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Volumetric and Dimensional Evaluation of the Liver in Patients with Different liver Pathologies: Computed Tomography Based study.

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Abstract

Knowledge of liver dimensions and volume is prerequisite for clinical assessment of liver disorders and has critical medical implication. The aims of this study were to evaluate the liver volume and dimensions changes in Sudanese adults with different liver diseases using Spiral Computed Tomography Scans (CT) and to observe it's relationship with various body indices (weight, height and body surface area (BSA)). In this prospective study, all patients underwent Spiral Computed Tomography (CT) of the abdomen .58 patients were selected: 37 were males and 21were females; their ages were extended from18-88years old. The study was obtained at ALKUATII hospital-Khartoum –Sudan. Study participants were evaluated clinically and also by CT triphasic technique and was diagnosed to have different liver pathologies. Results showed significant changes in the liver dimensions :Right lobe craniocaudal, Right lobe (Antero-Posterior),Right lobe (Lateral) Left lobe width, Left lobe length , were reduced in the cases of liver cirrhosis and hepatocelluler carcinoma (HCC),without any significant changes detected in the cases of Metastasis , Hydatid Cyst ,Hemangioma, Simple Cyst and Liver Nodules. However the right lobe (Antero-Posterior) measurements were significantly affected in the presence of Metastasis, Hydatid Cyst, Liver Nodule, and intrahepatic duct dilation (IHDD).Hepatic volume was reduced significantly in the cases of cirrhosis, and (HCC) and significantly correlated with body indices: height, weight, and BSA. CT number of liver (Hounsfield)/density was significantly changed in both cases of cirrhosis and (HCC) without any changes detected in other diffused or focal lesions. Triphase CT technique is an excellent method to be utilized for measurement of liver dimensions and volume in different liver diseases.

Keywords: Triphase CT, liver volume, dimensions, liver pathology.

المستخلص:

معرفة أبعاد الكبد وحجمه هو شرط أساسي للتقييم السريري لإضطرابات الكبد. تهدف هذه الدراسة إلى تقييم حجم الكبد وتغيرات الأبعاد لدي البالغين السودانيين المصابين بأمراض كبدية مختلفة باستخدام فحوصات التصوير المقطعي الحلزوني (CT) ومعرفة علاقتها بمؤشرات الجسم المختلفة (الوزن والطول ومساحة سطح الجسم). في هذه الدراسة ، خضع جميع المرضى 58 مريضاً للتصوير المقطعي الحلزوني (CT) للبطن: 37 من الذكور و 21 من الإناث. مدي أعمارهم 18-88 سنة أجريت الدراسة في المستشفى الكويتي – الخرطوم – السودان. تم تشخيص المشاركين في الدراسة سريرياً وكذلك عن طريق تقنية الاشعه المقطعية ثلاثية الاطواروتم إختيار المصابين بأمراض الكبد المختلفة. أظهرت النتائج تغيرات كبيرة في أبعاد الكبد: الفص الأيمن رأس- زيلي، الفص الأيمن أمامي-خلفي ، الفص الأيمن (الجانبي) ،عرض و طول الفص الأيسر في كلتا حالات تليف الكبد وسرطان الكبد (HCC) ، دون أي تغييرات تم اكتشافها في حالات النقائل ، كيس الهيدات، الورم الوعائي ، الكيس البسيط وعقيدات الكبد. بينما تاثرت قياسات الفص الامامي الخلفي بشكل كبير في وجود النقائل ، كيس الهيدات ، عقيدات كبد ، وتوسع قنوات الكبد الداخلية. يقل حجم الكبد بشكل كبير في حالات تليف الكبد و (HCC) ويرتبط بشكل كبير مع مؤشرات الجسم: الطول والوزن وBSA . تغيرت قراءات كثافة الاشعة المقطعية للكبد / (Hounsfield) بشكل كبير في كل من حالات تليف الكبد و (HCC) دون أي تغييرات في الآفات المنتشرة أو البؤرية الأخرى. عتبر تقنية الاشعة المقطعية ثلاثية الاطوارطريقة ممتازة تستخدام لقياس أبعاد وحجم الكبد في أمراض الكبد المختلفة.

Introduction

Estimation of liver size has critical clinical implication. Knowledge of liver dimensions and volume has great value in the clinical assessment of liver disorders and can facilitate decision making in liver transplant surgery to avoid complications.(Tutar *et al*., 2007;Ogasawara et al., 1996)

The liver volume has been measured using numerous diagnostic imaging techniques, including Scintigraphy (Rollo *et al.*, 1968 and Lin *et al*., 1979), Ultrasonography [Carr *et al.*, 1967 and Van *etal*., 1985), Single-Photon Emission Computed Tomography (Kan *et al*., 1979, Jansen *et al.* 1990), Computed Tomography (CT) (Nagasue *et al*., 1987, Chen *et al.*, 1991 and Ogasawara *et al.*, 1995) and Magnetic Resonance Imaging (MRI) (Ogasawara *et al*., 1995). It was first reported by(Heymsfield *et al*., 1979) that the liver volume determination by CT has been used in the fields of liver resection(Ogasawara *et al.*, 1995,Okamoto *et al.*, 1984 and Yamanaka *et al.*, 1993) and transplantation (Broelsch *et al*.,1990, Broelsch *et al.*,1953,Higashiyama *et al*.,1993and Kawasaki *et al.*, 1993) and for evaluation-the progression of various diseases(Henderson *et al.*, 1990).Volumetric determination is a multidisciplinary approach that closes the communication between the radiologist and the surgeon in the assessment of respectability and the visualization of tumor extension as well as evaluation of diseased liver including steatosis and cirrhosis(Lim *et al.* ,2014).Volumetric assessment is dependent on the CT scan phase (Lim *et al.*, 2014).CT volume measurements is based on the plain phase which is most accurately matches the actual intraoperative findings, however the venous phase is typically preferred in practice(Radtke *et al.* 2007). The reason for this is because contrast-enhanced CT delineates the vascular anatomy and the margins of any tumor better than unenhanced CT of the liver (Radtke *et al.*, 2007).Liver volume measurements are based on patient characteristics including body surface area (BSA) and body weight, that

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considered a good reflection of the hepatic metabolic burden of the individual and considered as an important parameter in the evaluation of the graft volume and in the estimation of volume of liver remnant prior to hepatic resections (Kawasaki *et al*., 1998, Nishizaki *et al.,* 2001andVauthey *et al*., 2000)

Considering the complexity of liver shape, liver dimensions alone cannot appropriately represent liver mass. As mentioned above, the liver size is an important factor when considering liver pathology. Liver span as measured previously is prone to inter-observer variability and poor repeatability (Heymsfield *et al.,* 1979). There are very few published studies on assessment of liver volume with CT and predicting its volume in different liver pathologies. The present study was therefore conducted to evaluate the liver volume and dimensions of adults using routine and triphasic CT abdomen where the reformatted images were used to measure the liver in porto- venous phase in which actual liver perfusion is optimally taken. An additional objective of this study was to observe its relationship with various body indices (age, weight height, and body surface area (BSA).

Materials and Methods

This study aimed to measure the liver volume and dimensions in patients in with different focal liver lesions and metastases using GE optima-16 slice machine. The study was obtained at Al- KUWAITTI specialized hospital-Khartoum -Sudan. The patients' ages ranged between 18-88 years old

All patients underwent Triphasic CT abdomen. The patients were prepared for Triphasic CT abdomen scan by fasting of 4-6 hours, and the oral positive contrast with omnipaque IV contrast was used. The true arterial angiographic phase aimed to assess the normal vasculature of the liver and abdomen and was given after 50-60 second .The next scan was porto-venous phase which was done where all abdominal organs are well perfused by contrast and specially the liver parenchyma, then delayed phase was also been done to assess the KUB organs and the liver lesions that need the delayed time which was done in mean time between 6-10 min after contrast injection.

In routine CT abdomen; only two scans were done which include axial cuts without contrast and Porto venous phase. Then the images were transferred to the PACS for proper image diagnosis where the images were recognized and classified to routine and Triphasic CT abdomen then the measurement was done in reformatted images. The volume was measured in axial slice, measurement was done in Porto venous phase in which actual liver perfusion was optimally taken at slice thickness equal to 0.625 mm and interval equal to 0.625 mm then the volume was measured every 2 mm interval and the collective volume was measured using software specified for volume measures. Then the rest of measurement were taken from reformatted images as follow: axial (AP for right lobe measures including the quadrate lobe from the upper most to lower most border at the level of mid clavicular line, then the lateral measurement from the tip of the quadate lobe to lateral most border . The craniocaudal measures was done at coronal section from the dome of the liver superiorly to the lower most corner of the liver, the length of the left lobe was also measured at sagittal section according to the longest part of the lobe then the width of the left lobe measured at axial section at stander stomach volume.

These measurements were then correlated with the patients' age, gender, weight and height then the body surface areas (BSA) was measured to estimate the liver volume accordingly.

Results

The following tables represented the results of the study

Table (1) Statistical measurement values of patient demographic data, and Body Surface Area (BSA)

Variables	Min	Max	Mean	Std. Deviation
Age/years	18.0	88.0	54.95	16.36
Weight/Kg	49.0	90.0	66.01	10.13
Height/cm	130.0	182.0	164.65	10.36
Body Surface Area BSA (m^2)	1.33	2.13	1.73	0.15

Table (2) Liver dimensions measurements classified according to gender

Group Statistics	Gender	N	Mean	Std. Deviation
CT number of liver(Hounsfield)	Male	37	115.16	14.32
	Female	21	119.52	17.32
Right lobe craniocaudal/cm	Male	37	17.15	2.60
	Female	21	17.21	2.51
Right lobe (Antero-Posterior)/cm	Male	37	15.67	2.19
	Female	21	15.12	2.23
Right lobe (Lateral)/cm	Male	37	12.84	2.36
	Female	21	12.16	1.77
Left lobe width/cm	Male	37	7.57	1.16
	Female	21	6.83	1.29
Left lobe length/cm	Male	37	11.54	2.85
	Female	21	11.21	2.59
Liver Volume/cm^3	Male	37	1610.94	400.36
	Female	21	1424.47	567.25

Table (3) Independent Samples Test for Liver dimensions measurements correlated with gender

		t-test for Equality of Means			
	t	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
				Lower	Upper
CT number of liver(Hounsfield)	-1.032	0.306	-4.36	-12.82	4.1
Right lobe craniocaudal/cm	-.084	0.933	-.059	-1.46	1.35
Right lobe (Antero-Posterior)/cm	.910	0.367	.54	-.65	1.76
Right lobe (Lateral)/cm	1.144	0.258	.68	-.51	1.9
Left lobe width/cm	2.232	0.030	.73	.07	1.4
Left lobe length/cm	.442	0.660	.33	-1.17	1.85
Liver Volume/cm^3	-	0.141	-	-	-

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Table (4) Statistical correlation of liver dimensions related to the liver diagnosis/findings

Group Statistics	Diagnosis	N	Mean	Std. v	p-value
Right lobe craniocaudal/cm	Cirrhosis	15	14.38	1.185	0.000
	HCC	17	19.06	1.925	0.000
	Metastasis	8	18.50	1.73	0.205
	Hydatid Cyst	2	20.30	0.84	0.205
	Hemangioma	2	18.75	2.89	0.184
	Simple Cyst	5	16.68	1.05	0.184
	Liver Nodule	5	16.10	1.95	0.575
	Intrahepatic duct dilation (**IHDD**)	1	14.80	0.00	0.575
	Abscess	3	17.20	2.59	0.576
Right lobe (Antero-Posterior)/cm	Cirrhosis	15	13.76	1.35	0.000
	HCC	17	17.24	1.65	0.000
	Metastasis	8	16.55	1.35	0.048
	Hydatid Cyst	2	14.20	0.42	0.048
	Hemangioma	2	14.90	0.70	0.356
	Simple Cyst	5	16.58	2.18	0.356
	Liver Nodule	5	13.42	2.15	0.050
	Intrahepatic duct dilation (**IHDD**)	1	13.80	0.00	0.050
	Abscess	3	14.46	2.55	0.880
Right lobe (Lateral)/cm	Cirrhosis	15	11.78	1.77	0.004
	HCC	17	13.62	1.60	0.004
	Metastasis	8	13.73	1.44	0.508
	Hydatid Cyst	2	12.80	2.96	0.508
	Hemangioma	2	13.45	0.77	0.544
	Simple Cyst	5	11.18	4.64	0.544
	Liver Nodule	5	11.02	1.36	0.943
	Intrahepatic duct dilation (**IHDD**)	1	11.20	0.00	0.943
	Abscess	3	12.60	1.41	0.910
Left lobe width/cm	Cirrhosis	15	6.33	1.13	0.000
	HCC	17	7.75	0.87	0.000
	Metastasis	8	8.20	1.34	0.809
	Hydatid Cyst	2	7.90	2.40	0.809
	Hemangioma	2	7.40	1.83	0.810
	Simple Cyst	5	7.70	1.28	0.810
	Liver Nodule	5	6.70	0.71	0.167
	Intrahepatic duct dilation (**IHDD**)	1	8.30	0.00	0.167
	Abscess	3	6.90	0.20	0.109
Left lobe length/cm	Cirrhosis	15	9.91	2.18	0.000
	HCC	17	12.97	1.95	0.000
	Metastasis	8	11.63	1.13	0.476
	Hydatid Cyst	2	12.55	3.18	0.476
	Hemangioma	2	8.70	3.67	0.685
	Simple Cyst	5	10.62	5.68	0.685
	Liver Nodule	5	10.160	1.29	0.864
	Intrahepatic duct dilation (**IHDD**)	1	10.800	0.00	0.864
	Abscess	3	14.333	1.20	0.676

Table (5) Statistical correlation of liver densities /Hounsfield related to the liver diagnosis/findings

Group Statistics	Diagnosis	N	Mean	Std. V	*p-value*
CT number of liver (Hounsfield)	Cirrhosis	15	124.46	20.60	0.009
	HCC	17	109.11	8.75	0.009
	Metastasis	8	117.25	9.61	0.679
	Hydatid Cyst	2	120.50	9.19	0.679
	Hemangioma	2	128.00	4.24	0.638
	Simple Cyst	5	120.00	21.26	0.638
	Liver Nodule	5	116.80	18.21	0.805
	Intrahepatic duct dilation (**IHDD**)	1	106.00	0.00	0.805
	Abscess	3	108.00	3.46	0.617

Table (6) Independent sample t-test showed the mean difference of liver related to the liver diagnosis/findings

Group Statistics	Diagnosis	N	Mean	Std. V	p-value
Liver volume	Cirrhosis	15	986.06	120.56	0.000
	HCC	17	2057.82	279.08	0.000
	Metastasis	8	1794.00	223.15	0.747
	Hydatid Cyst	2	1735.00	224.86	0.747
	Hemangioma	2	1726.00	107.48	0.156
	Simple Cyst	5	1486.20	189.51	0.156
	Liver Nodule	5	1220.80	138.45	0.213
	Intrahepatic duct dilation (**IHDD**)	1	1445.00	-	-
	Abscess	3	1496.66	266.78	0.882

Table (7) Correlation between patient data and liver volume

Correlations				
Control Variables		**Weight**	**Height**	**BSA(m^2)**
Liver volume	Correlation	1.000	.142	.935
	Significance (2-tailed)	.	.293	.000
	Correlation	.142	1.000	.481
	Significance (2-tailed)	.293	.	.000
	Correlation	.935	.481	1.000
	Significance (2-tailed)	.000	.000	.

Discussion

Taking into account the convolution of liver character, liver dimensions alone cannot properly signify it's mass. As mentioned above, the liver size is an essential issue when considering liver pathology. Liver length and width as measured previously; is prone to inter-observer variability and poor repeatability (Heymsfield *et al*.,1979), there are very few published studies on assessment of liver volume (LV) with CT and predicting liver volume in different liver pathologies. The present study was therefore conducted to evaluate the liver volume and dimensions changes in Sudanese adults with different liver findings using CT abdominal scans, as well to observe its relationship with various body indices {gender, weight, height, body surface area (BSA)}.The selected patients were those of both genders (37 were males, 21 were females), their demographic data were presented in table (1)

One previous study had mentioned that the organ volume must be related to an individual's gender and body habitués for a more accurate interpretation of abnormality (Madhu *et al.*, 2016).Studies showed that liver volume is decreased in pathologies leading to fibrosis and consequent shrinkage like cirrhosis of liver (Lin *et al.,* 1998)

The current study presented the CT number of liver(Hounsfield) , and liver dimensions including the Right lobe craniocaudal/cm ,Right lobe (Antero-Posterior)/cm, Right lobe (Lateral)/cm ,Left lobe width/cm, Left lobe length/cm as well as liver volume for both genders as presented in tables(2,3) and found that the measurements for the selected parameters showed no significant difference between the two genders except for left lobe width/cm at p=0.030

The statistical correlation of liver dimensions related to the liver diagnosis/findings were presented in table (4) and showed that the right lobe craniocaudal dimensions are changed significantly at p =0.000 in both cases of liver cirrhosis and HCC where the right lobe (Antero-Posterior) dimensions were significantly change more in the presence of Cirrhosis and HCC at $p=0.000$ than Metastasis and Hydatid Cyst at $p=0.048$ as well as liver nodule and IHDD at $p=0.050$. Right lobe (Lateral) dimensions and left lobe width and length were significantly changed in Cirrhosis and HCC at p=0.004 and $p=0.000$ in respectively.

Similarly one previous study had mentioned that the morphologic changes of the liver is associated with the cirrhotic condition include atrophy of the quadrate lobe and the right lobe and hypertrophy of the left lateral segment and the caudate lobe (Xiangping *et al.,* 2007).The justification of the detected changes in the current study is due to the redistribution of intra hepatic blood during the early stages of cirrhosis as mentioned by(Xiang-ping *el al*.,2007).The total liver volume has already atrophied and the left lateral segment instead swells to compensate for the atrophy and allow seemingly normal liver function. As the disease progresses to the latest age, the total liver volume has atrophied even more, and that change inevitably influences the left lateral segment so that it is unable to sustain the need for compensation; thus, the actual volume could not be significantly larger, but relatively larger. CT number of liver (Hounsfield) was also been affected in liver cirrhosis and HCC at p=0.009 without any significant change of the HU in the presence of metastases , Hydatid Cyst , Hemangioma, Simple Cyst, Liver Nodule, Intrahepatic duct dilation (IHDD), and Abscess as presented in (table 5)

The significant increasing of the liver HU of the HCC and cirrhosis cases was due to the fact that the scanning was done in the venous phase and using the triphasic technique which causes attenuation of the intrahepatic portal and hepatic venous branches, and the hepatic vascular bed was reduced as mentioned and justify by (McIndoe *et al*., 1928). Impaired drainage of blood from the liver, caused by compression of hepatic venous tributaries by regenerating nodules or fibrosis, increases the resistance to portal flow (Popper *et al*., 1977).This fact justifies the causes of the reduction of the liver density from normal.

Liver volume was reduced significantly at $p=0.000$ in cases of cirrhosis and HCC at $p=0.000$. The similarity of the significant results of changing the dimensions and volume in both HCC and cirrhosis was due to the fact that patients who have HCC often have underlying cirrhosis as an etiologic factor for their tumors (Philip *et al.,* 2004), as well the liver volume was significantly correlated with patients weight, height and BSA (m^2) as presented in tables (6and7)

Body surface area (BSA) was used to assess many body parameters including fluid requirement, drug doses, cardiac output and glomerular filtration rate. The aim of the current study was to examine the correlation between the Liver volume (LV) and BSA. Liver volume was calculated from the knowledge of adult body height, body weight and BSA and then was correlated in patients with different pathologic conditions; this correlation reflected the quantitative evaluation of hepatic volume variation in different cases, which could be a helpful supplement for evaluating liver function, selecting an appropriate treatment, and determining the prognosis. Similar results were stated in the study done by (Xiangping *et al*., 2007) provided high correlations between liver volume and BSA, and in agreement with previous studies. (Del *et al*., 1968; Urata *et al.*, 1995and Heinemann *et al.* 1999)

The accurate estimation of liver volume has a number of clinical and scientific applications. Since the liver is the main organ of elimination for most drugs and xenobiotic, liver size is important determinants of the capacity of an individual to clear such compounds. Accordingly, an accurate measure of liver size is an essential component of physiologically-based pharmacokinetic model therefore BSA is an important parameter that should be considered to evaluate patients liver volume in different pathological conditions it was recommend previously by (Vauthey *et al.* 2002) to use BSA to evaluate liver volume.

Conclusion:

Due to the complexity of liver shape, liver dimensions and liver volume should be used as an important issue when considering liver pathology. The evaluation of the liver volume and dimensions of adults using routine and Triphasic CT abdomen (porto-venous phase) was taken as well the liver volume relationship with various body indices (age, weight height, and body surface area (BSA). The results showed significant reduction in the liver dimensions : Right lobe craniocaudal/cm, Right lobe (Antero-Posterior)/cm Right lobe (Lateral)/cm Left lobe width/cm Left lobe length/cm in the cases of liver cirrhosis and HCC, as well Right lobe (Antero-Posterior)/cm measurement was significantly affected in the presence of Metastasis , Hydatid Cyst Liver Nodule, and IHDD . No significant changes in the dimensions were detected in the cases of Metastasis presence of focal lesions (Hydatid Cyst, Hemangioma, Simple Cyst, Liver Nodule. liver volume was reduced significantly in the cases of cirrhosis, HCC and significantly correlated with body indices (height, weight, and BSA).CT number of liver (Hounsfield)/density was significantly changed in both cases of cirrhosis and HCC without any changes detected in other diffused or focal lesions.

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