Artefacts and pitfalls with case studies

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Renal imaging includes several different imaging procedures for the evaluation of renal function and represents one of the original cornerstones of nuclear medicine imaging. The measurements are quantitative, and the tracers themselves do not disrupt function.[1]

Although measurement of renal function is helpful in the care of patients with all types of renal disease, radionuclide methods have found their greatest applications in the differentiation of the function of each kidney and in the detection of obstruction to urine flow. [1] Determination of kidney function provides necessary information in diagnosis and follow-up in a variety of disease states and is essential in making decisions regarding the transplantation or removal of a kidney. Given the variety of renal imaging procedures, in order to obtain the appropriate information regarding a given condition or disease state, it is essential to know the desired outcome from the procedure before choosing which procedure to perform.

The radionuclide retrograde or direct Cystogram is the procedure used for the diagnosis and follow-up of vesicoureteral reflux. When performing a Renal Glomerular Filtration Study one images ^{99m}Tc-DTPA as it passes through the vascular system, renal glomeruli, renal tubules and collecting system. This procedure allows for the evaluation of renal perfusion and passage of urine through the collecting system and can also be used to evaluate renovascular hypertension. The radiopharmaceutical, ^{99m}Tc-DMSA, is cleared from the blood into renal tubular cells, but not secreted into the tubular lumen and is a procedure which allows for the evaluation of tubular function without interference from radioactivity in the collecting system. And when performing a Renal Tubular Secretion Study, one images ^{99m}Tc-MAG3 as it passes through the vascular system, renal tubular cells, tubular lumens, and collecting system, thereby allowing sequential evaluation of renal perfusion, renal clearance by tubular secretion, renal parenchymal transit time and passage of urine through the renal collecting system. [2]

Renal imaging studies display different aspects of renal function based on the characteristics of the radiopharmaceuticals used and the radiopharmaceuticals can be divided between functional radiopharmaceuticals and morphological radiopharmaceuticals. Since the radiopharmaceuticals provide different information with respect to the function of the kidney, to maximize the clinically relevant information to be obtained from the procedure, the indications for performing the study must be known before getting started.

Despite the different types of studies and different information obtained from the procedures, the artefacts and pitfalls for renal imaging fall into the same major categories common to all procedures. There are artefacts or pitfalls associated with the patient; those associated with performing the procedure; artefacts or pitfalls associated with the equipment; as well as those that are introduced by or as a result of processing.

With respect to the patient, as with all medical imaging procedures, pertinent clinical history prior to imaging is necessary to achieve the optimal outcome. Degree of hydration, relevant anatomical information, complete drug history, and knowledge of prior diagnostic procedures are all essential pieces of information that are vital to renal imaging interpretation.

A common physiological variable is the state of hydration. Although there is typically no preparation required for renal imaging, ideally the patient should be well hydrated. The state of hydration can affect the images obtained, and as a result, have an impact on interpretation.

It is also helpful to have anatomical information such as the number and location of kidneys (if known) if a perfusion study is to be performed, to ensure that the patient is positioned properly to obtain the necessary images.

A number of drugs can significantly affect the function of the kidney or directly interfere with the uptake of the radiopharmaceutical. Drugs that block tubular secretion, e.g. probenecid, may interfere with the uptake of certain tracers despite otherwise normal renal function. So knowing the current medications that the patient is on, is necessary to better understand and interpret the images acquired.

Lastly, radiographic procedures using contrast agents that have been performed within a short time prior to the renal study could have an impact on the images obtained. For instance, if a renal arteriogram has been performed a few days before the radionuclide renal study, an inaccurate impression of renal function may be obtained because of the transient contrast-induced acute tubular necrosis (ATN). [3] Having this knowledge is helpful to determine the optimal scheduling time for the

procedure, or if the procedure is performed regardless, it is meaningful for proper interpretation.

The patient's anatomy or the positioning of the patient can also have an effect on the image obtained and as a result the image may not provide accurate information regarding the function of the kidney. With respect to planar imaging and the patient's anatomy, the kidney may appear smaller than is actual size if the long axis is not parallel to the surface of the crystal of the gamma camera. This artifact is called foreshortening. Also it should be noted that normally the kidneys are about an equal depth from the skin of the back, but in some patients the depths of the kidneys may be unequal. When the kidneys are at unequal depths, measurement of the relative activity in each kidney is inaccurate because of attenuation of radiation from the deeper kidney. And when a renal study is performed with a portable camera, the patient is often in the lateral decubitus or prone position. Either of these positions may exaggerate the asymmetrical depth of the kidneys because one kidney may fall forward more than the other. Sometimes a kidney is out of position or a patient has a congenital abnormality of a horseshoe kidney where the kidneys are joined. Because the spine can attenuate the radiation where the kidneys are combined this diagnosis can be missed.[3]

Functional renal imaging is performed using MAG 3 or DTPA. Although most medical centers do not measure absolute renal function because the most accurate methods are time-consuming and cumbersome requiring several timed blood samples, nuclear medicine is useful in having the ability to provide an index of relative individual kidney function. A major factor in the decision to treat or remove a diseased kidney is the degree to which the diseased kidney contributes to total renal function. There are several caveats associated with the determination of relative kidney function. Calculation of the relative renal function requires estimates of the number of counts in each kidney and the number of counts in a background region of interest. Normally, this calculation is quite robust, however, as renal function deteriorates, the number of counts in the background region of interest increases and becomes much more important in the calculation. Under these circumstance, (low kidney counts and high background counts), the choice of the background region of interest can significantly change the measured contribution of the diseased kidney, therefore a subjective estimate of the relative function may be just as accurate. Unfortunately, no universally accepted standards have been adopted for defining regions of interests. A second source of error for the measurement of relative renal function is attenuation. As previously noted, some of the radiation coming from the kidneys is absorbed by the soft tissue between the kidney and gamma camera. If there is significant difference in the depths of the kidneys, the contribution of the deeper kidney will be underestimated.[3]

When considering a renal imaging procedure for evaluation of renovascular hypertension or renal artery stenosis (RAS) using Captopril, often a contraindication for performing the study is if the patient is on adrenal cortical extract (ACE, or angiotension-converting enzyme) inhibitors. With a patient properly prepared and screened and the procedure properly performed, if the Captopril study is normal, a baseline study is not needed. However, if the Captopril study is abnormal a baseline study is required. Patients that have remained on an ACE inhibitor prior OMITTED SOME WORDS results in Captopril not being adequately absorbed thereby creating faulty data that could result in an inaccurate diagnosis.

In addition to these sources of error, a pitfall that technologists should guard against when processing renal images is drawing the cortical region of interest (ROI) inclusive of the renal pelvis. An ROI which includes the tubules won't appropriately indicate a crisp perfusion curve. In addition to patient variables, typical machine artefacts, and processing pitfalls, another area of pitfalls of which one should be mindful is in regard to the timing of the administration of procedure enhancing drugs. For instance in a study to rule out obstruction using furosemide, if the furosemide is administered before the radiopharmaceutical is in the renal pelvis it won't be an accurate representation of excretion. In addition, if a post void image is not taken, there may be the appearance of retention when in fact there is not due to back pressure created from a full bladder.

Renal imaging, shares with all nuclear medicine procedures, the possibility of artefacts or less then desirable images from infiltrated injections, non-bolus injections (when required), misalignment on positioning, power interruption to the camera, cracked crystal, etc. As with all procedures, hurriedness and lack of attention to details are pitfalls that are easily avoidable, but always present.

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