

技术与方法

基于图像融合的手术导航系统在头颈部低流量脉管畸形硬化治疗中的应用

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[摘要] **目的**·评估手术导航系统这一实时立体定向引导技术应用于头颈部危险区域低流量脉管畸形病灶硬化治疗的可行性和安全性。**方法**·回顾性纳入2017年5月—2019年9月在上海交通大学医学院附属第九人民医院整复外科接受了手术导航系统辅助硬化治疗的头颈部低流量脉管畸形患者。术前将患者计算机断层扫描图像和磁共振图像融合后,进行穿刺路径设计。术中利用导航系统,按预先设计的路径进行穿刺,通过数字减影血管造影验证穿刺结果。统计穿刺成功率和患者术后并发症情况。**结果**·共纳入10例头颈部低流量脉管畸形患者(6例眼眶内、4例咽部)30处病灶,治疗19次。初次治疗的平均年龄为20.9岁。穿刺成功率达到80.0%(24/30);除1次治疗后患者因硬化剂导致声门溃疡,继而引发肺炎外,未观察到其他并发症。**结论**·手术导航系统对头颈部危险区域低流量脉管畸形的硬化治疗是可行且安全的辅助技术。

[关键词] 手术导航系统;图像融合;脉管畸形;硬化治疗;头颈部

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Image-fusion-based surgical navigation in sclerotherapy for low-flow vascular malformations in the risky regions of head and neck

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[Abstract] **Objective**·To evaluate the feasibility and safety of image-guided surgical navigation, a real-time stereotactic guidance technique, in sclerotherapy of low-flow vascular malformations in the risky regions of head and neck. **Methods**·The patients with low-flow vascular malformations in the heads or necks who underwent surgical navigation-assisted sclerotherapy in the Department of Plastic and Reconstructive Surgery, Shanghai Ninth People's Hospital, Shanghai Jiao Tong University School of Medicine were retrospectively included. The preoperative CT images and magnetic resonance images were fused to design the puncture trajectory. During the operation, the navigation system was used to puncture according to the designed path, and the results were verified by digital subtraction angiography. The technical success rate of intralesional needle placement and postoperative complications were analyzed. **Results**·A total of 19 procedures for 30 lesions performed on 10 patients with low-flow vascular malformations (6 cases with intraorbital lesions, and 4 cases with pharyngeal lesions) were included. The average age of initial procedure was 20.9 years. The technical success rate was 80.0% (24/30). No other complications were observed except a case of pneumonia caused by sclerosing agent-induced glottic ulcer after one procedure. **Conclusion**·Image-guided surgical navigation is a feasible and safe auxiliary technique for the lesions in the risky regions of head and neck.

[Key words] surgical navigation; image fusion; vascular malformation; sclerotherapy; head and neck

脉管畸形是一类脉管内皮畸形扩张所引发的先天发育畸形,大致可分为低流量脉管畸形和高流量脉管畸形。根据经典定义,静脉畸形(venous malformation, VM)和淋巴管畸形(lymphatic malformation, LM)被归类为

低流量脉管畸形^[1-2]。当这些病变累及头颈部时,硬化治疗因其微创、便捷、应用广泛成为治疗首选,操作关键是将穿刺针准确插入目标病变中^[3-4]。然而,术中穿刺的实时引导目前主要依赖于超声或X光透视的二维图像,

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在可视化、精确度上始终存在局限性;其他引导技术,如磁共振(magnetic resonance, MR)、计算机断层扫描(computed tomography, CT)等^[5-7],用于术中引导的可行性已有诸多探索。

在诸多硬化治疗的引导技术中,手术导航系统是为数不多能满足精确图像引导需求的辅助技术,可在屏幕上实时显示患者的解剖结构与手术器械之间的空间关系。神经外科最早开始在临床上使用手术导航技术,也是目前该技术使用最广泛的领域^[8-10],但是该技术应用于脉管畸形治疗仍较少见。目前,仅1篇病例报道^[11]描述了规范的手术导航辅助硬化治疗处理1例眼眶内静脉淋巴畸形患者,而在国内至今未见类似报道。

1 对象与方法

1.1 研究对象

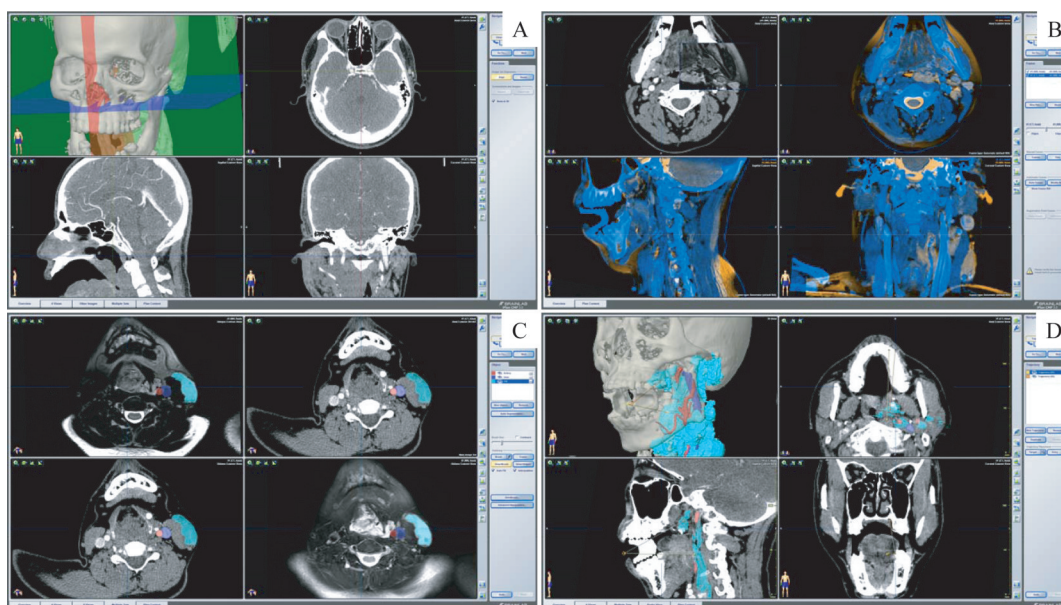
本研究纳入2017年5月—2019年9月在上海交通大学医学院附属第九人民医院整复外科接受了手术导航系统辅助硬化治疗的低流量脉管畸形患者。纳入标准:①年龄介于1~60岁。②低流量脉管畸形诊断明确,位于头颈部且伴有相应的局部症状。③若无特殊仪器(如喉镜)辅助,则无法直视目标病变。④既往硬化治疗已证实对其他浅表病变有效。⑤术中仅使用手术导航系统和数字减影血管造影(digital subtraction angiography, DSA)引导并验证穿刺结果。排除标准:①曾发生博莱

霉素、聚多卡醇或无水乙醇等常见硬化剂相关不良反应。②颅骨额部缺损或厚度小于1 cm(即植入钛钉的长度)。③有严重的凝血障碍、出血倾向、器官功能障碍或其他全身性疾病。④知情同意或磁共振随访资料不完善。

1.2 术前成像与设计

术前患者需要行CT和MR检查,并将轴向扫描的层厚限制为0.6~1.0 mm。咽部病变需要补充增强CT以明确病变与邻近颈动脉系统的毗邻关系。为使MR层厚与CT接近,提升重建图像的精度,MR还采用了高分辨率的序列T2 SPACE,通过Magnetom Verio 3.0T系统(德国Siemens Healthcare)进行平扫,扫描参数为:回波时间(TE)为130 ms,重复时间(TR)为1 000 ms,层厚为0.6~1.0 mm,视野(FOV)为200~360 mm(取决于检查区域的范围),信噪比(SNR)为1.00,同时采用脂肪抑制技术。此外,咽部病变的患者在尖齿的后方需放置1个或2个咬颌块以固定颞下颌关节。

CT和MR数据以DICOM(digital imaging and communications in medicine)格式被导入到手术导航系统[博医来(北京)医疗设备贸易有限公司]附带的iPlan CMF 3.0软件中。术前设计根据需要使用基于表面匹配或多点匹配的2种配准方法,一般根据面部皮肤选择“面配准”或根据牙槽骨选择“点配准”。然后,使用“图像融合”算法将2组图像数据集进行叠加重合,将不同的影像集成在同一个设计对象上(图1)。



Note: Before the first procedure of patient No.7, the venous malformation that diffused from the left pharynx to the superficial sternocleidomastoid muscle, the left internal jugular vein and the common carotid artery and its main branches could be segmented on the navigation system software. A. Alignment and reconstruction based on CT. B. Images fusion of CT and MR. C. Segmentation of the lesions and adjacent structures. D. Trajectory planning.

图1 手术导航系统软件进行术前规划

Fig 1 Preoperative planning with the software of surgical navigation system

完成图像融合后,病灶及其邻近结构(如视神经/眼球和颈动脉)可精确地被勾画出。最后,针对病变位置设置特定的穿刺路径(可经皮、经口或经口底)。这些预设的穿刺路径可与所有DICOM等影像数据一起导入导航系统以供术中参考。

1.3 术中配准与导航下穿刺

所有治疗均在患者全身麻醉下进行,咽部病变的患者需在术前影像扫描时的相同位置放置咬颌块造成稳固的张口状态。用1颗钛钉将一个带有3个可追踪反光标记(即导航球)的迷你头颅定位架通过发迹缘的一个小切口锚固在患者的颅骨上。导航球反射的光线可以通过导航系统的摄像机捕获,最终通过光学原理实现真实世界的患者与预先设计的模型的配准。

在手术导航系统利用光学原理创建的共同参考坐标系内,患者的解剖结构和配套手术器械均可实时跟踪和显示,如穿刺针(17.8G/7 cm或18G/15 cm,美国COOK Medical)和22G普通头皮针。术者操作时可观察导航系统屏幕,通过预先计划好的穿刺路径,将穿刺针插入目标病变,直到观察到血液或淋巴液回流(图2)。

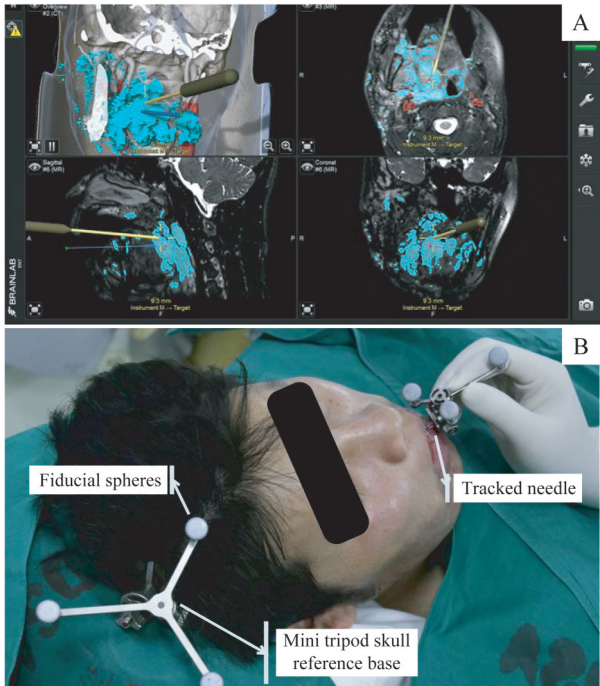
1.4 DSA造影确认并推注硬化剂

在将穿刺针准确置入WM或LM病灶之后,将碘克沙醇(美国GE Healthcare)在DSA辅助下注入病灶,显示出引流静脉则判定为穿刺成功,确认针尖位置后推注硬化剂。使用的硬化剂包括无水乙醇、博莱霉素、聚多卡醇泡沫及这些药物的组合。聚多卡醇泡沫是通过4 mL的1%聚多卡醇注射液(德国Kreussler公司)与空气按1:4的比例混合,在2个5 mL注射器和三通之间反复推挤产生泡沫。对于不适宜使用聚多卡醇或无水乙醇的病灶,可使用生理盐水溶解博莱霉素粉剂(15 000 IU,瀚晖制药有限公司)配置成浓度为1.5 mg/mL的溶液。

表1 研究对象的一般资料

Tab 1 General information of the subjects

Patient No.	Sex	Age/year	Site	Diagnosis	Previous treatment	Local symptom
1	Female	47	Left orbit	VM	Percutaneous sclerotherapy	Argamblyopia caused by blepharoptosis and swelling
2	Female	3	Left orbit	LM	Percutaneous sclerotherapy	
3	Female	19	Left orbit	VM	Percutaneous sclerotherapy and laser	
4	Male	6	Right orbit	LM	Percutaneous sclerotherapy	
5	Female	8	Left orbit	LM	Percutaneous sclerotherapy	
6	Male	16	Bilateral orbit	VM	Percutaneous sclerotherapy	Swelling



Note: Patient No.8 has undergone multiple sclerotherapies, laser, orthodontic and orthognathic treatments. In the intraoperative scene of the first navigation-assisted sclerotherapy, the tip of access needle was guided by navigation system and successfully reached the posterior wall of right oropharynx without direct vision. A. The real-time screenshot of the surgical navigation system. B. The operator held a tracked needle attached to a mini tripod with 3 fiducial spheres to accomplish intralesional placement of the needle.

图2 手术导航系统在硬化治疗中引导穿刺
Fig 2 Navigation-guided needle puncture during sclerotherapy

2 结果

2.1 一般资料

根据纳排标准,本研究共纳入接受手术导航系统和DSA辅助硬化治疗的10例头颈部低流量脉管畸形患者,共计19次治疗、30个病灶,6例眶内病变患者仅进行了单次治疗,另外4例咽部病变患者均接受了至少3次治疗。患者首次进行该治疗的平均年龄为20.9岁(3~47岁),平均随访时间(以末次治疗开始计)为6.9个月,确认知情同意材料完备、随访影像资料齐全,10位患者概况如表1所示。

Continued Tab

Patient No.	Sex	Age/ year	Site	Diagnosis	Previous treatment	Local symptom
7	Male	27	Left face and neck	VM	Percutaneous sclerotherapy and laser	Dyspnoea (before tracheotomy)
8	Male	29	Right face and neck	VM	Percutaneous sclerotherapy, laser, and orthodontic orthognathic treatment	
9	Male	33	Bilateral face and neck	VM	Laryngoscope-guided sclerotherapy, resection of phlebolith, and percutaneous sclerotherapy	
10	Male	21	Bilateral face and neck	VM	Percutaneous sclerotherapy	

眶内病变的6例患者除6号患者外，其余患者临床表现均为上睑下垂或球后部肿胀引起的废用性弱视。咽部VM可累及气道，常导致患者呼吸困难，故另外4例患者均行气管切开术、长期留置套管以减少气道风险。

2.2 穿刺成功率与并发症

经过治疗的30个病灶中有24个由DSA验证后判定为穿刺成功，即手术导航系统辅助DSA硬化治疗的穿刺

成功率为80.0%。唯一术后出现严重并发症的9号患者是由于无水乙醇注射部位过于集中导致声门溃疡，在治疗后第3日发展为由脱落坏死组织引起的肺炎，于当地医院静脉输注阿奇霉素抗感染等对症治疗后痊愈。具体治疗细节、结果及并发症见表2。硬化剂的选择依据DSA所显影的引流静脉特点，当引流静脉较粗且流速较快时，即使判定穿刺成功也会在权衡后不推注硬化剂（图3）。

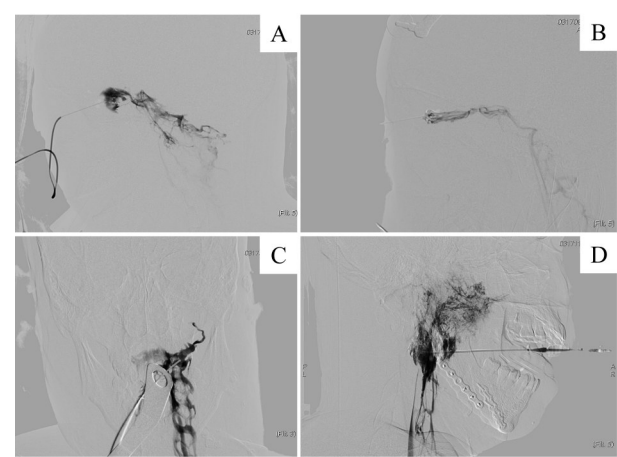
表2 手术导航系统辅助硬化治疗的穿刺结果和细节
Tab 2 Puncture outcomes and details of navigation-assisted procedures

Patient No.	Region	Approach	Result of puncture	Sclerosant	Complication	Follow-up/ month
1	Left retrobulbar	Percutaneously	Success	B	None	16
2	Left retrobulbar	Percutaneously	Success	B	None	9
3	Left nasal intraorbital	Percutaneously	Success	BPF	None	3
	Left inferior intraorbital	Percutaneously	Success	BPF	None	
4	Right superior nasal intraorbital	Percutaneously	Success	B	None	4
	Right inferior temporal intraorbital	Percutaneously	Success	B	None	
5	Left superior nasal intraorbital	Percutaneously	Failure	No delivery	None	6
6	Right nasal intraorbital	Percutaneously	Success	BPF	None	4
	Left retrobulbar	Percutaneously	Success	BPF	None	
7						
1st procedure	Left nasopharynx	Transorally	Success	No delivery ^①	None	2.5
	Lingual radix	Transorally	Success	BPF	None	
2nd procedure	Left lingual radix	Transorally	Success	BPF	None	7.5
	Left nasopharynx	Transorally	Failure	No delivery	None	
3rd procedure	Left nasopharynx	Transorally	Failure	No delivery	None	3
	Posterior wall of left oropharynx	Percutaneously through mouth floor	Success	BPF	None	
4th procedure	Left nasopharynx	Transorally	Success	BPF	None	5
	Posterior wall of left oropharynx	Percutaneously through mouth floor	Failure	No delivery	None	
8						
1st procedure	Posterior wall of right nasopharynx and oropharynx	Transorally	Success	BPF	None	3.5
2nd procedure	Right lingual radix	Transorally	Success	BPF	None	8.5
	Posterior wall of right nasopharynx and oropharynx	Transorally	Success	A & BPF	None	
3rd procedure	Right lingual radix	Percutaneously through mouth floor	Success	BPF	None	8
9						
1st procedure	Left supraglottic	Transorally	Success	BPF	None	4
	Right nasopharynx	Transorally	Failure	No delivery	None	

Continued Tab

Patient No.	Region	Approach	Result of puncture	Sclerosant	Complication	Follow-up/month
	Glottis	Percutaneously	Success	A	Pneumonia caused by glottic ulcer	
2nd procedure	Left laryngopharynx	Percutaneously through mouth floor	Success	BPF	None	1.5
	Right nasopharynx	Transorally	Failure	No delivery	None	
3rd procedure	Left supraglottic	Percutaneously through mouth floor	Success	BPF	None	11
10						
1st procedure	Right nasopharynx	Transorally	Success	BPF	None	6
2nd procedure	Right oropharynx	Transorally	Success	A & BPF	None	5
3rd procedure	Pre-epiglottic space	Percutaneously through mouth floor	Success	BPF	None	3

Note: ① Intralesional needle placement was confirmed to be technically successful by DSA while the drainage vein was considered unsuitable for sclerotherapy. BPF—bleomycin polidocanol foam; A—absolute ethanol; B—bleomycin.



Note: A. The intraorbital lesion of patient No.1. B. A thick and fast drainage vein was detected, which resulted in no effect of sclerotherapy on patient No.3. C. The intralesional needle placement within the left nasopharyngeal lesion in the first procedure of patient No.7 was confirmed but considered unsuitable for treatment due to its thick drainage veins. D. The lesions of posterior wall of right nasopharynx and oropharynx were found connected to those of right lingual radix in the second procedure of patient No.8 when the needle was punctured through the whole tongue.

图3 术中 DSA 造影图像
Fig 3 Intraoperative DSA images

3 讨论

基于脉管畸形影像学的共识^[12], T2 加权抑脂序列对于脉管畸形的诊疗不可或缺; 但常规序列的层厚为 3~6 mm, 远远无法达到导航术前计划的三维重建要求, 而手术导航领域最常用的成像技术是 CT, 其断层厚度可轻易达到 1 mm 以下。近年来, 高场强磁共振仪器逐渐开发出了高分辨率序列, 主要应用于软组织肿瘤^[13]、周围神经^[14]、脑脊液^[15]和动脉斑块^[16-17]等, 这些序列可将 MR 断层厚度压缩至 1 mm 以下。

针对脉管畸形硬化治疗, 手术导航的目标并非像其他常规应用(例如肿瘤切除和截骨)那样探查切缘边界,

而是在复杂解剖结构内找到一个局限的目标范围和入路, 类似于导航辅助颅内病变活检。实践中, 我们通过 MR 识别并勾画脉管畸形病变, 但仍然通过 CT 明晰骨解剖结构并设置参考点。术前设计通过“图像融合”将 CT 与 MR 在同一个空间坐标系内重建, 充分利用了 MR 图像的清晰和 CT 重建的稳定。“图像漂移”指因目标组织形变、位移或者红外光线传输异常而导致的图像位置与实际位置不符。所有导航技术都力求减小其在术中的影响。为了最大程度地减小“图像漂移”的影响, 术中咬颌块的放置、患者的体位应与术前获取图像时尽力做到一致。

眼眶是典型的半封闭骨性结构, 空间较小, 周围环绕着眶壁, 内接视神经和眼球。本报道中, 眶内病变的患者中仅病例 5 出现穿刺失败, 回顾术前设计时发现 MR 上该处病灶最长径仅 6 mm, 其体积是所有眼眶内病灶中最小的。该例穿刺的失败说明手术导航系统针对脉管畸形病灶体积大小有一定的要求。

口腔及咽部不是半封闭骨骼结构, 而更近似空心的腔隙, 故治疗中通过放置咬颌块来固定颞下颌关节使其成为类似眼眶的半封闭结构。本报道回顾发现 4 处穿刺失败的咽部病灶均位于鼻咽或口咽后壁, 术前设计的穿刺路径长度均超过 7 cm, 推测过长的路径造成“图像漂移”是导致穿刺失败的主要原因。

通过总结经验, 我们认为手术导航系统应用于头颈部低流量脉管畸形硬化治疗应符合如下特点: ①病灶具有足够的体积和相应局部症状。②因复杂的解剖结构以及缺乏直视性, 使用常规二维平面术中引导技术难以穿刺。③位于半封闭骨性结构内, 活动度较小。希望我们在手术导航辅助硬化治疗中的经验能为从事该领域的术者提供参考, 突破头颈部复杂解剖区域的脉管畸形病灶难以准确穿刺的困局。

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学术快讯

上海交通大学基础医学院童雪梅研究员团队发现结直肠癌微环境 Treg细胞代谢调控新机制

2021年4月23日,上海交通大学基础医学院生物化学与分子细胞生物学系童雪梅研究员课题组、上海市免疫学研究所李斌研究员课题组和上海交通大学医学院附属新华医院陈寒蓓主任医师等合作在 *Gastroenterology* 杂志在线发表题为“MondoA-TXNIP axis maintains regulatory T cell identity and function in colorectal cancer microenvironment”的研究论文,揭示MondoA-TXNIP调控结直肠癌微环境Treg细胞代谢模式和功能的新作用。该研究团队创新性地探索了靶向炎症的中和抗体和免疫检查点抑制剂联合治疗结直肠癌的新方案,为微卫星稳定性亚型的结直肠癌患者从肿瘤免疫治疗中获益提供了可能的干预靶点。