Original Article

^{99m}Tc-DTPA를 이용한 사구체여과율 검사에서 이소성 신장과 소아 환자의 신장 깊이 측정방법의 적절성

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Suitability of Measuring a Kidney Depth with Assessment of Glomerular Filtration Rateusing ^{99m}Tc-DTPA in the Ectopic Kidney and Pediatric Patients

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Abstract A glomerular filtration rate (GFR) study is a test that uses radioactive materials or tracers (radiopharmaceuticals) and a computer to see how well the kidneys are working. Asan Medical Center analyzed and compared data between kidney depth, acquired from kidney donors' CT image and acquired from Gates method's GFR value that are calculated by Tonnesen equation. This study was able to confirm that kidney depth measured from CT image was higher than the Gates Method's GFR value, which was calculated by Tonnessen equation; the direct relationship among pathologic results is confirmed. Particularly, kidney donor whose kidney was at the pelvic area had direct relationship with other clinical results. During the GFR test, it is necessary to confirm the location of kidney has no change with reference of CT image. If kidney depth is manually corrected using CT image when we measures GFR of deformed or horse-shoe kidney, it would be possible to acquire the compatible value which is equivalent to clinical result. There would be a possible issue of appropriateness that whether the applied GFR using CT image's kidney depth has clinical validity. In case of a pediatric patient, the GFR derived from Tonnesen was quiet underestimated while manual method and Gordon stay in normal range. Which results may be correct among them? There have been many reports about kidney depth, to be an accurate index of GFR in children. As one of the study performers, we should contemplate what the best option for pediatric patients would be.

Key Words Glomerular filtration rate (GFR), Kidney depth, Tonnesen, Taylor, Gordon

Introduction

Asan Medical center performed about 10 Glomerual Filtration Rate (GFR) study a day and there were approximately 200 patients who is performed a GFR study. When we performed a GFR study, Once in a while, there are some cases that we want to share with other technologists. We hope that this would be a good opportunity to look back on the method of a GFR study. The two different formulas, Tonnesen and Taylor formulas had been developed and generally used to calculate GFR value. Both of them are need patient's height and weight. Tonnesen et al. used ultra-sonography to measure kidney depth with the patient's sitting position.[1] Moreover, kidney depth was measured at a probe's oblique angle. However Taylor et al. measure kidney depth using CT images with the patient in the supine position.[2]

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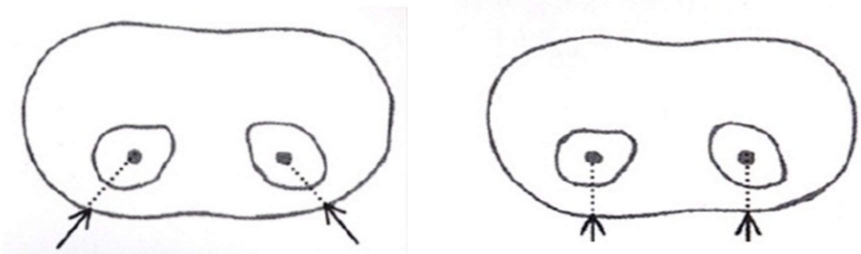

Fig. 1. Diagram showing the oblique angle used by Tonnesen (Left) and perpendicular angle used by Taylor(Right).

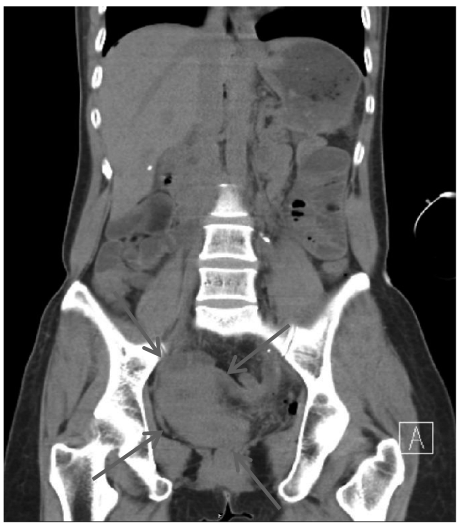

Fig. 2.A A left kidney(arrows)is placed in the pelvic area.The overlapped kidney is easily overlooked as a bladder. When we draw ROI, extreme caution should be made.

It is widely known that the Taylor's formula provides better accuracy than the Tonnesen's one (Fig. 1). The reason why I explain those formulas in the beginning is that there was a significant statistic difference of GFR values between the two.

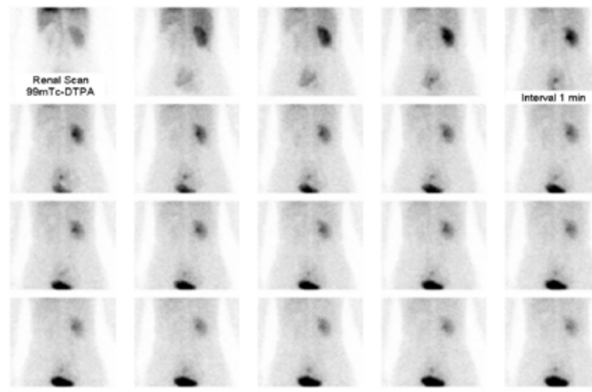

Fig. 2.B Kidney activity is seen at an early phase of GFR study.

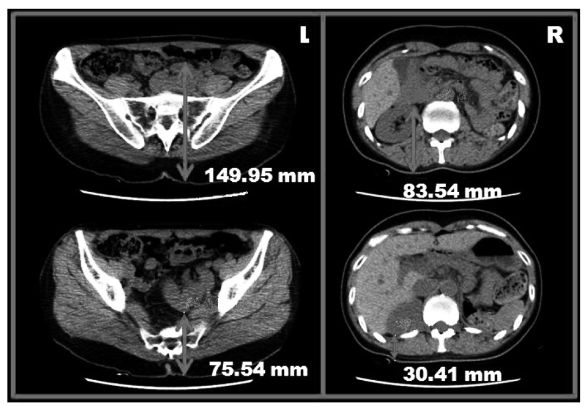

Fig. 3. Selected CT images. All images were reviewed and selected manually. The analysis system was developed at Seoul Asan medical center.

Case report

Case 1:A 49-y-old woman had a GFR study for kidney donation. It was easily recognized that the position of kidney was different from normal people (Fig. 2.A). The patient's kidney was in her pelvic area (Fig. 2.B).

Patient's pathologic results were as follows. Creatinine: 0.72 mg/dl, eGFR (MDRD): 86 mL/min, and Cr-EDTA: 89.396.0 mL/min/1.73m^2. A kidney depth correction was conducted. However, in case of people who are difficult to be distinguished abnormalities of their kidney depth, technologists or radiologists wouldn't conduct kidney depth correction.

As a result, there could be a divergence among pathologic results and GFR studies. In this case, derived GFR value from Tonnesen formula was 42.9 (Right), 18.8 (Left) mL/min while other pathologic results showed normal values. For this reason, we conducted kidney depth correction. For depth correction, abdominal CT scans which were conducted at Seoul Asan medical center were evaluated. They were obtained for clinical indications, with the patients in the supine position. Kidney depth was determined by averaging the anterior and posterior

Table 1. Comparison between Tonnesen and Manual of ectopic kidney

	LT Depth (cm)	RT Depth (cm)	LT GFR (mL/min)	RT GFR (mL/min)
Tonnesen	5.24	5.27	18.8	42.9
Manual	11.07	5.69	83.0	48.0

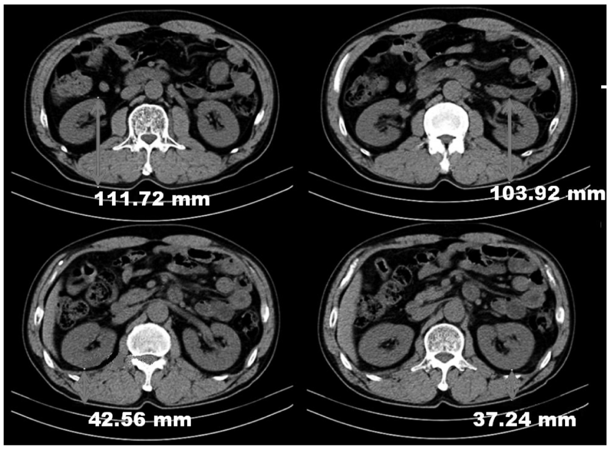

Fig. 4. Selected CT images for averaging kidney depth. All CT images were reviewed and selected manually.

Table 2.1 Comparison of kidney depth between Tonnesen and Manual method

	LT Depth (cm)	RT Depth (cm)
Tonnesen	5.241	5.275
Manual	6.833	7.988

Table 2.2 Comparison of GFR values between Tonnesen and Manual method

	LT GFR (mL/min)	RT GFR (mL/min)
Tonnesen	47.1	39.6
	41.6	35.9
Manual	54.8	47.9
	49.7	44.6

depth at the CT images. The two CT images that show the most superficial anterior kidney surface and the deepest posterior kidney surface were chosen (Fig. 3).

It was remarkable that there was a gap more than twice between Tonnesen's method and manual method. Consequently, deviation of GFR values between them was considerable (Table 1.).

Case 2: In this case, a 69-y-old man had a GFR study for kidney donation(Fig. 4). The patient had GFR studies twice at fortnightly intervals since right kidney's estimated GFR values (39.6/35.9 mL/min) derived from Tonnesen formula were below the normal value. Here, the Tonnesen formula was used. GFR slightly fell short of the normal value while Creatinine, eGFR (MDRD), and Cr-EDTA test showed as follows. Creatinine: 0.84 mg/dl, eGFR (MDRD):79mL/min, and Cr-EDTA:94.2mL/min/1.73m^2. Like the first case, kidney depth was determined by averaging the anterior and posterior depth at the CT images. The two CT images were chosen that show the most superficial anterior kidney surface and the deepest posterior kidney surface. As you can see from the Table 2, there was a remarkable change of the kidney depth and GFR values.

Table 3. Paired-T test between CT and Tonnesen Formula

		Mean±SD	t
Paired-T(RT kidney)	CT Depth (cm)	6.89±1.05	8.480^{**}
	Tonnesen Depth (cm)	5.97±0.79	
Paired-T(LT kidney)	CTDepth (cm)	6.88±1.61	3.996^{**}
	Tonnesen Depth (cm)	5.93±0.78	
Paired-T(RT kidney)	CT GFR (mL/min)	54.22±10.62	5.488^{**}
	Tonnesen GFR (mL/min)	47.55±9.97	
Paired-T(LT kidney)	CT GFR (mL/min)	56.17±11.95	5.911^{**}
	Tonnesen GFR (mL/min)	47.37±9.81	

**P<0.01

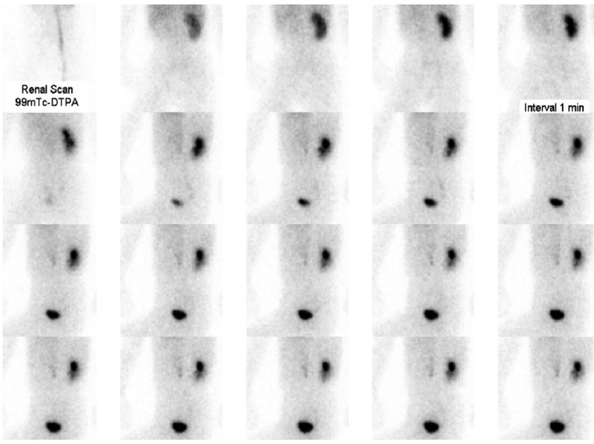

Fig. 5. A 3-y-old toddler had a GFR study. GFR was slightly lower than normal.

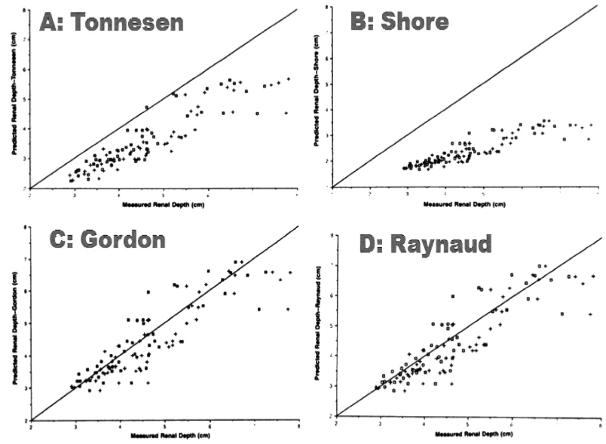

Fig. 6. Relations between CT measurements of left and right kidney depth and regression equations reported by Tonnesen(A), Shore(B), Gordon(C), and Raynaud(D)[12].

Table 4. Comparison of kidney depth and GFR value with three different methods

	LT Depth (cm)	RT Depth (cm)	LT GFR (mL/min)	RT GFR (mL/min)
Tonnesen	3.08	3.10	7.02	76.3
Manual	3.57	4.12	7.86	90.2
Gordon	3.66	3.66	7.92	83.7

Along with this report, we compared kidney depth in the same manner with the 39 kidney donors who had a GFR study for kidney donation. And the statistical analysis was performed with SPSS 13.0. As seen on the table 3.0, two methods showed significant differences.

Case 3: In this case, a 3-y-old toddler had a GFR study.GFR slightly fell short of the normal value while Creatinine and Cr-EDTA test showed normal value as follows. Creatinine: 0.50 mg/dL and Cr-EDTA: 89.0 mL/min/1.73 m^2.

The problem here is that we apply the Tonnesen or Taylor or Gordon (only for children) in young patients. As seen in the table 4, all the values are different. You can see that the Tonnesen's value is quiet underestimated while others stay in normal. How serious are these differences?

Child: Gordon

Left Kidney = 0.0742*Weight+2.3

Right Kidney = 0.0742*Weight+2.3

Table 5. Method used to calculate kidney depth. *This value is used only for pediatric patients as identified within the study information dialog. Not all camera manufacturers provide this method.

Discussion

During the GFR test, three technical factors that are coefficient of net counts, kidney depth, and coefficient of corrected kidney affect the experiment result. It is definitely essential for both technologists and radiologists to measure exact kidney depth when we calculate GFR values. However, not existing of absolute way to measure a kidney depth is a problem awaiting solution.[3-5] In case of a follow up study, consistency of a formula must be observed. As mentioned above, each scanner has its computational methods when calculating a GFR value. It is necessary to decide which one should be used when we performs a GFR study. Recently, there have been many reports about a kidney depth, to be an accurate index of GFR in children. The importance of measuring for skin to kidney distance has been well recognized in adults. Similar corrections have not generally been incorporated into algorithms which evaluate renal function in children.[6,7] Authors argued that skin-to kidney center distance varies little in the pediatric population.[8] Shore et al. considered the influence of tissue attenuation, but Shore et al. were unable to show a statistically significant influence of a kidney depth on either slope or area methods for evaluating a kidney function.[9] Comparison of the measured depths with the weight-based regression relationship using lateral scintigraphy[10] is shown in Fig. 6 (lower left), and comparison of the measurements with the predictions of Raynaud et al.[11] is shown in Fig. 6 (lower right). Several methods have been published regarding a measurement of pediatric kidney depth. As one of the study performers, we should contemplate what the best option for pediatric patients would be[11].

Emphasized limitation on this article is the lack of simultaneous data analysis of 24 hours urine creatinine clearance test and creatinine blood test. There is a possible issue of appropriateness that whether the applied GFR using CT image's kidney depth has clinical validity.

Acknowledgement

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요 약

증례: 첫 번째 임상 증례는, 신 기증을 위해 사구체 여과 율 검사를 실시했던 환자 중 한쪽 신장이 방광 내에 위치한 환자이다. 핵 의학 과 체외 검사를 비롯하여 혈액 검사와 요 검사 수치는 모두 정상 수치를 보였으나, 사구체 여과율 검사만 정상으로 나오지 않았고, 신장의 깊이 측정이 정확하지 않았던 것이 원인임을 알았다. Tonnesen 방정식을 이용해 감마 카메라에서 자동으로 계산되는 신장의 깊이와 서울 아산 병원에서 시행한 단층 영상을 이용해 도출된 신장 깊이를 통한 사구체 여과 율 비교는 주목할 만한 결과를 보여주었다. 두 번째로, 신장 기증을 하기 위해 사구체 여과 율 검사를 실시 하였으나, 결과값이 정상으로 나오지 않았다. 첫 번째 경우와 마찬가지로 다른 타 검사의 결과는 모두 정상 수치를 보였다. 단층 영상을 이용해 신장 깊이를 측정하였고, 그 값을 바탕으로 사구체 여과 율을 계산하였더니 다른 검사 결과(피 검사, 요 검사 등)와 상응하는 결과를 보여 주었다.위 두 가지 증례에 대해 통계적 유의성을 알아 보고자, 본원에서는 신 기증자 성인 남녀 39명의 단층 영상에서 측정한 신장 깊이를 이용하여 측정한 값과 Tonnesen 방정식을 적용한 Gates 방법의 사구체 여과 율 값 간에 통계적으로 유의한 차이가 있는지 조사 하였다. 그 결과 단층 영상을 바탕으로 신장 깊이를 측정한 경우 Tonnesen 방정식을 적용한 Gates 방법의 사구체 여과 율 보다 높은 것을 확인하였는데, 이는 신 기증자의 요 질소 수치와 Cr51-EDTA 그리고 MDRD의 값과 상응하는 결과임을 알 수 있었다. 마지막으로, 사구체 여과율 검사를 받은 소아 환자의 증례에서는 소아 환자의 경우 성인에게 적용했던 Tonnesen방정식을 적용할 수 있는지 알아 보았다. 더불어 장비 제조사에서 제공하는 Gordon 방정식의 결과와도 함께 비교해 보았다. **고찰** 사구체 여과 율 검사 시 주사기계수, 신장깊이, 그리고 교정신장계수의 3가지 기술적 요소가 측정에 영향을 주는 인자인데, 그 중 신장깊이를 단층 영상으로 참고하여 신장의 위치가 상이한 경우가 없는지 세심한 주의가 필요하다. 현재까지 신장 깊이를 측정하는 방법이 많이 있었지만, 절대적으로 정확한 신장 깊이를 측정하는 방법에 대해선 여전히 논의가 뜨겁다. 실제로 다른 방정식에 비해 신장 깊이를 정확히 측정하지 못하는 Tonnesen 법을 이용하는 경우를 많이 볼 수 있었다. 기형 신장, 말굽 형 신장의 사구체 여과율 측정 시 단층 영상을 이용하여 신장의 깊이를 보정한다면, 다른 임상 결과에 상응하는 값을 얻을 수 있다고 생각한다. 또한 신장 여과 율 추적 검사를 시행하는 환자의 경우, 같은 장비에서, 적어도 신장 깊이를 측정하는 같은 방정식을 이용하여 사구체 여과 율을 구해야 할 필요가 있겠으며, 마지막으로, 소아 환자의 사구체 여과 율 시행 시, 소아의 신장 깊이를 계산하는 방정식을 이용하도록 하고, 해당 기기에서 방정식을 선택할 수 없다면, 직접 신장 깊이를 계산하는 노력이 필요할 것으로 사료 된다.

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