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How many CT detector rows are necessary to perform adequate three dimensional visualization?

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ABSTRACT

Introduction: The technical development of computer tomography (CT) imaging has experienced great progress. As consequence, CT data to be used for 3D visualization is not only based on 4 row CTs and 16 row CTs but also on 64 row CTs, respectively. The main goal of this study was to examine whether the increased amount of CT detector rows is correlated with improved quality of the 3D images.
Material and Methods: All CTs were acquired during routinely performed preoperative evaluation. Overall, there were 12 data sets based on 4 detector row CT, 12 data sets based on 16 detector row CT, and 10 data sets based on 64 detector row CT. Imaging data sets were transferred to the DKFZ Heidelberg using the CHILI teleradiology system. For the analysis all CT scans were examined in a blinded fashion, i.e. both the name of the patient as well as the name of the CT brand were erased. For analysis, the time for segmentation of liver, both portal and hepatic veins as well as the branching depth of portal veins and hepatic veins was recorded automatically. In addition, all results were validated in a blinded fashion based on given quality index.
Results: Segmentation of the liver was performed in significantly shorter time ($p < 0.01$, Kruskal–Wallis test) in the 16 row CT (median 479 s) compared to 4 row CT (median 611 s), and 64 row CT (median 670 s), respectively. The branching depth of the portal vein did not differ significantly among the 3 different data sets ($p = 0.37$, Kruskal–Wallis test). However, the branching depth of the hepatic veins was significantly better ($p = 0.028$, Kruskal–Wallis test) in the 4 row CT and 16 row CT compared to 64 row CT. The grading of the quality index was not statistically different for portal veins and hepatic veins ($p = 0.80$, Kruskal–Wallis test). Even though the total quality index was better for the vessel tree based on 64 row CT data sets (mean scale 2.6) compared to 4 CT row data (mean scale 3.25) and 16 row CT data (mean scale 3.0), these differences did not reach statistical difference ($p = 0.53$, Kruskal–Wallis test).
Conclusion: Even though 3D visualization is useful in operation planning, the quality of the 3D images appears to be not dependent of the number of CT detector rows.

1. Introduction

In recent years, the technical development of computer tomography (CT) imaging has experienced great progress [1]. Nowadays, 64 or even 320 simultaneous detector rows are considered as state of the art [2]. The use of such multi detector CTs (MDCT) has gained acceptance among clinicians especially in the field cardiology [2–7]. In fact, the diagnostic quality of these MDCT was shown in studies, some of them performed in a randomized fashion [8–10].

We and others were dealing with three dimensional (3D) visualization of the liver anatomy based on CT data for many years [11–15]. The main goal of this research was to increase anatomical and surgical understanding for challenging surgical procedures such as liver transplantations [11,16–19]. That is, 3D visualization provides information about the individual anatomy including the course of the intrahepatic vessels and volumetric data about remnant liver tissue or the parenchyma to be resected much easier for the human eye than regular CT images would do [11,15,20,21].

Abbreviations: CT, computer tomography; MDCT, multi detector CT; 3D, three dimensional; 2D, two dimensional.

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In order to convert two dimensional CT images into 3D-data as exact as possible, the segmentation (= recognition) of relevant hepatic structures such as liver parenchyma, portal veins, hepatic veins, hepatic arteries, the bile duct system, and the gall bladder, respectively is mandatory. Because portal and hepatic veins are the corner stones of the Couinaud segmental classification [22], the segmentation quality of these intrahepatic vessels is considered most important [23,24]. During the last years, CT data to be used for 3D visualization was based on 4 row, 16 row, and 64 row CTs, respectively. So far, there is no data available describing whether the increased number of detector rows results in qualitative better 3D images of the human liver. Thus, the main goal of this study was to examine whether the amount of CT detector rows is correlated with increased quality of the 3D images.

2. Material and methods

CT scans were made available by the Department of Interventional and Diagnostic Radiology of the University of Heidelberg. All CTs were acquired during routinely performed preoperative evaluation. Overall, there were 12 data sets based on 4 detector row CT (Siemens Volume Zoom 4, Siemens, Erlangen, Germany), 12 data sets based on 16 detector row CT (Toshiba Aquilion 16 slice multidetector CT scanner, Japan) and 10 data sets based on 64 multidetector row CT (Siemens Definition 64 rows, Siemens, Erlangen, Germany).

Image data acquired with the 4 row Siemens Volume Zoom required two contrast enhanced spiral scans (5 mm collimation, 3 mm secondary image reconstruction) following an injection of 130 ml Imeron 300 (Bracco Altana Pharma, Konstanz, Germany) with a flow rate of 4–5 ml/s. Image data acquired with a Toshiba Aquilion 16 slice multidetector CT scanner (Toshiba, Japan) required a standard bi- or tri-phasic liver scan with an optimized portal venous phase. SureStart bolus tracking technique (130 ml Imeron 300, Bracco Altana Pharma, Konstanz, Germany, flow rate 4–5 ml/s) was used to optimize vascular contrast. Image data acquired with a 64 multidetector row Siemens CT required two contrast enhanced spiral scans (3 mm collimation, 2.0 mm secondary image reconstruction) following an injection of 150 ml of Ultravist 370 (Bayer Vital, Leverkusen, Germany, flow rate of 6 ml/s) at an injection rate of 6 ml/s. The first scan was started 15 s after an enhancement threshold of 100 HE was obtained in the aorta. These obtained acquisition data were then transferred via the PACS-system (GE^{TM} Centricity^{TM}, USA) to a specialized imaging workstation.

Imaging data sets were transferred to the Department of Medical and Biological Informatics of the German Cancer Research Center using the CHILI teleradiology system (CHILI GmbH, Heidelberg, Germany [25,26]). For the analysis all CT scans were examined in a blinded fashion, i.e. both the name of the patient as well as the name of the CT brand were erased. In a first step, all CT were randomly administered to the segmentation process which utilizes interactive region growing techniques. The portal and hepatic veins were segmented using a grey value based volume growing technique. The segmentation was then transformed automatically into a symbolic representation of the vascular anatomy, containing the vessel paths, locations of bifurcations as well as the vessels diameters. The time for segmentation of liver, both portal and hepatic veins as well as the depth of the branching of portal vein and hepatic veins was recorded automatically. In addition, all results were validated by a team consisting of surgeons, radiologists and medical computing specialists. Based on given quality index (Table 1 and Fig. 1) one surgeon and one radiologist rated the quality of the vessel tree of portal and hepatic veins independent of each other. Since, there were differences between the quality of the vessel tree of portal and hepatic veins the overall quality of the vessel tree was judged additionally. In 13 out of 34 samples the opinion of radiologist and surgeons differed. In these cases, a consensus was found after looking at the data together.

Table 1
Quality index as used to grade the portal and vessel trees of the according 3D liver visualization.

Scale	Synonym	Description
1	Excellent	Excellent quality of both portal veins and hepatic veins. (Fig. 1A)
2	Very good	Very good quality of both portal veins and hepatic veins with some vessel branches that are not plausible in their course
3	Good	Good quality of both portal veins and hepatic veins. The portal vein and the hepatic vein distribute branches in each liver segment. (Fig. 1B)
4	Satisfactory	Satisfactory quality of both portal veins and hepatic veins. At least one branch of both portal vein and hepatic vein can be assigned to each liver segment. The vessel tree seems thinner compared to good quality
5	Sufficient	Sufficient quality of both portal veins and hepatic veins. Parts of the portal vein or hepatic veins are missing. (Fig. 1C)
6	Insufficient	Of no use at all

3. Results

3.1. Transversion from CT to 3D

During this study, all livers underwent a transversion from 2D to 3D. The time needed was recorded (Table 2). Segmentation of the liver was performed in significantly shorter time ($p < 0.01$, Kruskal–Wallis test) in the 16 row CT (median 479 s, min 479, max 709 s) compared to 4 row CT (median 611 s, min 518, max 911 s), and 64 row CT (median 670 s, min 446, max 855 s), respectively.

3.2. Vessel segmentation

The time to segment both hepatic and portal veins was performed significantly faster ($p = 0.02$, Kruskal–Wallis test) in 4 row CT (median 358 s, min 185 s, max 933 s) and 16 row CT (median 411 s, min 202 s, max 1151 s) compared to 64 row CT (median 791 s, min 358 s, max 937 s).

3.3. Branching depth

One of the primary quality parameters of 3D visualization is to which deepness the computer-based segmentation tools recognize intrahepatic vessels. This pattern can be measured by counting the branching depth of both hepatic and liver veins (Fig. 2A). The median branching depth of the portal vein (Fig. 2B) did not differ significantly ($p = 0.37$, Kruskal–Wallis test) between 4 row CT (median 6th generation, min 4th, max 8th generation), 16 row CT (median 5.5th generation, min 3rd, max 8th generation), and 64 row CT (median 5th generation, min 4th, max 9th generation).

Table 2
Time needed to segment liver parenchyma and intrahepatic vessels. Shown are values in seconds for median, minimum, and maximum values.

	Segmentation time: liver (seconds)			Segmentation time: vessels (seconds)		
Number of CT detector rows	4	16	64	4	16	64
	$n = 12$	$n = 12$	$n = 10$	$n = 12$	$n = 12$	$n = 10$
Median	611*	479*	670*	358#	411#	791#
Minimum	518	381	446	185	202	358
Maximum	911	709	855	933	1151	937

* $p < 0.01$, Kruskal–Wallis test.
\# $p = 0.02$, Kruskal–Wallis test.