# 基于迭代算法小儿门静脉低剂量螺旋CT成像可行性

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【摘 要】目的：探讨多层螺旋CT基于迭代算法和低kV在小儿门静脉成像的可行性和相关图像质量评价。方法：收集10例在我院已经做过腹部血管CT检查，且因临床需要被要求复查的住院儿童纳入研究。经肘正中静脉入路，注射欧乃派克350对比剂，流速1.5 mL/s ~2.0 mL/s，完成动脉期（120 kV, 100 mAs）和门脉期（80 kV, 100 mAs）扫描，分别记录每位患儿动脉期和门脉期的平均容积CT剂量指数（Recorded Volume CT Dose Index , CTDIv）和辐射剂量长度乘积（Dose Length Product, DLP）值，并计算有效辐射剂量（Effective Dosage, ED）。将10例患儿首次腹部血管CT检查的门脉期图像（常规剂量）和本次检查的门脉期图像（低剂量）进行回顾性重建，分为A和B两组：A组为FBP+标准函数；B组为迭代4（iDose[4]）+标准函数。在工作站上分别完成门静脉血管重建的最大密度投影（Maximum Intensity Projection, MIP）、容积重现（Volume Rendering, VR）和多平面投影重建（Multi-Planar reformation, MPR），并在门脉分支中心层面分别测量腹主动脉、门静脉、肝右叶实质三个结构的CT值和图像噪声（Standard Deviation, SD）值。由2位资深放射科医生共同评价门静脉图像质量。结果：B组门脉期扫描（低剂量）的DLP与ED分别是（72.70±14.78）mGy·cm和（2.49±0.46）mSv，均低于动脉期扫描（常规剂量）的（152.00±25.12）mGy·cm和（14.78±1.71）mSv（$F$=440.65, $P$<0.001）；A、B两组间的门脉SD值无明显差异，门脉强化CT值分别为216.02±15.36 HU和323.39±7.98 HU，有显著性差异（$F$=384.87, $P$<0.01）。A、B两组门脉图像均符合诊断图像质量要求，B组门脉图像显示优于A组。结论：基于iDose4迭代算法的小儿低剂量门静脉成像切实可行。

【关键词】门静脉；辐射剂量；血管造影术；小儿体层摄影术；迭代算法
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## Feasibility of multi-slice computed tomography with low-dose based on iterative algorithms in children portal vein imaging

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**Abstract: Objective** To explore the feasibility of multi-slice computed tomography (MSCT) based on iterative algorithms and low kV in the portal vein (PV) imaging of children, and evaluate the related image quality. **Methods** Ten hospitalized children, who had been examined by CT abdominal agiography and had to undergo the same CT scan again for clinical needs, were selected. Omnipaque (350 mgI/ml) with the rate of 1.5-2.0 ml/s was administrated through the median cubital vein. The arterial phase (120 kV, 100 mAs) and PV phase (80 kV, 100 mAs) scans were undertaken. The average CT dose index volume and dose-length product (DLP) of the arterial phase and PV phase were recorded, and the effective dosage (ED) was calculated. Ten PV images examined by the first CT abdominal agiography (routine dose) and the second CT scan (low dose) were reconstructed in two ways. Group A was routine dose, processed by FBP+standard function, while group B was low dose, processed by iDose[4]-4+standard function. The maximum intensity projection, volume rendering and multiplanar reformation of PV were conducted on a workstation. The CT values of the abdominal aorta, PV, and liver parenchyma and the standard deviation (SD) of image noise were measured in the central layer of the PV branch. And the PV image quality was evaluated by two experienced radiologists. **Results** The DLP and ED were respectively (72.70±14.78) mGy·cm and (2.49±0.46) mSv in group B, and (152.00±25.12) mGy·cm, (14.78±1.71) mSv in group A, with significant differences ($F$=440.65, $P$<0.001). No significant differences were found between these two groups in the SD of PV. While the PV enhancement CT values was

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respectively (216.02±15.36) HU and (323.39±7.98) HU in group A and group B, with significant differences ($F$=384.87, $P$< 0.01). The PV images of these two groups met the quality requirement for diagnostic image, but the PV images in group B were better than those in group A. **Conclusion** MSCT with low-dose based on iDose$^4$-4+standard function is feasible in the children PV imaging.

**Key words:** portal vein; radiation dose; angiography; tomography of children; iterative algorithms

## 前 言

近年来,CT在儿童腹部检查和诊断中发展迅速,如在神经母细胞瘤的诊断和手术评估、门静脉高压合并各类并发症(脾肿大,肝硬化和腹水等)的确诊等。CT扫描速度快,图像后处理工作站功能强大,血管三维重建可进行任意层面和3D图像的呈现。然而随着CT使用的增加,其辐射剂量问题也慢慢成为不可被忽视的问题。有研究表明:接受过X线检查的人,当其寿命超过75岁时,癌症发生概率将增加0.6%,主要是膀胱癌、结肠癌和白血病[1]。儿童尤其是低龄小儿处于生长发育期,细胞分裂更新速度和比例远高于成人,所以对放射线的敏感性也远高于成人。小儿受辐照年龄越小,致癌危险越大[2]。CT检查时,相同扫描条件下辐射剂量引发的余生肿瘤致死率,小儿是成人的10~15倍[3],相同条件下进行CT检查时被检体越小,其受到的辐射剂量越高。因此低剂量扫描已经成为CT成像的主流。降低剂量的方法主要有降低管电压、降低管电流或者减少扫描时间或长度等[4-6]。近年来飞速发展的迭代重建算法以大幅降低噪声为特征,已经得到广泛认可[7-9]。本文同时使用低管电压和迭代重建算法,以小儿门静脉为目标,探讨复合CT血管成像技术在小儿腹部血管中的初步可行性研究[10]。

## 1 材料与方法

### 1.1 一般资料

收集10例在我院已经做过腹部血管CT检查,且因临床需要被要求复查的住院儿童。男6例,女4例。年龄范围1岁~5岁,平均年龄(2.6±1.5)岁,所有的患者家属都知情同意。

### 1.2 CT检查方法

采用PHILIPS Brilliance 256层ICT,探测器为(128*0.625)mm;使用MALLINCKRODT高压注射器;对比剂采用欧乃派克350(350 mgI/mL)。患儿采取仰卧位,于平静呼吸下进行扫描。对于不合作的患儿,待其熟睡或检查前服用10%水合氯醛0.5 mL/kg体质量镇静后进行扫描。扫描范围从膈面到髂嵴。经肘正中静脉入路,注射欧乃派克350对比剂(2 mL/kg),流速1.5 mL/s~2.0 mL/s,动脉期为20 s~25 s,门脉期为45 s~55 s。

本论文采用的扫描条件为动脉期使用常规剂量条件(120 kV,100 mAs)。门脉期使用低剂量条件(80 kV,100 mAs)。动脉期和门脉期除了扫描条件不同,其余条件均保持相同。螺距0.92,准直器(128*0.625)mm,球管旋转1周时间为0.4 s,层厚5 mm,间隔5 mm。分别记录每位患儿动脉期和门脉期的平均容积CT剂量指数(Recorded Volume CT Dose Index, CTDIv)和辐射剂量长度乘积(Dose Length Product, DLP)值。其中的动脉期相对于常规扫描,门脉期相当于低剂量扫描。并计算有效剂量(Effective Dosage, ED),ED=k*DLP,小儿1岁~5岁间的腹部转换系数k采用0.030 mSv·mGy$^{-1}$·cm$^{-1}$。

### 1.3 图像后处理与评价

将10例患儿首次腹部血管CT检查的门脉期图像(常规剂量)和本次检查的门脉期图像(低剂量)进行不同条件回顾性重建,分为A和B两组:A组为常规剂量组,B组为低剂量组。A组为FBP+标准函数;B组为迭代4(iDose$^4$)+标准函数。两组重建图像数据导入PHILIPS Extended Workspace工作站,重建层厚1.0 mm,层间隔0.5 mm,重叠层厚0.5 mm。重建FOV 350 mm。分别完成门脉三维重建,以门脉最佳显示层面位置(门脉主干、脾静脉和肠系膜上静脉显示最长的层面)为显示位置,显示模式包括最大密度投影(Maximum Intensity Projection, MIP)、容积重现(Volume Rendering, VR)和多平面投影重建(Multi-Planar reformation, MPR)。

以门脉分为左右支的中心层面为选定测量平面,分别测量该层面中腹主动脉、门脉、肝右叶肝实质三个结构的ROI的CT值及图像噪声(Standard Deviation, SD)值,以腹主动脉和门静脉的SD值定义为图像噪声值。

分别对两组重建门脉图像进行MIP冠状面及VR重建图像观察分级分支情况(MIP:窗宽300 HU、窗位180 HU;VR采用固定模式),2位资深放射科CT医生共同评价,分为优、良、中、差四个等级。以门脉

主干为第一分支：优秀（清晰显示5级及以上分支）；良好（略有伪影和噪声仍能显示4级以上分支）；中（有一定伪影和噪声，仍能显示3级以上分支，满足基本临床诊断）；差（噪声伪影大，无法显示3级以上分支，无法进行诊断）。

### 1.4 统计学分析

采用SPSS19.0统计学软件进行分析：计量资料采用均数±标准差表示。对两组图像的腹主动脉CT值、门脉（Portal Vein, PV）CT值、肝实质CT值及图像噪声SD值，用完全随机设计方差分析法（One-way ANOVA），组间比较采用LSD法。对重建VR和MIP图像分级进行$t$检验并对两位医师的评价一致性进行Kappa检验。以$P<0.05$作为差异有显著意义的检验标准。

## 2 结 果

### 2.1 常规剂量（动脉期）与低剂量（门脉期）指标比较

低剂量（门脉期）扫描的CTDIv、DLP和ED分别为1.95 mGy、(72.70±14.78) mGy · cm和(2.49±0.46) mSv；常规剂量（动脉期）扫描的CTDIv、DLP和ED分别为3.95 mGy、(152.00±25.12) mGy · cm和(14.78±1.71) mSv，低剂量扫描的上述3个指标均明显低于常规剂量（$F$=440.65, $P$<0.001），其量值约为常规剂量的1/2。

### 2.2 横断面测量客观比较

横断面两组图像腹主动脉增强CT值以及图像噪声SD值统计结果见表1。两组腹主动脉CT强化值有B组远大于A组，两组比较有显著性统计学差异（$F$=236.18，$P$<0.01），两组腹主动脉噪声值无统计学差异（$P$>0.05）；两组图像PV强化值比较有显著性差异（$F$=384.87，$P$<0.01），肝实质CT值、PV和肝实质SD值两两比较，差异无统计学意义。B组门脉对比度均大于300 HU。门脉CT密度均大于腹主动脉密度。

表1 两组图像腹主动脉，PV和肝实质CT测量值（HU, $\bar{x}\pm s$）

**Tab.1 CT values of the abdominal aorta, PV, and liver parenchyma (HU, *Mean±SD*)**

| Group | CT value of abdominal aorta | SD of abdominal aorta | CT value of PV | SD of PV | CT value of liver parenchyma | SD of liver parenchyma |
|---|---|---|---|---|---|---|
| A | 203.94±19.53 | 16.09±2.86 | 216.02±15.36 | 21.08±3.04 | 82.13±7.64 | 14.07±3.96 |
| B | 312.68±10.93 | 13.80±3.16 | 323.39±7.98 | 22.36±3.97 | 80.11±6.92 | 16.38±5.11 |
| *F* value | 236.18 | 2.88 | 384.87 | 0.657 | 4.632 | 1.277 |
| *P* value | <0.01 | >0.05 | <0.01 | >0.05 | >0.05 | >0.05 |

Note: Group A was routine dose, processed by FBP+standard function, while group B was low dose, processed by iDose4-4+standard function- PV: Portal vein; SD: Standard deviation

### 2.3 MIP和VR图像评价

A组和B组的MIP图像的优良率均为100%，VR图像的优良率分别为80%和100%，见表2。两组的MIP和VR重建图像均能较好地显示门脉各级分支，A和B两组间比较具有显著性差异()$P$<0.05)。两名医师MIP和VR图像评分一致性较好（Kappa=0.812, $P$<0.05）。

基于iDose[4]迭代算法技术结合低kV参数的B组PV图像质量和图像噪声评分均高于常规剂量结合FBP（Filter back projection）算法的A组PV图像。B组PV图像不仅降低辐射剂量，低kV参数的引入，使得B组PV的CT值明显高于A组，即血管对比度大大增加，见图1和2。

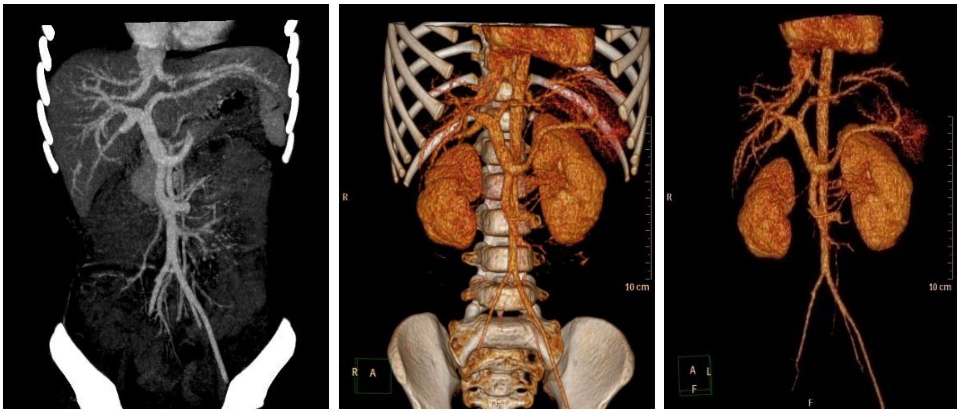
图1和图2分别是同一患儿低剂量扫描和常规剂量扫描图像。图1从左至右(a-c)分别为MIP冠状位、门脉VR带脊柱标志和VR去骨图像（iDose[4]）。图2从左至右(a-c)分别为MIP冠状位、门脉VR带脊柱

表2 两组VR图像和MIP图像评价（$\bar{x}\pm s$）

**Tab.2 Evaluation of VR images and MIP images (*Mean±SD*)**

| Group | VR | | | | | MIP | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Excellent | Good | Average | Poor | PV grading | Excellent | Good | Average | Poor | PV grading |
| A | 5 | 3 | 2 | 0 | 3.70±0.82 | 7 | 3 | 0 | 0 | 4.50±0.81 |
| B | 8 | 2 | 0 | 0 | 4.50±0.71 | 9 | 1 | 0 | 0 | 4.70±0.68 |

Note: VR: Volume rendering; MIP: Maximum intensity projection

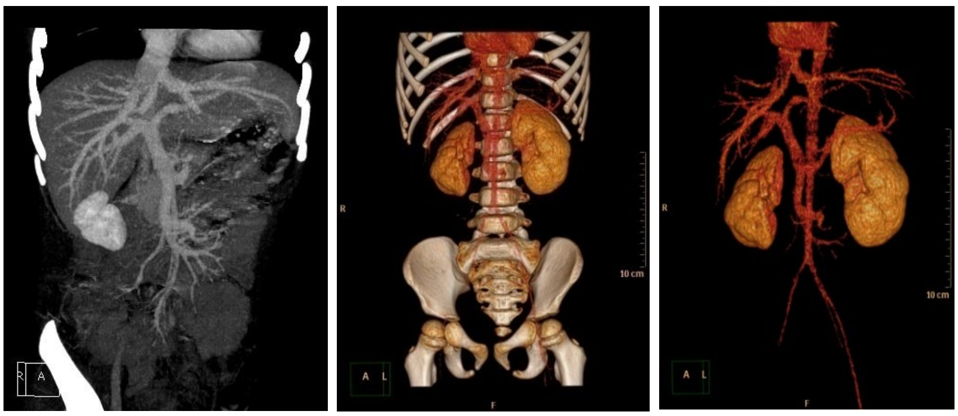


a: Coronal MIP of PV　　b: VR of PV with bone　　c: VR of PV without bone

图1　同一患儿低剂量扫描MIP与VR图

**Fig.1　MIP and VR of the same child undergoing low dose scan**

Note: MIP: Maximum intensity projection; VR: Volume Rendering



a: Coronal MIP of PV　　b: VR of PV with bone　　c: VR of PV without bone

图2　同一患儿常规剂量扫描MIP和VR图

**Fig.2　MIP and VR of the same child undergoing routine scan**

标志和VR去骨图像(FBP)。A组图像的CTDIv为1.91 mGy,B组图像的CTDIv为3.94 mGy,此患儿的两次门脉血管扫描,应用iDose4迭代算法技术后,辐射剂量下降约52%,冠状位MIP图像质量和视觉效果相当,但B组VR图像的对比度和清晰度明显高于A组。

## 3 讨论与结论

小儿低剂量CT扫描技术的使用应该遵循最优化原则,即满足临床诊断要求的基础上,尽可能降低患儿的辐射剂量。降低管电压可以大幅度降低辐射剂量,同时可以增加图像对比度,但是会大大增加图像噪声。iDose4迭代技术可以在滤波反投影重建的基础上降低图像的噪声,提高扫描图像质量,所以合理应用iDose4重建技术可以抑制重建图像噪声上升和图像质量的下降,达到还原图像来保证图像质量的目的。

本次小儿低剂量腹部血管可行性的初步研究采用80 kV+100 mAs+iDose4复合成像技术,在常规注射速率和检查方法条件下,获得了优质的小儿门脉图像,与常规剂量扫描相比,有效剂量下降了50%,所有的门脉CT值都超过300 HU,这是CT血管成像的重要前提[11]。

小儿体层薄,较成人更适合低剂量的复合成像方案,因此小儿低剂量CT检查可以具有普遍性和广泛性。本研究数据显示,基于迭代算法的小儿低剂量CT门静脉成像切实可行。

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