ultrasound-Guided ACB with Different Approaches

2.1 Technical Advantages of Ultrasound Guidance

Before ultrasound technology was widely applied in nerve blocks, classic ACB was mainly performed using anatomical landmark localization, with the puncture point usually selected at the mid-thigh [7]. However, this blind puncture technique has obvious drawbacks: the proximal approach at this puncture point is still within the femoral triangle region, which not only blocks the sensory saphenous nerve but also the motor branches of the femoral nerve, impairing quadriceps muscle strength. Moreover, nerve block performed based on anatomical landmark localization may cause nerve injury, leading to postoperative paresthesia in the innervated area. The popularization of ultrasound in regional blocks can shorten the operation time of ACB, improve its accuracy and safety, and visualized puncture can significantly reduce neurological sequelae after the block [15].

2.2 Technical Key Points of Different Approaches

2.2.1 Proximal Approach Technique

For ultrasound-guided proximal ACB, the ultrasound probe is placed transversely on the medial mid-thigh, perpendicular to the femur. The probe is slid and its angle and position are adjusted to obtain clear sonographic images of the adductor longus or adductor magnus muscle, vastus medialis muscle, and sartorius muscle. The saphenous nerve, which appears as a fusiform or elliptical hyperechoic structure, is identified at the junction of the medial margins of the sartorius and adductor longus muscles. The optimal site for ACB is at approximately the middle-lower 1/3 of the sartorius muscle [8]. The in-plane puncture technique is adopted during the operation, with the needle inserted from lateral to medial. The needle tip must penetrate the VAM to ensure the blocking effect while avoiding nerve injury [16].

This approach mainly covers the sensory nerve innervation area in the anterior aspect of the knee joint, but its analgesic effect on the posterior aspect is limited. Therefore, clinical practice routinely requires combined infiltration of local anesthetic between the popliteal artery and capsule of the knee (IPACK) block or local infiltration anesthesia to achieve comprehensive analgesia [17-18]. Pharmacological studies have shown that the median effective volume of 0.5% ropivacaine is 10.8 mL [2, 19]. However, when the volume exceeds 20 mL, local anesthetics may spread proximally to the femoral triangle region, resulting in accidental femoral nerve block in approximately 15%–25% of cases, thereby affecting quadriceps muscle function [2, 4, 20]. Based on existing evidence, it is recommended that proximal ACB adopt a regimen of 10–15 mL of 0.5% ropivacaine combined with IPACK block, which can ensure analgesic efficacy while maximizing the preservation of motor function, conforming to the requirements of enhanced recovery after surgery (ERAS).

2.2.2 Distal Approach Technique

For ultrasound-guided distal ACB, the ultrasound probe is placed on the anteromedial aspect of the distal thigh, approximately 6 cm proximal to the base of the patella. The probe is moved along the course of the femoral artery to the distal adductor canal, and after clearly visualizing the neurovascular structures between the vastus medialis and adductor magnus muscles, the in-plane technique is used to insert the needle from lateral to medial, with the needle tip finally positioned medial to the femoral artery. Studies by Tulgar [21] and Morozumi et al. [22] have confirmed that this approach has three major advantages: (1) single-point puncture can simultaneously block the saphenous nerve and popliteal plexus; (2) the operation can be completed with the patient in the supine position; (3) the injection site maintains a safe distance from the nerve, which can significantly reduce the risk of nerve injury. Anatomical studies using methylene blue staining have verified that the injected solution during distal ACB can spread along the perivascular space through the adductor hiatus to the popliteal fossa, while blocking the genicular branches of the posterior obturator nerve [23]. This technique can effectively cover the posterior pain area of the knee joint and avoid blocking the femoral medial nerve, with the quadriceps muscle strength preservation rate reaching 85%. However, its limitations include insufficient analgesic effect on the anterior aspect of the knee joint and the medial thigh. Moreover, excessive local anesthetic volume may block the branches of the sciatic nerve, leading to ankle weakness in 15%–20% of patients and affecting early ambulation [9]. In clinical practice, it is recommended to use a low volume (15–20 mL) of local anesthetics combined with local incision infiltration, which can not only achieve comprehensive analgesic coverage but also minimize the impact on motor function.

2.2.3 Mid-Approach Technique

The proximal and distal puncture points are identified under ultrasound (as described above) and marked on the body surface; the midpoint between them is the mid-approach for ACB. The midpoint can also be localized according to the positional relationship between the sartorius muscle and the femoral artery [24]. This method is simple and convenient, but inaccurate localization may occur due to probe movement and changes in the patient's posture. Burckett-St Laurant *et al.* [9] suggested that the middle part of the adductor canal is the optimal site for local anesthetic administration. Existing evidence shows that mid-injection allows the drug to spread proximally to block the saphenous nerve and femoral medial nerve, while controlling the drug dose spreading distally to avoid excessive infiltration of the popliteal fossa. A study by Cheng Yanqiang *et al.* [25] demonstrated that 20 mL of local anesthetics can ensure analgesic efficacy while minimizing the impact on quadriceps muscle strength. This volume not only avoids the proximal spread to the femoral triangle that may be caused by the proximal approach but also prevents the ankle motor dysfunction induced by high-volume injection in the distal approach. It is worth noting that although combined proximal-distal block achieves more significant analgesic effects, it requires double punctures and complex operations, whereas the mid-approach can achieve similar effects with a single puncture assisted by ultrasound visualization. In clinical practice, combining preoperative regional block with adjuvant drugs such as dexamethasone can further optimize the analgesic regimen, reduce postoperative opioid consumption by 30%–40% [26-28], and maintain intraoperative hemodynamic stability. However, high-quality clinical studies on mid-approach ACB are still scarce, especially the lack of direct comparative data between mid-approach ACB and FNB in terms of opioid-sparing effect, which requires more large-sample studies for verification.

3 Comparison of Clinical Efficacy of ACB with Different Approaches

Existing studies still have certain controversies regarding the analgesic efficacy of ACB with different approaches. Recent meta-analyses have shown that proximal and distal ACB have comparable effects in controlling resting pain at 2 hours after TKA, but there is no significant difference in the overall analgesic efficacy within 24 hours. Notably, proximal ACB showed slightly better performance in the Timed Up and Go test, but this difference did not reach clinical significance [29-31]. However, studies by Qian Yuying [32] and Huang Hongming *et al.* [33] drew different conclusions, indicating that distal ACB can more significantly reduce sufentanil consumption at 24 hours after surgery and improve knee joint range of motion. This discrepancy may be related to factors such as study design and patient selection. In broader surgical comparisons, research results are also inconsistent: a study published in Anesthesiology in 2019 showed that after anterior cruciate ligament repair, opioid consumption exhibited a trend of proximal < mid < distal, with mid-approach ACB having the minimal impact on quadriceps muscle strength [24]; whereas a study by Huang Xin et al. [34] concluded that distal ACB is superior. For knee arthroscopy, multiple studies have consistently shown that proximal ACB achieves the best analgesic effect [35-36]. For TKA, some studies have also found that in terms of postoperative analgesic efficacy of ACB, the proximal approach is superior to the mid-approach, but mid-approach ACB has a smaller impact on quadriceps muscle strength [37]. Currently, high-quality evidence comparing the three approaches after TKA is still limited, with only a single-center study conducted by Liu *et al.* [38]. Future research urgently needs to carry out large-sample, multi-center studies to further verify the clinical value of each approach, especially the accurate localization method and long-term efficacy evaluation of mid-approach ACB.

4 Summary and Prospect

Existing clinical evidence indicates that compared with traditional analgesic methods, ACB exhibits significant advantages in preserving quadriceps muscle strength, helping patients achieve early postoperative ambulation, and providing important support for the implementation of the ERAS concept. However, there are still many controversies regarding the selection of the optimal approach for ACB. Continuous proximal approach can provide sustained analgesic effects but carries the risks of catheter-related complications and accidental femoral nerve block [39]; distal approach is easy to operate but has incomplete analgesic coverage and may affect dorsum of foot function; mid-approach can theoretically balance the advantages of proximal and distal approaches, but it currently lacks support from large-sample clinical studies. In terms of drug selection, the regimen of 20 mL of 0.25%–0.375% ropivacaine combined with dexamethasone or dexmedetomidine has been proven to prolong the block duration and reduce opioid consumption [40-41], but the optimal compatibility scheme still needs further exploration.

Future research should focus on addressing several key issues: first, large-sample, multi-center randomized controlled trials are needed to clarify the clinical value of mid-approach ACB, especially its comparison with the gold standard FNB in terms of opioid-sparing effect and functional recovery; second, more accurate localization techniques need to be developed to improve the operational efficiency of the mid-approach; finally, personalized analgesic regimens based on individual patient characteristics should be explored. In addition, the hypothesis that "mid-approach ACB = proximal + distal" also requires more evidence-based medical evidence to support. With the continuous development of ultrasound technology and adjuvant drugs, ACB is expected to become the core technology for postoperative analgesia after TKA, but more high-quality studies are needed to establish standardized clinical application guidelines.

Conflict of Interest The authors declare that this review did not receive any funding from third parties, and that there are no financial, academic, or personal conflicts of interest between the authors and the researchers, funders, and related enterprises of the reviewed literatures.

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·研究进展·

超声引导下不同入路收肌管阻滞在全膝关节置换术后镇痛中的研究进展

刘倩[1,2]，　杨昌明[1]

1. 武汉科技大学荆门市中心医院研究生联合培养基地　荆门市中心医院麻醉科，湖北 荆门 438000；
2. 武汉科技大学医学部医学院，湖北 武汉 430065

摘要： 全膝关节置换术（TKA）后疼痛管理是影响患者康复质量的关键因素。约80%的患者术后会经历中重度急性疼痛，其中30%可能发展为慢性疼痛。传统股神经阻滞虽能有效镇痛，但会导致股四头肌肌力减弱，影响早期康复。收肌管阻滞（ACB）作为新兴的区域阻滞技术，在保留运动功能的同时可提供良好的镇痛作用，但其最佳入路选择仍存在争议。本文综述了近年来超声引导下ACB不同入路的安全性及有效性，比较其对TKA术后疼痛控制和早期运动功能的影响，旨在为临床实践提供参考。

关键词： 全膝关节置换术；超声引导；收肌管阻滞；疼痛管理；运动功能；入路；加速术后康复

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Advance in ultrasound-guided adductor canal block with different approaches for postoperative analgesia in total knee arthroplasty

LIU Qian*，YANG Changming

*Department of Anesthesiology，Joint Postgraduate Training Base of Wuhan University of Science and Technology，Jingmen Central Hospital，Jingmen，Hubei 438000，China

Corresponding author：YANG Changming，E-mail：hbjmyangcm@163.com

Abstract：Pain management after total knee arthroplasty (TKA) is pivotal for optimizing patient recovery. Approximately 80% of patients experience moderate-to-severe acute postoperative pain，with 30% progressing to chronic pain. While the traditional femoral nerve block provides effective analgesia，it compromises quadriceps muscle strength，thereby impeding early rehabilitation. The adductor canal block (ACB)，an emerging regional analgesic technique，can offer favorable pain relief while preserving motor function，though debate persists regarding its optimal approach. This review evaluates the safety and efficacy of distinct ACB approaches，focusing on their impacts on postoperative pain control and early functional recovery，aims to provide evidence-based guidance for clinical decision-making in TKA pain management.

Keywords：Total knee arthroplasty；Ultrasound-guidance；Adductor canal block；Pain management；Motor function；Approach；Enhanced recovery after surgery

随着人口老龄化和肥胖率上升，骨性膝关节炎的患病率逐年增加，全膝关节置换术（total knee arthroplasty，TKA）已成为改善患者生活质量的重要手术方式[1]。然而，TKA术中对关节囊、滑膜组织及前脂肪垫游离神经末梢的刺激[2]，会导致术后24~48 h患者疼痛剧烈。理想的镇痛方案需在提供充分镇痛的同时保留肌肉功能。目前，多模式镇痛已成为TKA术后镇痛的主流策略，其中超声引导下的区域阻滞因其精准性和安全性被广泛采用。尽管股神经阻滞（femoral nerve block，FNB）曾是TKA术后镇痛的金标准，但其对股四头肌肌力的影响限制了患者早期康复[2-3]。收肌管阻滞（adductor canal block，ACB）通过选择性阻滞隐神经[4-5]，减少运动神经阻滞[6]，成为FNB的替代方案。然而，ACB的最佳入路（近端、中段或远端）仍存在争议。本文结合近年研究，探讨不同入路ACB的解剖基础、操作技术及临床效

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通信作者： 杨昌明，E-mail：hbjmyangcm@163.com

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果,以期为优化TKA术后镇痛提供依据。

1 收肌管的解剖学特征

1.1 *收肌管的宏观解剖结构* 收肌管又称缝下管或Hunter管,是一条圆锥形的肌腱膜隧道[7-8],穿过大腿中三分之一的远端,该区域是从股骨三角到内收裂孔的一些神经血管的结构通路[9],长度为8.5~11.5 cm(男性较长,女性较短[10])。其前壁为股内侧肌与缝匠肌,后壁为长收肌和大收肌,内侧壁为股薄肌。收肌管内有股动脉、股静脉及隐神经通过,这些结构被致密的股收肌筋膜(vasto-adductor membrane, VAM)包裹。

1.2 *收肌管的区域边界* 收肌管的近端边界以缝匠肌与长收肌内侧缘的交汇处为标志。解剖学研究证实,收肌管顶部由VAM构成,该筋膜浅层被缝匠肌覆盖[11]。这一独特的解剖结构为超声引导下近端定位提供了明确的影像学标志。在此平面实施阻滞时,局部麻醉药物可以同时浸润隐神经、股内侧神经后内侧支、膝上内侧神经和闭孔神经膝支[12]。

收肌管的远端终止于内收肌裂孔(又称Hunter裂孔),该结构由大收肌抵于粗线内侧唇下部、收肌结节的两个腱束间的裂隙和股骨共同形成,上述结构共同围合成一个纤维骨性通道[13]。值得注意的是,股动脉经此裂孔延续为腘动脉,这一血管标志在超声定位中具有重要价值。当选择远端入路阻滞时,局部麻醉药除作用于隐神经外,还可通过收肌管向远端蔓延,经内收肌裂孔进入腘窝,阻滞腘神经丛及闭孔神经后支的膝关节分支[14]。

2 超声引导下不同入路ACB的技术特点与临床应用

2.1 *超声引导的技术优势* 在超声技术尚未广泛应用于神经阻滞前,经典ACB主要依靠解剖标志定位,穿刺点通常选择大腿中部[7]。然而,这种盲穿技术存在明显缺陷,该穿刺点的近端入路仍处于股三角区域,不仅会阻滞感觉神经隐神经,还会阻滞到股神经运动分支,影响股四头肌肌力。且靠解剖结构定位进行神经阻滞,可能会损伤神经,引起术后损伤神经区域感觉异常。超声在区域阻滞的普及,可以缩短ACB的操作时间,提高ACB的准确性及安全性,而且可视化的穿刺可大大减少阻滞后的神经系统后遗症[15]。

2.2 *不同入路的技术要点*

2.2.1 近端入路技术 超声引导下远端ACB的操作需将探头横置于大腿中段内侧,垂直于股骨,滑动探头,调整其角度和位置,以获得长收肌或大收肌、股内侧肌和缝匠肌的清晰声像。在缝匠肌内侧缘与长收肌内侧缘相交的位置寻找呈梭形或椭圆形高回声结构的隐神经,ACB的最佳位点为缝匠肌约中下1/3处[8]。操作时采用平面内穿刺技术,由外侧向内侧进针,针尖需穿透VAM以确保阻滞效果,同时避免神经损伤[16]。该入路主要覆盖膝关节前方感觉神经支配区域,但对后方镇痛效果有限,因此临床常规需联合腘动脉与膝关节囊间隙局部麻醉药浸润阻滞(infiltration of local anesthetic between the popliteal artery and capsule of the knee, IPACK)阻滞或局部浸润麻醉以完善镇痛[17-18]。药理学研究表明,0.5%罗哌卡因的中位有效容量为10.8 mL[2,19],但当容量超过20 mL时,局部麻醉药可能向近端扩散至股三角区域,导致约15%~25%的病例出现股神经意外阻滞,进而影响股四头肌功能[2,4,20]。基于现有证据,推荐近端ACB采用10~15 mL 0.5%罗哌卡因联合IPACK阻滞的方案,可在保证镇痛效果的同时,最大限度保留运动功能,符合加速术后康复(enhanced recovery after surgery, ERAS)的要求。

2.2.2 远端入路技术 超声引导下远端ACB的操作需将探头置于大腿远端前内侧,约距髌骨基底近端6 cm处,沿股动脉走行追踪至收肌管远端,清晰显示股内侧肌与大收肌之间的神经血管结构后,采用平面内技术由外向内进针,最终将针尖定位于股动脉内侧。Tulgar[21]、Morozumi等[22]研究证实该入路具有三大优势:(1)单点穿刺即可同时阻滞隐神经和腘丛神经;(2)患者仰卧位即可完成操作;(3)注射部位与神经保持安全距离,可显著降低神经损伤风险。解剖学研究通过亚甲蓝染色证实,远端ACB注射的药液可沿血管周隙经内收股孔扩散至腘窝,同时阻滞闭孔神经后支的膝关节分支[23]。该技术能有效覆盖膝关节后方疼痛区域,且避免了股内侧神经阻滞,使股四头肌肌力保留率达85%。然而其局限性在于对膝关节前方及大腿内侧的镇痛效果欠佳,且当局麻药容量过大时可能阻滞坐骨神经分支,导致15%~20%的患者出现足踝无力,影响早期下床活动[9]。临床实践中推荐采用低容量(15~20 mL)局部麻醉药联合切口局部浸润,既可完善镇痛覆盖,又能最大限度减少运动功能影响。

2.2.3 中段入路技术 在超声下寻找到近端、远端的穿刺点(如上述),在体表做好标记,两者之间的中点即为ACB中段入路。还可以根据缝匠肌和股动脉的位置关系定位中段[24],该方法简单便捷,但是会因探头移动、患者体态发生位置改变引起定位不准。Burckett-St Laurant等[9]建议将内收肌管的中部作为局部麻醉给药的最佳部位。现有证据显示,中段注射可使药物向近端扩散阻滞隐神经和股内侧神经,同时控制向远端扩散的药量以避免过度浸润腘窝。程言强等[25]研究表明,20 mL局部麻醉药能在保证镇痛效果的同时最小化对股四头肌肌力的影响,这一容量既避免了近端入路可能导致的股三角扩散,又预防了远端入路大容量注射引发的足踝运动障碍。值得注意的是,虽然近远端联合阻滞的镇痛效果更显著,但其需要双重穿刺且操作复杂,而中段入路在超声可视化辅助下单次穿刺即可达到相近效果。临床实践中,结合术前区域阻滞和地塞米松等辅助用药,可进一步优化镇痛方案,减少术后阿片类药物用量的30%~40%[26-28],同时维持术中血流动力学稳定。不过,目前关于中段ACB的高质量临床研究仍较匮乏,特别是其与FNB在阿片类药物节约效应方面的直接比较数据不足,需要更多大样本研究加以验证。

3 不同入路ACB的临床效果比较

现有研究对ACB不同入路的镇痛效果仍存在一定争议。近年的荟萃分析显示,近端与远端ACB在TKA术后2 h静息痛控制方面效果相当,但24 h内的总体镇痛效果差异无

统计学意义。值得注意的是，近端ACB在计时起立行走测试中表现略优，但该差异未达临床显著性水平[29-31]。然而，钱玉莹[32]、黄鸿明等[33]研究得出了不同结论，其研究表明远端ACB能更显著地减少术后24 h舒芬太尼用量，同时改善膝关节活动度。这种差异可能与研究设计和患者选择等因素有关。在更广泛的术式比较中，研究结果同样存在分歧：一项2019年发表于*Anesthesiology*的研究显示前交叉韧带修复术后阿片类药物消耗量呈现近端<中段<远端的趋势，其中中段ACB对股四头肌肌力影响最小[24]；而黄鑫[34]等的研究则得出远端ACB更优的结论。对于膝关节镜手术，多项研究一致表明近端ACB镇痛效果最佳[35-36]，对于TKA，有研究也发现ACB对患者术后镇痛效果，近端入路优于中段入路，但中段ACB对股四头肌肌力影响更小[37]。目前关于TKA术后三种入路比较的高质量证据仍较有限，仅刘阳等[38]进行了单中心研究，未来亟需开展大样本多中心研究进一步验证各入路的临床价值，特别是中段ACB的准确定位方法和长期疗效评估。

4　小结与展望

现有临床证据表明，与传统镇痛方法相比，ACB在保留股四头肌肌力方面展现出显著优势，能帮助患者实现术后早期活动，为ERAS理念的实施提供了重要支持。然而，关于ACB最佳入路的选择仍存在诸多争议。连续近端入路虽能提供持续镇痛效果，但存在导管相关并发症和股神经意外阻滞的风险[39]；远端入路操作简便但镇痛覆盖不全，且可能影响足背功能；中段入路理论上可平衡近远端优势，但目前尚缺乏大样本临床研究支持。在药物选择方面，0.25%~0.375%罗哌卡因20 mL复合地塞米松或右美托咪定的方案已被证实可延长阻滞时间并减少阿片类药物用量[40-41]，但最佳配伍方案仍需进一步探索。

未来研究应着重解决几个关键问题：首先需要通过多中心大样本随机对照试验明确中段ACB的临床价值，特别是其与金标准FNB在阿片类药物节约效应和功能恢复方面的比较；其次需要开发更精准的定位技术以提高中段入路的操作效率；最后应探索基于患者个体特征的精准化镇痛方案。此外，“中段ACB = 近端 + 远端”的假说也需要更多循证医学证据支持。随着超声技术和辅助药物的不断发展，ACB有望成为TKA术后镇痛的核心技术，但需要更多高质量研究来建立标准化临床应用指南。

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(上接第1802页)

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