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管电压对下肢 CT 血管成像辐射剂量及图像质量的影响研究 *

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摘要 目的：研究管电压对下肢 CT 血管成像辐射剂量及图像质量的影响。**方法：**选取 2016 年 1 月 -2017 年 10 月于我院行下肢 CT 血管成像的患者 102 例，将其以随机数字表法均分成观察组与对照组，每组 51 例。对照组管电压取 120kV，观察组管电压取 80kV，其他扫描参数相同。分别比较两组辐射剂量情况、客观图像质量以及主观图像质量情况。**结果：**观察组 CT 剂量指数（CTDIvol）、计量长度乘积（DLP）、有效辐射剂量（ED）水平均明显低于对照组，差异均有统计学意义（*P<0.05*）。观察组腹主动脉、髂总动脉、股动脉、腘动脉、胫前动脉、胫后动脉、腓动脉 CT 值以及图像噪声均明显高于对照组，差异均有统计学意义（*P<0.05*），两组动脉对比噪声比（CNR）和信噪比（SNR）比较差异无统计学意义（*P>0.05*）。观察组血管阶段显示评分、血管细节分支显示评分均明显高于对照组，而血管边缘锐利度评分明显低于对照组，差异均有统计学意义（*P<0.05*）。**结论：**下肢 CT 血管成像采用 80kV 管电压扫描可有效降低患者所接受的辐射剂量，且能获取较为满意的图像，值得临床推广应用。

关键词：下肢血管；CT 血管成像；管电压；图像质量；辐射剂量

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Effect of Tube Voltage on Radiation Dose and Image Quality of CT Angiography in Lower Extremities*

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ABSTRACT Objective: To study the effect of tube voltage on radiation dose and image quality of CT angiography in lower extremities. **Methods:** 102 patients with CT angiography of the lower extremities in our hospital in January 2016 to October 2017 were selected. The patients was divided into the observation group and the control group by the random digital table method, with 51 cases in each group. The control group was given tube voltage with 120 kV, the observation group was given tube voltage with 80 kV, and the other scanning parameters were the same. The radiation dose, the objective image quality and the subjective image quality of the two groups were compared. **Results:** The computed tomographic dose index (CTDIvol), dose length product (DLP) and effective dose (ED) levels in the observation group were significantly lower than those in the control group, the differences were statistically significant (*P< 0.05*). The CT value of abdominal aorta, iliac artery, femoral artery, popliteal artery, anterior tibial artery, posterior tibial artery, the peroneal artery and image noise in observation group were significantly higher than the control group, the differences were statistically significant (*P<0.05*). There was no significant difference in contrast noise ratio (CNR) and noise-signal ratio (SNR) between the two groups (*P>0.05*). The score of vascular phase and the score of vascular detail branch in the observation group were significantly higher than those of the control group, while the vascular edge sharpness score of the observation group was significantly lower than that of the control group, the difference was statistically significant (*P<0.05*). **Conclusion:** CT angiography of the lower extremities with 80 kV tube voltage scanning can effectively reduce the radiation dose accepted by the patients, and it can obtain satisfactory images, which is worthy of clinical application.

Key words: Lower extremity vessel; CT angiography; Tube voltage; Image quality; Radiation dose

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前言

下肢血管病变主要是指由糖尿病等发展的一种严重慢性并发症，对患者的日常生活活动能力以及生活质量造成了严重影响，如不给予及时有效的治疗，易导致患者残疾，甚至死亡，给患者家庭以及社会造成了严重的经济负担[1-3]。近年来，随着螺旋 CT 技术的不断发展，CT 血管成像在临床疾病诊断中得到了广泛的运用，其具有较高的准确度、敏感度，是一种无创的下肢动脉病变诊断方法[4-6]。然而，CT 检查所存在的高辐射性与潜在的危害性亦被广泛关注。如何在保证图像质量的基础上，

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进一步减少患者所受的辐射剂量是国内外所研究的热点。鉴于此，本文通过研究不同管电压对下肢 CT 血管成像辐射剂量及图像质量的影响并予以分析，旨在为临床下肢病变患者提供一种有效的 CT 血管成像检查方式。现作以下阐述。

1 资料与方法

1.1 一般资料

选取 2016 年 1 月 -2017 年 10 月于我院行下肢 CT 血管成像的患者 102 例。纳入标准[7]：(1)所有患者均经临床检查疑似存在下肢血管病变，均行 CT 血管成像检查；(2)年龄 >20 岁；(3)临床病历资料完整；(4)无精神疾病或交流沟通障碍。排除标准：(1)合并心、肝、肾等脏器功能严重障碍者；(2)对造影剂过敏者；(3)依从性较差者；(4)体质量指数≥ 25 kg/m² 者。将其以随机数字表法均分成观察组与对照组，每组 51 例。其中观察组男性 28 例，女性 23 例，年龄 21-82 岁，平均(43.42± 10.52)岁；病程 3-34 年，平均(22.12± 3.25)年；体质量指数 18-24 kg/m²，平均(20.15± 1.49)kg/m²。对照组男性 29 例，女性者 22 例，年龄 22-81 岁，平均年龄(43.52± 10.57)岁；病程 4-34 年，平均病程(22.16± 3.24)年；体质量指数 19-24 kg/m²，平均体质量指数(20.16± 1.49)kg/m²。两组一般资料比较差异无统计学意义(*P>0.05*)，说明组间存在可比性。两组患者均签署了知情同意书，我院伦理委员会已批准。

1.2 研究方法

所有患者入院后均采用 GE 公司 64 排螺旋 CT 予以扫描，仪器型号为 Lightspeed VCT，扫描参数：对照组管电压取 120 kV，观察组管电压取 80 kV。管电流均设置为 200 mAs，对比剂均为 350 mgI/mL 的欧乃派克，剂量为 100 mL，噪声指数设置为 15.40%ASiR，层厚取 5 mm，重组层厚取 0.625 mm，球管转速为 0.8 s/r，准直为 64× 0.625 mm，高清扫描模式。扫描时患者均取仰卧位，扫描范围自腹主动脉下段到足尖。预置 20G 套管针，对比剂由高压单筒注射器从右侧肘正中静脉进行注射，注射速率控制为 4 mL/s。在扫描过程中启用对比剂跟踪技术，兴趣区设置在肾动脉水平腹主动脉上，触发阈值设置为 100HU，当达到 100HU 后手动触发扫描。在扫描完成后，利用 GE ADW4.4 工作站处理图像。

1.3 观察指标

分别比较两组辐射剂量情况、客观图像质量以及主观图像质量情况。系统根据检测过程中的扫描参数自动计算辐射剂量情况，包括 CT 剂量指数(computed tomographic dose index，CTDIvol)、剂量长度乘积(dose length product，DLP)、有效辐射剂量(effective dose，ED)，其中 ED 计算公式如下：ED=k× DLP，k 属于组织权重因子，其值为 0.019。客观图像质量主要是通过测量腹主动脉、髂总动脉、股动脉、腘动脉、胫前动脉、胫后动脉、腓动脉 CT 值以及评估图像噪声、动脉对比噪声比(contrast noise ratio，CNR)、信噪比(noise-signal ratio，SNR)。其中 CNR=(血管 CT 值 - 背景肌肉 CT 值)/ 图像噪声；SNR= 血管 CT 值 / 图像噪声[8]。主观图像质量评价方式如下：由我院 2 名副主任医师通过双盲法，采用 5 分评价法分别对图像血管节段显示、血管细节分支显示以及血管边缘锐利度进行评估，评分越高表示图像质量越好。

1.4 统计学方法

本研究数据均采用 SPSS20.0 软件进行统计分析，CTDIvol、DLP、ED 水平等计量资料用（$\bar{x}\pm s$）表示，采用 t 检验，将 α=0.05 作为检验标准。

2 结果

2.1 两组辐射剂量情况对比

观察组 CTDIvol、DLP、ED 水平均明显低于对照组（*P< 0.05*），见表 1。

表 1 两组辐射剂量情况对比($\bar{x}\pm s$)

Table 1 Comparison of radiation doses of two groups($\bar{x}\pm s$)

Groups	n	CTDIvol(mGy)	DLP(mGy/cm)	ED(mSv)
Observation group	51	7.76± 0.05	414.59± 2.48	1.87± 0.45
Control group	51	10.01± 0.03	1157.23± 5.25	22.14± 0.12
t	-	275.568	913.409	310.820
P	-	0.000	0.000	0.000

2.2 两组客观图像质量结果对比

观察组腹主动脉、髂总动脉、股动脉、腘动脉、胫前动脉、胫后动脉、腓动脉 CT 值以及图像噪声均明显高于对照组（*P< 0.05*），两组 CNR 和 SNR 比较差异无统计学意义(*P>0.05*)，见表 2。

2.3 两组主观图像质量评价结果对比

观察组血管阶段显示评分、血管细节分支显示评分均明显高于对照组，而血管边缘锐利度评分明显低于对照组（*P< 0.05*），见表 3。

3 讨论

随着近年来螺旋 CT 技术的飞速发展，CT 血管成像因具有无创性、高准确性开始被广泛应用于周围血管疾病的诊断中[9-11]。然而，CT 检查的高辐射性及其潜在的危害性亦日益受到关注。如何在满足临床需求的基础上，尽量降低患者所受的辐射剂量是目前临床研究的热点。有研究报道显示，管电压、管电流、扫描时间、螺距以及曝光时间等均是影响 CT 辐射剂量的因素[12-14]。临床上主要通过增加螺距、降低管电流以及降低管电压等方式来降低 CT 辐射剂量[15,16]，增加螺距可以缩减曝光时间，进而降低辐射剂量，但螺距的增加程度不宜过大，主要因为螺距过大会导致 Z 轴分辨率下降，同时增加了小病灶漏检的概

表 2 两组客观图像质量结果对比($\bar{x}\pm s$)

Table 2 Comparison of objective image quality results of two groups($\bar{x}\pm s$)

Objective image quality indexes	Observation group(n=51)	Control group(n=51)	t	*P*
CT value of abdominal aorta	485.87± 34.28	341.29± 40.27	19.524	0.000
CT value of iliac artery	473.58± 36.01	330.21± 39.98	19.029	0.000
CT value of femoral artery	455.87± 47.52	331.59± 40.24	14.253	0.000
CT value of popliteal artery	395.27± 53.81	282.50± 28.94	13.181	0.000
CT value of anterior tibial artery	297.77± 47.51	211.27± 29.05	11.093	0.000
CT value of posterior tibial artery	287.25± 47.27	211.28± 30.15	9.677	0.000
CT value of peroneal artery	282.59± 52.46	211.17± 28.84	8.520	0.000
Image noise	15.49± 0.72	11.14± 1.12	23.332	0.000
CNR	25.42± 3.29	24.85± 3.28	0.876	0.383
SNR	29.41± 3.45	29.78± 3.15	0.566	0.573

表 3 两组主观图像质量评价结果对比($\bar{x}\pm s$,分)

Table 3 Comparison of subjective image quality evaluation results between two groups($\bar{x}\pm s$, scores)

Groups	n	Vascular phase display score	Vascular detail branches display score	Vascular edge sharpness score
Observation group	51	4.38± 1.02	4.61± 0.42	3.75± 0.60
Control group	51	3.49± 1.08	3.36± 0.73	4.61± 0.52
t	-	4.279	10.599	7.735
P	-	0.000	0.000	0.000

率,存在一定的局限性[17,18]。而电流量与辐射量存在线性关系,因此通过降低管电流可减少患者所受的辐射剂量,然而随着管电流的降低,图像信噪比也会相应降低,从而对结果产生一定程度的影响[19-21]。而管电压的降低不仅会促使辐射剂量减少,同时亦会降低 X 线能力,导致组织对 X 线的吸收量增加,降低信噪比,为临床诊断提供更为准确、可靠的图像信息[22,23]。因此,通过降低管电压以减少患者收缩辐射剂量逐渐受到重视。

本研究结果发现,观察组 CTDIvol、DLP、ED 水平均明显低于对照组(*P<0.05*)。这与葛涌钱等人的研究报道相一致[24],表明了降低管电压可有效降低辐射剂量。分析原因在于:按照 X 射线强度公式 $I=KiZU^2$(其中 I 为 X 射线强度;K 为比例系数;Z 为阳极靶材料的原子序数;i 为管电流;U 为管电压)可知,X 射线强度与管电压的评分存在正相关关系,因此辐射剂量会随着管电压的降低而减少,且在公式中管电压是以二次方的形式存在,因此与降低管电流相比,降低管电压能更明显的减少辐射剂量。此外,观察组腹主动脉、髂总动脉、股动脉、腘动脉、胫前动脉、胫后动脉、腓动脉 CT 值以及图像噪声均明显高于对照组(*P<0.05*),这提示了降低管电压可获得较为满意的图像质量。分析原因,可能是由于 CT 图像中组织结构的 CT 值主要受到 X 线光子的能量水平和组织密度的影响,而 X 线和人体组织的相互作用主要形式为康普顿散射效应以及光电效应。随着管电压的降低,其所发射的 X 线光子能力降低,当光子能力水平与含高原子序数的组织和结构相近时,光电效应会增大[25,26]。因此,管电压的降低会促使 X 线能力水平更接近对比剂碘原子 K 层结合能,从而增强其产生的光电效应,进一步导致 CT 值升高。然而,两组 CNR 和 SNR 比较差异无统计学意义(*P>0.05*)。这与既往研究存在一定差异[27]。分析原因,作者认为可能与采用了自动毫安技术有关,从而有效弥补了低管电压导致的噪声增加。另外,观察组血管阶段显示评分、血管细节分支显示评分均明显高于对照组,而血管边缘锐利度评分明显低于对照组(*P<0.05*),这提示了在一定程度上降低管电压对图像质量具有较好的提升作用。究其原因,可能是由于管电压的降低会导致血管强化值增加,从而促使血管节段与细小分支显示增加。而血管边缘锐利度的下降可能与噪声增加相关。需要指出的是,本研究也存在以下不足之处[28-30]:(1)样本量较少,从而可能导致研究结果发生一定程度的偏倚。(2)本研究只针对体质量指数 <25 kg/m^2 者,存在一定的局限性;(3)螺距会对辐射剂量产生影响,未对其进行研究。因此,在今后的研究中应增大样本量,纳入体质量指数≥ 25 kg/m^2 的患者,并对螺距与辐射剂量的关系进行研究,从而为临床下肢 CT 血管成像检查寻找一种既能有效降低辐射剂量又能保证图像质量的方式。

综上所述,80kV 的管电压应用于下肢 CT 血管成像检查中可显著降低患者所受的辐射剂量,同时有利于增加血管 CT 值与血管节段、细小分支的显示,具有较高的临床推广应用价值。

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