Can Gd-DTPA MR Renography Could be a One Stop Imaging Technique for Assessment of Human Renal Allograft Complications?

AHMED A. MAHMOUD, M.D.*; NADINE R. BARSOUM, M.D.** and HANY M. EL-ASSALY, M.D.*

The Department of Radiology, Theodor Bilharz Research Institute* and Cairo University**

Abstract

Introduction: MRI technique with fast pulse sequences and renal eliminated contrast agent has the capability of combining both anatomic and functional information; having advantages over both computed tomography and nuclear scintigraphy for assessing renal function, because it combines high spatial resolution with information on perfusion and function.

Aim of Work: Evaluate the role of MR Renography in the assessment of renal allograft complications during the post transplantation period.

Subjects and Methods: Thirty nine renal transplant recipients (29 males and 10 females), their age range was 18 to 65 years with a mean age of 40±11 years were referred for assessment of deteriorating renal function (31 patients) or other reasons as pain or swelling at the site of the graft, fever or hypertension (8 patients). All patients underwent a full MRI examination, including conventional MR, magnetic resonance angiography (MRA) and magnetic resonance renography (MRR) examinations. Four patients who had urological complications were examined in addition by MR urography (MRU).

Ultrasound and Doppler studies, renal scan, were also done for all cases. The final diagnosis used for reference was based on graft biopsy (20 cases), constellation of clinical and laboratory data, or clinical response to specific treatment for the other 19 cases.

Results: In the cases of acute rejection in this study, the MRR showed a sensitivity and specificity of 82.2% and 94.6% respectively, ultrasound showed a sensitivity and specificity of 75% and 78.7% respectively, while RNS showed a sensitivity and specificity of 80% and 78.9% respectively. MRR in cases of cyclosporine nephrotoxicity showed a sensitivity of 90.7% and a specificity of 92%, ultrasound showed a sensitivity of 70% and a specificity of 79.2%, while RNS showed a sensitivity of 70% and a specificity of 69.7%. Cases with chronic rejection showed 100% sensitivity and specificity by both MRR and RNS, while they showed 92.3% sensitivity and 98.7% specificity by ultrasound and Doppler examinations.

RNS showed high sensitivity in detection of cases of ATN with a sensitivity of 100%, while the two other modalities showed 50% sensitivity in detection of these cases. In ATN as well, the specificity by MRR was 77.1%, by ultrasound was 80.2%, while by RNS was 68.3%. Vascular complications were accurately detected by both Doppler and MRA techniques, yet the Doppler examination provided more details about the velocity and the resistance of the blood flow within the main renal vascular stump as well as the intrarenal vasculature, which could not be quantitatively assessed by MRA studies.

Ultrasound and Doppler are more accurate in detection of urological complications than RNS, where the ultrasound and MRI showed a sensitivity and specificity of 100% for the detection of cases with hydronephrosis as well as their causative agents, while RNS was only sensitive in the detection of hydronephrosis. Also cases with renal stones were detected by ultrasound examination (sensitivity 100%), but neither by MRI or RNS examinations could detect them.

Moreover, in the cases with perinephric collections, both MRI and ultrasound showed sensitivity of 100%, while RNS showed a sensitivity of 51.6%, yet the ultrasound was more specific (80.7% specificity) in detection of the nature of the collection (with the exception of cases of urinomas, where RNS is very specific) as compared with the MRI (46.7% specificity).

Conclusion: A full MRI examination, including conventional MRI, MRR, MRA and MRU will give the treating physician and full documented report about the renal allograft morphology and function, which, although expensive and not yet readily available in a lot of medical centers, it provides a one-stop technique for evaluation of almost possible complications. However, ultrasound better detects renal stones and vascular complications the Doppler examination provided more details about the velocity and the resistance of the blood flow within the main renal vascular stump as well as the intrarenal vasculature, which could not be quantitatively assessed by MRA studies.

To conclude the combination of ultrasound, Doppler and RNS examinations can give similar results as those given by MRI, yet they are more available, show all possible complications and at a much lower cost for the patient.

Key Words: MR renography – Human renal allograft – Renal functional imaging.
Can Gd-DTPA MR Renography Could be a One Stop Imaging

Introduction

A wide variety of complications may occur after renal transplantation. These include A- Non-mechanical causes of allograft dysfunction (e.g. acute rejection, acute tubular necrosis (ATN), cyclosporine nephrotoxicity, infection), B- Mechanical causes of allograft dysfunction (e.g. hydronephrosis), C- Vascular complications (e.g. renal artery stenosis or occlusion, renal vein thrombosis, pseudoaneurysms formation, infarction), D- Peritransplant fluid collections (e.g. urinoma, lymphocele, abscess, haematoma) and E- Posttransplant lymphoproliferative disorder. These processes may occur singly or in combination [1].

The imaging modalities that are currently used to evaluate transplanted kidneys are ultrasound (US), Doppler, computed tomography (CT), scintigraphy, intravenous urography (IVU), contrast angiography and magnetic resonance imaging (MRI) [1].

MRI with its different applications including MRA and MRU remains an attractive modality when compared with US or RNI because of superior contrast resolution, multiplanar capability and lack of operator dependence. These advantages has evolved into an excellent alternative means for the diagnosis of most renal transplantation problems and for the examination of the living related donor [2].

The evaluation of renal perfusion with MR imaging has become feasible with the development of rapid acquisition techniques, which provide adequate temporal resolution to monitor the rapid signal changes during the first passage of the contrast agents in the kidneys. Measurements of signal intensity in three regions of interests (cortex, medulla, renal pelvis) are taken resulting in a graphic description of the dynamics of the contrast enhancement [2].

Qualitative assessment of the renal function by this method has shown differences in the curves pattern between well functioning kidneys and pathologic kidneys. Furthermore studies proved that functional MRI could discriminate between acute rejection, acute tubular necrosis (ATN) and cyclosporine toxicity in post transplantation patients undergoing renal failure [3].

Patients and Methods

Thirty nine renal transplant recipients (29 males and 10 females), all patients were referred 3 months to 4 years following their transplants. Their age range was 18 to 65 years with a mean age of 40±11 years were referred for assessment of deteriorating renal function (31 patients) or other reasons as pain or swelling at the site of the graft, fever or hypertension (8 patients). The study was done in a alfa scan Radiology Center during March 2012 to July 2013. Each patient signed consent for participating in the study. All patients underwent a full MRI examination, including conventional MR, magnetic resonance angiography (MRA) and magnetic resonance renography (MRR) examinations. Four patients who had suspected ureteric or pelvicalyceal abnormalities were examined in addition by MR urography (MRU).

Ultrasound and Doppler studies, renal scan were also done for all cases. The final diagnosis used for reference was based on graft biopsy (20 cases), constellation of clinical and laboratory data, or clinical response to specific treatment for the other 19 cases.

MR imaging examination protocol:

MR imaging was performed on a 1.5T MR system (Philips) operating at 1.5T using a body coil. An axial, coronal and sagittal T1WI locator was performed upon which the rest of the examination was planned, as follows:

A- T1 weighted images of the pelvis (from the level of the upper border of the renal graft down to the urinary bladder neck) by use of a non-fat suppressed magnetization gradient echo technique (TR/TE/slice thickness/n = 600/19/10mm/15) in the coronal plane, and matrix size was 128x128.

B- T2 weighted images (planned on the coronal images) by means of the fast spin echo technique (TR/TE/slice thickness/n = 1600/100/10mm/25) in the axial plane. The scan time was 1.52m.

C- Precontrast imaging was performed as a baseline image.

D- Gd-DTPA (2ml, 0.5mmol/ml) (Magnevist, Schering, Germany) was injected intravenously as a bolus, followed by 10ml of saline to insure the passage of the contrast, and Dynamic imaging was performed simultaneously at the same place for 128 images at a rate of 1 image/second, followed by one image every 10 seconds for 1 minute (TR/TE/FA/slice thickness /FOV/n = 6.9/2.0/8/10mm/375/128).

E- 3D Phase contrast MRA to evaluate the renal arteries, renal perfusion and renal veins, was started approximately 4 minutes following the
gadolinium administration (TR/TE/FA/n = 15/5/15/3), with a field of view = 32cm; matrix = 256x128; velocity encoding along the axes at 50-90cm/s; scan time = 4 minutes.

F- After 10 minutes from the contrast administration another set of dynamic MR scans were performed at the same place, one image every 10 seconds for 1 minute to assess the renal excretory function.

G- 3D gradient echo contrast enhanced MR urography was done in four patients with suspected ureteric or pelvicalyceal abnormalities.

MRI data analysis:
Measurement of the renal size, shape, size of pyramids, the size of the collecting system and the presence of focal parenchymal changes were assessed on the baseline T1 and T2 weighted images.

Cursors were placed on the region of interest (ROI) on the renal cortex (CX), renal medulla (M) and the renal pelvis (P). Time-intensity curves were plotted for each ROI in each patient, and the mean curves of signal intensity vs. time curves were plotted in all recipients.

MRA and MRU source and reconstructed images were used for assessment of vascular and urological complications.

Results
Thirty nine renal transplant recipients (29 males and 10 females) their age range was 18 to 65 years with a mean age of 40±11 years were included in the study all patients were referred 3 months to 4 years following their transplants. According to final diagnosis after biopsy, constellation of clinical and laboratory data, clinical response to specific treatment, Nine (9/39) 23% had normal functioning renal allograft, and 30 (30/39) 77% with renal graft complications. Five patients had acute rejection (5/39) 12.8%, eight patients showed cyclosporine toxicity (8/39) 20.5%, four patients proved to have chronic graft nephropathy (4/39) 10.3%, two patients had acute tubular necrosis (2/39) 5.1%, one patient had evidence of grade II renal artery stenosis (1/39) 2.6%, two patients showed hydronephrosis and two had renal stones (2/39) 5.1%. Perinephric collections were seen in 5 patients (5/39) 15.5%, Table (1).

Considering the nine patients with normal renal allografts; they demonstrated cortical signal intensity versus time curves that showed a rapid increase in the intensity, with a significant peak occurring within the first 60 seconds of the dynamic scans. Peaks of the medulla occurred later than those of the cortex, occurring within the range from 85 to 230 seconds. The cortical and medullary curves were seen to be converging to meet by the end of the first 2 minutes, where the medullary curve is seen to be higher than that of the cortex.

The peaks of the renal pelvis occurred after 3 minutes from the onset of the gadolinium injection, and then reaches a plateau for about 10 minutes before its downslope (Fig. 1).

Five patients with acute rejection demonstrated a blunted upraise of the cortical and medullary curves with no definite peak detected. The medullary curve maintained a constant distance from the cortical curve throughout the dynamic study, and the amplitude of these two curves was significantly lower than that seen in the normal group. The renal pelvis curve showed a peak rise in the signal intensity at the same time corresponding with the normal group, but with lower amplitude Fig. (2).

The eight patients with cyclosporine toxicity showed low to normal amplitude, normal upraise of the early phases of both the cortical and medullary curves. The signal peak in these cases was significantly higher than those seen in the acute rejection group. There was an earlier medullary peak than the cortical peak in most of the examined cases. There was no significant gap seen in between the cortical and medullary curves throughout the dynamic study. The renal pelvis signal intensity measurements, on the other hand, did not show the sharp peak that was seen in cases of the normal or the acute rejection cases and the upstroke was seen to be very gradual throughout the dynamic study denoting delayed excretion (Fig. 3) for Male patient 39 years old, had his transplant 2 weeks prior to the examination, from a living non-related donor. He was complaining of a slight elevation of his renal functions (Cr.=2.1ml).

Table (1): Final diagnosis of the 39 renal allografts.

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>9</td>
<td>23</td>
</tr>
<tr>
<td>Acute rejection</td>
<td>5</td>
<td>12.8</td>
</tr>
<tr>
<td>Cyclosporine toxicity</td>
<td>8</td>
<td>20.5</td>
</tr>
<tr>
<td>Chronic graft nephropathy</td>
<td>4</td>
<td>10.3</td>
</tr>
<tr>
<td>Acute tubular necrosis</td>
<td>2</td>
<td>5.1</td>
</tr>
<tr>
<td>Renal artery stenosis</td>
<td>1</td>
<td>2.6</td>
</tr>
<tr>
<td>Hydronephrosis</td>
<td>2</td>
<td>5.1</td>
</tr>
<tr>
<td>Renal stones</td>
<td>2</td>
<td>5.1</td>
</tr>
<tr>
<td>Perinephric collections</td>
<td>6</td>
<td>15.5</td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>100</td>
</tr>
</tbody>
</table>
Four patients with chronic graft rejection included in the current study, demonstrated a deep initial decrease in the signal intensities in all the three curves, with no definite peaks seen in any of them. The cortical and medullary curves had a lower amplitude than that seen in the normal functioning group with an increase in the signal intensity seen in the later phases (delayed excretion of the contrast). The cortex and medullary curves converged toward each other as in the normal curve, but they gave closer readings than those seen in the normal curve. The Amax showed the best sensitivity and specificity in these cases (100% and 56% respectively).

Fig. (1): Female patient, 34 years old, had her transplant 3 years prior to the examination, from a living non-related donor. She was coming for follow-up (Cr=1.6 ml). A- Dynamic T1WI scans through the renal hilum. Time vs signal intensity curves from the cortex, medulla and renal pelvis, in the first 128 seconds B- The 3rd minute (C) and After 10 minutes D- The time versus intensity curves taken from the cortex, medulla and the renal pelvis appear normal with normal cortical peak, preceding the medullary peak.

Fig. (2 A): Male patient, 34 years old, had his transplant 1 year prior to the examination, from a living non-related donor. He had an elevated creatinine level (Cr=2) Dynamic MRI of the renal graft at the level of the renal hilum.
Fig. (2 B): Time vs SI dynamic MR curves from the cortex (A) at the 1st 2 min. (A1), the 3rd min. (A2) and after 10 min. (A3), medulla (B) at the 1st 2 min. (B1), the 3rd min. (B2) and after 10 min. (B3) and renal pelvis (C) at the 1st 2 min. (C1), the 3rd min. (C2) and after 10 min. (C3). The time versus intensity curves taken from the cortex, medulla and the renal pelvis appeared low with respective peak signal maximum values at the respective peak times showing markedly reduced maximum value of SI in all the curves, with delay in the maximum time of the cortex and medulla suggestive of acute rejection.

Fig. (3 A-D): Fig. (3a): Grey Scale US examination showing a normal US morphological appearance of the graft. Fig. (3b): Color Doppler US showing normal intrarenal vasculature. Fig. (3c): Coronal T1W1 showing normal MRI appearance of the graft in the right iliac fossa. Fig. (3d): Axial T2W1 showing normal MRI appearance of the graft located in the right iliac fossa.
The 3D PC MRA technique was done in all patients and it showed the anastomosis and the renal transplant artery well, but the limited axial field of view made the evaluation of the larger vessels difficult. One patient had evidence of grade 2 renal artery stenosis at the site of the vascular anastomosis which was apparent in the MIP reconstructed images, his Doppler showed marked discrepancy between the PSV at the hilum and that at the site of renal anastomosis which was highly suggestive of RAS, yet with no evidence of decreased intrarenal perfusion Fig. (4). This 36 years old male patient had renal transplant 3 years prior to the examination. He was hypertensive (150/95mmHg) and was suspected of having renal artery stenosis. The MR Renography showed normal time versus intensity curves taken from the cortex, medulla and the renal pelvis.
Fig. (4 C-F): Dynamic MRI images of the renal graft at the level of the renal hilum (C) Time vs SI dynamic MR curves from the cortex (D) at the 1st 2min. (D1), the 3rd min. (D2) and after 10min. (D3), medulla (E) at the 1st 2min. (E1), the 3rd min. (E2) and after 10min. (E3) and renal pelvis (F) at the 1st 2min. (F1), the 3rd min. (F2) and after 10min (F3). The time versus intensity curves taken from the cortex, medulla and the renal pelvis were normal.

Fig. (4-G): 3D volume rendering MRA showing the stenotic segment at the site of anastomosis (red arrow). The final diagnosis was grade 2 renal artery stenosis, with no affection of the renal function.
The two transplant recipients having pelvicalyceal dilatation who were examined by MRU, one showed compression of the dilated proximal ureters by a cystic structure (haematoma) and visualized the non-dilated ureter distal to the cyst. In the other case, the dilated upper calyx was visualized but the rest of the pelvicalyceal system was not identified.

Two patients with renal graft stones were examined by MRI, there was no associated pelvicalyceal dilatation noted, hence the urinary tract was insufficiently visualized by MRU, and the stones could not be identified.

Five patients showed perinephric collections; two urinomas, two hematomas and one lymphocele Fig. (5).

The MRI results (including conventional MRI, MRR, MRA and MRU) showed 100% sensitivity and 88.3% specificity in detection of the nine renal transplants which showed no complications, while the ultrasound and Doppler examination showed 96.3% sensitivity & 91.9% specificity and the radioisotopic scan showed a sensitivity of 100% and a specificity of 71.5%.

In the cases of acute rejection in this study, the MRI showed a sensitivity and specificity of 82.2% and 94.6% respectively, ultrasound showed a sensitivity and specificity of 75% and 78.7% respectively, while RNS showed a sensitivity and specificity of 80% and 78.9% respectively. MRI in cases of cyclosporine nephrotoxicity showed a sensitivity of 90.7% and a specificity of 92%, ultrasound showed a sensitivity of 70% and a specificity of 79.2%, while RNS showed a sensitivity of 70% and a specificity of 69.7%. Cases with chronic rejection showed 100% sensitivity and specificity by both MRI and RNS, while they showed a 92.3% sensitivity and 98.7% specificity by ultrasound and Doppler examinations. RNS showed high sensitivity in detection of cases of ATN with a sensitivity of 100%, while the two other modalities showed a 50% sensitivity in detection of these cases. In ATN as well, the specificity by MRI was 77.1%, by ultrasound was 80.2%, while by RNS was 68.3%.

The sensitivity and specificity of the MRI, US and radioisotopic scans in the detection of complications encountered in the thirty renal transplants is displayed in Table (2).

<table>
<thead>
<tr>
<th></th>
<th>MRI</th>
<th>US &amp; Doppler</th>
<th>Radioisotopes</th>
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<tbody>
<tr>
<td>AR</td>
<td>82.2%</td>
<td>94.6%</td>
<td>75%</td>
</tr>
<tr>
<td>CsA Toxicity</td>
<td>90.7%</td>
<td>92%</td>
<td>70%</td>
</tr>
<tr>
<td>CAN</td>
<td>100%</td>
<td>100%</td>
<td>92.3%</td>
</tr>
<tr>
<td>ATN</td>
<td>50%</td>
<td>77.1%</td>
<td>50%</td>
</tr>
<tr>
<td>Hydronephrosis</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Stones</td>
<td>0%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Collections</td>
<td>100%</td>
<td>76.7%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Fig. (5-A): Grey Scale US examination showing the multilocular cystic collection situated between the graft & the urinary bladder.

Fig. (5-B): Fat supressed Coronal T2WI showing the high signal cystic collection, proved to be a lymphocele. MRR was normal.
Discussion

Given the prolonged survival now possible for renal transplant recipients because of newer medical and surgical techniques, it is increasingly important to use non-invasive methods of screening these patients and evaluating their symptoms or signs of complications. By understanding the appearances of potential complications as depicted with the most commonly used modalities, radionuclide imaging and ultrasound, and the newer functional MRI techniques; early diagnosis of complications may lead to therapeutic interventions that prolong the life of the graft [4].

Gd-DTPA MR renography provides a good basis for perfusion and functional studies with MRI. Dynamic MRI with injection of Gd-DTPA is a non-invasive procedure that permits visual demonstration and computer-aided analysis of the contrast agent’s passage from the circulation to various regions of the allograft and the urinary bladder. This method also provides quantitative dynamic functional data that can be analyzed to assess perfusion in the renal allograft. It can help to assess the functional and morphologic state of the renal allograft and to differentiate various causes of renal allograft dysfunction [5].

MR renography (MRR) is a dynamic MR examination that provides functional information of the kidney and renal transplant in terms of changes in signal intensity of the cortex, medulla and pelvicalyceal system after contrast injection. Signal intensity curves in various areas of interest in the kidney can be plotted as a function to time to allow comparison between various alterations in renal perfusion in allograft dysfunction [6].

This study included 39 renal transplant recipients (29 males and 10 females), with a mean age of 40±11 years. According to final diagnosis after biopsy, constellation of clinical and laboratory data, clinical response to specific treatment, Nine (9/39) 23% had normal functioning renal allograft, and 30 (30/39) 77% with renal graft complications. Five patients had acute rejection (5/39) 12.8%, eight patients showed cyclosporine toxicity (8/39) 20.5%, four patients proved to have chronic graft nephropathy (4/39) 10.3%, two patients had acute tubular necrosis (2/39) 5.1%, one patient had evidence of grade II renal artery stenosis (1/39) 2.6%, two patients showed hydrenephrosis and two had renal stones (2/39) 5.1%. Perinephric collections were seen in 5 patients (5/39) 15.5%.

The MR renography curves in the patients with acute rejection in this study were in agreement with the curves of Sharma et al., 1995 [7] where there was a blunted upraise of cortical and medullary curves with no definite peaks detected. The medullary curve maintained a constant distance from the cortical curve throughout the dynamic study, and the amplitude of these two curves were lower than that seen in the normal cases.

Our results were in agreement with Sommerer et al., 2002 [8] findings where the patients with cyclosporine nephrotoxicity showed low amplitude, blunted upraise of the early phases of both the cortical and medullary curves, as compared to the normal grafts. However, they were higher than those seen in the acute rejection group. There was an earlier medullary peak than the cortical peak. There was no significant gap seen in between the cortical and medullary curves throughout the dynamic study.

The one patient had evidence of grade 2 renal artery stenosis at the site of the vascular anastomosis upon MRA examination, which was apparent in the MIP reconstructed images. Sharfuddin, 2014 [9] stated that Some reports have found that MR angiography correlated well with the gold standard digital subtraction angiography, whereas others have reported that compared with color Doppler US and digital subtraction angiography, MR angiography may be of limited diagnostic value for diagnosing renal artery stenosis because of an up to 75% false-positive rate with MR angiography. This is thought to be due to a major intravoxel phase dispersion, which may result from tortuosity of the vessel or a sharp angulation between the artery and the parent vessel.

Our study showed ultrasound and Doppler examinations were the least sensitive in detection of renal transplants with no complications (96.3%) yet they were the most specific (91.9%), as compared to the MRI and RNS studies (100% sensitivity each with 88.3% and 71.5% specificity, respectively).

In the cases of acute rejection in this study, the MRI showed a sensitivity and specificity of 82.2% and 94.6% respectively, ultrasound showed a sensitivity and specificity of 75% and 78.7% respectively, while RNS showed a sensitivity and specificity of 80% and 78.9% respectively.

MRI in cases of cyclosporine nephrotoxicity showed a sensitivity of 90.7% and a specificity of 92%, ultrasound showed a sensitivity of 70% and
a specificity of 79.2%, while RNS showed a sensitivity of 70% and a specificity of 69.7%.

Cases with chronic allograft nephropathy showed 100% sensitivity and specificity by both MRI and RNS, while they showed a 92.3% sensitivity and 98.7% specificity by ultrasound and Doppler examinations.

RNS showed high sensitivity in detection of cases of ATN with a sensitivity of 100%, while the two other modalities showed a 50% sensitivity in detection of these cases. The specificity by MRI was 77.1%, by ultrasound was 80.2%, while by RNS was 68.3%.

From these findings we can show that MRI is more accurate than RNS and US and Doppler examinations in detection of parenchymal renal transplant complications.

We also agree with Brown et al., 2000 [10] who stated that US and Doppler are more accurate in detection of urological complications than RNS, where the ultrasound and MRI showed a sensitivity and specificity of 100% for the detection of cases with hydropnephrosis as well as their causative agents, while RNS was only sensitive in the detection of hydropnephrosis. Also cases with renal stones were detected by ultrasound examination (sensitivity 100%), but neither by MRI or RNS examinations could detect them.

Moreover, in the cases with perinephric collections, both MRI and ultrasound showed sensitivity of 100%, while RNS showed a sensitivity of 51.6%, yet the ultrasound was more specific (80.7% specificity) in detection of the nature of the collection (with the exception of cases of urinomas, where RNS is very specific) as compared with the MRI (46.7% specificity). These results are concordant with Park et al., 2007 [11] where the study concluded that the US characteristics of peritransplant fluid collections are entirely non specific and diagnosis may be made only by percutaneous aspiration.

Blondin et al., 2009 [12], showed that contrast enhanced MRU yielded a sensitivity of 85.7% (non enhanced-MRU 76.2%), and a specificity of 83.3% (non enhanced-MRU: 73.7%), however statistical significance was not reached. The subjective image quality was significantly better in contrast enhanced MRU.

By this we can propose that ultrasound and Doppler examination should be done as a screening modality for all renal transplant recipients whether symptomatizing or not, yet this technique is operator dependent and should be done only by an experienced radiologist, as subtle abnormalities could be easily missed.

A full MRI examination, including conventional MRI, MRR, MRA and MRU will give the treating physician a full documented report about the renal allograft morphology and function providing a one-stop technique for evaluation of all possible complications. However, it is expensive and not yet readily available in a lot of medical centers.

However, in cases of renal transplant dysfunction, RNS is still the method of choice in differentiating cases of acute rejection from ATN and chronic renal graft rejection. Hence, the combination of ultrasound, Doppler and RNS examinations can give comparable results as those given by MRI, yet they are more available and at a much a lower cost for the patient.

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