Determination of Local Reference Renal Volumetric Ellipsoid Coefficient For Clinical Application In Ghana

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ABSTRACT

Mathematically modelled kidneys are described as variably ellipsoid representing a type of quadric surface of a 3D analogue. Hence this mathematical descriptive of the volume of a kidney can be represented by mathematical relationship using the three dimensions of its quadrant surface **and** an ellipsoid constant. Therefore, with a known renal volumetric ellipsoid constant, a measured renal length, renal width and renal thickness, the volume of an ellipsoid kidney can be estimated. In clinical practice this ellipsoid model is used to estimate kidney volume in other to determine a possible kidney condition using varied ellipsoid constants. The objective of this study was to determined renal volumetric ellipsoid constant, that will provide a simplified approach in estimating renal volume. This would aid Clinicians in estimating renal volume for various diagnostic interpretation. The methodology involved the voxel count method used to determine the renal volume on clinical real acquired images and the result divided by the product of the linear measurements of the renal length, renal width and renal thickness of the kidney. The results showed that the renal volumetric ellipsoid coefficient determined was approximately 0.53±0.01 for both age and gender variations. Generally, the volumetric ellipsoid coefficient was not affected by either age or gender variation. In conclusion, GUI has been designed for a comfortable working process in clinical application of renal volume calculation by clinicians and researchers in Ghana.

Key words: Renal volume, volumetric ellipsoid constant, renal length, renal width and renal thickness

Introduction

Generally, kidneys are described as rotational ellipsoid which can be ued to describe the volume and associated various dimensions of the kidney. Mathematically, the volume of an ellipsoid is calculated by estimating the product of the length, width, thickness and the ellipsoid constant. This is expressed mathematically as:

$$V = \frac{4\pi}{3} abc, \quad (1)$$

where 'a' is the longitudinal (length), 'b' is the transverse (width), 'c' is the A-P (thickness) diameter of the ellipsoid and $\frac{4\pi}{3}$ is the ellipsoid constant. From Equation (1), unknown ellipsoid coefficient, K^* (ellipsoid like shape, e.g. kidney) can be estimated as:

$$V \text{ x } K = \frac{4\pi}{3} abc \text{ x } K$$

$$\text{If } V \text{ x } K = V^* \text{ and } \frac{4\pi}{3} K = K^*$$

Then,

$$K^* = \frac{V*}{abc}, \quad (2)$$

where K^*, a, b and c are the renal volumetric ellipsoid coefficients, renal length (longitudinal diameter), renal width (transverse diameter) and renal thickness (A-P diameter) respectively. Thus, renal volume (V^*) can be estimated with known longitudinal diameter, transverse diameter, renal thickness and renal volumetric ellipsoid coefficient K^*. However, in regular clinical practice the K^* is determined as a reference standard value and usually multiplied by the three estimated linear dimensions (length, width and thickness) to determine the renal volume (Equation (3)).

With known K^*, the RV (where is RV defiend?) is determined from the expression:

$$RV = K^* * \text{renal length (a)} * \text{renal width (b)} * \text{renal thickness (c)} \quad (3)$$

It is of interest to note that the application of the rule of estimating renal volume among radiologist in Ghana varied hence there is the need for unification based on data from Ghanaian population.

Objectives

The aim of this study is to determine a unified local based standard reference renal volumetric ellipsoid coefficient to be used in Ghana for clinical application.

Methodology

The data collection involved the use of blinded images in two processes: the measurements of renal linear parameters and renal voxel measurements on MeVisLab (MVL) application software. The measured parameters include measurements of longitudinal diameter, transverse and A-P diameters. The renal volume on the MVL application platform using voxel count method to determine the total voxel in the image.

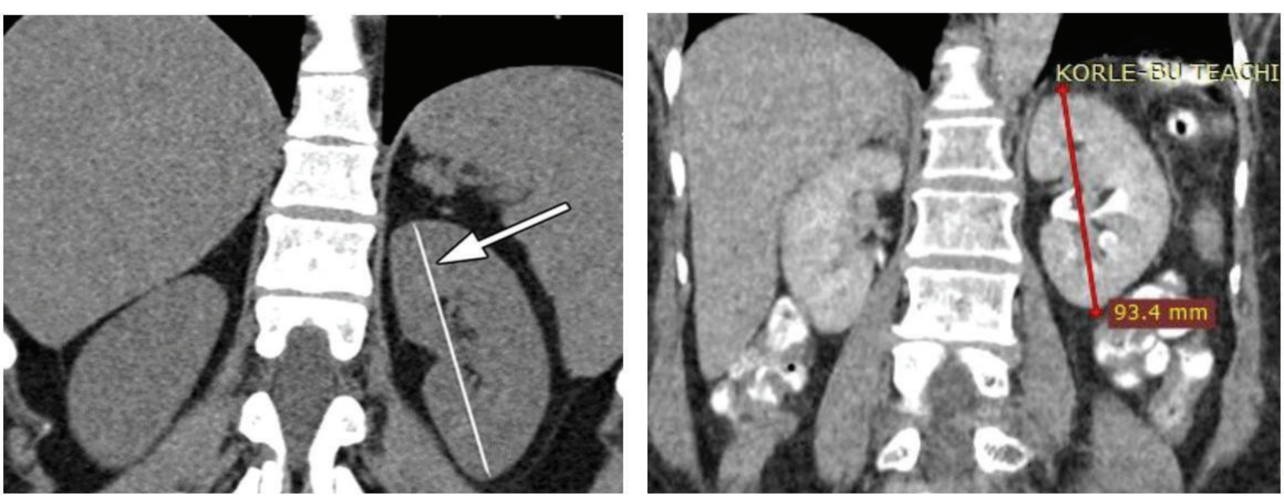

Figure. 1: Measurements of renal length using what methodology? using what methodology and how do you choose the section to measure

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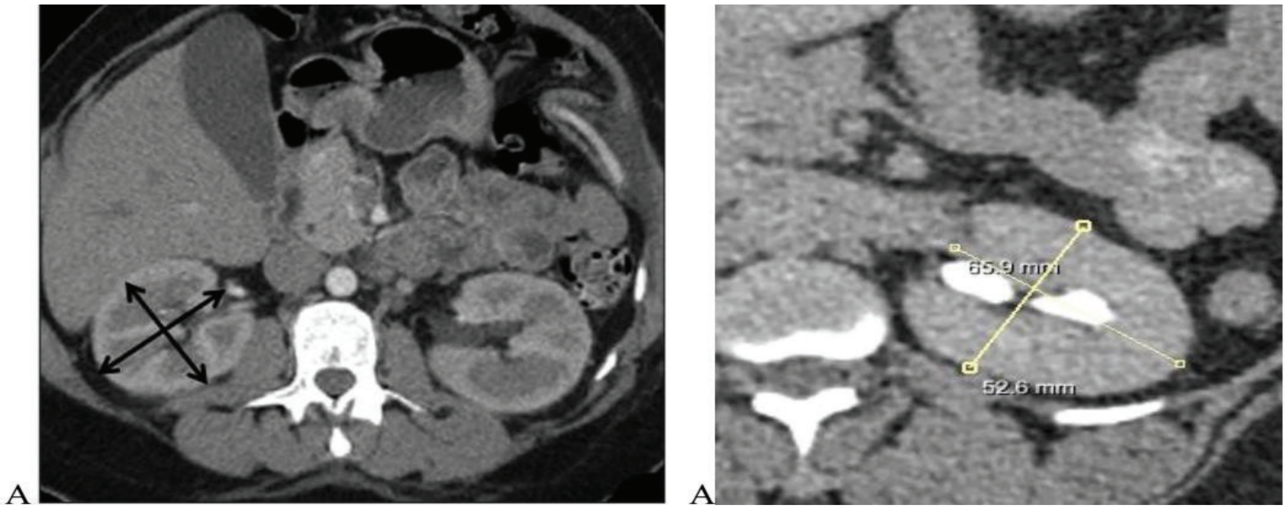

Figure 2: Measurements of lateral and A-P diameters using what methodology and how do you section the place to measure

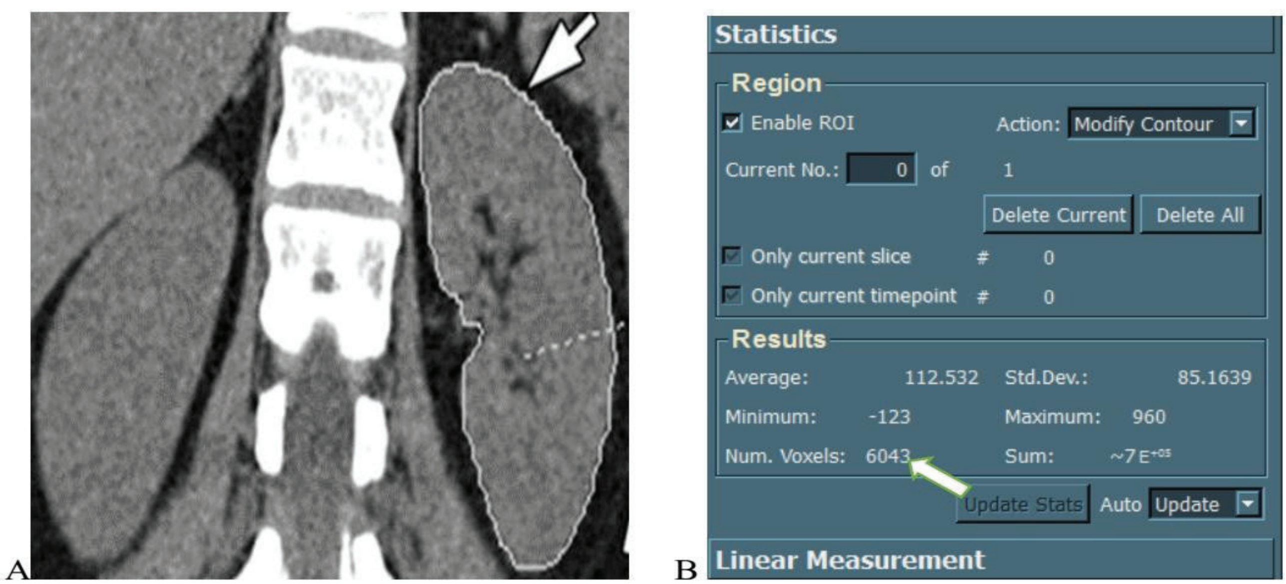

Figure 3: Measurements of RSA using what methods?

Renal Linear and Volume Measurements

Measurements of Linear Renal Dimensions

The first measured parameters include three linear dimensions, renal length, renal width and renal thickness. All these dimensions were measured at maximum values of strictly longitudinal, transverse and Anterior-Posterior sections through the center of the kidney respectively. The renal lengths were evaluated using the coronary images while the axial images were applied to measure Anterior-Posterior and lateral diameters. The width and thickness were evaluated in the transverse plane perpendicular to the longitudinal axis of the kidney. The level of this transverse section was placed at the level of the hilum.

Renal length was measured on the coronary images by drawing a single straight line from one edge of the renal parenchyma to another end with the linear measuring tool on the MVL platform as shown in Figure 1. Renal with was measured from the lateral extent of the kidney to the renal sinus and renal thickness measured perpendicular to the lateral diameter as shown in Figure 2.

The second component of this study was the measurements of renal volume from contiguous CT slices with voxel measuring tool on the MVL application software as shown in Figure 4B. These measurements were done using 3D volume-rendered image of the kidney shown in Figure 4A. The maximum length of the kidney was measured in the longitudinal plane and was visually estimated to represent the largest longitudinal section. Two different methods were also applied to estimate renal volumes. The first method was the calculation of the total renal volume by using the voxel-count method of the MVL application software (block white arrow in Figure 3A), with a region of interest (ROI) drawn for both right and left kidneys on each slice to indicate the renal boundaries. The total voxel was generated on each slice (block white arrow in figure 3B) by considering the amount of the voxel lying within the boundaries, including the central sinus fat but excluding perinephric fat.

Furthermore, with a known pixel size, slice thickness and the total number of voxels (black arrow in Figure 4B), in addition to computing for each average count and standard deviation of the voxels (yellow and blue arrows in Figure 4 respectively) equation 3 was used to estimate renal volume:

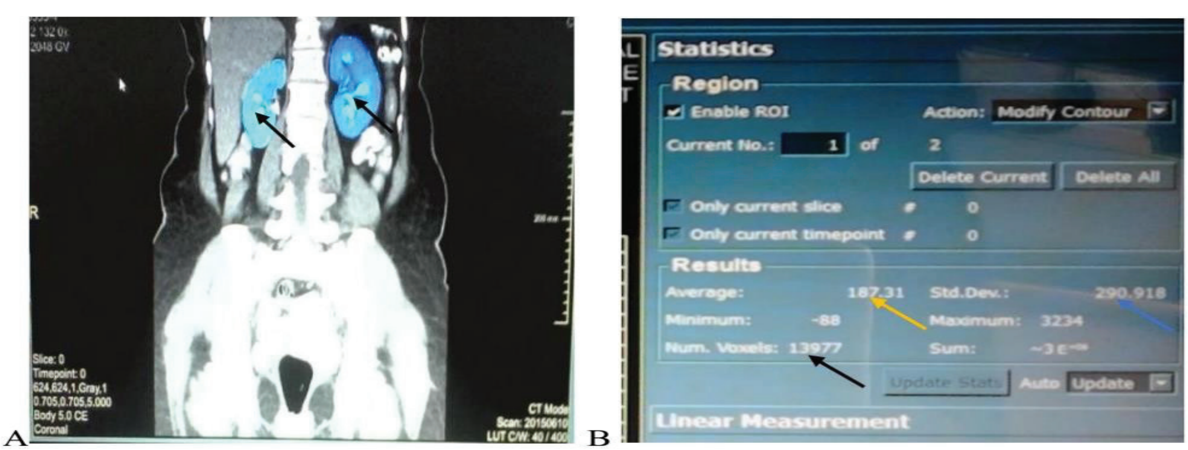

Figure 4: Measurements of renal volume by voxel count method using what instrument and parameter set.

Estimate of Renal Volumetric Ellipsoid Coefficient

The renal volumetric ellipsoid coefficient K^*, was calculated by dividing the measured renal volume by the product of the linear renal length, renal width and renal thickness. It is the constant of proportion in the ellipsoid equation as shown in equation 2. The K^*-values were determined by using the ellipsoid equation for estimating renal volume define as:

RV = K^* * renal length (RL) * renal thickness (RT) * renal width (RW),

This means that,

$$K^* = \frac{RV}{RL*RT*RW}. \qquad (4)$$

Therefore, with a known renal volume by the voxel count method, renal length, renal width and renal thickness by linear measurements using MVL, then K^* was estimated and the standard reference ellipsoid equation with known K^* defined as:

$$RV = K^* * RL * RT * RW. \qquad (5)$$

Results

Table 1 is presented as left and right renal thickness (Anterior-Posterior), renal width (Lateral) and renal length (Longitudinal) diameters, in terms of the mean, maximum and minimum values based on age and gender variation. Whilst Table 2 is a presentation of three measured renal parameters, including left and right RV and K parameters. These measurements of the renal volume and the ellipsoid constant are presented in terms of their mean, maximum and minimum values based on age and gender variation which are summarized in Table 3 and Table 4 for male and female respectively (not clear). This represent a reference chat of renal volumetric ellipsoid coefficient which has been made available to clinicians for clinical application. The summary of renal volume are presented in Table 5, for various age and gender variations. Whilst the overall summary are presented in Table 6 independent of age, but depends on gender variations.

Table 1: Estimated renal linear parameters with volume for male The letters have shadows. Create a table for the results

Table 1A: Measured A-P, LT and LNG diameters and renal volume

Sex/Age	STATS	AGE Yrs	$A\text{-}P_R$ mm	$A\text{-}P_L$ mm	LT_R mm	RV_R mL^3	LT_L mm	LNG_R mm	LNG_L mm	RV_L mL^3
MALE	MEAN	32	45.39	45.3	62.3	147.4	61.7	104.9	107.9	153.6
20-40	MAX	40	63.9	62.7	75.5	183.4	73	124.8	126.6	195.7
	MIN	20	39.3	39.1	51.5	97.52	48.1	85.9	88.5	116.1
41-60	MEAN	54	44.59	45.6	61.8	146.0	61.1	105.2	106.9	153.8
	MAX	60	58.3	59.5	71.3	229.8	76.8	118.3	121.6	254.4
	MIN	41	37.6	38.5	50.4	100.3	47.8	89	75.3	96.27
61-80	MEAN	73	42.0	43.6	57.7	124.5	57.9	98.9	99.6	132.3
	MAX	80	53.7	59.1	66.3	211.5	68.8	119.3	119.2	297.1
	MIN	61	31.9	26.7	49.3	74.41	47.9	84.2	83.6	66.89
20-80	MEAN	52	44.1	45.0	60.8	146.7	60.4	103.4	105.1	151.8
	MAX	80	63.9	62.7	75.5	312.0	76.8	124.8	126.6	272.9
	MIN	20	31.9	26.7	49.3	75.54	47.8	84.2	75.3	77.85

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Table 2: Estimated renal linear parameters with volume for female The letters have shadows. Create a table for the results

Table 1B: Measured A-P, LT and LGN diameters and renal volume

Sex/Age	STATS	AGE Yrs	A-P$_R$ mm	A-P$_L$ mm	LT$_R$ mm	RV$_R$ mL^3	LT$_L$ mm	LNG$_R$ mm	LNG$_L$ mm	RV$_L$ mL^3
FEMALE	MEAN	34	43.46	45.2	60.2	155.5	59.2	105.4	107.6	159.5
20-40	MAX	40	52.6	54.8	68.4	311.9	66.0	124.1	126.6	272.9
	MIN	20	38.8	37.9	53.5	103.7	47.1	83.8	90.9	104.8
41-60	MEAN	51	44.0	45.3	60.1	152.6	60.5	103.9	105.3	158.0
	MAX	60	56.2	65.6	69.5	224.9	68.7	121.7	120.3	218.0
	MIN	41	38.8	39.1	47.4	108.5	47.1	86.4	87.4	108.8
61-80	MEAN	72	42.0	44.2	57.8	128.3	57.5	97.0	98.3	133.9
	MAX	80	56	59.8	68.8	205.7	71.7	124.3	134.8	190.3
	MIN	61	32.9	34.7	41.6	75.53	43.6	75.6	74.8	77.85
20-80	MEAN	56	43.1	44.8	59.2	142.0	59.0	101.4	103.0	148.3
	MAX	80	56.2	65.6	69.5	311.9	71.7	124.3	134.8	297.1
	MIN	20	32.9	34.7	41.6	74.41	43.6	75.6	74.8	66.89

Table 3: Estimated renal ellipsoid constant for male---The letters have shadows. Create a table for the results

Table 2A: *Estimated Renal K and RSI Parameters*

Sex/Age	STATS	Age (yrs.)	K$_R$	K$_L$	RSI$_R$	RSI$_L$
MALE	MEAN	34	0.526	0.532	1.0	1.0
20-40	MAX	40	0.596	0.578	1.2	1.3
	MIN	20	0.493	0.500	0.8	0.9
41-60	MEAN	52	0.528	0.532	1.0	1.0
	MAX	60	0.606	0.620	1.3	1.2
	MIN	43	0.495	0.490	0.9	0.9
61-80	MEAN	72	0.529	0.530	1.0	1.0
	MAX	80	0.606	0.588	1.2	1.3
	MIN	61	0.491	0.495	0.8	0.7
20-80	MEAN	52	0.528	0.530	1.0	1.0
	MAX	80	0.595	0.595	1.3	1.3
	MIN	20	0.485	0.491	0.8	0.7

Table 4: Estimated renal ellipsoid constant for female The letters have shadows. Create a table for the results

Table 2B|: *Estimated Renal K and RSI Parameters*

Sex/Age	STATS	Age (yrs.)	K_R	K_L	RSI_R	RSI_L
FEMALE 20-40	MEAN	32	0.529	0.529	1.0	1.0
	MAX	40	0.586	0.595	1.2	1.2
	MIN	20	0.489	0.491	0.8	0.8
41-60	MEAN	53	0.528	0.530	1.0	1.0
	MAX	60	0.568	0.593	1.2	1.2
	MIN	41	0.485	0.491	0.9	0.7
61-80	MEAN	73	0.529	0.530	1.0	1.0
	MAX	80	0.595	0.588	1.3	1.3
	MIN	61	0.491	0.498	0.9	0.8
20-80	MEAN	54	0.528	0.530	1.0	1.0
	MAX	80	0.606	0.620	1.3	1.3
	MIN	20	0.485	0.490	0.8	0.7

Table 5: Summary of Renal ellipsoid constant with age and gender variation The letters have shadows. Create a table for the results

Table 3: Summary of Estimated K and RSI Parameters

Age	Age (yrs)	Sample	K_R	K_L	RSI_R	RSI_L
Male	Mean		±0.008	±0.009	±0.02	±0.01
	33	107	0.529	0.5289	1.02	1.02
	53	122	0.528	0.5303	1.00	1.01
	70	59	0.529	0.5301	0.99	1.01
	49	288	0.528	0.5297	1.00	1.01
Female	Mean		±0.020	±0.019	±0.01	±0.02
	34	68	0.526	0.532	1.02	1.03
	53	135	0.528	0.532	1.02	1.02
	70	122	0.529	0.530	0.97	0.98
	55	325	0.528	0.530	1.00	1.01

Table 6: Over all summary of Renal ellipsoid constant for both gender

Table 4: *Ghanaian Reference Renal K and RSI Parameters*

PARAMETER	M/R	M/L	MEAN	F/R	F/L	MEAN
K	0.5283	0.5297	0.5290	0.5280	0.5304	0.5292
RSI	1.00	1.01	1.01	1.00	1.01	1.00

Discussions

The K is an important renal parameter that represents the constant of proportionality for a renal ellipsoid equation and for the estimate of a unique Ghanaian renal volume. This has been made available to be used by clinicians in a comfortable working process in the form of GUI for clinical application. The statistical detailed age and gender representation of these renal parameters are shown in Table 1 and 2 as reference chat for clinicians and researchers.

The renal volumetric ellipsoid coefficient (K) was determined as summarized in Table 6??? The highlight of the summarized measurements are presented in Table 4?? and 5?? (this must come first before 6) with an average maximum and minimum values. The average K was approximately the same for both gender and age variations with the value of 0.53±0.01 for right and left, male and female and with all age variations.

Conclusion

In conclusion, an accepted unified local based standard reference renal volumetric ellipsoid coefficient was determined and led to the establishment of renal volume model for clinical application in Ghana. The results shows that the renal volumetric ellipsoid coefficient was approximately 0.53±0.01 for both age and gender variations. Generally, the mean volumetric ellipsoid coefficient were not affected by either age or gender variation. In conclusion, GUI has been designed to be used to estimate renal volume by clinicians.

Recommendation

The radiologist should use the results obtained by this method in relation to the renal volumetric ellipsoid coefficient for clinical application in Ghana. It is recommended that the established reference values be used as clinical guidelines values for estimation of renal volume for clinical application.

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