Establishing a new formula for estimating renal depth in a Chinese adult population

Jianjun Xue, MSa, Huixing Deng, MSa, Xi Jia, MSa, Yuanbo Wang, BSb, Xueni Lu, BSb, Xiaoming Ding, MDb, Qiang Li, MDb, Aimin Yang, PhD, MDa,b,c∗

Abstract

We aimed to establish a new formula for estimating renal depth, based on anthropometric variables, and to compare the estimates with actual data from a group of living kidney donors undergoing computed tomography angiography (CTA).

Renal depths in 167 living kidney donors were measured by CTA. Regression analysis was used to derive the formulae for estimation of renal depth of both kidneys based on patient age, sex, body height, body weight, and body mass index (BMI). The results of the renal depth estimation from the derived formulae were compared with those using existing formulae. Using regression analysis, we derived 2 new formulae as follows; for left kidney, renal depth (cm) = 0.083 × W - 0.058 × H + 11.541 (male) or 10.89 (female), for right kidney, renal depth (cm) = 13.498 × W/H + 2.141 (male) or 1.816 (female), in which W represents the weight (kg) and H represents the height (cm). The correlation coefficients between our left or right renal depth estimates and those obtained from other formulae in another 271 kidney donors were 0.864 (left) or 0.893 (right) by the Tønnesen, 0.937 (left) or 0.97 (right) by the Taylor, 0.937 (left) or 0.97 (right) by the Itoh, 0.927 (left) or 0.951 (right) by the Li-qian, and 0.937 (left) or 0.97 (right) by the Inoue formula.

Our formula may be more precise than the Tønnesen formula in estimating the renal depth. Estimating formulae based on CT findings might be useful in clinical practice.

Abbreviations: BMI = body mass index, CT = computed tomography, CTA = computed tomography angiography, ERPF = effective renal plasma flow, GFR = Glomerular filtration rate, SPECT = single-photon emission computed tomography, T = thickness, W/H = weight / height.

Keywords: computed tomography, formula, glomerular filtration rate, kidney, renal depth

1. Introduction

The increasing prevalence of chronic kidney disease with the aging population necessitates the evaluation of renal function in clinical practice. Glomerular filtration rate (GFR) and effective renal plasma flow (ERPF) are useful surrogates for evaluating renal function, and a simple, practical, and accurate method for estimating GFR or ERPF is urgently required. Currently, a scintigraphy-based technique for renal dynamic imaging is widely adopted to gauge GFR and ERPF.

Several factors can affect GFR and ERPF estimation using renal scintigraphy, and renal depth is one of them. At present, the Tønnesen formula based on ultrasound findings is frequently utilized to estimate the renal depth for GFR measurement, while the Taylor and the Itoh formulae based on the findings of computed tomography (CT) are used for the estimation of ERPF. However, GFR and ERPF are often measured using different formulae to estimate the renal depth in the same individual, resulting in inconsistent conclusions. Further, most formulae are derived from data of Caucasian individuals or Japanese patients, and whether they are applicable to the Chinese population remains unclear. In the current study, we first retrieved the renal depths measured by CT, and then established a new formula for estimation of renal depth on the basis of different anthropometric variables. Finally, we compared the results obtained using our new formula with those from other commonly used formulae, including the Tønnesen, the Taylor, the Itoh, and the Li-qian, and the Inoue.[1–7]

2. Materials and methods

2.1. Participant recruitment

This study was approved by the Ethics Committee of the First Affiliated Hospital of Xi’an Jiaotong University (Xi’an, China), and all participants provided written informed consent. A total of 438 healthy, potential kidney donors belonging to Chinese Han race were selected and their age, body height, and body weight were recorded. The height- and weight-measuring instruments were calibrated using the following approach: the participants were placed on the flat ground in a corner, and any error in 2 measurements of body height was less than 0.5 cm. These patients were randomly divided into 2 groups according to their wishes...
and choices, one of which included 167 donors (66 male and 101 female) who underwent abdominal computed tomographic arteriography (CTA). Their mean age was 47.3 ± 8.5 (range, 22–65) years. The other group included 271 donors (152 male and 119 female) who did not undergo CTA. Their mean age was 42.8 ± 12.7 (range, 18–63) years. None of the donors had any history of renal disease, hypertension, diabetes mellitus, or injury before enrollment. All participants underwent tests such as blood routine and urine routine, blood sugar, liver function, and renal function (serum creatinine and blood urea nitrogen), none of which showed any abnormalities. Hepatic and renal ultrasound examinations also showed normal results.

2.2. CT imaging and formula derivation

CTA was performed using Toshiba Aquilion 64-SCT scanner (Kyushu, Japan), and the procedure was as outlined below. The participants were made to lie in supine position and were subjected to volume scanning from the upper pole of the liver to the level of the iliac spine. The slice thickness was 0.5 mm, with the rotation speed of X-ray tube at 0.4 seconds per rotation, a tube voltage of 120 to 135 kV, and a tube current of 300 to 440 mA. Data from the volume scanning were reconstructed with a slice thickness of 1 mm. Iohexol solution with a concentration of 350 mg iodine/mL and a volume of 2.5 mL/kg of patient body weight was injected at a rate of 4.0 to 4.5 mL/s to enhance the visualization of abdominal viscerum and vasculature.

Renal depths were determined by measuring the distance between the skin and the anterior as well as the posterior surface of each kidney at the level of renal hilum. The average of these 2 values was then determined to acquire the mean renal depth (Fig. 1). Right and left renal depths were measured independent of each other. Renal depths were also estimated by the Tønnesen, the Taylor, the Itoh, the T.itoh, the Li-qian, and the Inoue formulae (Table 1).

2.3. Statistical analysis

Data were analyzed using SPSS version 15.0 (SPSS Inc., Chicago, IL) statistical software. All data were expressed as mean ± standard deviation (SD). In the first part of the study, a multiple stepwise linear regression analysis was performed and new formulae were derived to estimate bilateral renal depths. The variables chosen in the regression analysis included patient age, sex, body weight, body height, the ratio of body weight to body height (weight/height), and body mass index (BMI) [weight (kg)/height (m²)]. Regressions using stepwise regression methods were utilized; only variables with significant associations (P < 0.05) were retained in the regression equation.

In the second part of the study, renal depths were calculated using our new formula, and the Tønnesen, the Taylor, the Itoh, the T.itoh, the Li-qian, and the Inoue formulae. The differences between the actual renal depths on CT and those calculated by the above formulae were then analyzed using correlation coefficients.

3. Results

3.1. Derivation of a new formula for estimating renal depths

Data regarding body weight, body height, and renal depth conformed to normal distribution, and they were then analyzed using regression analysis. Variables including age, gender, height, body weight, body height, weight/height, and BMI were selected. We first conducted a multiple linear stepwise regression analysis of the data obtained from all the 167 kidney donors [66 males, with a mean age of 47.3 ± 8.5 (range, 22–65) years]. The results showed that variables with potential influences included body weight, body height, weight/height, and sex, while age did not play an important role in determining renal depth among these participants. Finally, we derived new estimating formulae for renal depth based on CTA findings; for the left kidney, renal depth (cm) = 0.083 × W – 0.058 × H + 11.541 (male) or 10.89 (female), and for the right kidney, renal depth (cm) = 13.498 × W/ H + 2.141 (male) or 1.816 (female), in which W represented body weight (kg) and H represented body height (cm).

3.2. Estimating renal depths by the 7 formulae

The mean renal depths of the left and right kidneys measured by CT among the 167 donors were 6.82 ± 0.95 and 7.03 ± 0.99 cm, respectively. The estimated renal depths using the 7 existing formulae are presented in Table 2. The differences between the mean renal depths from values measured by CT and those derived from the formulae were calculated. It was observed that the difference was the greatest using the Tønnesen formula (−1.14 vs −1.32 cm) and the smallest using the Inoue formula (−0.08 vs 0.05 cm).

3.3. Residual analysis between the results from different formulae

The results from CT were compared with those from the Tønnesen, the Taylor, the Itoh, the T.itoh, the Li-qian, and the Inoue formulae. Residual description of the renal depths estimated using formulae and measured using CT is presented in Table 3. Single factor analysis (Table 4) and multiple comparisons (Table 5) of residuals showed that the renal depths derived from the Tønnesen formula, as measured by renal ultrasound, were significantly lower than those measured by CT. There was no significant difference between results from our new formula and those from other formulae based on CT findings.

3.4. Correlation analysis

The correlation coefficients using Pearson correlation method between the renal depths derived from the new formula in
another 271 living donors and those from the Tønnesen, the Taylor, the Itoh, the Li-qian, and the Inoue formulae were 0.864 (left) or 0.893 (right), 0.937 (left) or 0.97 (right), 0.937 (left) or 0.97 (right), 0.927 (left) or 0.951 (right), and 0.937 (left) or 0.97 (right), respectively.

4. Discussion

Gates’ method of measuring GFR was first used in 1982 to 1984, and is now widely adopted when single-photon emission CT (SPECT) is performed to estimate GFR\(^6\). Owing to its simplicity and efficacy, Gates’ method is now popularly used for measuring the GFR of each kidney. However, the accuracy of this approach is influenced by several factors, the most important one being the renal depth.\(^{13}\) This is also supported by Taylor’s observation that renal depth estimation is one of the 2 common sources of error in Gates’ method.\(^{[1,16]}\) Therefore, the accurate measurement or estimation of renal depth is of paramount importance.

Both ultrasonography-based\(^{[13]}\) and lateral renography-based methods\(^{[14]}\) for measuring renal depth have limitations,\(^{[14,15]}\) and CT-based methods are considered to be more accurate than the other methods. The existing formulae for estimating the renal depth include the Tønnesen, the Taylor, the Itoh, the T.itoh, the Li-qian, and the Inoue formula. Among these, the Tønnesen formula is based on data derived from ultrasonography findings, while the other formulae are based on data derived from CT. CT-derived renal depth measurement may be theoretically more accurate than those derived from ultrasonography, and our findings support this view. In addition, we found that there was no significant difference between the results obtained from different formulae based on CT findings.

Previous reports showed that age and gender may also affect GFR in addition to the renal depth. Our findings suggested that renal depths slightly differ between males and females, but age had a little influence on renal depths. It is possible that the size of the kidney in males is larger than that in females, and the differences in perfusion might contribute to the discrepancy in estimating the renal depths. Our finding that age did not affect the measurement of the renal depths is consistent with the results obtained from the Tønnesen, the Itoh, and the Inoue formulae, but not with those from the Taylor and the Li-qian formulae.

Taylor et al\(^{[1,16]}\) suggested that the age-related increase in central adipose tissues could be responsible for the correlation between age and renal depths. Although the Inoue formula is derived on the basis of data from 232 adults and 74 children of an average age of 6.9±5.1 years, the coefficients assigned to the variable “age” are small, suggesting that age might have a little effect on the estimation of the renal kidney depths.

The Tønnesen formula is a traditional formula for estimating the renal depth. Tønnesen et al\(^{[2]}\) used ultrasonography to measure renal depths in 55 adult patients with an average age of 46 years, when they were seated. In contrast, during CT, patients are in a supine position, which facilitates the measurement of the renal depth compared with the sitting position; moreover, patients are supine during a radionuclide renal scan as well. Therefore, it is reasonable that formulae based on results from CT can derive estimates that are more accurate than those derived from the Tønnesen formula. The small sample size of the study by Tønnesen et al, the patients’ position during the ultrasonography examination, and the oblique angle of the ultrasound probe to the kidney prompted Taylor et al\(^{[1,16]}\) to suggest that the renal depths obtained from the Tønnesen formula were likely underestimated. This view is also shared by other researchers.\(^{[1,16]}\) To improve the Tønnesen formula, Taylor et al\(^{[1,16]}\) proposed that a more accurate method to measure the renal depth would be as follows; first, examiners should measure the vertical distances between the anterior or the posterior surface of each kidney and the patients’ back. Second, the examiners should calculate the mean of the 2 values obtained above as the renal depth of each kidney. Using this method on 126 patients, they derived Taylor’s formula based on the patients’ body height, body weight, and age. This approach was later adopted by other researchers,\(^{[17,18]}\) including Itoh et al\(^{[13]}\), Li-qian et al\(^{[6]}\), Inoue et al\(^{[7]}\), and us. Our residual analysis also showed that there are small differences between the results from the Taylor, the Itoh, the Li-qian, the Inoue formulae, and our new formula. This indicated that renal depth measurement based on CT is more accurate than that based on

| Table 1
Formulae for estimating renal depths in study patients. |
|----------------|----------|-------|----------|-------------------------------|-------------------------------|
| Formula         | Method   | Year  | Cases    | Age, y                        | Left kidney depth formula, cm  | Right kidney depth formula, cm |
| Tønnesen et al\(^{[7]}\) | Ultrasound | 1982  | 55       | 46                            | 13.2 × W / H + 0.7             | 13.3 × W / H + 0.7             |
| Taylor et al\(^{[1]}\)  | CT       | 1993  | 126      | 54.7 ± 6.2                    | 16.17 × W / H + 0.027 × A - 0.94 | 15.13 × W / H + 0.022 × A + 0.077 |
| Itoh et al\(^{[2]}\)  | CT       | 1987  | /        | /                             | 14.0285 × W / H + 0.7554       | 13.6361 × W / H + 0.6996       |
| T.itoh           | /        | /     | /        | /                             | 17.05 × W / H + 0.13           | 16.55 × W / H + 0.66           |
| Li-qian et al\(^{[6]}\) | CT       | 2007  | 147      | 57.4 ± 15.2                   | 16.772 × W / H + 0.01025 × A + 0.224 | 15.449 × W / H + 0.009637 × A + 0.782 |
| Inoue et al\(^{[7]}\) | CT       | 2000  | 74       | 6.9 ± 5.1                     | 16.825 × W / H + 0.397         | 16.778 × W / H + 0.752         |

H=height, in cm, W=weight, in kg.

| Table 2
Estimates of renal depths using the 7 formulae among the 167 healthy kidney donors (mean ± standard deviation). |
|----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                | Tønnesen        | Taylor          | Itoh            | T.itoh          | Li-qian         | Inoue           | Current study   |
| Left renal depth, cm | 5.68±0.59       | 6.43±0.77       | 6.63±0.6        | 6.56±0.76       | 7.03±0.75       | 6.74±0.75       | 6.82±0.65       |
| Right renal depth, cm | 5.71±0.59       | 6.82±0.71       | 6.88±0.57       | 6.9±0.73        | 7.06±0.69       | 7.08±0.74       | 7.03±0.6        |
ultrasound. Recently, abdominal thickness was also introduced as a variable in renal depth estimation formulae such as the Taylor formula,[19,20] and there are reports suggesting that abdominal thickness was more important than weight/height (W/H) in their formula.[25] The total thickness (T) of the body at the level of kidneys was also measured by CT. We also constructed a new regression formula including the following: for the left kidney, renal depth (cm) = 0.2839 + 0.18525 × T + 7.148011 × W/H; for the right kidney, renal depth (cm) = 0.689708 + 0.171129 × T + 0.044754 × W. However, we believe that there are several concerns about the formulae that include T. First, there is no clear mark of renal hilum on the body surface, and the right kidney may be lower than the left kidney for about 2 to 3 cm. This is why accurate measurement of T is not easy during clinical practice. Using an L-square scale might assist in the measurement of T in patients without CT, but it is inaccurate. Second, although T is measured using CT, the depths of the kidney can also be measured. Third, the renal depths greatly influence the measurement of GFRs, and small changes in renal depths may lead to greater differences in estimating the values of GFRs. Consequently, we speculate that if T can be measured accurately from the body surface, the formula that includes T will play a greater role in estimating the renal depth. The Taylor formula can be expressed as follows: left renal depth (mm) = 161.7 (weight/height) + 0.27 age – 9.4, and right renal depth (mm) = 151.3 (weight/height) + 0.22 age + 0.77. However, the formula for right renal depth was incorrectly written as “15.31 × W/H + 0.022 × A + 0.077” in their abstract, although this was corrected later.[21] The Taylor formula was still misquoted repeatedly. For example, it was cited wrongly in the operation manual of GE Millennium VG Hawkeye 1SPECT/CT and GE Infinia VC Hawkeye 4SPECT/CT.[22] Similar errors were also noted in 3 Chinese reports,[23,24] and the formula for left renal depth was also cited incorrectly as “16.17 × W/H + 0.027 × A + 0.94.”[25] Similar to the Taylor formula, the Itoh formula was as follows: left renal depth (cm) = 14.0283 × (W/H) + 0.7554 and right renal depth (cm) = 13.6361 × (W/H) + 0.6996; however, in some studies,[26] it was misquoted as “left renal depth (cm) = 14.0283 × W/H + 0.7554” and “left right depth (cm) = 13.6361 × W/H + 0.6996.” In our study, the average renal depths of the left and the right kidney, estimated by the Tønnesen formula, were 5.68 ± 0.39 and 5.71 ± 0.39 cm, respectively. These values are significantly lower than those estimated from other formulae and those measured using CT. Judging from these potential interfering factors of the renal depth formulae, it is likely that the GFR values measured by Gates’ method might have some limitations.

Researchers[26,27] have evaluated the relationship between renal depths and BMI. Hu et al[27] stated that renal depths calculated with the Tønnesen formula are reliable when the BMI is within the normal range, and renal depths should be measured using CT rather than by the Tønnesen formula in individuals whose BMI is beyond the normal range. However, in our study, BMI is a variable in the regression equation, and subsequent analysis showed that BMI was not associated with the renal depth. We will investigate the relationship between BMI and renal depth in the future.

W/H has no significant effect on the renal depth of the left kidney as per the results of statistical analysis; hence, we did not include this variable in our formula. This could be attributed to certain unrecognized differences between the 2 kidneys. One of the notable differences is that the left kidney is approximately 0.5 cm to 1.5 cm larger than the right one. Moreover, the location of the left kidney is slightly higher than that of the right kidney. In view of the different anatomical locations and variable proximity to other organs, the position and tilt angle of the left kidney differ from those of the right one.[28] All the above arguments can explain that W/H is not a significant variable in our formula.

The Li-qian formula was the first to estimate the renal depth in patients from China, and it was reported that renal depths might differ between patients of Caucasian and Han origin; in other words, the formulae for estimating the renal depth in European and American individuals might not be applicable to Chinese individuals.[6] Subsequent reports showed that the Li-qian formula is more accurate than the Taylor formula,[6,24] but our findings are unable to support this conclusion. We showed

| Table 3 |
| --- |
| Residual descriptions of renal depths between estimates from different formulae and actual measurements from computed tomography. |

| Formula | Effective sample | Mean square | Sum of squares | Effective sample | Mean square | Sum of squares |
| --- | --- | --- | --- | --- | --- | --- |
| Current study | 167 | 0.4917 | 82.11 | 167 | 0.5751 | 96.05 |
| Tønnesen | 167 | 1.8630 | 311.12 | 167 | 2.3402 | 390.81 |
| Taylor | 167 | 0.738 | 123.25 | 167 | 0.6883 | 114.94 |
| Itoh | 167 | 0.5833 | 97.41 | 167 | 0.624 | 104.21 |
| Tito | 167 | 0.6425 | 107.3 | 167 | 0.6329 | 105.7 |
| Li-qian | 167 | 0.6089 | 101.68 | 167 | 0.6147 | 102.66 |
| Inoue | 167 | 0.5575 | 96.14 | 167 | 0.6194 | 103.45 |

| Table 4 |
| --- |
| Single factor analysis of the left and right renal depth residuals comparison. |

| Sum of squares (left/right) | DF | Mean Squares (left/right) | F (left/right) | Probe (left/right) |
| --- | --- | --- | --- | --- |
| Model | 231.475/421.844 | 6 | 38.579/70.307 | 78.159/110.576 | 0.000/0.00 |
| Case | 979.673/1502.633 | 166 | 5.902/9.052 | 11.956/14.237 | 0.000/0.00 |
| Error | 491.623/633.283 | 996 | 0.4940/0.636 | / | / |
| C total | 1702.771/2557.76 | 1168 | / | / | / |
that the renal depths estimated from these formulae based on results from CT have a high correlation, especially those of the right kidney, with a correlation coefficient up to 0.951 to 0.97. This finding stands despite the fact that the Taylor formula is derived from the Americans, the Itoh and the Inoue formulae are derived from the Japanese, while the Li-qian formula is derived from the Chinese. As the Taylor, Li-qian, Inoue formulae, and our formula are all based on the results in middle-aged and older patients (Table 1), our findings indicated that no significant difference exists between the results from formulae based on patients of different ethnicity. It is likely that the renal depths of the middle-aged and older patients are similar across ethnicity as well. We propose that middle-aged and older patients tend to be obese, and their renal depths are more likely to be affected by their body shape than by their ethnicity. However, whether this conclusion is applicable to younger patients warrants further investigation.

In conclusion, our study showed that the renal depth estimates derived from the ultrasound-based Tønnesen formula underestimate those derived from the CT-based formula. We also revealed that the renal depth estimates from formulae based on results from CT exhibited high correlation with each other, and these estimates were more accurate compared with those from the Tønnesen formula, especially for middle-aged and older patients. However, the formulae were not suitable for children. Patient age and gender have a little effect on the estimation of renal depth. Our new formula is based on a group of potential kidney donors undergoing CT examination, and can serve as a better method for estimating renal depth. This accuracy is expected to improve the calculation of GFR in potential kidney donors.

**References**

1. Taylor A, Lewis C, Giacometti A, et al. Improved formulas for the estimation of renal depth in adults. J Nucl Med 1993;34:1766–9.
2. Tønnesen KH, Munk O, Hald T, Zum Winkel K, Mlaufox MD, Funck-Brentano JL. Influence on the radiorenogram of variation in skin to kidney distance and the clinical importance hereof. Proceedings of the International Symposium on Radiouclide in Nephrourology, Themen, Stuttgart, 1974:79–86.
3. Itoh K, Arakawa M. Re-estimation of renal function with 99mTc-DTPA by the Gates’ method. Kaku Igaku 1987;24:389–96.
4. Murase K, Tanada S, Masakazu I, et al. Methods for measuring the renal uptake rate of 99mTc-dimercapto succinic acid (DMSA): a comparative study. Eur J Nucl Med 1990;16:725–31.
5. Itoh K, Toshima S, Tsukamoto E, et al. Reappraisal of single-sample and gamma camera methods for determination of the glomerular filtration rate with 99mTc-DTPA. Ann Nucl Med 2000;14:143–50.
6. Qian LI, Zhang C-L, Zhan-Li FU, et al. Measuring kidney depth of Chinese people with kidney dynamic imaging. Clin J Med Imaging Technol 2007;23:288–91.
7. Inoue Y, Yoshikawa K, Suzuki T, et al. Attenuation correction in evaluating renal function in children and adults by a camera-based method. J Nucl Med 2000;41:823–9.
8. Gates GF. Glomerular filtration rate: estimation from fractional renal accumulation or 99Tcm-DTPA (stannous). Am J Roentgenol 1982;138:565–70.
9. Gates GF. Split renal function testing using 99mTc-DTPA: a rapid technique for determining differential glomerular filtration. Clin Nucl Med 1983;8:400–7.
10. Gates GF. Computation of glomerular filtration rate with 99mTc-DTPA: an in-house computer program. J Nucl Med 1984;25:613–8.
11. Lythgoe MF, Gradwell MJ, Evans K, et al. Estimation and relevance of depth correction in paediatric renal studies. Eur J Nucl Med 1998;25:115–9.
12. Inoue Y, Ohtake T, Homma Y, et al. Evaluation of glomerular filtration rate by camera-based method in both children and adults. J Nucl Med 1999;40:1784–8.
13. Granerus G, Moonen M. Effects of extra-renal background subtraction and kidney depth correction in the measurement of GFR by gamma camera renography. Nucl Med Commun 1991;12:279–87.
14. Maneval DC, Magill HL, Cypess AM, et al. Measurement of skin-to-kidney distance in children: implications for quantitative renography. J Nucl Med 1990;31:287–91.
15. Granerus G, Moonen M. Effects of extra-renal background subtraction and kidney depth correction in the measurement of GFR by gamma camera renography. Nucl Med Commun 1991;12:519–27.
16. Taylor AT. Radionuclides in nephrourology, part I: radiopharmaceuticals, quality control, and quantitative indices. J Nucl Med 2014;55:608–15.
17. Palmer MR, Donohoe KJ, Francis JM, et al. Evaluation of relative renal function for patients who had undergone simultaneous liver-kidney transplants using Tc-99m-MAG3 scintigraphy with attenuation correction from anatomical images and SPECT/CT. Nucl Med Commun 2011;32:738–44.
18. Lythgoe MF, Gradwell MJ, Evans K, et al. Estimation and relevance of depth correction in paediatric renal studies. Eur J Nucl Med 1998;25:115–9.
19. Uchiyama K, Kuniyasu Y, Niso Y, et al. Proposal on new formulas for renal depth in the technetium-99m-mercaptoproxyliclylcine (MAG3) scintigraphy. Kaku Igaku 1997;34:159–66.
20. Ma G, Shao M, Xu B, et al. Establish new formulas for the calculation of renal depth in both children and adults. Clin Nucl Med 2015;40:357–62.
21. Taylor A. Formulas to estimate renal depth in adults. J Nucl Med 1994;35:2014–5.
22. Renal Analysis Operation Guide. Renal Analysis REV.1 Copyright © 2007 by GE Healthcare B-11.

**Table 5**

Multiple comparisons of residuals (left/right).

|                | Mean difference (left/right) | Standard error (left/right) | Probe (left/right) | 95% confidence interval (left/right) |
|----------------|-----------------------------|----------------------------|-------------------|-------------------------------------|
| Current study  |                             |                            |                   |                                     |
| Tønnesen       | −1.3713/−0.1765             | 0.12314/0.14837            | 0.000/0.00        | −1.629/−0.2561                      |
| Tønnesen       | −0.24637/−0.11312           | 0.12314/0.14837            | 0.050/0.045       | −0.4880/−0.4042                     |
| Tønnesen       | −0.09162/−0.04987           | 0.12314/0.14837            | 0.460/0.74        | 0.332/−0.34                        |
| Tønnesen       | −0.15083/−0.05779           | 0.12314/0.14837            | 0.220/0.7         | −0.392/−0.3489                      |
| Tønnesen       | −0.11718/−0.03959           | 0.12314/0.14837            | 0.340/0.79        | −0.3588/−0.3307                     |
| Inoue          | −0.08404/−0.04431           | 0.12314/0.14837            | 0.50/0.77         | −0.3265/−0.3354                     |
| Inoue          | 1.22047/1.7023              | 0.12314/0.14837            | 0.00/0.00         | 0.8633/1.3606                       |
| Inoue          | 1.25412/1.72545             | 0.12314/0.14837            | 0.00/0.00         | 1.0381/1.4251                       |
| Inoue          | 1.28726/1.7027              | 0.12314/0.14837            | 0.00/0.00         | 1.0457/1.4296                       |

* P < 0.01.
[23] Qian LI, Zhang C-L, Wang R-F. Influence elements in the process of dynamic renal imaging to measure glomerular filtration rate. Chin J Med Imaging Technol 2004;20:962–4.

[24] Yang H, Qiang LI, Wenliang LI, et al. Applicability of three formulas in measuring renal depth of Chinese people. Chin J Med Imaging 2013;21:632–5.

[25] Guang-Yu MA, Shao MZ, Chen YS, et al. Impact of kidney depth on the measurement of glomerular filtration rate with SPECT. Chin J Med Imaging Technol 2013;29:800–4.

[26] Shu-guang C, Hong-cheng S, Peng-cheng H. Accuracy of the Tønnesen formula and its relationship with body mass index. J Chin J Nucl Med Mol Imaging 2012;32:430–3.

[27] Hu P. Measurement of skin-to-kidney distance in patients’ estimated glomerular filtration rate using Gates’ method: implications for abdominal CT in Chinese people. Society of Nuclear Medicine Annual Meeting Abstracts 2012;53(Suppl 1).

[28] Tarzamni MK, Nezami N, Rashid RJ, et al. Anatomical differences in the right and left renal arterial patterns. J Folia Morphol 2008;67:104–10.