·疼痛·

单纯微血管减压术治疗三叉神经痛的有效性和安全性分析

宋刚　鲍遇海　陈革　郭宏川　李茗初　王旭　梁建涛

【摘要】　目的　探讨微血管减压术治疗原发性三叉神经痛的有效性和安全性,并筛查其复发相关危险因素。方法　共 286 例单纯行微血管减压术的原发性三叉神经痛患者,分别于术前、术后和随访期间采用 Barrow 神经病学研究所(BNI)三叉神经痛分级评价疼痛缓解;记录术后并发症,包括术侧面部麻木感、术侧听力下降、脑脊液漏、手术切口愈合欠佳、颅内感染、脑积水;记录随访期间复发情况。单因素和多因素前进法 Logistic 回归分析筛查三叉神经痛复发相关危险因素。结果　286 例患者中术后 18 例(6.29%)出现术侧面部轻度麻木感,13 例(4.55%)术侧听力下降,1 例(0.35%)脑脊液漏,1 例(0.35%)手术切口愈合欠佳,2 例(0.70%)颅内感染,1 例(0.35%)脑积水。随访期间 26 例(9.09%)失访,13 例(4.55%)术后疼痛无缓解,13 例(4.55%)术后疼痛部分缓解,234 例(81.82%)术后疼痛完全缓解。234 例术后疼痛完全缓解患者平均随访 31.29 个月,1 例(0.35%)死于心脏病,28 例(9.79%)复发。Kaplan-Meier 曲线显示,术后疼痛完全缓解率随着随访时间的延长而逐渐下降,其中术后 1 年复发率 5.4%、术后 3 年 15.2%、术后 5 年 21.2%。单因素和多因素前进法 Logistic 回归分析显示,术前 BNI 分级 V 级是三叉神经痛复发的独立危险因素($OR = 2.385$, 95%CI: $1.063 \sim 5.353$; $P = 0.035$)。结论　微血管减压术治疗三叉神经痛安全、有效,无死亡或神经功能障碍等严重并发症。

【关键词】　三叉神经痛;　显微外科手术;　复发;　危险因素;　回归分析

Safety and efficacy of pure microvascular decompression for trigeminal neuralgia

SONG Gang, BAO Yu-hai, CHEN Ge, GUO Hong-chuan, LI Ming-chu, WANG Xu, LIANG Jian-tao
Department of Neurosurgery, Xuanwu Hospital, Capital Medical University, Beijing 100053, China
Corresponding author: LIANG Jian-tao (Email: liangjt0001@163.com)

【Abstract】　Objective　To analyze the efficacy and safety of pure microvascular decompression (MVD) for trigeminal neuralgia (TN), and to screen related risk factors for TN recurrence. Methods　A total of 286 primary TN patients underwent pure MVD. Barrow Neurological Institute (BNI) grade was used to evaluate the relief of TN before and after surgery and during the follow-up. Postoperative complications were recorded, including facial numbness of operation side, hearing loss of operation side, cerebrospinal fluid (CSF) leakage, poor wound healing, intracranial infection and hydrocephalus. The recurrence during follow-up was also recorded. Univariate and multivariate forward Logistic regression analysis were used to screen related risk factors of recurrent TN. Results　Of all patients, 18 cases (6.29%) had slight facial numbness of operation side after surgery, 13 cases (4.55%) had hearing loss of operation side after operation. One (0.35%) had CSF leakage, and was cured after lumbar cistern drainage. One (0.35%) had no wound healing, and was cured after bone wax and repairing titanium mesh were removed in the reoperation. Two cases (0.70%) had intracranial infection and were cured by antibiotic therapy. One (0.35%) had hydrocephalus and was cured after external ventricular drainage. Of 286 patients, 26 cases (9.09%) were lost during the follow-up, 13 cases (4.55%) had no pain relief after surgery, 13 cases (4.55%) had partial pain relief after surgery and 234 cases (81.82%) had complete pain relief after surgery. The follow-up period of 234 cases was a mean of 31.29 months. During follow-up, one case (0.35%) died of heart disease, and 28 cases (9.79%) had pain recurrence. Kaplan-Meier curve showed the rate of complete pain relief was decreased with time, the recurrence rate was 5.4% one year after surgery, 15.2% 3 years after surgery, and 21.2% 5 years after surgery. Univariate and multivariate forward Logistic regression

analysis showed preoperative BNI grade Ⅴ was independent risk factor for recurrence of TN (*OR* = 2.385, 95%CI: 1.063–5.353; *P* = 0.035). **Conclusions** Pure MVD for treating TN is safe and effective, without postoperative death or severe complications.

【**Key words**】 Trigeminal neuralgia; Microsurgery; Recurrence; Risk factors; Regression analysis

20世纪初,Dandy[1]提出"血管压迫学说",阐释原发性三叉神经痛的病因,认为动脉压迫三叉神经入脑桥区(REZ),从而导致三叉神经痛。1967年,Jannetta[2]率先报告微血管减压术(MVD)治疗三叉神经痛有效,此后,微血管减压术成为治疗三叉神经痛的标准方法,但存在一定的复发率。本研究回顾分析单中心286例单纯行微血管减压术患者的临床资料,评价其有效性和安全性,并筛查其复发相关危险因素。

对象与方法

一、研究对象

选择2011年1月–2016年12月在首都医科大学宣武医院神经外科住院治疗的原发性三叉神经痛患者共316例,均经卡马西平或奥卡西平等药物治疗效果欠佳、药物过敏或不愿长期服药,其中286例行单纯微血管减压术、30例行微血管减压术联合三叉神经感觉根部分离断术。286例行单纯微血管减压术患者,男性120例,女性166例;年龄25～81岁,平均(58.23±11.25)岁;病程1～300个月,中位病程76.61(24.00,120.00)个月;既往有高血压45例(15.73%),冠心病7例(2.45%),糖尿病13例(4.55%),脑卒中病史3例(1.05%);疼痛累及三叉神经V1支11例(3.85%),三叉神经V2支68例(23.78%),三叉神经V3支50例(17.48%),V1和V2支36例(12.59%),V2和V3支101例(35.31%),V1、V2和V3支20例(6.99%);术前MRI三维稳态构成干扰(3D-CISS)序列或三维时间飞跃(3D-TOF)MRA显示责任血管分别为小脑上动脉(SCA)223例(77.97%)、椎-基底动脉(VBA)23例(8.04%)、小脑前下动脉(AICA)18例(6.29%)、不知名动脉5例(1.75%),静脉20例(6.99%),动脉和静脉19例(6.64%),无血管压迫5例(1.75%),其中82例(28.67%)三叉神经成角扭曲;行左侧微血管减压术103例(36.01%)、行右侧微血管减压术183例(63.99%);微血管减压术前行立体定向伽马刀放射治疗7例(2.45%),射频热凝术21例(7.34%),甘油

注射术11例(3.85%)。

二、研究方法

1. 微血管减压术 患者侧俯卧位,气管插管全身麻醉,于患侧枕下经乙状窦后作弧形切口,上至上项线上1.50 cm、下至乳窦尖下1 cm处,分层切开皮肤和皮下组织,枕骨钻孔,咬除枕鳞,骨窗大小约3 cm×3 cm,前至乙状窦、上至横窦,充分释放脑脊液,经小脑水平裂和小脑脑桥裂入路,锐性分离三叉神经入脑桥区周围蛛网膜,显露三叉神经桥前池段全程,松解并游离三叉神经,小心游离责任血管并将Teflon垫片置于责任血管与三叉神经之间,使二者充分垫离,严格止血,连续水密缝合硬脑膜,逐层关颅和缝合皮肤。

2. 疗效和安全性评价 所有患者术后电话或门诊随访,包括疼痛缓解、并发症和复发。(1)疼痛缓解:分别于术前、术后和随访期间采用Barrow神经病学研究所(BNI)三叉神经痛分级评价疼痛缓解,术后BNI分级降至Ⅰ级为疼痛完全缓解,Ⅱ～Ⅲ级为疼痛部分缓解,Ⅳ～Ⅴ级为疼痛无缓解。(2)并发症:记录术后并发症,主要包括术侧面部麻木感、术侧听力下降、脑脊液漏、手术切口愈合欠佳、颅内感染、脑积水。(3)复发:"复发"定义为,术后疼痛完全缓解(BNI分级Ⅰ级)患者随访期间BNI分级达Ⅱ～Ⅴ级,终点事件为三叉神经痛复发或死亡。

3. 统计分析方法 采用SPSS 22.0统计软件进行数据处理与分析。计数资料以相对数构成比(%)或率(%)表示,呈正态分布的计量资料以均数±标准差($\bar{x}±s$)表示。三叉神经痛复发相关危险因素的筛查采用单因素和多因素前进法Logistic回归分析;采用Kaplan-Meier曲线绘制术后疼痛完全缓解率。以*P* ≤ 0.05为差异具有统计学意义。

结 果

本组患者术后18例(6.29%)出现术侧面部轻度麻木感;13例(4.55%)术侧听力下降;1例(0.35%)脑脊液漏,行腰大池引流术后痊愈;1例(0.35%)手术切口愈合欠佳、出现排异反应,再次手术将骨蜡和
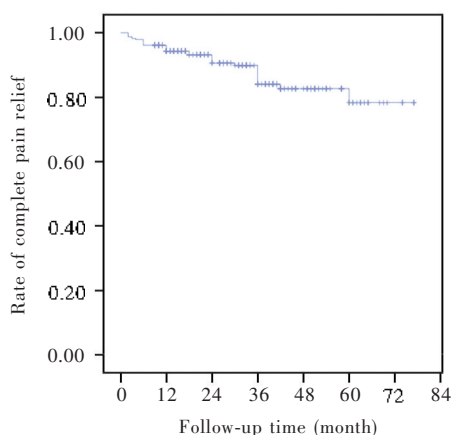
图1　Kaplan-Meier曲线显示，随着随访时间的延长，术后疼痛完全缓解率逐渐下降
Figure 1　Kaplan - Meier curve showed that the rate of postoperative complete pain relief decreased with follow-up time.

修补钛网取出后愈合良好；2例（0.70%）颅内感染，予抗生素治疗后痊愈；1例（0.35%）脑积水，考虑与术中岩静脉分支损伤致小脑水肿有关，行脑室外引流术后痊愈。

　　本组患者均电话或门诊随访，26例（9.09%）失访，13例（4.55%）术后疼痛无缓解，13例（4.55%）术后疼痛部分缓解，234例（81.82%）术后疼痛完全缓解。234例术后疼痛完全缓解患者随访2~77个月、平均31.29个月，1例（0.35%）随访期间死于心脏病，28例（9.79%）随访期间复发。Kaplan-Meier曲线显示，随着随访时间的延长，术后疼痛完全缓解率逐渐下降，其中术后1年复发率为5.4%、术后3年为15.2%、术后5年为21.2%（图1）。

　　进一步筛查三叉神经痛复发相关危险因素，单因素Logistic回归分析显示，术前BNI分级V级是三叉神经痛复发的危险因素（$P = 0.035$；表1，2）；将该自变量代入多因素Logistic回归模型，结果显示，术前BNI分级V级是三叉神经痛复发的独立危险因素（$OR = 2.385$，$95\%CI : 1.063 \sim 5.353$，$P = 0.035$；表3）。

讨　　论

　　三叉神经痛是最常见的颅内神经痛，高峰发病年龄＞50岁、平均63岁[3]，年发病率约4.7/10万[4]，好发于女性，男女比例为1 : 2~3 : 4[2,5]，临床多见右侧三叉神经痛。本研究患者男女比例为120 : 166，平均年龄（58.23±11.25）岁，右侧三叉神经痛多于左侧，人口学特征与文献报道相一致。

　　三叉神经痛的病因多样，包括脑肿瘤、颅内动脉瘤、脑血管畸形、囊肿或正常动脉和静脉压迫，其中正常动脉和静脉压迫是最常见病因[1]。其发病机制目前普遍认为是，血管压迫三叉神经致神经脱髓鞘，使脱髓鞘的轴突紧密接触，形成新的异位三叉神经入脑桥区，导致触觉和痛觉纤维之间形成假突触传递，使兴奋传导过程中发生短路现象。根据上述理论，微血管减压术可以将植入物置于责任血管与三叉神经之间，将刺激源与脱髓鞘的神经隔离，从而达到治疗效果[6-7]。

　　20世纪80年代以来，微血管减压术在治疗三叉神经痛方面的有效性和安全性业已得到证实，随着显微外科技术的发展，术后并发症发生率显著降低；与此同时，一些更安全的治疗方法如立体定向伽马刀放射治疗、射频热凝术等微创技术逐渐开展起来，有研究显示，立体定向伽马刀放射治疗后3年疼痛缓解率仅34%~56%[8-10]，经皮微创治疗后5年疼痛缓解率仅45.3%~66.0%[11-13]，因此，微血管减压术治疗三叉神经痛的有效性是目前所有治疗方法中最高的，术后即刻疼痛完全缓解率达87%~98%，术后1~2年疼痛完全缓解率为78%~80%、术后5年为72%~76%[14-15]、术后8~10年仍为58%~68%[16-17]。本研究Kaplan-Meier曲线显示，微血管减压术后1年复发率为5.4%、术后3年为15.2%、术后5年为21.2%，与国外研究结果相近[14-15,18]。因此，尽管微血管减压术是目前治疗三叉神经痛最有效的方法，但仍需进一步筛查复发相关影响因素，从而有效控制复发。

　　研究显示，性别、年龄、病程、责任血管来源和类型、三叉神经压迫程度等均是微血管减压术预后相关影响因素[14-15,18]。本研究结果显示，术前BNI分级V级是三叉神经痛复发的独立危险因素，但不同研究结论不尽一致，可能与本研究为回顾性、样本量较小、术者经验和其他混杂因素有关。既往研究显示，高龄患者三叉神经痛复发率较低，考虑与压迫神经的血管动脉粥样硬化和脑池宽、手术空间大有关，微血管减压术可以解除血管对神经的压迫，但本研究并未得出这一结论，年龄并非三叉神经痛复发的危险因素，可能与术者对手术入路的理解和术区的充分显露有关，本研究微血管减压术骨窗大小为3 cm×3 cm，完全满足充分分离三叉神经周围蛛网膜，且清晰辨认自三叉神经入脑桥区至Meckel囊周围所有结构，故确保完全垫离血管与三叉神

表1　三叉神经痛复发相关危险因素变量赋值表
Table 1.　Variable assignment table of risk factors for recurrent TN

Variable	Assignment (score)			
	0	1	2	3
Age (year)	≤ 60	> 60		
Duration (year)	≤ 3	> 3		
Pain distribution (number)		1	2	3
Preoperative BNI grade V	No	Yes		
Preoperative MVD, radiofrequency thermocoagulation, stereotactic gamma knife, glycerol injection	No	Yes		
Compression of offending vessels	No	Yes		
Angular distortion of trigeminal nerve	No	Yes		

BNI, Barrow Neurological Institute, Barrow 神经病学研究所。The same for tables below

表2　三叉神经痛复发相关危险因素的单因素 Logistic 回归分析
Table 2.　Univariate Logistic regression analysis of risk factors for recurrent TN

Variable	b	SE	Wald χ^2	P value	OR value	OR 95%CI
Age	0.417	0.404	1.063	0.303	1.517	0.687–3.350
Duration	-0.393	0.404	0.949	0.330	0.675	0.306–1.489
Pain involving trigeminal nerve V1	-0.880	0.649	1.839	0.175	0.415	0.116–1.480
Pain involving trigeminal nerve V2	-0.932	0.648	2.064	0.151	0.394	0.111–1.404
Preoperative BNI grade V	0.869	0.412	4.442	0.035	2.385	1.063–5.352
Preoperative MVD, radiofrequency thermocoagulation, stereotactic gamma knife, glycerol injection	0.167	0.530	0.100	0.752	1.182	0.419–3.338
Compression of offending vessels	19.227	20 096.496	0.000	0.999	223 927 226.125	> 0.001
Angular distortion of trigeminal nerve	-0.457	0.485	0.886	0.346	0.633	0.245–1.639

表3　三叉神经痛复发相关危险因素的多因素前进法 Logistic 回归分析
Table 3.　Multivariate forward Logistic regression analysis of risk factors for recurrent TN

Variable	b	SE	Wald χ^2	P value	OR value	OR 95%CI
Preoperative BNI grade V	0.869	0.412	4.442	0.035	2.385	1.063–5.353
Constant	-2.430	0.314	59.721	0.000		

经。有研究显示,无血管压迫的三叉神经痛患者约占20%[19],较有血管压迫的患者预后更差,术后1和5年疼痛缓解率分别为58%和47%。Zhang 等[14]的研究表明,术前 MRI 显示或术中发现明显血管压迫的患者预后良好且复发率较低,但本研究并未得到这一结论,可能是由于本研究仅5例无血管压迫患者,样本量较小。研究显示,术前三叉神经压迫程

度越严重,预后越佳,特别是出现动脉压痕或三叉神经压迫致神经萎缩的患者预后更佳[19-20],但本研究并未发现这一特点。本研究结果显示,术前 BNI 分级 V 级是三叉神经痛复发的独立危险因素,但其作用机制尚不清楚,尚待进一步深入研究。

此外,本研究结果显示,术前行微血管减压术、立体定向伽马刀放射治疗、射频热凝术和甘油注射术并非三叉神经痛复发的危险因素,但值得注意的是,对于再次行微血管减压术的患者,由于 Teflon 垫片与脑组织粘连,增加手术难度,需将原来的 Teflon 垫片分离取出,再仔细辨认责任血管,将其与三叉神经垫离,故手术难度较高,若操作不慎可能出现严重并发症。术后并发症主要包括面瘫、听力下降、三叉神经分布区痛温觉减退,有文献报道其发生率为 0.2%～24.0%[14-16,21-22];亦可出现脑脊液漏、手术切口愈合欠佳、颅内感染等,但发生率较低。本研究有18例(6.29%)出现术侧面部麻木感但均可忍受,13例(4.55%)出现术侧听力下降,但未出现面瘫和听力丧失,上述神经功能障碍可能与以下原因有关:(1)尽管对青年或颅后窝脑池较小的患者采用小脑水平裂-小脑脑桥裂入路手术,但术中为增加三叉神经及其入脑桥区的显露,牵拉周围脑组织仍可能导致邻近面神经、前庭蜗神经和三叉神经轻微损伤。(2)本研究强调对三叉神经周围蛛网膜进行充分松解,彻底解除三叉神经入脑桥区、脑池段和 Meckel 囊周围蛛网膜粘连和血管压迫,可能会对面神经、前庭蜗神经和三叉神经造成轻微损伤。(3)尽管本研究术中予尼莫地平-生理盐水冲洗术区以防止脑血管痉挛,但仍不排除手术操作致脑血管痉挛的可能,从而引起供血不足致轻微神经功能障碍。

综上所述,微血管减压术治疗三叉神经痛安全、有效,未出现死亡或神经功能障碍等严重并发症,随访期间疼痛缓解率与国外研究结果相近。但本研究为回顾性研究,样本量较小,可能存在一定偏倚;此外,尽管本研究通过保持手术骨窗大小、对青年或颅后窝脑池较小的患者采用小脑水平裂-小脑脑桥裂入路、术中尼莫地平-生理盐水冲洗等方法增加术野的显露,尽量减少对周围脑神经的干扰,防止脑血管痉挛,但仍可能对神经产生轻微损伤。

参　考　文　献

[1] Dandy WE. The treatment of trigeminal neuralgia by the cerebellar route[J]. Ann Surg, 1932, 96:787-795.

［2］ Jannetta PJ. Arterial compression of the trigeminal nerve at the pons in patients with trigeminal neuralgia［J］. J Neurosurg, 1967, 26:159-162.

［3］ Katusic S, Beard CM, Bergstralh E, Kurland LT. Incidence and clinical features of trigeminal neuralgia, Rochester, Minnesota, 1945–1984［J］. Ann Neurol, 1990, 27:89-95.

［4］ Bizzozero I, Ferrari F, Pozzoli S, Saetti MC, Spinnler H. Who is who: Italian norms for visual recognition and identification of celebrities［J］. Neurol Sci, 2005, 26:95-107.

［5］ Mendoza N, Illingworth RD. Trigeminal neuralgia treated by microvascular decompression: a long-term follow-up study［J］. Br J Neurosurg, 1995, 9:13-19.

［6］ Sabalys G, Juodzbalys G, Wang HL. Aetiology and pathogenesis of trigeminal neuralgia: a comprehensive review［J］. J Oral Maxillofac Res, 2013, 3:E2.

［7］ Love S, Coakham HB. Trigeminal neuralgia: pathology and pathogenesis［J］. Brain, 2001, 124:2347-2360.

［8］ Gronseth G, Cruccu G, Alksne J, Argoff C, Brainin M, Burchiel K, Nurmikko T, Zakrzewska JM. Practice parameter: the diagnostic evaluation and treatment of trigeminal neuralgia (an evidence-based review). Report of the quality standards subcommittee of the American Academy of Neurology and the European Federation of Neurological Societies［J］. Neurology, 2008, 71:1183-1190.

［9］ Maesawa S, Salame C, Flickinger JC, Pirris S, Kondziolka D, Lunsford LD. Clinical outcomes after stereotactic radiosurgery for idiopathic trigeminal neuralgia［J］. J Neurosurg, 2001, 94:14-20.

［10］ Sheehan J, Pan HC, Stroila M, Steiner L. Gamma knife surgery for trigeminal neuralgia: outcomes and prognostic factors［J］. J Neurosurg, 2005, 102:434-441.

［11］ Brown JA, Mcdaniel MD, Weaver MT. Percutaneous trigeminal nerve compression for treatment of trigeminal neuralgia: results in 50 patients［J］. Neurosurgery, 1993, 32:570-573.

［12］ Kanpolat Y, Savas A, Bekar A, Berk C. Percutaneous controlled radiofrequency trigeminal rhizotomy for the treatment of idiopathic trigeminal neuralgia: 25-year experience with 1, 600 patients［J］. Neurosurgery, 2001, 48:524-532.

［13］ Udupi BP, Chouhan RS, Dash HH, Bithal PK, Prabhakar H. Comparative evaluation of percutaneous retrogasserian glycerol rhizolysis and radiofrequency thermocoagulation techniques in the management of trigeminal neuralgia［J］. Neurosurgery, 2012, 70:407-412.

［14］ Zhang H, Lei D, You C, Mao BY, Wu B, Fang Y. The long-term outcome predictors of pure microvascular decompression for primary trigeminal neuralgia［J］. World Neurosurg, 2013, 79:756-762.

［15］ Jo KW, Kong DS, Hong KS, Lee JA, Park K. Long-term prognostic factors for microvascular decompression for trigeminal neuralgia［J］. J Clin Neurosci, 2013, 20:440-445.

［16］ Barker FN, Jannetta PJ, Bissonette DJ, Larkins MV, Jho HD. The long-term outcome of microvascular decompression for trigeminal neuralgia［J］. N Engl J Med, 1996, 334:1077-1083.

［17］ Li ST, Wang X, Pan Q, Hai J, Liu N, Shen F, Liu Z, Guan Y. Studies on the operative outcomes and mechanisms of microvascular decompression in treating typical and atypical trigeminal neuralgia［J］. Clin J Pain, 2005, 21:311-316.

［18］ Wei Y, Pu C, Li N, Cai Y, Shang H, Zhao W. Long-term therapeutic effect of microvascular decompression for trigeminal neuralgia: Kaplan-Meier analysis in a consecutive series of 425 patients［J］. Turk Neurosurg, 2018, 28:88-93.

［19］ Leal PR, Barbier C, Hermier M, Souza MA, Cristino-Filho G, Sindou M. Atrophic changes in the trigeminal nerves of patients with trigeminal neuralgia due to neurovascular compression and their association with the severity of compression and clinical outcomes［J］. J Neurosurg, 2014, 120:1484-1495.

［20］ Cheng J, Meng J, Liu W, Zhang H, Hui X, Lei D. Nerve atrophy in trigeminal neuralgia due to neurovascular compression and its association with surgical outcomes after microvascular decompression［J］. Acta Neurochir (Wien), 2017, 159:1699-1705.

［21］ Mclaughlin MR, Jannetta PJ, Clyde BL, Subach BR, Comey CH, Resnick DK. Microvascular decompression of cranial nerves: lessons learned after 4400 operations［J］. J Neurosurg, 1999, 90:1-8.

［22］ Barker FN, Jannetta PJ, Bissonette DJ, Jho HD. Trigeminal numbness and tic relief after microvascular decompression for typical trigeminal neuralgia［J］. Neurosurgery, 1997, 40:39-45.

（收稿日期：2018-07-15）

·小词典·

中英文对照名词词汇（二）

弥散性血管内凝血
　disseminated intravascular coagulation（DIC）

面肌痉挛　hemifacial spasm（HFS）

Boston命名测验　Boston Naming Test（BNT）

脑干听觉诱发电位
　brain stem auditory-evoked potential（BAEP）

脑桥小脑角　cerebellopontine angle（CPA）

帕金森病　Parkinson's disease（PD）

皮质脊髓束　corticospinal tract（CST）

匹兹堡睡眠质量指数　Pittsburgh Sleep Quality Index（PSQI）

青少年肌阵挛癫痫　juvenile myoclonic epilepsy（JME）

情感淡漠评价量表　Apathy Evaluation Scale（AES）

丘脑底核脑深部电刺激术
　subthalamic nucleus deep brain stimulation（STN-DBS）

扰相梯度回波　spoiled gradient-recalled（SPGR）

三叉神经痛　trigeminal neuralgia（TN）

三维时间飞跃　three-dimensional time-of-flight（3D-TOF）

三维稳态构成干扰
　three-dimensional constructive interference in steady state
　（3D-CISS）

Barrow神经病学研究所　Barrow Neurological Institute（BNI）

神经微丝蛋白　neurofilament protein（NF）

神经元核抗原　neuronal nuclei（NeuN）

神经元型一氧化氮合酶
　neuronal nitric oxide synthase（nNOS）