ORIGINAL ARTICLE

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A simple objective parameter for perfusion study of renal transplant

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We proposed a simple parameter, the kidney-to-aorta ratio (KAR), for evaluation of renal transplant perfusion. KAR was calculated from the peak counts of the kidney and the aorta. The calculated values were compared with the visual interpretation of the radionuclide first-pass flow study, percent renal uptake (%RU), and tubular extraction rate (TER) by Bubeck's one point sampling method in 37 studies. KAR correlated well with the visual interpretation of the flow study and the other quantitative parameters. Representative cases, which showed the usefulness of KAR for the objective assessment of the perfusion status of renal transplants, were presented. In conclusion, KAR is a simple and practically useful parameter for objective evaluation and follow-up of renal transplant perfusion.

Key words: renal transplantation, renal perfusion, Tc-99m-MAG3, renal scintigraphy

INTRODUCTION

A RADIONUCLIDE first-pass flow study of the kidney provides important information about the renal perfusion status, especially for patients who have undergone renal transplantation. Some complications after renal transplantation can be diagnosed by the flow study.[1,2] Not only visual assessment but also quantitative evaluation is important to evaluate transplant perfusion. There have been many quantitative methods for evaluation of renal transplant perfusion.[3–9] Among them the "perfusion index" is a standard and popular evaluation method, though there are some drawbacks. We proposed a new simple index, the kidney-to-aorta ratio (KAR), and compared it with visual assessment in patients after renal transplantation.

MATERIALS AND METHODS

Patients and data acquisition

A total of 37 renal perfusion studies in 23 renal transplant patients were included in this study. The duration after renal transplantation was from 3 days to 9 years, and the clinical condition was various, such as well controlled status, acute or chronic rejection, and acute tubular necrosis.

Renal scintigraphy was performed with a Siemens ZLC 7500 Digitrac gamma camera interfaced with Scintipac-2400 computer (Shimadzu, Kyoto, Japan). After intravenous administration of 350–600 MBq (9 MBq/kg body weight) Tc-99m-MAG3, sequential data were acquired every 2 seconds for the first 4 minutes and every 60 seconds for the next 16 minutes with a matrix size of 64 × 64.

Quantitation of perfusion

ROIs were placed over the distal abdominal aorta just above the iliac artery bifurcation and over the transplanted kidney (Fig. 1A). Time-activity curves were drawn for both ROIs. The peak of the aortic curve was easily detected, whereas that of the kidney was sometimes difficult to identify. In such a situation, the turning point from a rapid increase in the count to a gradual increase was regarded as the peak (Fig. 1B, arrow). After identifying the peak of each curve (Fig. 1C, two arrows), peak counts for the kidney (H_K) and the aorta (H_A) were determined. The kidney-to-aorta ratio (KAR) was calculated as follows:

$$KAR = H_K/H_A \text{ (with correction for the ROI size)}$$

Background counts were obtained by placing the ROI on

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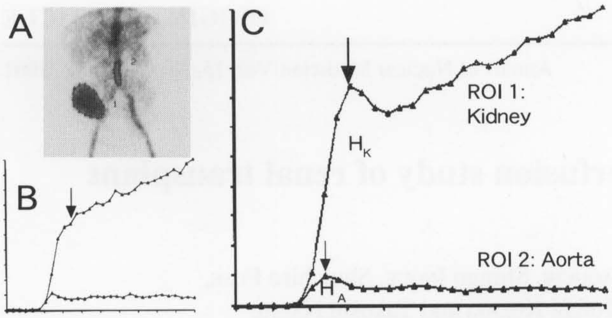


Fig. 1 ROIs placed over the transplanted kidney and the aorta (A). A representative curve of the kidney without any apparent peak (B) and with an apparent peak (C). Peak counts were obtained from the curves.

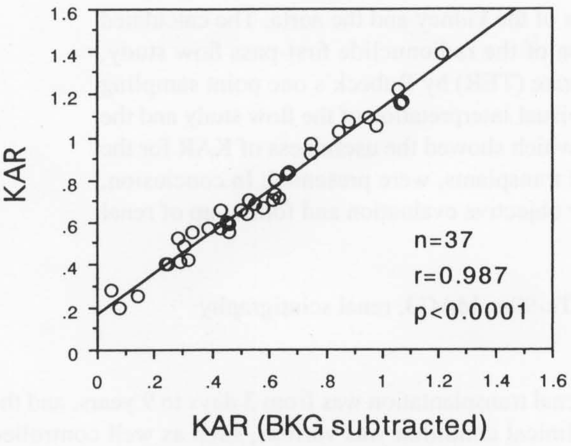


Fig. 2 Correlation of KAR between background un-subtracted and subtracted.

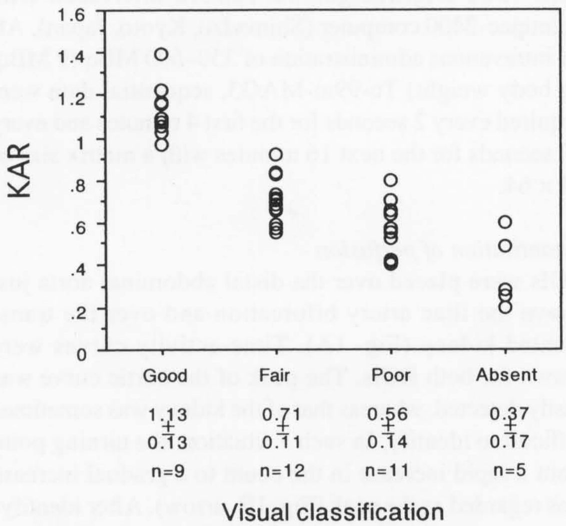


Fig. 3 Distribution and mean values of KAR in each group of visual classification of the perfusion status.

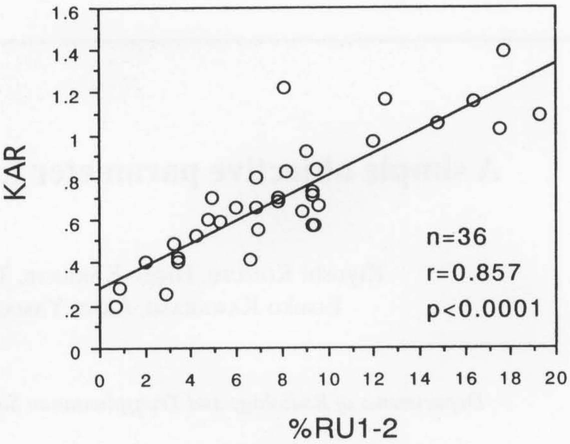


Fig. 4 Correlation between KAR and %RU1–2.

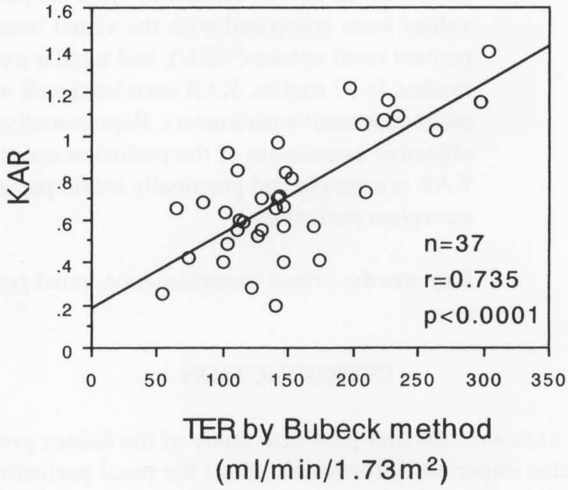


Fig. 5 Correlation between KAR and tubular extraction rate by Bubeck's method.

the contra-lateral region of the renal transplant. KAR with or without background subtraction was evaluated. No attenuation correction for the depth of the aorta and the kidney was made.

Visual assessment of perfusion

Visual classification of the perfusion status was done by observing two-second images on the films and evaluating the density of the kidney during the first circulation phase of the flow study compared with the density of the abdominal aorta. The visual pattern was classified into four groups: Good, the peak density of the kidney during the first circulation phase is equal to or higher than that of the aorta; fair, the peak density of the kidney is lower than that of the aorta although fair perfusion is observed; poor, the peak density of the kidney is apparently decreased; absent, no activity of the kidney is observed. Each scintigram of the flow studies was observed and judged independently by three radiologists/nuclear medicine physicians.

A B

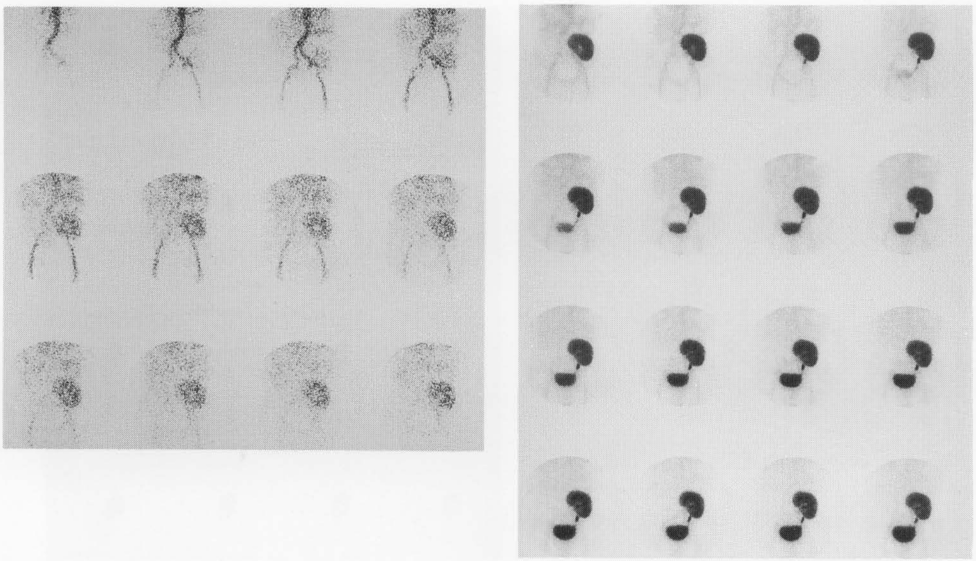


Fig. 6 Renal scintigraphy of case 1 during stable status. A; first-pass flow study. B; following 1-minute sequential images.

A B

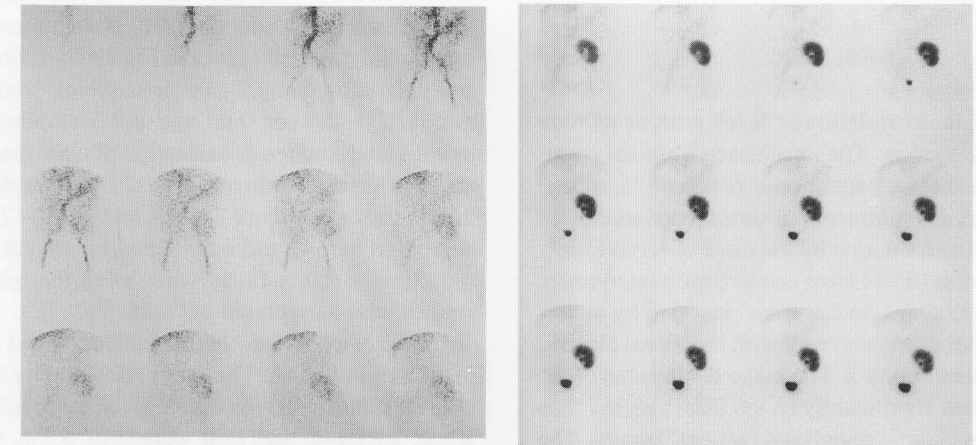


Fig. 7 Renal scintigraphy of case 1 during acute rejection. A; first-pass flow study. B; following 1-minute sequential images. Though the flow study was interpreted as "poor" as the previous study, KAR showed decreased level.

Quantitation of renal uptake in accumulation phase

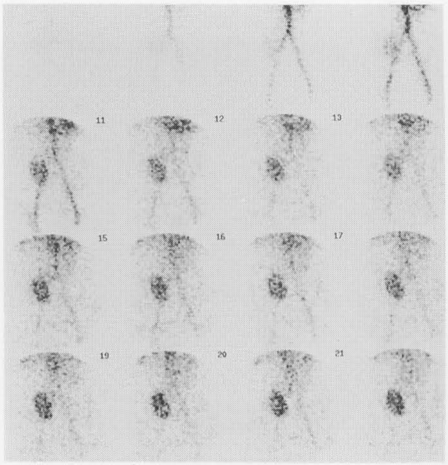
The percent renal uptake (%RU) was calculated by dividing the renal integral count from 1 to 2 minutes by the net injected count of the tracer (%RU1–2). Attenuation correction for the depth of the kidney was made by measuring the depth from the lateral view and using a real value of 0.119 as the attenuation coefficient.

Calculation of tubular extraction rate

The tubular extraction rate (TER) was calculated by Bubeck's one point sampling method.[10]

Reproducibility and statistical analysis

The intra- and inter-observer coefficients of variation were determined by drawing two technicians' ROIs three or four times for each of two patients'data. Data were expressed as the mean ± SD. Statistical significance was



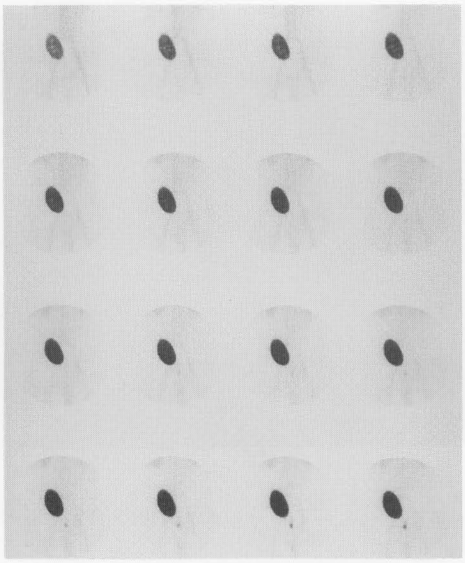


Fig. 8 Renal scintigraphy of case 2 during acute tubular necrosis. A; first-pass flow study. B; following 1-minute sequential images.

evaluated by Student's t-test, and $p < 0.05$ was considered significant.

RESULTS

Figure 2 shows the correlation of KAR with or without background subtraction. The unsubtracted values correlated well with the subtracted ones ($r = 0.987$), so that background was not subtracted in subsequent studies.

In the visual interpretation by the three observers, only 24 of the 37 studies (65%) were concordantly interpreted. The other 13 discordant studies were classified by majority decision. KAR correlated well with the visual classification as shown in Figure 3. The mean KAR value of the "good" group was significantly ($p < 0.0001$) higher than the values of the "fair," "poor," and "absent" groups. The level of discrimination between "good" and "fair" groups was about 0.9 to 1.0. The KAR values in the "fair," "poor," and "absent" groups overlapped, but the mean values gradually decreased.

The correlation between KAR and %RU1–2 is shown in Figure 4. There was a significant positive correlation ($p < 0.0001$), and the correlation coefficient was fairly good ($r = 0.857$).

The correlation between KAR and TER by Bubeck's method is shown in Figure 5. The correlation is also positive ($p < 0.0001$) even though the correlation coefficient was only fair ($r = 0.735$).

In the calculation of KAR, the intra-observer coefficient of variation was 2.7–5.8% (mean 4.6%), whereas the inter-observer coefficient of variation was 0.7–8.7% (mean 4.7%).

Case presentation

Case 1 is a 49-year-old man who had received renal transplantation 2 years before. His routine follow-up renal scintigraphy is shown in Figure 6 (A, first-pass flow study; B, subsequent 1-minute sequential images). KAR and %RU1–2 were 0.64 and 8.9% respectively. Two months later, sudden deterioration of renal function due to acute rejection occurred. Renal scintigraphy repeated then is shown in Figure 7. KAR and %RU1–2 at that time decreased to 0.41 and 6.6%, respectively. KAR reflects the clinical status fairly well, even though both flow studies were interpreted as "poor."

Case 2 is a 33-year-old man who received a live transplant 3 days before. The renal scintigraphy (Fig. 8) and clinical status made the diagnosis acute tubular necrosis. KAR, %RU1–2, and TER were 0.59, 5.3%, and 119 $ml/min/1.73\ m^2$, respectively. Renal scintigraphy repeated about one and a half months after recovery of acute tubular necrosis is shown in Figure 9. Tubular excretory function was apparently improved visually as well as quantitatively (%RU1–2 14.8% and TER 184 $ml/min/1.73\ m^2$) though improvement in renal perfusion detected by visual observation was less apparent, but KAR was apparently improved to 1.06.

DISCUSSION

Concerning the accuracy and reproducibility of KAR, the mean inter- and intra-observer coefficients of variation were both less than 5%, which means good reproducibility as a clinical examination and acceptability for routine use. Background subtraction is not required, probably due to low background counts during this first-pass phase.

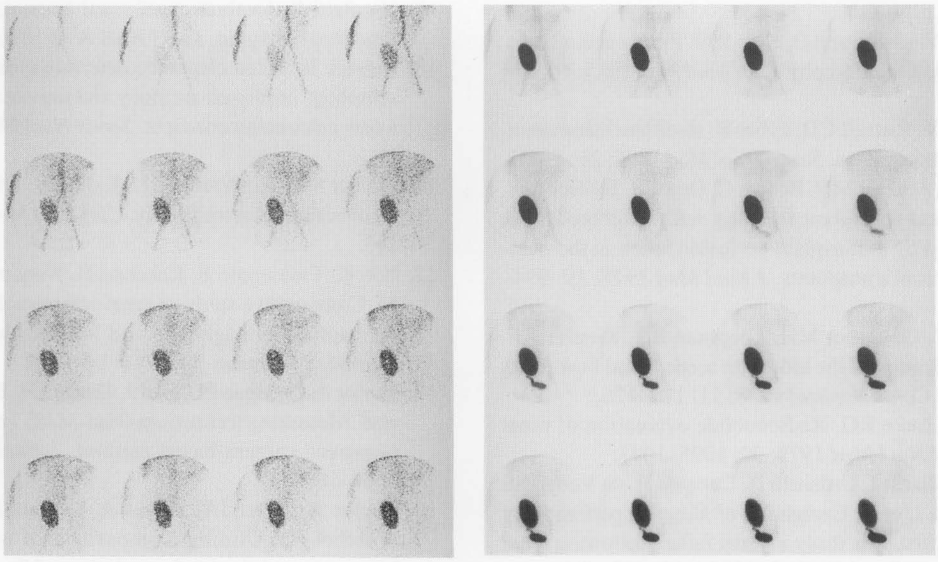


Fig. 9 Renal scintigraphy of case 2 after recovery of acute tubular necrosis. A; first-pass flow study. B; following 1-minute sequential images. Renal perfusion was improved more apparently by quantitative interpretation than visual one.

Acquisition every 2 seconds instead of every 1 second might cause depression of the peak height, but peaks for both the kidney and aorta might be depressed identically; therefore the final KAR values may not be affected very much. Two-second acquisition is rather preferable because of less statistical fluctuation.

It is very important to evaluate transplant perfusion for the differential diagnosis of complications after renal transplantation.[11] Although visual interpretation of the first circulation phase of a flow study might be sufficient in typical cases, quantitation of the perfusion is required in borderline cases or for more objective interpretation. In our study the three observers actually concordantly interpreted in only 65% of the studies. Moreover, objective quantitation is more reliable for the follow-up after transplantation, especially after treatment for transplant complications.

There are some quantitative methods available for evaluating renal transplant perfusion. The "perfusion index" is one of the most commonly used indices reported, but this index is not widely used routinely, probably because it has some drawbacks. The reference ROI of the ipsilateral iliac artery distal to the transplant is sometimes hard to draw because of a decreased count density due to arteriosclerotic changes or a poor bolus injection. Furthermore, the original calculation formula for the "perfusion index" is the ROI count for the artery divided by the count for the kidney, which shows an inverse relationship; the lower the value, the better the perfusion.

We proposed a new index, the KAR. This index is simple to calculate and clearly discriminates good perfusion cases from fair or poor perfusion cases. Usually we visually interpret renal perfusion by comparing the density of the abdominal aorta and that of the kidney in the first circulation phase of the flow study. Therefore, KAR is a reasonable quantitative parameter. In visual interpretation, discrimination between "good" and "absent" is easily done, although a "fair" or "poor" decision is objectively difficult. In such a situation, quantitation might be useful. Indeed, the cases presented here clearly showed such discrimination. A similar "K/A ratio" has been reported[4] although the calculation is slightly different; that is, they used the slopes of the time-activity curves for calculation in the same location as our ROI.

KAR correlated well with the %RU1–2 ($r = 0.857$). The %RU of MAG3 is known to correlate with MAG3 clearance (TER),[12,13] which reflects the effective renal plasma flow.[14,15] Therefore, good correlation between KAR and %RU1–2 is explainable. KAR was not evaluated as a parameter for the differential diagnosis of several complications after renal transplantation. This issue is yet to be evaluated further, even though perfusion parameters themselves might not be helpful for differential diagnosis.

CONCLUSION

A new simple parameter, KAR, for evaluating renal transplant perfusion correlated well with the visual interpretation of the first-pass flow study, %RU, and TER of MAG3. KAR is a simple and practically useful parameter for objective evaluation and follow-up of renal transplant perfusion.

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