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Article

Validation of 2D-ultrasound and volume estimation formulae for volume assessment of kidneys and spleens - An in-vitro study

Validación de la fórmula de estimación de volumen y ultrasonido 2D para la evaluación del volumen de los riñones y el bazo: un estudio in vitro

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ABSTRACT

The accuracy of internal organ volume estimation done with ultrasound (US) was found to be multifactorial. Hence, we aimed to describe and validate the volume assessment of ultrasound and standard volume estimation formulae for different shaped intra-abdominal organs using spleens and kidneys.

Dissected cadaveric kidneys (n=25) and spleens (n=29) were scanned to obtain linear measurements and ultrasound auto-generated volumes (USV). Linear measurements were used to calculate the volumes manually with ellipsoid, prolate, and Lambert volume estimating formulae. The actual volumes (AV) of organs were obtained by the water displacement method. Volume assessment accuracy of USV and different formulae were compared by comparing bias, precision and Bland-Altman plot analysis. The US linear and volume measurement procedure was reliable with high inter and intra-observer agreements (linear: Chronbach's α=0.983 to 0.934; volumes: Chronbach's α=0.989). USV estimates were accurate with a high correlation to AV and low estimation bias (-5.9%). Also, prolate (bias=-0.75%) and ellipsoid formulae (bias=-3.75%) were reliable with a negligible bias in estimated volumes. Contrary, the Lambert formula was unreliable due to a high bias (41.6%). For all evaluated methods, the estimation error found to be related to the organ size (T=3.483; p=0.001), mainly when the assessed organ is larger than 50 ml. Also, the shape related estimation error found to be related to the volume estimation formula used.

This study has validated the USV for kidney and splenic volume assessments while describing volume-calculating formula employed, organ size and shape as significant contributors for volume estimation accuracy.

Keywords: ultrasound; validation of volume estimation; abdominal organs; prolate; ellipsoid; Lambert formula

1. Introduction

Techniques that are used for volume assessment in clinical practice have enormously evolved over the past few decades, demonstrating the pivotal role of measured volume in disease diagnosis and management (Zapassky, et al., 2012; Weisstein, 2020). Measuring the volume of fluid-filled organs, such as the bladder, is easy, is usually measured after voiding. In contrast, estimating the volume of a solid organ is more complicated; by obtaining several measurements, the volume is to be calculated using a mathematical formula. The appropriate volume calculating mathematical formula has to be chosen considering the shape of the measured object (Zapassky, et al., 2012; Weisstein, 2020). The Mathematical formulae commonly used for volume estimation include prolate, ellipsoid and Lambert formula (Rasmussen, 1979; Zapassky, et al., 2012; Weisstein, 2020).

Since the internal organ volume evaluation process is complex, the organ size is commonly predicted using single or multiple linear measurements. However, in some instances having organ volume is more informative. For example, when the renal size is required to predict the renal function, the renal volume is more informative than linear measurements. Similarly, the splenic volume is a more reliable indicator in assessing haematological or liver diseases (Rasmussen, 1979; Linguraru, et al., 2013; Benjamin, el al., 2020;). Therefore, the need of identifying a reliable, less complex method for internal organ volume assessment is high.

Many invasive and non-invasive volume assessment methods are currently being used in clinical practice. Out of them, non-invasive imaging techniques such as ultrasound, computed tomography (CT), and magnetic resonance imaging (MRI) are increasingly gaining acceptance for lack of related

complications (Linguraru, et al., 2013; Maclaren, et al., 2014; Benjamin, el al., 2020). The ultrasound volume assessment method is considered safe for lack of having ionizing radiation. Moreover, the 2D US is freely available and cheap (Yetter, et al., 2003; Asghar, et al., 2011; Cheong, et al., 2017; Magistroni, et al., 2018). Thus, validation of the 2D US volume assessment system (US) is a timely need. The US uses an inbuilt volume calculation formula to generate the volume using the linear measurements obtained by the sonographer (Yetter, et al., 2003; Abdelwahab, et al., 2014; Sharma, et al., 2017; Kodikara, et al. 2020a; Kodikara, et al. 2020b).

It is essential to maintain a high accuracy in volumes estimation procedure when utilized for patient management (Abdelwahab, et al., 2014). Despite wide acceptance and high utility, the US volume estimation accuracy seems to be affected by the shape of the measured object. Our previous study found this estimation error is related to the volume calculation formula used (Sharma, et al., 2017; Kodikara, et al. 2020; Kodikara, et al. 2020). Though volume estimation accuracy has been assessed previously for different shaped objects and few isolated internal organs (Sharma, et al., 2017; Kodikara, et al. 2020a; Kodikara, et al. 2020b), there is an unfulfilled need to compare the accuracy and reproducibility of the US volume assessment for different shaped solid internal organs. Considering all available facts, as stated by our previous studies, we hypothesized that the said shape-dependent volume estimation error demonstrated for the US is related to the volume estimation formula used by the scanner. Moreover, the shape related error probably could be minimized by selecting the most appropriate formula for the shape of the measured organ.

Since the accuracy of in situ- studies are affected by many factors such as bowel gas shadows, the validation process believed to be more precise under in-vitro settings. Therefore, this study was aimed to systematically compare the volume estimating-accuracy of US for different shaped internal organs under in-vitro settings. Kidneys and spleens were selected for the study considering the diversity in shape. These two organs are not spherical, but the shape of the kidney deviates slightly away from the sphere, while the spleen does more extensively. Since these shapes represent many shapes encountered in humans, the authors believe that the results can be generalized other organs to a certain extent. Also, this study was aimed to compare the volume estimating-accuracy of commonly used volume estimation formulae (prolate, ellipsoid and Lambert formulae) and recommend the appropriate volume estimating formula for each organ/ shape.

2. Material and methods

This experimental study has evaluated the volumes of cadaveric kidneys (n = 25; 46.3%) and spleens (n = 29; 53.7%). The study has been carried out in the Department of Anatomy, Faculty of Medicine, University of Ruhuna, from June to August 2019, adhering to institutional ethical guidelines. At the time of cadaveric donation, informed, written consent was obtained from the next of kin for cadavers to be used for research purposes. To overcome low ultrasound wave transmission encountered in formalin-fixed cadavers, the organs were dissected and processed before scanning, by removing visceral fat, vascular remnants, and fasciae, leaving the capsules intact. This study included all available organs by adhering to convenient sampling method. Damaged or grossly deformed organs were excluded from the study. The organ volumes were estimated in two different methods.

1. ultrasonically as auto-generated volume (US)
2. manually, using ultrasonically obtained linear measurements in a volume calculation formulae.

The actual volume (AV) of organs were obtained by the water displacement method. AV was considered as the true volume of the organs. Compared to the AV, the volume estimation accuracy of each method was calculated.

The water displacement method

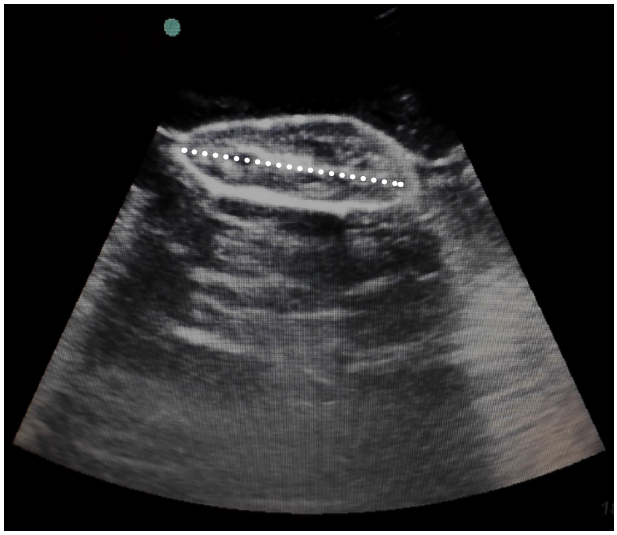
The water displacement method was used to obtain the AV of organs. The accuracy of the procedure was maintained by taking precautions to collect all displaced water; using standard volume measuring equipment; repeating each measurement thrice to obtain the average as AV. Furthermore, the water displacement method was validated before the study by obtaining the volumes of test objects (n = 7). The difference between the actual and displaced water volume of the test objects was compared to identify the accuracy of water displacement method.

Ultrasound volume estimation method

Two experienced Radiologists (IK and DG who are experienced for over ten years) independently obtained the measurements by repeating each measurement thrice. The 2D curvilinear probe (3.5MHz) of the same high-end US unit (GE LOGIQ E9 XD clear-Seongnam, Gyeonggi, Korea-released to the market in July 2016), was used to measure the maximum length, width, thickness, and the auto-generated US volume of each organ. The US volume measurement procedure is considered unbiased: the investigators were blind to the AV and other investigator's measurements. The instrument related bias eliminated by using the same scanner for all measurements.

The accuracy of US measurement procedure was maintained throughout as follows: by keeping a water-filled glove in-between the probe and the object; using an adequate amount of conducting gel to achieve maximum wave transmission; maintaining the image quality by adjusting time-gain compensation and tissue harmonic effects; keeping two focal points at near and far-fields of the organ (shown in Fig. 1). The US auto-generated volume is the volume of the object estimated by the US scanner by in-built volume calculating software. The maximum length (L), width (W), and thickness (T) of each kidney and spleen measured thrice using an electronic caliper, to the nearest 0.1 mm. During the measurement procedure, precautions were taken to avoid diagonal measurements.

Fig. 1
Ultrasound image of a cadaveric kidney demonstrating the length measurement.



Manual volume calculation method

Manually, the volume was estimated by using the means of US obtained linear measurements (L, W, T) in following standard volume calculation formulae: ellipsoid formula (L x W x T x 0.52); prolate formula (L x W x W x 0.52); Lambert formula (L x W x T x 0.71) (Sakamoto, et al., 2007).

Statistical analysis

Data analyzed using IBM SPSS statistics software, version 25. A preliminary analysis was performed to identify normality and linearity of the data set. Measurements were tabulated and means, and standard deviations were obtained for each organ and methodology. The volume measurement error (compared to AV) and error percentages were calculated.

The measurements were compared using T-test and Chi-square analysis. The internal integrity of measurements was investigated with Chronbach's alpha, while the correlations were investigated with the Pearson correlation coefficient. Different estimation methods were compared using both percentage error methods and Bland-Altman analyses; 95% confidence interval was calculated for differences.

An ideal volume estimation formula should have a low bias and variability. High, either positive or negative bias, is considered equally significant. Similarly, high, either positive or negative precision is considered as an indicator of variability in measurements. Following agreements were set as tolerance limits: less than 10% estimation error (bias) was considered negligible, and less than 30% estimation error (bias) was considered a tolerable bias (Mbaeri, et al., 2014; Basikaran, et al., 2018). The bias and precision values of different systems and organs were compared to validate each method for each organ.

3. Results

The study evaluated volumes of fifty-four (n = 54) kidneys (n = 25; 46.3%) and spleens (n = 29; 53.7%). Table 1 compares the distribution of mean volumes estimated by different estimation methods. The mean actual volume (AV) of the studied organs was 50.9 ml, and the volume ranged from 12 to 134 ml. A half (27 out of 54) of the studied organs measured less than 50ml. No significant difference in the AVs of kidneys and spleens (T = 0.541; p = 0.591): the mean AV±SD of kidneys was 52.3 ml (range 14 to 98 ml); spleens was 47.9 ml (range 12 to 134 ml).

Table 1.
Mean volumes of the organs obtained by different methods of volume estimation

Volume	Kidney (ml)	Spleen (ml)
Actual volume	52.3	47.9
Actual volume range	14 to 98	12 to 134
Auto generated - Ultrasound	41.2 ± 15.5	48.1 ± 22.8
Prolate formula	40.2 ± 13.7	44.1 ± 20.7
Ellipsoid formula	40.9 ± 15.4	46.7 ± 21.6
Lambert formula	55.8 ± 21.0	63.7 ± 29.5

Internal consistency of the measurement procedure

Validation of water displacement method

The validity of water displacement method was high depicting a high correlation to AV ($r = 0.999$; $p < 0.001$). Also, there was no significant difference between actual and displaced water volumes ($T = 0.307$; $p = 0.771$). Similarly, a high correlation was observed between two displaced water volume measurements ($r = 1.00$; $p < 0.001$).

Validation of ultrasound measurement procedure

The validity of ultrasound measurement procedure was high with a high correlation between two ultrasound measurements - length (Chronbach's $\alpha = 0.983$), width (Chronbach's $\alpha = 0.934$), thickness (Chronbach's $\alpha = 0.983$), and volume (Chronbach's $\alpha=0.989$). Also, reproducibility of ultrasound measurements was high with a high intra-observer (Chronbach's $\alpha = 0.983$) and inter-observer agreements (Chronbach's $\alpha = 0.983$).

The reliability of the ultrasound volume estimation method disregarding the shape of the organ

Table 2 depicts data comparing the volume assessment accuracy of different estimation methods. Confirming the reliability, the US volume estimates were with a low bias (the mean bias =− 5.9%), a high agreement to AV with no significant difference to AV ($T = 0.810$; $p = 0.422$; Table 2). Despite organs being frequently underestimated by the US (63%; 34/54), there was no significant volume estimation error ($T = 1.522$; $p = 0.134$). However, the volume estimation error and the degree of underestimation in US assessments were related to the organ size, was significant when the organ volume is larger than 50 ml ($T = 3.483$; $p = 0.001$; shown in Fig. 2).

Table 2.

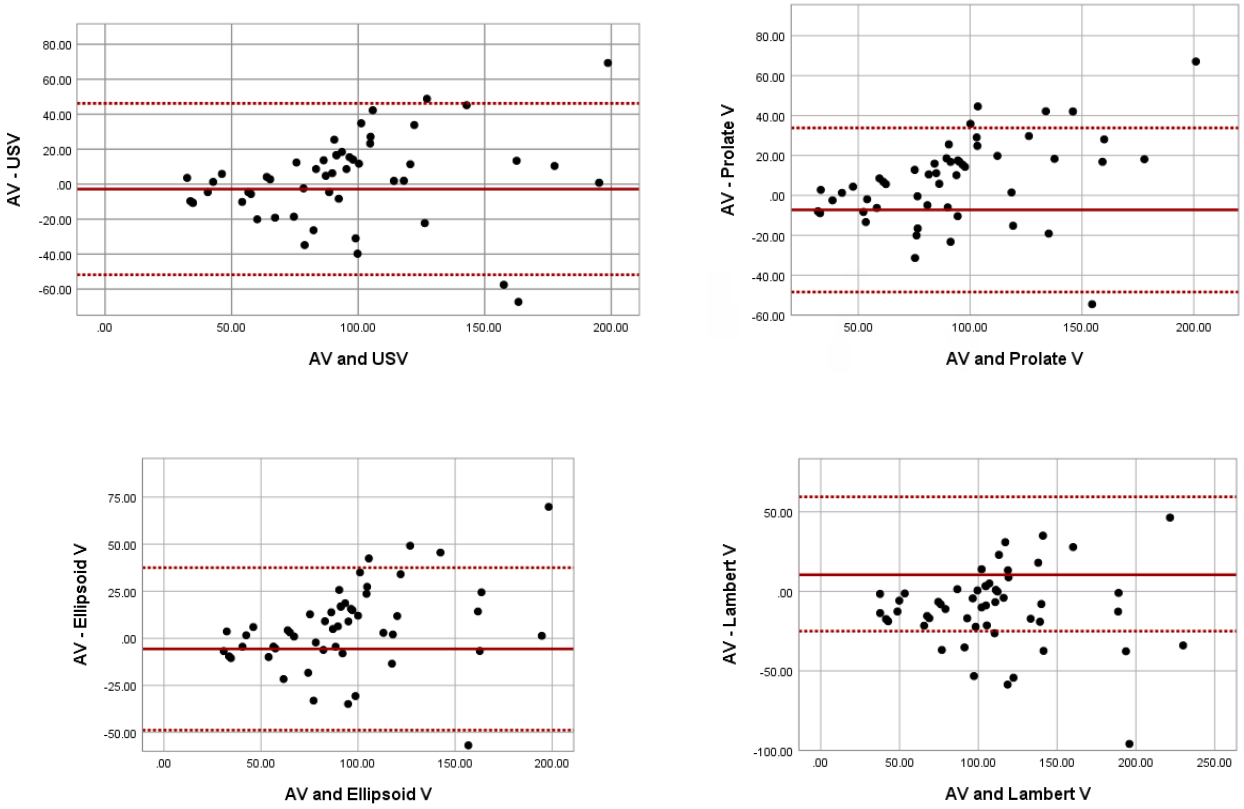
Mean volumes, volume estimation error and error percentages obtained for different methods of volume estimation.

	AV	Estimated volumes			
		Prolate	Ellipsoid	Lambert	AVUS
MV (ml)	50.9±20.2	46.83±33	48.39±38	62.92±33	44.8±19.7
ME (ml)	-	-7.28±21	-5.63±22	10.4±25	-2.81±25
Bias	-	-0.75	-3.75	-41.6	-5.92
Precision	-	45.0	49.6	67.8	51.5
95% CI	-	34 - (48)	37 - (-49)	59 - (-39)	46 - (-52)

(AVUS= auto generated ultrasound estimated volume; AV= actual volume; MV= mean volume; ME= mean error; 95% CI- 95% confidence interval (CI) was calculated from Bland Altman plot analysis; bias represent the mean error %; precision represent the standard deviation of mean error %; **$p<0.001$)

Fig. 2.

Bland Altman plot analysis demonstrating the agreement between the actual volume and the estimated volumes obtained by different methods.



(V**:** volume; AV: actual volume; USV: ultrasound estimated volume)

The reliability of volume estimation formulae in volume assessment disregarding the shape of the organ

Confirming the reliability, prolate (the mean bias =– 0.75%) and ellipsoid formulae (the mean bias =– 3.75%) estimated with low bias and a high agreement to AV, with no significant error in estimated volumes (prolate: T = 1.75; p = 0.094; ellipsoid: T = 1.077; p = 0.287) (Table 2; shown in Fig. 2). Reciprocally, the Lambert formula estimated with a high bias (mean bias = +41.6%) and a significant error (T = 2.213; p = 0.002). The organ volumes were frequently underestimated by the prolate (65 %; 35/54) and ellipsoid (65 %; 35/54) formulae but overestimated by the Lambert formula (69 %; 37/54) (Table 2). Also, we found, the estimation error of prolate and ellipsoid methods was related to the size of the organ. The estimation error was significantly higher (prolate: T = 4.66; p < 0.001; ellipsoid: T = 4.49; p < 0.001) when the organ is larger than 50ml. A similar size-related error (T = 2.70; p = 0.009) was observed for the Lambert formula as well (shown in Fig. 2).

Table 3.

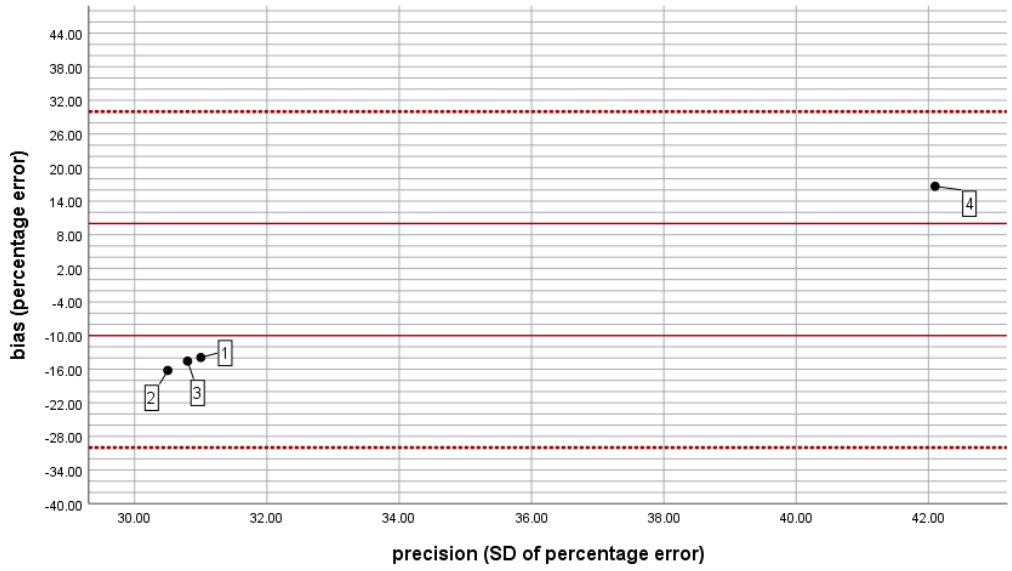
Mean volumes, volume estimation error and error percentages obtained for different methods of volume estimation according to the shape of the organ.

	Estimated volumes (kidney)				Estimated volumes (spleen)			
	Prolate	Ellipsoid	Lambert	AVUS	Prolate	Ellipsoid	Lambert	AVUS
MV (ml)	40.2±14	40.9±1	55.8±2	41.2±15	44.2±21	46.7±22	63.8±29	48.1±23
ME (ml)	-12.9±16	-12.2±17	2.7±18	-11.1±18	-2.0±24	0.5±24	17.5±28	4.9±28
Bias	-16.2	-14.6	16.5	-13.9	-13.6	20.7	64.8	24.3
Precision	30.5	30.8	42.0	31.0	51.7	57.8	78.9	59.9
95% CI	18 to -44	21 to -45	38 to -32	24 to -46	45 to -49	47 to -46	72 to -37	60 to -50

(AVUS= autogenerated ultrasound estimated volume; MV= mean volume; ME= mean error; 95% CI - 95% confidence interval (CI) was calculated from Bland Altman plot analysis; bias represent the mean error %; precision represent the standard deviation of mean error %; **p<0.001)

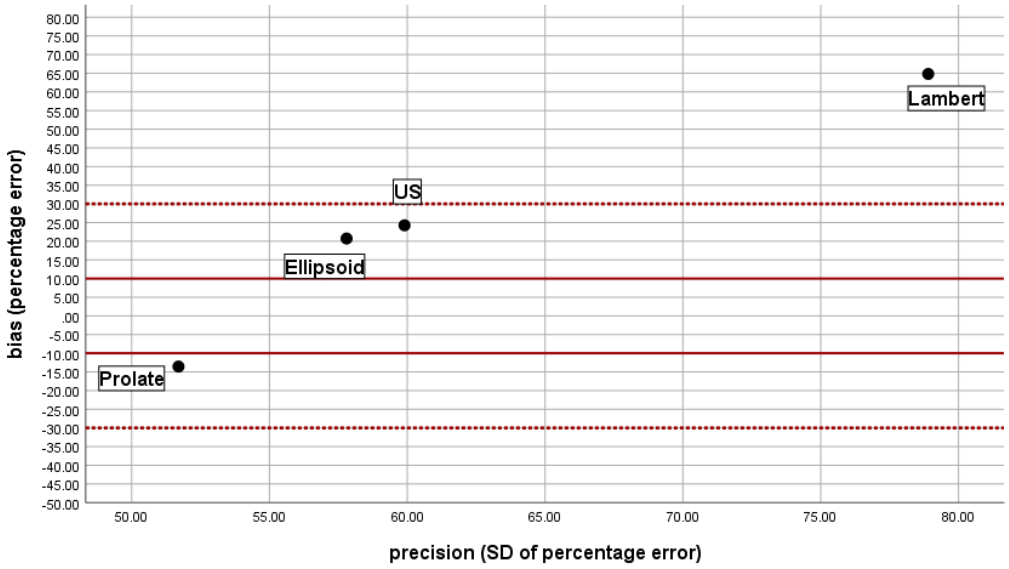
Fig. 3.

Plot of bias vs. precision for kidney volume estimation obtained by different methods.



(1:US; 2:Prolate formula; 3:Ellipsoid formula; 4:Lambert formula; solid horizontal line: negligible bias limits; dotted horizontal line: agreed bias limits)

Fig. 4.
Plot of bias vs. precision for splenic volume estimation obtained by different methods.



(Solid horizontal line: negligible bias limits; dotted horizontal line: agreed bias limits)

The reliability of different volume assessment methods for different shaped organ

The US volume estimation accuracy appears to be influenced by the shape of the measured organ (Table 3; shown in Fig. 3 & 4). The US has frequently (72 %) underestimated the kidney volume while overestimating the splenic volumes (52 %; $\chi 2 = 12$; $p < 0.001$)). Also, it was noted that the organ shape has an influence on measurement bias ($T = 2.352$; $p = 0.006$): the bias for renal estimates was -13.9 %, and for splenic estimates, it was +24.3%. Similarly, the precision values were influenced by the shape of the organ; for renal volumes (31.0 %) and splenic volumes (59.9 %) (shown in Fig. 3 & 4).

Similar to the US, the volume estimation accuracy of the studied calculating formulae was also influenced by the organ's shape (Table 3; shown in Fig. 3 & 4). Kidneys (prolate: 76 %, 19/25; ellipsoid: 65%, 19/25) and spleens (prolate: 76 %, 22/29; ellipsoid: 65 %, 19/29) were underestimated in equal proportions by both prolate and ellipsoid formulae. Reciprocally, the Lambert formula overestimated the spleens more frequently (76%, 22/29) than kidneys (52 %; 13/25). Though all formulae estimated kidney volumes with a low, more or less equal bias (< 20 %), and the bias in splenic estimates varied widely with the formula used. The bias of splenic estimates for prolate and ellipsoid formulae was maintained below 25 %, which reciprocally has reached 65 % when assessed with Lambert formula (Table 3; shown in Fig. 3 & 4). Thus, a strong relationship has been observed between the shape and the measurement accuracy of different formulae. In fact, the volume of the kidney, of which the shape is approximately spherical, has better evaluated by all methods than the spleen suggesting the high impact of shape on accurate volume assessment.

The kidney volumes were best estimated by the US (bias: -13.9; precision: 31; 95% confident interval: +24 to - 46) and ellipsoid formula (bias: - 4.6; precision: 30.8; 95% confident interval: +21 to - 45). Reciprocally, the splenic volumes were best estimated by the prolate formula (bias: -13.6; precision: 51.7; 95% confident interval: +45 to - 49).

Notably, regardless of organ shape, the US, prolate and ellipsoid formulae estimated the organs with considerably low bias (< 30 %) and high agreement to AV. Hence, US, prolate, and ellipsoid formulae can be validated for estimating the volumes of organs with different shapes. Anyhow, the high precision and 95% confidence interval downgrade the reliability of splenic estimation. Notably, the shape-dependent error for the studied shapes was more pronounced with the Lambert formula indicating the influence of mathematical formula on estimation accuracy

4. Discussion

Factors influencing volume assessment accuracy are identified as volume assessment methodology, the shape & size of the object (Kodikara, et al. 2020; Kodikara, et al. 2020). Although the 2D US is a widely accepted volume assessment tool, data are scarce on validating its function for various-shaped internal organs. Hence, this study was aimed to validate the US and standard volume estimation formulae for renal and splenic volume assessments. This study has also examined the impact of organ shape on volume estimation accuracy. The tested study hypothesis is proven by demonstrating a relationship between the shape of the organ and the estimation error. Additionally, the US, prolate, and ellipsoid methods were validated to assess volumes of evaluated internal organs. Further, the reliability of the US measurement procedure was confirmed due to a low operator bias.

The findings of this study are on par with previous studies that have validated the US volume estimation by demonstrating a high correlation to the AV (Kodikara, et al. 2020a; Kodikara, et al. 2020b) and high inter and intra-observer agreements for both volume and linear measurements (Sharma, et al., 2017; Kodikara, et al. 2020a). With different methodologies, these studies have consistently proven the reliability of the US in volume assessment. Additionally, as in previous studies, this has also reported a volume over and under-estimation by the US (Ghani, et al., 2008; Liang, at al., 2009; Gruber, et al., 2013).

Variability in volume assessment accuracy has been reported for different volume estimation formulae. Mbaeri et al. have reported a high accuracy in the Lambert formula for testicular volume assessment (Sakamoto, et al., 2007; Mbaeri, et al., 2014). On the contrary, the prostate volume assessment is more accurate with an ellipsoid formula than with prolate formula (Eri, et al., 2002). Also, a volume underestimation with prolate and ellipsoid formulae and an overestimation with Lambert formula have been reported (Eri, et al., 2002; Sakamoto, et al., 2007; Kodikara, et al., 2020b). With exception to previous studies, this study has described that the variability in the accuracy of volume estimation formulae is related to the shape of the measured organ.

Undoubtedly, the volume estimation technique has to be precise and reproducible (Anderson, et al., 2007). This study reported a higher variability in precision for splenic estimates (52 % to 79 %) than renal estimates (30.5 % to 42 %). This error can be attributed to the shape of the organ; kidneys have a reasonably uniform (reniform) shape while the shape of the spleens is highly variable (Kodikara, et al., 2017). The volume estimation formulae used in this study are primarily designed to estimate volumes of spherical objects. Even if they are used to estimate a different shaped structure, the formula calculates the volume of a spherical-shaped object with similar measurements. Though some spleens are nearly spherical, many are semilunar or wedge-shaped. This shape variability creates

a wide variability in the accuracy of splenic estimates. Therefore, we analyzed further to find the best methodology to assess splenic and renal volumes and found that the lowest error is for US, prolate and ellipsoid formulae. Hence, prolate and ellipsoid, and the US are validated to evaluate the splenic and renal volumes. However, the accuracy of splenic estimates is not as accurate as renal estimates due to high precision variability.

For this study, the tolerable bias limit for volume assessment is set 30% (Mbaeri, et al., 2014). When defining the tolerable bias limit, the clinical implication of the measurement is a crucial factor. For example, when the clinical impact of estimated volume is high, as in liver volume estimates done before liver transplantation, the tolerable bias limit has to be low as 10 to 15 % (Mbaeri, et al., 2014). Similarly, a 10 % bias limit is acceptable for testicular estimates. When implications are low, as for gastric volume estimates, the tolerable bias could be increased up to 30 % (Sakamoto, et al., 2007; Riestra-Candelaria, et al., 2016). Thus, the tolerable bias limit of a study should be individualized considering the clinical implications.

As a novelty, this study has pinpointed the reasons for volume estimation error for the evaluated methods. The methodology used in this study is reliable due to several reasons. Firstly, the internal validity of the measurements was high. Secondly, the investigator related bias has eliminated by demonstrating a negligible inter and intra-observer variability. Thirdly, a well-planned in-vitro study design has eliminated the measurement in-accuracies related to biological tissue-beam interactions (Riestra-Candelaria, et al., 2016). Since kidneys and spleens represent a broad spectrum of shapes, the findings could be generalized to many shapes encountered in clinical assessments (Sakamoto, et al., 2007; Mbaeri, et al., 2014; Kodikara, et al., 2017).

Anyhow, several limitations of this study are also admitted. Considering the feasibility, we have evaluated the volumes of kidneys and spleen instead of assessing all possible shaped internal organs. Increasing the sample size and spectrum of shapes by including many other organs would allow better generalization in the study findings. The actual volumes studied using formalin preserved cadaveric organs may not represent the exact sizes of living human organs. The findings of in-vitro study design may differ from in-vivo study design, as measurements of in-vivo studies are usually less precise due to biological tissue interactions, interferences of bowel gas and patient movements (Kruisselbrink, et al., 2017).

In conclusion, the ultrasound volume estimation method can be validated to estimate the volumes of internal organs. Since the accuracy of ultrasound volume estimation is influenced by the size, shape of the organ and the volume-calculating formula employed, volume interpretation has to be done cautiously only after considering the shape and the size of the object. For volume estimation of bizarre shapes, US, prolate and ellipsoid formulae can be recommended.

5. Highlights

- Measurement procedure of ultrasound is reliable with low error and operator bias.
- Kidneys and splenic volumes are reliably estimated by the ultrasound, prolate, and ellipsoid volume estimation formulae.
- Kidney and splenic volumes are underestimated by the ultrasound, prolate, and ellipsoid volume estimation formulae.
- The Lambert formula has shown a high error for renal and splenic volume assessments.

- The accuracy of ultrasound volume estimates is related to the shape and the size of the measured object.

6. Conflicts of interest:

All authors have no conflicts of interests regarding this study.

7. Funding:

Did not receive any specific grant for this research from any funding agency in the public, commercial, or not-for-profit sectors.

8. Ethical statement:

Since the research done on cadavers that have been donated for study and research purposes, ethical approval was not considered essential. Informed written consent, for cadavers to be used for research purposes and publication was obtained from the next of kin during cadaveric donation.

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RESUMEN

Se encontró que la precisión de la estimación del volumen de órganos internos realizada con ultrasonido (US) es multifactorial. El objetivo fue describir y validar la evaluación de volumen mediante ecografía y las fórmulas estándar de estimación de volumen para órganos intraabdominales de diferentes formas utilizando bazos y riñones.

Se evaluaron riñones cadavéricos disecados (n = 25) y bazos (n = 29) para obtener medidas lineales y volúmenes autogenerados por ultrasonido (USV). Se utilizaron medidas lineales para calcular los volúmenes manualmente con fórmulas de estimación de volumen elipsoide, prolate y Lambert. Los volúmenes reales (AV) de los órganos se obtuvieron mediante el método de desplazamiento de agua. Se comparó la precisión de la evaluación del volumen de USV y diferentes fórmulas comparando el sesgo, la precisión y el análisis de la gráfica de Bland-Altman. El procedimiento de medición lineal y de volumen mediante US fue confiable con alta concordancia inter e intraobservadores (lineal: α de Chronbach = 0,983 a 0,934; volúmenes: α de Chronbach = 0,989). Las estimaciones de USV fueron precisas con una alta correlación con AV y un bajo sesgo de estimación (-5,9%). Además, las fórmulas prolate (sesgo= -0,75%) y elipsoide (sesgo = -3,75%) fueron confiables con un sesgo insignificante en los volúmenes estimados. Por el contrario, la fórmula de Lambert no fue confiable debido a un alto sesgo (41,6%). Para todos los métodos evaluados, se encontró que el error de estimación estaba relacionado con el tamaño del órgano (T = 3.483; p = 0.001), principalmente cuando el órgano evaluado es mayor de 50 ml. Además, se encontró que el error de estimación de forma está relacionado con la fórmula de estimación de volumen utilizada.

Este estudio ha validado el USV para evaluaciones de volumen renal y esplénico al mismo tiempo que describe la fórmula de cálculo de volumen empleada, el tamaño y la forma de los órganos como contribuyentes significativos de la precisión de la estimación de volumen.

Palabras clave: ecografía; validación de la estimación de volumen; órganos abdominales; prolato elipsoide Fórmula de Lambert