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Original Article

Role of B-Mode Ultrasonography and Doppler Imaging in the Evaluation of Renal Transplant Recipients

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ABSTRACT

Background: Ultrasonography is central to the surveillance of a renal allograft because the graft is superficially located and can be assessed repeatedly without ionizing radiation or nephrotoxic contrast. B-mode imaging depicts graft morphology, the collecting system, and perigraft abnormalities, while color and spectral Doppler provide information about perfusion and vascular flow. The present study evaluated the practical role of these techniques in renal transplant recipients managed at a tertiary-care teaching hospital. The study is designed to evaluate renal transplant recipients with B-mode ultrasonography and Doppler imaging, document graft and vascular parameters, and correlate imaging observations with the recorded clinical outcome.

Materials and Methods: Thirty-two consenting renal transplant recipients were evaluated during hospitalization and scheduled follow-up. B-mode assessment included graft location, size, echogenicity, collecting-system appearance, and perigraft pathology. Doppler assessment included global perfusion, main renal arterial and venous flow, peak systolic velocity, resistive index, pulsatility index, and acceleration time. Clinical status at the last recorded follow-up was categorized as alive/on follow-up or death. Data were analyzed using IBM SPSS Statistics version 28.0.

Results: The cohort contained 21 males and 11 females. Seventeen recipients had living-donor grafts and 15 had deceased-donor grafts. Age was available for 31 participants; the mean age was 35.8 ± 10.5 years, with a range of 14 to 62 years. At last recorded follow-up, 25 recipients were alive/on follow-up and seven had died. Mortality was higher among deceased-donor recipients than among living-donor recipients (40.0% versus 5.9%; chi-square = 5.43; Fisher exact $p = 0.033$; odds ratio 10.67, 95% confidence interval 1.10-103.15). Mortality did not differ significantly by sex (chi-square = 0.13; $p = 0.715$) or age group (chi-square = 2.33; $p = 0.507$). Serial Doppler data available for two deceased-donor recipients showed contrasting trajectories. In one case, resistive index increased from 0.49 to 0.60. In the other, it remained elevated and rose from 0.86 to 0.92, accompanied by prolongation of acceleration time and a fall in peak systolic velocity at the final examination.

Conclusion: B-mode and Doppler ultrasonography provided a practical, repeatable framework for assessing graft morphology, perigraft abnormalities, perfusion, and vascular waveforms. Serial measurements were more informative than isolated values. The higher mortality recorded among deceased-donor recipients warrants cautious interpretation because the cohort was small and complete participant-level imaging data were not available for diagnostic-performance analysis.

Keywords: *renal transplantation; B-mode ultrasonography; color Doppler; spectral Doppler; resistive index; peak systolic velocity; transplant renal artery.*

INTRODUCTION

Kidney transplantation is the preferred renal replacement option for many patients with end-stage kidney disease because a functioning graft can restore endocrine and excretory activity, reduce dependence on dialysis, and improve survival and quality of life. The allograft is usually placed in the iliac fossa, where its superficial position makes it particularly accessible to sonographic examination. This anatomical advantage permits rapid bedside assessment in the immediate postoperative period and repeated evaluation during later follow-up [1-3].

The postoperative course may be complicated by parenchymal dysfunction, urinary obstruction, urine leak, perigraft fluid collections, infection, renal artery stenosis, arterial or venous thrombosis, and abnormalities related to the vascular anastomosis. Some complications are clinically silent at an early stage, while others produce nonspecific findings such as reduced urine output, rising serum creatinine, fever, graft tenderness, or hypertension. Imaging must therefore be interpreted together with clinical and biochemical data rather than treated as an isolated diagnostic endpoint [1,2,5,6].

B-mode ultrasonography provides an overview of graft position, renal dimensions, cortical echogenicity, corticomedullary differentiation, pelvicalyceal dilatation, ureteric dilatation, and adjacent collections. Color Doppler demonstrates the distribution of intrarenal perfusion and helps localize the main renal artery and vein. Spectral Doppler permits measurement of peak systolic velocity (PSV), end-diastolic velocity, resistive index (RI), pulsatility index (PI), and acceleration time (AT). These measurements are useful for recognizing altered vascular resistance and for screening suspected transplant renal artery stenosis, although no single Doppler variable is entirely specific [4,10-12].

The RI is calculated from the difference between peak systolic and end-diastolic velocities divided by peak systolic velocity. It is influenced by graft parenchymal resistance, recipient age, pulse pressure, heart rate, vascular compliance, and systemic hemodynamics. Consequently, an elevated RI may occur in several forms of graft dysfunction and may also reflect recipient-related factors. Serial assessment and correlation with previous examinations are therefore more meaningful than rigid interpretation of a single threshold [4,7,8,14].

This prospective observational study was conducted at Osmania General Hospital to evaluate the practical role of B-mode ultrasonography, colour Doppler, and spectral Doppler imaging in the assessment of renal transplant recipients. The investigation focused on documenting graft morphology, echogenicity, location, perfusion, perigraft collections or other abnormalities, and relevant vascular parameters such as resistive index, pulsatility index, peak systolic velocity, and acceleration time. The available sonographic findings were then compared with the recorded clinical outcomes to determine whether imaging features reflected graft status or subsequent complications. In recipients who underwent repeated examinations, serial Doppler measurements were also reviewed to identify changes in renal perfusion and vascular indices during follow-up.

MATERIALS AND METHODS

Study Design

A prospective observational study design was used. Imaging formed part of the clinical assessment of renal transplant recipients, and no experimental intervention was introduced. The design allowed sequential documentation of B-mode and Doppler variables during the inpatient period and at planned follow-up visits.

Study Setting

The study was conducted in the Department of Radiodiagnosis, Osmania Medical College and Osmania General Hospital, Hyderabad, Telangana, India. Osmania General Hospital is a tertiary-care teaching hospital that receives patients requiring renal transplantation, postoperative monitoring, and multidisciplinary follow-up.

Study Duration

The study was conducted over a period of 24 months, beginning in April 2023 and continuing until March 2025. This timeframe allowed adequate opportunity for participant recruitment, data collection, follow-up, and systematic evaluation of the study outcomes.

Study Population and Sampling

All renal transplant recipients who underwent transplantation at Osmania General Hospital or were evaluated in the transplant follow-up pathway during the study period were considered for inclusion. Consecutive eligible patients who provided consent were enrolled. The protocol proposed a sample size of 30; the study presentation reported a final cohort of 32 recipients.

Inclusion and Exclusion Criteria

Recipients were included when they had undergone renal transplantation at Osmania General Hospital and provided written informed consent for participation. Patients who did not provide consent were excluded. No additional clinical exclusion criterion was documented in the supplied protocol.

Ethical Considerations

Ethical clearance was obtained from the Institutional Ethics Committee, Osmania Medical College, Hyderabad, before commencement of the study. Written informed consent was obtained from each participant. The participant information sheet stated that participation was voluntary, confidentiality would be maintained, and refusal or withdrawal would not affect clinical care.

Clinical Data Collection

Demographic and clinical information was recorded using the study pro forma. The recorded variables included age, sex, symptoms, relevant medical history, surgical history, type of donor, date of transplantation, and clinical status during follow-up. Details of the transplant operation and the duration or progression of symptoms were documented where available.

B-mode Ultrasonography

B-mode examination was performed using the available departmental ultrasound systems. The graft was assessed in longitudinal and transverse planes. The protocol required documentation of graft location, size, echogenicity, collecting-system appearance, and perigraft pathology. Particular attention was given to pelvicalyceal dilatation and adjacent collections because these findings may indicate obstruction, urine leak, hematoma, lymphocele, or another postoperative process. The source documents did not specify a single ultrasound model or transducer frequency, so these details are not assigned retrospectively.

Color and Spectral Doppler Assessment

Color Doppler was used to evaluate global intraparenchymal perfusion and to localize the main transplant renal artery, renal vein, and the vascular anastomosis. Spectral waveforms were obtained from the main renal artery and intrarenal vessels. The protocol variables were peak systolic velocity, resistive index, pulsatility index, and acceleration time. Measurements were interpreted in the clinical context because elevated RI is a nonspecific marker and isolated PSV elevation may be influenced by vessel tortuosity, anastomotic geometry, and the early postoperative state [4,11,12,15-18].

Follow-up and Outcome Definition

Participants were examined during their hospital stay, with planned reviews at one month and three months. For the present analysis, the final recorded clinical status in the presentation was classified as alive/on follow-up or death. The source data did not consistently distinguish patient death, graft loss, or death with a functioning graft. Therefore, the outcome is reported as all-cause mortality recorded at last follow-up and should not be interpreted as imaging-proven graft failure.

Data Completeness and Reconstruction Rules

The study presentation reported 32 participants in aggregate, but the patient-level table contained 31 identifiable rows. The aggregate summary contained 21 males, 11 females, 17 living-donor recipients, 15 deceased-donor recipients, and seven deaths. Age-based analyses used the 31 listed ages without imputation. Aggregate sex, donor-type, and outcome analyses used the reported cohort totals. The listed table already contained all seven deaths, so the single unlisted participant contributed only to the non-mortality aggregate count. Complete participant-level B-mode and Doppler measurements were not available, and no prevalence or sensitivity estimates were manufactured.

Statistical Analysis

Data were entered in Microsoft Excel and analyzed using IBM SPSS Statistics for Windows, version 28.0 (IBM Corp., Armonk, New York, USA). Continuous variables were summarized as mean, standard deviation, median, and range. Categorical variables were summarized as frequencies and percentages. Mean age was compared using an independent-samples t test. Associations between categorical variables and mortality were assessed using the Pearson chi-square test; Fisher exact p values were emphasized when expected cell counts were small. Odds ratios with 95% confidence intervals were calculated for donor type and mortality. All tests were two-sided, and $p < 0.05$ was considered statistically significant.

RESULTS

Participant Flow and Cohort Composition

The final study summary included 32 renal transplant recipients. All were reported to have undergone B-mode and Doppler assessment after consent. Seventeen recipients had living-donor grafts and 15 had deceased-donor grafts. At the last recorded follow-up, 25 were alive/on follow-up and seven had died. The study flow and outcome distribution are shown in Figure 1.

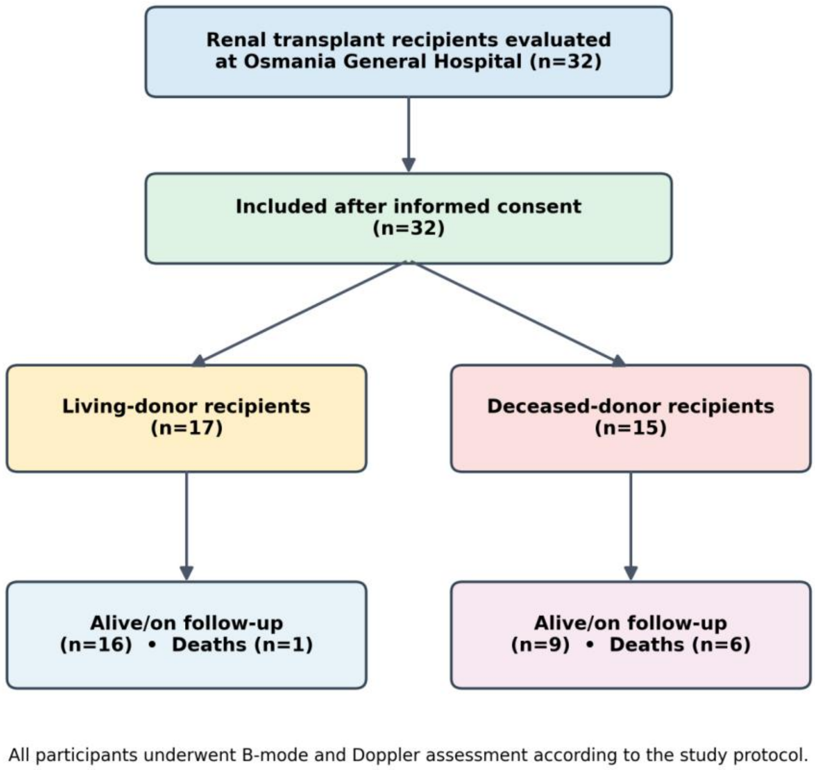

Figure 1: Flow of renal transplant recipients included in the study and their recorded outcome according to donor type

Table 1: Overall demographic and transplant profile of the study cohort

Characteristic	Value
Total participants	32
Age, years	35.8 ± 10.5
Male sex	21 (65.6%)
Female sex	11 (34.4%)
Living-donor transplant	17 (53.1%)
Deceased-donor transplant	15 (46.9%)
Alive/on follow-up	25 (78.1%)
Deaths	7 (21.9%)

Age was available for 31 of the 32 participants. Percentages for sex, donor type, and outcome use the aggregate cohort denominator of 32.

Age and Sex Distribution

The mean age among the 31 participants with a recorded age was 35.8 ± 10.5 years. The median age was 35 years, and the age range extended from 14 to 62 years. Fourteen participants were aged 30-39 years, making this the largest age category. The mean age of recipients who died was 33.4 ± 13.0 years compared with 36.5 ± 9.8 years among those alive/on follow-up; the difference was not statistically significant ($p = 0.574$). Mortality also did not vary significantly across the four age categories (chi-square = 2.33; $p = 0.507$), as illustrated in Figure 2.

Males formed approximately two-thirds of the cohort. Five of 21 males and two of 11 females died. The difference in mortality by sex was not significant (chi-square = 0.13; $p = 0.715$; Fisher exact $p = 1.000$).

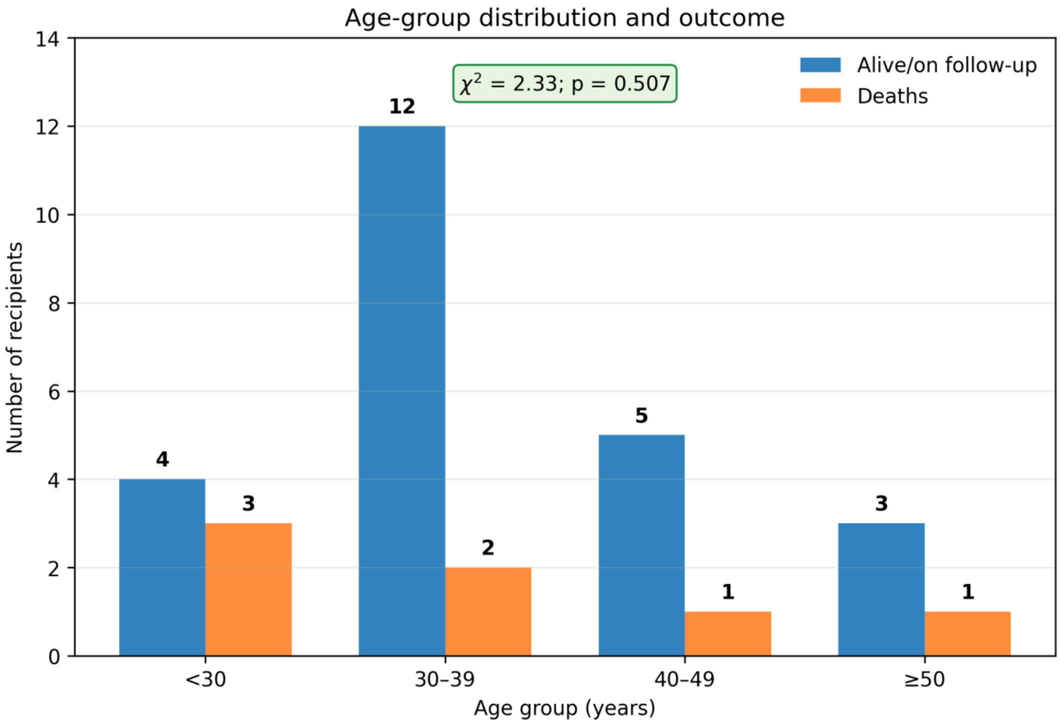

Figure 2: Distribution of participants by age group and recorded outcome. Age-group association with mortality was not statistically significant

Table 2: Association of demographic variables and donor type with mortality

Variable	Category	Alive/on follow-up	Deaths	Chi-square	p value
Sex	Male	16	5	0.134	0.715
	Female	9	2		
Age group	<30 years	4	3	2.331	0.507
	30-39 years	12	2		
	40-49 years	5	1		
	≥50 years	3	1		
Donor type	Living donor	16	1	5.428	0.020
	Deceased donor	9	6		

Pearson chi-square values are shown. Because of small expected counts in the donor-type table, Fisher exact p = 0.033 is the preferred exact result. Age-group analysis used n=31 because one age was missing

Donor Type and Clinical Outcome

The proportion of deaths was 5.9% among living-donor recipients and 40.0% among deceased-donor recipients. This difference was statistically significant by the chi-square test (chi-square = 5.43; p = 0.020) and remained significant by Fisher exact testing (p = 0.033). The odds of death were 10.67 times higher in the deceased-donor group than in the living-donor group, although the 95% confidence interval was wide (1.10-103.15) because of the small sample. Figure 3 presents the outcome counts by donor type.

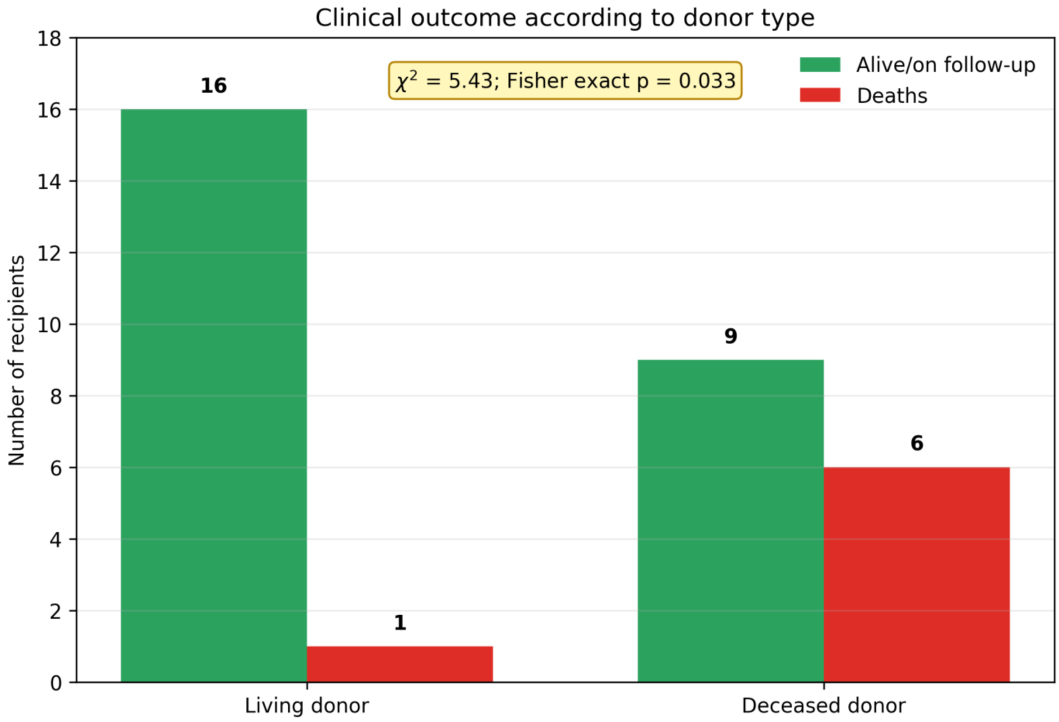

Figure 3: Recorded clinical outcome according to donor type. Mortality was more frequent among deceased-donor recipients

Table 3: Comparison of living-donor and deceased-donor recipient groups

Characteristic	Living donor	Deceased donor	Test statistic	p value
Participants, n	17	15	Not applicable	Not applicable
Age, years, mean ± SD	35.4 ± 11.0	36.4 ± 10.1	t = -0.248	0.806
Male sex, n (%)	10 (58.8%)	11 (73.3%)	chi-square = 0.744	0.388
Deaths, n (%)	1 (5.9%)	6 (40.0%)	chi-square = 5.428	0.020
Odds ratio for death	Reference	10.67 (95% CI 1.10-103.15)	Fisher exact	0.033

Age comparison used 17 living-donor and 14 deceased-donor recipients because age was absent for one participant. CI, confidence interval; SD, standard deviation

B-mode Findings

B-mode imaging was used to assess graft morphology, the collecting system, and perigraft spaces. The study presentation contained a representative examination in which a perigraft collection was measured, demonstrating the ability of grayscale ultrasonography to detect and quantify a postoperative fluid collection (Figure 5A). Other images documented graft morphology and collecting-system assessment. A complete participant-level table of B-mode abnormalities was not available; therefore, the frequencies of hydronephrosis, collections, altered echogenicity, or graft enlargement could not be estimated reliably.

Doppler Findings and Serial Measurements

Color Doppler images demonstrated intrarenal perfusion and the vascular anastomosis, while spectral Doppler enabled measurement of PSV, RI, PI, and AT (Figure 5B-C). Complete Doppler measurements for all 32 recipients were not present in the supplied files. Serial values were available for two illustrative deceased-donor recipients, both of whom were recorded as deaths at final follow-up.

In the first case, a 35-year-old male recipient, RI increased from 0.49 to 0.54 and then to 0.60 across three assessments. PSV varied from 31 to 45 and then 40 cm/s, while AT increased from 90 to 100 and 101 ms. In the second case, a 29-year-old male recipient, RI was elevated at the initial examination and increased from 0.86 to 0.89 and 0.92. PSV decreased from 95.0 to 92.5 and then 40.0 cm/s, while AT increased from 80 to 95 and 101 ms. These trajectories are summarized in Table 4, and the serial RI pattern is shown in Figure 4.

Table 4: Serial Doppler measurements

Case	Assessment	RI	PSV (cm/s)	AT (ms)
Case A, 35 years	1	0.49	31.0	90
	2	0.54	45.0	100
	3	0.60	40.0	101
Case B, 29 years	1	0.86	95.0	80
	2	0.89	92.5	95
	3	0.92	40.0	101

No inferential p value was calculated because each case had only three serial measurements and the observations were not independent. AT, acceleration time; PSV, peak systolic velocity; RI, resistive index

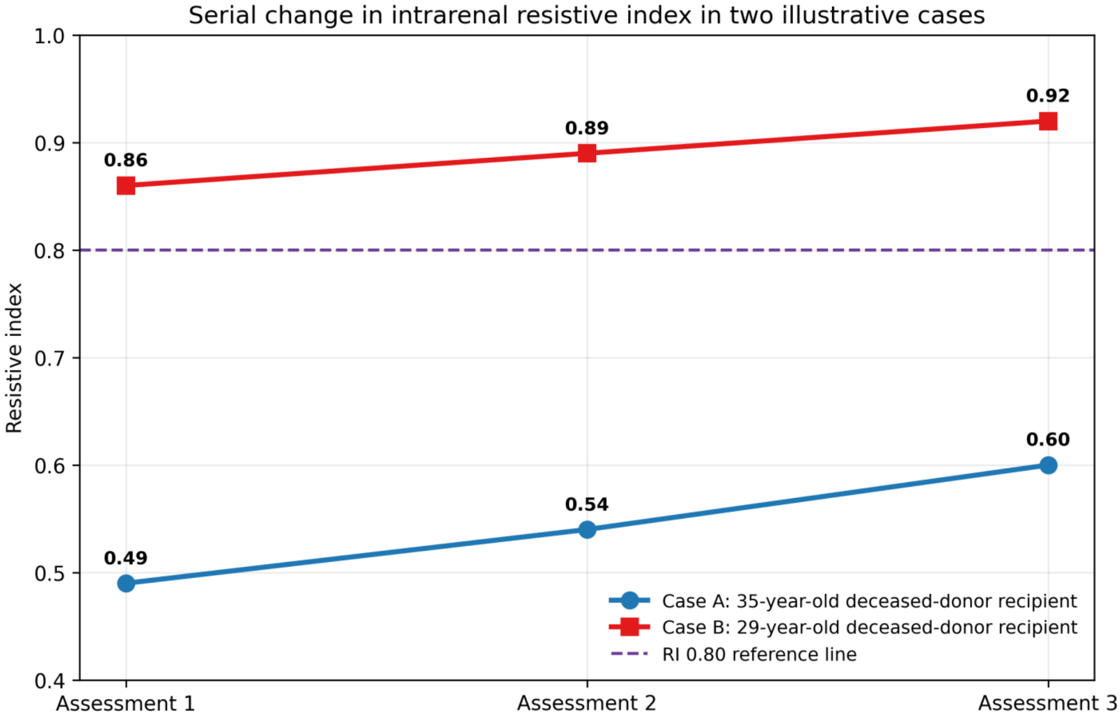

Figure 4: Serial resistive-index measurements in two illustrative deceased-donor recipients. The dashed line marks RI 0.80 as a commonly used reference threshold, not a stand-alone diagnosis

DISCUSSION

Principal Findings

This prospective observational study describes the use of B-mode and Doppler ultrasonography in 32 renal transplant recipients at a tertiary-care teaching hospital. The cohort was young, with a mean age of approximately 36 years, and included almost equal numbers of living-donor and deceased-donor grafts. Seven deaths were recorded. Mortality was significantly more frequent among deceased-donor recipients, whereas age and sex were not associated with outcome. The available images demonstrated how B-mode identified a perigraft collection and how color and spectral Doppler assessed the anastomosis, intrarenal perfusion, and vascular waveforms. Serial data in two cases emphasized that trends in RI, PSV, and AT can be clinically more informative than a single examination.

Role of B-mode Ultrasonography

B-mode ultrasonography is the foundation of renal allograft imaging because it provides immediate structural information. The graft can be examined for enlargement, altered echogenicity, loss of corticomedullary differentiation, pelvicalyceal dilatation, and perigraft fluid. A fluid collection can be measured, followed over time, and interpreted according to its location and clinical timing. This is relevant because a hematoma, lymphocele, urinoma, or abscess may have similar grayscale appearances and may require correlation with symptoms, laboratory findings, aspiration, or cross-sectional imaging [1,2,5,6].

The representative collection in this series illustrates an important practical strength of B-mode imaging: it can answer a focused postoperative question rapidly and without exposing the recipient to contrast. However, the presence of a collection alone does not establish its nature or clinical significance. Small collections may be incidental, while larger or strategically located collections may compress the graft, ureter, or vessels. The absence of a complete case-wise B-mode dataset in the source files prevented calculation of complication prevalence, and this limitation should be preserved rather than replaced with speculative figures.

Interpretation of Doppler Parameters

Doppler ultrasound extends the examination from morphology to hemodynamics. PSV at the anastomosis and along the transplant renal artery is used to screen for focal acceleration, while downstream waveforms may show prolonged acceleration time and a tardus-parvus pattern when a hemodynamically important proximal stenosis is present. Baxter and colleagues reported that PSV was the most sensitive Doppler criterion for transplant renal artery stenosis, and later studies emphasized the value of combining velocity, waveform morphology, and clinical probability rather than relying on a single cutoff [11,12,15,16].

The RI is attractive because it is easy to obtain and repeat, but its interpretation is complex. Radermacher and colleagues linked elevated RI measured later after transplantation with poor graft and patient outcomes [7]. Other studies found associations between early RI or PI and delayed graft function, serum creatinine, or later renal function [8-10,13,14,19-21]. At the same time, RI is affected by systemic vascular compliance and recipient hemodynamics. It cannot distinguish acute tubular injury, rejection, obstruction, infection, and venous congestion with sufficient specificity on its own [4,19].
In the two illustrative cases from the present series, one recipient had RI values within a lower range that gradually increased, whereas the other had persistently high and rising RI values accompanied by longer AT and lower final PSV. These findings do not permit causal inference, but they show why serial comparison is useful. A rising RI, a change in waveform shape, or loss of diastolic flow should prompt review of volume status, blood pressure, graft function, venous patency, arterial inflow, and the possibility of parenchymal dysfunction. The examination should be repeated when technical factors or systemic instability could have influenced the initial result.

Donor Type and Outcome

The association between deceased-donor grafts and mortality was the only statistically significant outcome relationship in this dataset. Six of 15 deceased-donor recipients died compared with one of 17 living-donor recipients. Living-donor transplantation generally permits planned surgery, shorter ischemic exposure, and careful donor selection, while deceased-donor grafts may be exposed to longer ischemia and greater donor-related variability. These factors may partly explain the observed difference, but the study did not contain sufficient information on cold ischemia time, donor age, delayed graft function, rejection, infection, or comorbidity to identify the mechanism.

The odds ratio was large, but the confidence interval was extremely wide because only seven deaths occurred. The result should therefore be interpreted as a signal within this cohort rather than a precise estimate of risk. Moreover, the outcome was all-cause mortality, not confirmed graft-related mortality. A larger study would require time-to-event analysis, adjustment for recipient and donor variables, and separation of graft loss from death with a functioning graft.

Clinical Implications

A structured transplant ultrasound examination should begin with graft morphology and the surrounding spaces, followed by assessment of the collecting system, renal vein, main renal artery, anastomosis, and intrarenal arterial waveforms. Measurements should be compared with prior studies and interpreted alongside urine output, serum creatinine, blood pressure, and symptoms. When ultrasound findings are equivocal or discordant with clinical deterioration, additional evaluation with computed tomography, magnetic resonance angiography, nuclear medicine, or biopsy may be required [1-3].

The findings also support consistent documentation. A standardized worksheet that records graft dimensions, echogenicity, pelvicalyceal status, perigraft collections, venous patency, anastomotic PSV, intrarenal RI and PI, AT, and relevant clinical variables would permit more reliable follow-up and stronger statistical analysis. Standardization is particularly important when scans are performed on different machines or by different operators.

Strengths

The study reflects real-world transplant imaging in a public tertiary-care hospital and includes both living-donor and deceased-donor recipients. It used a prospective observational protocol, included planned follow-up, and captured both structural and hemodynamic aspects of graft assessment. The presentation also preserved representative B-mode and Doppler images, allowing direct demonstration of perigraft and vascular evaluation.

Limitations

The principal limitation was incomplete participant-level data. Although the final cohort summary contained 32 recipients, only 31 patient-level rows were listed, and full B-mode and Doppler measurements were available for only a small number of illustrative cases. Serum creatinine, urine output, blood pressure, biopsy findings, computed-tomography or angiographic confirmation, graft survival time, and cause of death were not provided in a complete analyzable format. As a result, sensitivity, specificity, predictive values, and multivariable associations could not be calculated.

The sample was small and from a single center. Doppler measurements may have been obtained using different ultrasound machines, and operator reproducibility was not documented. The inclusion criterion based mainly on consent may also have introduced selection effects. Finally, mortality was treated as a binary last-follow-up outcome, without accounting for duration of follow-up or competing clinical events. These limitations mean that the paper should be read as a descriptive clinical study rather than a definitive test-accuracy investigation.

CONCLUSION

B-mode ultrasonography and Doppler imaging formed a useful, noninvasive, and repeatable first-line approach for the evaluation of renal transplant recipients at Osmania General Hospital. B-mode imaging enabled assessment of graft morphology, the collecting system, and perigraft collections, while color and spectral Doppler provided information about perfusion, anastomotic flow, PSV, RI, PI, and AT. The serial cases showed that changes over time may be more informative than an isolated measurem

ent. Deceased-donor recipients had a higher recorded mortality than living-donor recipients in this small cohort. Larger prospective studies with complete longitudinal imaging, biochemical, histopathological, and outcome data are required to define diagnostic thresholds and independent predictors of graft and patient outcome.

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