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Research Paper

Kidney Ultrasound in Human Cadavers: Usefulness for Clinical Biopsy Training and Accuracy of Volume Estimation

Medical Science

KEYWORDS : Ultrasound, kidney, kidney volume, corpses, accuracy, teaching, renal biopsy, training

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ABSTRACT

Investigations, demonstrations and procedural practices in human corpses are increasingly used to optimize clinical practice and skills of medical staff and physicians. We tested, if cadaver kidneys in the anatomy setting are appropriate for renal biopsy training and conducted an investigation comparing kidney volume by water replacement and by ultrasound (US) calculation with the standard equation

Volume = (Length x Depth x Width) / (π/6)

in 25 kidneys from 13 corpses. US yielded an average kidney volume of about 38mL and thereby underestimated the real volume more than 2fold but was strongly correlated with the true (water replacement) volume. We therefore confirmed the systematic value of the equation for volume calculation but must consider that kidneys from corpses do show a behaviour making them improper for conventional US volume calculation. However, biopsy procedures were fully performed including a controlled needle transition through tissue and muscle and a pre-shot capsule impression. Kidneys from human corpses could be successfully used for training of renal biopsy procedure with young fellow nephrologists.

Introduction

Renal biopsy is a technique to establish final and groundbreaking renal diagnosis but is associated with eventually life-threatening complications if the procedure is performed by untrained staff. To improve practical biopsy skills for fellow nephrologists, we used kidneys in renal corpses for both ultrasound (US) investigation as well as core needle biopsy. Use of such anatomical corpses for biopsy training have never been described before, while animal kidneys in a artificial setting (turkey breast overlay) [6, 12, 13] or artificial materials [11, 22] have been used to successful perform biopsy teaching. Beside the intrinsic training process, kidneys were measured to explore renal volume (V) and compare V with the real kidney volume, which was established after dissection of the organs by water replacement method.

Volume (V) estimation of kidneys by ultrasound (US) is an important parameter in clinical evaluation of renal disease and living kidney donors and is thought to be principally superior to measurement of length or depth or thickness of parenchyma only. However, the question of the best morphometric measure of renal function (volume or length) is under scientific debate. Of notice, all measures do not entirely correspond to true anatomical or radiological values, because the kidney is skewed within the body and the ultrasound measures are smaller compared to reality. In general, because no real-live human organ with pertained perfusion can be used as a gold-standard for comparisons, all estimations hamper by the fact, that size measurement is only possible against organs under non-living non-real conditions.

Some authors prefer relative renal length (adjusted for body length) because this was best correlated with age and gender [1]. Renal size change was associated with pyelonephritis [20], blood pressure [16], diabetes [4, 5], and transplant changes [21].

For volume estimation, different equations do exist. Presumably most performed is an equation using length (L), hilar width (W) and transversal depth (D). L and W are be assessed at the hilum diameter in a longitudinal ultrasound section and D at the hilum in a transversal section [10].

1) V (mL) = L x W x D1 x π/6.

Because investigators have assumed kidneys to be ellipses, equations based on 3-dimensional measurement of length, width and depth were developed. In such, D was assed and processed in 2 planes perpendicular to each other again assessed in the hilum transversal section [2, 3, 7].

2) V (ml) = L x W x [(D1 + D2) / 2] x π/6.

Advancements of the elementary formulas were inaugurated by using not distances, but areas to estimate volume. Cross-sectional areas at the hilum or maximum transversum level can be manually traced and introduced into more complicated equations which are nowadays incorporated into US or CT and MRI diagnostic algorithms.

In general, there are not much data available comparing the living organ volume with ultrasound results. There have been early experiments with kidneys from slaughtered animals, transplant ex situ [18] and in human corpses [14]. The latter investigation was performed using full 3-dimensional volume datasets and not equations which we have referenced above. Other studies compared US renal volume with CT or MR results. In the present work, we aimed to compare US results of volume measurements in corpses with water displacement method (water plethysmography) after resecting the kidneys. We used bodies from the institute of Anatomy in Leipzig, which were prepared by alcohol-based embalmment [9] or Thiel´s preparation [19]. This latter method is not widely used. It is based on perfusion and emersion of the bodies by a solution from ethylene glycol, salts, boric acid and disinfectants. Fluids do partly remain in the vasculature and therefore it can be hypothesized that no significant volume reduction of organs takes place. This technique is used for surgical training purposes and has been approved by several scientific associations [15] but is not very common for student´s educational purposes. The aim of our research was to evaluate available volume equations in these different techniques and to investigate how dewatering of organs in alcohol-prepared organs affects both natural and ultrasound organ size as well as the usefulness of organs in corpses for training courses of renal biopsy technique.

Methods

Anatomical preparation

Body donors had given written informed consent to the donation of their bodies for educational purposes before their passing. This personal consent is filed in the records of the Anatomical Institute of the University of Leipzig. Consenting for body donation in general includes usage of body samples and data for educational-scientific purpose. As in all type of anatomical research, the approval of Institute-internal IRB (prosector and chief) with donation was retrieved. Identifying information of body donors was not carried to researchers by pseudonomyzing corpse identification.

External IRB´s or EC´s will not handle approvals of studies with body donors in Germany in general. Body donors were aged between 70 and 95 years, 2 were male, 11 female. The cadavers were prepared either by ethanol-glycerin fixation [9] (n=2) or by a modified Thiel technique (n=7) [8, 19]. Four corpses were investigated freshly after disinfection but without conserving embalming. One or two corpses per year were used starting 2006 for demonstrating the technique of renal biopsy and foregoing US examination. Such training was only performed after Thiel´s preparation for causes related to natural, live-similar behaviour of skin and tissues.

Dissection of the kidneys was done by abdominal access. Ex situ size measurements were performed by a standard ruler with organs lying on the preparation table (Fig. 1). Volume was measured by water displacement with calculation of the difference between volume 1 and volume 2 before and after immersion of the dissected kidney in a water-filled graded container.

Ultrasound procedures and biopsy

US was performed by a Toshiba "Tosbee"™ device using a standard 2,5Mhz curved array (abdominal) probe. Measurements were done comparable to the organs ex situ as follows: maximum longitudinal parameter (L) with the US probe in longitudinal orientation, transversal hilar diameter (D) with the US probe in longitudinal orientation, and depth (D) with the probe in transversal orientation. D was measured as D1 (hilar) and D2 perpendicular to D1.

Biopsy training was conducted within 9 one–day CME courses since 2006 under the patronage of the European Renal Association – European Dialysis and Transplant Association (ERA-EDTA). In average, 15 fellows per year took part in these CME events. Course participants were teached in theoretical background of renal biopsy, equipment handling, US probe placement in living sample persons and finally the whole procedure including biopsy shot and tissue core harvest in corpses. For biopsy performance, a routine clinical needle holder set (attached to the US probe) and a 16G automatic biopsy needle with a semi-automatic biopsy system (Bard™, Tempe, AZ, USA) was used.

Statistics and morphometrics

Volume displacement and US measurements were performed three times and the standard deviation of the methods are given.

Comparison for correlation have been performed between

- Ex situ length measurements and the means of the US measurements,
- Water displacements volume measurements and US volume calculation by equation 1)

Results

Visibility of kidneys was sufficient in all cases to perform biopsy training (Fig. 2). Every single of an overall of about 100 course participants during 9 course transits was able to harvest biopsy cores from kidneys after structured education and demonstration of biopsy methodology.

Mean volume results by US, ex situ measures and water replacement methods for right kidneys were 44.3 ± 22.7, 64.6 ± 27.9 and 109.9 ± 44.5 ml, resp. For left kidneys, these values were found as 32.1 ± 16.7, 44.3 ± 16.9 and 105.1 ± 38.8 ml (Tab. 1).

Tab. 1: Length, diameters and volumes of kidneys assessed by ultrasound (US), ex situ measurement and water replacement (repl) in corpses prepared by different embalmment techniques (all values in mm).

	Alcohol (n=2)	No Fixation (n=4)	Thiel (n=7)	Total
Left kidneys (n=12)				
V_{us}	41.9 ± 32.2	38.6 ± 12.8	24.6 ± 9.7	32.1 ± 15.7
$V_{ex\ situ}$	55.0 ± 31.7	43.0 ± 8.7	41.6 ± 18.0	44.3 ± 16.9
V_{repl}	116.7 ± 42.4	115.4 ± 39.0	94.3 ± 41.9	105.1 ± 38.8
L_{us}	80.2 ± 14.4	79.4 ± 8.8	72.0 ± 13.7	75.8 ± 11.9
$L_{ex\ situ}$	106.0 ± 7.1	111.2 ± 5.2	87.8 ± 14.9	98.7 ± 15.6
W_{us}	21.2 ± 5.9	20.1 ± 5.3	18.8 ± 4.5	19.6 ± 4.6
$W_{ex\ situ}$	32.5 ± 6.4	28.8 ± 6.3	28.2 ± 4.9	29.1 ± 5.3
$D1_{us}$	42.3 ± 16.5	46.2 ± 8.1	33.8 ± 4.4	39.3 ± 9.3
$D1_{ex\ situ}$	29.0 ± 9.9	26.0 ± 3.2	31.5 ± 8.5	29.3 ± 7.1
$D2_{us}$	37.2 ± 24.3	30.2 ± 8.3	34.5 ± 7.6	33.5 ± 10.3
Right kidneys (n=13)				
V_{us}	55.6 ± 36.8	52.2 ± 32.5	36.6 ± 11.1	44.3 ± 22.7
$V_{ex\ situ}$	65.3 ± 17.9	82.7 ± 40.7	54.0 ± 18.0	64.6 ± 27.9
V_{repl}	121.7 ± 21.2	118.3 ± 48.0	101.6 ± 50.6	109.8 ± 44.5
L_{us}	78.4 ± 16.3	82.5 ± 4.0	71.0 ± 8.9	75.7 ± 9.8
$L_{ex\ situ}$	112.0 ± 4.2	110.8 ± 9.2	85.2 ± 10.2	97.2 ± 16.0
W_{us}	34.8 ± 18.5	30.8 ± 16.2	28.8 ± 4.4	30.3 ± 10.5
$W_{ex\ situ}$	45.0 ± 4.2	49.5 ± 6.8	37.5 ± 7.7	42.3 ± 8.6
$D1_{us}$	37.7 ± 2.1	37.3 ± 11.9	33.7 ± 5.7	35.4 ± 7.5
$D1_{ex\ situ}$	24.5 ± 3.5	27.8 ± 8.0	32.5 ± 8.5	29.8 ± 8.0
$D2_{us}$	28.9 ± 10.8	30.5 ± 9.6	39.9 ± 7.4	35.3 ± 9.3

Although there were large absolute differences between the estimated volumes, these values were correlated with each other (Fig. 5) pointing to the fact that there was a large systematic error when estimating the volume from measures either taken by US or ex situ measurement. US and also ex situ measurement underestimated the kidney volume by the factor 2 to 3 in both right and left kidneys. For right kidneys, a correction term for adjusting VUS to Vrepl. was computed by adding 65.8 ± 36.1 mL (regression: Vrepl. = 0.33 x VUS + 8.28 mL) to VUS and for left kidneys this term was computed with 72.9 mL ± 32.9 mL (regression: Vrepl. = 0.25 x VUS + 17.8 mL).

Diameters or lengths correlated with each other as given in Tab. 1 and Fig. 4. Correlation was better for L in both kidneys compared to W and D.

Discussion

Our US studies of kidneys in corpses and ex situ yielded roughly a 2.5-fold lower calculated kidney volume based on diameters and lengths compared to organ volume measured by water replacement method. However, although there was such large absolute deviation, volumes either calculated by diameters/lengths or measured by water replacement correlated significantly with each other. And interestingly, volume calculations based on ex situ diameter and length measurements showed similar differences when compared to water replacement. In other words, volume calculation by US and by ex situ measurement both yielded inadequately small volumes in average. Based on this finding, we repeated all calculations with an alternative equation 2), addressing the ellipsoid shape of kidneys (data not shown). Again compared to water replacement volume, no significant change to the values discussed above could be shown.

It must be addressed, that in ex situ measurement D2 was not systematically assessed because, under conditions of organs which were not fixated in the body and due to a mushy tissue even after fixation, D2 or D1 ex situ could only hardly be distinguished from each other. Also acknowledgeable, D1 and D2 by US and ex situ were found fairly minor at least if compared to US values known from living individuals. This phenomenon can also be explained by the mushy character of the kidney tissue, which was independent from the preparation method. Such tissue condition induced varying diameters when kidneys changed position on the preparation table.

Our results can be compared with a study performing renal US before autopsy [14], although these authors used an equation based on traced areas rather than diameters. Comparable to our results, they yielded a volume difference of 31 mL. However, they performed autopsies in human cadavers in the pathology setting, while we did anatomical preparation in corpses, which were at least disinfected and in most cases embalmed. Taking their and our (greater) volume difference, it can be assumed, that length and diameters for volume calculation may result in growing non-concordance with past time after death. In porcine kidneys after slaughtering and transplants ex situ before transplantation [18], differences were smaller pointing to the role of in vivo conditions for the concordance between US volume and replacement method. The bodies we used for examination were in their 8th or 9th life decade at the time of death and therefore the reduced renal volume could be thought to be related to senescent age. From a more clinical viewpoint, our results add some arguments to scepticism concerning volume calculation at least in older adults and support the clinical use of length instead of volume. Secondly, area equations [17] might be more precisely compared to diameter calculating equations. However, corpse kidneys were well suited for biopsy training as this was experienced by the successful harvest of biopsy cores by our course participants and the good visibility of all organs. This is important, because such practice allows improvement of personal skills in biopsy with the aim to minimize risks to living patients in need of such diagnostics. It must be stressed, that for biopsy training, only Thiel´s embalmment was used. Although there were no significant volume differences between Thiel´s and conservative technique, the structure and haptic behaviour of kidneys, tissue and skin made this technique very appropriate for biopsy training [8]. The setting of the cadaver biopsy procedure, with penetration of the skin, visible transition of the needle through normal muscle and adipose tissue and final impression at the renal capsule before biopsy shot is completely the same as in the clinical setting with the exception of missing breathing movements. This similarity to the clinical procedure makes our training procedure different compared to the more artificial setting in explanted animal kidneys [13] or with even complete artificial phantoms [22].

In summary, we conducted an investigation comparing kidney volume by water replacement of kidneys from human corpses and by US calculation and tested if such kidneys in human corpses are appropriate for renal biopsy training. US as well as ex situ measurement underestimated the volume more than 2fold but were correlated with the true values. Therefore, we can confirm the systematic value of the equation for volume calculation but must consider that kidneys from corpses derived from aged patients do show a behaviour making them improper for conventional US volume calculation. Kidneys in human corpses prepared by Thiel´s technique can be successfully used for valuable training purpose in renal biopsy.

Acknowledgement

The heraldic motto of our and other´s Anatomy "Hic locus est, ubi mors gaudet succurrere vitae" may be acknowledged in the results of our investigation and undertaking. We are therefore awesome to individuals having donated their bodies to the Leipzig Anatomical Institute and grateful for advice and assistance from the technical staff of that Institute.

Conflict of interest statement

I herewith declare that the results presented in this paper have not been published previously in whole or part in any other journal.

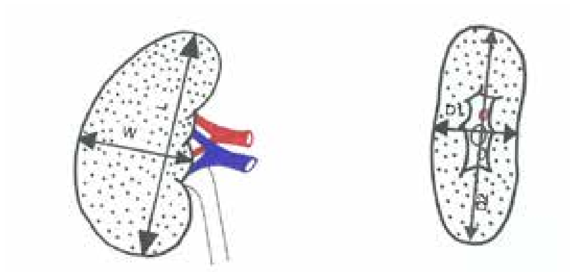

Fig. 1: Measurement of diameters in organs ex situ and by ultrasound. L (lenght)=maximum longitudinal diameter, longitudinal US probe position. W (width)=maximum transversal diameter, longitudinal US probe position. Dhil(hilar depth)=maximum transversal diameter in hilar transection, transversal US probe position. Dmax=Dmax (maximum depth)=transversal diameter in maximum length transversal section, transversal US probe position.

Fig. 2

Fig. 2: Typical renal biopsy course situation showing the US picture of a corpse kidney, Thiel embalmment (A) with biopsy needle tip adjacent to renal capsule (B) and the placement of the US probe with the biopsy needle and holder (C)

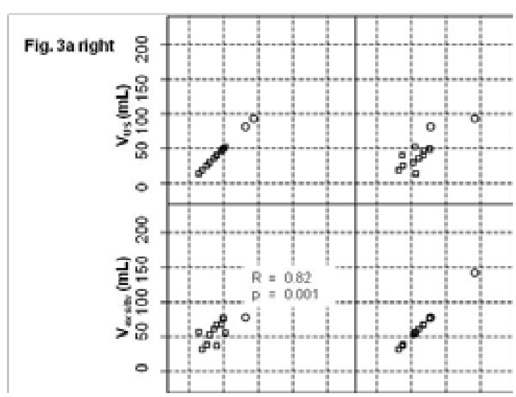

Fig. 3a: Correlation of volume measured by water replacement or calculated by ex situ measures and ultrasound in right kidneys (Pearson´s R, two-tailed p)

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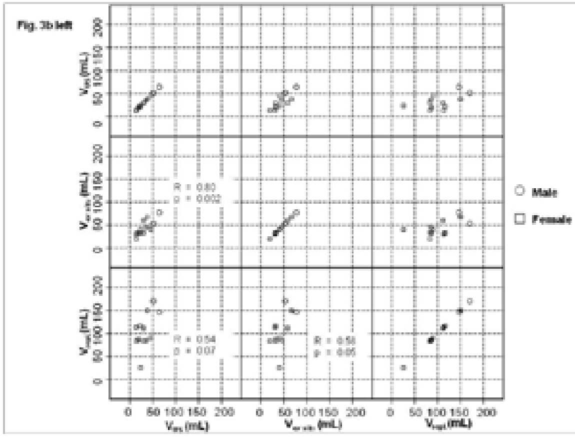

Fig. 3b: Correlation of volume measured by water replacement or calculated by ex situ measures and ultrasound in left kidneys (Pearson´s R, two-tailed p)

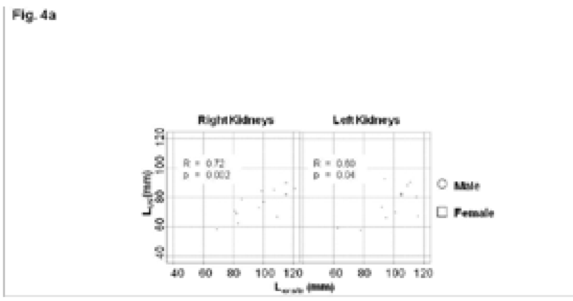

Fig. 4a: Correlation of lengths (L) measured by US and ex situ (Pearson´s R, two-tailed p)

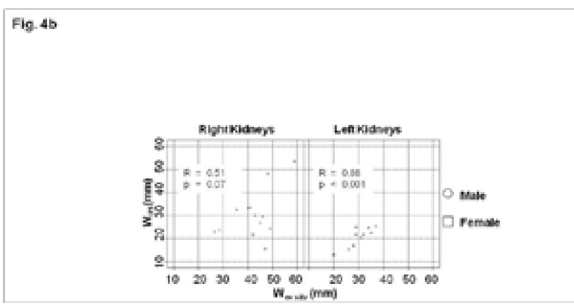

Fig. 4b: Correlation of hilar widths (W) measured by US and ex situ

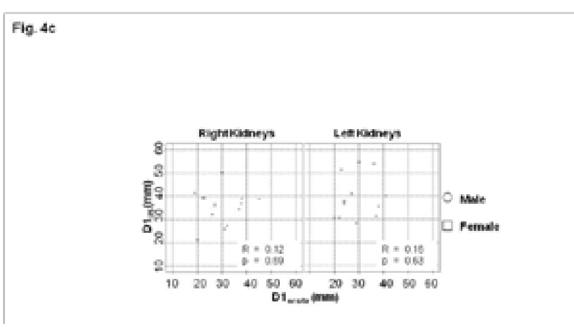

Fig. 4c: Correlation of transversal diameter 1 (D1) measured by US and ex situ (Pearson´s R, two-tailed p)

REFERENCE

1. Akpinar IN, Altun E, Avcu S, Tuney D, Ekinci G, Biren T. Sonographic measurement of kidney size in geriatric patients. J Clin Ultrasound 2003; 31(6):315-318. | 2. Bakker J, Olree M, Kaatee R, de Lange EE, Beek FJ. In vitro measurement of kidney size: comparison of ultrasonography and MRI. Ultrasound Med Biol 1998; 24(5):683-688. | 3. Bakker J, Olree M, Kaatee R, de Lange EE, Moons KG, Beutler JJ, et al. Renal volume measurements: accuracy and repeatability of US compared with that of MR imaging. Radiology 1999; 211(3):623-628. | 4. Christiansen JS, Gammelgaard J, Frandsen M, Orskov H, Parving HH. Kidney function and size in type 1 (insulin-dependent) diabetic patients before and during growth hormone administration for one week. Diabetologia 1982; 22(5):333-337. | 5. Christiansen JS, Gammelgaard J, Frandsen M, Parving HH. Increased kidney size, glomerular filtration rate and renal plasma flow in short-term insulin-dependent diabetics. Diabetologia 1981; 20(4):451-456. | 6. Dawoud D, Lyndon W, Mrug S, Bissler JJ, Mrug M. Impact of ultrasound-guided kidney biopsy simulation on trainee confidence and biopsy outcomes. Am J Nephrol 2012; 36(6):570-574. | 7. Dixit PK, Sahai SB, Rath B, Garg A, Chowdhury V. Norms for renal parenchymal volume in Indian children. Indian Pediatr 1994; 31(9):1059-1064. | 8. Hammer N, Loffler S, Bechmann I, Steinke H, Hadrich C, Feja C. Comparison of modified thiel embalming and ethanol-glycerin fixation in an anatomy environment: Potentials and limitations of two complementary techniques. Anat Sci Educ 2014; 10. | 9. Hammer N, Loffler S, Feja C, Sandrock M, Schmidt W, Bechmann I, et al. Ethanol-glycerin fixation with thymol conservation: a potential alternative to formaldehyde and phenol embalming. Anat Sci Educ 2012; 5(4):225-233. | 10. Hricak H, Lieto RP. Sonographic determination of renal volume. Radiology 1983; 148(1):311-312. | 11. Hunt A, Ristolainen A, Ross P, Opik R, Krumme A, Kruusmaa M. Low cost anatomically realistic renal biopsy phantoms for interventional radiology trainees. Eur J Radiol 2013; 82(4):594-600. | 12. Konno K, Nakanishi K, Hishikawa S, Tanaka H, Yoshikawa N, Yasuda Y, et al. Cryo-preserved porcine kidneys are feasible for teaching and training renal biopsy: "the bento kidney". Transplant Res 2012; 1(1):5-1. | 13. Mrug M, Bissler JJ. Simulation of real-time ultrasound-guided renal biopsy. Kidney Int 2010; 78(7):705-707. | 14. Partik BL, Stadler A, Schamp S, Koller A, Voracek M, Heinz G, et al. 3D versus 2D ultrasound: accuracy of volume measurement in human cadaver kidneys. Invest Radiol 2002; 37(9):489-495. | 15. Prasad RB, Tang B, Eisma R, Soames RW, Wen H, Nabi G. A qualitative assessment of human cadavers embalmed by Thiel's method used in laparoscopic training for renal resection. Anat Sci Educ 2012; 5(3):182-186. | 16. Raman GV, Clark A, Campbell S, Watkins L, Osmond C. Is blood pressure related to kidney size and shape? Nephrol Dial Transplant 1998; 13(3):728-730. | 17. Scholbach T, Weitzel D. Body-surface-area related renal volume: a common normal range from birth to adulthood. Scientifica (Cairo) 2012; 2012:949164. doi: 10.6064/2012/949164. Epub;%2012 Jun 17.:949164. | 18. Solvig J, Ekberg H, Hansen F, Brunkvall J, Lanne T. Accuracy of noninvasive ultrasonic volume measurements on human kidney transplants. Presentation of a new formula. Nephron 1998; 80(2):188-193. | 19. Thiel W. [The preservation of the whole corpse with natural color]. Ann Anat 1992; 174(3):185-195. | 20. Troell S, Berg U, Johansson B, Wikstad I. Ultrasonographic renal parenchymal volume related to kidney function and renal parenchymal area in children with recurrent urinary tract infections and asymptomatic bacteriuria. Acta Radiol Diagn (Stockh) 1984; 25(5):411-416. | 21. Tublin ME, Dodd GD, III. Sonography of renal transplantation. Radiol Clin North Am 1995; 33(3):447-459. | 22. Woywodt A, How T, Schulz M. A purpose-built simulator for percutaneous ultrasound-guided renal biopsy. Clin Nephrol 2013; 79(3):241-245. |