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Kalshabay Ye.
orcid.org/0000-0003-0493-6685
Zholdybay Zh.
orcid.org/0000-0003-0553-9016
Baiguissova D.
orcid.org/0000-0001-5724-7707
Battalova G.
orcid.org/0000-0003-4261-3537

Author for correspondence:
Kalshabay Ye. – Radiologist, the 3th year PhD-student of the Asfendiyarov Kazakh National medical university, Almaty, Kazakhstan,
e-mail: tulkubas16@gmail.com

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The authors declare that they have no conflicts of interest

METHOD FOR OPTIMIZING CT VOLUMETRY OF THE LIVER IN RELATED TRANSPLANTATION

Kalshabay Ye.Ye.[1,2], Zholdybay Zh.Zh.[1], Baiguissova D.Z.[2], Battalova G.A.[2]

[1]Asfendiyarov Kazakh National medical university, Almaty, Kazakhstan,
[2]A.N. Syzganov National scientific center of surgery, Almaty, Kazakhstan

Abstract

Computed tomography volumetry is the standard method for preoperative estimation of liver volume. Despite the development of various software, the trend towards discrepancy in the calculation of liver volume compared with any of the methods and intraoperative graft weight remains.

***The aim of the study** was to optimize the manual method of CT volumetry donor' liver, determine its accuracy and compare it with the standard method.*

***Material and methods.** A single-center prospective study including data from 60 liver donors who underwent computed tomography, CT volumetry and liver transplantation at the National Scientific Surgery Center named after A.N. Syzganov for the period 2018-2022.*

***Results**. The Pearson correlation between the right liver lobe volume estimated by the standard method and the graft weight was 0.730 (p<0.01), the Pearson correlation between the liver volume calculated by the optimized method (-10 HU) and the graft was 0.757 (p<0.01), and the correlation between the optimized method (-20 HU) and graft weight – 0.860 (p<0.01). The Pearson correlation coefficient of the optimized method (-20 HU) is statistically significantly higher than the correlation coefficient of the standard manual method (p=0.026), the difference between the correlation coefficient of the optimized method (-10 HU) and the standard one is statistically insignificant (p=0.375). The degree of discrepancy between the optimized method (-20 HU) was 8.4%, manual method - 12.7%. There is a statistically significant difference between the degree of discrepancy between the standard manual and optimized method (-20 HU) (p=0.029).*

***Conclusions**. Optimization of the manual CT volumetry method with a decrease in the liver density threshold by 20 HU demonstrated a statistically significantly high correlation coefficient with the graft weight, and also significantly reduced the degree of discrepancy.*

Keywords:
Computed tomography, CT volumetry, liver transplantation, liver donor, optimization.

Туыстық трансплантация кезінде бауырдың КТ-волюметриясын оңтайландыру әдісі

Хат алысатын автор:
Қалшабай Е.Е. - сәулелі диагностика дәрігері, С.Ж. Асфендияров атындағы Қазақ Ұлттық медицина университетінің 3 жыл PhD-докторанты, Алматы қ., Қазақстан,
e-mail: tulkubas16@gmail.com

Қалшабай Е.Е.[1,2], Жолдыбай Ж.Ж.[1], Байгуисова Д.З.[2], Батталова Г.А.[2]

[1]С.Ж. Асфендияров атындағы Қазақ Ұлттық медицина университеті, Алматы қ., Қазақстан,
[2]А.Н. Сызғанов атындағы Ұлттық ғылыми хирургия орталығы, Алматы қ., Қазақстан

Мүдделер қақтығысы:
Авторлар мүдделер қақтығысының жоқтығын мәлімдейді

Аңдатпа

Компьютерлік-томографиялық волюметрия – бауыр көлемін операция алдында бағалауға арналған стандартты әдіс. Түрлі бағдарламалық жасақтамалардың дамуына қарамастан, трансплантаттың интраоперациялық салмағы мен бауыр көлемін есептеудің кез-келген әдістерімен салыстырғанда сәйкессіздік тенденциясы сақталып отыр.

***Зерттеудің мақсаты** – донор бауырының КТ-волюметриясы мануальды әдісін оңтайландыру, оның нақтылығын анықтау және стандартты әдіспен салыстыру.*

***Материалдар мен әдістері**. 2018-2022 жж. аралығында А.Н. Сызғанов атындағы Ұлттық ғылыми хирургия орталығында бауыр трансплантациясы және КТ-волюметрия, Компьютерлік томографиядан өткен 60 бауыр донорының мәліметтерін қамтитын бір орталықтық проспективтік зерттеу.*

***Нәтижелері**. Стандартты әдіс арқылы есептелген бауырдың оң жақ үлесінің көлемі мен графт массасы аралығындағы Пирсон корреляциясы 0.730 (p<0.01) құрады, оңтайландырылған әдіс (-10 HU) арқылы есептелген бауыр көлемі мен графтың арасындағы Пирсон корреляциясы 0.757 (p<0.01), ал оңтайландырылған әдіс (-20 HU) арасындағы корреляция (p<0.01) құрады.*

Түйін сөздер:
Компьютерлік томография, КТ-волюметрия, бауыр трансплантациясы, бауыр доноры, оңтайландыру.

Оңтайландырылған әдістің (-20 HU) Пирсон корреляциясының коэффициенті стандартты мануальды әдіс корреляциясының коэффициентіне қарағанда статистикалық тұрғыдан жоғары (p=0.026), оңтайландырылған әдіс (-10 HU) пен стандартты әдіс корреляциясының коэффициенттері арасындағы айырмашылық статистикалық тұрғыдан елеусіз (p=0.375). Оңтайландырылған әдістің айырмашылық дәрежесі 8,4%-ды, ал мануальды әдістің алшақтық дәрежесі 12,7%-ды құрады. Стандартты мануальды және оңтайландырылған әдістің (-20 HU) айырмашылық дәрежелері арасында статистикалық тұрғыдан маңызды айырмашылық байқалады (p=0.029).

***Қорытынды**. Бауырдың тығыздық шегін 20 HU-ға азайта отырып КТ волюметрияның мануальды әдісін оңтайландыру графт салмағы мен корреляциясының статистикалық жоғары коэффициентін көрсетті, сондай-ақ алшақтық дәрежесін едәуір төмендетті.*

Метод оптимизации КТ-волюметрии печени при родственной трансплантации

Қалшабай Е.Е.[1,2], Жолдыбай Ж.Ж.[1], Байгуисова Д.З.[2], Батталова Г.А.[2]

[1]Казахский Национальный медицинский университет имени С.Д. Асфендиярова, г. Алматы, Казахстан,
[2]Национальный научный центр хирургии имени А.Н. Сызганова, г. Алматы, Казахстан

Автор для корреспонденции:
***Қалшабай Е.Е.** - врач лучевой диагностики, PhD докторант 3 года обучения, Казахский Национальный медицинский унивесрситет имени С.Д. Асфендиярова, г. Алматы, Казахстан, e-mail: tulkubas16@gmail.com*

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Ключевые слова:
Компьютерная томография, КТ- волюметрия, трансплантация печени, донор печени, оптимизация.

Аннотация

Компьютерно-томографическая волюметрия является стандартным методом предоперационной оценки объема печени. Несмотря на развитие различных программных обеспечений, тенденция к расхождению в расчёте объема печени по сравнению с любым из методов и интраоперационным весом трансплантата сохраняется.

***Цель исследования** - оптимизировать мануальный метод КТ-волюметрии печени донора, определить его точность и сравнить со стандартным методом.*

***Материал и методы.** Одноцентровое проспективное исследование, включающее данные 60 доноров печени, прошедших Компьютерную томографию, КТ-волюметрию и трансплантацию печени в Национальном научном центре хирургии имени А.Н. Сызганова за период 2018-2022 гг.*

***Результаты.** Корреляция Пирсона между объемом правой доли печени рассчитанный стандартным методом и массой графта составила 0,730 (p<0,01), корреляция Пирсона между объемом печени рассчитанный оптимизированным методом (-10 HU) и графтом составила 0,757 (p<0,01), а корреляция между графтом и оптимизированным методом (-20 HU) – 0,860 (p<0,01). Коэффициент корреляции Пирсона оптимизированного метода (-20 HU) статистически значимо выше, чем коэффициент корреляции стандартного мануального метода (p=0,026), различие между коэффициентом корреляции оптимизированного метода (-10 HU) и стандартного - статистически незначимо (p=0,375). Степень расхождения оптимизированного метода (-20HU) составило - 8,4%, мануального метода -12,7%. Отмечается статистическое значимое различие между степенью расхождения стандартного мануального и оптимизированного метода (-20 HU) (p=0,029).*

***Выводы.** Оптимизация мануального метода КТ-волюметрии с уменьшением порога плотности печени на 20 HU продемонстрировало статистически значимо высокий коэффициент корреляции с весом графта, а также значимо снизила степень расхождения.*

Introduction

Owing to technical improvements and the standardization living donor liver transplantation (LDLT) has become as effective as cadaveric liver transplantation. Inadequate liver volume is among the most common cause donor exclusion [1]. Accurate quantification of the liver volume necessary for avoiding metabolic mismatches between donor and recipient which may result in "small for size" of "large -for-size syndrome" and ultimately in an increased risk of graft rejection [2] The remnant volume in living donors should be at least 30% of the liver volume since donor safety has absolute priority [3]. CT volumetry has been widely used for preoperative graft volume measurement in LDLT [4].

Liver transplantation from a related donor in Kazakhstan has been carried out since 2011[5].

Heymsfield S. et al. [6] were the first to calculate preoperative liver volume in 1970, since then many software packages have been developed.

Our previous study showed that the manual method was more accurate than the semi-automatic method, had a lower degree of discrepancy compared to the semi-automatic and automatic methods [7]. However, the degree of discrepancy of the manual method still remained high – 12,7%. In this study, we considered methods for optimizing the manual method, compared it with the standard one, and determined its accuracy.

The aim of the study was to optimize the manual method of CT volumetry donor' liver, determine its accuracy and compare it with the standard method.

Materials and methods

Single center prospective study including data from 60 liver donors. All donors underwent Computed tomography of the abdominal with the introduction of a contrast agent, CT volumetry and liver transplantation at the Hepatopancreobiliary Surgery and Liver Transplantation Department of the National Scientific Center of Surgery named after. A.N. Syzganov for the period 2018-2022 years.

This study was approved by the ethics committee of the Kazakhstan National Medical University named after. S.D. Asfendiyarov (No. 3 (109) dated March 31, 2021).

Inclusion criteria were adult transplantation (over 18 years of age) with a right-sided hepatectomy and a left lobe volume of at least 35%. Patients who had CT scans at other hospitals were excluded. All liver donors had healthy livers, and patients with hepatic steatosis were also excluded from the study.

Computer Tomography

Multiphasic CT was performed in the cranio-caudal direction using a 160-slice MDCT scanner (Canon Aquilion, Prime SP) and slice thickness in the axial and coronal planes: 5 mm (pre-contrast) or 3 mm (post-contrast) with no interslice gap. A soft tissue B20 kernel was used in all cases. All patients received 1.6 ml/kg of body weight (corresponding to 560 mg Iodine/kg) of a non-ionic, iso-osmolar dimeric contrast medium (Iodixanol, Visipaque 320, GE Healthcare, Inc., Milwaukee, WI). Pre-warmed contrast medium (CM) was administered.

Images were obtained during the hepatic arterial, portal-venous and delayed phases (25–40, 70 and 180 s, respectively, after the start of contrast medium injection).

Portal-venous dataset from all examinations was transferred from Picture Archiving and Communication System (PACS), and volume of the right lobe of the liver was calculated using Volume analysis software.

The estimation was carried out in calculation of the total liver volume and calculation of the left lobe plus segment I in order to establish the remnant liver volume. Resection planes for liver segmentation passed through the right side of the middle hepatic vein and gallbladder bed. The resulting volume was further compared with the intraoperative weight of the graft. Estimated liver volumes are presented in milliliters (ml), graft weight in grams (g).

Standard manual CT volumetry method on the Vitrea -Volume Analysis workstation

On each axial scan, the outline of the liver was drawn manually with the mouse cursor using the pencil tool. The inferior vena cava, portal vein with major branches, and gallbladder were excluded from the ROI. Total liver volume and residual liver volume were obtained by summing the volume at each section. To determine the volume of the liver without vessels, an allowable density threshold was set in the toolbar, which corresponded to the density of the liver, thus the volume of vessels was excluded. The minimum threshold was 30 HU., the maximum varied based on the density of each liver. The program changed the coverage intensity of the isolated liver parenchyma based on the given density. Thus, the maximum density threshold was set, which covered the entire liver parenchyma without blood vessels. The results were saved as a screenshot (Figure 1).

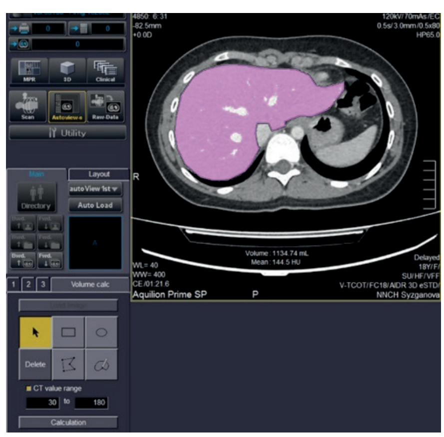

Figure 1.
Calculation of the volume of the liver by the standard method. The maximum density threshold is 180 HU

Optimized CT volumetry method on the Vitrea workstation

With the optimized method, the volume calculation was carried out in the same way as with the standard one: on each axial scan, the contour of the liver was drawn manually with the mouse cursor using the pencil tool. Vessels were also excluded from the study area. For optimization, we changed the allowable density threshold. The minimum remained the same 30 HU. For the optimization method, we lowered the maximum density threshold by 10 HU and by 20 HU. The results obtained were saved as a screenshot (Figure 2).

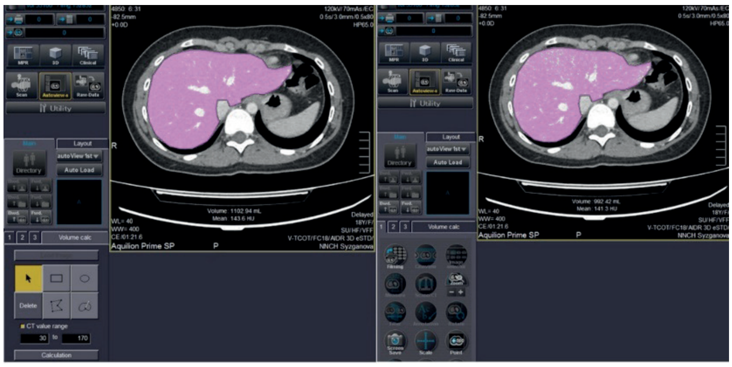

Figure 2.
Calculation of the liver volume by the optimized method. Maximum density threshold
a) 170 HU
b) 160 HU

Intraoperative graft weight measurement

At the back table after resection, the graft was flushed by a surgeon with saline and histidine-tryptophan-ketoglutarate (Custodiol) solutions to remove blood. Afterward, the graft was weighed on electric scales.

Statistics: The Kolmogorov-Smirnov test was used to determine the normality of the sample distribution. For descriptive statistics, mean ± standard deviation (SD) was used. The liver volume calculated by the standard method and two optimization methods (-10 HU) and (-20 HU) was compared with the weight of the graft. The discrepancy of each program was presented as a percentage (%), the 100% value of which was the weight of the graft. Pearson's correlation was also applied to compare each of the method.

A p value <0,05 was used to determine statistical significance. Statistical analysis was carried out using the SPSS program (IBM corp., 19 version).

Results

The average volume of the whole liver estimated by the standard method was 1322±

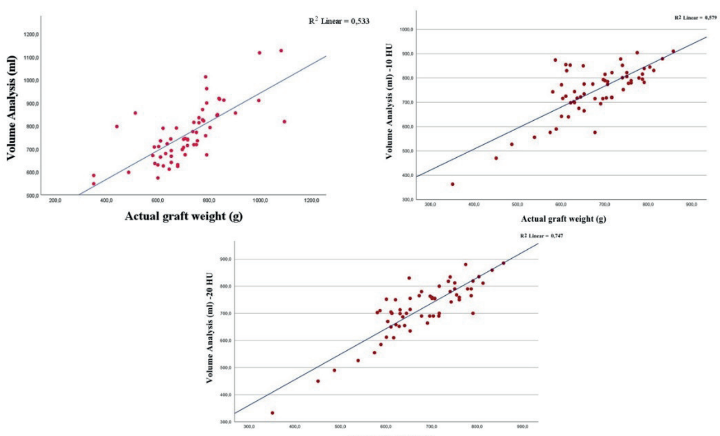

Figure 3.
Pearson correlation between
a) standard manual method with graft weight,
b) optimized method (-10 HU) with graft weight,
c) optimized method (-20 HU) with graft weight

There is a statistically significant difference between the correlation coefficient of the standard and optimized manual method (-20 HU) (p=0,026) and a non-significant difference between the standard and optimized (-10 HU) method (p=0,375).

The degree of discrepancy between the optimized method (-20 HU) was 8,4%, the manual method -12.7%. There is a statistically significant difference between the degree of discrepancy between the standard manual and the optimized method (-20 HU) (p=0,029).

Discussion

Martel et al. [8] reported in their study that a discrepancy of about 5% between the calculated volume and the actual graft weight can affect the clinical outcome. Binomial proportions and 95% confidence intervals were created for this comparison. When using measured volume as a reference standard, estimated volume has been shown to result in a clinically significant overestimation in up to one-third of patients, which may influence clinical decision making to prevent liver failure or small size syndrome.

These syndromes include residual liver weight unable to maintain adequate organ function, resulting in hyperbilirubinemia, coagulopathy, ascites, encephalopathy, and hypoalbuminemia, and ultimately postoperative death.

Depside of investigation of the automated method Park R et al. in his work studies the accuracy of the automatic method using a deep learning algorithm (deep learning assisted), however, the automatic program shows a large error in comparison with the mass of the graft and is 17% [4].

Mayer et al. [9] in his study, he provides data on the absence of statistically significant differences between the studied volume of the liver with a small slice thickness (<3 mm) and with a larger slice thickness (>3 mm). In our study, we performed CT volumetry on 3 mm slices.

Xie T et al. [10] in his work was studies Couinaud automatic segmentation during liver resection; in this work, an automated program is compared with a manual one. However, there are no statistically significant results when comparing the two methods, moreover, the authors state that the manual method remains the gold standard for calculating liver volume.

In our study, the optimized method (-20 HU) showed a percentage of discrepancy of 8.4%, despite the fact that this figure is more than 5%, it still showed more accurate results compared to the previous methods we studied. Thus, the optimized method helps to reduce the risk of postoperative complications.

Some studies have compared the estimated liver volume and graft weight with and without blood [11]. In the present study, the weight of the actual graft was measured intraoperatively after blood drainage. When assessing the volume of the liver in each program, vessels were excluded.

Manual assessment of liver volume included a liver density threshold. Despite the given liver density threshold, CT volumetry showed an overestimation of the results and, consequently, a discrepancy between the calculated liver volume and the transplant. Taking into account the influence of the above factors, the change in the rheological properties of the graft, we used a decrease in the liver density threshold as a method for optimizing CT volumetry.

To reduce the calculated liver volume and obtain more accurate results, we changed the maximum liver threshold: decreased by 10 HU and by 20 HU. Thus, a decrease in the density threshold by 20 HU demonstrated a statistically significant correlation coefficient with the weight of the graft, and also significantly reduced the degree of discrepancy to 8,4%.

Conclusion

The optimized manual method (-20 HU) showed a statistically significant Pearson correlation coefficient with graft weight, as well as a decrease in the degree of discrepancy compared to the standard manual method.

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