Section: Miscellaneous

Original Research Article

PRESERVING THE LIFELINE: AN INTEGRATED MULTIMODALITY DIAGNOSTIC IMAGING AND INTERVENTIONAL RADIOLOGY APPROACH TO EARLY COMPLICATIONS OF RENAL TRANSPLANTATION

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ABSTRACT

Background: Renal transplantation is the standard of care for end-stage renal disease (ESRD), but the early postoperative period is frequently complicated by events that threaten allograft survival. An integrated diagnostic and interventional radiology workflow are crucial for the timely and effective management of these complications. This study aims to validate a clinical pathway that synergizes multimodality imaging with minimally invasive, image-guided interventions.

Materials and Methods: This prospective, single-center observational study enrolled 84 consecutive recipients of renal allografts. A standardized, tiered diagnostic protocol was implemented, beginning with gray-scale and Doppler ultrasound (US) as the primary surveillance tool. Equivocal findings or specific clinical questions prompted second-line imaging with multi-detector computed tomography (MDCT) or magnetic resonance imaging (MRI). A spectrum of image-guided interventional procedures, including graft biopsy, percutaneous drainage of collections, and urological interventions, were performed as the definitive diagnostic or therapeutic step based on integrated clinical and imaging findings.

Results: The cohort was predominantly male (82.1%), with the largest age demographic being 21-39 years (70.2%). Chronic kidney disease of unknown etiology was the leading indication for transplant (61.9%). Early complications were frequent, with perinephric collections and biopsy-proven graft rejection each identified in 15.5% of patients. Doppler US revealed a raised Resistive Index (RI>0.8) in 18 patients (21.4%), a finding that served as a robust, albeit nonspecific, indicator of graft distress, effectively triaging patients for further action. A total of 30 major interventional radiology procedures were performed in 25 patients (29.8%), including 14 US-guided biopsies confirming rejection, 11 percutaneous drainages of symptomatic collections, and 2 successful ureteral stricture dilatations.

Conclusion: The contemporary management of renal transplant recipients hinges on a synergistic partnership between diagnostic and interventional radiology. This study validates a clinical pathway where multimodality imaging, led by Doppler US, effectively stratifies risk and identifies complications, while minimally invasive, image-guided interventions provide safe and definitive diagnosis and therapy. This integrated approach is fundamental to salvaging graft function, reducing patient morbidity, and avoiding the need for open surgical revision.

Keywords: Renal Transplantation; Postoperative Complications; Interventional Radiology; Multimodality Imaging; Doppler Ultrasonography; Graft Rejection; Image-Guided Biopsy; Percutaneous Drainage.

INTRODUCTION

1.1. The Modern Era of Renal Transplantation: Success and Enduring Challenges

Kidney transplantation stands as the definitive therapeutic milestone for patients with end-stage renal disease (ESRD), offering a profound improvement in both quality of life and long-term survival compared to chronic dialysis.[1-5] Over the past half-century, the field has been revolutionized by parallel advancements in surgical precision, the sophistication of immunosuppressive regimens, and the capabilities of diagnostic imaging. Consequently, renal transplantation has evolved into the most common and successful solid organ transplant procedure performed worldwide.[2,6-12] This success has fundamentally shifted the clinical focus from the viability of the procedure itself to the long-term preservation of the allograft. This creates a new set of clinical challenges centered on vigilant surveillance and the effective management of postoperative complications, underscoring the necessity of a robust, integrated radiology workflow not merely as a supportive service, but as an essential component of modern transplant care.

The Spectrum of Post-Transplantation Complications: Despite these remarkable successes, the post-transplantation period remains a critical window fraught with potential complications that can jeopardize graft function and patient health. Postoperative complications occur in approximately 12% to 25% of all recipients and represent a major cause of morbidity and graft loss.[3,13-18] These complications can be broadly classified by their nature—vascular, urological, parenchymal, and perigraft collections—and by their timeline of onset.[19-30] Vascular complications include transplant renal artery stenosis (TRAS), thrombosis, pseudoaneurysms, and arteriovenous fistulas (AVFs).[7] Urological issues, such as ureteral obstruction from strictures and urinary leaks, are often related to ischemia of the distal ureter.[30] Parenchymal dysfunction, most critically acute rejection (AR) and acute tubular necrosis (ATN), presents a significant diagnostic challenge.[19] Finally, perigraft fluid collections, such as hematomas, lymphoceles, urinomas, and abscesses, are common findings that can become clinically significant. The unique, heterotopic placement of the allograft in the iliac fossa creates a distinct surgical anatomy that predisposes it to this specific set of challenges.[8]

The Paradigm Shift: From Diagnostic Imaging to an Integrated Interventional Workflow

In this complex clinical landscape, the role of the radiologist has evolved from a purely diagnostic consultant to an essential, hands-on member of the multidisciplinary transplant team.[13] The paradigm has shifted towards an integrated workflow where diagnostic imaging and minimally invasive therapy are intrinsically linked. This begins with multimodality imaging, a tiered approach spearheaded by Doppler ultrasound (US) as the primary surveillance tool.[11] US is non-invasive, cost-effective, and provides real-time anatomical and hemodynamic data at the bedside. For more complex diagnostic dilemmas, computed tomography (CT) and magnetic resonance imaging (MRI) offer superior spatial resolution and tissue characterization, clarifying ambiguous US findings and guiding subsequent management.[9]

Crucially, this diagnostic pathway now seamlessly transitions to interventional radiology (IR), which offers a robust portfolio of minimally invasive, image-guided procedures to manage the majority of post-transplant complications.[4] Endovascular techniques, such as percutaneous transluminal angioplasty (PTA) and stenting, have become the first-line treatment for vascular stenoses.[5,31-35] Percutaneous drainage is the standard of care for symptomatic fluid collections, and image-guided nephrostomy and stenting can effectively resolve urological obstructions.[4,28] Furthermore, the definitive diagnosis of parenchymal dysfunction, such as acute rejection, relies on the cornerstone IR procedure of US-guided core needle biopsy.[18] This integrated diagnostic-interventional model has fundamentally altered post-transplant care, offering effective solutions that minimize patient morbidity, shorten hospital stays, and preserve graft function, often obviating the need for high-risk open surgical revision.[6]

Aims and Objective

The primary aim of this study was to conduct a comprehensive, prospective evaluation of an integrated diagnostic and interventional radiology workflow for the detection, characterization, and management of early complications following renal transplantation.

The primary objective was to correlate multimodality imaging findings with definitive histopathological and procedural outcomes, thereby validating the clinical pathway and demonstrating the central role of interventional radiology in providing definitive diagnosis and therapy for this patient population.

MATERIALS AND METHODS

Study Design, Setting, and Ethical Considerations: This prospective, single-center observational study was conducted at Mahatma Gandhi Medical College and Hospital, Jaipur, a tertiary care university hospital. The study protocol received full approval from the Institutional Ethical Committee, and written informed consent was obtained from all participants prior to enrollment.

Patient Population: A total of 84 consecutive patients who underwent renal transplantation were enrolled in the study. The sole inclusion criterion was having received a renal allograft at the institution during the study period. The only exclusion criterion was the refusal to provide consent.

The Tiered Diagnostic Imaging Protocol: A standardized, tiered imaging algorithm was employed for all patients, beginning with US as the primary modality.

Tier 1: Ultrasound (US) and Doppler Examination: All initial and follow-up surveillance examinations were performed using a Fujifilm Sonosite Edge II system with a 2-5 MHz curvilinear transducer. The gray-scale evaluation assessed graft size, parenchymal echotexture, cortico-medullary differentiation (CMD), the pelvicalyceal system, and the presence of any perigraft fluid collections. This was immediately followed by a comprehensive color and spectral Doppler examination to assess the patency and flow dynamics of the main transplant artery and vein, their anastomoses, and intrarenal vessels (segmental and interlobar arteries). The key hemodynamic parameter calculated was the Resistive Index (RI), defined as RI=(PeakSystolicVelocity−EndDiastolicVelocity)/PeakSystolicVelocity. An RI>0.8 was considered a nonspecific but significant indicator of graft dysfunction, while an RI<0.6 was considered normal.

Tier 2: Cross-Sectional Imaging (CT and MRI): CT and MRI were utilized as problem-solving tools for equivocal US findings or to answer specific clinical questions. All CT scans were performed on a 128-slice GE Optima multidetector scanner. Non-contrast CT (NCCT) was the preferred method for characterizing perinephric collections (especially for hemorrhage) and detecting urolithiasis. When vascular evaluation was required in patients with adequate graft function, CT Angiography (CTA) was performed using 1.5-2 ml/kg of non-ionic iodinated contrast. MRI was used selectively, with MR Pyelography being the primary indication for delineating the collecting system in cases of hydronephrosis where the cause was not clear on US.

The Interventional Radiology Armamentarium: Based on the synthesis of clinical data and imaging findings, a range of interventional procedures were performed as the definitive diagnostic or therapeutic step. All interventional procedures were performed in a dedicated digital subtraction angiography (DSA) suite.

Image-Guided Biopsy: Renal allograft biopsy was the gold standard for diagnosing parenchymal dysfunction. All biopsies were performed percutaneously under real-time US guidance using an 18-gauge core biopsy needle to obtain tissue for histopathological examination.

Percutaneous Drainage and Aspiration: Symptomatic or suspected infected perigraft fluid collections (e.g., hematomas, abscesses, lymphoceles, urinomas) were managed with US- or CT-guided percutaneous aspiration for diagnosis, often followed by the placement of an 8-12 Fr pigtail drainage catheter for therapeutic drainage.

Urological Interventions: Obstructive uropathy, such as that caused by ureteral strictures, was managed via a percutaneous approach. This typically involved initial US-guided nephrostomy for urinary diversion, followed by antegrade balloon ureteroplasty and/or placement of a double-J stent across the stricture.

Endovascular Procedures: While no cases in this cohort required endovascular therapy during the study period, the institutional protocol includes catheter-based angiography (DSA) for definitive diagnosis of vascular complications like TRAS, with PTA and stenting as the primary treatment modality.

Data Collection and Statistical Analysis: All demographic, clinical, laboratory, imaging, and procedural data were prospectively collected. Descriptive statistics were used to analyze the data, with frequencies and percentages calculated for all categorical variables.

RESULTS

Cohort Demographics and Baseline Clinical Characteristics

The study population of 84 patients showed a significant male predominance (n=69, 82.1%). The 21-39 year age group was the largest, comprising 59 recipients (70.2%). The leading cause of ESRD necessitating transplantation was chronic kidney disease of unknown etiology (n=52, 61.9%), followed by chronic glomerulonephritis (n=13, 15.5%) and systemic hypertension (n=11, 13.1%). All grafts (100%) were from live donors, and all utilized an end-to-side vascular anastomosis technique. The baseline characteristics of the study population are detailed in [Table 1].

Table 1: Baseline Demographics and Clinical Characteristics of Study Population (n=84)

Characteristic	Category	Number of Patients (n)	Percentage (%)
Age Group	<20 Years	5	6.0
	21-39 Years	59	70.2
	40-59 Years	18	21.4
	≥60 Years	2	2.4
Gender	Male	69	82.1
	Female	15	17.9
Indication for Transplant	Chronic Kidney Disease	52	61.9
	Chronic Glomerulonephritis	13	15.5
	Systemic Arterial Hypertension	11	13.1
	Diabetic Nephropathy	4	4.8
	Polycystic Kidney Disease	2	2.4
	Other	2	2.4
Donor Type	Live Donor	84	100

Anastomosis Type	End-to-Side	84	100

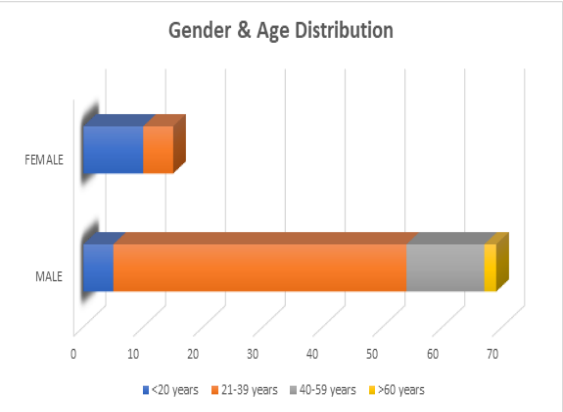


Figure 1: Gender and Age Distribution of the Patient Cohort, n=84

The Landscape of Early Post-Transplant Complications: A substantial number of patients experienced early postoperative complications requiring diagnostic workup and, frequently, intervention. The most common major complications were perinephric collections and graft rejection, each affecting 13 patients (15.5% of the cohort). This equal incidence of a primarily structural complication (collections) and a purely parenchymal/immunological one (rejection) is a critical finding. It highlights the necessity for a robust diagnostic triage system, as the clinical presentation (e.g., rising serum creatinine) can be identical for problems requiring vastly different management pathways—percutaneous drainage versus medical anti-rejection therapy. Significant blood loss requiring transfusion occurred in 12 patients (14.3%), and other renal parenchymal issues distinct from rejection were diagnosed in 13 patients (15.5%). The full spectrum of complications is presented in [Table 2].

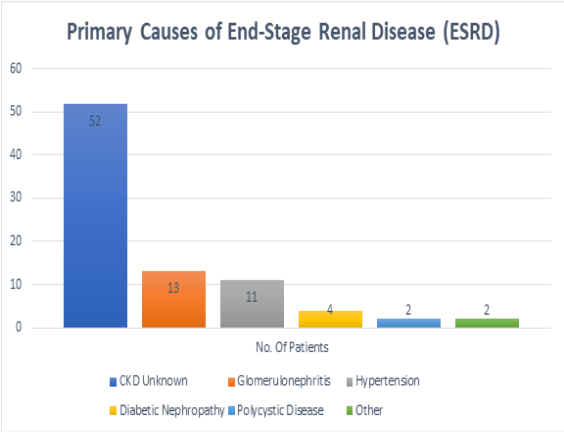


Figure 2: Primary Causes of End-Stage Renal Disease (ESRD).

Table 2: Spectrum and Frequency of Observed Post-Transplant Complications (n=84)

Complication Category	Finding	Number of Patients (n)	Percentage (%)
Perinephric Collection	Present	13	15.5
Graft Rejection (Biopsy-Proven)	Present	13	15.5
Blood Loss (Clinically Significant)	Present	12	14.3
Other Renal Parenchymal Complication	Interstitial Nephritis	5	6.0
	Acute Tubular Injury	4	4.8
	Glomerulonephritis	2	2.4
	Pyelonephritis	1	1.2
	Focal Segmental Glomerulosclerosis	1	1.2
Pulmonary Complication	Pulmonary Edema	3	3.6
	Bacterial Pneumonia	2	2.4
	Pleural Effusion	2	2.4
	Viral Pneumonia	1	1.2

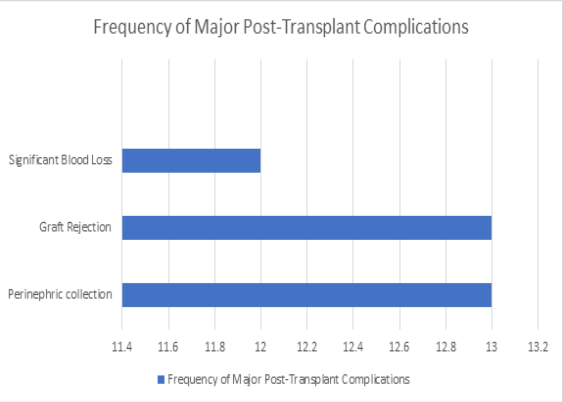


Figure 3: Frequency of Major Post-Transplant Complications.

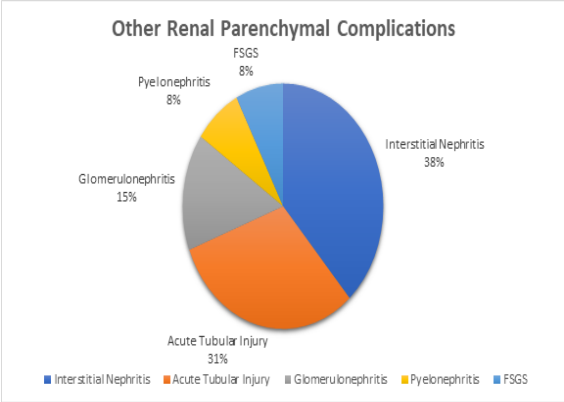


Figure 4: Breakdown of Other Parenchymal Complications.

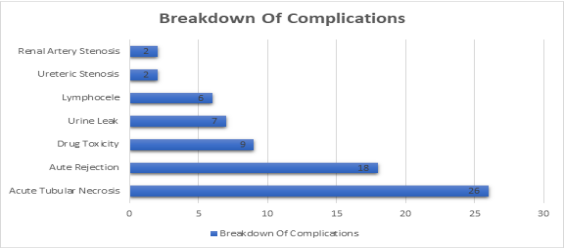


Figure 5: Breakdown of Complications.

The Diagnostic and Interventional Workflow in Action:

The tiered imaging and intervention strategy proved highly effective. A total of 30 major interventional radiology procedures were performed in 25 patients (29.8% of the cohort), underscoring the critical and frequent role of IR in managing this patient population. The types and indications for these procedures are summarized in [Table 3].

Table 3: Summary of Interventional Radiology Procedures Performed (n=30 procedures in 25 patients)

Procedure Type	Indication	Number of Procedures
US-Guided Core Biopsy	Suspected Graft Rejection / Parenchymal Dysfunction	14
US/CT-Guided Collection Drainage	Symptomatic/Infected Hematoma, Urinoma, Abscess	11
Percutaneous Nephrostomy	Obstructive Uropathy / Urinary Diversion for Leak	3
Antegrade Balloon Ureteroplasty	Distal Ureteral Stricture	2
Total Procedures		30

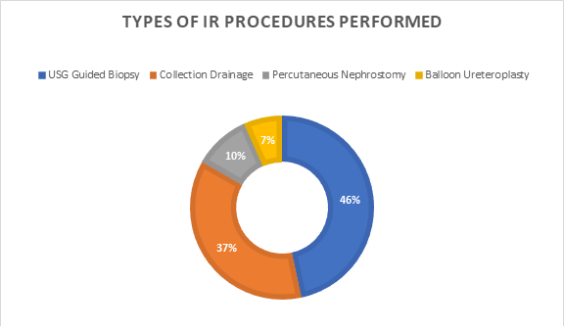


Figure 6: Distribution of Interventional Radiology Procedures.

4.4. Key Imaging Findings and Histopathological Correlation

Doppler US was the most impactful initial examination. An elevated RI (>0.8) was found in 18 patients (21.4%). Of these 18 patients, 12 ultimately underwent biopsy, which confirmed rejection or significant ischemic injury in all 12 cases. This highlights the RI's role as a powerful, though non-specific, triage tool. In one patient, Doppler US was immediately diagnostic, showing absent flow in the renal vein, confirming renal vein thrombosis.

Cross-sectional imaging was vital for problem-solving. NCCT confirmed and delineated the extent of perinephric collections in 11 patients, guiding the decision for percutaneous drainage. In the two patients with hydronephrosis on US, MR Pyelogram definitively identified a distal ureteral stricture, allowing for targeted and successful percutaneous intervention.

Histopathology from the 14 biopsies provided the definitive diagnosis of parenchymal disease. The most common finding was a mixed acute cellular and antibody-mediated rejection (n=7), followed by isolated antibody-mediated rejection (n=3) and isolated acute cellular rejection (n=2). The correlation between a raised RI and the need for biopsy is detailed in [Table 4].

Table 4: Correlation of Raised Resistive Index (RI>0.8) with Biopsy-Proven Graft Pathology (n=14 Biopsies)

Biopsy Finding	Total Biopsies (n)	Number with Raised RI
Acute Cellular & Antibody Mediated Rejection	7	7
Antibody Mediated Rejection	3	2
Acute Cellular Mediated Rejection	2	2
Ischemic Graft Injury	1	1
Thrombotic Microangiopathy	1	0
Total	14	12

Case Series Findings: Illustrative Interventional Management

The following cases illustrate the practical application of the integrated diagnostic and therapeutic workflow.

Case 1: Perinephric Urinoma

A patient on post-operative day 11 presented with graft site pain. US revealed a large perinephric collection (Figure 1). US-guided aspiration yielded fluid with high creatinine levels, confirming a urinoma from a urinary leak. This diagnosis prompted minimally invasive management. A percutaneous nephrostomy was placed to divert urine, followed by antegrade placement of a double-J ureteral stent across the leak site, leading to complete resolution without the need for open surgery.[1]

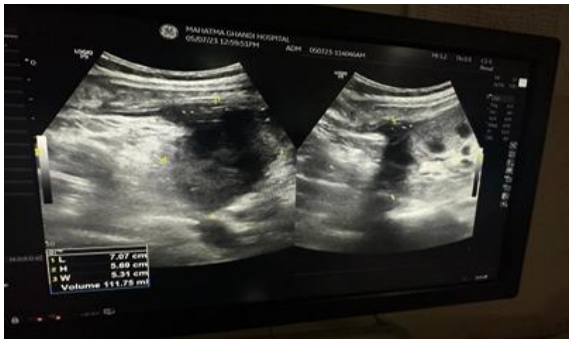


Figure 7: Perinephric Urinoma

Caption: Gray-scale ultrasound image of a transplanted kidney on post-operative day 11 shows a large, well-defined anechoic perinephric collection (measured) consistent with a urinoma.

Case 2: Acute Graft Rejection

A patient presented with rising serum creatinine. Doppler US demonstrated a swollen graft and a significantly raised resistive index (Figure 2). These findings are non-specific but effectively excluded a surgically correctable cause (like obstruction), thereby triaging the patient for immediate US-guided core needle biopsy. The biopsy confirmed acute rejection, allowing for prompt initiation of antirejection therapy.[1]

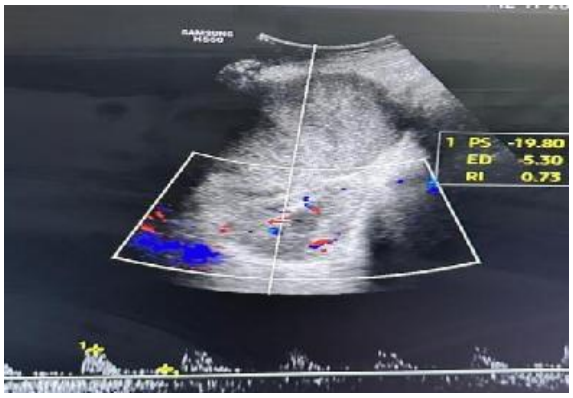


Figure 8: Acute Graft Rejection on Doppler Ultrasound

Caption: Color and spectral Doppler image of a transplanted kidney shows loss of cortico-medullary differentiation and a raised resistive index (RI=0.73) & mildly reduced end diastolic pressure, suggestive of acute graft rejection and indicating the need for biopsy.

Case 3: Ureteral Stricture and Hydronephrosis

A patient presented with graft dysfunction weeks after transplant. US demonstrated moderate hydronephrosis (Figure 3). Antegrade pyelography via a percutaneous nephrostomy confirmed a distal ureteral stricture. The stricture was successfully treated with percutaneous balloon dilatation followed by the placement of an internal double-J stent, restoring normal urine flow and resolving the hydronephrosis.[1]

Figure 9: Ureteral Stricture with Hydronephrosis

Caption: Gray-scale ultrasound image shows moderate dilatation of the transplanted kidney's pelvicalyceal system and mild dilatation of proximal 3rd of transplanted ureter with abrupt narrowing and smooth tapering, suggestive of benign stricture at the distal end of distal.

Case 4: Transplant Renal Artery Stenosis (TRAS) on Doppler

A patient developed refractory hypertension two months post-transplant. Doppler US revealed classic findings of TRAS, including a peak systolic velocity exceeding 250 cm/s and a raised resistive index. While no patients in this study's early follow-up period required endovascular intervention, this case illustrates how Doppler US serves as the essential, non-invasive screening tool for this critical vascular complication. Such findings would trigger a referral for definitive catheter angiography and endovascular treatment with angioplasty and stenting.

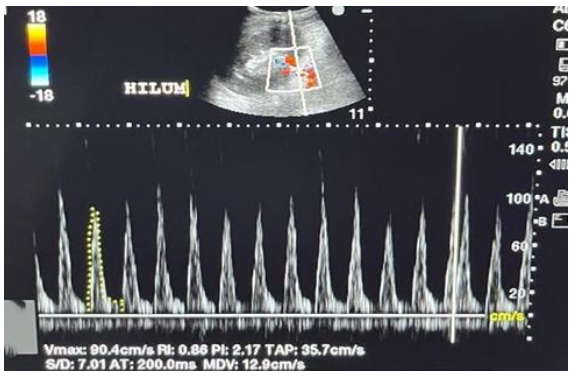


Figure 10: Transplant Renal Artery Stenosis

Caption: Color and spectral Doppler image of the transplant renal artery hilum shows a markedly raised resistive index (RI=0.86) and high peak systolic velocity & acceleration time, findings consistent with significant stenosis (main / anastomotic site) requiring endovascular treatment.

DISCUSSION

The Centrality of Interventional Radiology in Modern Transplant Care: This study provides a detailed snapshot of the modern, integrated management of early renal transplant complications, confirming that a significant proportion of recipients require advanced diagnostic imaging and minimally invasive intervention. The most striking finding is the sheer necessity of interventional radiology in post-transplant care. Nearly one-third of our cohort (29.8%) required at least one major IR procedure. This reflects a global shift in practice, where IR has become the primary modality for both diagnosing and treating a vast array of complications, displacing open surgery as the first-line option.[4,6]

- Vascular Complications: TRAS is the most common vascular complication, with a reported incidence of 1-23%.[26] Although no patients in our early follow-up cohort required intervention for TRAS, the established treatment pathway is endovascular, with PTA and stenting offering technical success rates of over 90% and excellent long-term graft survival.[27] Post-biopsy vascular injuries, such as AVFs and pseudoaneurysms, occur in up to 18% of biopsies. While most are

self-limiting, symptomatic lesions are effectively managed with superselective transcatheter coil embolization, a technique that boasts a technical success rate of 71-100% while preserving maximal renal parenchyma.[24]

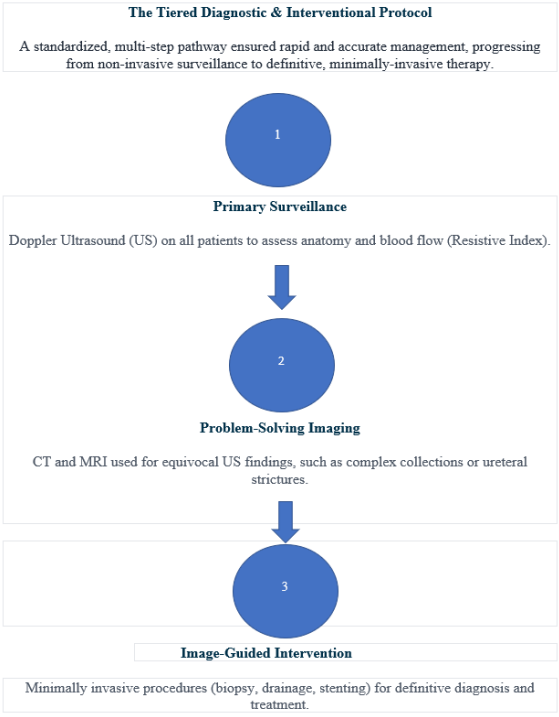
- Urological Complications: Ureteral stenosis and leaks occur in 2-10% of recipients, often due to ischemia of the distal ureter.[28] As demonstrated in our cohort, the management is primarily percutaneous. An initial nephrostomy relieves obstruction and diverts urine, followed by antegrade balloon dilatation and stenting, which has a success rate between 58% and 95%.[17,25] This approach effectively salvages the graft without the morbidity of surgical ureteral revision.
- Perigraft Fluid Collections: Fluid collections are common, but become clinically significant in 15-20% of cases. As our results show, US and CT are excellent for detection and characterization, but definitive diagnosis often requires percutaneous aspiration. For symptomatic or infected collections (abscesses, large hematomas, lymphoceles), percutaneous catheter drainage is the treatment of choice, with reported success rates exceeding 80%.[29]

Doppler Ultrasound as the Cornerstone of Surveillance and Triage: Our study confirms that the primary role of non-invasive imaging is to serve as an intelligent triage system that directs patients to the correct intervention. Doppler US is the undisputed workhorse of this system.[11] The Resistive Index (RI), while nonspecific, is a highly sensitive marker of underlying pathology. An elevated RI (>0.8) is a powerful indicator of intrarenal vascular impedance, which can be caused by rejection, ATN, or external compression.[33] In our study, a high RI had a strong positive predictive value for identifying patients who required a biopsy for definitive diagnosis, as shown in [Table 4]. Conversely, a normal RI is a reassuring finding that can help avoid unnecessary procedures.

The true clinical power of the RI is its binary function in decision-making. In the high-stakes environment of post-transplant care, a normal RI provides a degree of reassurance, allowing for de-escalation of care or consideration of non-urgent causes of graft dysfunction. A high RI, however, serves as an undeniable call to action. It compels the clinical team to immediately and systematically investigate for surgically or interventionally correctable causes like obstruction, significant collections, or vascular compromise. If these are absent, the high RI provides a strong, evidence-based rationale to proceed with a biopsy. This binary function simplifies a complex clinical picture and standardizes the response, which is a hallmark of an effective and efficient clinical pathway.[16]

Corroboration and Context: Comparing Findings with the Wider Literature: The incidence of complications observed in this study aligns well with rates reported in the broader literature. The finding of perinephric collections and acute graft rejection as the most frequent major adverse events, each affecting 15.5% of the cohort, falls squarely within the reported overall postoperative complication rates of 12% to 25% [3,22]. This consistency serves to validate the study's findings and confirms that the patient population and clinical challenges encountered are representative of those at other major transplant centers.

The Integrated Pathway as a Model for Graft Salvage: The results of this study collectively validate a clinical model where diagnostic and interventional radiology are not viewed as separate, sequential services but as a single, integrated continuum of care. This synergy—from initial non-invasive detection with US, to problem-solving with CT/MRI, to definitive diagnosis with biopsy or therapy with drainage or stenting—is the key to rapid diagnosis, targeted minimally invasive treatment, and ultimately, the preservation of precious allograft function.



Implications, Limitations, and Future Research Clinical and Institutional Implications: The findings strongly support the implementation of a standardized post-transplant surveillance protocol centered on serial Doppler US, with a low threshold for cross-sectional imaging and interventional radiology consultation. A rising serum creatinine coupled with a newly elevated RI should trigger an immediate workup to exclude obstruction or vascular compromise, and if these are absent, should lead to strong consideration for graft biopsy. This integrated pathway ensures that patients receive timely, targeted, and minimally invasive care. From a health economics perspective, this workflow has significant implications for resource allocation. By establishing

Doppler US as an effective and inexpensive gatekeeper, this model optimizes the use of more costly and resource-intensive modalities like CT, MRI, and the angiography suite. It justifies institutional investment in high-quality sonography services and skilled personnel as a cost-effective strategy to improve outcomes in a high-cost patient population.

Study Limitations: This study has limitations inherent to its design that must be acknowledged. As a single-center study, the findings may be influenced by local protocols and patient demographics, potentially limiting generalizability. The sample size of 84 patients, while substantial for a prospective study of this nature, is modest, and a larger cohort would provide greater statistical power. The follow-up period was confined to the early postoperative hospital stay, precluding the assessment of long-term complications such as chronic allograft nephropathy, late-onset strictures, or malignancy.

Future Research Directions: The Role of Advanced Functional Imaging: Future research should focus on large, multi-center trials to validate these workflow models and establish more definitive imaging thresholds. Furthermore, the field is moving towards more advanced, functional imaging techniques. Modalities like contrast-enhanced ultrasound (CEUS), ultrasound elastography, and functional MRI (including blood-oxygen-level-dependent and diffusion-weighted imaging) hold the promise of non-invasively differentiating between causes of parenchymal dysfunction like AR and ATN.[15] If validated, these techniques could further refine the diagnostic pathway and potentially reduce the number of invasive biopsies required, representing the next frontier in the minimally invasive management of these complex patients.[32]

CONCLUSION

The success of modern renal transplantation is not only a testament to surgical skill and pharmacology but also to the robust support provided by an integrated radiology service. This study demonstrates that a structured, intervention-forward workflow is essential for managing the complex array of early post-transplant complications. Doppler ultrasound serves as the cornerstone of surveillance, effectively triaging patients based on hemodynamic parameters like the Resistive Index. When complications are detected, a seamless transition to advanced imaging and, ultimately, to minimally invasive interventional procedures provides safe, definitive, and graft-salvaging management. This synergy between diagnostic and interventional radiology is a critical component of modern transplant care, ensuring the longevity of the precious gift of a new kidney.

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