# Background Correction and Measurement of Injected Activity in Quantification of Renal Function

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***We have compared four regions of interest frequently used for kidney background correction during renography: left and right circular (C), semilunar (S), below (I), and between both kidneys (B), in patients with four types of kidneys: bilateral normal, bilateral subnormal, bilateral abnormal, and left abnormal/right subnormal. C and S give similar results, I overestimates the function of both kidneys, and B overestimates right kidney function because of the lack of liver activity correction. To test measurements of injected activity, we measured pre- and postinjection activity in the syringe at the collimator surface, with and without depth correction, in a syringe holder at 24 cm from the collimator, and in a phantom containing a known activity, immersed in water and separated from the collimator surface by perspex plates at a distance representing kidney depth. We found a high correlation between the phantom and syringe methods: the phantom, however, most closely approaches the in vivo situation.***

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A valid radionuclide assessment of renal function with gamma camera methods (*1–12*) supposes complete intravenous injection of a stable compound, accurate kidney depth correction, stable patient position during data acquisition, precise delineation of regions of interest (ROIs) for kidneys, background correction, and accurate measurement of injected activity. These last two technical aspects were the subject of our investigation as they are the most important sources of error in the quantification of renal function using gamma camera renography. Nonnegligible bias may already be introduced when using compounds with high renal extraction such as hippuran or technetium-99m- ($^{99m}$Tc) $MAG_3$ (*11*), but even more so with glomerular filtration agents such as $^{99m}$Tc-DTPA.

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## MATERIALS AND METHODS

Renograms were obtained from a 20-min dynamic acquisition, with 30 1-sec frames followed by 117 10-sec frames, in word mode and a 128 × 128 matrix. After reframing, renal and background ROIs were drawn on the first 1-min frame (0'30–1'30) in order to precisely outline renal parenchyma.

Besides relative kidney uptake, we determined separate renal function using the accumulation index (AI), which is defined as the background-corrected amount of iodine-123 ($^{123}$I) hippuran measured using the ROI technique in each kidney—between 30 and 90 sec after the vascular peak (heart or aorta curve), divided by the injected activity, and expressed as a percentage (Fig. 1). This index has been shown to correlate well with PAH clearance in children who are at least 3 yr old (*12*).

We have studied the influence of background correction on different levels of kidney function in 12 patients (10 male, 2 female, mean age: 51 yr). Patients were assigned to one of four groups based on their levels of kidney function: bilaterally normal (2N), bilaterally subnormal (2SN), bilaterally abnormal (2AN), and left abnormal and right subnormal (1AN) (Fig. 2). Three patients were assigned to each group. We defined bilaterally subnormal kidneys as those with a serum creatinine level of 110–150 μmol/l and a split function on renogram of 45%–55%. We defined bilaterally abnormal kidneys as those with a serum creatinine level of >150 μmol/l and a split function on renogram of 45%–55%.

Four ROIs frequently used for background correction were compared (Fig. 3): circular (C), semilunar (S), infrarenal (I), and between the left and right kidneys (B).

C and S are two-pixel wide, irregular ROIs manually drawn at a distance of one pixel from the respective kidney ROIs. The C ROI starts and ends in the middle of the kidney's hilus concavity. Semilunar regions follow kidney convexity from upper to lower pole.

I and B are rectangular ROIs. I is positioned manually two pixels below the lower pole of each kidney, with a two-pixel height and a width that corresponds to that of the respective kidney. B is placed between the kidneys; it covers a four-pixel width and is double the average height of the two kidneys.

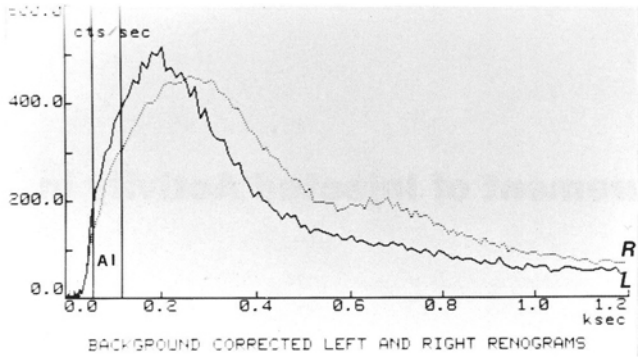


**FIG. 1.** Accumulation index calculated from background-corrected renograms.

We studied three methods of measuring injected activity, using static acquisitions of 60 sec, in word mode and a 128 × 128 matrix (Fig. 4). In the contact method (Fig. 4A), we measured activity on the collimator surface before and after injection with a syringe containing 1 mCi of $^{123}$I or 5 mCi of $^{99m}$Tc in a volume of 0.5 ml.

In the 24-cm method (Fig. 4B), we measured activity before and after injection with a syringe containing 1 mCi of $^{123}$I or 5 mCi of $^{99m}$Tc in a volume of 0.5 ml, by using a syringe holder set at 24 cm from the collimator surface.

In the phantom method (Fig. 4C), we measured a 0.1 ml aliquot of the injected solution containing either 0.2 mCi of $^{123}$I or 1 mCi of $^{99m}$Tc diluted in a volume of 100 ml of saline, contained in a bottle with a 5-cm diameter and a 10-cm height. This phantom was immersed in a perspex container (30 × 20 × 7.5 cm) filled with water, which was separated from the collimator surface by perspex plates by a distance equal to kidney depth. In order to obtain the injected activity, the phantom activity (cpm) was corrected for the injected volume. For the present comparison, this meant that the activity measured in the phantom was multiplied by five, to account for the syringe volume of 0.5 ml.

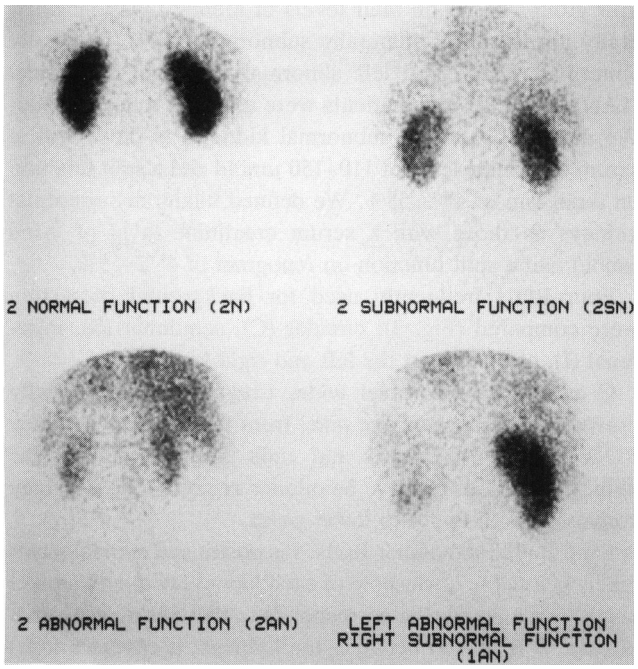


**FIG. 2.** The four types of patients studied for delineation of background regions of interest.

All patient studies were performed with $^{123}$I-OIH; injected activity was 1 mCi in adults and 0.014 mCi/kg of body weight in children. Before injection, activity was measured in a dose calibrator, and volumes were adjusted with saline.

Kidney distance was measured on 1-min lateral views (128 × 128 matrix) after completion of acquisition. A cobalt-57 ($^{57}$Co) point source was positioned in the middle of the patient's back between the two kidneys, with the patient remaining in the same position as during renogram acquisition. When examining infants (Fig. 4D), a special perspex container (30 × 10 × 7.5 cm) was used, which fitted into the immobilization device: this container corrected for the smaller scattering medium of an infant's body. In kidney transplant patients, the phantom was measured from above.

## RESULTS

Figure 5A shows the importance of background activity in comparison with kidney activity, according to the various levels of kidney function: 2N, 2SN, or 2AN. Background values, obtained in the three individuals of each patient group (six kidneys per group) were expressed as a percentage of the corresponding kidney activity. Figure 5 shows the average background activity versus kidney activity (in percent) for each of the patient groups, according to the type of background ROI: C, S, I, or B. In bilaterally normal kidneys, background activity varied between 18% and 31% of kidney activity; in bilaterally abnormal kidneys, activity ranged from 51% to 77%. In all instances, the highest amounts of activity were found in C, and the lowest in I. Figure 5B–D shows the average percent background activity, separated for left and right kidneys, in these three patient groups. At all function levels, the difference between the various regions is more pronounced for the right kidney than for the left kidney.

We also studied the influence of background correction using the scatter of left kidney relative uptake (Table 1). For this study, we have added to the three previous patient groups another group of three subjects (3 male, mean age: 52 yr) who presented with abnormal left kidneys and subnormal right kidneys. For each subject, split function was calculated according to the ROI (C, S, I, B) used for background correction. The average left kidney split function expressed as a percentage of total function was calculated for the four groups. These mean values, as well as the standard deviation and variation coefficient, are shown in Table 1. Standard deviation increases with decreasing renal function; thus, the least reliable results were found in kidneys with highly impaired function.

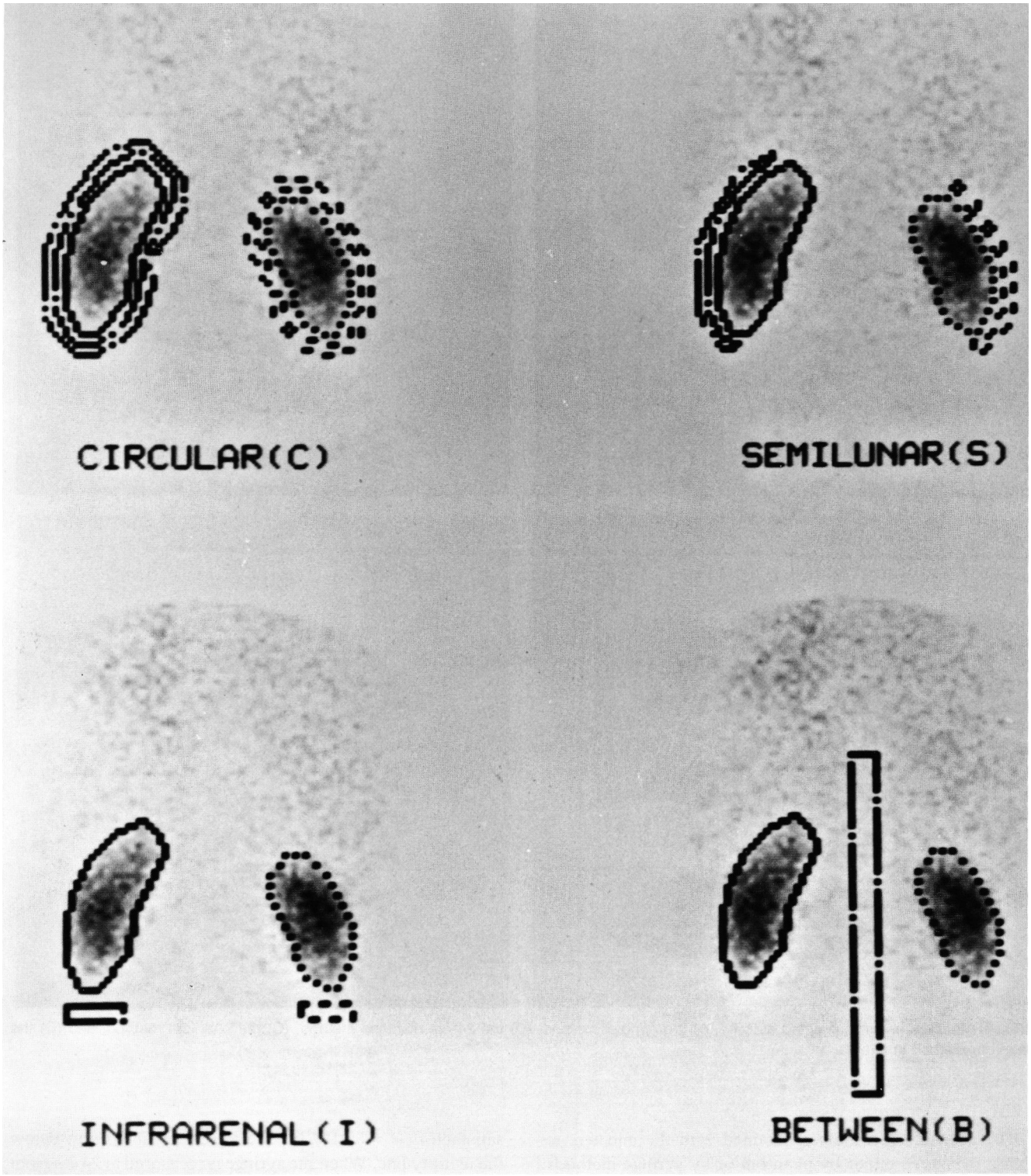


**FIG. 3.** The 4 regions of interest used for background correction.

Figure 6 shows the activity measured in the syringe either at the collimator surface (contact) or in the syringe holder (24 cm from surface) in comparison to that of the standard (multiplied by five in order to correct for the difference in volume). For $^{123}I$ (Fig. 6A), measured activity is 29% less in the syringe at contact than when diluted in 100 ml of saline (phantom). At 24 cm, this difference decreases to 21%. With $^{99m}Tc$ (Fig. 6B), (5 mCi/0.5 ml in the syringe versus 1 mCi/100 ml in the phantom multiplied by 5), this difference is even more striking (49% and 38%, respectively).

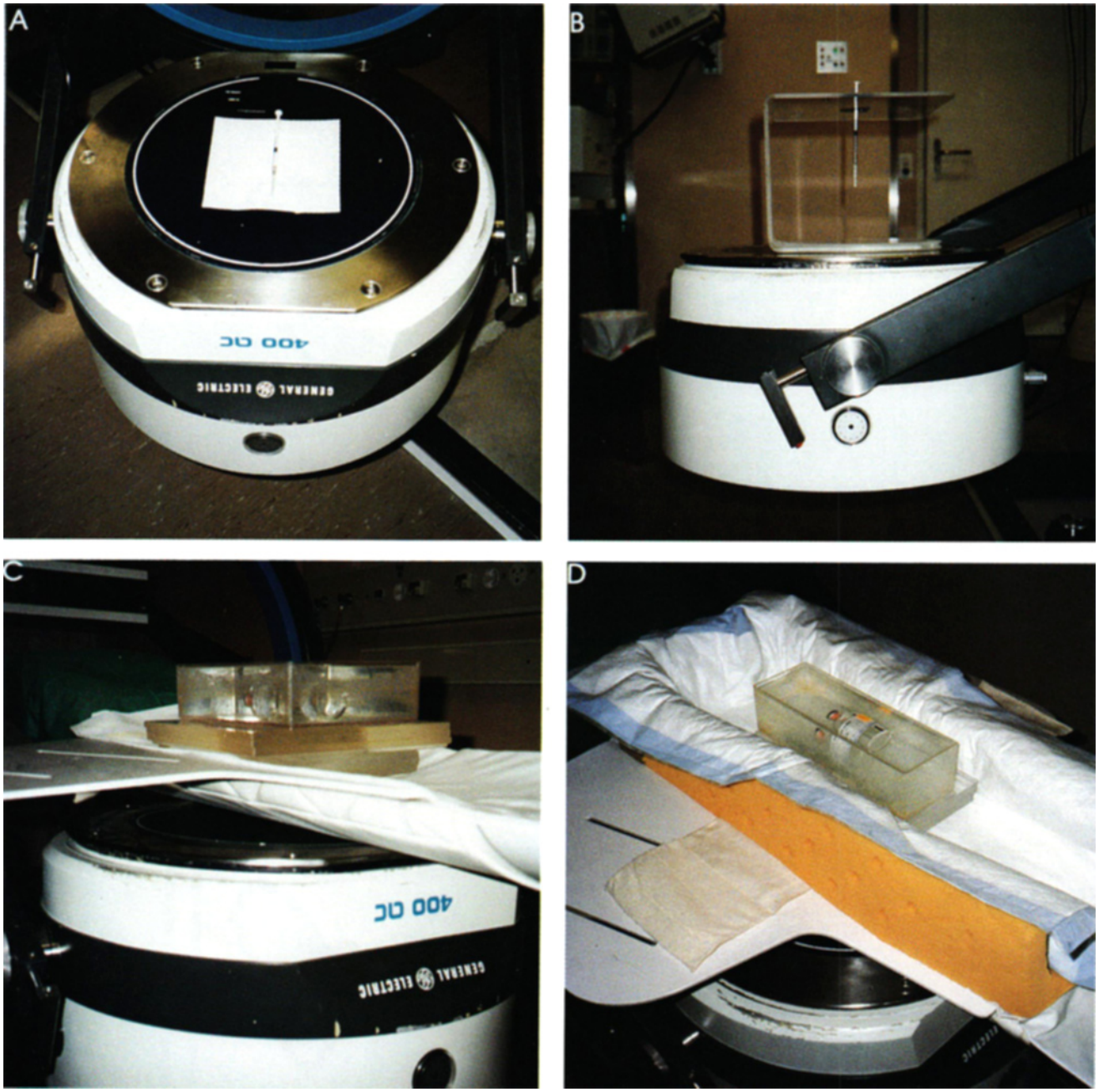


**FIG. 4.** Measurements of injected activity: (A) the contact method, (B) the 24-cm distance method, (C) the phantom method, and (D) the phantom method in infants.

The accumulation indices obtained with the injected activity, measured either by phantom or by syringe methods, are compared in Figure 7. We have correlated 22 accumulation indices, six in three children (mean age: 3 yr), and 12 in six adults (mean age: 60 yr) who have various levels of kidney function. Also, four accumulation indices were obtained in patients with kidney transplants (mean age: 32 yr). The highest correlation (r = 0.956) was obtained between a phantom and syringe measured on the collimator surface and corrected for kidney depth (Fig. 7B). Without depth correction (Fig. 7A), correlation is still satisfactory (r = 0.914), but the regression line is now below the identity line. When the syringe is measured at 24 cm from the collimator (Fig. 7C), the distribution of results is more random (r = 0.892).

## DISCUSSION

Our study shows that the background correction results (Fig. 5A) in the C and S ROIs are comparable, whereas the results in the I ROI are consistently lower. Thus, renal function will be overestimated when using the I ROI for

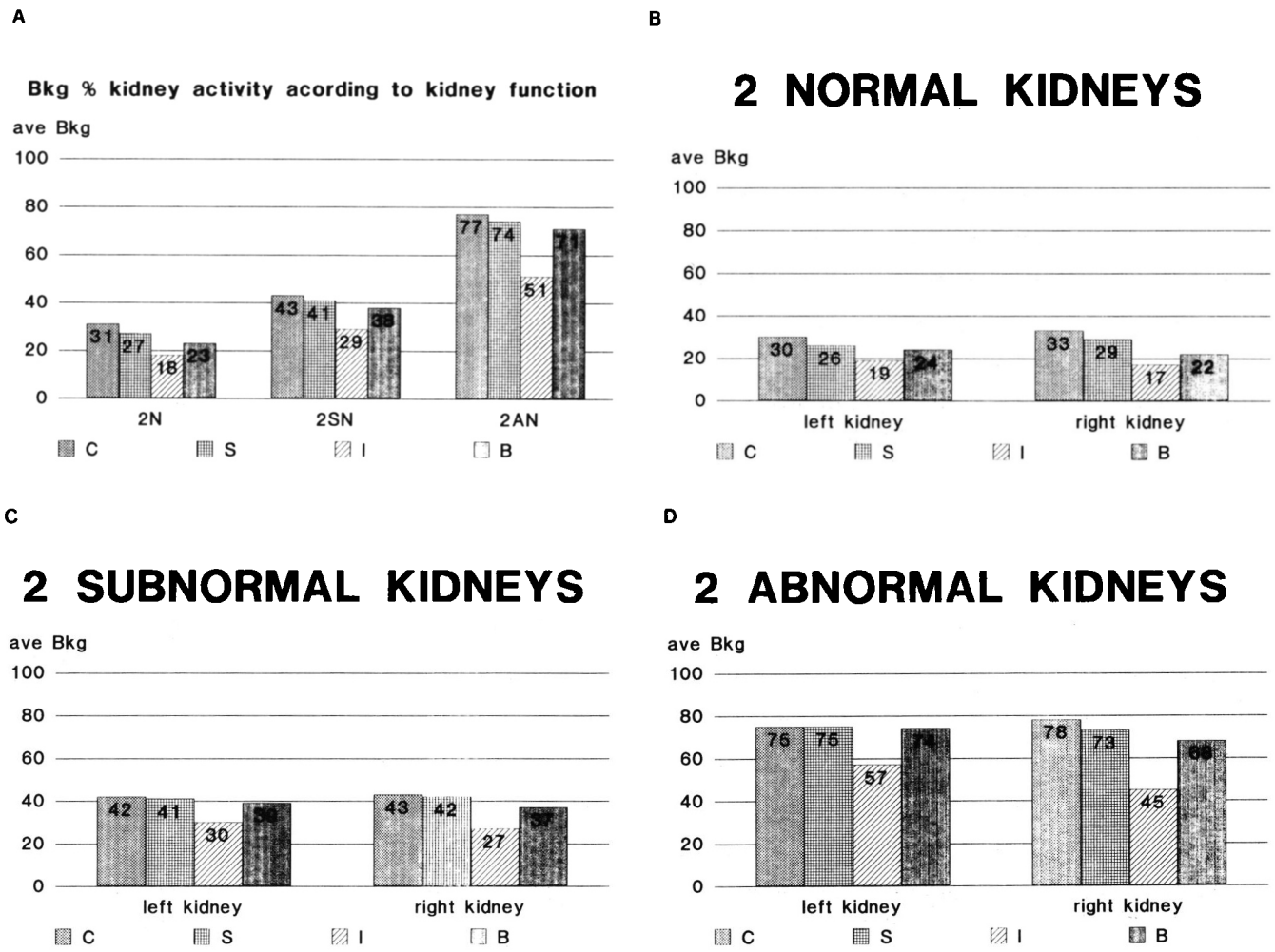


**FIG. 5.** (A) Background ROIs as a % of kidney activity, displayed by type of kidney function. (B) Detailed ROIs for left and right kidneys with normal function, (C) subnormal function, and (D) abnormal function.

background correction. At first glance, the B ROI gives results close to those of the C and S ROIs, but when results for left and right kidneys are considered separately, we noticed that the B ROI underestimates right kidney background because it does not take into account the overlapping liver. This is not very important in normal kidneys (Fig. 5B), but it may lead to overestimation of right kidney function in abnormal kidneys (Fig. 5D).

**TABLE 1. Scatter of Left Kidney Relative Uptake According to Background Correction**

| Level of Kidney Function | Sample Number | Mean | Standard Deviation | Variation Coefficient |
|---|---|---|---|---|
| 2N | 3 | 50.29 | 1.63 | 0.0324 |
| 2SN | 3 | 46.95 | 3.26 | 0.0696 |
| 2AN | 3 | 51.29 | 4.79 | 0.0933 |
| 1AN | 3 | 20.93 | 9.59 | 0.4584 |

These difficulties are well shown by the broad scatter of relative kidney function, which is inversely proportional to the functional state of the given kidney (Table 1). With a standard deviation of almost 10 for a split function of about 20%, the kidney can be considered to have 10%–30% of total renal function. Such results are too vague to be clinically useful. Any method of background correction introduces a bias. So it is important to always use similar regions to keep the error constant.

As for background correction, measurement of injected activity is subject to erroneous estimation of single kidney function. When measuring the syringe directly on the camera, but without correction for kidney depth (Fig. 7A), the regression line is well below the identity line. This is because, without depth correction, renal activity is underestimated. After depth correction (Fig. 7B), the regression line is steeper than the identity line. When measuring a rather high activity in a small volume directly on the collimator surface, saturation occurs and counts will be lost. It is necessary to correct for the dead-time of the system; otherwise,

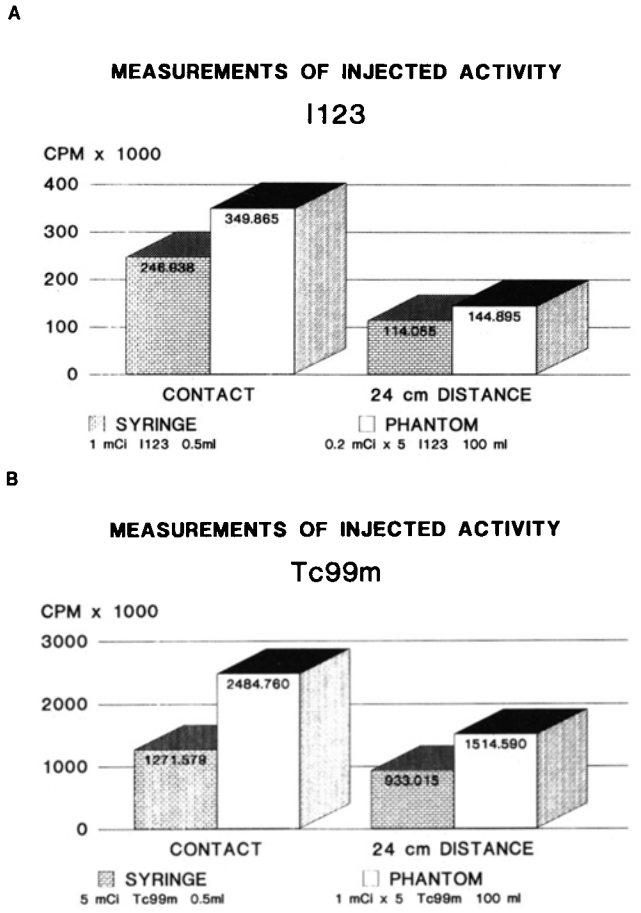


**FIG. 6.** Phantom and syringe measured at point of contact with collimator and at 24 cm from collimator using (A) $^{123}I$ and (B) $^{99m}Tc$.

injected activity will be underestimated and renal function overestimated. When measuring injected activity at 24 cm from the collimator (Fig. 7C), the regression line is closer to the identity line, but the correlation decreases because the AI values are more randomly distributed. This method assumes that differences in kidney depth are of no importance when counting the syringe at 24 cm from the collimator: this is obviously not the case.

## CONCLUSION

When estimating separate renal function by gamma camera methods without blood or urine sampling, it is important to keep the errors of measurement of injected activity, as well as "true" kidney activity, as small and as constant as possible. With respect to measuring injected activity in the syringe, we prefer to use a method that simulates the measurement of kidney activity. We introduce a small aliquot of the injected solution and measure it, after dilution in a larger volume (100 ml), in a scattering medium (water, perspex) at kidney-detector distance. Furthermore, we try to choose a similar ROI for background correction. In our opinion, circular and semilunar ROIs give satisfactory results. Any impact of more sophisticated background correction methods on clinical decisions remains to be proved.

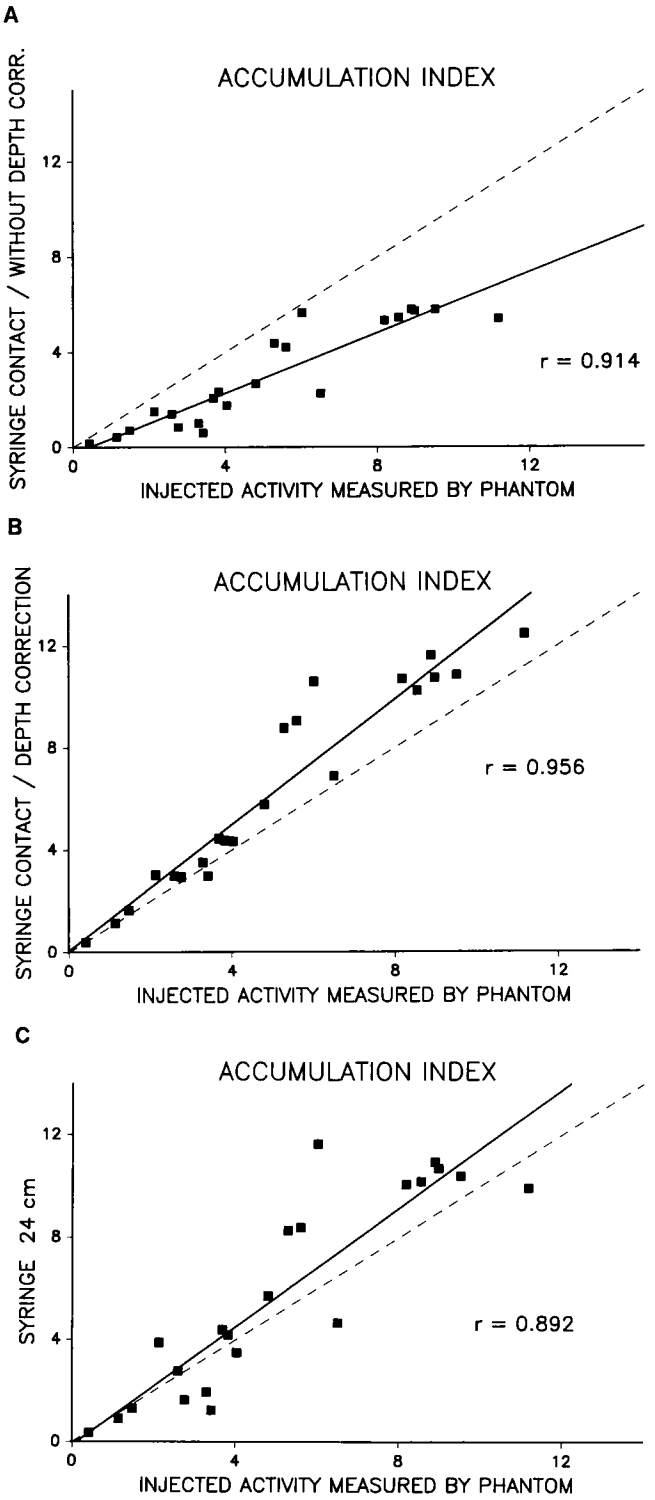


**FIG. 7.** Correlation of accumulation indices obtained by phantom with syringe methods at contact, (A) without and (B) with depth correction, as well as (C) at 24 cm from collimator.

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