

## 一站式CTP对预测急性脑梗死患者预后的评估价值

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**摘要:**【目的】分析急性脑梗死患者治疗前一站式CT灌注成像(CTP)及治疗前后临床影像资料,明确与预后相关的临床及影像特征。【方法】纳入CT/MRI随访证实的39例急性脑梗死患者(男:女=21:18,平均年龄65岁,平均起病时间8.4h),所有患者均随访90天获取其mRS评分(平均2.8分)。对上述患者行320排螺旋CT一站式CTP[非增强CT(NCCT)-CT血管成像(CTA)-CTP]扫描,对NCCT图像行ASPECTS(alberta stroke program early ct score)评分,经后处理获得脑血管图,脑梗死核心区、缺血半暗带体积及其相应比值,并获得CTP各灌注参数图[CBF, CBV, MTT, TTP, 延迟达峰时间(Delay-TTP)]。将大小一致的感兴趣区分别放置在脑梗死核心区、缺血半暗带及其相应对侧脑实质,分别测量3次,取平均值。【结果】39例患者中,20例预后良好(mRS≤2)。相关分析发现,治疗前后NIHSS评分、梗死核心体积、缺血半暗带MTT及相应区域Delay-TTP与随访90天mRS评分成明显正相关( $P<0.04$ );而治疗后ASPECTS评分及梗死核心区CBF值与90天mRS评分成明显负相关( $P<0.05$ )。进一步两组对比分析发现,治疗前后NIHSS、治疗后ASPECTS、CTP示梗死核心区体积及梗死核心CBF值与患者预后明显相关并具有统计学差异( $P<0.03$ )。ROC分析显示治疗后NIHSS评分对于预测急性脑梗死患者预后有着最高的诊断效能(AUC为0.90),其中敏感度、特异度及拐点值分别为79%,85%和4.5;而梗死核心区CBF具有最佳的特异度(89%),治疗后ASPECTS评分在预测预后方面具有最高的敏感度(94%)。【结论】急性脑梗死患者梗死核心区体积、CBF、治疗前后NIHSS及治疗后ASPECTS评分与患者的预后密切相关。相比较NIHSS评分,梗死核心区CBF对于预测急性脑梗死预后有着更高的特异度。

**关键词:**NIHSS; ASPECTS; CT灌注成像; 急性脑梗死; 预后

**中图分类号:**R743.3; R816.1 **文献标志码:**A **文章编号:**1672-3554(2021)02-0279-08

### Value of CT Perfusion in Predicting the Prognosis of Patients with Acute Cerebral Infarction

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**Abstract:**【Objective】To analyze the clinical data of CT perfusion imaging (CTP) before and after treatment in acute ischemia stroke (AIS) patients, and to identify the imaging and clinical features related to prognosis.【Methods】A total of 39 CT/MRI confirmed AIS patients (Male: Female = 21:18, mean age: 65 years, mean onset time: 8.4 h) were prospectively included, and they were followed for 90 days to obtain their mRS score (mean 2.8). All patients underwent 320-row

收稿日期:2019-12-26

基金项目:广东省自然科学基金(2020A1515011436)

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spiral CTP scan, and non-contrast CT (NCCT), CT angiography (CTA) and CT perfusion (CTP) were generated. ASPECTS score and CTP perfusion parameters (CBF, CBV, MTT, TTP, Delay-TTP) were calculated. In addition, the volume of cerebral ischemia core, ischemic penumbra and their ratio were obtained. Three ROIs with similar size were placed in the cerebral infarction core, ischemic penumbra and corresponding contralateral brain parenchyma, and all the parameters were measured three times respectively, to take the average value.【Results】Of 39 AIS patients, 20 patients showed good prognosis ( $mRS \leq 2$ ). Correlation analysis showed that NIHSS score, ischemia core volume, MTT and delayed-TTP in ischemic penumbra were significantly positively correlated with mRS scores at 90 days ( $P \leq 0.04$ ), while the post-treatment ASPECTS and CBF in the ischemia core were significantly negatively correlated with mRS scores at 90 days ( $P < 0.05$ ). Further comparative analysis demonstrated that NIHSS score before and after treatment, ASPECTS after treatment and ischemia core volume and CBF in ischemia core were significantly different in AIS patients with good or bad prognosis ( $P \leq 0.03$ ). ROC analysis showed that NIHSS score had the highest diagnostic value in predicting the prognosis of AIS patients (AUC: 0.90), and the sensitivity, specificity and cut-off values were 79%, 85% and 4.5, respectively. CBF in the ischemia core had the best specificity (89%) and the post-treatment ASPECTS demonstrated the highest sensitivity (94%) in prognosis predicting of AIS patients.【Conclusions】Ischemia core volume, CBF, NIHSS score before and after treatment, and post-treatment ASPECTS of AIS patients are closely related with their prognosis. Compared with NIHSS score, the ischemia core CBF has a higher specificity in predicting the prognosis of AIS patients.

**Key words:** NIHSS; ASPECTS; CT perfusion; acute ischemia stroke; prognosis

[J SUN Yat-sen Univ(Med Sci), 2021, 42(2): 279-286]

急性缺血性脑梗死 (acute ischemic stroke, AIS) 是临床常见的威胁人类生命和健康的脑血管病,随着人口老龄化趋势的加快,其发病率逐年增加,给家庭和社会造成了沉重的负担<sup>[1]</sup>。为了对个体患者做出合理的预测、提供合理的治疗方案以及帮助患者和家属理解疾病病程,临床医生有必要了解影响预后的重要因素。如何通过影像学评价并预测 AIS 预后一直是研究的热点。对于 AIS 患者,首先需要应用非增强 CT (non-contrast CT, NCCT) 排除颅脑出血,基于 NCCT 的 Alberta Stroke Program Early CT Score (ASPECTS) 评分也广泛适用于临床来评价和预测 AIS 预后<sup>[2]</sup>。随着 CT 灌注成像 (CT perfusion imaging, CTP), CT 血管造影 (CT angiography, CTA) 和一站式 CTP 技术 (NCCT-CTA-CTP) 的问世,CT 在急性脑卒中的实用性已有所增强。与单用 NCCT 评估相比,联合 3 种技术 (NCCT、CTA 和 CTP) 的一站式 CTP 评估检测急性脑梗死的能力增强<sup>[3-6]</sup>。此外,包括 CTA 和 CTP 的多模式评估可评估血管闭塞的位置、梗死核心、可挽救的脑组织及侧枝循环的程度<sup>[7-8]</sup>。研究认为就评估 AIS 而言,头颅 CT 联合 CTP 的效用可能与 MRI 相当<sup>[9]</sup>,而在实践中, MRI 相对于 CT 更容易因患者禁忌证或不耐受而受限。然而,鲜有研究探讨定量的一站式 CTP 与 AIS 患者预后的关系,定量一站式

CTP 参数能否反映 AIS 患者的预后尚不得而知。因此,在这项研究中,我们根据 AIS 患者不同的临床预后分组,分析一站式 CTP 灌注参数与临床预后的相关性。

## 1 材料与方 法

### 1.1 一般资料

收集 2016 年 1 月至 2019 年 5 月连续收治的发病时间  $< 24$  h,并愿意接受重组组织型纤溶酶原激活剂 (recombinant tissue plasminogen activator, rt-PA) 进行溶栓、抗凝或血管腔内治疗的急性脑梗死患者 113 例。本研究得到中山大学附属第一医院伦理委员会批准,所有接受检查患者均由本人或法定代表人签署知情同意书。纳入标准:① 18 岁  $\leq$  年龄  $\leq 80$  岁;② 发病时间  $\leq 24$  h 的临床疑诊急性脑卒中患者;③ 完成颅脑一站式 CTP 检查;④ 基线病史采集 (由神经科医师完成): 症状或体征出现的时间、持续的时间,若于睡眠中起病,应以最后表现正常的时间作为起病时间;其他包括神经症状发生及进展特征;血管及心脏病危险因素,感染、创伤、肿瘤及妊娠史等;一般体格检查与神经系统检查;进行治疗前后美国国立卫生研究院卒中量表 the National Institutes of Health Stroke Scale (NIHSS) 评分。

⑤由临床医师决定下一步的临床决策:rtPA 静脉溶栓和/或抗凝治疗和/或血管腔内治疗。记录相关临床信息,包括:治疗决策/方法,溶栓时间、剂量;⑥首诊 5~7 d 时进行临床及影像复查。排除标准:①CT 平扫确诊脑出血患者( $n=23$ );②CT 增强造影剂禁忌症( $n=3$ );③有过大面积陈旧脑梗死/或出血软化灶,病灶容积 $\geq 20$  mL( $n=11$ );④临床资料不全( $n=37$ )。

所有 AIS 患者均在确诊后 4.5~6 h 内进行溶栓( $n=11$ ),抗凝( $n=20$ )或血管腔内介入( $n=8$ )治疗;首诊 5~7 d 对 AIS 患者行临床和影像学复查(CT:  $n=18$  或 MRI:  $n=21$ ),记录当时的 NIHSS 评分。以复查时 CT 或 MRI T2WI 上病变范围作为最终病变大小。首诊 90 d,电话随访获取患者的 Modified Rankin Scale (mRS)评分,mRS 评分越高表明预后越差,90 d 后 mRS 评分 $\leq 2$  分表明远期预后良好,90 d 后 mRS 评分 $>3$  分表明远期预后不良<sup>[10]</sup>。

## 1.2 一站式 CTP 检查

采用东芝 320 排 640 层螺旋 CT (Aquilion ONE, Toshiba Medical Systems)。首先,CT 平扫排除颅脑出血,扫描参数:120 kV,300 mAs,0.5 mm 层厚容积扫描,10 mm 层厚重建。如无颅脑出血,则进行动态容积全脑 CTA-CTP 检查:在肘静脉埋置 18 G 静脉留置针,采用双通道高压注射器,根据患者体质量的不同,以 5 mL/s 注入 40 mL 非离子对比剂(碘普罗胺,370 mgI / mL,拜耳,德国)后续以 30 mL 生理盐水冲管;扫描参数:80 kV,150 mAs,层厚 0.5 mm,延迟 7 s 开始扫描,11~34 s 为动脉期扫描,间隔时间为 2 s,37~60 s 为静脉期扫描,间隔时间为 5 s,扫描总时间 60 s,覆盖范围 16 cm,平均有效剂量:5.25 mSv。

## 1.3 一站式 CTP 图像后处理和灌注参数分析

由两名经验丰富的神经影像诊断医师对平扫 CT 图像行 ASPECTS 评分(层厚 10 mm)<sup>[2]</sup>,两者评分不一致时由 20 年工作经验的神经影像诊断医师做出决定。

采用佳能后处理工作站灌注软件(Vital Images VES Client 6.9.2, Vital Images, Minnetonka, MN)对动态容积灌注图像行后处理。手动选择输入动脉和输出静脉,选择健侧大脑中动脉为输入动脉,上矢状窦或直窦为输出静脉,由分析软件自动获得感兴趣区的时间-密度曲线,利用 SVD+去卷积算法生成灌注参数图。包括脑血容量(cerebral blood

volume, CBV)、脑血流量(cerebral blood flow, CBF)、平均通过时间(mean transit time, MTT)、达峰时间(time to peak, TTP)及延迟达峰时间(delay time to peak, Delay-TTP)。每个灌注参数图由 320 幅层厚为 0.5 mm 的图像组成。

根据双侧大脑半球的 TTP 和 CBV 差异,后处理自动生成梗死核心区标记为红色(CBV 较对侧正常脑实质下降大于 41%)和缺血半暗带标记为黄色(TTP 较对侧正常脑实质延长大于 6.8 s)。分别记录梗死核心区和缺血半暗带体积及其比值。

在灌注图像上手动绘制感兴趣区(region of interest: ROI),尽量避开大血管,分别放置大小相仿的 3 个(大小:直径约 1 cm)ROI 于梗死核心区(红色)、缺血半暗带(黄色)及镜像对侧正常脑实质区域(绿色),取各参数平均值进行统计,并计算病侧与健侧比值。以上结果均由两名经验丰富的神经影像诊断医师采用盲法独立完成测量(图 1)。

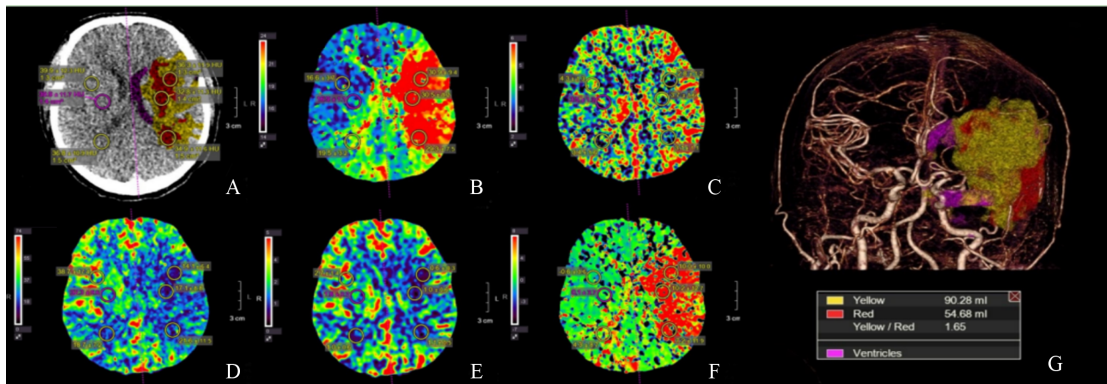
## 1.4 统计学方法

根据 AIS 患者 90 d mRS 评分,将患者分为两组。分析临床及 CTP 参数同治疗后 90 d mRS 评分之间的相关性,比较两组间临床及 CTP 灌注参数差异,分析临床及 CTP 参数同治疗后 90 d mRS 评分之间的相关性。数据分析采用 SPSS 20.0 统计软件,其中性别变量为定性资料,采用卡方检验,其余纳入的临床和 CTP 参数均为定量资料,首先对数据进行正态性检验,如数据符合正态分布则行两独立样本的  $t$  检验和 Pearson 相关;如若不符合正态性分布,则行 Mann-whitney  $U$  test 检验和 Spearman 秩相关检验,均为双侧检验;进一步通过 ROC 分析各临床和灌注参数的诊断效能,并计算其敏感度、特异度和拐点值。 $P < 0.05$  认为存在统计学差异。

## 2 结果

### 2.1 患者基本资料

最终入组 AIS 患者 39 例,其中男性 21 例,女性 18 例,年龄 23~75 岁,平均(65 $\pm$ 12)岁。根据 AIS 患者 90 d mRS 评分,将患者分为两组,A 组:mRS 评分 $\leq 2$  ( $n=20$ ),B 组:mRS 评分 $>3$  ( $n=19$ ),两组 AIS 患者的详细临床和影像资料详见表 1、2。其中 CTA 发现颈内动脉闭塞 8 例、重度狭窄 2 例;大脑中动脉闭塞 13 例、重度狭窄 5 例;大脑后动脉重度狭窄 1 例;椎动脉闭塞 3 例;合并两支及以上颈部血管、脑



A 45 year old female presented with right limb weakness for 4.5 hours. A-F: One stop CTP examination showed a large area of cerebral infarction (red) in the left middle cerebral artery feeding area and the presence of peripheral ischemic penumbra (yellow). Three ROIs of similar size were manually placed in the infarct core area (red), ischemic penumbra (yellow) and normal brain parenchyma area on the opposite side of the mirror image. G: CTP post-processing showed that the infarct core volume (red) was about 54.68 mL and the ischemic penumbra volume (yellow) was about 90.28 mL.

图1 急性脑梗死CTP后处理参数图

Fig. 1 Parameters map of CTP after acute cerebral infarction

表1 不同预后的两组患者一般临床资料比较

Table 1 General clinical data of two groups with different prognosis

$[\bar{x} \pm s, M (P_{25} \sim P_{75})]$

Items	Group A (mRS score ≤ 2) n=20	Group B (mRS score > 2) n=19	$\chi^2/t/Z$	P
Age/years	55.85±15.62	71.5±10.60	-3.649	0.001
Gender/(male:female)	12:8	9:10	2.055	0.152
Onset time/h	6.00(3.00~12.75)	5.00(3.00~19.00)	-0.57	0.095
Pre-NIHSS	3.00(3.00~7.25)	10.00(5.00~16.00)	-3.507	0.000
Later-NIHSS	2.00(1.00~4.00)	13.00(5.00~20.00)	-4.329	0.000
mRS at 90 days	1.00(0.00~2.00)	5.00(4.00~6.00)	-5.408	0.083
Pre-ASPECTS	9.00(8.00~10.00)	8.00(5.00~10.00)	-1.297	0.195
Later-ASPECTS	8.00(6.50~9.00)	4.00(1.00~7.00)	-3.992	0.000

Pre-NIHSS: NIHSS score before treatment; Later-NIHSS: NIHSS score after treatment; mRS at 90 days: mRS score after 90 days; Pre-ASPECTS: ASPECTS score before treatment; Later-ASPECTS: ASPECTS score after treatment.

血管闭塞4例,其中颈内动脉合并大脑中动脉闭塞2例。其中,5例患者合并无症状脑动脉瘤,分为位于大脑中动脉(n=2),大脑后动脉(n=1)和椎动脉(n=2),并未对上述动脉瘤行急诊腔内介入治疗。

### 2.2 定量CTP灌注参数与AIS患者预后的相关性

数据不满足正态性和方差齐性, Spearman秩相关分析发现,治疗前后NIHSS评分、梗死核心区体积、缺血半暗带MTT及相应区域Delay-TTP与随访90 d mRS评分成明显正相关( $P \leq 0.04$ );而梗死核心区CBF值和治疗后ASPECTS评分与90 d mRS评分成明显负相关( $P < 0.05$ )。其余各临床指标和灌注

参数与90 d mRS评分不存在明显相关性。

### 2.3 临床和一站式CTP灌注定量参数的单因素分析

数据不满足正态性和方差齐性, Mann-whitney U test 两组对比分析发现,临床和一站式CTP灌注定量参数可以预测AIS患者预后。在所有的临床和CTP灌注参数中,治疗前后NIHSS评分、治疗后ASPECTS评分、梗死核心区体积及梗死核心CBF值在组间差异有统计学意义( $P \leq 0.03$ )。其中,预后较好组(A组)较预后较差组(B组)具有较低的治疗前后NIHSS评分平均值(治疗前A组3.00分, B组10.00分; 治疗后A组2.00分, B组13.00分)及较低

表2 不同预后的两组患者一站式CTP参数比较  
 Table 2 CT perfusion parameters of two groups with different prognosis  $[\bar{x} \pm s, M(P_{25} \sim P_{75})]$

Items	Core infarct group				Ischemic penumbra group			
	A (n=20)	B (n=19)	t/Z	P	A (n=20)	B (n=19)	t/Z	P
CBF/(mL/100 g·min)	17.30 (13.65~21.55)	14.10 (12.05~15.43)	-2.163	0.029	26.80 (24.40~47.50)	25.70 (22.90~31.10)	-1.358	0.175
CBV/(mL/100 g)	0.85±0.23	0.77±0.24	1.098	0.785	2.20±0.50	2.18±0.46	0.101	0.960
MTT/s	3.07±0.85	3.45±1.03	-1.184	0.121	4.26±1.06	5.05±1.33	-2.028	0.246
TTP/s	29.37±6.23	29.35±5.66	0.010	0.868	22.85±6.67	23.27±5.29	-0.213	0.488
CBF/%	0.65±0.25	0.57±0.24	0.916	0.870	1.00±0.35	0.96±0.25	0.479	0.290
CBV/%	0.50±0.24	0.40±0.20	1.028	0.555	1.04±0.27	1.10±0.23	-0.838	0.854
MTT/%	0.79±0.25	0.76±0.23	0.868	0.868	1.10±0.20	1.18±0.22	-1.743	0.308
TTP/%	1.96 (1.56~2.34)	2.03 (1.77~2.21)	-0.644	0.520	1.58 (1.37~1.78)	1.62 (1.50~1.78)	-0.715	0.474
Volume/mL	6.80 (2.46~32.45)	35.99 (8.76~102.32)	-2.529	0.011	22.34 (5.81~70.53)	59.23 (18.38~95.80)	-1.714	0.087

CBF%: CTF ratio of lesion side to contralateral side; CBV%: CBV ratio of lesion side to contralateral side; MTT%: MTT ratio of lesion side to contralateral side; TTP%: TTP ratio of lesion side to contralateral side.

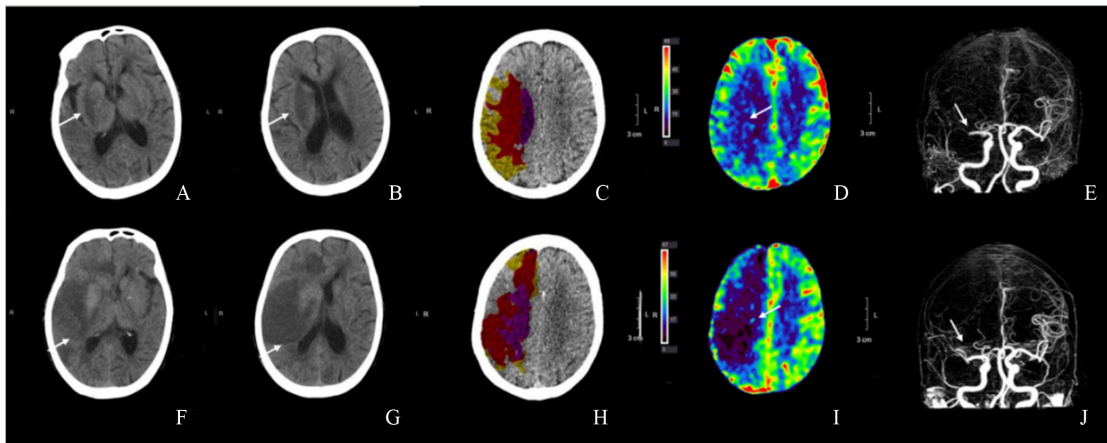
的梗死核心体积(A组6.80 mL, B组35.99 mL);然而, A组的梗死核心区CBF值(A组每100 g脑组织内每分钟的血流17.30 mL, B组每100 g脑组织内每分钟的血流14.10 mL)和复查ASPECTS评分(A组8.00分, B组4.00分)明显高于B组(表1, 图2、3)。ROC分析显示治疗后NIHSS评分对于预测AIS患者预后有着最高的诊断效能[AUC: 0.90, AUC95%CI: (0.891, 1.000)], 其中敏感度、特异度及拐点值分别为79%, 85%和4.5;而梗死核心区CBF具有最佳的特异度(89%), 治疗后ASPECTS评分在预测预后方面具有最高的敏感度(94%;图4)。

### 3 讨论

脑梗死是由脑缺血部位血液供应障碍引起的

缺血、缺氧从而导致脑组织缺血性坏死, 其发病的主要原因包括动脉粥样硬化、血栓或异物阻塞血管, 使血管狭窄, 血流量减少。本研究纳入39例AIS患者, 通过分析其临床和一站式CTP影像, 发现梗死核心区体积、梗死核心区CBF值、治疗前后NIHSS评分及治疗后ASPECTS评分与患者的预后密切相关。其中, 单因素和多因素分析显示治疗后NIHSS评分对于预测急性脑梗死患者预后有着最高的诊断效能, 而梗死核心区CBF具有最佳的特异度(89%), 治疗后ASPECTS评分在预测预后方面具有最高的敏感度(94%)。

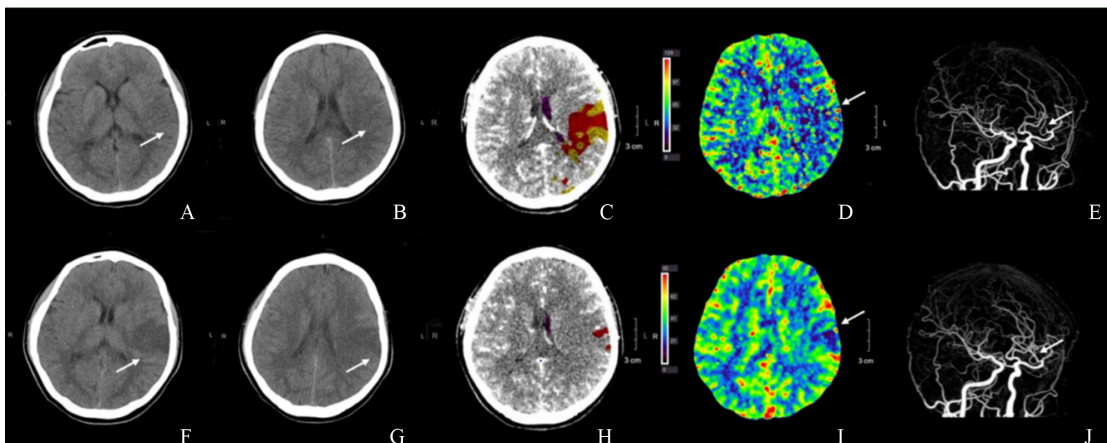
在很多调查研究和越来越多的临床实践中, 采用NIHSS评分来定量评估神经功能障碍。若干研究已证实NIHSS评分是脑梗死结局的良好预测指标<sup>[11]</sup>。这与本文的研究结论相一致, 认为治疗前后NIHSS评分均可以预测急性脑梗死的预后;但是以



A 70-year old female presented with left limb weakness and dysphasia for 4 hours. A-B: ASPECTS 4 scores before treatment; C-D: Large area of decreased density and CBF ( $15.40 \text{ mL} / 100 \text{ g} \cdot \text{min}$ ) were found in the blood supply area of right middle cerebral artery, and the volume of infarct core area was about  $66.72 \text{ mL}$  before treatment; E: CTA showed M1 segment occlusion of right middle cerebral artery and sparse distal branches. CTP was reexamined 7 days after thrombectomy by DSA, F-G: ASPECTS 3 scores; H-I: the lesion area of right middle cerebral artery was larger than before, CBF was significantly lower than before ( $7.32 \text{ mL} / 100 \text{ g} \cdot \text{min}$ ), infarct core volume was larger than before, about  $91.57 \text{ mL}$ ; J: After treatment, CTA showed that M1 segment of right middle cerebral artery was occluded and recanalized, and the number of branches was larger than before.

图2 急性脑梗死治疗后预后不良病例

Fig. 2 The case with poor prognosis after treatment of acute cerebral infarction



A 23-year-old female presented with right limb weakness for 3 hours and had a history of patent foramenovale. A-B: ASPECT 9 scores before treatment; C-D: Patchy slightly low density shadow in the blood supply area of the left middle cerebral artery, CBF decreased ( $14.10 \text{ mL} / 100 \text{ g} \cdot \text{min}$ ), the infarct core volume was about  $33.85 \text{ mL}$  before treatment; E: CTA showed occlusion of M2 branch of the left middle cerebral artery. CTP was reexamined 7 days after thrombolytic therapy, F-G: ASPECT 8 scores; H-I: Left middle cerebral artery ischemic infarct size was significantly reduced, perfusion was significantly increased, infarct core volume was about  $10.48 \text{ mL}$ , significantly reduced; J: CTA showed recanalization of M2 branch of left middle cerebral artery.

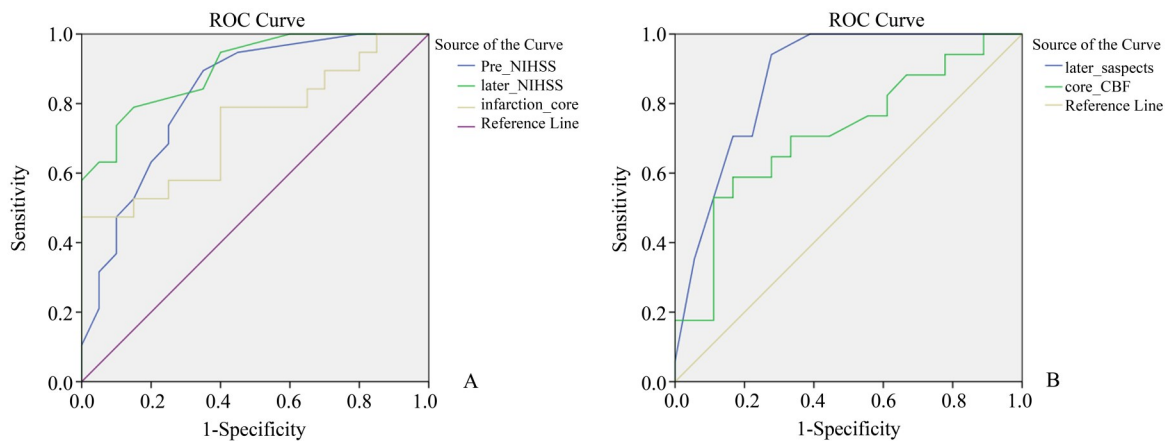
图3 急性脑梗死治疗后预后良好病例

Fig. 3 The case with good prognosis after treatment of acute cerebral infarction

治疗后5~7 d的NIHSS评分预测价值最高,认为当NIHSS评分 $>4.5$ 时预后可能不佳;这与Sumer<sup>[12]</sup>等研究相仿,他们认为NIHSS评分 $\leq 6$ 预示恢复良好,而评分 $\geq 16$ 时发生死亡或严重失能的可能性高。

ASPECTS评分有着良好的观察者本身和观察者间信度,也常常用来预测AIS的预后,早在2000

年Barber<sup>[2]</sup>的研究表明通过ASPECTS评分可以预测AIS患者的功能结局有着较高的敏感性和特异性,这与我们研究的结论相仿。但是,现有数据显示对NCCT结果进行ASPECT分析不能鉴别出可能通过溶栓治疗获益的患者<sup>[13-14]</sup>,这可能是因为,NCCT上低密度影并不完全代表不可逆脑梗死,与



NIHSS scores before and after treatment, ASPECTS scores after treatment, infarct core volume and CBF for predicting prognosis of patients with acute cerebral infarction. A: NIHSS scores after treatment (later-NIHSS) showed the highest diagnostic value [AUC=0.90, AUC95%CI: (0.891, 1.000)]. The diagnostic value of NIHSS scores (pre-NIHSS) and infarct core volume before treatment were 0.83 and 0.74 respectively. B: After treatment, ASPECTS scores were slightly better than CBF.

图4 梗死核心体积、CBF值及结合临床特征预测急性脑梗死患者预后的ROC曲线

Fig. 4 ROC curve of Core infarct volume, CBF and clinical characteristics for predicting prognosis of patients with acute cerebral infarction

NCCT相比,分析CTA和CTP的源图像进行ASPECT评分可以更好地确定最终梗死体积<sup>[15]</sup>,更好地预测患者预后。此外,ASPECT评分并不适用于腔隙性脑梗死或大脑中动脉分布区外的脑梗死,进一步限制了ASPECT评分的临床应用。

通过分析CTP灌注参数,本研究发现相比较预后较差的AIS患者,预后较好的AIS患者有着较小的梗死核心区体积和较低的CBF值。这与Vogt<sup>[16]</sup>和Schiemanck<sup>[17]</sup>的研究结果相仿。近年来,血管腔内治疗开始逐渐应用于临床,血管腔内治疗可以将急性脑梗死患者的治疗时间窗延长至24 h。Lansberg<sup>[18]</sup>的研究表明CTP可以用来预测筛选能通过血管介入治疗获益的患者。另外两个临床随机对照研究<sup>[19-20]</sup>表明,小的梗死核心与AIS患者的预后明确相关。进一步,Jelle研究<sup>[21]</sup>表明与ASPECT评分相比,急性脑梗死梗死核心区体积更能反映AIS患者的预后。然而,本研究发现多因素分析发现梗死核心的体积,梗死核心区CBF值用来预测急性脑梗死的预后价值有限。Rüdiger<sup>[22]</sup>认为当CBF值低于15 mL/100 g·min时,脑组织将发生不可逆损伤;而本文发现AIS患者预后较差组的平均CBF值均低于上述该阈值。这一研究结果支持本研究中

单因素分析中CBF可以用来预测AIS患者,然而本研究较少的样本量,或许会对研究结果产生偏倚,本研究结果尚需更大样本量的证实。

本文的研究局限性有以下几点:病例数较少,未双盲、随机分组对统计分析会产生一定的影响。影响脑梗死结局的其他重要影响因素包括梗死部位、缺血性脑卒中的机制、共存疾病、流行病学因素及脑卒中并发症,本文因为病例数较少,并没有涉及该方面讨论。此外,本文多因素分析发现纳入治疗后NIHSS评分和年龄,同AIS患者预后最相关,而CBF和梗死核心区体积同AIS的预后尚不具有明确相关性。这也恰恰说明了急性脑梗死预后相关的影响因素很多。但是,预测AIS患者预后,通过研究手段去选择合理的治疗人群,一站式CTP可以作为一个很好的方法提供更多有价值的信息。

AIS患者梗死核心区体积、CBF、治疗前后NIHSS及治疗后ASPECTS评分与患者的预后密切相关。相比较NIHSS评分,梗死核心区体积及CBF对于预测急性脑梗死预后有着更高的特异度。

致谢:感谢高振华教授在统计学和论文撰写方面给予的指导。感谢广东省卒中学会的支持。

## 参考文献

- [1] Khandelwal P, Yavagal DR, Sacco RL, et al. Acute ischemic stroke intervention [J]. *J Am Coll Cardiol*, 2016, 67(22): 2631-2644.
- [2] Barber PA, Demchuk AM, Zhang J, et al. Validity and reliability of a quantitative computed tomography score in predicting outcome of hyperacute stroke before thrombolytic therapy. ASPECTS Study Group. Alberta Stroke Programme Early CT Score [J]. *Lancet*, 2000, 355(9216): 1670-1674.
- [3] Becks MJ, Manniesing R, Vister J, et al. Brain CT perfusion improves intracranial vessel occlusion detection on CT angiography [J]. *J Neuroradiol*, 2019, 46(2): 124-129.
- [4] Kim EY, Shin DH, Noh Y, et al. Comparison of imaging selection criteria for intra-arterial thrombectomy in acute ischemic stroke with advanced CT [J]. *Eur Radiol*, 2016, 26(9): 2974-2981.
- [5] Hopyan J, Ciarallo A, Dowlatshahi D, et al. Certainty of stroke diagnosis incremental benefit with CT perfusion over noncontrast CT and CT angiography [J]. *Radiology*, 2010, 255(1): 142-153.
- [6] Campbell BC, Weir L, Desmond PM, et al. CT perfusion improves diagnostic accuracy and confidence in acute ischaemic stroke [J]. *Neurol Neurosurg Psychiatry*, 2013, 84(6): 613-618.
- [7] 田冰, 刘崎, 许兵, 等. 一站式CT成像对成人烟雾病重建手术疗效的评估 [J]. *影像诊断与介入放射学*, 2015, 24(6): 476-481.
- Tian B, Liu Q, Xu B, et al. One-stop 320-slice CT before and after revascularization of adult Moyamoya disease [J]. *Diagn Imaging & Interv Radiol*, 2015, 24(6): 476-481.
- [8] 马光铄, 刘勇, 冯学泉, 等. 4D-CTA在脑血管疾病诊断中的应用进展 [J]. *中国神经精神疾病杂志*, 2020, 46(5): 300-303.
- Ma GS, Liu Y, Feng XQ, et al. Application progress of 4D-CTA in the diagnosis of cerebrovascular diseases [J]. *Chin J Nerv Ment Dis*, 2020, 46(5): 300-303.
- [9] Schramm P, Schellinger PD, Klotz E, et al. Comparison of perfusion computed tomography and computed tomography angiography source images with perfusion-weighted imaging and diffusion-weighted imaging in patients with acute stroke of less than 6 hours' duration [J]. *Stroke*, 2004, 35(7): 1652-1658.
- [10] Menon BK, D'Esterre CD, Qazi EM, et al. Multi-phase CT angiography: a new tool for the imaging triage of patients with acute ischemic stroke [J]. *Radiology*, 2015, 275(2): 510-520.
- [11] Frankel MR, Morgenstern LB, Kwiatkowski T, et al. Predicting prognosis after stroke: a placebo group analysis from the National Institute of Neurological Disorders and Stroke rt-PA Stroke Trial [J]. *Neurology*, 2000, 55(7): 952-959.
- [12] Sumer MM, Ozdemir I, Tascilar N. Predictors of outcome after acute ischemic stroke [J]. *Acta Neurol Scand*, 2003, 107(4): 276-279.
- [13] Srivatsan A, Christensen S, Lansberg MG. A relative noncontrast CT map to detect early ischemic changes in acute stroke [J]. *J Neuroimaging*, 2019, 29(2): 182-186.
- [14] Nagel S, Joly O, Pfaff J, et al. e-ASPECTS derived acute ischemic volumes on non-contrast-enhanced computed tomography images [J]. *Int J Stroke*, 2020, 15(9): 995-1001.
- [15] 林印, 陈燕浩, 余波, 等. 急性脑梗死患者应用256层MSCT行全脑CTP与CTA检查的诊断价值 [J]. *中国CT和MRI杂志*, 2019, 17(5): 4-6.
- Lin Y, Chen YH, Yu B. Diagnostic value of whole brain CTP and CTA of 256-slice MSCT in patients with acute cerebral infarction [J]. *Chin J CT MRI*, 2019, 17(5): 4-6.
- [16] Vogt G, Laage R, Shuaib A, et al. Initial lesion volume is an independent predictor of clinical stroke outcome at day 90: an analysis of the Virtual International Stroke Trials Archive (VISTA) database [J]. *Stroke*, 2012, 43(4): 1266.
- [17] Schiemanck SK, Kwakkel G, Post MW, et al. Predictive value of ischemic lesion volume assessed with magnetic resonance imaging for neurological deficits and functional outcome poststroke: A critical review of the literature [J]. *Neurorehabil Neural Repair*, 2006, 20(4): 492-502.
- [18] Lansberg MG, Christensen S, Kemp S, et al. Computed tomographic perfusion to predict response to recanalization in ischemic stroke [J]. *Ann Neurol*, 2017, 81(6): 849-856.
- [19] Nogueira RG, Jadhav AP, Haussen DC, et al. Thrombectomy 6 to 24 Hours after Stroke with a mismatch between deficit and infarct [J]. *N Engl J Med*, 2018, 378(1): 11-21.
- [20] Albers GW, Marks MP, Kemp S, et al. Thrombectomy for stroke at 6 to 16 hours with selection by perfusion imaging [J]. *N Engl J Med*, 2018, 378(8): 708-718.
- [21] Jelle D, Lauranne S, Sandra AC, et al. Alberta stroke program early CT score versus computed tomographic perfusion to predict functional outcome after successful reperfusion in acute ischemic stroke [J]. *Stroke*, 2018, 49(10): 2361-2367.
- [22] Rüdiger K, Imanuel D. Imaging of cerebral ischemic edema and neuronal death [J]. *Neuroradiology*, 2017, 59(6): 545-553.