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术中分子病理指导下的脑胶质瘤诊疗进展

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摘　要

胶质瘤是最常见的恶性脑肿瘤，具有恶性程度高、手术切除困难、术后易复发等特点。随着脑胶质瘤诊疗分子时代的来临，单一的术中组织病理检查已不能满足手术的需求。术中快速获取患者分子突变信息将为胶质瘤的精准分型诊断、指导手术切除及术后辅助治疗提供新的依据。本文对近十年已发表的术中快速分子诊断技术应用于脑胶质瘤的相关研究进行了回顾和梳理，探讨了分子病理指导下成人弥漫性胶质瘤不同分子亚型患者的诊疗特点，并总结了术中辅助识别胶质瘤边界的相关技术，最后对分子病理指导脑胶质瘤切除的应用前景加以展望。

关键词

脑胶质瘤，IDH突变，TERTp突变，切除范围，肿瘤边界

Advances in Intraoperative Molecular Pathology-Guided Diagnosis and Treatment of Gliomas

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Abstract

Glioma is the most common intracranial malignant tumor and is recognized as being one of the most difficult tumors to treat because of the difficulty of complete surgical removal and the poor effectiveness of post-operative radiotherapy. With the advent of the molecular era in the diagnosis

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and treatment of gliomas, a single histopathological examination is no longer sufficient for surgery. The detection of molecular mutation information in patients intraoperatively will provide a new basis for accurate staging and diagnosis of gliomas, guiding surgical resection and postoperative adjuvant therapy. In this paper, we review the published studies on the application of intraoperative rapid molecular diagnosis to glioma in the past decade, summarize the characteristics of the treatment of patients with different glioma subtypes under the guidance of molecular pathology, and finally look forward to the application of molecular pathology to guide the resection of glioma.

Keywords

Glioma, IDH Mutation, TERTp Mutation, Extent of Resection, Tumor Margins

1. 引言

脑胶质瘤是最常见的原发性中枢神经系统恶性肿瘤[1]。其浸润性生长模式及瘤内异质性的存在导致肿瘤完全切除困难及术后放化疗抗性增加[2]-[6]。虽然神经外科近几十年飞速发展，胶质瘤的主要治疗方案却仍以手术切除为主，术后联合放化疗为辅，整体效果不佳。手术方案及切除范围(Extent of resection, EOR)是影响患者预后的独立影响因素[7]-[10]。随着基因检测技术的快速发展，分子信息逐渐主导了胶质瘤的诊断和治疗，似乎为攻克胶质瘤这一难题提供了一种新的方案。在第五版世界卫生组织中枢神经系统肿瘤分类(WHO CNS5)中强调了遗传和分子信息对胶质瘤诊断、预后的重要性，其中异柠檬酸脱氢酶(Isocitrate dehydrogenase, IDH)突变型胶质母细胞瘤已被修改为 IDH 突变型星形细胞瘤[11]。根据分子病理结果将成人弥漫性胶质瘤重新划分为三种亚型：星形细胞瘤，IDH 突变型；少突胶质细胞瘤，IDH 突变联合 1p/19q 共缺失型；胶质母细胞瘤，IDH 野生型[12]-[14]。不同胶质瘤亚型患者术后生存期存在显著差异，低级别胶质瘤患者术后生存期为 148.1 个月，而胶质母细胞瘤患者术后生存期仅为 14.6 个月[15] [16]。

目前胶质母细胞瘤的标准治疗方案为最大范围安全切除，术后辅助放疗联合替莫唑胺(Temozolomide, TMZ)同步化疗(也称 STUPP 方案)，但患者的术后生存期并未显著改善[17]-[19]。2009 年以来，肿瘤电场治疗(Tumor-treating fields, TTFields)逐步受到国内外胶质瘤诊疗指南的推荐。但 Stupp 等[20]研究发现 TTFields 联合 TMZ 治疗 GBM 的中位生存期也仅为 20.9 个月，5 年生存率 15%，且全身不良事件发生率为 48%。因此，针对脑胶质瘤患者的首要治疗方案应是尽力实现最大范围安全切除。相关研究已证实，最大程度的安全切除可以显著改善患者术后生活质量、无进展生存期(Progression-free-survival, PFS)及总生存期(Overall survival, OS) [21] [22]。胶质瘤的切除主要依赖于主刀医生的经验，由于胶质瘤浸润性生长及瘤内异质性的存在，导致肿瘤完全切除困难。随着术中磁共振、术中超声、神经导航、荧光素钠术中造影及术中唤醒等技术辅助识别肿瘤边界，胶质瘤完全切除率进一步提升[23]-[26]。当前分子病理诊疗的时代大背景下，基因突变信息在胶质瘤的分型诊断及预后判断中发挥着主导作用。在第五版世界卫生组织中枢神经系统肿瘤分类(WHO CNS5)中，基于分子病理对成人弥漫性脑胶质瘤重新分型，分为星形细胞瘤，IDH 突变型；少突胶质细胞瘤，IDH 突变联合 1p/19q 共缺失型；胶质母细胞瘤，IDH 野生型[12]。不同胶质瘤亚型患者的手术切除范围及辅助方案存在显著差异，因此术中快速明确基因突变类型有助于

指导手术决策。但目前患者基因突变信息的获取依赖于术后的免疫组化(Immunohistochemistry, IHC)及二代测序技术(Next-generationsequencing, NGS)，检测步骤繁琐、检测时间长及检测成本昂贵限制了其在术中的应用。因此，如何在术中快速、准确获取肿瘤基因突变信息是目前亟待解决的难题。本文重点整理了国内外有关脑胶质瘤术中快速分子检测的相关研究，探讨了不同分子突变亚型胶质瘤的手术切除策略，并总结了目前临床中可用于辅助识别胶质瘤边界的相关技术。

2. 脑胶质瘤术中快速分子诊断研究进展

相关研究证实 IDH 基因突变、1p/19q 共缺失、TERTp 突变及 MGMT 启动子区甲基化在胶质瘤发生、发展、分型诊断及预后转归中发挥着重要的作用[27]-[29]。目前关于脑胶质瘤术中快速分子检测的相关研究主要分为两个方向：一是通过质谱技术检测 IDH 突变型胶质瘤患者肿瘤组织代谢产物 2-羟基戊二酸(2-hydroxyglutarate, 2-HG)浓度来预测 IDH 突变[30]-[34]；二是基于 PCR 改良技术直接检测基因突变位点[35]-[39]。

2.1. 质谱技术

质谱技术可以利用色谱分析技术定量检测组织中某种物质[40]。异柠檬酸脱氢酶是三羧酸循环的关键酶之一，在 IDH 突变型胶质瘤中，由于 IDH 酶活性降低导致 2-HG 大量堆积，抑制 DNA 损伤修复及细胞分化，进而导致肿瘤恶性进展[41] [42]。质朴技术通过检测肿瘤代谢产物 2-HG 的含量判断 IDH 基因突变状态。Xu 等[31]利用气相色谱－质谱联用(Gas chromatography mass spectrometry, GC-MS)技术分析了 87 例胶质瘤标本来检测 IDH 突变情况，检测时间仅需 40 min。随着检测技术的进步，Alfaro 等[32]提出应用解吸电喷雾电离质谱(Desorption electrospray ionization-mass spectrometry, DESI-MS)可以通过检测 2-HG 含量在 5 分钟内明确 IDH 突变；同样，Kanamori 等[30]利用高效液相色谱－电喷雾串联质谱法(Liquid chromatography/electrospray ionization tandem mass spectrometry, LC/ESI-MS/MS)检测了 105 例胶质瘤样本，平均检测时间为 10 分钟。在另一项研究中，Lan 等[34]利用基质辅助激光解吸电离－质谱成像技术(Matrix-assisted laser desorption/ionization mass spectrometry imaging, MALDI-MSI)定量了 34 例胶质瘤患者的 2-HG 含量来评估 IDH 突变，发现当设置检测临界值为 0.81 pmol/μg 时，该技术的敏感度及特异度为 100%。较短的检测时间是质谱检测技术的绝对优势，但其只能通过检测代谢产物来推断 IDH 突变，并不能够区分突变类型，及其他重要突变。而且质谱分析仪器不能实现床旁检测，限制了其在术中指导手术的作用。

2.2. PCR 技术

IDH 突变常见突变位点为 IDH1 R132H、IDH1 R132L 及 IDH2 R172K 位点，TERTp 突变常见位点为 C228T 及 C250T 位点[38]。基于 PCR 改良的相关技术可以直接检测目的基因突变状态。单个核苷酸位点的突变会使双链 DNA 溶解的温度发生改变，低温变性共扩增 PCR (CO-amplification at Lower Denaturation temperature PCR, COLD-PCR)利用这一特征，在 PCR 过程中通过精确控制温度，使突变频率很低的目的片段呈指数级扩增[43]。Boisselier 等[44]发现 COLD-PCR 可准确检测 IDH1 R132H 突变，且可检测 DNA 突变丰度可低至 2%。Shankar 等[37]利用 PCR 改良的 OperaGen 技术检测了 190 例胶质瘤患者的 IDH/TERTp 突变，可在 60 分钟内完成。在另一项研究中，Kanamori 等[39]提出利于 COLD-PCR 检测 IDH 突变可辅助组织病理诊断不明的样本明确诊断。但传统的 PCR 检测技术涉及到 DNA 的提取、底物加样等繁琐的步骤，限制了其在临床中的应用价值。Xue 等[36]基于实时荧光 PCR 技术改良的全自动核酸检测分析系统(Automatic integrated gene detection system, AIGS)，利用微流控卡槽将试剂预先封装，实现了从加样到结果分析的自动化检测，可将整个检测控制在 1 h 内。虽然，基于 PCR 技术的术中快速分子检测技术可准确的检测 IDH 及 TERTp 突变亚型，但操作复杂、试剂种类繁多及检测时间仍较长。目前多

数相关研究仍处于临床研究阶段(表 1)。

Table 1. Research related to the application of gene mutation detection techniques to gliomas
表 1. 基因突变检测技术应用于脑胶质瘤的相关研究

作者/出版时间	基因检测技术	n	检测指标	检测时间(min)
Xue, H., *et al.* (2022)	AIGS	105	IDH1 + TERT	59.2
Avsar, T., *et al.* (2020)	3m-ARMS	236	IDHI/2	60
Alfaro, C.M., *et al.* (2019)	DESI-MS	25	2-HG	5
Diplas, B.H., *et al.* (2019)	PCR	39	IDH1 + TERT	60
Xu, H., *et al.* (2019)	GC-MS	87	2-HG	40
Kanamori, M., *et al.* (2018)	LC/ESI–MS/MS	105	2-HG	10
Ohka, F., *et al.* (2017)	PCR	11	IDH1	90~100
Aibaidula, A., *et al.* (2016)	Microfluidics	47	IDH1	30
Shankar, G.M., *et al.* (2015)	PCR	190	IDH1 + TERT	60
Santagata, S., *et al.* (2014)	DESI-MS	35	2-HG	<10
Kanamori, M., *et al.* (2014)	PCR	18	IDH1/2	60~65

3. 不同分子亚型脑胶质瘤手术切除策略

随着 WHO CNS5 的发布，脑胶质瘤是第一个将分子信息纳入亚型划分标准的肿瘤。分子病理在胶质瘤的分型诊断及手术治疗中发挥着重要作用，不同亚型胶质瘤患者预后差异较大。因此，针对不同分子突变类型的胶质瘤应该制定个性化的手术方案。

3.1. 星形细胞瘤，IDH 突变型

在 WHO CNS5 中，将伴有 IDH 突变的胶质瘤诊断为星形细胞瘤，组织学等级分为 2~4 级，多数为低级别胶质瘤(Low-grade gliomas, LGGs)，预后较好[45]。Barzila 等[46]研究发现，对于 LGGs (IDH 突变型，WHO 2~3 级)，早期、积极的手术治疗可以明显改善患者术后生存级神经认知功能。Hervey-Jumper 等[47]研究发现对于星形细胞瘤，当 EOR 超过 75%可改善患者 OS，而当 EOR 达 80%即可改善患者 PFS。Rossi 等[48]研究发现扩大 LGGs 切除范围可使患者进一步获益。然而，对于星形细胞瘤(IDH 突变型，WHO 3~4 级)患者，目前并未有明确的手术方案推荐。Pessina 等[49]发现，对于星形细胞瘤(WHO3 级)，如果不能全切，则应最大限度地切除强化区域(EOR > 76%, RTV < 3 cm^3)。但是并非所有的 LGG 患者都有明显的影像学强化灶，因此对于非强化胶质瘤的手术切除范围尚存争议。Xue 等[36]提出可使用 PCR 改良技术术中检测 IDH 突变来判断胶质瘤分子边界，为 IDH 突变型胶质瘤全切除提出了新的方案，但是否有助于改善患者预后有待进一步验证。相关研究表明，与单纯术后放疗相比，联合 PVC 化疗有助于改善患者预后，而术后单独应用 TMZ 化疗效果不如放疗[50] [51]。尽管缺乏 RCT 验证，TMZ 因其安全和便捷性而被广泛应用。因此，该部分患者应至少做到影像学边界的全切，在技术支持条件下应做到肿瘤分子边界的全切，对于高风险因素患者术后辅以放疗及 TMZ 化疗。

3.2. 少突胶质细胞瘤，IDH 突变联合 1p/19q 共缺失

在 WHO CNS5 中，将分子分型为 IDH 突变联合 1p/19q 缺失的胶质瘤诊断为少突胶质细胞瘤(WHO2~3 级)，多为 LGGs。该型患者属于胶质瘤患者中预后最好的类型，术后中位生存期可达 10 年以上[52]。在

一项针对 2358 例少突胶质细胞瘤患者的回顾性研究中，Alattar 等[53]发现肿瘤的完全切除(Gross total resection, GTR)不能使病人更加受益。而 Garton 等[54]研究发现，少突胶质细胞瘤患者更大的 EOR 可以带来的更好的生存优势。两项 RCT 证实，少突胶质细胞瘤(WHO3 级)患者术后辅以放疗联合 PCV 化疗，可提高患者生存率[51] [55]。因此对于这部分患者，可以根据肿瘤位置制定个性化的手术切除方案，对肿瘤位于非功能区的患者采取 GTR，对肿瘤主体位于功能区的患者采取次全切除术(Subtotal resection, STR)，适当残留少许肿瘤组织并不会影响患者的术后生存，但却能极大的改善患者的术后生存质量。

3.3. 胶质母细胞瘤，IDH 野生型

在 WHO CNS5 中，将 IDH 野生型胶质瘤诊断为胶质母细胞瘤(GBM, WHO4 级)。该部分患者预后最差，即使选择 STUPP 方案联合 TTFields 电场治疗术后中位生存期也仅为 20.9 个月。Chaichana 等[10]研究发现，GBM 患者术后生存($P = 0.0006$)和复发($P = 0.005$)的最低 EOR 阈值为 70%；生存($P = 0.01$)和复发($P = 0.01$)的最大肿瘤残留体积(Residual volume, RV)阈值为 5 cm^3。但是胶质母细胞瘤细胞浸润性生长模式，往往侵入到 T2WI/Flair 异常区域(肿瘤周围脑水肿区)，甚至更远的脑组织。在一项针对 967 例新诊断 GBM 患者的多中心、回顾性研究中，Molinaro 等[56]发现切除肿瘤 T1w 增强区域可显著改善患者生存期，而对于年龄 < 65 岁的 GBM 患者进一步扩大切除非强化区域(T2WI/Flair 异常区域)可使患者进一步获益。Zigiotto 等[57]研究发现，对 GBM 患者 T1w 增强区域进行扩大切除(supra-total resection, SupTR)不仅可以显著延长患者的 OS，还有助于保留患者神经认知功能，进而改善患者的生活质量。Hathout 等[58]通过数学模型模拟肿瘤的生长迁移发现，对于高度侵袭性 GBM，只有切缘超出 T1w 增强区域才能让患者有额外的生存获益，并且这种益处随着手术切缘的扩大而显着增加。因此对于 GBM 患者早期准确诊断十分重要，并对这一部分患者进行扩大切除可改善患者术后生存(图 1)。

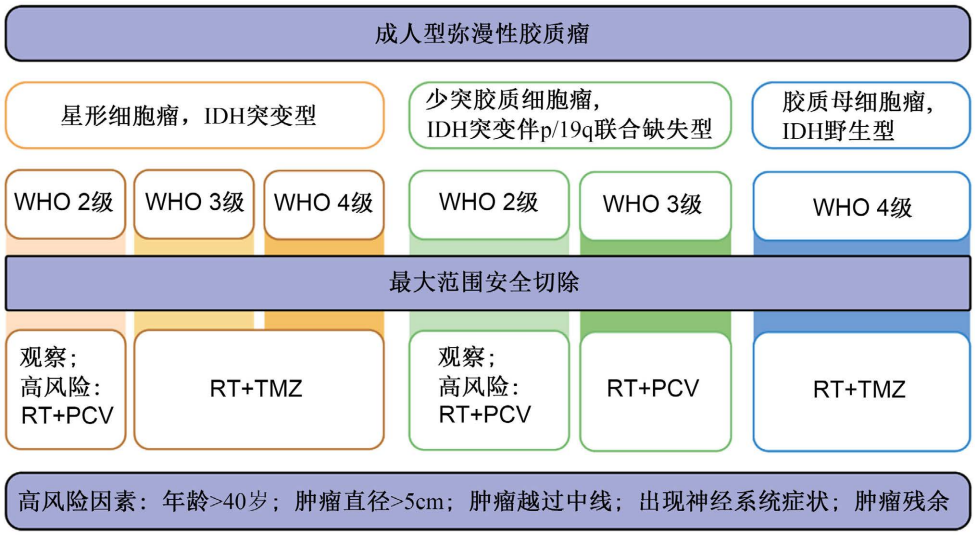

Figure 1. Diagnostic and treatment options for each glioma subtype
图 1. 各亚型胶质诊疗方案

4. 胶质瘤手术切除边界判断

虽然替莫唑胺、TTFeilds 电场治疗和贝伐珠单抗等新兴辅助治疗方案已广泛应用胶质瘤，患者整体预后不佳。显微镜下最大范围安全切除仍是胶质瘤患者首选治疗方案。但胶质瘤脑内呈浸润性生长，难以准确识别肿瘤边界，术中只能依赖于神经外科医生进行经验性切除。近年来，神经外科飞速发展，随

着术中磁共振、术中超声、神经导航和电生理监测等新技术的应用，胶质瘤全切除率进一步提升。

4.1. 影像学边界

基于术前颅脑 MRI 指导下最大范围安全切除是目前脑胶质瘤的手术切除标准。手术切除范围是影响患者预后的最重要因素之一。对于 HGGs，术前伴有强化的患者切除 T1WI 强化区域为准；而对于强化不明显的 LGGs，以切除 T2WI/Flair 异常区域为准。然而，手术过程中伴随体位变化、释放脑脊液后颅内压降低及手术操作挤压的等因素会导致脑漂移，这在一定程度上影响了手术切除效率。随着术中磁共振(Intraoperative MRI, iMRI)和术中超声(intraoperative ultrasound, iUS)的应用，可通过实时成像纠正脑漂移，并识别残余肿瘤组织，指导手术切除范围至肿瘤解剖边界。早在 1999 年，Knauth 等[59]发现 iMRI 可有效辅助胶质瘤完全切除。在一项针对 135 例胶质母细胞瘤患者的回顾性研究中，Kuhnt 等[60]行 iMRI 发现 88 例患者存在肿瘤组织残余，其中 19 例患者继续行手术切除，肿瘤全切除率从 34.80%增加到 41.49%。在另一项针对 170 例 HGGs 的前瞻性研究中，Nickel 等[61]发现 iMRI 组的 GTR 为 94%，且患者术后健康相关生命质量(Health-related quality of life, HRQoL)稳定。Prada 等[62]认为 iUS 可以在术中实时、动态地识别胶质瘤和周围脑组织结构，有助于提高患者 EOR。在一项针对 98 例胶质瘤患者的回顾性研究中，Wang 等[63]发现 iUS 可有效识别 LGGs 肿瘤边界，但是由于 HGGs 多表现为边界不清，难以通过 iUS 与周围水肿相鉴别。相关研究已证实，iMRI 可有效提高胶质瘤患者 EOR，但是术后获益程度仍缺乏有力证据。直到 2024 年，Li 等[64]通过一项针对 321 例胶质瘤患者的 RCT 发现术中磁共振指导下的胶质瘤切除术可显著改善 HGGs 的 PFS。iMRI 及 iUS 的广泛应用进一步提高了脑胶质瘤全切除率。

4.2. 功能边界

对于累及运动区、感觉区及语言区等功能区胶质瘤切除方案缺乏明确的标准。如何平衡患者术后生存期及术后生活质量是该部分胶质瘤切除的最大难题。针对这部分患者，Bello 等[65]发现使用神经电生理监测辅助识别胶质瘤功能边界，有助于增加患者 EOR 并保留患者神经功能完整性。而在另一项针对 102 例胶质瘤患者的回顾性研究中，Pan 等[26]研究发现术中神经电生理监测组患者神经功能保留优于对照组，但两组术后生存期无显著差异。Clavreul 等[66]研究发现术中唤醒手术同样有助于保留功能区胶质瘤患者的神经功能。并没有相关研究证实两种手术方式的优劣。在一项针对 148 例 GBM 患者的回顾性研究中，Gerritsen 等[67]研究发现，相较于传统全麻手术，术中唤醒联合神经电生理检测组患者的平均 EOR 为 94.89%，显著优于对照组的 70.30%，且术后并发症发生率更低。术中唤醒联合神经电生理监测已成为指导幕上功能区胶质瘤手术切除的主要方案。总之，两种技术联合应用可辅助识别大脑功能区边界，实现胶质瘤最大安全范围切除的同时保护患者重要机能。但是否改善患者术后生存期，仍需要进一步研究。

4.3. 荧光边界

胶质瘤浸润性生长模式易侵犯周围血管，损伤血管内皮致密结构，增加了血脑屏障通透性。荧光素钠、5-氨基乙酰丙酸(5-ALA)和吲哚菁绿等荧光显影药物可通过血脑屏障蓄积在肿瘤组织中，并在显微镜下辅助识别肿瘤荧光边界，指导手术切除[68]。早在 1948 年，Moore 等[69]首次使用荧光素来定位颅内肿瘤。随后在 1982 年，Murray 等[70]通过对 23 例脑肿瘤患者标本荧光染色，首次报道基于荧光素钠染色可识别肿瘤边界。在一项针对 36 例 GBM 患者的回顾性研究中，Díez Valle 等[71]利用 5-ALA 荧光引导的肿瘤 EOR 可达 99.8%。Katsevman 等[72]研究发现，与非荧光素钠治疗组相比，接受荧光素钠引导切除的胶质瘤患者组 EOR 显著提高。在另一项前瞻性研究中，Cordova 等[24]研究发现 5-ALA 引导的 GBM 切除术可显著提高 EOR，并改善患者总生存期。Stummer 等[73]通过一项 RCT 研究发现，5-ALA

荧光引导切除的 HGGs 全切除率为 65%，显著优于白光显微切除组的 36%，且 6 个月 PFS 更佳。Cao 等[74]提出吲哚菁绿的近红外二区(NIR-II)荧光成像有助于识别胶质瘤血管分布及肿瘤边界。Zhang 等[75]研究发现利用拉曼光谱检测类胡萝卜素含量同样可识别胶质瘤边界。然而，Belykh 等[76]通过构建不同等级的胶质瘤模型评估 5-ALA、荧光素钠和吲哚菁绿用于检测胶质瘤边界的准确性，发现都没有准确识别出所有的肿瘤边界。基于荧光素聚集原理，该技术仅对伴有明显强化的 HGGs 具有较好的显影，而在 LGGs 显影不佳。因此，可能需要新的可视化技术或分子检测技术来评估胶质瘤边界。

4.4. 代谢边界

代谢重编程是肿瘤细胞为获取源源不断的增殖能量和原料而对代谢途径进行调整的现象，是胶质瘤恶性进展的重要标志之一。基于这一特征，针对胶质瘤异常代谢途径及产物来识别胶质瘤代谢边界的相关研究逐步应用于临床，包括磁共振波普成像及拉曼光谱技术。Cakmakci 等[77]提出利用一项靶向代谢组学的高分辨魔角旋转核磁波谱技术(HRMAS NMR)分析 37 种胶质瘤代谢产物可识别肿瘤分子边界。Cakmakci 等[78]发现基于 HRMAS NMR 机器学习可有效区分胶质瘤和对照标本。Jin 等[79]提出利用拉曼光谱技术可视化肿瘤代谢酸性区域，可有效识别胶质瘤代谢边界。Zhang 等[75]发现基于拉曼光谱技术的机器学习从正常脑组织中识别胶质瘤细胞的准确率超过 80%。相关研究均处于临床研究阶段，是否有效仍需要进一步研究佐证。

4.5. 分子边界

目前临床中常用 iMRI 及荧光素辅助识别胶质瘤边界，指导手术切除。但两种监测方法均基于肿瘤细胞侵犯血管导致血管壁通透性增加，其本质是识别血脑屏障破坏区域，并不能代表整个肿瘤浸润区域[68]。随着基因检测技术飞速发展，分子病理成为胶质瘤分型诊断及预后判断的重要依据。早在 2010 年，Boisselier 等[44]利用 COLD-PCR 技术检测了 10 例组织学认为不含肿瘤细胞的低级别胶质瘤边缘样本，均检测出 IDH 突变。这表明胶质瘤浸润性生长，导致肿瘤细胞侵袭范围十分广泛，单一的组织病理检查已经不足以手术的需求。随后在 2015 年，Shankar 等[37]认为利用 IDH/TERTp 等特征性突变可区分肿瘤组织和非肿瘤组织，并进一步提出了“分子边界”概念。但是由于基因检测技术限制，该手术理念仍未实现。Xue 等[36]提出利用 PCR 改良技术通过术腔“多点取材”检测 IDH 突变来识别 IDH 突变型胶质瘤分子边界，实现胶质瘤分子层面完全切除。目前，针对如何快速识别胶质瘤分子边界的研究较少，基于分子病理特征指导下胶质瘤切除相关的前瞻性或随机对照研究更是缺乏[80]。因此，对于 EOR 达到肿瘤分子边界的胶质瘤患者获益程度尚未可知。

5. 总结

分子病理已在胶质瘤的分型诊断及预后判断中占据了主导地位，单一的组织病理检测已经不能满足手术的需求。在手术中快速获取肿瘤基因突变信息，将有助于实现胶质瘤术中精准分型，进而指导手术决策。虽然脑胶质瘤的诊疗已经进入“分子时代”，但是由于基因检测技术的限制，术中如何快速获取胶质瘤患者分子突变信息仍是亟待解决的难题。随着检测技术的不断发展，检测时间逐步缩短、检测精度不断提高，分子病理将有助于实现胶质瘤术中精准亚型划分，同时利用相关技术快速明确肿瘤分子边界，进而实现胶质瘤的精准切除。

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