Al-Azhar International Medical Journal

Volume 5 | Issue 2 Article 30

2024

Section: Radiology & Radiodiagnosis

Comparison between manual and automated Volumetric study of LDLT

Wafik Ebrahiem Ali
Professor of Radiodiagnosis, Faculty of Medicine, Al-Azhar University, Cairo, Egypt

Ahmed Mohamed Mostafa
Lecturer of Radiodiagnosis, Faculty of Medicine, Al-Azhar University, Cairo, Egypt

Zeinab Mostafa Mostafa
Assistant consultant Radiodiagnosis , National Hepatology Institute, Cairo, Egypt

Muhammad Abd El Wahab Muhammad
M.B.B.ch of Radiodiagnosis, Faculty of Medicine, Al-Azhar University, Cairo, Egypt,
mabodakik@hotmail.com

How to Cite This Article

Ali, Wafik Ebrahiem; Mostafa, Ahmed Mohamed; Mostafa, Zeinab Mostafa; and Muhammad, Muhammad Abd El Wahab (2024) "Comparison between manual and automated Volumetric study of LDLT," *Al-Azhar International Medical Journal*: Vol. 5: Iss. 2, Article 30.
DOI: https://doi.org/10.58675/2682-339X.2246

ORIGINAL ARTICLE

Comparison Between Manual and Automated Volumetric Study of Living Donor Liver Transplantation

Wafik Ebrahiem Ali [a], Ahmed Mohamed Mostafa [a], Zeinab Mostafa Mostafa [b], Muhammad Abd El Wahab Muhammad [a],*

[a] Department of Radiodiagnosis, Faculty of Medicine, Al-Azhar University
[b] Department of Radiodiagnosis, National Hepatology Institute, Cairo, Egypt

Abstract

Background: **The only therapy option for end-stage liver disease is liver transplantation while living donor liver transplantation has emerged as a substitute. Evaluation of the preoperative volume is crucial for both the donor and the recipient. To conserve the recipient from small-for-size phenomena, the calculated volume-to-weight ratio of the graft should be at least 0.8%, and it should be 3% to prevent large-for-size phenomena. To prevent the donor from suffering potentially fatal repercussions, the volume of the donor's liver should be at least 30%. Furthermore, the liver graft should not be too large because compression might result in liver necrosis and hinder the healing of the wound, both of which could be catastrophic for the recipient.**

Aim: **To compare manual and automated computed tomography volumetry in determining the graft weight in living donor liver transplantation in relation to intra-operative graft volume.**

Patients and methods: **This prospective observational study was performed at the National hepatology and Tropical Medicine Research Institute.**

Results: **A total of 40 cases were included with a mean age of 28.23 years and a mean BMI was 25.2 as regards sex there was a male predominance 65% versus female 35%. There was a significant difference between surgical and automated and a difference between surgical and manual estimations.**

Conclusion: **Automated computed tomography liver volumetry results in reasonable volumetric assessments that can be adequately accurate for estimation of weight/volume of liver graft for operation.**

Keywords: CT Volumetry (CTV), Living donor liver transplantation (LDLT), Automated volumetry, Manual volumetry

1. Introduction

Liver transplantation is the only treatment option for end-stage liver illness. Living donor liver transplantation (LDLT) has emerged as an alternative in nations where cadaveric liver transplantation is infrequently practiced, yet, it necessitates a challenging and careful initial evaluation. One of these difficult stages, preoperative volume evaluation, is crucial for both the donor and the recipient. For the protection of the recipient from small-for-size phenomena (a decreased capacity for metabolism computed tomography volumetry (CTV) and synthesis in the liver, cellular damage, and ascites), the calculated volume's ratio to the graft weight should not be below 0.8%, and it should be less than 3% to prevent large-for-size phenomena (poor liver perfusion, elevated abdominal pressure). To prevent the donor from suffering potentially fatal repercussions, the volume of the donor's liver should be at least 30%.[1] Furthermore, the liver graft should not be too large because

Accepted 10 October 2023.
Available online 1 July 2024

* Corresponding author at: 13, Elmadares Street, Itay El Baroud, El Behira, 5775004, Egypt.
E-mail address: mabodakik@hotmail.com (M.A. El Wahab Muhammad).

https://doi.org/10.58675/2682-339X.2246

compression might lead to liver necrosis and hinder healing, both of which could be catastrophic for the recipient (large-for size).[2]

In the absence of steatosis and other underlying liver conditions, a donor's remaining liver volume of 30% is thought to be the minimal requirement for transplantation to proceed in an adult donor.[3] It is significant to highlight that pre-existing illness in the liver of the donor before surgery may affect graft function and survival as well as graft size.[4]

Understanding the biliary and intrahepatic vascular anatomy is crucial for proper liver volume measurement. Accurate assessment of the liver volume of a donor requires thorough knowledge of the surgical method. The anatomical variations that could influence the surgical approaches should be emphasized.[5]

With CTV, there is typically a good connection between the estimated volume and the measured graft weight.[6] According to research by Frericks *et al.*[7] the average adult liver weight is 881.1 g, while its average estimated volume is 956.99 cm^3.[7]

In LDLT, computed tomography (CT) and automated volume computation software are frequently used to determine the preoperative donor graft volume.[8]

Non-automated CTV is currently the preoperative gold standard for determining the size of the prospective graft and the anatomy of the liver.[9] The most appropriate segments for liver donation can be determined based on CTV following clinical calculation of the appropriate graft size for the recipient (e.g. the ratio of graft to body weights).[10–12]

CTV has traditionally been performed by a radiologist summarizing the liver area on every cross-sectional slice and manually delineating the liver boundaries. The conventional optical mouse is employed for margin delineation. The utilization of a handheld electromagnetic pen tablet is one of the innovative approaches for outlining the liver edges that have been devised.[13]

These two techniques are precise and accurate. The method of freehand electromagnetic pen contour tracing dramatically reduces the mean time of segmentation per patient. Nonetheless, these manual techniques depend on the operator and take a lot of time and effort. The automated method of volumetric assessments has been suggested to speed up the procedure even further and prevent laborious tasks.[10,12,13]

In a study done by Mohapatra *et al.*, after draining the blood from the graft, the weight of the actual graft was determined intraoperatively, leading to the premise that three dimensional volumetry would better correlate with graft weight than standard CTV.[14]

Automated volumetry preoperatively exhibited great agreement with the actual graft volume with no significance, according to a study recently conducted at Theodor Bilharz Research Institute; automated volumetry's P value was 0.068. Additionally, we discovered that the majority of instances overestimated graft weight. The study demonstrated the effectiveness of automated volumetry, with three-quarters of subjects getting less than 15% variation from actual transplanted mass.[15]

Automated CT liver volumetry provided reliable measurements of the intraoperative weight/volume of the grafts, making it a suitable and precise method for determining the weight/volume of the liver grafts during the procedure. Additionally, it precisely predicted the preoperative liver volume and significantly reduced the time needed for liver volumetry.[15]

This work aims to compare between manual and automated CTV regarding the evaluation of the weight of graft in living donor liver transplantation in relation to intra-operative graft volume.

2. Patients and methods

Study type: A prospective observational.

Setting: National hepatology and tropical medicine research institute.

Study Period: one year.

Study Population: the patient population was candidate and actually being living liver donors.

Inclusion Criteria: the study will be performed on patients who undergo liver donation, age between 18 and 45 years and female gender is included.

Exclusion Criteria: Strong history of hypersensitivity diseases to the CT contrasts agents.

Sampling Method: convenience sampling method.

Sample Size: 40 cases.

Ethical Considerations: official permissions will be obtained from the dean National hepatology and tropical medicine research institute, and from the GIT surgery department of the same institute. The scientific ethical committee of the patients will be respected, the study group will be informed about the study objective and nature and before interview, and verbal consent will be taken.

Tools: all patients will be subjected to complete history and full clinical examination by referring clinician.

Study Procedures: the procedure will be conducted using a combined CT scan, an automated software is added to evaluate the liver volume and volume of the graft.

Evaluation and statistical analysis: CT findings and images are analyzed both qualitatively and quantitatively through measurement of standardized uptake values (SUVs) and the results will be tabulated and statistically analyzed.

2.1. Statistical analysis

The collected data will be presented by tables and graphs, and processed by a data base software program.

Statistical Package: statistical Package of Social Services version 19 (SPSS).

3. Results

40 cases were included with mean age 28.23 years and mean BMI was 25.2 as regard sex there was male predominance 65% versus female 35% (Fig. 1 and Table 1).

There were insignificant differences between graft volumes estimated by surgery, automated or manual as mean volume was 857.1, 858.35, and 880.48 respectively (Figs. 2 and 3, Table 2). There was significant difference between surgical and automated and difference between surgical and manual estimations (Figs. 4–6, and Tables 3–6).

Table 1. Distribution of the studies cases according to demographic data (n = 40).

	No. (%)
Sex	
Male	26 (65.0)
Female	14 (35.0)
Age (y)	
Min. – Max.	19.0–45.0
Mean ± SD.	28.23 ± 5.08
Median (IQR)	27.0 (25.0–30.0)
BMI (Kg/m^2)	
Minimum–maximum	24.0–27.0
Mean ± SD.	25.20 ± 0.97
Median (IQR)	25.0 (24.0–26.0)

IQR, Inter quartile range; SD, Standard deviation.

4. Discussion

The best course of action for people with end-stage hepatic illness is liver transplantation. In liver transplantation candidates, the liver size is thought to be a significant prognostic factor. It has been possible to estimate the volume of the liver quantitatively using imaging techniques. Because ensuring the right graft size is one of the major indicators of a successful and safe outcome for both recipient and donor, determination of total and segmental volumes of the liver is essential.[14]

Contrast-enhanced Multi-detector CT (MDCT) is widely used as the technique of scan in many institutions for preoperative assessment of hepatic masses. In living donor liver transplantation, it is crucial for the donor to have a remaining liver volume of 30–40% of their original hepatic mass, while the recipient typically requires a minimum of 40% of the standard liver mass based on body surface area. Underestimating the recipient's standard liver

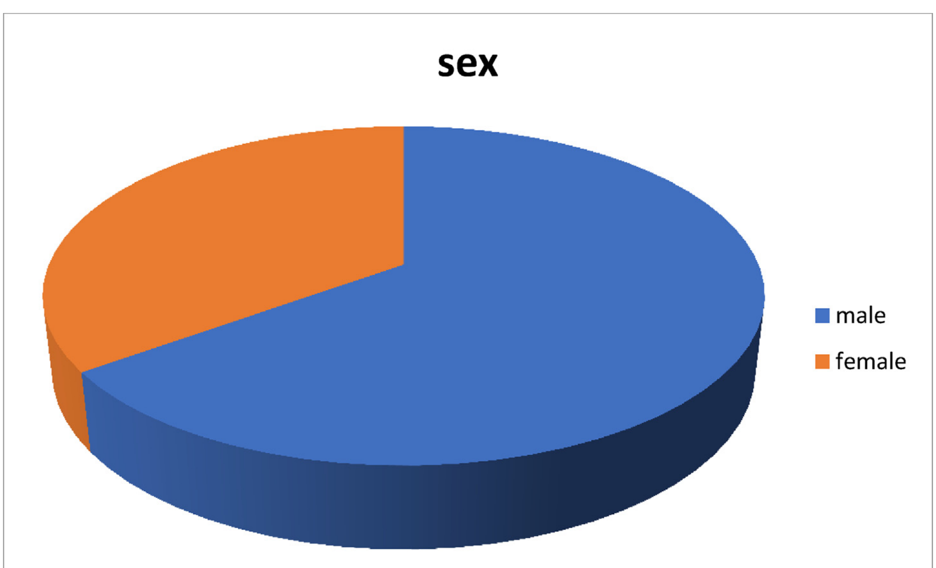

Fig. 1. Distribution of the studies cases according to sex.

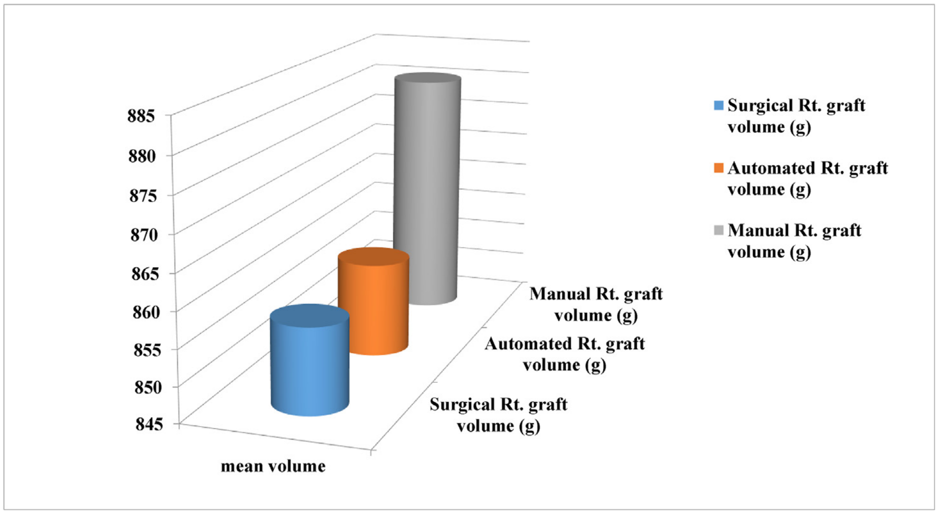

Fig. 2. Comparison between different graft volumes.

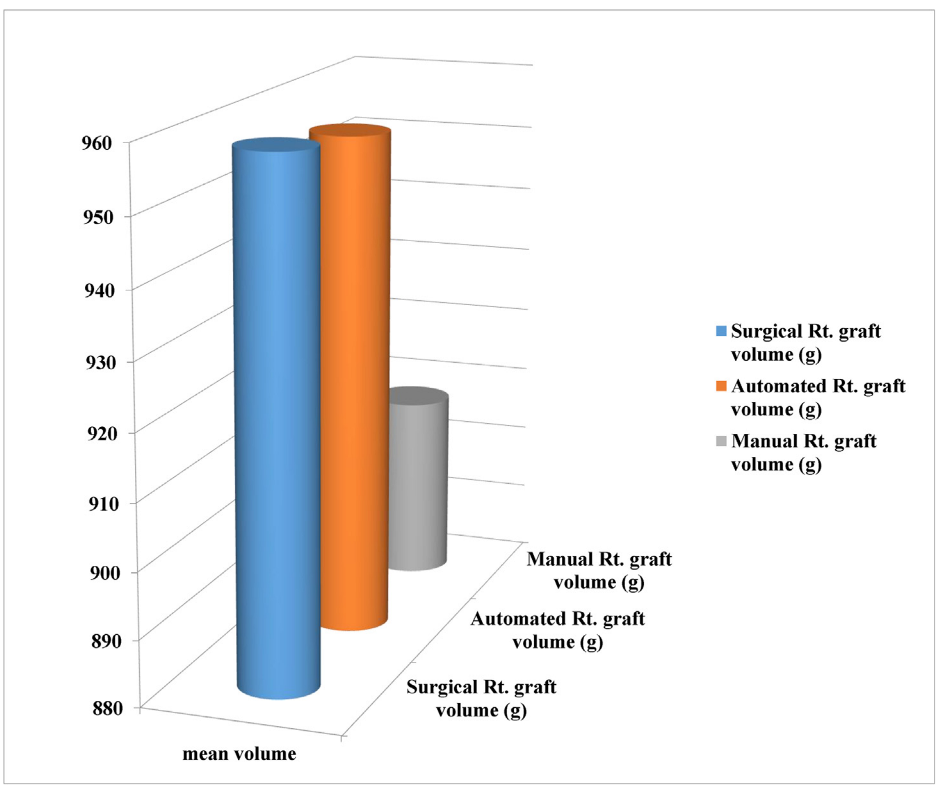

Fig. 3. Comparison between different graft volumes adding hepatic veins.

Table 2. Comparison between different graft volumes.

	Surgical graft volume (g)	Automated graft volume (g)	Manual graft volume (g)	*P* value
Mean ± SD	857.1 ± 221.32	858.35 ± 231.54	880.48 ± 260.54	*P*1: 0.9804 *P*2: 0.6666 *P*3: 0.6891
Median (IQR)	879 (650–1025)	835 (656.5–981.25)	756.5 (728–1020)	
Range (Minimum–maximum)	684 (550–1234)	791 (517–1308)	940 (479–1419)	

*P*1: Surgical and Automated |*P*2: Surgical and Manual |*P*3: Automated and Manual *T*-test |*P* less than 0.05 significant.

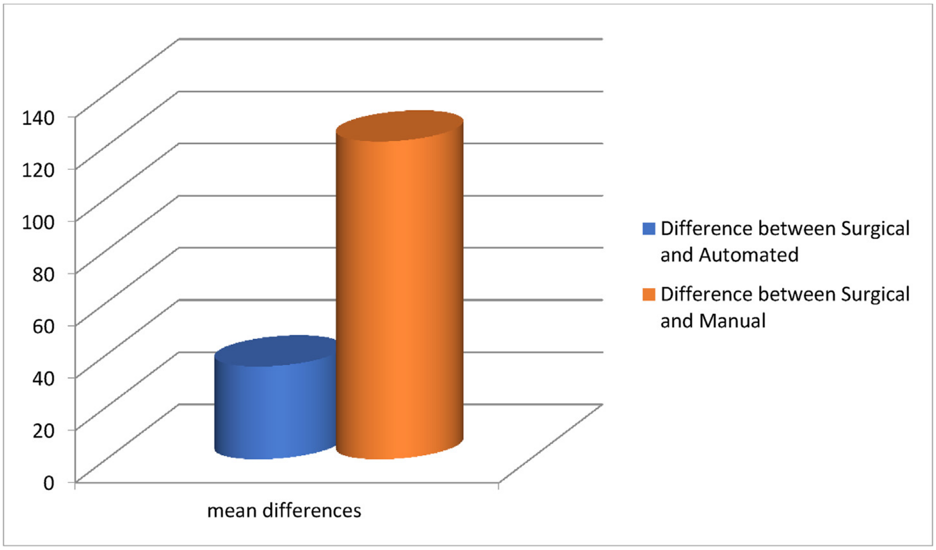

Fig. 4. Comparison between difference between surgical and automated and difference between surgical and manual estimations.

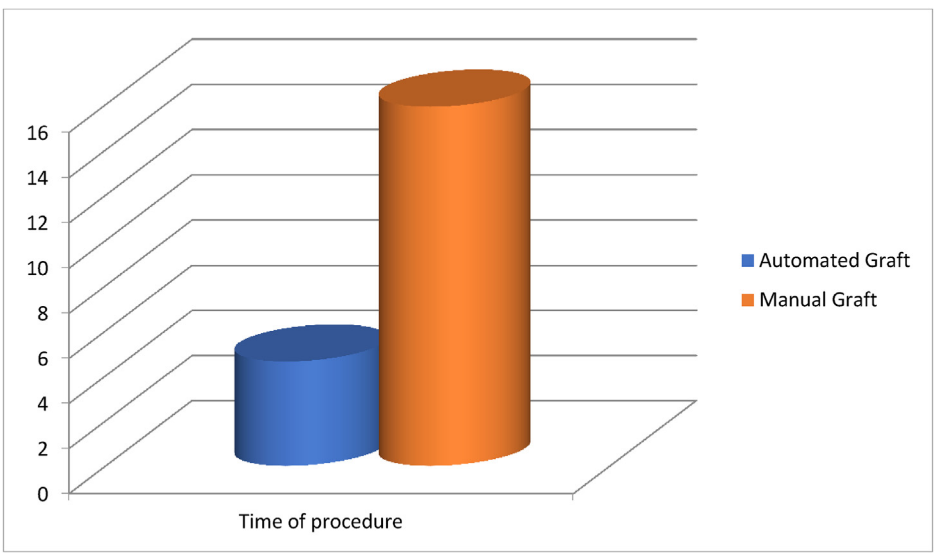

Fig. 5. Automated and manual graft time of procedure.

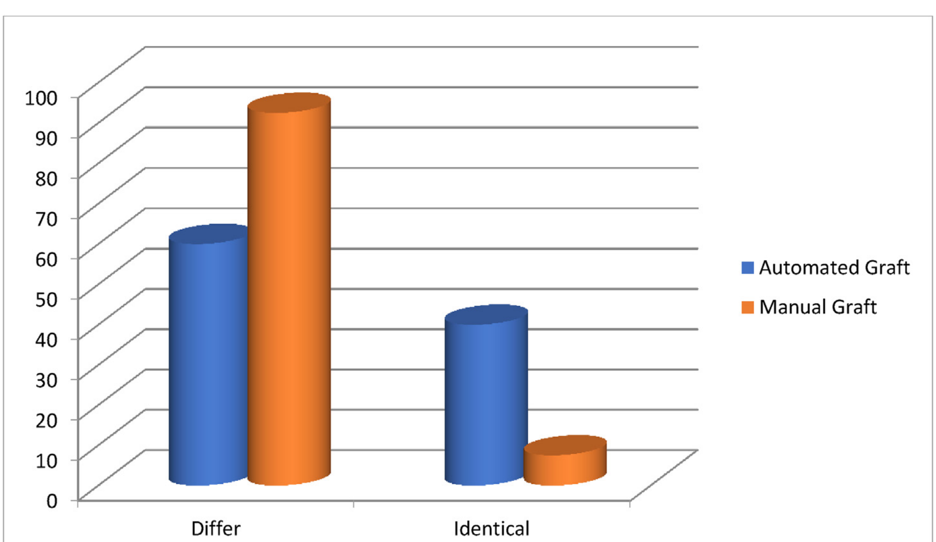

Fig. 6. Automated and manual graft similarity with actual graft size.

Table 3. Comparison between different graft volumes adding hepatic veins.

	Volume after HV	Automated Volume after HV	Manual Volume after HV	*P*. Value
Mean ± SD	958.23 ± 221.41	955.63 ± 226.75	907.8 ± 230	*P*1: 0.971 *P*2: 0.675 *P*3: 0.678
Median (IQR)	978.5 (752–1127.25)	949.5 (752–1247.75)	853.5 (725.75–1197.25)	
Range	647–1338	647–1304	613–1299	

Table 4. Comparison between difference between surgical and automated and difference between surgical and manual estimations.

	Difference between Surgical and Automated	Difference between Surgical and Manual	*P* value
Mean ± SD	35.55 ± 14.37	121.78 ± 33.92	
Median (IQR)	32.5 (25.75–48)	114 (95.5–141)	<0.0001
Range (Minimum–maximum)	61 (13–74)	121 (71–192)	

T-test |*P* less than 0.05 significant.

Table 5. Automated and manual graft time of procedure.

	Automated Graft	Manual Graft	*P* value
Time of procedure (min)	4.63 ± 1.31	15.9 ± 3.66	<0.0001
Median (Range)	5 (2–7)	15.5 (10–23)	

There was significant increase in time of procedure in manual graft procedure.

Table 6. Automated and manual graft similarity with actual graft size.

	Automated Graft	Manual Graft	*P* value
Differ	24 (60%)	37 (92.5%)	0.000637
Identical	16 (40%)	3 (7.5%)	

Similarity with actual volume was significantly increased with automated procedure.

volume can result in small-for-size graft syndrome, whereas overestimating the donor's standard liver volume can lead to extensive hepatic resection and liver failure.[11]

The ‘gold-standard’ method currently used to calculate liver volume on CT images is manual volumetry. A relatively accurate result can be produced by manual volumetry; however, its use in normal clinical practice is discouraged because of the laborious and time-consuming process, subjective assessment, and intra- and inter-observer disagreement.[16]

Manual tracing is painful and time-consuming for determining hepatic volumes; post-processing time is typically more than 60 min. The rapid development of image analysis and machine learning has made it possible to replace manual calculations of clinical liver volume with very accurate computerized volumetry methods.[6]

Preoperative planning of LDLT, involves CT scans and computers that automatically estimate the volume of donor graft. Nevertheless, differences in volume estimations between preoperative and intraoperative treatments are still seen today, despite technological advancements. Currently, CTV is used to determine the size of potential donor organs and the liver anatomy prior to surgery. Finding the best liver segments for donation can be done by CTV after clinical evaluations of the ideal transplant size (e.g., using the ratio of graft to body weights).[5]

The main objective of this research was to compare manual and automated CTV in the evaluation of the weight of graft in living donor liver transplantation in relation to intra-operative graft volume.

This prospective observational study included 40 patient population candidates and actually living liver donors.

The main results of this study were as follows: there were insignificant differences between graft volumes estimated by surgery, automated or manual as mean volume was 857.1, 858.35, and 880.48, respectively. There was a highly significant variation between Surgical and Automated and between Surgical and Manual estimations. There was a significant increase in time of procedure in manual graft procedure. There was no considerable difference between Volume after HV and Automated Volume after HV, Volume after HV and Manual Volume after HV as well as Automated Volume after HV and Manual Volume after HV.

Our findings were supported by Nakayama *et al.*[6] where automated and manual techniques required 4.4 min ± 1.9 and 32.8 min ± 6.9, respectively with significant differences between them. The automated technique decreased the duration for performing volumetry and provided reasonable assessments.

Similarly, In the study of Madbouly *et al.*[15] The automated volumetry method had a relatively short average processing time per case, with a range of processing times observed. The mean volume calculated using the automated approach was in good agreement with the actual graft weight, with no significant difference observed.

Mussin *et al.*[1] utilized automated algorithms to accurately calculate right liver volumes, achieving a variation of less than 15% compared with the actual transplanted mass. They discovered that in the manual volumetry group, 55.1% of patients had a modest change (less than 15%), while 44.9% of patients had a significant variation (more than 15%).

Lemke *et al*.[17] in their study reported that the mean difference between the intra-operative and pre-operative readings was 34.3%, according to the measurement data. Nakayama *et al*.[6] showed that when compared with the actual liver volume measured after resection, liver volume as determined by CTV is likewise overstated. In a preoperative volume evaluation that is automatically determined, a variance of about 10% is to be expected. Previous research has claimed that liver volume calculations in donors under the age of 36 years are more closely related to intra-operative measures as reported in previous studies.[18,19]

The primary theory for this phenomenon is that less blood is present in the hepatic arteries when actual liver volumes are assessed. Therefore, it could be preferable to exclude the main hepatic arteries. The graft actual cutting line is decided by transient clumping of the hepatic arteries, which is another explanation for why it might not match the preoperative estimate. A portion of the CTV inaccuracy can be ascribed to the hepatic graft's fluctuating physiologic density. The findings of a previous study[17] on 16 living liver contributors, nonetheless, demonstrated notable individual discrepancies in density, and the mean density of the liver was approximately 12% higher than 1.00 g/ml.

Karlo *et al*.[15] additionally suggested transformation of magnitude to mass using a coefficient of 0.85 for CT, but their discoveries are limited and may not be relevant to live liver contributors as the excised hepatic samples uncovered fundamental abnormalities that could have led to a density discrepancy compared with that of a healthy liver.

The most crucial element influencing surgical approach, morbidity and postsurgical mortality in LDLT is preoperative assessment of donor liver volume. The surgical plan may be modified as a result of both underestimation and overestimation of the FLR ratio, including the use of procedures or revisions to the surgical resection plan—or, in the case of a low FLR ratio, the cancellation of the donor. Inaccurate FLR ratio calculation can have a big impact on both donor and recipient care, depending on which direction it goes. It's crucial to calculate the recipient's proper weight and resect no more than 70% of the liver's capacity of the donor.

A 5% difference between preoperative and postoperative graft volumes (prospective and retrospective CTV, respectively) was reported by Kwon *et al*.[20] in 1970. When compared with the actual graft weight recorded at the time of the procedure, this mistake can grow by up to 10%. They ascribed this overestimation to a liver that was loaded with blood.

Furthermore, Taema *et al*.[21] reported that the average volume was 21.7 + 33.65 cm^3 for the difference between pre-surgical and actual graft assessments, and the average volume between pre-surgical and actual graft volumes was 51.96 + 33.65 cm^3 (range 4–131 cm^3). Between the mean pre-surgical volume and the total volume of the graft, a significant correlation was discovered. The conclusions had statistical significance.

The preoperative and intraoperative liver volumes were 816.5 + 142.5 g and 812.1 + 136.2 g, respectively according to Sharma *et al*.[22] They came to the conclusion that the volume discrepancy between the graft's preoperative and actual volumes was 21.7 + 33.65 cm^3.

In the study of Bozkurt *et al.*[23] the surgeon's estimation of the volume of the right and left lobe grafts demonstrated a positive association with the actual graft weight. Similarly, the determination of the graft volume for both the right and left lobes exhibited a positive correlation with the actual graft weight. No significant differences were published.

The two most important parameters in determining the effectiveness of the transplant are the graft size and the quantity of remaining volume of donor's liver. A small graft may produce hepatic dysfunction, including ascites, hyperbilirubinemia, and portal hypertension because of the recipient's higher metabolic needs. Instead, large grafts may result in anatomical issues such poor blood flow, difficulty closing the abdomen, and undesirable vascular orientation. The subject of liver transplantation can survive if the size of the donor's liver is a minimum of 40% of the recipient's liver or if the ratio of the graft weight to the recipient's body weight exceeds 0.8%. Additionally, it is essential for the donor's remaining liver tissue to be healthy and functioning normally. Correct measurement of the liver volume of potential living donors is essential to avoiding issues with transplant size and leftover liver volume.[24]

In the study of Tamulevicius *et al.*[25] intraoperative estimation of an actual graft weight (AGW) and the manual segmentation of the hepatic left lateral lobe for volume (GV) was done. The average AGW and GV were almost 283.4 ± 68.5 g, and 244.9 ± 63.86 ml, respectively. A strong relationship between the GV and AGW ($r = 0.804$, $P < 0.001$) was found.

4.1. Conclusion

We concluded that the weight/volume of the liver graft for surgery can be determined using automated CT liver volumetry, which, in our opinion, provides adequate volumetric measures that can be deemed sufficiently precise.

Conflicts of interest

No conflict of interest: yes.

References

1. Mussin N, Sumo M, Lee KW, et al. The correlation between preoperative volumetry and real graft weight: comparison of two volumetry programs. *Ann Surg Treat Res*. 2017;92:214–220.
2. Fukazawa K, Yamada Y, Nishida S, Hibi T, Arheart KL, Pretto EA. Determination of the safe range of graft size mismatch using body surface area index in deceased liver transplantation. *Transpl Int Off J Eur Soc Organ Transplant*. 2013;26:724–733.
3. Tsang LLC, Chen CL, Huang TL, et al. Preoperative imaging evaluation of potential living liver donors: reasons for exclusion from donation in adult living donor liver transplantation. *Transplant Proc*. 2008;40:2460–2462.
4. Singh AK, Cronin CG, Verma HA, et al. Imaging of preoperative liver transplantation in adults: what radiologists should know. *Radiographics*. 2011;31:1017–1030.
5. Wei L, Zhu ZJ, Lü Y, et al. Application of computer-assisted three-dimensional quantitative assessment and a surgical planning tool for living donor liver transplantation. *Chin Med J (Engl)*. 2013;126:1288–1291.
6. Nakayama Y, Li Q, Katsuragawa S, et al. Automated hepatic volumetry for living related liver transplantation at multisection CT. *Radiology*. 2006;240:743–748.
7. Frericks BB, Caldarone FC, Nashan B, et al. 3D CT modeling of hepatic vessel architecture and volume calculation in living donated liver transplantation. *Eur Radiol*. 2004;14:326–333.
8. Fischer L, Tetzlaff R, Schöbinger M, et al. How many CT detector rows are necessary to perform adequate three dimensional visualization? *Eur J Radiol*. 2010;74:e144–e148.
9. Neumann JO, Thorn M, Fischer L, et al. Branching patterns and drainage territories of the middle hepatic vein in computer-simulated right living-donor hepatectomies. *Am J Transplant Off J Am Soc Transplant Am Soc Transpl Surg*. 2006;6: 1407–1415.
10. Perandini S, Faccioli N, Inama M, Pozzi Mucelli R. Freehand liver volumetry by using an electromagnetic pen tablet: accuracy, precision, and rapidity. *J Digit Imag*. 2011; 24:360–365, 8.
11. Suzuki K, Epstein ML, Kohlbrenner R, et al. Quantitative radiology: automated CT liver volumetry compared with interactive volumetry and manual volumetry. *AJR Am J Roentgenol*. 2011;197:W706–W712.
12. Suzuki K, Kohlbrenner R, Epstein ML, Obajuluwa AM, Xu J, Hori M. Computer-aided measurement of liver volumes in CT by means of geodesic active contour segmentation coupled with level-set algorithms. *Med Phys*. 2010;37: 2159–2166.
13. Frericks BBJ, Kiene T, Stamm G, Shin H, Galanski M. [CT-based liver volumetry in a porcine model: impact on clinical volumetry prior to living donated liver transplantation]. *ROFO Fortschr Geb Rontgenstr Nuklearmed*. 2004;176:252–257.
14. Mohapatra N, Gurumoorthy Subramanya Bharathy K, Kumar Sinha P, Vasantrao Sasturkar S, Patidar Y, Pamecha V. Three-dimensional volumetric assessment of graft volume in living donor liver transplantation: does it minimise errors of estimation? *J Clin Exp Hepatol*. 2020;10:1–8.
15. Karlo C, Reiner CS, Stolzmann P, et al. CT- and MRI-based volumetry of resected liver specimen: comparison to intraoperative volume and weight measurements and calculation of conversion factors. *Eur J Radiol*. 2010;75:e107–e111.
16. Cai W, He B, Fan Y, Fang C, Jia F. Comparison of liver volumetry on contrast-enhanced CT images: one semiautomatic and two automatic approaches. *J Appl Clin Med Phys*. 2016;17:118–127.
17. Lemke AJ, Brinkmann MJ, Schott T, et al. Living donor right liver lobes: preoperative CT volumetric measurement for calculation of intraoperative weight and volume. *Radiology*. 2006;240:736–742.
18. Yonemura Y, Taketomi A, Soejima Y, et al. Validity of preoperative volumetric analysis of congestion volume in living donor liver transplantation using three-dimensional computed tomography. *Liver Transplant Off Publ Am Assoc Study Liver Dis Int Liver Transplant Soc*. 2005;11:1556–1562.
19. Kayashima H, Taketomi A, Yonemura Y, et al. Accuracy of an age-adjusted formula in assessing the graft volume in living donor liver transplantation. *Liver Transplant Off Publ Am Assoc Study Liver Dis Int Liver Transplant Soc*. 2008;14:1366–1371.
20. Kwon HJ, Kim KW, Kim B, et al. Resection plane-dependent error in computed tomography volumetry of the right hepatic lobe in living liver donors. *Clin Mol Hepatol*. 2018;24: 54–60.
21. Taema MI, Fawz MMT, Ali AMAER, Al-Fawal MM. Assessment of role of computed tomography volumetry in preoperative evaluation of liver volume in living donor liver transplantation. *Egypt J Hosp Med*. 2022;88:2400–2405.
22. Sharma A, Ashworth A, Behnke M, Cotterell A, Posner M, Fisher RA. Donor selection for adult-to-adult living donor liver transplantation: well begun is half done. *Transplantation*. 2013;95:501–506.
23. Bozkurt B, Emek E, Arikan T, et al. Liver graft volume estimation by manual volumetry and software-aided interactive volumetry: which is better? *Transplant Proc*. 2019;51: 2387–2390.
24. Sharma M, Somani P, Rameshbabu CS, Sunkara T, Rai P. Stepwise evaluation of liver sectors and liver segments by endoscopic ultrasound. *World J Gastrointest Endosc*. 2018;10: 326–339.
25. Tamulevicius M, Koitka S, Theysohn J, et al. Preoperative computed tomography volumetry and graft weight estimation of left lateral segment in pediatric living donor liver transplant. *Exp Clin Transplant*. 2023 Oct;21(10):831–836. https://doi.org/10.6002/ect.2023.0176. PMID: 37965959.