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基于图像重建的 CT 三维重建提升腹部增强扫描图像质量的价值 *

叶 菊 何绪成 陈晓霞 韩文娟 王贵生△

(解放军总医院第三医学中心放射诊断科 北京 100039)

摘要 目的:探讨基于图像重建的电子计算机断层扫描仪器(Computed Tomography,CT)三维成像提升腹部增强扫描图像质量的价值。**方法:**2019 年 11 月到 2020 年 10 月选择在本院进行腹部 CT 增强扫描的患者 76 例作为研究对象,采用电脑随机数字法将研究对象分为对照组和重建组各 38 例,对照组给予常规扫描成像,重建组给予基于自适应统计迭代重建(adaptive statistical iterative reconstruction,ASIR)的 CT 三维成像,记录两组成像质量与噪声情况。**结果:**两名医师对重建组的图像主观质量评分都高于对照组(P<0.05)。重建组的图像相对细腻柔和,能清晰显示图像细小血管断面,末梢血管显示良好,血管壁光滑柔和。重建组的动脉期、门静脉期、平衡期的肝脏 CT 值高于对照组(P<0.05),动脉期、门静脉期、平衡期的肝脏、胰腺对比噪声比(contrast to noise ratio,CNR)值低于对照组(P<0.05)。重建组的容积剂量指数(volume CT dose index,CTDIvol)和剂量长度乘积(Dose-Length product,DLP)、有效剂量(effective dose,ED)值都低于对照组(P<0.05)。**结论:**基于图像重建的 CT 三维成像能提升腹部增强扫描主客观图像质量,降低图像噪声,更利于腹部疾病的显示,从而提高正确诊断率。

关键词:图像重建;CT 三维成像;图像质量;图像噪声;腹部增强扫描

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The Value of CT Three-dimensional Imaging Based on Image Reconstruction to Improve the Image Quality of Abdominal Enhanced Scan*

YE Ju, HE Xu-cheng, CHEN Xiao-xia, HAN Wen-juan, WANG Gui-sheng△

(Department of Radiology, Third Medical Center, General Hospital of Chinese People's Liberation Army, Beijing, 100039, China)

ABSTRACT Objective: To explore the value of Computed Tomography (CT) three-dimensional imaging based on image reconstruction to improve the image quality of abdominal enhanced scan. **Methods:** From November 2019 to October 2020, 76 cases of patients who underwent enhanced abdominal CT scans in our hospital were selected as the research objects. All the cases were divided into the control group and reconstruction group with 38 cases in each group. And the control group were given routine scanning imaging, the reconstruction group were given CT three-dimensional imaging based on adaptive statistical iterative reconstruction (ASIR), and the imaging quality and noise of the two groups were recorded. **Results:** The subjective quality scores of the two doctors in the reconstruction group were higher than those in the control group (P<0.05). The images of the reconstruction group were relatively delicate and soft, and could clearly show the sections of small blood vessels, the peripheral blood vessels were well displayed, and the blood vessel walls were smooth and soft. The CT values of the liver and pancreas in the arterial, portal and balance phase of the reconstruction group were higher than those of the control group (P<0.05), and the contrast to noise ratio (CNR) values of the liver and pancreas in the arterial, portal and balance phases were lower than those of the control group (P<0.05). The volume CT dose index (CTDIvol), Dose-Length product(DLP) and effective dose (ED) values of the reconstruction group were lower than those of the control group (P<0.05). **Conclusion:** CT three-dimensional imaging based on image reconstruction can improve the subjective and objective image quality of abdominal enhanced scanning, reduce image noise, and is more conducive to the display of abdominal diseases, thereby increase the correct diagnosis rate.

Key words: Image reconstruction; CT three-dimensional imaging; Image quality; Image noise; Abdominal enhanced scan

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前言

随着诊断图像空间、时间分辨力的不断提高,电子计算机断层扫描仪器(Computed Tomography,CT)成像技术得到了广泛应用。CT 是依靠 X 线衰减的密度成像,优质的 CT 图像质量是准确诊断病变的前提[1,2]。多层螺旋 CT 成像是评估腹部病变的主要手段和方法,其中 CT 门静脉增强扫描成像可以很好地显示门静脉的解剖结构及其病变关系,明确门静脉背景状况和提供足够小的图像噪声,从而获得良好 CT 增强门脉图像,为临床治疗提供依据[3-5]。特别是 CT 三维成像可以获得单能量

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作者简介:叶菊(1983-),女,本科,主治医师,研究方向:CT、影像诊断,电话:15901492742,E-mail:yejuuu83@163.com

△ 通讯作者:王贵生(1969-),男,博士,主任医师,研究方向:CT、影像诊断,电话:15313302627,E-mail:wgs6969@163.com

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(monochromatic，MONO)、混合能量(polychromatic，QC)等多种重建模式图像，可对同一检查部位进行同时成像，能实现瞬时高低管电压切换，也可减少对比剂用量[6,7]。但是由于重建图像较多，选择适宜的图像重建模式具有重要价值。自适应统计迭代重建(adaptive statistical iterative reconstruction，ASIR)为当前比较新的图像重建计数，能够有效降低图像噪声，不仅能能获得组织器官功能和成分信息，也获得常规的解剖学信息[9-11]。本文具体探讨了基于图像重建的 CT 三维成像提升腹部增强扫描图像质量的价值，希望为临床上筛选最佳图像重建方法提供参考。现总结报道如下。

1 资料与方法

1.1 研究对象

2019 年 11 月到 2020 年 10 月选择在本院进行腹部 CT 增强扫描的患者 76 例作为研究对象，纳入标准：行上腹部双期(动脉期和门静脉期)增强 CT 扫描；患者没有碘对比剂过敏史；年龄 20~80 岁；扫描期间无死亡情况发生；本院伦理委员会批准了此次研究；患者均签署知情同意书。排除标准：妊娠期女性；重度脂肪肝患者；意识不清者或精神疾病患者；腹主动脉及分支动脉血栓或癌栓患者；呼吸不能配合患者；主动脉夹层、腹部动脉介入术后患者；肝脏、胰腺弥漫性病变患者。

采用电脑随机数字法将研究对象分为对照组和重建组各 38 例，两组患者的 BMI、性别、年龄、心率、血压等对比差异无统计学意义(P>0.05)，见表 1。

表 1 两组一般资料对比

Table 1 Comparison of two general data

Groups	n	BMI (kg/m2)	Gender (M/F)	Age (years)	Heart rate (sub/min)	SPB (mmHg)	DPB (mmHg)
Reconstruction group	38	22.49±1.48	21/17	54.11±4.18	87.22±3.54	123.87±12.57	78.22±3.83
Control group	38	22.87±2.22	22/16	54.98±3.33	88.14±4.44	124.09±14.82	78.87±4.11

1.2 CT 成像方法

所有患者扫描范围膈顶至双肾下极，采用 GEHD750 CT 机。

对照组：给予常规扫描成像，CT 参数：自动管电流调制、扫描视野(50 cm×50 cm)、噪声指数 10 HU、管电压 120 kVp、X 线管转速 0.7 s/ 周、螺距 1.375、探测器宽度 40 mm、层厚 5 mm、层间距 5 mm。对比造影剂使用 350 mgI/mL 的碘海醇，流率(mL/s)= 对比剂总量 (mL)/30 s，对比剂注射总量 = 体重×450 mgI/kg/350 mgI/mL，对比剂开始注射后 30 s、60 s、90 s 行动脉期、门静脉期、平衡期扫描。

重建组：给予基于 ASIR 图像重建的 CT 三维成像，CT 参数：管电压 140 kVp 和 80 kVp 瞬时切换，转速 0.5-1.0 s/ 周，选取 40-65 keV 单能量图像分别联合 40 %~60 %ASIR 重建，其余参数同对照组。对比造影剂使用 300 mgI/kg 的碘海醇，流率(mL/s)= 对比剂总量 (mL)/30 s，对比剂注射总量 = 体重×300 mgI/kg/350 mgI/mL。

1.3 观察指标

(1) 主观图像质量评价：由两名工作 3~5 年和 6~10 年的 CT 影像学诊断医师按 5 分法分别进行评定，5 分：优：图像背景噪声较少，病变与正常腹部组织器官很好区分；4 分：良：图像背景噪声少，病变组织与正常肺组织区分较好；3 分：中：图像背景噪声一般，病变组织与正常腹部组织器官勉强可以区分；2 分：差：图像背景噪声较重，病变组织与正常腹部组织器官区分困难；1 分：非常差：图像背景噪声重，病变显示不清。(2)客观图像质量评价：将感兴趣区(region of interest，ROI)置于动脉期、门静脉期、平衡期的肝脏 CT 值。同时记录与计算动脉期、门静脉期、平衡期的肝脏、胰腺对比噪声比(contrast to noise ratio，CNR)，上述指标测定三次取平均值。(3)在所有患者的剂量报告中记录扫描对应的容积剂量指数(volume CT dose index，CTDIvol)和剂量长度乘积(Dose-Length product，DLP)，计算有效剂量(effective dose，ED)。

1.4 统计方法

选择 SPSS 22.00 软件对本研究所有数据进行分析，计量资料用均数±标准差表示 (对比为 t 检验、Wilcoxon 符号秩检验等)，计数数据以百分比表示(对比为卡方 χ^2 检验)，P<0.05 为差异有统计学意义。

2 结果

2.1 图像主观质量评分对比

两名医师对重建组的图像主观质量评分都高于对照组(P<0.05)，见表 2。重建组的图像相对细腻柔和，能清晰显示像细小血管断面，末梢血管显示良好，血管壁光滑柔和。

表 2 两名医师对不同组别的图像主观质量评分对比(分，$\bar{x}\pm s$)

Table 2 Comparison of the subjective quality scores of two doctors in different groups (points, $\bar{x}\pm s$)

Groups	n	Doctors working 3-5 years	Doctors working 6-10 years
Reconstruction group	38	4.66±0.22*	4.72±0.18*
Control group	38	4.11±0.18	4.14±0.15

Note: *Compared with the control group, P<0.05.

2.2 图像客观质量对比

重建组的动脉期、门静脉期、平衡期的肝脏 CT 值高于对照组(P<0.05)，动脉期、门静脉期、平衡期的肝脏、胰腺 CNR 值低于对照组(P<0.05)，见表 3。

表 3 两组图像 CT 值与 CNR 值对比($\bar{x}\pm s$)

Table 3 Comparison of CT values and CNR values of the two groups of images ($\bar{x}\pm s$)

Groups	n	Liver CT(HU)			Liver CNR			Pancreas CNR		
		Arterial phase	Portal vein phase	Balance phase	Arterial phase	Portal vein phase	Balance phase	Arterial phase	Portal vein phase	Balance phase
Reconstruction group	38	14.66±1.48*	14.43±1.49*	14.02±1.48*	0.94±0.14*	3.10±0.48*	3.19±0.22*	2.23±0.14*	1.82±0.17*	1.67±0.13*
Control group	38	11.87±2.22	11.09±1.74	11.09±2.37	1.17±0.18	3.89±0.87	4.18±0.33	3.18±0.16	3.48±0.22	3.78±0.77

Note: *Compared with the control group, $P<0.05$.

2.3 剂量参数对比

重建组的 CTDIvol、DLP、ED 值都低于对照组($P<0.05$),见表 4。

表 4 两组剂量参数对比($\bar{x}\pm s$)

Table 4 Comparison of dose parameters between the two groups ($\bar{x}\pm s$)

Groups	n	CTDIvol(mGy)	DLP(mGy.cm)	ED(mSv)
Reconstruction group	38	11.38±2.09*	368.87±43.09*	5.49±0.87*
Control group	38	19.33±1.48	527.98±38.77	7.98±1.33

Note: *Compared with the control group, $P<0.05$.

3 讨论

腹部来源肿瘤是临床常见病，外科手术是主要的治疗方法。但是在术前需对肿瘤情况进行鉴别与诊断,了解肿瘤与周围血管关系,以判断肿瘤可切除性,为制定最佳的手术方案提供参考[10]。超声是影像学诊断腹部来源不明肿瘤最常见的一种检查方法,具有快速、受腹腔肠道气体影响小,但是诊断的特异性有待提高[11,12]。CT 增强成像因空间分辨率高、图像后处理功能强大、采集层厚薄等优点而广泛应用于腹部疾病的诊断。但是传统 CT 成像容易产生硬化伪影,从而影响图像质量及对疾病的正确诊断[13,14]。特别是当前螺旋 CT 使得腺体强化的微小改变能迅速被发现,较小的肿瘤也能检出;也可在不增加患者辐射剂量的情况下,可通过多期扫描以提供更多的影像诊断信息。CT 三维成像采用瞬时 kVp 切换技术,可在短时间内实现两组数据的瞬时同时采样,通过双能量解析可获得不同能量水平的能量图像,从而改善图像质量[15,16]。特别是在三维成像中,可通过两组数据的重建，从而得到动态性的质量吸收系数,可计算出单能量点组织对 X 线的吸收,重建最佳多参数图像。而在图像重建中,ASIR 能够自动匹配扫描参数,也在不增加对比剂用量的基础上,提高图像质量[17]。不过当肿瘤与周围多个脏器空间关系密切、肿瘤体积较大超出其所属脏器时,常规依据 CT 平扫与增强期图像难以判断肿瘤来源。

当腹部肿瘤体积巨大时,腹部各器官移位变形显著,失去了原来的解剖位置与正常形态,肿瘤与腹部各器官关系显示欠清,肿瘤的定位不确切,导致鉴别诊断比较困难。本研究显示两名医师对重建组的图像主观质量评分都高于对照组;重建组的动脉期、门静脉期、平衡期的肝脏 CT 值高于对照组,动脉期、门静脉期、平衡期的肝脏、胰腺 CNR 值低于对照组。与庞瑞奕[18]的研究类似,比较分析原发性肝癌患者多层螺旋 CT 动脉期,全肝静脉期及病灶平衡期扫描结果,对照组患者仅进行多层螺旋 CT 平扫,实验组患者进行三期扫描,结果实验组患者多层螺旋 CT 检查动脉期,全肝静脉期,病灶平衡期病灶显示率均显著高于对照组。但是对于基于图像重建的 CT 三维成像能提升腹部增强扫描的动脉期、门静脉期、平衡期的肝脏、胰腺 CNR 值目前还没有报道。从机制上分析,CT 值、SNR 值是腹部疾病血管图像质量评价最重要的客观指标,CT 值增加表明血管强化程度高,意味着在 CT 扫描中可获得良好的动脉图像[19]。足够的 CNR 是显示腹部血管的根本保证，也是显示腹部动脉解剖结构及病变的基础,但是过高的 CNR 可造成图像模糊[20]。当前有学者将 40-65 keV 的低单能量图像纳入研究,也可获得相当于或高于常规扫描的 CT 值[21]。能够使 CT 可根据高低能量的扫描原始数据重组得到基底物质与图像,利用相应基底物质的吸收曲线计算出特定范围内的单能量图像,然后获得混合能量图像,通过 ASIR 图像重建可以调整适宜能量水平,从而改善图像质量[22-24]。

虽然随着部分肿物体积增大可诱导部分起源器官外动脉参与供血,但绝大多数肿瘤由起源器官的动脉供血。多层螺旋 CT 检查具有无创伤、速度快、价格优惠等优点,增强扫描在获得常规断面图像的同时可显示腹部肿瘤的供血动脉[25,26]。CT 三维成像能追踪血管走行及其与肿块的关系,可在任意平面显示包括细小血管在内的肿块周围血管的侵犯情况,也显示腹部肿瘤主要的和变异的供血动脉[27]。有研究显示能谱 CT 也增加图像噪声,特别是管电流可选择的范围比较有限,使得辐射剂量较高 [28,29]。ASIR 重建技术将扫描参数预设为多种三维成像模式,基于患者的体重指数和所设定的扫描参数,自动选择最佳三维成像模式,有利于获得与常规扫描相当的辐射剂量[30]。本研究显示重建组的 CTDIvol、DLP、ED 值都低于对照组。目前对于基于图像重建的 CT 三维成像能提升腹部增强扫描的 CTDIvol、DLP、ED 值没有类似研究,于鹏[31]的研究探讨了 MSCT 增强扫描动脉期、静脉期、延迟期 3 个扫描时期对消化道活动

性出血的诊断价值，结果显示动脉期＋静脉期 CTDIvol 、DLP、ED 值低于动脉期＋静脉期＋延迟期，静脉期模型出血点 CT 值普遍高于动脉期及延迟期出血点 CT 值，与本研究不同。从机制上分析，ASIR 技术采用统计迭代算法进行修正，通过建立系统噪声模型，能够有效降低图像噪声[32]。不过本研究没有对 ASIR 技术的权重值进行分析，未考虑患者体型对辐射剂量的影响，纳入的病例数量较少；并且图像重建的 CT 三维成像效果取决于扫描时段血管内造影剂浓度及含量，当肿瘤内出现多支供血动脉时，诊断的敏感性会显著降低，需要在后续研究中进一步完善分析。

总之，基于图像重建的 CT 三维成像能提升腹部增强扫描主客观图像质量，降低图像噪声，更利于腹部疾病的显示，从而提高正确诊断率。

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