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·临床研究·

改良3D数字化导板辅助穿刺在微球囊压迫术治疗原发性三叉神经痛中的应用

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【摘要】 目的 探讨改良3D打印数字化导板在微球囊压迫术(percutaneous microballoon compression，PMC)治疗原发性三叉神经痛(primary trigeminal neuralgia，PTN)的应用价值。**方法** 纳入2019年9月至2022年1月于徐州市中心医院口腔科治疗的42例原发性三叉神经痛患者，按随机数字表法分为试验组(采取3D打印技术制作导板引导穿刺，共22例)和对照组(采取传统Hartel前入路法定位穿刺，共20例)。比较两组患者术中一次穿刺成功率、穿刺时间、手术时间及患者承受辐射量、术后并发症等，记录患者术后巴罗神经病学研究所疼痛强度表(Barrow Neurological Institute Scale，BNI)评分、面部麻木、角膜反射减退及咀嚼无力等情况。**结果** 试验组患者在术中一次穿刺成功率(χ^2 = 21.51，P < 0.001)、穿刺时间(Z = −5.51，P < 0.001)、手术时间(t = 9.37，P < 0.001)及C形臂扫描次数(Z = −4.59，P < 0.001)等方面明显优于对照组；试验组患者术后BNI评分Ⅰ级21例(95.5%)、Ⅱ级1例(4.5%)，对照组患者术后BNI评分Ⅰ级17例(85.0%)、Ⅱ级2例(10.0%)、Ⅲ级1例(5.0%)，差异无统计学意义(P > 0.05)；试验组术后出现咀嚼无力16例、结膜炎1例、唇周疱疹10例，对照组术后出现咀嚼无力18例、结膜炎2例、唇周疱疹11例、单眼失明1例，两组术后并发症差异无统计学意义(P > 0.05)；术后平均随访12个月，试验组和对照组均无复发。**结论** 改良3D数字化导板引导经皮穿刺微球囊压迫术治疗原发性三叉神经痛，能在一定程度上提高穿刺的准确性和安全性，明显缩短手术时间，减少患者辐射损伤，提高手术成功率，有较高的临床应用价值。

【关键词】 3D打印技术；数字化；导板；原发性三叉神经痛；微球囊压迫术；精准定位；穿刺；卵圆孔；面部麻木；失明
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Application of improved 3D digital guide plate-assisted guided puncture in microballoon compression for primary trigeminal neuralgia

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【Abstract】 Objective To investigate the clinical efficacy and application value of an improved 3D-printed guide plate for the treatment of primary trigeminal neuralgia (PTN) by percutaneous microballoon compression (PMC). **Methods** This prospective study included 42 patients with primary trigeminal neuralgia treated at the Department of Stoma-

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tology, Xuzhou Central Hospital, from September 2019 to January 2022. The group was divided by the random number table method into the experimental group (adopting 3D printing technology to make guide plates to guide the puncture, 22 cases) and the control group (adopting the traditional Hartel anterior approach to position the puncture, 20 cases). The intraoperative success rate of the first puncture, puncture time, operative time, radiation exposure of patients and postoperative complications were compared between the two groups. Postoperative Barrow Neurological Institute Scale (BNI) scores, facial numbness, diminished corneal reflexes and chewing weakness were recorded. The t-test, rank-sum test and chi-square test were used for statistical analysis, with $P < 0.05$ indicating a statistically significant difference. **Results** The experimental group was significantly better than the control group in terms of the success rate of the first puncture ($\chi^2 = 21.51$, $P < 0.001$), puncture time ($Z = -5.51$, $P < 0.001$), operative time ($t = 9.37$, $P < 0.001$), and the number of C-arm scans ($Z = -4.59$, $P < 0.001$). Postoperative BNI scores of the experimental group included 21 cases of grade Ⅰ (91.5%) and 1 case of grade Ⅱ, while the control group included 17 cases of grade Ⅰ (85.0%), 2 cases of grade Ⅱ (10.0%) and 1 case of grade Ⅲ (5.0%), with no statistical significance ($P > 0.05$). In the experimental group, 16 patients had postoperative masseter weakness, 1 had keratitis and 10 had perilabial herpes, while in the control group, 18 patients had postoperative masseter weakness, 2 had keratitis, 11 had perilabial herpes and 1 had monocular blindness. There was no significant difference in postoperative complications between the two groups ($P > 0.05$). At 12 months of follow-up, there was no recurrence in either the experimental or control group. **Conclusions** 3D digital guide plate-guided percutaneous microballoon compression for primary trigeminal neuralgia can improve the accuracy and safety of puncture to a certain extent, obviously shorten the operation time, reduce radiation exposure of the patients, improve the success rate of the operation, meaning it has a high clinical application value.

【Key words】 3D printing technology; digital; guide plate; primary trigeminal neuralgia; percutaneous microballoon compression; precise location; puncture; foramen ovale; facial numbness; blindness

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【Trial registration】 ChiCTR2200059222, the Central Hospital of Xuzhou

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原发性三叉神经痛(primary trigeminal neuralgia, PTN)是临床上常见的一种神经疾病,以三叉神经分布区域的阵发性剧烈性疼痛为特征,多见于老年人,严重影响患者的生活质量[1-2]。PTN首选药物治疗,如卡马西平、奥卡西平[3];药物治疗效果不佳或无法耐受药物不良反应时选择手术治疗,如射频温控热凝术、微血管减压术及经皮穿刺微球囊压迫术(percutaneous microballoon compression, PMC)等[4-7]。经皮穿刺微球囊压迫术最早由Mullan[8]在1983年首先报道,通过采用传统Hartel前入路法将Fogarty球囊经穿刺针导入麦氏腔内,向球囊内注射碘海醇造影剂使其充盈,选择性压迫三叉神经半月节,阻断其传导功能,从而达到缓解疼痛的效果[9-10];因其创伤小、操作简单、手术效果好、术后并发症发生率低而逐渐成为PTN的一种新的治疗途径[11];手术成功的关键在于准确穿刺卵圆孔,引导球囊进入麦氏腔,压迫三叉神经半月神经节。传统Hartel前入路法通常在患侧口角外侧2~3 cm处穿刺进针,主要依赖于术者的经验和手感,穿刺点及穿刺角度无法确定,需多次调整穿刺角度和深度,手术时间较长,术后并发症的发生率高。随着3D数字化打印技术的发展和成熟,3D数字化打印技术在临床中的应用也较为广泛[12]。本研究采用改良3D数字化导板引导卵圆孔穿刺,辅助PMC治疗PTN,探讨其在精准穿刺卵圆孔、减少患者承受辐射量、缩短手术时间中的临床应用价值。

1　资料和方法

1.1　一般资料

选取2019年9月至2022年1月徐州市中心医院口腔科收治的42例原发性三叉神经痛患者,其中男性18例,女性24例,年龄(69.10 ± 7.18)岁。纳入标准:①年龄18岁以上,符合PTN相关诊断标准[13];②既往有卡马西平等药物治疗史,疗效不佳或无法耐受;③无颅脑外伤史。排除标准:①继发

性三叉神经痛患者；②血常规、肝肾功能、凝血功能等检查异常者；③穿刺部位有感染；④既往有精神疾病史。按随机数字表法将患者随机分为试验组和对照组，试验组采取3D打印技术制作导板引导穿刺；对照组采取传统Hartel前入路法定位穿刺。本研究经徐州市中心医院生物医学研究伦理委员会批准（XZXY-LJ-20190610-040）。所有患者术前均签署知情同意书。

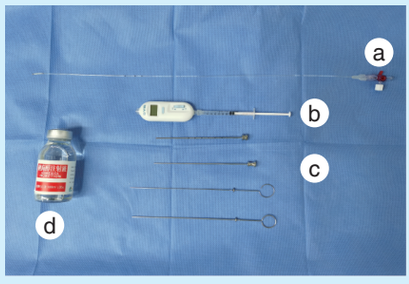
1.2　主要设备及器械

3D打印数字化导板（包括一代导板和二代导板）（上海联泰科技股份有限公司，中国）（图1）；4#Fogarty球囊（QK-08S50，深圳市肇源医疗器械有限公司，中国）（图2a）；1 mL注射器（山东威高集团医用高分子制品有限公司，中国）（图2b）；带刻度内含钝头针芯的14#穿刺针（CTZ-15L，深圳市肇源医疗器械有限公司，中国）（图2c）；碘海醇注射液（北京北陆药业股份有限公司，中国）（图2d）；移动式C形臂X射线机（BV Endura，飞利浦医疗系统荷兰有限公司，荷兰）；光固化3D打印机（上海联泰科技股份有限公司，中国）。

a: first-generation guide plate, a hollow cylinder at the end; b: first-generation guide plate to try on before surgery; c: first-generation guide plate to guide the puncture of the foramen ovale during surgery; d: second-generation improved guide plate, a metric hollow conduit at the end; e: second-generation guide plate to try on before surgery; f: second-generation guide plate to guide the puncture of the foramen ovale during surgery. The puncture needle needs to be finely adjusted in eight different directions after pulling out the cylindrical guide tube

Figure 1　3D printed digital guide plate to assist guided puncture in the treatment of primary trigeminal neuralgia by microballoon compression

图1　微球囊压迫治疗原发性三叉神经痛术中辅助引导穿刺的3D打印数字化导板



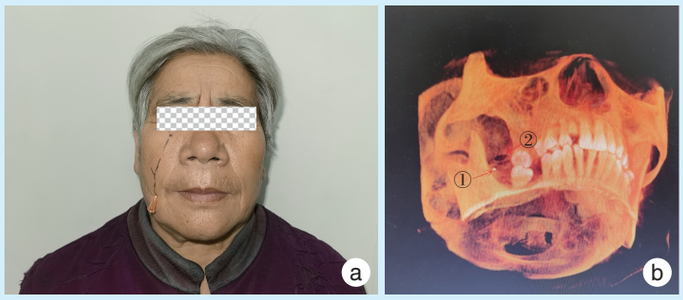
a: 4#Fogarty balloon; b: 1 mL syringe and pressure indicator; c: 14# puncture needle; d: iohexol injection

Figure 2　Instruments and drugs used in the treatment of primary trigeminal neuralgia by microballoon compression

图2　微球囊压迫治疗原发性三叉神经痛术中使用的药械

1.3　术前准备及数字化导板的制作

对两组患者术前采用Hartel前入路法，进针点位于患侧口角外侧2.5 cm处稍下，用5 mL注射器针头行预穿刺（图3a），根据锥体束CT进行卵圆孔实时重建（图3b），在重建图上观察进针点与卵圆孔关系，两者重叠位置好则采用标准定点；一旦患者出现卵圆孔解剖变异，及时调整并确定最佳穿刺点位置。①试验组：根据锥体束CT重建并调整的穿刺点位置，在患者面部相应位置针刺10%的亚甲蓝溶液进行标记，指导手术穿刺位置，并放置金属指示贴，同期进行头颅CT扫描，扫描范围从头部至上颈部，采集的数据用光盘刻录保存。将采集的DICOM数据导入Mimics软件，在水平视图上找到卵圆孔，在卵圆孔中心位置处重建出一点，并重建出病人脸颊上的金属标记物。通过SolidWorks软件的3D建模功能，根据重建出的两点，模拟穿刺针，设计出最佳穿刺路径，并测量穿刺深度，设计个体化导板。通过3-Matic软件选择整个鼻背部结构、鼻翼硬组织点、颧部骨组织点、额骨骨组织点、整个耳廓外形作为固定点裁剪，重建厚



a: before microballoon compression, a 5 mL syringe needle was used to perform a prepuncture on the affected side of the trigeminal neuralgia for a 69-year-old female patient, right third branch; b: 3D reconstruction under CT of the cone bundle, simulating the perforated foramen ovale. ①: prepuncture needle; ②: foramen ovale

Figure 3　Prepuncture was performed on the affected side of the trigeminal neuralgia, and 3D reconstruction was performed by the cone beam CT before microballoon compression

图3　微球囊压迫治疗原发性三叉神经痛术前患侧行预穿刺并利用锥体束CT进行三维重建

3 mm的三维模型，根据穿刺针型号设计出合适的套筒和可调针向的米字型轨道。采用高分子光敏树脂材料通过光固化3D打印机制作出数字化导板，患者试戴导板后封装，低温等离子消毒备用。②对照组：在口腔锥体束CT软件中查看预穿刺通道与卵圆孔的位置关系，以利于术中调整穿刺位置及角度。所有患者均行碘过敏试验，碘过敏试验阴性。

1.4　手术方法与步骤

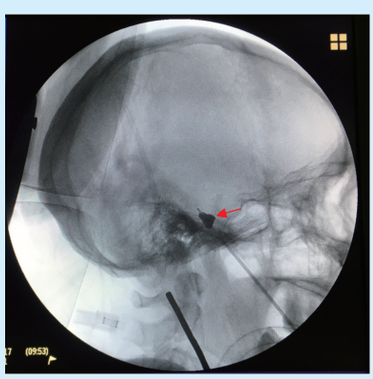
所有患者术前禁食水8 h，患者取仰卧位，经口气管插管全麻，常规消毒铺巾。①试验组：将消毒过的3D打印数字化导板覆盖于患者面部，利用整个鼻背部结构、鼻翼硬组织点、颧部骨组织点、额骨骨组织点、整个耳廓外形使导板与面部紧密贴合并固定（图4a）；在C形臂X射线侧位透视下确认蝶鞍、斜坡、颞骨岩部等卵圆孔周围骨性标志，使双侧外耳道影像重叠；用带刻度内含钝头针芯的14#穿刺针沿导板上预留的米字型空心圆柱导管穿刺卵圆孔（图4b）；当针尖触及卵圆孔并出现落空感时撤出针芯，通过穿刺针将4#Fogarty球囊置入麦氏腔内，撤出导丝后缓慢注射碘海醇充盈球囊，注射的同时检查球囊的形状及位置，一旦不理想，立即排空，此时可通过拔出二代导板中米字型结构中间圆柱状固定引导管，使穿刺针可向8个不同方向调整角度，直至球囊在垂体窝附近呈现理想的“倒梨形”。②对照组：采用传统Hartel前入路法，在患者嘴角外侧2～3 cm处进针，另外2个参照点分别为同侧瞳孔下方1 cm及颧弓水平外耳道前3 cm（图4c）；当针尖触及卵圆孔并出现落空感时撤出针芯，置入4#Fogarty球囊至麦氏腔内，撤出导丝后缓慢注射碘海醇充盈球囊，微调导管直至出现理想的“倒梨形”球囊（图5）。两组球囊充盈量均为0.4～1.0 mL，压迫时间均为3 min，同时密切观察患者心率和血压。时间结束后排空球囊，撤出穿刺针和球囊导管，穿刺点缝合止血，覆盖敷贴，手术结束。所有患者的手术均由同一位

a: the improved 3D-printed guide plate was used to fit the face to determine the location of the puncture site intraoperatively; b: the 3D-printed guide plate was used to guide the puncture of the foramen ovale; c: the foramen ovale was punctured by the traditional Hartel anterior approach. a & b: the same patient in the experimental group; b: the control group

Figure 4　Comparison of different ways of puncturing the foramen ovale during microballoon compression for primary trigeminal neuralgia

图4　微球囊压迫治疗原发性三叉神经痛患者术中不同穿刺方式穿刺卵圆孔对比

副主任医生完成。需要注意的是，有些患者在球囊压迫期间可能会出现三叉神经抑制反射[14]，术前在加压前观察心率，并控制心率在80～100次/分，球囊加压过程中心率、血压可能突然降低，严重者可发生心率监测消失，此时应立即排空球囊，静脉给予0.5 mg阿托品，待心率、血压和血氧分压恢复正常后可继续进行手术。



The arrow in the figure points to the filled pear-shaped balloon

Figure 5　During the treatment of primary trigeminal neuralgia by microballoon compression surgery, the C-arm image shows an ideal pear shape after balloon filling

图5　微球囊压迫治疗原发性三叉神经痛患者术中C形臂成像下球囊充盈后呈理想“梨形”

1.5　疗效评价方法和标准

监测指标：①一次穿刺成功率；②穿刺时间：术者开始穿刺至穿刺针成功穿刺卵圆孔进入麦氏腔的时间；③手术时间：全麻成功后至手术结束的时间；④术中C形臂扫描次数。采用单盲法对所有患者进行跟踪随访，由非手术组人员采用巴罗神经研究所疼痛强度评分（Barrow Neurological Institute Scale，BNI）对患者进行疼痛评分[15]（表1）。按BNI分级Ⅰ～Ⅱ级为有效，有效率=（Ⅰ+Ⅱ）/总例数×100%。“复发”定义为首次术后疼痛完全缓解的患者在随访期间再次发生较为严重的疼痛（BNI分级Ⅳ～Ⅴ级），并符合PTN诊断标准[16]。

表1　巴罗神经病学研究所疼痛强度评分

Table 1　Barrow Neurological Institute pain intensity score

Pain level	Definition
Ⅰ	No pain, no medication
Ⅱ	Occasional pain, no medication
Ⅲ	Pain can be controlled after taking medication
Ⅳ	Pain is slightly relieved after taking medication, but not controlled
Ⅴ	No pain relief from medication

1.6　统计学分析

采用SPSS 25.0软件对数据进行统计分析，符合正态分布的计量资料以均数±标准差（$\bar{x} \pm s$）表示，采用独立样本t检验进行比较；非正态分布数据以$M(P_{25}, P_{75})$表示，采用Wilcoxon秩和检验进行比较。定性资料采用Pearson卡方检验进行比较。$P<0.05$表示差异有统计学意义。

2　结　果

2.1　一般资料

42例病人中左侧疼痛14例，右侧疼痛28例；三叉神经第Ⅱ支疼痛18例，第Ⅲ支疼痛15例，第Ⅰ、Ⅱ支疼痛2例，第Ⅱ、Ⅲ支疼痛7例。2例患者曾行射频热凝术。两组患者术前一般资料无明显差异（表2）。

2.2　两组术中相关情况

试验组一次性成功穿刺卵圆孔20例，余2例经调整位置后成功穿刺；对照组一次性成功穿刺4例，多次穿刺16例，两组一次穿刺成功率间差异有统计学意义（$\chi^2=21.51$，$P<0.001$）。试验组在穿刺时间（$Z=-5.51$，$P<0.001$）、手术时间（$t=9.37$，$P<0.001$）、C形臂透视次数（$Z=-4.59$，$P<0.001$）方面明显优于对照组，差异有统计学意义（表3）。

2.3　两组术后BNI评分

试验组患者术后BNI评分Ⅰ级21例（95.5%），

表2　两组原发性三叉神经痛患者临床资料对比

Table 2　Comparison of clinical data between the two groups of primary trigeminal neuralgia patients

Group	n	Sex (male/female)	Age/year	Affected side (left/right)	Painful site (n)			
					Ⅱ	Ⅲ	Ⅰ+Ⅱ	Ⅱ+Ⅲ
Experimental group	22	10/12	69.14 ± 7.68	6/16	6	9	2	5
Control group	20	8/12	69.05 ± 6.98	8/12	12	6	0	2
t/χ^2		0.130	0.040	0.760	5.300			
P		0.721	0.970	0.382	0.133			

Ⅰ: first branch of the trigeminal nerve; Ⅱ: second branch of the trigeminal nerve; Ⅲ: third branch of the trigeminal nerve

表3　两组原发性三叉神经痛患者术中情况对比

Table 3　Comparison of intraoperative conditions between the two groups of primary trigeminal neuralgia patients　$\bar{x} \pm s/M$ (P_{25}, P_{75})

Group	n	One-time success puncture (n)	Puncture time/min	Operation time/min	C-arm scans
Experimental group	22	20	2.50 (1.00, 3.00)	26.82 ± 4.63	1.00 (1.00, 2.00)
Control group	20	4	12.50 (8.25, 15.75)	40.40 ± 4.76	3.00 (2.00, 4.00)
$t/Z/\chi^2$		21.51	−5.51	9.37	−4.59
P		< 0.001	< 0.001	< 0.001	< 0.001

Ⅱ级1例(4.5%)；对照组患者术后BNI评分Ⅰ级17例(85.0%)，Ⅱ级2例(10.0%)，Ⅲ级1例(5.0%)，两组术后BNI分级差异无统计学意义($P > 0.05$)。

2.4　两组术后并发症、复发情况

试验组术后并发咀嚼无力16例，结膜炎1例，唇周疱疹10例；对照组术后并发咀嚼无力18例，结膜炎2例，唇周疱疹11例，单眼失明1例(表4)，两组术后并发症发生率差异无统计学意义($P > 0.05$)。42例患者中最高随访24个月，最低随访3个月，平均随访12个月，所有患者均无复发。

表4　两组原发性三叉神经痛患者术后1周并发症对比

Table 4　Comparison of complications at 1 week after surgery between the two groups of primary trigeminal neuralgia patients　n (%)

Group	n	Masseter weakness	Keratitis	Blindness	Perilabial herpes
Experimental group	22	16 (72.7)	1 (4.5)	0 (0.00)	10 (4.5)
Control group	20	18 (90.0)	2 (10.0)	1 (5.0)	11 (55.0)
χ^2		1.06	0.01	0.01	0.38
P		0.303	0.932	0.962	0.537

3　讨　论

PMC以其微创、便捷、安全、有效等优点在世界范围内广泛应用，尤其适合高龄体弱、对开颅手术依从性差的患者[17]。PMC治疗的关键在于快速、精准地穿刺卵圆孔并进入麦氏腔，手术多在C臂机透视下进行。因卵圆孔形态差异及解剖变异较大，可以呈现为卵圆形、圆形、杏仁形、裂隙状，边缘可有骨性隆起、结节、棘突或中间存在骨性分隔[18]，使得卵圆孔穿刺存在较多的困难，对术者要求较高。反复的穿刺可能会损伤卵圆孔周围重要的神经血管，增加并发症发生的风险[19]，此外，长时间的透视也不利于医师和患者的身体健康[20]。

传统手术采用Hartel前入路法对所有患者进行穿刺，穿刺点的选择较随意，可因术者的不同而产生较大的差异。本研究在术前进行预穿刺，在口腔锥体束CT的引导下调整穿刺点位置，并放置金属指示点，拍摄头颅CT，进行三维重建，精准分析卵圆孔的大小、形态和变异，评估穿刺难度并可模拟穿刺，术前可以确定较为准确的口外穿刺点，有助于手术入路的选择及穿刺术中的准确定位。同时，采用的数字化导板由于术前进行模拟穿刺，确定了最佳穿刺点和卵圆孔这两点的位置，所以穿刺针的设计和实施具备高度的精确性。同时由于同时确定了整个鼻背部结构、鼻翼硬组织点、颧部骨组织点、额骨骨组织点、整个耳廓外形这5个硬组织定位点，使导板在面部固定形变上发生率较低，这一点在术中比较数字化导板穿刺点和预留在患者面部亚甲蓝指示点是否重合进行验证。一旦进针点与导板设计时穿刺点吻合，穿刺准确率也可以得到保障，而面部皮肤弹性下陷则是在穿刺深度上的影响，对穿刺准确率并未有影响。Wang等[21]采用计算机辅助设计模板辅助温控射频治疗孤立性第二支疼痛的原发性三叉神经患者，缩短了手术时间，取得良好疗效。但此种模板应用于PMC手术中出现穿刺角度无法调整，虽然能准确穿刺卵圆孔，但无法进入麦氏腔，从而达不到治疗所需要的“梨形”球囊。本研究中试验组22例患者术中使用3D打印数字化导板辅助穿刺，提高了穿刺精确度，减少了穿刺次数和手术时间。通过导板上预留米字型穿刺通道和活动圆柱塞，当进入卵圆孔后，由于穿刺角度的问题无法形成治疗所需要的“梨形”球囊时，可以取下活动圆柱塞，米字型穿刺通道便可以从8个不同的方向上调整穿刺针穿刺角度和方向。本研究试验组患者在穿刺时间、手术时间、穿刺次数、首次穿刺成功率及CT扫描次数等方面明显优于对照组，导板辅助

穿刺具有明显优势。两组在手术疗效及术后并发症发生率方面虽无明显差异，考虑本研究主要实施医师为同1名经验丰富的高级主任医师，所以在卵圆孔穿刺成功率上并未有较大的差异，这也恰好证明如何准确穿刺卵圆孔是PMC手术成功的关键。

试验组出现术后咀嚼无力16例，对照组出现术后咀嚼无力18例，这是因为三叉神经第Ⅲ支包含运动纤维，在压迫过程中出现的短暂症状，未行特殊处理，多在术后3～6个月逐渐恢复；试验组出现术后结膜炎1例，对照组2例，给予左氧氟沙星滴眼液，2周后症状消失；试验组10例患者出现术后唇周疱疹，对照组11例患者出现术后唇周疱疹，给予阿昔洛韦软膏局部涂抹，1周左右疱疹结痂愈合。对照组1例患者出现术后单眼失明，患者术后第2天凌晨出现左眼对光反射消失，视力消失，无光感，眼科急会诊发现左眼无光感，给予复方樟柳碱，鼠神经生长因子，丹参川芎嗪，甲泼尼龙等药物治疗，左眼视力无改善；患者既往脑梗、高血压病史10年余，视神经无损伤，排除术中损伤视神经可能，最终考虑为术后患者长期管状视野，手术应激反应引起眼动脉栓塞导致左眼视力消失。王子伟等[22]报道了1例PMC术后致单眼失明，其原因是采取常规穿刺进入破裂孔从而损伤视神经。而采用3D打印数字化导板引导穿刺可以避免因穿刺到破裂孔而损伤视神经致失明的风险。建议术前常规对患者进行眼底检查，术中及时注意监测同侧瞳孔变化，减少误穿刺带来的失明。

球囊形状、位置、体积、大小、压迫时间等是影响患者预后的重要因素，根据球囊位置和麦氏腔形态的不同，球囊可呈“梨形”、“哑铃形”、“椭圆形”等[23]。目前绝大多数学者认为，球囊呈现出“梨形”是手术成功的标志，患者术后疼痛消失率可达到100%[24-25]。有学者测得球囊在不同位置时压力是不同的[26]，研究表明，球囊压力在750～1 250 mmHg时术后疗效最佳，若低于600 mmHg则很难达到最佳止痛效果[27]。笔者课题组将在研究中监测球囊压力变化，以期获得理想的压力值来指导手术，为治疗的有效性提供一个更加客观的指标。

本研究使用的个体化数字导板包括一代导板和二代改良导板。一代导板的尾部穿刺通道为空心圆柱体，试验组2例患者使用了一代导板，手术过程中发现，在穿刺针准确穿刺卵圆孔后，很难再精细地调整穿刺针的方向，使得形成的球囊形状不能改变，治疗效果不能保证。于是对数字化导板进行了改良，第二代导板尾部的穿刺通道为米字型空心导管，穿刺针穿刺卵圆孔后，还可以沿导管上预留的米字型通道向8个方向精细地调整角度，使球囊以最佳角度进入麦氏腔，从而达到理想的治疗效果（第二代导板已申请实用新型专利：一种基于3D打印的可调式颅内麦氏腔引导穿刺器，专利号：202120180441.X）。卵圆孔周围解剖关系复杂，穿刺角度、深度、及穿刺的准确性不仅影响术后疗效，对于减少术后的并发症也至关重要。术中应用3D打印数字化导板避免了反复、多次穿刺。本研究中试验组与对照组相比，在成功穿刺的基础上，两组均达到理想的“梨形”，所以手术疗效无明显差异，但试验组明显缩短了穿刺时间及手术时间。

改良3D打印数字化导板的应用使PMC手术规范化、标准化，不再单一依赖于术者的手感和经验，使低年资的医师也能掌握手术方法并取得良好的效果，有利于PMC手术向基层医院的推广，有较高的临床应用价值。

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参考文献

[1] Scranton RA, Shah K, Cohen-Gadol AA. Alternative customized instrumentation and technique for percutaneous balloon compression rhizotomy for trigeminal neuralgia [J]. J Neurosurg, 2019, 132(6): 1938-1941. doi: 10.3171/2019.2.JNS182896.

[2] Bendtsen L, Zakrzewska JM, Heinskou TB, et al. Advances in diagnosis, classification, pathophysiology, and management of trigeminal neuralgia [J]. Lancet Neurol, 2020, 19(9): 784-796. doi: 10.1016/S1474-4422(20)30233-7.

[3] Ruscheweyh R, Lutz J, Mehrkens JH. Trigeminal neuralgia: modern diagnostic workup and treatment [J]. Schmerz, 2020, 34(6): 486-494. doi: 10.1007/s00482-020-00496-4.

[4] Debta P, Sarode G, Sarode S, et al. Natural history of trigeminal neuralgia-a hospital-based retrospective study [J]. Oral Dis, 2020, 26(3): 647-655. doi: 10.1111/odi.13263.

[5] 张清彬, 邓力, 张颖, 等. 多点射频微创治疗三叉神经痛的临床研究 [J]. 口腔疾病防治, 2016, 24(2): 74-78. doi: 10.12016/j.issn.2096-1456.2016.02.002.
Zhang QB, Deng L, Zhang Y, et al. Clinical study on trigeminal neuralgia treatment with minimally invasive multipoint radiofrequency thermal coagulation [J]. J Prev Treat Stomatol Dis, 2016, 24(2): 74-78. doi: 10.12016/j.issn.2096-1456.2016.02.002.

[6] Bendtsen L, Zakrzewska JM, Abbott J, et al. European Academy of Neurology guideline on trigeminal neuralgia [J]. Eur J Neurol, 2019, 26(6): 831-849. doi: 10.1111/ene.13950.

[7] Cheng J, Meng J, Lei D, et al. Repeat microvascular decompression for patients with persistent or recurrent trigeminal neuralgia: prognostic factors and long-term outcomes [J]. Medicine (Baltimore), 2019, 98(18): e15167. doi: 10.1097/MD.0000000000015167.

[8] Mullan S, Lichtor T. Percutaneous microcompression of the trigeminal ganglion for trigeminal neuralgia [J]. J Neurosurg, 1983, 59 (6): 1007-1012. doi: 10.3171/jns.1983.59.6.1007.

[9] Noorani I, Lodge A, Vajramani G, et al. The effectiveness of percutaneous balloon compression, thermocoagulation, and glycerol rhizolysis for trigeminal neuralgia in multiple sclerosis [J]. Neurosurgery, 2019, 85(4): E684-E692. doi: 10.1093/neuros/nyz103.

[10] Cruccu G, Di Stefano G, Truini A. Trigeminal neuralgia [J]. N Engl J Med, 2020, 383(8): 754-762. doi: 10.1056/nejmra1914484.

[11] Li MW, Jiang XF, Niu CS. Efficacy of and risk factors for percutaneous balloon compression for trigeminal neuralgia in elderly patients [J]. Br J Neurosurg, 2021, 35(3): 280-284. doi: 10.1080/02688697.2020.1787341.

[12] Peng Y, Xie Z, Chen S, et al. Evaluation of the effects of personalized 3D-printed jig plate-assisted puncture in trigeminal balloon compression [J]. Br J Neurosurg, 2021: 1-7. doi: 10.1080/02688697.2021.1886241.

[13] Lambru G, Zakrzewska J, Matharu M. Trigeminal neuralgia: a practical guide [J]. Pract Neurol, 2021, 21(5): 392-402. doi: 10.1136/practneurol-2020-002782.

[14] Wang CM, Guan ZY, Zhao P, et al. The effect of atropine on trigeminocardiac reflex-induced hemodynamic changes during therapeutic compression of the trigeminal ganglion [J]. J Neurosurg Anesthesiol, 2022, 34(1): e40-e45. doi: 10.1097/ANA.0000000000000702.

[15] Abdel-Rahman KA, Elawamy AM, Mostafa MF, et al. Combined pulsed and thermal radiofrequency versus thermal radiofrequency alone in the treatment of recurrent trigeminal neuralgia after microvascular decompression: a double blinded comparative study [J]. Eur J Pain, 2020, 24(2): 338-345. doi: 10.1002/ejp.1489.

[16] Xie E, Garzon-Muvdi T, Bender M. Association between radiofrequency rhizotomy parameters and duration of pain relief in trigeminal neuralgia patients with recurrent pain [J]. World Neurosurg, 2019, 129: e128-e133. doi: 10.1016/j.wneu.2019.05.059.

[17] Ni H, Wang Y, Chen X, et al. Outcomes of treatment for elderly patients with trigeminal neuralgia: percutaneous balloon compression versus microvascular decompression [J]. J Craniofac Surg, 2020, 31(7): e685-e688. doi: 10.1097/SCS.0000000000006544.

[18] Prakash KG, Saniya K, Honnegowda TM, et al. Morphometric and anatomic variations of foramen ovale in human skull and its clinical importance [J]. Asian J Neurosurg, 2019, 14(4): 1134-1137. doi: 10.4103/ajns.AJNS_243_19.

[19] Texakalidis P, Xenos D, Tora MS, et al. Comparative safety and efficacy of percutaneous approaches for the treatment of trigeminal neuralgia: a systematic review and meta-analysis [J]. Clin Neurol Neurosurg, 2019, 182: 112-122. doi: 10.1016/j.clineuro.2019.05.011.

[20] Schultz CH, Fairley R, Murphy LS, et al. The risk of cancer from CT scans and other sources of low-dose radiation: a critical appraisal of methodologic quality [J]. Prehosp Disaster Med, 2020, 35 (1): 3-16. doi: 10.1017/S1049023X1900520X.

[21] Wang R, Han Y, Lu L. Computer-assisted design template guided percutaneous radiofrequency thermocoagulation through foramen rotundum for treatment of isolated V2 trigeminal neuralgia: a retrospective case-control study [J]. Pain Res Manag, 2019, 2019: 9784020. doi: 10.1155/2019/9784020.

[22] 王子伟, 司昕, 高磊, 等. 经皮穿刺半月节微球囊压迫术治疗三叉神经痛致单眼失明一例 [J]. 中华医学杂志, 2020, 100(24): 1911-1912. doi: 10.3760/cma.j.cn112137-20200119-00131.
Wang ZW, Si X, Gao L, et al. Percutaneous balloon compression of semilunar ganglion in the treatment of one case of monocular blindness caused by trigeminal neuralgia [J]. Natl Med J China, 2020, 100(24): 1911-1912. doi: 10.3760/cma.j.cn112137-20200119-00131.

[23] Jianwei, Shi. Research on the relationship between meckel's cavity shape, balloon shape, and intracapsular pressure during percutaneous balloon compression [J]. World Neurosurg, 2022, 168: e369-e375. doi: 10.1016/j.wneu.2022.10.033.

[24] Asplund P, Linderoth B, Lind G, et al. One hundred eleven percutaneous balloon compressions for trigeminal neuralgia in a cohort of 66 patients with multiple sclerosis [J]. Oper Neurosurg (Hagerstown), 2019, 17(5): 452-459. doi: 10.1093/ons/opy402.

[25] Sun C, Zheng W, Zhu Q, et al. The transformation of the balloon shape in percutaneous balloon compression for trigeminal neuralgia [J]. J Pain Res, 2021, 14: 3805-3814. doi: 10.2147/JPR.S343783.

[26] Wang Q, Chen C, Guo G, et al. A prospective study to examine the association of the foramen ovale size with intraluminal pressure of pear-shaped balloon in percutaneous balloon compression for trigeminal neuralgia [J]. Pain Ther, 2021, 10(2): 1439-1450. doi: 10.1007/s40122-021-00311-7.

[27] Brown JA, Pilitsis JG. Percutaneous balloon compression for the treatment of trigeminal neuralgia: results in 56 patients based on balloon compression pressure monitoring [J]. Neurosurg Focus, 2005, 18(5): E10. doi: 10.3171/foc.2005.18.5.11.

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