

. 论 著 .

3D Slicer 三维重建技术辅助手术治疗枕骨大孔区硬脑膜动静脉瘘:附 1 例报道并文献复习

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【摘要】目的 探讨枕骨大孔区硬脑膜动静脉瘘(DAVF)的影像学特征以及 3D Slicer 三维重建技术辅助手术治疗的疗效。**方法** 回顾性分析 2021 年 6 月收治的 1 例枕骨大孔区 DAVF 的临床资料,并结合相关文献进行分析。**结果** 50 岁男性,因双下肢麻木及疼痛不适 1 个月入院。脊柱 MRI 显示延髓至颈 5 水平颈髓异常信号。双侧颈内动脉、双侧颈外动脉、右侧椎动脉造影未发现异常,左侧椎动脉造影显示枕骨大孔区 DAVF,由脑膜后动脉多个分支供血,经小脑表面及数支硬脑膜迂曲扩张的皮质静脉引流汇入左侧横窦、岩上窦及基底窦,并可见迂曲的硬脊膜前、后静脉参与瘘口血液引流;左侧小脑后下动脉(PICA)靠近瘘口部位走行且迂曲。3D Slicer 三维重建影像清晰显示 DAVF 的位置、供血动脉和引流静脉,多模态重建显示瘘口位于枕部后正中枕骨大孔上区域并靠近硬脑膜。采取枕颈部后正中入路手术,术中吲哚菁绿荧光造影确认 DAVF 消失。术后 3 个月,双下肢麻木及疼痛感均有减轻;复查 MRI 显示脑干和脊髓水肿消失,DSA 显示 DAVF 完全闭塞。**结论** 枕骨大孔区 DAVF 手术治疗可以显著改善病人预后,应用 3D Slicer 三维重建技术对 DAVF 进行精准定位能够在很大程度上节省手术时间并提高手术质量。

【关键词】 硬脑膜动静脉瘘;枕骨大孔区;手术治疗;3D Slicer 三维重建技术

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Surgical treatment assisted by three-dimensional image reconstruction based on 3D Slicer software for dural arteriovenous fistula in the foramen magnum: a case report and literature review

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【Abstract】Objective To investigate the imaging features of patients with dural arteriovenous fistula (DAVF) in the foramen magnum region and the efficacy of surgical treatment assisted by three-dimensional image reconstruction based on 3D Slicer software for such patients. **Methods** The clinical data of a patient with DAVF in the foramen magnum region admitted in June 2021 were retrospectively analyzed, and the relevant literatures were reviewed. **Results** A 50-year-old man was admitted to hospital due to numbness and pain in the lower limbs for 1 month. Spinal MRI showed abnormal signals of cervical spinal cord from medulla oblongata to the C5 spinal cord. Angiographies via bilateral internal carotid arteries, bilateral external carotid arteries, and the right vertebral artery showed no abnormalities, while angiography via the left vertebral artery showed DAVF in the foramen magnum region, which was supplied by multiple branches of the posterior meningeal artery, and drained into the left transverse sinus, suprapetrosal sinus, and basilar sinus through the severely tortuous dilated cortical veins of the dura mater. The tortuous anterior and posterior dural veins were involved in the blood drainage of the fistula. The left posterior inferior cerebellar artery (PICA) was running and tortuously near to the fistula. The three-dimensional reconstructed images using 3D Slicer software clearly showed the location of DAVF, the feeding arteries and draining veins, and multimodal reconstructed images showed that the fistula was located in the posterior median region of the occipital foramen magnum and close to the dura mater. The patient underwent microsurgery through posterior median approach, and intraoperative indocyanine green fluorescence angiography showed the disappearance of DAVF. Three months after operation, the numbness and pain in the lower limbs were relieved; reexamination of MRI showed that the edema of brainstem and spinal cord disappeared, and DSA showed complete occlusion of DAVF. **Conclusions** Surgical treatment of DAVF in the foramen magnum can significantly improve the prognosis of patients. The application of 3D Slicer three-dimensional reconstruction technology to accurately locate DAVF can greatly reduce the operation time and improve the quality of operation.

【Key words】 Dural arteriovenous fistula; Foramen magnum region; Surgery; 3D Slicer software; 3D reconstruction technology

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硬脑膜动静脉瘘(dural arteriovenous fistula, DAVF)占颅内血管畸形的10%~15%,其典型特征是位于硬脑膜内的脑膜动脉与硬脑膜静脉窦以及皮质静脉之间的异常分流^[1]。显微手术灼闭瘘口是一种安全有效的治疗 DAVF 的方法^[2, 3]。枕骨大孔区

DAVF 存在瘘口的位置较深、供血动脉细小弯曲及引流静脉复杂多变的情况,术中瘘口寻找困难,若未能完全灼闭,术后容易复发。本文报道 1 例表现为脊髓炎的枕骨大孔区 DAVF,利用 3D Slicer 三维重建技术制定手术计划,实现了对 DAVF 的精准定位并灼闭瘘口,取得了良好的疗效,现结合相关文献分析如下。

1 病例资料

50 岁男性,因双下肢麻木及疼痛不适 1 个月于 2021 年 6 月 15 日入院。病人否认近期头部外伤及抗凝、抗血小板药物治疗史。入院体格检查:神志清楚;双侧瞳孔等大、等圆,直径约 3 mm,对光反射灵敏;颈项强直阴性;四肢肌力、肌张力正常,病理征未引出。脊柱 MRI 显示延髓至颈 5 水平颈髓异常信号,考虑脊髓炎性病变;颈 3/4、颈 4/5、颈 5/6 椎间盘突出;颈椎退行性变(图 1A)。颈椎 MRI 增强显示延髓及颈髓异常信号,符合急性脊髓炎表现。双侧颈内动脉、双侧颈外动脉、右侧椎动脉造影未发现异常,左侧椎动脉造影显示枕骨大孔区 DAVF,由脑膜后动脉多个分支供血,经小脑表面及数支硬脑膜迂曲扩张的皮质静脉引流汇入左侧横窦、岩上窦及基底窦,并可见迂曲的硬脊膜前、后静脉参与瘘口血液引流;左侧小脑后下动脉(posterior inferior cerebellar artery, PICA)靠近瘘口部位走行且迂曲(图 1B、1C)。

为了制定理想的手术入路并在术中精准定位枕骨大孔区 DAVF,将病人的颅脑薄层 CT、CTA、DSA 数据以 DICOM 格式导入 3D Slicer 影像后处理软件,重建三维图像,显示 DAVF 的位置、供血动脉和部分引流静脉。此外,用不同颜色对 DAVF 的供血动脉(红色)和瘘口位置(粉红色)及正常 PICA(绿色)进行区分(图 1D),多模态重建影像显示 DAVF 位于枕部后正中的枕骨大孔上区域并靠近硬脑膜(图 1E),因此决定采取枕颈部后正中入路,暴露枕骨大孔和寰椎后弓,暴露后枕部硬脑膜。由于 DAVF 的主要供血动脉为左侧脑膜后动脉,因此显微镜下从右侧硬脑膜进入,再向顶部延伸,显示 DAVF 穿过硬脑膜处,然后剪开左侧硬脑膜,可见小脑表面多根迂曲扩张的血管,辨认并保护左侧 PICA。游离并切断硬脑膜后动脉发出的细小供血动脉,使用双极电凝烧灼并切除瘘口和引流静脉起始部,探查引流静脉起始部未发现其他供血动脉,术中吲哚菁绿荧光造影确认 DAVF 消失(图 1F)。术后 3 个月,双下肢麻木及

疼痛感均有减轻;复查 MRI 显示脑干和脊髓水肿消失(图 1G),DSA 显示 DAVF 完全闭塞(图 1H)。

2 讨论

DAVF 属于一种特发的获得性疾病,只有一小部分病例与颅脑损伤、手术、静脉狭窄或静脉窦血栓形成有关^[4]。枕骨大孔区 DAVF 主要表现为脑出血(43.1%)、脊髓病变(37.1%)和脑干功能障碍(3.3%)^[5,6]。枕骨大孔区 DAVF 向上流入皮质静脉时,会引起静脉高压,经常导致急性脑出血,并且脑出血的风险会因为静脉扩张的形成明显增加;DAVF 向下流入脊髓髓周静脉时,会导致脑干或颈髓出现充血性水肿和缺血缺氧性改变,主要表现为缓慢而隐匿的进行性脊髓病变^[7,8]。DSA 是诊断枕骨大孔区 DAVF 的金标准,可以显示 DAVF 的解剖位置、供血动脉、引流静脉以及皮质静脉的扩张情况。枕骨大孔区 DAVF 可能有一条或多条供血动脉,完整的 DSA 必须包括双侧颈内动脉、颈外动脉和椎动脉造影^[9]。

研究表明,没有皮质静脉引流的 DAVF(Borden 分型 I 型和 Cognard 分型 I 型、II a 型)引起不良结局的风险较小,通常可以采取保守治疗^[10];而伴有皮质静脉引流的 DAVF(Borden 分型 II、III 型和 Cognard 分型 II b~V 型)具有侵袭性,引起的脑出血年发生率为 8.1%、非出血性神经功能障碍年发生率为 6.9%、年病死率为 10.4%,需要进行积极治疗,治疗方式主要包括血管内治疗、手术治疗和立体定向放射外科治疗^[11]。

本文报道的 DAVF 属于 Borden 分型 III 型、Cognard 分型 V 型,由于存在供血动脉细小弯曲、引流静脉复杂的情况,相比于血管内治疗,显微手术灼闭瘘口是更为安全和有效的选择^[7]。而手术的关键在于设计一条可以准确到达瘘口的手术入路^[12]。传统的方法是通过仔细研究术前 DSA 影像,根据引流静脉和瘘口的位置来确定手术入路。该方法虽然操作简单,但其精准度不能满足手术需要^[12]。随着神经外科术中图像引导系统的发展,无框架立体定向技术可以实现对 DAVF 的精准定位,但这不仅对操作者有较高的技术要求,而且会增加病人的经济负担^[13]。3D Slicer 软件利用薄层 CT、CTA、DSA 等数据,对血管、正常脑组织、颅骨和头皮等进行重建,可以根据病变与头皮的关系设计理想的手术入路;此外,3D Slice 软件还具有成本低、操作简单易学、定位准确的优势^[14]。基于以上原因,我们利用 3D Slicer

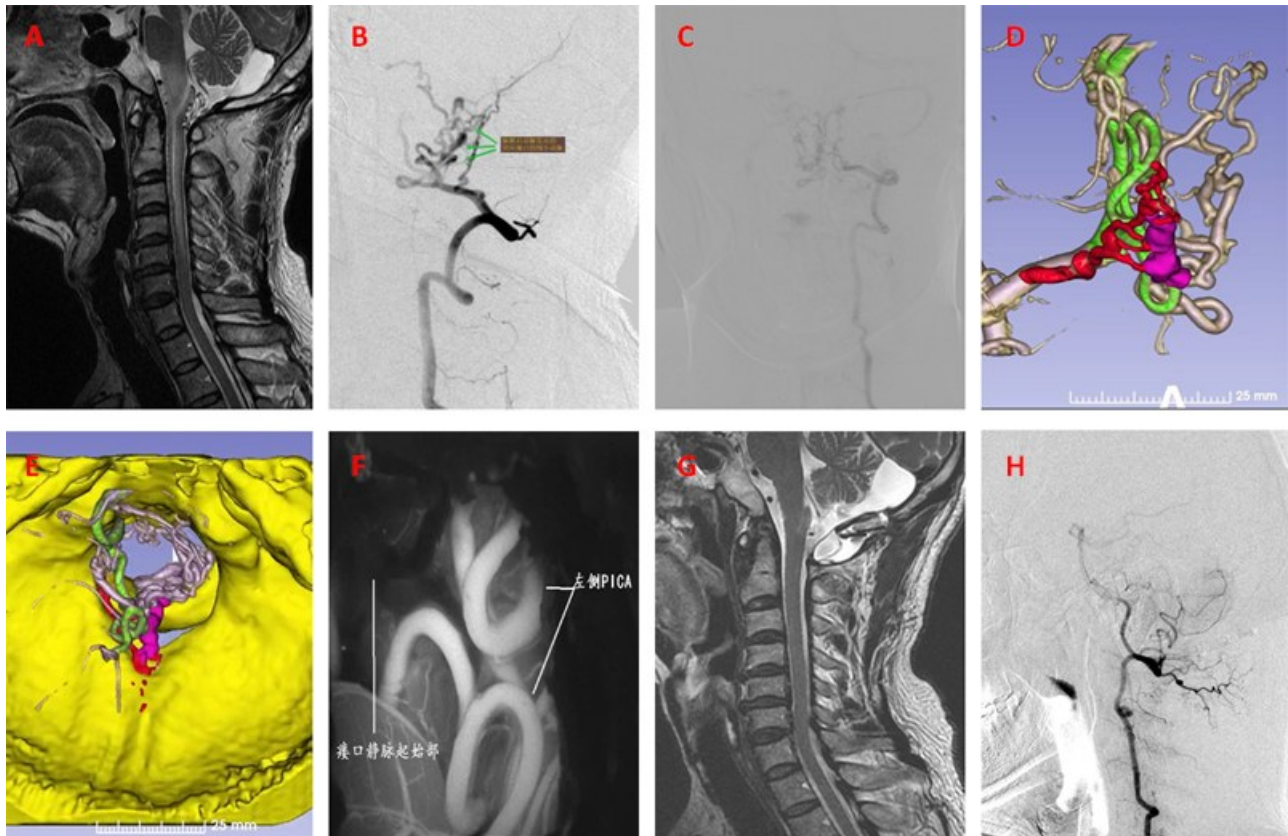


图1 3D Slicer 三维重建技术辅助手术治疗枕骨大孔区硬脑膜动静脉瘘

A. 术前 MRI 显示延髓至颈 5 颈髓水平异常信号;B、C. 术前左侧椎动脉造影显示枕骨大孔区硬脑膜动静脉瘘,由左侧脑膜后动脉的多个分支供血,直接流入迂曲扩张的皮质静脉和硬脊膜前、后静脉;D. 3D Slicer 三维重建影像显示供血动脉(红色)、瘘口(粉红色)和正常小脑后下动脉(绿色);E. 3D Slicer 三维重建影像显示瘘口靠近枕骨大孔后部上方;F. 术中吲哚菁绿荧光造影显示 DAVF 消失;G. 术后 3 个月复查 MRI 显示脑干和脊髓水肿消失;H. 术后 3 个月复查 DSA 显示 DAVF 完全闭塞

Figure 1 Surgical treatment assisted by three-dimensional image reconstruction based on 3D slicer software for a patient with dural arteriovenous fistula in the foramen magnum

A: Preoperative MR images showed abnormal signals from the medulla oblongata to the C5 spinal cord. B–C: Preoperative DSA images showed a dural arteriovenous fistula in the foramen magnum region, which was supplied by multiple branches of the left posterior meningeal artery, and was directly drained into the tortuous dilated cortical veins and the anterior and posterior dural veins. D: Three-dimensional images reconstructed by 3D Slicer software showed the feeding artery (red), the fistula (pink) and the normal posterior inferior cerebellar artery (green). E: Three-dimensional images reconstructed by 3D Slicer software showed that the fistula was close to the posterior upper part of the foramen magnum. F: Intraoperative indocyanine green fluorescence images showed that the DAVF disappeared. G: The reexamination of MRI at 3 months after surgery showed disappearance of brainstem and spinal cord edema. H: The reexamination of DSA at 3 months after surgery showed complete occlusion of DAVF.

软件对本文病人的原始图像进行多模态重建,结果显示 DAVF 位于枕部后正中的枕骨大孔上区域并靠近硬脑膜,因此我们选择枕颈部后正中入路,经此入路快速准确地找到瘘口并进行灼闭,术中吲哚菁绿荧光造影显示 DAVF 消失,术后 3 个月复查 DSA 显示 DAVF 完全闭塞,双下肢麻木及疼痛感均有减轻。该病例表明应用 3D Slicer 三维重建技术对枕骨大孔区 DAVF 进行精准定位并设计理想的手术入路是可行的,在提高手术质量的同时,并不会增加病人的经济负担。

总之,对于其他原因无法解释的脊髓病变,特别是 MRI 异常信号从颈髓延伸到脑干的病例,应当进行 DSA 检查以避免误诊。枕骨大孔区 DAVF 手术治疗可以显著改善病人的预后,应用 3D Slicer 三维重建技术对 DAVF 进行精准定位能够在很大程度上节省手术时间并提高手术质量。

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