GUIDELINES FOR STANDARD AND DIURETIC RENOGRAM IN CHILDREN

Isky Gordon[1], Paula Colarinha[2], Jure Fettich[3], Sibylle Fischer[4], Jörgen Frökier[5], Klaus Hahn[4], Levent Kabasakal[6], Mercedes Mitjavila[7], Pierre Olivier[8], Amy Piepsz[9], Ute Porn[4], Rune Sixt[10], Jeannette van Velzen[11].

Great Ormond Street Hospital for Children, London, UK[1]; Instituto Português de Oncologia, Lisboa, Portugal[2]; Department for Nuclear Medicine, University Medical Centre Ljubljana, Slovenia[3]; Dept of Nuclear Medicine, University of Munich, Germany[4]; Aarhus University Hospital - Skejby, Denmark[5]; Cerraphasa Tip Fakultesi, Nukleer Tip Ana Bilim Dali, Aksaray, Turkey[6]; Hospital Universitário de Getafe, Madrid, Spain[7]; CHU Nancy, France[8]; CHU St Pierre, Brussels, Belgium[9]; The Queen Silvia Children's Hospital, Göteborg, Sweden[10]; liaison person ARPES[11]

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I Purpose

The purpose of this guideline is to offer to the nuclear medicine team a framework, which could prove helpful in daily practice. This guideline contains information related to the acquisition, processing, interpretation and indications for standard renography in children. The present document is inspired by the desire of EANM and the American Society of Nuclear Medicine to have guidelines for most nuclear medicine procedures [(1,2,3,4)]. Part of this guideline has been strongly influenced by the recent consensus report on quality control of quantitative measurements of renal function published by the International Scientific Committee of Radionuclides in Nephro-Urology, following the meeting in Copenhagen, May 1998 [(4)], which also reflects the European practice.

Standard renography has been in use for some time; whilst there are variations in many aspects of renography, agreement has been reached about certain aspects. The consensus document from International Radionuclides in Nephro-Urology has made various recommendations relating to estimation of differential renal function (DRF). Where evidence existed, that was used, otherwise the consensus document represents the considered opinion of a body of experts, based on their long experience and unpublished data. However there is little data to support certain opinions and practices currently in use.

This guideline summarises the views of the Paediatric Committee of the European Association of Nuclear Medicine. The guideline should be taken in the context of "good practice" and any local/national rules, which apply to nuclear medicine examinations.

II Background information and definition

Standard renography allows estimation of two aspects of renal function.

The first aspect is renal clearance, i.e. the extraction of a tracer from the blood. In this guideline only estimation of relative clearance, or differential renal function (DRF), will be discussed. The Paediatric Committee believes that there are important errors attached to the estimation of absolute clearance using only the gamma camera and therefore recommends a plasma clearance technique based on blood sampling for this purpose.

DRF estimation is best undertaken approximately between one and two minutes after tracer injection [(4)]: after two minutes, there is a possibility that some tracer has left the renal space, therefore invalidating the DRF estimation. The information obtained during this one – two minute interval still, however, contains non-renal activity (background), which should be corrected. The tissue component and part of the vascular component can

be removed by subtracting some activity around the kidney (see G.Processing); the remaining part of the vascular component may be eliminated by introducing the Patlak /Rutland correction [5]. Controversy exists whether one or both corrections should be applied. Both corrections might be more relevant when tracers with low extraction rate such as diethylene triamine pentaacetic acid (DTPA) are used. Background correction is particularly important in estimation of DRF when there is asymmetrical renal function or decreased overall function.

The second function, which can be assessed by renography is the excretion, or disappearance, of the tracer from the kidney. This disappearance can simply be estimated by inspecting the renogram curve: an early peak followed by a rapidly descending phase is typical for normal excretion. An important delay in excretion is characterised by a continuously ascending curve. Several techniques have been proposed for quantifying the transit of tracer through the kidney. These range from simple descriptive parameters, such as the time to reach the maximum of the curve, i.e. Tmax, to more sophisticated parameters, such as deconvolution analysis, output efficiency (OE)/pelvic excretion efficiency (PEE) or normalised residual activity (NORA) (see V- Issues requiring further clarification). Sufficient information is provided by the shape of the renogram and the Tmax to discriminate between normal transit (Tmax around 3 minutes), or very delayed transit (Tmax of 20 minutes); there is no proof that in clinical practice the more sophisticated techniques can improve the information. When dilatation of the collecting system exists, the standard renogram is generally characterised by a continuously rising curve, reflecting poor drainage of the kidney. In this condition, Furosemide should be administered which increases urinary flow and may distinguish between good, intermediary and poor drainage.

Controversy exists in four areas, these are hydration of the child, bladder status / bladder catheterisation, assessment of drainage post Furosemide and the interpretation of impaired drainage [6].

1. Hydration of the child:

The child should be adequately hydrated for both the standard and diuretic renogram. Controversy exists as to how best to achieve this state. Every parent receives information with the appointment letter and this letter stresses that they should encourage oral fluid intake on the day of the study. Furthermore since an anaesthetic cream is applied to many children and this takes 60 minutes to be fully effective, there is a second opportunity to encourage oral fluid intake. Infants could receive an additional bottle/breast feed while older children could be encouraged to drink liberally (250 - 500 ml.) water/orange juice. Thus the need for intravenous fluids for prehydration is considered unnecessary in the majority of patients. Almost all children undergoing diuretic renography are outpatients and following the above recommendations they are neither salt nor water depleted at the time of the renogram.

2. Bladder status and effect of gravity:

In the presence of a full bladder, drainage from the kidney may be delayed, even in the normal kidney resulting in a flat renal curve. Young children cannot be expected to void immediately prior to the renogram, however the use of a diuretic usually causes the child to void, often within 15-20 minutes of the administration of the diuretic. Additional data should be routinely acquired after micturition so that analysis of the kidneys can be undertaken when the bladder is empty. A further important aspect of this approach is that there should be a change in the child's position some time after the administration of the diuretic and so the erect position allows gravity to have its effect and further reduces apparent poor renal drainage simply due to the supine position. The

change in posture should be for approximately 5 minutes before the one-minute late series dynamic data is acquired. This final image series has been termed Post Micturition Images (PM).

If the drainage after the standard renogram (0-20 min.) is moderate and there is previous data to suggest that this is not due to obstruction, then some institutions undertake PM Images first, if the drainage is still poor then Furosemide may still be given followed by a second PM Images. Bladder catheterisation has been advocated in children undergoing diuretic renography to maintain an empty bladder throughout the procedure. Using the PM Images, bladder catheterisation is not recommended and is rarely undertaken in most European nuclear medicine departments. In rare cases (e.g. neurogenic bladder) placing a catheter is advisable, but this can be postponed until the end of the Furosemide test and following PM images if spontaneous bladder emptying does not occur.

3. Assessment of drainage post Furosemide:

Assessment of drainage is controversial. The shape of the washout curve has been proposed to assess drainage [(4)]. The classical method of analysis of the post diuretic curve is to assess the slope of this curve; however the determination of this slope is not straightforward and many variants have been proposed, each resulting in a different slope value [(7)]. Analysis of the post Furosemide curve on its own is inadequate since important physiological variables are not taken into account; these include the function of the kidney, bladder status, the effect of gravity and the volume of the renal pelvis. One cannot expect the same washout slope from a poorly functioning kidney as one would from a good functioning kidney and new processing algorithms are being tested (see G.5.3 Diuretic response and V - Issues requiring further clarification). The PM Images will take into account the variables of bladder status and the effect of gravity. There are no nuclear medicine techniques, which take into account the volume of the renal pelvis (see V- Issues requiring further clarification).

4. The interpretation of impaired drainage:

Good drainage is easy to define, since the images, curves and numerical data all reveal little tracer in the kidney and collecting system at the end of the study. However when drainage is reduced then there is little agreement as to what constitutes impaired drainage. The significance of impaired drainage is also strongly debated and the relationship between impaired drainage and different treatment modalities is debated. Sequential renography providing sequential DRF can be helpful in the treatment strategy since a progressive fall in DRF may lead to surgery immaterial of the degree of impaired drainage. These guidelines can only describe good drainage and await further evidence on how best to define and interpret impaired drainage.

Radiopharmaceuticals used: There are three tracers that rely on tubular extraction, ^{123}I - Hippuran, ^{99m}Tc-Mercaptoacetyltriglycine (^{99m}Tc-MAG3) and ^{99m}Tc-Ethylenedicysteine (^{99m}Tc-EC) and one tracer dependent on filtration, ^{99m}Tc-DTPA. The tracers, reflecting tubular extraction have a greater renal extraction than ^{99m}Tc-DTPA resulting in a lower background activity and a higher kidney to background ratio. For these reasons the tubular agents are preferred to^{99m}Tc-DTPA for estimation of DRF particularly in infants, for diuretic renography and indirect cystography. ^{99m}Tc-DTPA may be useful following renal transplantation when both blood flow as well as formal glomerular filtration rate (GRF) estimation (with blood sample analysis) is required.

The kidney of the young infant is immature and the renal clearance, even corrected for body surface, progressively increases until approximately 2 years of age. Therefore renal uptake of tracer is particularly low in infants, with a high background activity. In young children, preference must be given to tracers with high

extraction rate, such as ^{123}I-Hippuran or ^{99m}Tc-MAG3. These tracers provide reasonable images and the DRF can already be estimated at the end of the first week of life. With ^{99m}Tc-DTPA, estimation of DRF may be inaccurate in early infancy.

III Common Indications

Indications

A. All uropathies, which require evaluation of individual renal function at diagnosis and during the different phases of surgical or conservative treatment and evaluation of the drainage function. Examples include dilatation immaterial of the cause (e.g. Pelvi-Ureteric and Vesico-Ureteric dilatation), bladder dysfunction, complicated duplex kidney, post trauma, asymmetrical renal function and reflux nephropathy.

B. When dilatation of the collecting system exists, the standard renogram should be complemented by a diuretic renogram.

C. Preceding Indirect Radionuclide Cystography (IRC).

D. Evaluation of sustained systemic hypertension. If reno-vascular disease is suspected then Captopril provocation may be used [(3)].

E. Renal Trauma.

F. Follow up of renal transplantation. Here the dose of tracer is increased and a rapid acquisition is required, (full details are not within the scope of this guideline) [(8)].

Contra Indications

There are no contra indications. However there are limitations: in the presence of poor renal function, accurate estimation of DRF and/or drainage may not be possible. In the presence of marked hydronephrosis, the interpretation of poor drainage is difficult since this could be due to either "partial hold-up" or simply because of the reservoir effect of the dilated system. In the presence of calculus obstruction, a renogram may be undertaken but no Furosemide should be administered.

IV Procedure

A. Information about previous examinations relevant to this procedure

The clinical history, ultrasound data and previous radionuclide imaging should be reviewed. This may help the decision whether a standard renogram, a renogram followed by an indirect radionuclide cystogram or a diuretic renogram should be performed.

B. Patient preparation

B.1 Information with appointment letter:

The parent/child should receive detailed written information, which explains the entire procedure. The parents should be told to offer the child drinks liberally before getting to the department. This is especially important in hot weather. When Furosemide has been given, the parent should be warned that the child, who is

toilet trained, may have an urgent need to void on more than one occasion following the procedure.

B.2 Prior to injection:

Hydration: The child should be encouraged to drink from the time of arrival in the department to the actual injection of tracer. The child (if co-operative) should be encouraged to void prior to the injection [9,10,11,12].

Anaesthetic cream: can be applied to relieve the discomfort of the injection, this requires a 60-minute wait for the cream to have its effect and so provides an opportune time for ensuring good hydration.

If ^{123}I -Hippuran is used, the thyroid should be blocked using perchlorate given 60 minutes before the tracer.

This guideline does not support the routine use of a bladder catheter.

C. Precautions

Nil.

D. Radiopharmaceutical

D.1 Radionuclide

Technetium-99m (^{99m}Tc), (Iodine-123 (^{123}I) for Hippuran only).

D.2 Pharmaceutical

MAG3 (Mercaptoacetyltriglycine)

EC (Ethylenedicysteine)

DTPA (diethylene triamine pentaacetic acid)

Hippuran.

D.3 Dose schedule

Minimum doses are: ^{99m}Tc-MAG3 = 15 MBq.

^{99m}Tc-DTPA = 20 MBq.

^{123}I- Hippuran = 10 MBq.

Recommended maximum doses are: ^{99m}Tc-MAG3 = 70 MBq.

^{99m}Tc-DTPA = 200 MBq.

^{123}I- Hippuran= 20 – 75 MBq.

Administered doses should be scaled on a body surface basis [13].

D.4 Injection technique

Position the patient supine, then start the computer and inject the radiopharmaceutical as a bolus.

D.5 Radiation burden

Recent publications suggest the radiation burden to be lower than proposed in ICRP 62.

For a 5-year-old using ^{99m}Tc-DTPA the effective dose (ED) is 0.54 to 0.82 mSv, the lower figure relating to a one-hour voiding interval.

For ^{99m}Tc-MAG3 the corresponding figures are 0.20 and 0.38 mSv respectively [14,15].

The ED to a 5-year-old using ^{123}I-Hippuran is 0.41 mSv.

E. Image acquisition

E.1 Timing for imaging

Nil.

The acquisition starts immediately before the injection of the radiopharmaceutical, as a bolus.

E.2 Collimator

Low energy-all-purpose collimator.

E.3 Position of detector

Position camera with the collimator facing up. The exception to this is in the patient who has undergone renal transplantation when an anterior scan is recommended.

E.3 Positioning of the child

Supine position, which will minimise renal depth difference and assist in keeping movement to a minimum. To reduce movement, support the child with either sandbags or Velcro straps on either side of the child or place the child in a vacuum cushion. When possible, the child should lie directly on the collimator surface. One must ensure that the heart, kidneys and bladder are all included in the field of view. Having the heart in the field of view is important if one is planning to use the Patlak/Rutland plot in the analysis of the renogram. In the tall adolescent one might have to choose whether the heart or bladder should be included in the field of view. Check the patient's position with a radionuclide marker to ensure that the lower chest (marker in axilla) and all of the abdomen (marker below pubic symphysis) are included in the field of view.

E.4 Views

Posterior.

E.5 Computer acquisition set up

Matrix: 128 x 128 and word (or byte) mode is recommended as the first choice, 64 x 64 matrix size and word mode being the second choice.

Zoom: A zoom for acquisition is recommended for paediatric studies, varying between 1 to 2 as function of body size.

Frame rate: 10- to 20-second per frame. Some institutions will wish to collect data in the blood flow phase, this will require a rapid frame rate (0.5 sec/frame for 40 sec). Whatever the processing method used, the DRF estimation is independent of frame time and will be the same using either 10- or 20-second frames [4,16].

Duration of study: The Minimum Data set is 0 - 20 minutes. If a diuretic is given, an additional 15 - 20 minutes acquisition, using the same technique as above, should be obtained followed by the PM Images (see below). The recommended acquisition times aim to standardise the renographic technique.

F. Interventions

F. 1 Diuretic administration (Furosemide)

Dose: 1mg/Kg with a maximum dose of 20 mg.

Timing of administration: There are three variations.

- F + 20 - Furosemide is injected 20 minutes after the injection of tracer.
- F – 15 - Furosemide is injected 15 minutes prior to the tracer
- F – 0 - Furosemide is injected at the beginning of the study. This method is gaining popularity since there is only a single i.v. injection, especially in the young child with small veins. In some departments using the Patlak/Rutland plot, the Furosemide is given 2 minutes after the injection of tracer since the very quick transit of tracer through the kidney due to the effect of Furosemide might invalidate the fitting process for estimation of DRF.

There is no evidence at the present time to suggest that any one of the above timings is "better" than the other. However if there is difficult venous access then one single injection is to be recommended.

F.1.1 Post Furosemide Acquisition

Acquisition parameters: Use the same frame rate, zoom factor and matrix size as for the renogram

F.1.2 Post Micturition Images

Positioning of the Child: Supine, after the child has been upright for at least 5 minutes and has voided, the data should be acquired for one minute.

Acquisition parameters: Use the same frame rate, zoom factor and matrix size as for the renogram.

F.1.3 Indications for the PM Images include

This series is essential at the end of the diuretic renogram if emptying is incomplete.

In children with known pathology in whom the need for a diuretic renogram is unlikely, PM Images may be sufficient. In this case the PM Images may be acquired after the 0-20 minute renogram. However for consistency a PM Images should be acquired within 60 minutes after the injection of tracer, each institution should ensure that there is an attempt to standardise the entire renogram including the time frame. This will allow for comparison with sequential studies as well as comparison between different children.

TABLE

Time of Diuretic Administration	Duration of ACQUISITION		
	RENOGRAM	**Post - DIURETIC**	**Post Micturition Images** Within 60 minutes
F-15	20 minutes	-	1 minute
F-0 or **F+2**	20 minutes	-	1 minute
F+20	20 minutes	15 - 20 minutes	1 minute

F. 2 ACE Inhibitors (Captopril)

This is indicated in the presence of hypertension when reno-vascular disease is suspected. See guideline on Captopril renography [3].

G. Processing

These guidelines recognise that some departments may have a camera/computer, which does not allow any variation in the computer program for data analysis. The user must however be aware of the pitfalls as well as the suggested method for the analysis of the renogram.

Prior to processing the data, quality control is essential (see J. Quality control).

G.1 ROI

Every acquisition series should have ROI drawn.

G.1.1 Renal

The renal ROIs should be drawn on a summed image depending on the renal function (sum performed on a later series of images as renal function is decreased, in order to obtain a better signal-to-noise ratio) [4].

We recommend:

- the renal ROIs should ensure that the entire kidney and pelvis are included in the ROI for the duration of each acquisition. A generous ROI is preferred to a very tight ROI, which might cut the kidney [17,18,19,20].

G.1.2. Background ROI

The different background ROIs, which perform well according to published works, are:

- rectangular
- elliptical
- surrounding the kidney outline, appropriately apart from the kidney (e.g. one or two pixels depending on the matrix size) to avoid scatter from the kidney activity. A peri-renal ROI is the best compromise for the various components responsible for background activity in the renal areas [4]. In the presence of gross pelvic dilatation in the young infant, a peri-renal background may not be possible since the kidneys extends virtually to the edge of the child, in such circumstances a background ROI above and below the kidney might be the best compromise.

G.1.3 Cardiac ROI

Those institutions using the Patlak/Rutland plot for the analysis of the renogram requires a cardiac ROI (centred on the highest count rate in the region of the left ventricle).

G.2 Background correction

Background correction should be applied to the renogram curves. If Furosemide and/or the PM Images have been acquired then these also require background correction. The background ROI counts should be size normalised to the kidney ROI, before subtraction from the kidney ROI counts[21,22,23,24,25,26,27,28,29,30,31].

G.3 Curve creation for each ROI

For every dynamic series there should be curve generation.

Renogram Curves: The background corrected time activity curves should be used. The estimated DRF should be compared with the early one-minute image (see below).

G.4 Images

A summed image of all the frames during the clearance or uptake phase i.e. 60 -120 seconds after the peak of the cardiac curve (vascular phase) should be created. This image reflects the regional parenchymal function and may allow the detection of regional abnormalities. Although the consensus document on ^{99m}Tc-DMSA has

shown that DMSA is more appropriate for that purpose, one should not neglect the possibility of detecting parenchymal abnormalities when performing a renographic study [32]. Differential function should be visually assessed on this image and compared to the DRF estimated from the curves to ensure that there is congruity of results.

In addition, a series of timed images over duration of study should be created. The optimum is to add frames into one-minute images covering the duration of the study, including the PM Images. All images should be displayed with the same scaling factor. The final display may include, either 20 one-minute images, or the 1, 2, 10 and 20-minute images plus an image of the late series.

With Furosemide and the F + 20 protocol, summed images over the duration of this post diuretic acquisition should be created with the same parameters as the images of the renogram and the same scaling factor. Functional images during the early phase may be useful, (see V- Issues requiring further clarification).

G.5 Quantification

The minimum quantification data of a renogram should be the DRF (uptake phase) and excretion (third phase with response to Furosemide if used).

G.5.1 Differential renal function (DRF)

The relative function of each kidney is expressed as a percentage of the sum of the right and left kidneys. It is computed from the same time interval of the renogram, this is 60-120 seconds from the peak of the cardiac (vascular) curve. No renal depth correction is required in children [33,34,35]. This guideline recommends either the integral method or the Patlak-Rutland plot method [4,18,36,37,38,39]. If a diuretic has been given at the same time as the tracer, the rapid transit of the tracer through the kidney suggests that the DRF could be measured between 40-100 seconds.

The integral method:

The parameter determined is the area under the background-corrected renogram, representing the cumulative uptake during the selected time interval.

The Patlak-Rutland plot method:

The parameter estimated is the mean slope of the ascending portion of the curve plotting the background-corrected kidney ROI counts [R(t)] divided by the cardiac ROI counts [H(t)] as a function of the integral of the cardiac ROI counts divided by [H(t)].

When overall function is good and DRF falls between 40% - 60% then all methods work and will provide similar results. However when global function is reduced and/or there is asymmetrical renal function then only these above methods have been recommended by The International Scientific Committee of Radionuclides in Nephro-Urology. There comes a point however, when renal function is so impaired that no method can be recommended for assessment of DRF [40,41].

G.5.2 Excretion during renogram

Numerous methods to assess this phase have been referred to in the background section of this guideline. The simplest method is inspection of the curve, normal excretion (early peak with a rapidly descending curve) as well as slightly delayed excretion are readily distinguished from very abnormal excretion (continuously rising curve).

G.5.3 Diuretic response

Assessment of the response to the diuretic must include the analysis of the PM Images and may be expressed

in analysis of both images and numerical quantification.

Visual assessment of drainage can be achieved by reviewing the sequential one-minute images over the duration of the entire study, including the PM Images using the same scaling. This is a subjective approach and is not quantifiable, but will give the first evaluation of the response to the diuretic challenge e.g. no or almost no emptying, good emptying or partial emptying.

Quantification of the residual activity after the PM Images [42,43] can be achieved in one of the following ways:

- as a percentage of the maximal activity (peak of the renogram);
- relative to the first image of the Furosemide acquisition;
- as a ratio of the radionuclide taken up by the kidney [44,45];
- as a % of the activity taken up at 2-3 minutes [46]. These latter two may be used for the standard renogram or for the PM Images (see V- Issues requiring further work).

There is however no cut off values available to differentiate between partial and poor emptying.

G.6 Results

The sequential images must be carefully reviewed and taken in conjunction with the curves and quantification data.

H. Hard copy output

The following is the minimum data set, which should be produced.

H.1 Time of injection

Must be stated in order to know the time of acquisition of the late series images relative to the injection of tracer.

H.2 Images

Series of timed images over duration of study and labelled right or left side should be produced. See G.4 above for details.

H.3 ROIs

These used should be displayed on a summed image.

H.4 Curves

Background subtracted kidney curves over duration of study. Each kidney should be identified by colour or line structure.

H.5 Quantification

This should include the DRF calculated as per recommendations and Tmax (time to peak). If this is abnormal then either PM Images alone or a diuretic should have been given followed by PM Images. The results of either OE/PEE or NORA should be displayed.

I. Interpretation/Reporting/Pitfalls

Relative function: Normal values of DRF are between 45% and 55% uptake [4]. DRF should be interpreted in clinical context, since values within the normal range maybe seen either when there is bilateral renal damage

and/or in the presence of chronic renal failure. Values outside this normal range may be seen when there is an uncomplicated unilateral duplex kidney as well as in unilateral renal damage.

Ectopic kidney: In the presence of an ectopic kidney, the DRF estimation will underestimate the function of the ectopic kidney in all cases. A ^{99m}Tc-DMSA scan with both posterior and anterior projection is suggested in such cases. Drainage may be difficult assess if the kidney lies close to or behind the bladder.

Images: The images should be reviewed. With the tubular agents the 60-120 sec. image may show a focal renal defect [32]. Dilated calyces and/or renal pelvis and/or a dilated ureter may be evident. Comparison between the renogram and PM Images is important to assess the effect of a change of posture and micturition.

Drainage function: Good drainage is easy to define, since the images, curves and numerical data all reveal little tracer in the kidney and collecting system at the end of the study. However when drainage is reduced there is little agreement as to what differentiates moderate from poor drainage. The significance of impaired drainage and its implications for treatment is also strongly debated. These guidelines can only describe good drainage and await further evidence on how best to define and interpret impaired drainage.

J. Quality control [47,48]

1. Extravasation at the site of the injection may give rise to difficulties in processing the data. Extravasation may lead to incorrect interpretation of the study. The normal shape of the curve from a ROI over the heart will be lost or reduced when extravasation has occurred.
2. Position of the child: Is the child straight, have the heart, kidneys and bladder been included in the field of view? A simple means for quality control is to run the study in cine mode. Movement, kidney uptake of the tracer, transit from parenchyma to pelvis as well as drainage of the collecting systems are easily noted.
3. Adequate child immobilisation plus a helpful parent is better than any post acquisition data manipulation for motion. Check for patient motion using cine mode.

   If motion exists then an experienced operator is required to judge whether the movement is so marked that no numerical or graphical analysis is possible although viewing of the images may permit useful information from the study to be gained. With less movement, the operator may either use a large ROI on a summed image (over 1 min) or use a realignment program (using manufacture's software) [49,50].
4. The beginning of the analysis of the study should be from the first frame when tracer is seen in the kidney. Check that the computer was started early enough, i.e. no tracer is in the kidney on the first frame, but also that the computer was not started too early, i.e. no tracer on the first 2- 3 frames. All timings should refer to the image where the cardiac (vascular) activity is highest.

V Issues requiring further clarification (weaknesses)

1. ROI: Exact details of how to draw both the kidney and background ROIs should be defined better but there is no data to support any one technique
2. The best technique for estimation of DRF in the presence of marked asymmetrical kidney function and/or reduced global function is yet to be established.
3. There is a need to demonstrate that more complex parameters in the analysis of the transit impairment on the renogram (deconvolution techniques) will improve the information already provided by simple

parameters.

4. Data manipulation will allow the computer to generate pixel-by-pixel parametric images, based on either the uptake function or the transit function.

   Until now, the functional images based on cortical transit (T max image, Mean Transit Time image, factor analysis) have not shown to be useful to differentiate between simple dilatation and high probability of obstruction. One can consider the 1 to 2 minutes summed image as a parametric image, which, as described in G5, can offer useful information about regional cortical impairment. An alternative is the use of a pixel-by-pixel Patlak/Rutland plot image, which offers the advantage of a vascular correction.

5. Techniques, which assess drainage relative to that kidney's uptake function:

   The output efficiency (OE) [44] or pelvic excretion efficiency (PEE) [45] adjusts the early part of the renogram to the integral of the heart curve to obtain the percentage of activity which has left the renal compartment during the time interval studied. Although there is data of normal renal excretion in paediatrics [45], there is no data in children to define degrees of impaired drainage. No criteria are universally accepted which allow interpretation of impaired drainage as obstruction [51,52,53].

   Another approach is simply to express the residual activity after micturition as a percentage of the renal activity 2 minutes after tracer injection. This has been called normalised residual activity (NORA) [46]. Both parameters have the advantage of taking the level of renal uptake into account and can be used whatever the time of Furosemide administration. More work is still needed to estimate the cut-off values for good, moderate and poor drainage.

   The volume of the renal pelvis is another variable, which cannot be taken into consideration using only diuretic renography, integration of post diuretic ultrasound volume measurements is one possible technique to determine this variable. How these results would then be incorporated with the results of the diuretic renogram remains to be worked out.

6. The definition of obstruction, or better, the definition of the risk factors of renal deterioration and therefore the operative indications are still a matter of debate. It is the task of the surgeon to integrate the radionuclide information into a comprehensive strategy. At the present time, only empirical attitudes are available, based on all kinds of combinations of clearance values, quality of drainage and degree of renal dilatation, which is fully discussed in an editorial [54]

7. Usefulness of Captopril enhanced studies in case of arterial hypertension also requires further clarification

VI Concise bibliography

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