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自由呼吸状态下冠状动脉 CT 血管成像的可行性研究 *

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摘要 目的:探讨自由呼吸状态下冠状动脉 CT 血管成像(Coronary CT Angiography, CCTA)的可行性。**方法:**收集 187 例疑似冠心病患者,所有患者均行 CCTA 检查,其中 108 例采用传统屏气法扫描,79 例采用自由呼吸法扫描。扫描采用前门控预估法(Auto Gating)测得冠脉扫描期相,设置扫描范围和参数(准直宽度 256×0.625、224×0.625、192×0.625,球管转速 0.28 s, kV100,智能管电流,噪声指数 25)。对比剂浓度为 370 mgI/mL,注药量为 0.86 mL/kg,注药时间维持 12 s。由 2 名高年资放射科医师对冠状动脉图像采用 5 分法评分。测量升主动脉根部(冠状动脉左主干开口水平)和胸壁肌肉的 CT 值及标准差,计算图像的信噪比和对比噪声比。**结果:**自由呼吸状态下右冠状动脉(Right coronary artery, RCA)、左前降支(Left ascending artery, LAD)、左旋支(Left circumflex artery, LCx)的优良血管率分别为 46.5%(87/187)、51.9%(97/187)及 48.7%(91/187);屏气状态下 RCA、LAD、LCx 的优良血管率分别为 32.6%(61/187)、36.4%(68/187)及 36.9%(69/187),两组之间无统计学差异(Fisher 值分别为 6.94、1.54、0.81, P 均>0.05)。采用自由呼吸和屏气状态下 CCTA 检查的主动脉 CT 值、噪声、SNR 和 CNR 均无统计学差异(P 均>0.05)。**结论:**采用超宽探测器 CT,自由呼吸法 CCTA 可完全取代传统屏气法 CCTA 检查,从而降低受检者的配合难度,提高工作效率。

关键词:体层摄影术;X 线计算机;血管成像;冠状动脉;自由呼吸;图像质量;前瞻性心电门控

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Feasibility of Free-breathing Coronary CT Angiography*

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ABSTRACT Objective: To investigate the feasibility of free-breathing coronary CT angiography (CCTA). **Methods:** Coronary CT angiography was performed in 187 patients with suspected coronary heart disease. Of all cases, 108 were scanned under traditional breath holding and 79 were scanned under free breathing. The scanning phase estimation technique (Auto Gating) was used to determine the optimum phase of coronary scan, and the scanning range and sequence parameters were arranged (collimation width: 256×0.625 mm, 224×0.625 mm, 192×0.625 mm, rotation rate: 0.28 s, kV100, intelligence tube current, noise index: 25). The concentration of contrast medium was 370 mgI/mL, the injection dose was 0.86 mL/kg, and the injection maintenance time was 12s. Image quality of coronary artery was scored by two experienced radiologist using five point scales. The CT value and standard deviation of aortic root and chest wall muscle were measured, and noise-signal ratio and contrast-noise ratio were calculated. **Results:** Under the condition of free respiration, the excellent and good image quality (score 4 and 5) ratio of RCA, LAD and LCx were 46.5% (87/187), 51.9% (97/187) and 48.7% (91/187), respectively. Under the condition of breath holding, the excellent and good image quality ratio of RCA and LAD, excellent rate of LCx was 32.6% (61/187), 36.4% (68/187) and 36.9% (69/187). There was no significant difference between the two groups (Fisher=6.94, 1.54, 0.81, all P values > 0.05). The CT value, noise, SNR and CNR of the aorta were not statistically different(P>0.05) between the two groups. **Conclusion:** When using the ultra wide detector CT, the free breathing CCTA can replace the traditional breath holding CCTA, thus reducing the cooperation difficulty of patient and improving the work efficiency.

Key words: Tomography, X-ray computed; Angiography; Coronary artery; Free breathing; Image quality; Prospective gated

Chinese Library Classification (CLC): R445; R541 **Document code:** A

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前言

冠状动脉 CT 血管成像(Coronary CT Angiography, CCTA)是冠心病最佳的无创筛查方法,已广泛应用于临床^[1]。但患者行 CCTA 检查时一般需要屏气扫描,否则呼吸伪影将严重影响图

像质量。随着新一代超宽排 CT 设备的出现,时间分辨率得到了很大提高。从理论上讲,呼吸运动对心脏成像质量影响将会变得非常小。另外,超宽排 CT 能在一个心动周期内完成扫描,增强了图像对抗运动伪影干扰能力,明显提高了检查成功率。目前国内、外对自由呼吸与屏气 CCTA 对比研究较少。本文通

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过对照自由呼吸和屏气状态下 CCTA 的图像质量,探讨自由呼吸状态下冠状动脉 CT 血管成像的可行性。

1 资料与方法

1.1 患者资料

搜集本院 2016 年 12 月至 2017 年 2 月临床疑诊冠心病且均行 CCTA 检查的患者 187 例,其中采用自由呼吸状态下扫描的患者 108 例,平均扫描时心率为 (70.4 ± 14.8) 次/分钟;采用屏气状态下扫描的患者 79 例,平均扫描时心率为 (71.5 ± 12.5) 次/分钟。女性 75 例,男性 112 例,年龄范围为 $(35 \sim 87)$ 岁,平均年龄为 (62.6 ± 9.8) 岁。

1.2 仪器与方法

所有患者均采用 GE Revolution CT(GE Healthcare)进行图像采集。检查时患者采用仰卧位,使用 370 mgI/mL 对比剂(碘普罗胺注射液,拜耳医药保健有限公司广州分公司),注射剂量为 0.86 mL/kg,注药时间维持 12 s。采用前门控预估法(Auto Gating)测得冠状动脉扫描期相,设置扫描范围和序列参数(准直宽度 256×0.625 mm, 224×0.625 mm, 192×0.625 mm,检查床不动,球管转速 0.28 s/r,KV100,智能 mA,噪声指数设置为 25)。图像采集使用自动触发扫描,监测点为剑突下 1 cm 的升主动脉处,注药 10 s 后球管开始曝光监测,间隔 1 s 监测一次,阈值设定为 70 HU,达阈值后延迟 9.9 秒开始图像采集,图像采集时间为 0.4 s~0.7 s。

1.3 图像后处理

采用 Smart Phase 技术根据软件血管自动评分的结果为依据选取最佳期相。自由呼吸状态下和屏气状态下采集的图像设为 A 组,Smart Phase 技术自动期相选择后的图像设为 B 组,经 SSF 矫正的标准算法图像设为 C 组,经 SSF 矫正的 Smart Phase 组图像设为 D 组。

1.4 图像质量评价

由两名高年资放射科医师在不知道分组的情况下对两组

图像采用 5 分法分别对左前降支(Left ascending artery, LAD)、右冠状动脉(Right coronary artery, RCA)和左旋支(Left circumflex artery, LCx)进行主观评价,存在差异时经协商后得出一致结论。图像评价标准:1 分代表血管横断面边界模糊,有明显运动伪影,血管对比很差,伪影干扰非常严重,无法进行诊断;2 分代表血管横断面边界模糊,有较多运动伪影;3 分代表血管横断面边界清晰,有运动伪影,血管对比差,连续性差;4 分代表血管横断面边界清晰,无漂移、运动伪影,血管对比良好,血管边缘清晰,连续性好,无伪影。图像质量评分 ≥ 4 分为优良。根据美国心脏协会(AHA)的分段标准将冠状动脉分为 15 段,逐段评估。由一名放射科医师在工作站上测量每名患者四组图像升主动脉根部(冠状动脉左主干开口水平)及胸壁肌肉的 CT 值及标准差,将主动脉根部的 CT 值标准差作为图像噪声。计算图像的信噪比(signal-to-noise ratio, SNR)和对比噪声比(contrast-to-noise ratio, CNR)。

1.5 统计学方法

采用 SPSS 16.0 软件。各组间主动脉根部的噪声、SNR、CNR 之间比较采用配对样本的 t 检验。各组间图像质量主观评分的比较采用 Fisher 精确检验。 $P < 0.05$ 为统计学具有显著性差异的标准。

2 结果

2.1 主观图像评分比较

自由呼吸状态下三支血管的优良血管数大于屏气状态下的优良血管数,自由呼吸状态下 RCA、LAD、LCx 的优良血管(4 分+5 分)率分别为 46.5%(87/187)、51.9%(97/187)及 48.7%(91/187);屏气状态下 RCA、LAD、LCx 的优良血管(4 分+5 分)率分别为 32.6%(61/187)、36.4%(68/187)及 36.9%(69/187)。自由呼吸和屏气状态下的 RCA、LAD 和 LCx 主观评分之间无统计学差异(Fisher 值分别为 6.94、1.54、0.81, P 均 > 0.05)(表 1,图 1、2)。

表 1 两组冠脉主观评分比较

Table 1 Comparison of subjective scores for coronary artery between two groups

	Free breathing				Breath holding				Fisher value	P value
	2 points	3 points	4 points	5 points	2 points	3 points	4 points	5 points		
RCA	2	19	56	31	6	12	30	31	6.94	0.07
LAD	1	10	46	51	1	10	28	40	1.54	0.74
LCx	3	15	38	53	2	8	29	40	0.81	0.87

2.2 客观图像质量比较

自由呼吸和屏气状态下主动脉 CT 值、噪声、SNR 和 CNR 均无统计学差异(P 均 > 0.05)(表 2)。

3 讨论

CCTA 图像质量受多种因素影响,其主要取决于患者检查中的配合和扫描时心率及扫描方案选择^[2-6]。在以往的 CCTA 检查中,患者在检查中的屏气配合十分关键。随着 CT 设备不断更新换代,超宽排探测器的应用,扫描时间明显缩短,从而使得呼吸运动在理论上对 CCTA 扫描的影响可忽略不计^[7-10]。本研

究入组 187 例患者验证这一理论的可行性。

本研究采用超宽排 CT 行屏气状态和自由呼吸状态下前门控扫描,其它扫描条件均保持一致。心脏 CCTA 扫描后所有患者数据均采用 Smart Phase 技术和运动追踪冻结技术(Snapshot Freeze, SSF)进行后处理,保证两组内均采用最佳质量图像进行对比^[11]。本研究中 187 例患者的 CCTA 均扫描成功,自由呼吸状态下扫描得到的三支主要冠状动脉 RCA、LAD 和 LCx 的优良血管率分别为 46.5%、51.9%及 48.7%,屏气状态下 RCA、LAD 和 LCx 的优良血管率分别为 32.6%、36.4%及 36.9%。自由呼吸扫描组三支冠状动脉的优良血管率较屏气组

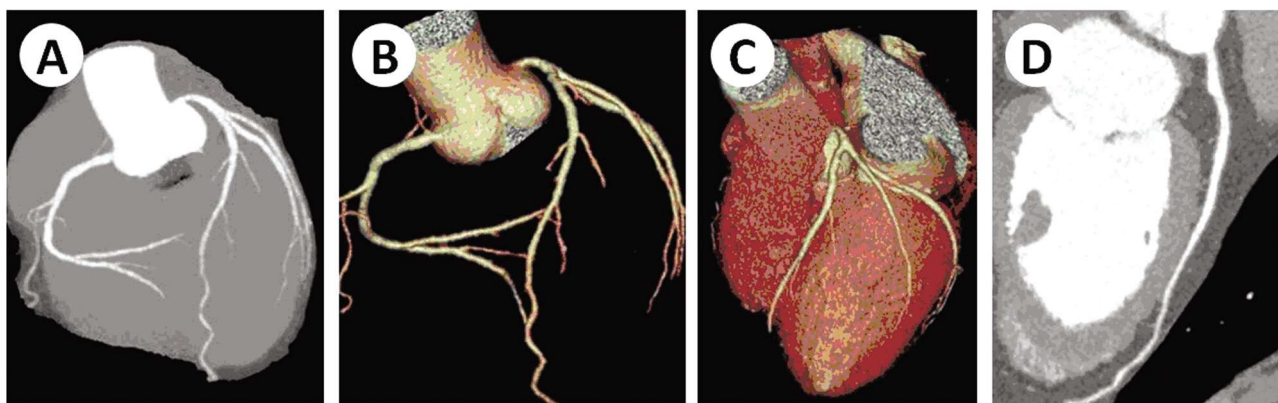


图1 60岁男性患者,BMI 26 千克/平方米 2,扫描心率 57 次/分钟,采用自由呼吸状态下前门控扫描,冠状动脉显影清晰,未见运动伪影干扰,图像主观评分为 5 分

注:1A 最大密度投影图像,1B 冠状动脉树 VR 图像,1C 心脏 VR 图像,1D LAD 曲面重建图像。

Fig.1 60-year-old male, BMI 26kg.m-2, heart rates during scanning 57 bpm, free breathing prospective acquisition. No obvious motion artifact was observed. The image scored 5 points

Note: 1A MIP image, 1B VR image of coronary artery tree, 1C VR image of heart, 1D Curved projection reconstruction image.

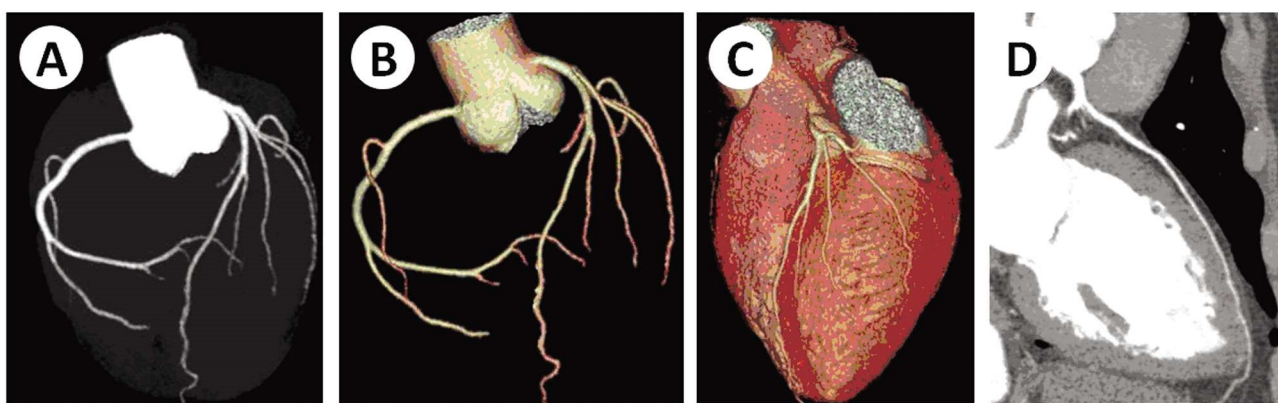


图2 45岁男性患者,BMI :19 千克/平方米 2,扫描心率:58 次/分钟,采用屏气状态下前门控扫描。冠状动脉显影清晰,未见运动伪影干扰,图像主观评分为 5 分。

注:2A 最大密度投影图像,2B 冠状动脉树 VR 图像,2C 心脏 VR 图像,2D LAD 曲面重建图像

Fig.2 45-year-old male, BMI:19kg.m-2, heart rates during scanning: 58 bpm, breathing hold prospective acquisition. No obvious motion artifact was observed. The image scored 5 points

Note: 2A MIP image, 2B VR image of coronary artery tree, 2C VR image of heart, 2D Curved projection reconstruction image.

表 2 两组客观图像质量比较

Table 2 Comparison of objective scores between two groups

	CT values of aorta	Noise	SNR	CNR
Free breathing	538.96± 93.74	36.44± 7.57	15.16± 3.17	13.53± 2.97
Breath holding	522.31± 129.52	36.77± 4.88	14.30± 3.56	12.71± 3.48
F value	7.57	6.66	1.86	2.57
P value	0.25	0.33	0.09	0.09

有所提高,但统计学上无差异($P>0.05$)。这可能是患者在自由呼吸状态下不会产生由于紧张情绪和屏气带来的心率不确定性变化所致伪影干扰,同时呼吸运动所致伪影在超快的扫描模式下产生的影响可忽略不计,从而使得图像主观质量评分反而较屏气状态下高。另外,自由呼吸状态下扫描所得到的图像噪声较屏气状态下略降低,而图像的 SNR 和 CNR 则稍有提高,但差异无统计学意义,这表明自由呼吸状态下 CCTA 扫描的图像客观质量不但没有受到影响,且有一定程度的提高。

我们的研究结果显示自由呼吸状态下 CCTA 图像主动脉根部感兴趣区 CT 值为(538.96 ± 93.74)HU,而屏气状态下为(522.31 ± 129.52)HU。自由呼吸状态下的血管密度较屏气状态下略有提高,使得在造影剂量和注射速率相同的情况下得到对比度更高的图像。Bischoff B 等^[12]对屏气不好的患者采用大螺距冠状动脉 CT 扫描,与屏气患者的图像质量无显著差异。但这种方法对心率要求很高,且数据采集不完整,有一定弊端。而我们采用的是超宽排 CT 扫描,且扫描速度极快,并采用了

Smart Phase 和 SSF 技术,对患者心率几乎无特殊要求^[13-17]。另外,我们采用了轴位扫描模式,重建后图像质量较螺旋扫描得到改善^[18-20]。综上所述,采用超宽排 CT 冠状动脉血管成像完全可以用自由呼吸法取代传统屏气法,大大简化了冠状动脉成像检查流程,降低受检者的配合难度,节省了患者呼吸训练所花费的时间,明显提高了工作效率和成功率。

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