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Clinical report

Accuracy of liver volume measurement using multidetector computed tomography

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Background: Measurement of liver volume has been used in planning radiotherapy dosimetry, assessing the progressiveness of various diseases and measuring the response to treatment.

Objective: To measure liver volume using multidetector computed tomography (MDCT), and to evaluate the accuracy and inter-observer reliability of liver volume measurement using MDCT.

Methods: Measurements were done using a track-ball to draw its outline manually, and calculate by summation of each slice volume which was measured in 8 mm thickness. The calculated liver volume was compared to the actual liver volume which was measured by water replacement.

Results and conclusion: There was a strong correlation between the calculated and actual liver volumes performed by a radiologist and a technician (98.0 % and 97.1 % agreement, respectively). High observer reliability was identified (99.2 % agreement). This technique can be easily used by well-trained personnel such as radiologists or technicians.

Keywords: Liver volume, measurement, MDCT.

Imaging has been used to provide qualitative data concerning human *in vivo* anatomy and pathology. It is increasingly called upon to provide quantitative data. The liver is one of the organs where numerous attempts have been made to employ imaging techniques and effective quantitative volumetric measurement.

Measurement of liver volume can be used to determine functional reserve status of the liver in patients before hepatectomy to support decision-making regarding hepatic resection or transplantation. Pre-operative volumetric liver measurement can help predict which patients can withstand major hepatic resection and who may require portal venous embolization in order to retain a viable liver remnant [1].

Previous studies revealed that future liver remnants, that were less than 25 % of the total liver volume, were associated with an increased incidence of postoperative hepatic dysfunction (increased bilirubin and prothrombin time) in patients with a normal liver [1, 2]. Future liver remnants, that were less than 20 %, were associated with a 2-fold increase in the incidence of complications compared with standardized future liver remnants of greater than 20 % [3]. Abdalla *et al.* [4] recommended consideration of pre-operative portal vein embolization to increase liver volume and function of the future liver remnant when the future liver remnant was less than 20 % of the predicted normal liver volume. An increase of liver remnant volume was associated with improved liver function. Determination of lobar liver volume was used for evaluating the graft size and the volume of the remaining donor's left lobe [5, 6].

Measurement of liver volume can also be used in planning radiotherapy dosimetry, assessing the progressiveness of various diseases and response to treatment. Liver volumes have not been evaluated by previous measurement at King Chulalongkorn Memorial Hospital, Bangkok. In this study, we measured liver volume using multidetector computed tomography (MDCT) and evaluated the accuracy of MDCT scan technique.

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Material and methods

This study was approved by our institutional Ethics Committee. This was a cross-sectional study. Sample size calculations were performed based on a previous study [7], using PS program from Dupont and Plummer, Jr. (1996). The minimal sample size was three patients. This study was conducted on patients who were scheduled for hepatectomy or liver segmentectomy between Sept 1, 2005 to Aug 31, 2006. Liver function was assessed using Child's classification.

Multidetector computed tomography (MDCT) scanning was performed with standard protocol during suspended respiration within one month prior to the operation. The MDCT study was performed with a Somatome Sensation 4 or 16 (SIEMENS). The Somatome Sensation 4 was using a 4 mm slice width, 4.5 mm collimator, 12.5 mm feed per rotation and 0.5 sec rotation time. The Somatome Sensation 16 was using a 16x1.5 mm^2 collimator, 24.0 mm feed per rotation and 0.5 sec rotation time [8, 9]. The scanning started at the level of a diaphragm until the whole liver was obtained.

The MDCT data was transferred to the work-station for liver volume assessment. The border of the liver was outlined manually in portovenous phase using a track-ball excluding the gallbladder, inferior vena cava, interlobar fissure and portal vein (see **Fig. 1**).

Liver volume was calculated by summation of the slice volumes, each slice being 8 mm thick, the slice volume being determined by multiplying the surface area by each slice thickness, using a volume program, calculating CT-derived total liver volume in cubic centimeters (**Table 1**). Liver volume was individually measured by two observers (radiologist and technician).

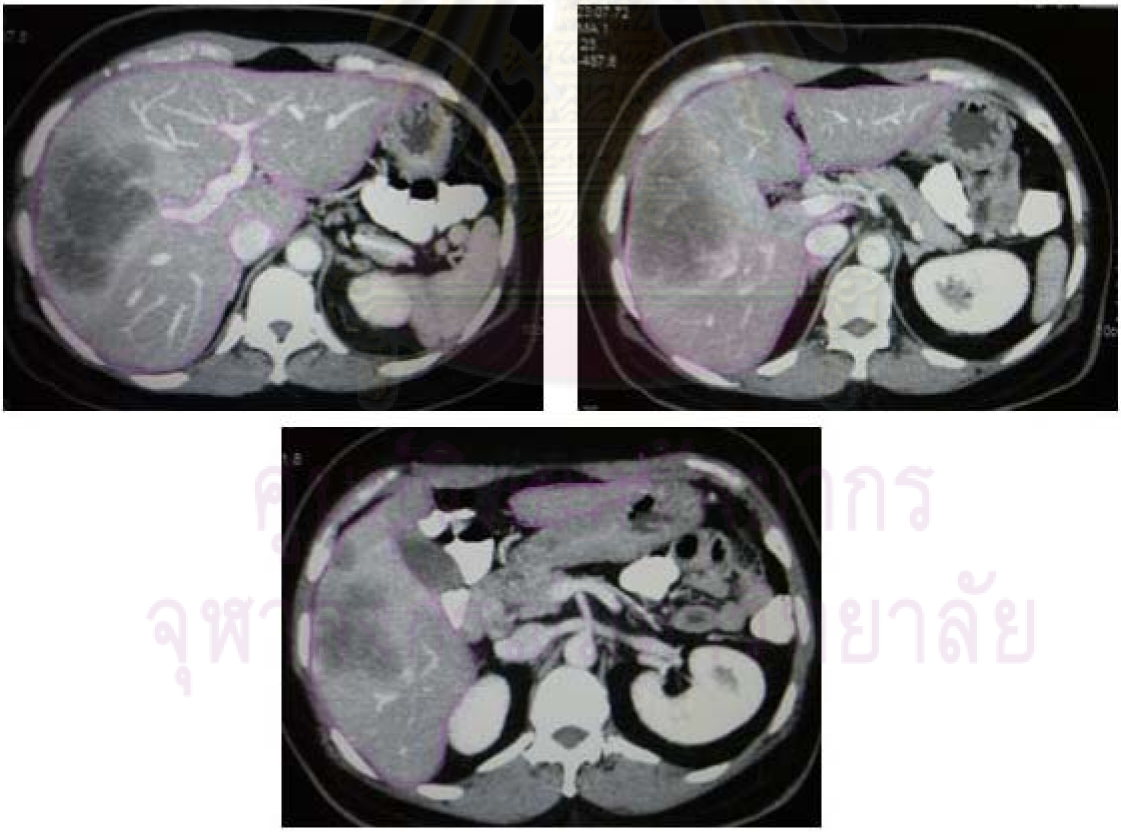

Fig. 1 Examples of manual outline border of liver which excluding gallbladder, inferior vena cava, interlobar fissure and portal vein, shown as pink line.

Table 1. Example of liver volume calculated using the volume program, the total (calculated) volume (cm^3), height of volume, mean and standard deviation (SD) of density and limitation of density.

Volume (cm^3)	868.0
Height (cm)	13.0
Mean (HU)	67.8
SD	26.0
L Eval Limit (HU)	-1024
U Eval Limit (HU)	3071

The reference actual volumes were obtained immediately after hepatectomy by volume replacement in a water bath. The actual liver volume was not disclosed to the radiologist during CT volume measurement. After hepatectomy, patients underwent a post operative MDCT scan within 5 days.

Post-operative MDCT scan was performed by using the same technique used for the pre-operative scan. The measured liver volume was obtained by calculating the difference between the pre-operative volume measurement and post-operative volume measurement.

The liver volume measurements were compared to the actual liver volume using Intraclass correlation power analysis (SPSS analysis software version 11.5; statistical package for Social Sciences, Chicago, IL). An Intraclass Correlation Coefficient (ICC) close to 1.0 was considered in agreement and a *p-value* that was less than 0.05 was considered significant.

Results

Fourteen patients enrolled in this study (11 male and 3 female) (average age: 56.7 years, average body weight: 62.6 kg, average height: 162.9 cm; see **Table 2**). Indications for hepatectomy were hepatocellular carcinoma in 5 patients (35.7 %), cholangiocarcinoma in 5 patients (35.7 %) and liver metastases in 4 patients (28.6 %), details as shown in **Table 3**. Most patients had good liver function. Thirteen patients had Child's classification A (92.9 %) and one patient had Child's classification B (7.1 %).

Table 2. Basic characteristics of 14 patients.

Gender	Male = 11 (78.6 %)	Female = 3 (21.4 %)
Age	Range = 29-72 years	Mean = 56.7 $\pm$ 10.2 years
Body weight	Range = 46-81 kg	Mean = 62.6 $\pm$ 11.2 kg
Height	Range = 153-180 cm	Mean = 162.9 $\pm$ 7.6 cm

Table 3. Details of all enrolled patients and results of liver volume measurements.

Number	Age	Weight(kg)	Height(cm)	Diagnosis	Measured volume – a radiologist (cm^3)	Measured volume – a technician (cm^3)	Actual volume (cm^3)
1	72	46.0	153	metastasis	279.7	262.5	275
2	54	53.0	169	HCC	568.9	581.4	600
3	51	69.0	170	HCC	954.7	803.5	1095
4	56	80.5	167	metastasis	2270.8	2073.2	2277
5	53	70.0	156	Cholangio-carcinoma	1160.1	1011.5	1385
6	56	49.0	160	Cholangio-carcinoma	206.9	142.4	228
7	62	64.0	160	Cholangio-carcinoma	948.8	922.3	950
8	29	70.7	180	HCC	178.5	146.8	180
9	61	76.0	165	Cholangio-carcinoma	427.8	443.2	442
10	70	65.0	170	Cholangio-carcinoma	763.3	695.3	695
11	58	59.4	160	metastasis	712.2	717.7	570
12	61	51.0	155	metastasis	319.2	314.7	305
13	60	50.0	154	HCC	274.4	230.1	260
14	51	73.3	162	HCC	1334.5	1202.7	1300

MDCT liver volumes measured by the radiologist and a technician are shown in **Table 3.**

Graphs **A, B** and **C** in **Fig. 2** show the relationships between the liver volumes measured using MDCT by a radiologist or technician and the actual liver volume. The MDCT levels measured by a researcher and a technician agreed well with the actual liver volume. The intraclass correlation coefficients (ICC) were 0.99 and 0.97 ($p<0.05$) in **A** and **B**, respectively. As shown in **C**, the reliability of both observers was very good; its ICC was 0.99 ($p<0.05$).

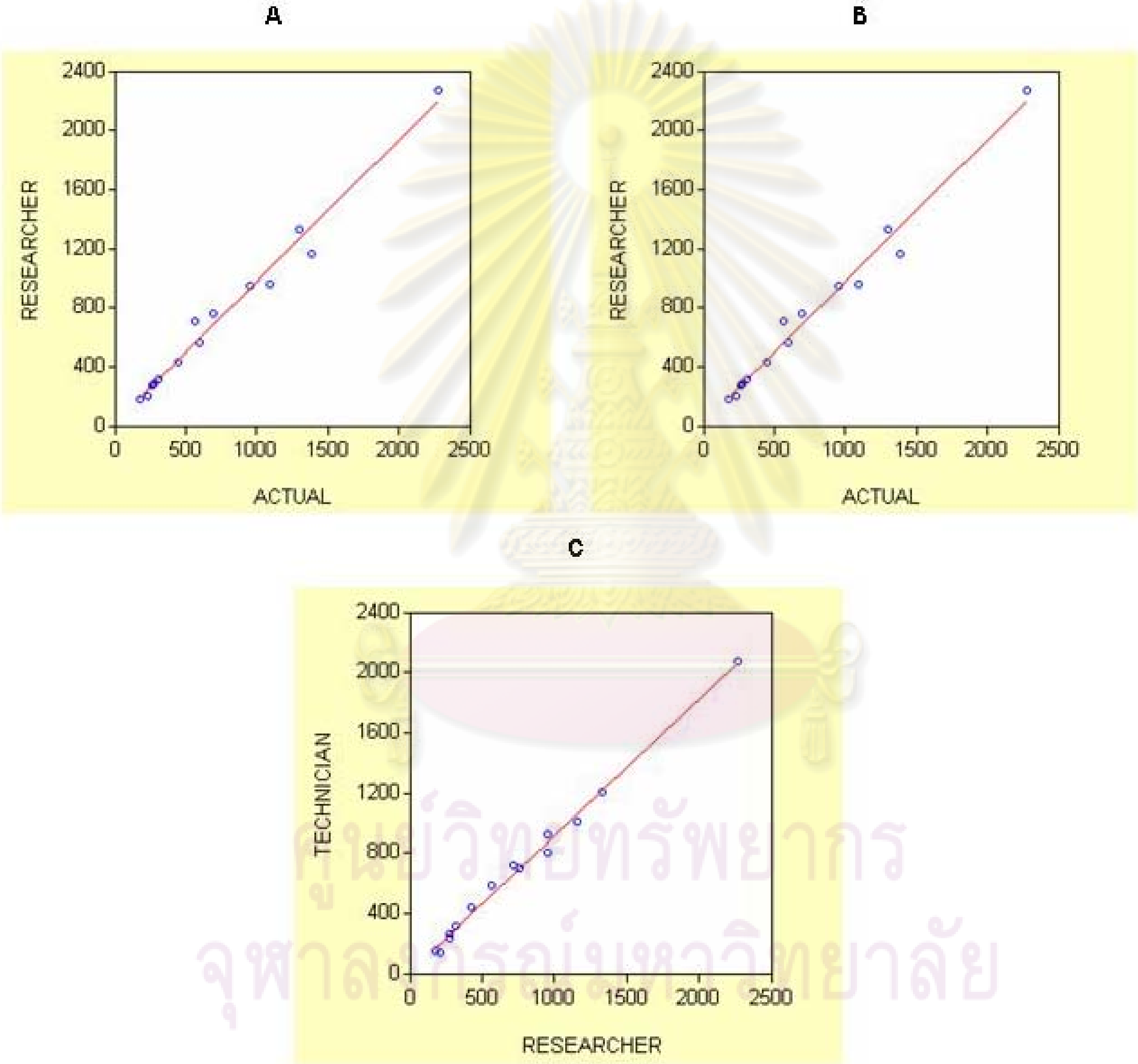

Fig. 2 The graphs demonstrate a correlation between MDCT liver volume measurement and actual liver volume, using "intraclass correlation power analysis". Liver volume measurements by a researcher and a technician correlated well with the actual liver volume (ICC=0.99 and 0.97 in **A** and **B**, respectively). The reliability of observers was excellent (ICC=0.99 in **C**).

Discussion

Previous studies used several methods for measuring liver volume such as CT scan with manual tracing of the entire liver contour on every CT slice [10-14], measurement of sectional areas of liver via a graphic program then calculating from combined sectional areas using mean-area, end-area and prismodial methods [7] and using software for volume measurement [15]. These previous studies revealed that CT scan equipment was highly accurate for estimating liver volume.

In this study, we used manual tracing of the entire liver contour using an electronic mouse on every 8-mm slice. We found that the use of 8-mm slices in portovenous phase scan gave great reliability in liver volume estimation whether measured by the researcher or a technician. Measurement of the liver volume can be done by well-trained medical personnel of such as radiologists or technicians.

In the volume program of the MDCT scan, we can limit the optimum upper and lower Hounsfield unit thresholds for liver parenchyma, but we did not apply this technique because some patients enrolled in this study had prior transarterial oil-chemoembolization or portal venous embolization or low attenuation metastatic liver lesion.

MDCT measurement using manual tracing of every 8-mm slice combined with limited optimum attenuation of enhanced liver parenchyma is very helpful for liver volume estimation in pre-operative evaluation of liver transplant and evaluation of the remaining liver volume before hepatectomy.

Conclusion

The MDCT measurement of liver volume by manual tracing of 8 mm slices of the entire liver contour the actual liver volume. This technique is easily performed by well-trained personnel such as a radiologist or technicians.

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