Normal Values for Camera-based $^{99m}$Tc-MAG3 Clearance, MAG3 Curve Parameters, Excretory Parameters and Residual Urine Volume

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ABSTRACT

Objective: Specific quantitative measurements have been recommended to assist in the interpretation of $^{99m}$Tc mercaptoacetyltriglycine (MAG3) renal studies. Our objective was to define the gender and age specific normal ranges for these recommended parameters. Subjects and Methods: Data were obtained from a retrospective analysis of 106 subjects evaluated for kidney donation. The MAG3 clearance was calculated using a common camera-based method. The relative uptake, pre-void/post-void and post-void/maximum count ratios were determined using whole kidney regions of interest (ROIs). Time to peak, time to half-peak, 20 min/maximum and 20 min/2-3 minute count ratios were determined for cortical and whole kidney ROIs. Residual urine volume was calculated based on the pre- and post-void bladder counts and voided urine volume.

Results: The mean camera-based MAG3 clearance was 321 ± 69 mL/min/1.73m$^2$, essentially the same as mean plasma sample MAG3 clearance in comparable populations. The percent relative uptake in the right and left kidneys was 49% and 51% ± 4% respectively; there was no difference between males and females. Cortical values were lower than the whole kidney values (p<0.001); the mean cortical 20 min/max count ratio was 0.19 with a SD of 0.07 and 0.04 for the right and left kidneys, respectively. The mean post-void/max whole kidney count ratio was < 0.1 and the mean post-void residual bladder volume was < 30 mL. Conclusion: Normal limits adjusted for age and gender have been established. Applying normal ranges to quantitative MAG3 parameters may assist in the interpretation of MAG3 scintigraphy and facilitate appropriate patient management.
KEY WORDS: camera-based MAG3 clearance, $^{99m}$Tc MAG3 normal values, 20 minute/maximum count ratios, relative renal uptake of MAG3

INTRODUCTION

The use of technetium-99m mercaptoacetyltriglycine (MAG3) has increased significantly since its introduction in 1986 (1, 2). Because of the favorable imaging characteristics of $^{99m}$Tc and the more efficient renal extraction of $^{99m}$Tc-MAG3 compared to $^{99m}$Tc diethylenetriaminepentaacetic acid (DTPA), $^{99m}$Tc MAG3 has become the radiopharmaceutical of choice in many clinical contexts, particularly for patients with suspected obstruction and/or impaired renal function (3-6). Today, $^{99m}$Tc MAG3 is estimated to account for approximately 70% of the 590,000 renal scans performed annually in the United States but many renal scans are interpreted by diagnosticians in sites that perform less than three studies per week (4,7).

Clearance measurements and other specific quantitative parameters have been recommended to assist in scan interpretation and patient management (8-13). For example, to assist in the interpretation of angiotensin converting enzyme inhibition renography, the Santa Fe consensus report and the Society of Nuclear Medicine procedure guideline on renovascular hypertension recommend measurements of time to maximum counts (Tmax) and 20 min/maximum count ratios for whole kidney and cortical regions of interest (14, 15). The 20 min/2-3 minute count ratio has been proposed as a useful parameter to simultaneously evaluate clearance and excretion and may be especially useful in monitoring transplant patients to distinguish between acute tubular necrosis and rejection (16). A measurement of urine drainage based on a quantitative comparison of post-void kidney counts to the counts obtained during the pre-
void period improves the sensitivity and specificity for detecting an obstructed kidney (17-19). Finally, the post-void urine volume can easily be determined at the time of the scan and may provide important additional information regarding excretory function (20).

This study was conducted to define the normal ranges for these recommended quantitative parameters and to determine if the normal ranges vary based on age and gender.

**MATERIALS AND METHODS**

**Subjects**

The study population consisted of 127 subjects evaluated for kidney donation at Emory University Hospital between February, 1998 and March, 2001. Review of patient records was approved by the Institutional Review Board. Preoperative imaging studies included $^{99m}$Tc MAG3 renography as a functional study; the majority of subject also had an anatomical study, either percutaneous contrast renal angiography, magnetic resonance angiography or computed tomography angiography. Ten patients were excluded because the technologist entered a whole number, i.e., 10.0 mCi, as the dose injected; the dose has to be assayed in a dose calibrator and it is highly unlikely that exactly 10.0 mCi would be in the injection syringe. An incorrect dose entry would invalidate the clearance measurement. Five more patients were excluded from analysis because data sets were missing; four were excluded because of $^{99m}$Tc MAG3 dose infiltration exceeding 1%, four were excluded because the camera was started late, one was excluded due to an unsuspected renal mass and one was excluded due to unexpected bilateral renal artery
stenosis. Of the remaining 106 potential renal donors, 54 had normal MRA, 32 had normal percutaneous angiography and 5 had normal 3D-CT; anatomical data were not obtained or not available in the remaining 15 subjects. A creatinine clearance was obtained in 99 of the 106 subjects, mean = 133 ± 38 mL/min/1.73 m$^2$. All but 4 subjects (2 males and 2 females) had a normal 24-hour urinary creatinine clearance (normal range for our laboratory is 90-139 mL/min/1.73 m$^2$ for males and 80-125 mL/min/1.73 m$^2$ for females). The 4 subjects with a reduced creatinine clearance had serum creatinines ranging from 0.9 to 1.1 mg/dL which all fall within our normal laboratory range of 0.6 to 1.4 mg/dL; in addition, 3 had a normal MRA and the fourth had a normal 3D-CT. Because of the normal serum creatinines, absence of history of renal disease and normal anatomic studies, they were included in the data analysis. A creatinine clearance was not obtained in 7 subjects; 5/7 subjects had a normal serum creatinine (mean of 1.04 mg/dL, range of 0.6-1.2 mg/dL) and in 2 subjects the serum creatinine was not measured or not available. These remaining 106 subjects comprised the study group. Forty-four males and 62 females were evaluated. The mean age and SD of the subject population was 39.9 ± 10.8 years with a mean age of 41.0 ± 11.9 for males and 39.1 ± 9.9 for females. The mean body surface area (BSA) for males was 2.04 m$^2$ and for females was 1.80 m$^2$. 
Radiopharmaceutical

Each study was performed with 7-11 mCi (259-407 MBq) of $^{99m}$Tc MAG3 (Mallinckrodt Medical, St. Louis, MO). Radiochemical purity was $95.0 \pm 2.7\%$ (Sep-Pak Cartridge - Millipore, Milford, MA).

Data Acquisition

The subjects were hydrated with approximately 500 ml of water 30 minutes prior to the study. Images were acquired in a 128 x 128 matrix with a 15-inch field of view General Electric gamma camera fitted with a low-energy all-purpose collimator. Each subject was imaged supine with the kidneys and bladder within the field of view. Following the intravenous injection of $^{99m}$Tc MAG3, serial 2-second/frame digital images were obtained for the first 48 seconds followed by sixteen 15-second/frame images and forty 30-second/frame images for a total study duration of 24 minutes and 48 seconds. Time zero was defined as the 16-second interval that the dose reached the kidney (21). At the end of the acquisition, one additional post-void 2-minute image was obtained of the kidneys with the patient in the supine position and one minute anterior pre-void and post-void bladder images were also obtained to determine residual urine volume (20) and post-void (30 min) over maximum (post-void/max) count ratios. The data were processed using the QuantEM 2.0™ software, which was developed specifically for $^{99m}$Tc MAG3 renography (21, 22); processing details are summarized below. The display of a representative study is shown in Fig 1.
Counting the Dose Injected

All subjects received a dose of 7-11 mCi (259-407 MBq) $^{99m}$Tc MAG3. Dead-time losses may be significant when counting larger doses, depending on the camera used. For this reason, a syringe containing approximately 1 mCi (37 MBq) was counted by placing it in a syringe holder 30 cm above the face of the camera. The 1 mCi (37MBq) syringe counted over the camera and the syringe containing the injected dose were also counted in a dose calibrator to yield the injected dose to counted dose ratio. The software multiplied the counted dose by the ratio obtained in the dose calibrator and decay corrected counts in the post-injection syringe were subtracted to yield the counts injected.

Dose Infiltration

Infiltration was calculated by first drawing a region of interest (ROI) over the injection site at the conclusion of the study. Counts in the injection site ROI were corrected for decay and divided by dose injected to obtain a conservative estimate of the infiltrated dose. Four subjects were excluded from the study because of infiltration that exceeded 1% of the injected dose.

Regions of Interest (ROIs) and Background Correction

Whole kidney ROIs were automatically assigned over each kidney using the 2-3 minute post-injection image and modified by the operator as necessary. An automated cortical ROI was assigned using an algorithm to identify the area of renal pelvis and calyces and then subtracting this area from the whole kidney ROI to generate the cortical
ROI. A two pixel wide perirenal background ROI was generated one pixel outside of the whole kidney ROI. To calculate relative uptake, the counts/pixel in the perirenal background ROI were normalized to the number of pixels in the whole kidney ROI and subtracted from counts in the whole kidney ROI to determine the background-corrected counts. The background-corrected counts were then corrected for renal depth using published equations with weight in kg and height in cm: right renal depth (mm) = 151.3 weight/height + 0.22 age – 0.77 and left renal depth (mm) = 161.7 weight/height + 0.27 age – 9.4 (23, 24) and subsequently corrected for attenuation (21, 22). To generate the background subtracted renogram curve, an automated C-shaped perirenal region of interest was assigned so that the background region of interest would not overlap the ureter and lead to an inappropriately high background correction when there was marked retention of activity in a ureter or enlarged renal pelvis. The counts/pixel in the C-shaped background ROI were normalized to the number of pixels in the kidney ROI and subtracted from counts in the whole kidney and cortical ROIs to determine the background-corrected counts used to generate the renogram curve.

**Clearance Measurement**

The clearance of $^{99m}$Tc MAG3 was measured in all subjects using a camera-based method without blood or urine sampling as previously described (21). Briefly, the counts in the kidneys from 1-2.5 minutes post injection were corrected for background, renal depth and attenuation and then divided by the dose injected to calculate percent injected dose in the kidneys at the 1-2.5 minute interval. The value was adjusted for body surface
area (BSA) and a regression equation was used to convert the BSA adjusted percent dose in the kidney at 1-2.5 minutes to a MAG3 clearance (21).

**Data Analysis**

The following parameters were generated from the $^{99m}$Tc MAG3 renograms: time to maximum counts (Tmax), time to half-peak activity (T ½), the ratio of renal counts at 19-20 minutes to the maximum counts (20 min/max), and the ratio of counts at 19-20 minutes to the 2-3 minute counts (20 min/2-3 min). These parameters were generated for both whole kidney and cortical or parenchymal ROIs; the terms “cortical” and “parenchymal” are used interchangeably and refer to a ROI over the renal cortex or parenchyma that excludes any activity in the collecting system (calices or pelvis).

Relative renal uptake was determined using whole kidney ROIs and the 1-2.5 minute interval as described above. The whole kidney ROI was repositioned over the post-void image of the kidney and whole-kidney post-void/pre-void and post-void/maximum count ratios (post-void/max) were generated. Finally, the camera-based MAG3 clearance (mL/min/1.73 m$^2$) was calculated for each subject.

Post-void urine determinations were available in 63 subjects; in the remaining subjects, the data were either not obtained or not recorded.

**Statistical Analysis**

The mean, standard deviation, range and percentiles were used to describe the normal values. Two-way analysis of variance was used to determine whether there was a difference between gender and age groups (age ≤ 40 versus age > 40). (No change was
made. Adults age 40 were included in the younger age group for purposes of analysis, hence ≤ 40.) A simple linear regression analysis was used to determine the association between MAG3 clearance and age. Statistical tests were performed at the 5% level of significance.

RESULTS

MAG3 and Creatinine Clearances

The MAG3 and creatinine clearances were normalized to 1.73 m². The mean body surface area (BSA) corrected MAG3 and creatinine clearances were significantly higher in males than in females, p<0.001; however, there was no decrease in the MAG3 clearance with age for either males or females (Table 1). For adult males, the lower range of a normal MAG3 clearance defined by the 5th percentile was 238 ml/min/1.73 m² versus 226 ml/min/1.73 m² for females.

Relative Uptake

The relative uptake was 51 ± 4.0% for the left kidney and 49 ± 4.0% for the right kidney (Table 2). There was no significant difference in relative uptake between males and females or among different age groups.

Renogram Parameters

Time to maximum counts (Tmax): The Tmax for both kidneys was significantly greater in females than in males (p < 0.05) using whole kidney ROIs but there was no significant difference between the genders when a cortical ROI was used to calculate the
Tmax; moreover, the Tmax for both the right and left kidneys using cortical ROIs was significantly less than the Tmax obtained with whole kidney ROIs, p < 0.005 (Tables 3 and 4).

*Time to half-maximum activity (T ½):* The T ½ was calculated from the time of the maximum counts to the time when the renogram curve decreased to half of the maximum counts. The T½ for the right kidney using whole kidney ROIs was significantly higher in females than in males, 8.29 min versus 5.64 min, respectively, but this difference was minimized when cortical ROIs were used, Tables 3 and 4. The mean values for cortical T ½ were significantly less than the mean whole kidney T ½ values for both males and females, p < 0.01.

*Twenty minute/maximum count ratio (20 min/max):* The mean right cortical 20-min/max count ratio was 0.19 ± 0.07 for the right kidney and 0.19 ± 0.05 for the left kidney. They were both significantly less than the whole kidney values, p < 0.001 (Tables 3 and 4). There was no significant difference between genders and no significant change with age.

*Twenty-minute/2-3 minute count ratio (20 min/2-3 min):* The mean right cortical 20 min/2-3 min ratio was 0.16 ± 0.07 for the right kidney and 0.15 ± 0.04 for the left kidney (Table 4). There was no significant difference between genders and no significant change with age.

*Post-void/maximum renal count ratio:* The post-void/max renal count ratio was determined using whole-kidney ROIs (Table 5). The mean left post-void/max count ratio was 0.09 ± 0.03. There was no significant difference between the right and left kidneys nor was there a significant difference between males and females. The post-void/max
ratio increased slightly with age for the left kidney, $p < 0.05$, but the mean values for both age groups and both genders were all $< 0.1$.

*Post-void/pre-void renal count ratio:* The post-void/pre-void renal count ratio was also determined using whole-kidney ROIs (Table 6). The mean left post-void/pre-void count ratio was $0.59 \pm 0.16$ and the mean right post-void/pre-void count ratio was $0.52 \pm 0.19$. There was no significant difference between males and females. The post-void/pre-void ratio increased slightly with age for the left kidney, $p < 0.05$.

**Voided Volume and Residual Bladder Volume**

There was no significant difference in the voided volume between males and females. When the data were analyzed by age groups, there was no significant difference in voided volume between males and females less than or equal to 40 years of age but there was a significant difference in voided volume between younger ($< 40$ years) and older ($> 40$ years) males, $p < 0.01$ (Table 6). There was no significant difference in the residual urine volumes of males and females (Table 6). For females and males $\leq 40$ years, the $95^{th}$ percentile for residual bladder volume did not exceed 42 mL. Older males had a significantly higher residual volume than younger males (Table 6), possibly due to prostatic hypertrophy.

**DISCUSSION**

MAG3 is the most widely used renal radiopharmaceutical in the United States; however, the mean and normal ranges for many of the recommended parameters are
based on limited numbers of patients, abstract publications, have not been determined or have not been comprehensively defined for age, gender and both cortical and whole kidney regions of interest (ROIs) (25-29). This study presents the mean and normal ranges for recommended MAG3 renogram parameters as well as the normal values for the post-void kidney to maximum count ratio, residual urine volume and the normal values for the MAG3 clearance using a common camera based technique.

The tables provide the mean, SD, minimum, maximum, 5th percentile and 95th percentile for each of the variables. We have elected not to provide confidence intervals to determine a normal range because confidence intervals depend on the sample size; a larger sample size will result in a smaller confidence interval. We believe more useful values are the actual data representing the 5th and 95th percentile. For example, if a sampled population were unchanged, the 5th and 95th percentiles would tend to remain constant even if the sample size were increased whereas the confidence intervals would decrease. Optimally, the best cutoff value to separate normal from abnormal values would be obtained by comparing results obtained in normal and diseased populations. In practice, however, it is often difficult to generalize such a comparison because the degree of abnormality can vary substantially depending on the selection criteria used to define the disease population. For a new patient, we consider any value lying outside of the 5th or 95th percentile as abnormal. In some cases such as the Tmax, values outside of the lower range of normal are likely to represent processing or quality control problem rather than an abnormality of renal function. An expanded review page shows the patient values for selected measurements as well as the normal ranges for these values (Fig 2B); this display can be customized to display all or a selected sample of the calculated values;
abnormal results are highlighted in red on the computer display. A similar format could be incorporated into other software programs to display the normal range and flag abnormal results.

A measurement of plasma clearance can easily be obtained at the time of the renogram and the clearance measurement can often aid in the interpretation of the study and facilitate appropriate patient management (8-13). Plasma sample clearance methods are considered to be superior to camera-based clearances (12) and can be calculated with reasonable accuracy from a single plasma sample obtained 40-45 minutes post-injection (10); however, many nuclear radiology services in the United States do not offer plasma sample clearances because of the additional technical expertise required to perform a plasma sample measurement and the necessity of complying with CLIA (Clinical Laboratory Improvement Act) regulations required for in vitro plasma sample clearances. Instead, they elect to perform a camera-based clearance.

Camera based clearances are generated at the time of renal scintigraphy, do not require blood or urine collection and generally provide an acceptable estimate of renal function that is equivalent to or superior to the creatinine clearance (30-32). Other studies have been conducted to calculate a camera based MAG3 clearances in normal populations but they have either used a clearance index expressed as a percent of the injected dose, not mL/min, used a technique that is not commercially available or used software designed for I-131 OIH which gives a normal MAG3 clearance value almost twice that obtained by plasma and urine sample methods (10-12, 25, 26, 28). The camera based clearance technique used in this study has been validated in a multicenter trial (22), is currently commercially available on General Electric systems and provides values that
appear to be more reproducible than the creatinine clearance (33). Other vendors provide
software to measure the MAG3 clearance using a camera-based technique similar to the
one described here but data comparing the results using software from other vendors have
not been published.

The camera-based MAG3 clearance is comparable to the plasma based MAG3
clearance. This assertion is supported by the fact that the mean and standard deviation
for the BSA corrected camera-based MAG3 clearance (321 ± 69 mL/min/1.73 m$^2$) was
essentially the same as the plasma sample MAG3 clearance measured in two separate
populations of potential renal donors at different institutions, 304 ± 70 and 317 ± 74
mL/min/1.73 m$^2$ (14, 15). A slight decline in the MAG3 clearance with age has been
reported by others (10, 24, 25) and parallels a similar decrease in the creatinine clearance
with age (34). We did not observe a decrease in the camera-based MAG3 clearance with
age in our subject population; this result may be due to relatively high clearances in the
older members of the population because there was also no decrease in creatinine
clearance with age. Finally, the ratio of the standard deviation of the MAG3 clearance in
normal subjects to the mean MAG3 clearance (21%) was less than that of the ratio of the
standard deviation of the creatinine clearance to the mean creatinine clearance (29%); this
ratio provides a measure of dispersion of the data. Dispersion is less with the camera
based MAG3 clearance and this finding suggests the camera based MAG3 clearance is at
least comparable to or probably superior to the creatinine clearance in defining normal
renal function. Finally, recent data also suggest that the camera based MAG3 clearance
is superior to the creatinine clearance for monitoring changes in renal function (33).
Camera based MAG3 clearances are available on most nuclear medicine camera/computer systems. The particular software program, QuantEM™, we used for this study is currently available on the General Electric Xpert computer system and an upgraded version, QuantEM™ 2.0, will soon be available that could be used by other vendors. As with Klingensmith’s study (25), other in house or commercial camera-based software programs for determining the MAG3 clearance should obtain results comparable to those reported here as long as the programs incorporate similar quality control features (dose infiltration, avoiding potential dead-time loses, a standardized time zero and the vendors provide validation studies to ensure the software is performing as specified.

In females, drainage from the right and left renal pelvis appears to be slightly slower than drainage from the right and left renal pelvis of males based on a significantly greater whole kidney time to peak for both kidneys and greater time to half peak (left kidney) for females compared to males (Table 3). This trend may be related to dilatation of the collecting system during pregnancy that did completely resolve but we have no data on the reproductive history of women in our sample; importantly, this difference is minimized or eliminated by use of cortical ROIs (Table 4). Our data show that the values for these parameters generated by cortical ROIs are significantly lower than the values generated with whole kidney ROIs, have less scatter (smaller standard deviation) and support the conclusions of an earlier study that ratios generated using cortical ROIs are more reliable and give a more accurate estimation of the parenchymal function than values generated using whole kidney ROIs (25). Retention of $^{99m}$Tc MAG3 in the calyces or renal pelvis can distort the Tmax, $T_{1/2}$, 20-min/max count ratios and the 20-min/2-3 min count ratios. Due to the variation in hydration and collecting system activity...
among normal subjects, cortical or parenchymal ROIs that exclude the renal pelvis and calyces provide a better assessment of renal function; cortical regions of interest may give misleading values when there is significant patient motion, very poor renal function or when the cortical region of interest includes activity in the renal calyces or pelvis. The radiologist or nuclear medicine physician interpreting the study should visually inspect the cortical ROI to make certain it is appropriately assigned.

Patients should be encouraged to void once the dynamic renal images are completed to reduce radiation exposure to the bladder and gonads (35). Static post-void images of the kidneys and bladder are easy to perform and should be a routine step in renal scintigraphy. In all our subjects, the post-void to maximum kidney count ratio for both the right and left kidney was always less than 0.25. This type of calculation can be particularly useful when assessing patients with suspected obstruction (18, 19). A post-void image of the kidneys at approximately 30 min post-injection of the tracer may also reveal unsuspected urinary retention in the bladder and is an easy adjunct to MAG3 renography. A large post-void residual urine volume may represent bladder outlet obstruction and may also interfere with drainage from the collecting system and lead to a spurious diagnosis of UPJ obstruction.

**Conclusion:**

In summary, a number of specific parameters have been recommended to assist in the interpretation of MAG3 renography. Normal limits for these recommended parameters, adjusted for age and gender, have been established. Applying these normal limits to quantitative MAG3 parameters should assist in the interpretation of the study,
facilitate appropriate patient management and provide a quantitative basis for the
development of decision support systems to assist physicians in the interpretation of renal
scintigraphy (36, 37).

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Figure Legends:

Fig 1A: The standard display shows demographic data, the dose injected, dose counted on the camera, percent dose infiltrated, the MAG3 clearance and the expected MAG3 clearance followed by the percent uptake, Tmax, T ½ and 20 min/max ratios for the whole kidney ROI. The voided volume and post-void residual are also displayed. The urine flow rate was not measured. The upper central panel shows 2 sec images as the initial bolus reaches the kidney. The upper right panel shows the injection site; just beneath is a frame for viewing a dynamic cine, and pre and post-void bladder images. The central panel shows 12 2-minute images followed by a post-void image of the kidneys with the patient lying on the camera in the same position as the initial images. The lower left panel shows the whole kidney ROIs and the whole kidney renogram curves; the lower right panel shows the cortical ROIs and the cortical renogram curves.

Fig 1B: An expanded review display shows the patient values for the MAG3 clearance, residual urine volume, percent relative uptake and the Tmax, 20 min/max, T ½ and postvoid/max ratio for whole kidney and cortical ROIs as well as the normal ranges for each of these values. The expanded review page also shows an enlarged parenchymal image obtained at 2-3 min, an enlarged display of the 19-20 min image and quality control images showing the pre and post-injection syringe counts and time of the bolus arrival in the kidneys.
Table 1. Camera-based MAG3 Clearances (ml/min/1.73m²)

<table>
<thead>
<tr>
<th></th>
<th>Gender</th>
<th>N</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Minimum</th>
<th>5&lt;sup&gt;th&lt;/sup&gt; percentile</th>
<th>95&lt;sup&gt;th&lt;/sup&gt; percentile</th>
<th>Maximum</th>
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<td>MAG3 Clearance*</td>
<td>M</td>
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<td>338</td>
<td>63</td>
<td>211</td>
<td>238</td>
<td>433</td>
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<td>62</td>
<td>309</td>
<td>71</td>
<td>188</td>
<td>226</td>
<td>439</td>
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<tr>
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<td>106</td>
<td>321</td>
<td>69</td>
<td>188</td>
<td>226</td>
<td>439</td>
<td>503</td>
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</table>

* The difference is significant (p<0.0277) between males and females.
Std. Dev. = standard deviation
Table 2. Relative Uptake*

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<th>N</th>
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<th>Std. Dev.</th>
<th>Minimum</th>
<th>5th percentile</th>
<th>95th percentile</th>
<th>Maximum</th>
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<tr>
<td>Right</td>
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<td>49%</td>
<td>4.0%</td>
<td>40%</td>
<td>42%</td>
<td>55%</td>
<td>57%</td>
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<tr>
<td>Left</td>
<td>106</td>
<td>51%</td>
<td>4.0%</td>
<td>42%</td>
<td>45%</td>
<td>58%</td>
<td>60%</td>
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* There is no significant difference in relative uptake between males and females or between younger (< 40 years) and older (> 40 years) adults.
Std. Dev. = standard deviation
Table 3. $^{99m}$Tc MAG3 Normal Values Using Regions of Interest over the Whole Kidney

<table>
<thead>
<tr>
<th></th>
<th>Gender</th>
<th>N</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Minimum</th>
<th>5th percentile</th>
<th>95th percentile</th>
<th>Maximum</th>
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<td>Tmax, right kidney (min)</td>
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<td>44</td>
<td>3.57</td>
<td>2.1</td>
<td>2.1</td>
<td>2.3</td>
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<tr>
<td>Tmax, left kidney (min)</td>
<td>M</td>
<td>44</td>
<td>3.16</td>
<td>1.0</td>
<td>2.1</td>
<td>2.1</td>
<td>5.8</td>
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<td></td>
<td>F</td>
<td>62</td>
<td>3.72</td>
<td>1.7</td>
<td>2.3</td>
<td>2.3</td>
<td>6.8</td>
<td>11.3</td>
</tr>
<tr>
<td>T $\frac{1}{2}$, right kidney (min)</td>
<td>M</td>
<td>44</td>
<td>5.64</td>
<td>2.3</td>
<td>2.0</td>
<td>3.3</td>
<td>8.3</td>
<td>16.5</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>62</td>
<td>8.29</td>
<td>8.4</td>
<td>3.5</td>
<td>4.0</td>
<td>17.0</td>
<td>50.0</td>
</tr>
<tr>
<td>T $\frac{1}{2}$, left kidney (min)</td>
<td>M</td>
<td>44</td>
<td>5.36</td>
<td>1.4</td>
<td>3.0</td>
<td>3.5</td>
<td>7.5</td>
<td>9.5</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>62</td>
<td>6.26</td>
<td>2.8</td>
<td>3.0</td>
<td>3.7</td>
<td>10.5</td>
<td>18.3</td>
</tr>
<tr>
<td>20 min/max count ratio (right)</td>
<td>106</td>
<td>0.24</td>
<td>0.14</td>
<td>0.11</td>
<td>0.12</td>
<td>0.54</td>
<td>0.96</td>
<td></td>
</tr>
<tr>
<td>20 min/max count ratio (left)</td>
<td>106</td>
<td>0.22</td>
<td>0.08</td>
<td>0.11</td>
<td>0.13</td>
<td>0.35</td>
<td>0.61</td>
<td></td>
</tr>
<tr>
<td>20 min/2-3 min count ratio (right)</td>
<td>106</td>
<td>0.24</td>
<td>0.19</td>
<td>0.09</td>
<td>0.11</td>
<td>0.64</td>
<td>1.35</td>
<td></td>
</tr>
<tr>
<td>20 min/2-3 min count ratio (left)</td>
<td>106</td>
<td>0.20</td>
<td>0.09</td>
<td>0.09</td>
<td>0.11</td>
<td>0.34</td>
<td>0.62</td>
<td></td>
</tr>
</tbody>
</table>

*There is no significant difference between younger (< 40 years) and older (> 40 years) adults.

$^c$There is a significant difference (p<0.05) between males and females.

Std. Dev. = standard deviation
Table 4. $^{99m}$Tc MAG3 Normal Values Using Regions of Interest over the Renal Cortex

<table>
<thead>
<tr>
<th></th>
<th>Gender</th>
<th>N</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Minimum</th>
<th>$5^{th}$ percentile</th>
<th>$95^{th}$ percentile</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_{\text{max}}, \text{right kidney (min)}$</td>
<td></td>
<td>106</td>
<td>2.57</td>
<td>0.51</td>
<td>1.6</td>
<td>2.1</td>
<td>3.6</td>
<td>4.6</td>
</tr>
<tr>
<td>$T_{\text{max}}, \text{left kidney (min)}$</td>
<td></td>
<td>106</td>
<td>2.62</td>
<td>0.56</td>
<td>1.8</td>
<td>2.1</td>
<td>3.3</td>
<td>6.3</td>
</tr>
<tr>
<td>$T_{\frac{1}{2}}, \text{right kidney (min)}$</td>
<td></td>
<td>106</td>
<td>5.44</td>
<td>2.1</td>
<td>3.0</td>
<td>3.3</td>
<td>8.8</td>
<td>15.8</td>
</tr>
<tr>
<td>$T_{\frac{1}{2}}, \text{left kidney (min)}$ *</td>
<td>M</td>
<td>44</td>
<td>4.84</td>
<td>1.5</td>
<td>3.3</td>
<td>3.5</td>
<td>6.0</td>
<td>13.0</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>62</td>
<td>5.36</td>
<td>1.4</td>
<td>2.8</td>
<td>3.8</td>
<td>7.3</td>
<td>11.3</td>
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<tr>
<td>20 min/max count ratio (right)</td>
<td></td>
<td>106</td>
<td>0.19</td>
<td>0.07</td>
<td>0.11</td>
<td>0.12</td>
<td>0.34</td>
<td>0.51</td>
</tr>
<tr>
<td>20 min/max count ratio (left)</td>
<td></td>
<td>106</td>
<td>0.19</td>
<td>0.04</td>
<td>0.10</td>
<td>0.13</td>
<td>0.27</td>
<td>0.32</td>
</tr>
<tr>
<td>20 min/2-3 min count ratio (right)</td>
<td></td>
<td>106</td>
<td>0.16</td>
<td>0.07</td>
<td>0.09</td>
<td>0.10</td>
<td>0.27</td>
<td>0.45</td>
</tr>
<tr>
<td>20 min/2-3 min count ratio (left)</td>
<td></td>
<td>106</td>
<td>0.15</td>
<td>0.04</td>
<td>0.08</td>
<td>0.10</td>
<td>0.23</td>
<td>0.33</td>
</tr>
</tbody>
</table>

*There is a significant difference (p<0.05) between males and females.

Std. Dev. = standard deviation
### Table 5. Post-Void / Maximum and Post-Void / Pre-Void Count Ratios Using Regions of Interest over the Entire Kidney

<table>
<thead>
<tr>
<th>Ratio Type</th>
<th>N</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Minimum</th>
<th>5&lt;sup&gt;th&lt;/sup&gt; percentile</th>
<th>95&lt;sup&gt;th&lt;/sup&gt; percentile</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-void/max ratio right kidney</td>
<td>106</td>
<td>0.08</td>
<td>0.04</td>
<td>0.02</td>
<td>0.03</td>
<td>0.16</td>
<td>0.24</td>
</tr>
<tr>
<td>Post-void/max ratio left kidney</td>
<td>106</td>
<td>0.09</td>
<td>0.03</td>
<td>0.03</td>
<td>0.05</td>
<td>0.15</td>
<td>0.20</td>
</tr>
<tr>
<td>Post-void/pre-void ratio right kidney</td>
<td>106</td>
<td>0.52</td>
<td>0.19</td>
<td>0.13</td>
<td>0.22</td>
<td>0.85</td>
<td>1.21</td>
</tr>
<tr>
<td>Post-void/pre-void ratio left kidney</td>
<td>106</td>
<td>0.59</td>
<td>0.15</td>
<td>0.20</td>
<td>0.34</td>
<td>0.83</td>
<td>0.97</td>
</tr>
</tbody>
</table>

*There is a minor but significant difference in the post-void to pre-void and post-void to maximum count ratios for the left kidney between younger (< 40 years) and older (> 40 years) adults.

&There is no significant difference between males and females.

Std. Dev. = standard deviation
Table 6. Voided Volume and Bladder Residual*

<table>
<thead>
<tr>
<th></th>
<th>Gender</th>
<th>Age</th>
<th>N</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Minimum</th>
<th>5th percentile</th>
<th>95th percentile</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voided volume</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(ml)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>≤ 40</td>
<td>12</td>
<td>199</td>
<td>157</td>
<td>15</td>
<td>15</td>
<td>500</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>M</td>
<td>&gt;40</td>
<td>16</td>
<td>322</td>
<td>182</td>
<td>80</td>
<td>80</td>
<td>750</td>
<td>750</td>
<td>750</td>
</tr>
<tr>
<td>F</td>
<td>≤ 40</td>
<td>18</td>
<td>225</td>
<td>132</td>
<td>50</td>
<td>50</td>
<td>500</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>F</td>
<td>&gt;40</td>
<td>16</td>
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<td>80</td>
<td>80</td>
<td>500</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Residual volume</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(ml)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>≤ 40</td>
<td>12</td>
<td>9</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>23</td>
<td>23</td>
<td>23</td>
</tr>
<tr>
<td>M</td>
<td>&gt;40</td>
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<td>30</td>
<td>28</td>
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<td>8</td>
<td>91</td>
<td>91</td>
<td>91</td>
</tr>
<tr>
<td>F</td>
<td>≤ 40</td>
<td>18</td>
<td>15</td>
<td>10</td>
<td>5</td>
<td>5</td>
<td>36</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td>F</td>
<td>&gt;40</td>
<td>16</td>
<td>17</td>
<td>9</td>
<td>5</td>
<td>5</td>
<td>42</td>
<td>42</td>
<td>42</td>
</tr>
</tbody>
</table>

* There is no significant difference in voided volume or residual bladder volume between males and females.
& There is a significant difference in residual bladder volume between younger (< 40 years) and older (> 40 years) males.
Std. Dev. = standard deviation

#One female patient had a residual volume of 256 mL; this value was considered to be abnormal and deleted from the analysis.