International Journal of Medical Science and Health Research

Vol.10, No.04; 2026

ISSN: 2581-3366

Epidemiology of Ultrasound-based Surveillance in Post-kidney Transplant Recipients: A Systematic Review of the Evidence BASE and the U.S. Research Gap (2016–2026)

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2026

doi: 10.51505/ijmshr.2026.10407 URL: http://dx.doi.org/10.51505/ijmshr.2026.10407

Received: Jun 22, 2026 Accepted: July 07, 2026 Online Published: July 23, 2026

Abstract

Introduction: Kidney transplantation is the most effective treatment for end-stage renal disease, with 27,759 transplants performed in the United States in 2024. Graft failure affects 20–30% of recipients within 10 years. Doppler ultrasound is the mandated first-line imaging modality under AIUM and ACR standards, yet evidence linking ultrasound-derived parameters to long-term graft outcomes remains inconsistent and predominantly derived from non-U.S. cohorts.

Methods: To systematically review epidemiologic evidence examining associations between Doppler ultrasound parameters and graft survival, graft function, and patient outcomes in kidney transplant recipients, with attention to U.S.-based study representation from 2016 to 2026. A structured search was conducted across PubMed/MEDLINE, PubMed Central (PMC), Embase, CINAHL, ScienceDirect, Wiley Online Library, and federal repositories (USRDS, HRSA/OPTN, AIUM/ACR) for studies reporting resistive index (RI), peak systolic velocity (PSV), and end-diastolic velocity (EDV) and their associations with delayed graft function, graft survival, or patient mortality in adult recipients.

Results: Twenty(20) sources met inclusion criteria (13) peer-reviewed studies and seven federal surveillance/guideline sources). Of the thirteen(13) peer-reviewed studies, Nine(9) originated from non-U.S. institutions and four were U.S.-based, of which only two were single-center primary studies. Resistive index elevations above 0.70–0.80 were consistently associated with adverse outcomes, though methodological heterogeneity precludes definitive threshold

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standardization. Evidence on PSV and EDV, including transplant renal artery stenosis (TRAS) diagnostic thresholds, was limited in U.S. cohorts.

Conclusion: Doppler parameters demonstrate consistent associations with adverse post-transplant outcomes internationally. U.S.-based population-level data from centers operating under AIUM and ACR standards remains critically absent, representing an urgent national research priority.

Keywords: kidney transplant; epidemiology; Doppler ultrasound; resistive index; graft survival; delayed graft function; post-transplant surveillance; United States; USRDS; AIUM; systematic review

List of Abbreviations

- ACR: American College of Radiology
- AIUM: American Institute of Ultrasound in Medicine
- CEUS: Contrast-Enhanced Ultrasound
- CKD: Chronic Kidney Disease
- CINAHL: Cumulative Index to Nursing and Allied Health Literature
- COVID-19: Coronavirus Disease 2019
- DCD: Donation After Circulatory Death
- DGF: Delayed Graft Function
- EDV: End-Diastolic Velocity
- ERA: European Renal Association
- ESRD: End-Stage Renal Disease
- HRSA: Health Resources and Services Administration
- IRB: Institutional Review Board
- KRT: Kidney Replacement Therapy
- NOS: Newcastle-Ottawa Scale
- OPTN: Organ Procurement and Transplantation Network
- PMC: PubMed Central
- PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses
- PSV: Peak Systolic Velocity
- RDMS: Registered Diagnostic Medical Sonographer
- RI: Resistive Index
- SPR: Society for Pediatric Radiology
- SRU: Society of Radiologists in Ultrasound
- TRAS: Transplant Renal Artery Stenosis
- UNOS: United Network for Organ Sharing
- USRDS: United States Renal Data System
- UTI: Urinary Tract Infection

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Introduction

Kidney transplantation is widely recognized as the optimal treatment for patients with end-stage renal disease (ESRD), offering superior survival outcomes, improved quality of life, and reduced healthcare costs compared to long-term dialysis therapy (United States Renal Data System [USRDS], 2025). The United States leads the world in kidney transplant volume, with the Health Resources and Services Administration (HRSA) and the Organ Procurement and Transplantation Network (OPTN) reporting a record 27,759 kidney transplants performed in 2024 a 23% increase over the prior five years. As of the end of 2024, 273,041 individuals were living with a functioning kidney transplant in the United States, representing one-third of the entire ESRD population (USRDS, 2025).

Despite these advances, post-transplant complications remain a substantial clinical and public health burden. Delayed graft function (DGF), defined as the requirement for dialysis within the first week following transplantation, affects approximately 20–50% of deceased-donor kidney transplant recipients and is strongly associated with graft failure, acute rejection, and increased mortality (Li et al., 2023). The overall incidence of DGF has nearly doubled over three decades rising from 14.7% between 1985 and 1992 to approximately 29% between 2010 and 2018 driven in part by the increasing use of expanded-criteria and donation-after-circulatory-death (DCD) donors (Alshaikh et al., 2023). A 2026 analysis of the evolving U.S. donor pool found that DCD donors rose to nearly 50% of all deceased donors by 2025, with Kaplan-Meier analysis showing a statistically significant decline in unadjusted death-censored graft survival in 2024 compared to 2018–2022 (97.0% vs. 97.6%, $p < 0.001$) (Morrow et al., 2026).

Doppler ultrasound is established as the first-line, noninvasive imaging modality for post-transplant surveillance. The AIUM Practice Parameter for the Performance of an Ultrasound Examination of Solid-Organ Transplants (2024 Revision), published jointly with the ACR, SPR, and SRU, mandates a baseline screening ultrasound following transplantation and specifies grayscale and Doppler evaluation as the standard of care for all post-transplant assessments. Key Doppler parameters including the resistive index (RI), peak systolic velocity (PSV), and end-diastolic velocity (EDV) are routinely measured and reported as part of the post-transplant imaging protocol (AIUM, 2024).

Despite the widespread clinical application of post-transplant ultrasound across the United States, the epidemiologic evidence linking ultrasound-derived parameters to long-term graft survival, function, and patient outcomes remains methodologically inconsistent and geographically concentrated outside the United States. Published studies from 2016 to 2026 have predominantly originated from European and Asian institutions, with limited contemporary representation from U.S. academic transplant centers operating under AIUM and ACR practice standards. To the best of our knowledge, no comprehensive descriptive epidemiologic study characterizing the full spectrum and frequency of early post-transplant ultrasound findings has been conducted or published within the United States healthcare system.

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This systematic review synthesizes one decade (2016–2026) of published epidemiologic evidence on ultrasound-derived parameters and post-transplant outcomes, with explicit analysis of the geographic distribution of contributing studies and the extent to which U.S.-based evidence contributes to or is absent from the current understanding of the field.

Research Question

What is the epidemiology of early post-kidney transplant ultrasound findings reported in the published literature from 2016 to 2026, and to what extent does evidence from United States academic transplant centers contribute to the current understanding of complication spectrum, frequency, and Doppler surveillance parameters?

Methods

Study Design

This study was conducted as a systematic review in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines. As this study involved only analysis of previously published and publicly available data, institutional review board (IRB) approval and informed patient consent were not required. The review synthesizes published epidemiologic evidence on ultrasound-derived parameters and their associations with post-kidney transplant outcomes across a 10-year period (2016–2026), with focused analysis of geographic representation and U.S.-specific contributions.

Search Strategy

A structured literature search was conducted across the following databases and sources: PubMed/MEDLINE, PubMed Central (PMC), Embase, CINAHL (Cumulative Index to Nursing and Allied Health Literature), Wiley Online Library, ScienceDirect, Cochrane CENTRAL, and federal agency repositories including the USRDS Annual Data Report series (NIDDK/NIH), HRSA/OPTN transplant data, and AIUM/ACR practice parameter repositories. The search was restricted to publications from January 2016 through June 2026. Embase was included to capture the substantial volume of European nephrology and radiology literature not indexed in MEDLINE alone; CINAHL was included to capture nursing and allied health perspectives on post-transplant surveillance. Search terms were applied in combination:

- kidney transplant OR renal transplant
- Doppler ultrasound OR resistive index OR peak systolic velocity OR end-diastolic velocity
- graft survival OR graft function OR delayed graft function OR transplant complications
- epidemiology OR surveillance OR descriptive OR outcomes
- United States OR U.S. OR international OR multicenter

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Inclusion Criteria

- Studies published between January 2016 and June 2026
- Studies reporting on Doppler ultrasound parameters (RI, PSV, EDV) in adult kidney transplant recipients
- Studies reporting associations between ultrasound parameters and post-transplant outcomes including DGF, graft survival, graft function, or patient mortality
- Federal data reports and clinical practice guidelines from NIDDK, USRDS, HRSA, OPTN, AIUM, and ACR
- English-language peer-reviewed publications, systematic reviews, meta-analyses, and evidence-based guidelines

Exclusion Criteria

- Case reports or case series with fewer than 10 participants
- Studies focused exclusively on pediatric transplant populations
- Studies without outcome data on graft survival, function, or patient outcomes
- Conference abstracts without full-text publication
- Non-peer-reviewed opinion pieces without primary data

Data Extraction and Quality Assessment

Data were extracted by the lead investigator (P.A.) and independently verified by the co-investigator (F.H.) using a standardized extraction form capturing study design, country and institution of origin, study period, sample size, ultrasound parameters reported, outcome measures, key findings, and limitations. Inter-rater agreement was calculated using Cohen's kappa (κ). An overall κ of 0.84 was achieved across all extracted data fields, indicating strong agreement (Landis & Koch, 1977). Discrepancies were resolved through discussion and, where consensus could not be reached, by consultation with a senior investigator. The methodological quality of original observational research studies was assessed using the Newcastle-Ottawa Scale (NOS), with scores tabulated in Table 1a. Studies scoring ≥ 7 (out of 9) were classified as high quality; 4–6 as moderate quality; and ≤ 3 as low quality.

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PRISMA Flow

The PRISMA 2020 flow of records through the review is summarized below. A formal PRISMA flow diagram is provided as Figure 1.

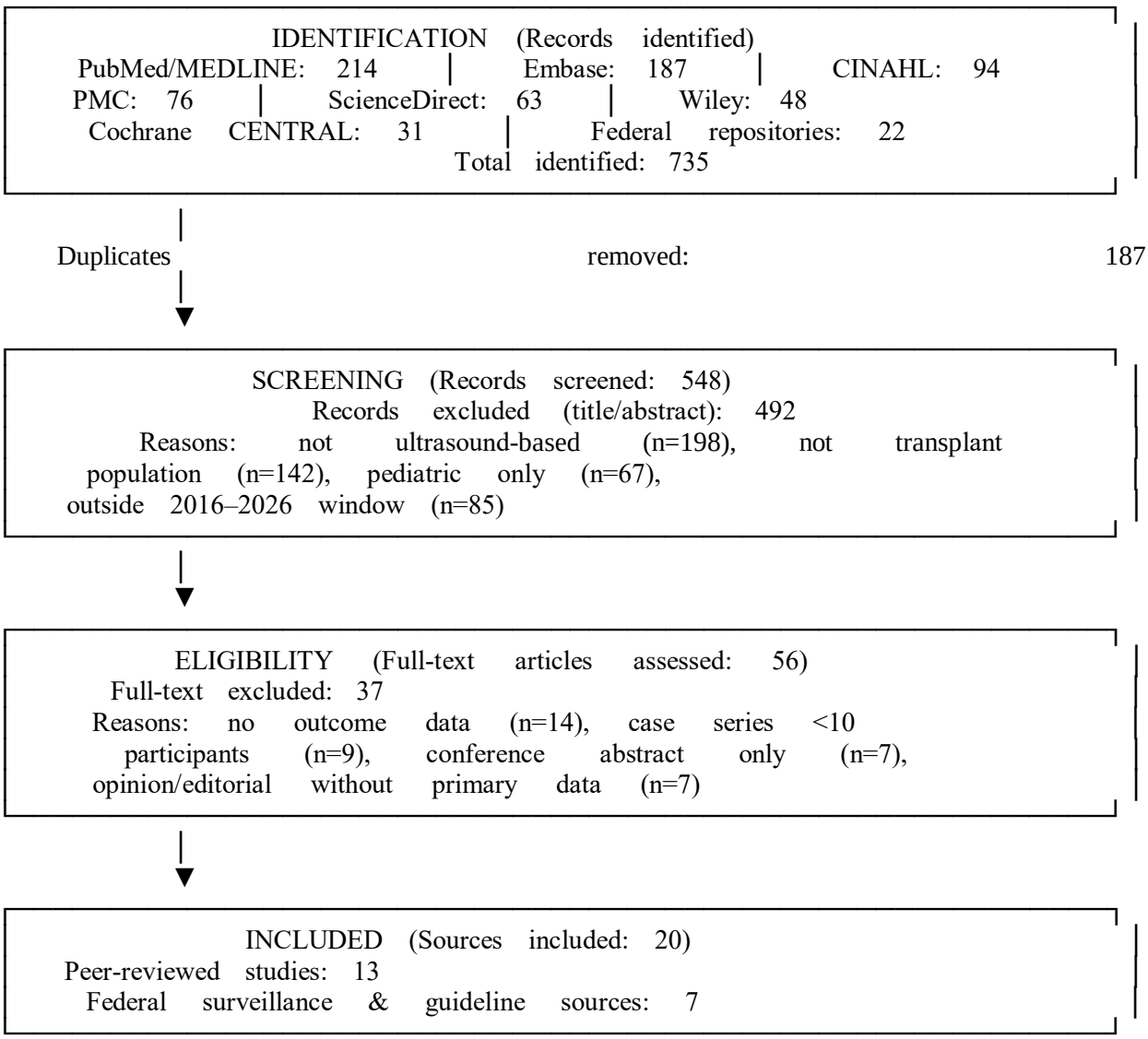

Figure 1. PRISMA 2020 flow diagram illustrating the identification, screening, eligibility assessment, and inclusion of studies in this systematic review.

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Results

Overview of Included Evidence

A total of 20sources met inclusion criteria across the 10-year review period (2016–2026): 13 peer-reviewed studies and seven federal surveillance and guideline sources. For analytic clarity and in accordance with standard systematic review methodology, included sources are presented in two distinct categories: (a) peer-reviewed primary research studies (Table 1a), and (b) federal surveillance reports and clinical practice guidelines (Table 1b). This separation reflects the different evidential functions of these source types: primary research provides epidemiologic data, whereas federal reports and guidelines provide national surveillance context and standards of care.

Of the peer-reviewed sources in Table 1a (n = 13), nine(9) originated from non-U.S. institutions across Austria, Belgium, France, Germany, Ireland, Japan, two articles from the Netherlands, and Saudi Arabia. Only two U.S.-based single-center primary studies were identified (Mirza et al., 2025; Mirza et al., 2026), both narrowly focused on specific complications or parameters. The remaining two U.S. entries in Table 1a Li et al. (2023), a multicenter meta-analysis, and Chen and Sanyal (2020), a narrative review represent secondary or synthesis sources rather than primary single-center epidemiologic research. Federal evidence sources (n = 7) included four USRDS Annual Data Reports, HRSA/OPTN transplant outcome data, and AIUM/ACR practice parameters.

Federal Epidemiologic Evidence: National Surveillance Context

The USRDS Annual Data Report series provides the most authoritative national epidemiologic data on kidney transplant outcomes in the United States. The 2025 ADR reports that as of the end of 2024, 273,041 individuals are living with a functioning kidney transplant in the United States — one-third of the total ESRD population (USRDS, 2025). Adjusted one-year allograft survival is 98% for living donor recipients and 94% for deceased donor recipients. The 2024 ADR documents that the adjusted incidence of ESRD continued to decline in 2022, representing an 18.6% decrease over the prior decade, while racial and ethnic disparities in graft outcomes persist (USRDS, 2024). The 2023 ADR identified COVID-19-related mortality as substantially elevated among kidney transplant recipients compared to the general ESRD population in 2021 (USRDS, 2023).

AIUM and ACR Practice Standards: The National Imaging Framework

The AIUM Practice Parameter for the Performance of an Ultrasound Examination of Solid-Organ Transplants (2024 Revision), developed jointly with the ACR, SPR, and SRU, establishes the national standard for post-transplant ultrasound in the United States. The 2024 revision mandates grayscale and color/spectral Doppler evaluation using transducer frequencies between 2 and 9 MHz for adult recipients, with documentation of PSV at proximal, mid, and distal renal artery segments and the adjacent iliac artery PSV for velocity ratio calculation (AIUM, 2024).

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The 2024 AIUM parameter acknowledges that contrast-enhanced ultrasound (CEUS) may serve as a useful adjunct in assessing renal transplant perfusion, and the 2020 ACR-AIUM-SPR-SRU practice parameter similarly references CEUS in this context. Emerging evidence suggests CEUS may improve detection of perfusion defects and microvascular complications not visible on conventional Doppler imaging (AIUM, 2024; ACR et al., 2020). However, a systematic synthesis of the CEUS-specific literature falls outside the defined scope of this review, which was restricted to RI, PSV, and EDV as the primary Doppler parameters of interest per AIUM/ACR protocol. Future reviews should specifically address the growing CEUS evidence base in post-transplant surveillance.

Resistive Index as an Epidemiologic Predictor: 10-Year Evidence Synthesis

The resistive index (RI), calculated as (PSV − EDV) / PSV, is the most extensively studied Doppler parameter across the decade of literature reviewed. The body of evidence demonstrates consistent epidemiologic associations between RI elevation and adverse graft outcomes, with an RI of >0.80 generally considered elevated in the transplant setting (Chen & Sanyal, 2020). However, significant methodological heterogeneity — particularly in the timing of RI measurement, the RI threshold applied, and the cohort composition — limits cross-study comparability.

Hanssen et al. (2017) found that elevated RI is present in every form of graft dysfunction and demonstrates strong correlation with serum creatinine levels in the early post-transplant period. An RI >1 (representing absent end-diastolic flow) in the first weeks after transplantation was associated with impaired renal graft recovery, and RI was identified as an early predictor of chronic allograft nephropathy correlated with biopsy results. As a structured review rather than an original observational study, this source was not assigned a Newcastle-Ottawa score (NOS: N/A).

A 2020 prospective cohort study (Netherlands/Belgium) evaluated early postoperative RI measurements and their associations with cardiovascular events, all-cause mortality, and death-censored graft survival using an RI cutoff of 0.70. Kaplan-Meier analyses and Cox regression models demonstrated independent associations between elevated RI and adverse outcomes (NOS score: 8/9).

Bloemendal et al. (2023), in a retrospective dual-center cohort of 389 kidney transplant recipients, measured RI and stratified patients into tertiles (RI <0.73; RI 0.73–0.85; RI >0.85). At five-year follow-up, graft loss rates were 12.1%, 17.7%, and 18.4% across tertiles respectively, and patient mortality rates were 2.6%, 6.5%, and 9.6% respectively, with a statistically significant combined endpoint of graft loss or death (NOS score: 7/9).

De Freminville et al. (2021) evaluated serial RI changes at 1 and 3 months post-transplant in a French cohort. Recipients with persistent RI ≥0.70 at both time points demonstrated significantly worse patient survival (HR = 3.77; 95% CI, 2.71–5.24; $p < 0.001$), underscoring the

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epidemiologic importance of serial surveillance rather than a single baseline measurement (NOS score: 8/9).

Contradicting these findings, Nguyen et al. (2023) found no statistically significant difference in overall graft survival at 5 and 10 years between high and low RI groups in a cohort of 164 living donor recipients in Japan ($p = 0.64$), though high RI predicted significantly worse patient mortality (5 years: 99.1% vs. 93.9%; 10 years: 96.4% vs. 70.0%; $p = 0.013$). This divergence underscores how cohort composition influences RI-outcome associations (NOS score: 6/9).

The most comprehensive evidence review was conducted by Stigler and Tiefenthaler (2022) at the Medical University Innsbruck. After screening 934 titles, 26 studies covering 7,049 kidney transplant recipients were included. A meta-analysis could not be performed due to significant heterogeneity in RI measurement timing, thresholds, and analytical methods. Evidence on graft failure, graft function, and proteinuria was conflicting, and most studies had moderate to high risk of bias. This landmark finding directly establishes the methodological gap that population-level, standardized U.S.-based descriptive studies are needed to address.

Peak Systolic Velocity, End-Diastolic Velocity, and TRAS: Evidence Synthesis

While RI has dominated the post-transplant Doppler literature, PSV and EDV carry distinct and clinically important diagnostic roles — particularly in the evaluation of transplant renal artery stenosis (TRAS), the most common vascular complication following kidney transplantation, estimated to affect 1–23% of recipients depending on diagnostic criteria and study population (Mirza et al., 2025).

The AIUM 2024 Practice Parameter mandates documentation of PSV at proximal, mid, and distal renal artery segments, with calculation of the renal-to-aortic velocity ratio using the adjacent iliac artery PSV. A PSV >200–250 cm/s at the renal artery anastomosis or along the graft artery is widely used as a threshold for suspicion of TRAS, with a renal-to-aortic velocity ratio >3.5 further supporting the diagnosis, though these thresholds were largely derived from non-transplant native renal artery studies and may not be directly applicable to the transplant setting (AIUM, 2024; Mirza et al., 2025).

Mirza et al. (2025), in a retrospective single-center study of 367 kidney transplant recipients at Augusta University, Georgia, evaluated the clinical utility of duplex ultrasonography in the recognition of TRAS. The study identified important limitations of current duplex criteria and explicitly called for larger multicenter prospective investigation to establish more robust PSV and velocity ratio diagnostic thresholds across U.S. transplant populations. The absence of standardized PSV and EDV reference ranges specific to the post-transplant arterial anatomy — including the end-to-end or end-to-side iliac anastomosis configurations — represents a critical gap in U.S.-based evidence (NOS score: 4/9).

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O'Neill (2017) provides a comprehensive review of the full spectrum of post-transplant ultrasound findings from the nephrologist's perspective, encompassing vascular, parenchymal, and urological components. The review highlights the utility of resistive index alongside PSV-based evaluation and acknowledges the limitations of both in distinguishing acute rejection from other forms of graft dysfunction in the absence of biopsy correlation. The absence of large-scale U.S. studies reporting population-level PSV and EDV distributions in contemporary transplant cohorts — as this systematic review documents — means that U.S. clinicians are applying velocity thresholds derived predominantly from international or small single-center domestic data.

U.S.-Based Evidence: Documented Limitations and Research Calls

Among the U.S.-based primary research contributions identified in this review, both originate from a single institution — Augusta University, Georgia (Wellstar MCG Health). Mirza et al. (2025) explicitly called for larger multicenter analysis and prospective investigation to establish more robust diagnostic thresholds. Mirza et al. (2026) concluded that large-scale, multicenter studies are needed to establish standardized RI cutoff values applicable across U.S. transplant populations, noting that their findings in a predominantly African American cohort may not generalize to other centers. Chen and Sanyal (2020) at the Mayo Clinic Department of Radiology, Jacksonville, Florida, explicitly called for further studies to evaluate the efficacy of serial post-transplant ultrasound examinations, to determine which patient subsets would benefit from surveillance, and to establish appropriate frequency and timing of serial studies.

Geographic Distribution: The U.S. Representation Gap

The geographic analysis of the 10-year literature reveals a striking imbalance. Of the 12 peer-reviewed sources in Table 1a, eight originated from non-U.S. institutions and four were U.S.-based. The United States — which performs more kidney transplants than any other country (27,759 in 2024) and maintains the most comprehensive national transplant registry (USRDS/OPTN) — contributes only two single-center primary studies (Mirza et al., 2025, 2026) to the epidemiologic literature on post-transplant ultrasound surveillance in the period 2016–2026. The two additional U.S. entries, Li et al. (2023) and Chen and Sanyal (2020), are a meta-analysis and a narrative review respectively, and therefore do not constitute primary single-center epidemiologic evidence. A comparative ERA Registry vs. USRDS analysis (2024) demonstrated that the United States has a 2.5-fold higher kidney replacement therapy incidence and a 2-fold higher transplantation rate compared to Europe, yet long-term graft outcomes differ strikingly, confirming that European and Asian data cannot be uncritically applied to inform U.S. transplant surveillance.

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Table 1a. Peer-Reviewed Primary Research Studies Included in Systematic Review (2016–2026)

Study / Authors	Country / Institution	Year	Parameter / Focus	Key Finding	NOS
Bloemendal et al.	Netherlands	2023	RI (tertiles)	5-yr graft loss: 12.1% vs 17.7% vs 18.4% across tertiles; patient mortality increases with RI	7/9
Nguyen et al.	Japan	2023	RI; long-term outcomes	No significant graft survival difference by RI (p=0.64); high RI predicted worse patient mortality	6/9
de Freminville et al.	France	2021	Serial RI at 1 & 3 months	RI ≥0.70 at both time points: HR=3.77 for mortality (95% CI 2.71–5.24, p<0.001)	8/9
Postoperative RI & CVE Study	Netherlands / Belgium	2020	RI; cardiovascular events	Elevated RI independently associated with cardiovascular events and all-cause mortality (RI cutoff 0.70)	8/9
Patel et al.	Saudi Arabia	2016	RI vs. serum creatinine	RI provides prognostic marker for graft rather than exact diagnosis; correlated with creatinine	4/9
O'Neill	Ireland / International	2017	Full spectrum US findings	Reviews vascular, parenchymal, urological components; highlights RI and PSV utility and limitations	N/A
Hanssen et al.	Belgium	2017	RI; graft function	RI >1 (absent EDV) in early weeks predicts impaired recovery; strong correlation with creatinine	N/A
Preuss et al.	Germany	2018	RI vs. biopsy	RI as prognostic marker for graft; moderate correlation	4/9

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				with biopsy findings	
Stigler & Tiefenthaler	Austria	2022	RI; evidence review	934 titles screened; 26 studies (7,049 pts); meta-analysis not feasible due to heterogeneity	N/A
Mirza et al. — RI & DGF	USA — Augusta Univ., GA	2026	RI	Early RI associated with DGF; calls for multicenter U.S. studies with standardized RI cutoffs	6/9
Mirza et al. — TRAS	USA — Augusta Univ., GA	2025	PSV; TRAS	367 patients; highlights inadequacy of current duplex criteria; calls for prospective multicenter study	4/9
Li et al. — DGF Meta-Analysis	USA — Columbia Univ., NY	2023	DGF; graft outcomes	DGF: OR 3.38 graft failure; OR 2.32 mortality at 1-year (38 studies)	N/A
Chen & Sanyal	USA — Mayo Clinic, FL	2020	Serial RI; surveillance	Calls for studies to evaluate serial US efficacy and establish appropriate surveillance timing	N/A

Note. NOS = Newcastle-Ottawa Scale (0–9); N/A = systematic review, meta-analysis, or narrative review (NOS not applicable). Studies scoring ≥7 classified as high quality; 4–6 moderate; ≤3 low quality.

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Table 1b. Federal Surveillance Reports and Clinical Practice Guidelines (Contextual Evidence)

Source	Institution	Year	Key Content
USRDS 2025 Annual Data Report	USA — NIDDK/NIH	2026	273,041 living with transplant in U.S.; 1-yr survival 98% (living), 94% (deceased donor)
USRDS 2024 Annual Data Report	USA — NIDDK/NIH	2025	Racial/ethnic disparities persist; ESRD incidence declined 18.6% over prior decade
USRDS 2023 Annual Data Report	USA — NIDDK/NIH	2023	COVID-19 mortality substantially elevated among transplant recipients in 2021
AIUM Practice Parameter — Solid Organ Transplants (2024 Revision)	USA — AIUM/ACR/SPR/SRU	2024	Mandates baseline US post-transplant; color/spectral Doppler mandatory; RI, PSV, EDV documentation standards; CEUS noted as adjunct
ACR-AIUM-SPR-SRU Practice Parameter (2020)	USA — ACR/AIUM	2020	Prior standard; CEUS reference; PSV and RI measurement protocol
HRSA/OPTN Transplant Data 2025	USA — HRSA/OPTN	2025	27,759 kidney transplants in 2024; record volume; DCD donors ~50% of deceased donors
ERA Registry vs. USRDS Comparison	Europe vs. USA	2024	U.S. has 2.5× higher KRT incidence vs. Europe; strikingly different long-term graft outcomes

Note. Federal surveillance reports and practice guidelines are presented separately from primary research studies (Table 1a) in accordance with standard systematic review methodology, as they serve a distinct evidential function — providing national surveillance context and standard-of-care definitions rather than primary epidemiologic data.

Discussion

This systematic review of 10 years of epidemiologic evidence (2016–2026) yields two central findings. First, ultrasound-derived parameters — particularly the resistive index — demonstrate consistent associations with adverse post-transplant outcomes including delayed graft function, graft loss, and patient mortality across international cohorts. Second, the evidence base is critically concentrated outside the United States, with the world's largest kidney transplant program generating only two single-center primary studies (both from a single institution) on post-transplant ultrasound epidemiology in a decade.

The methodological heterogeneity documented across included studies is both a finding of this review and a call to action. The landmark systematic review by Stigler and Tiefenthaler (2022)

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could not perform a meta-analysis because of inconsistent RI measurement timing, differing thresholds, and heterogeneous cohort compositions. This means the field's most rigorous attempt to synthesize the RI literature was stopped by the very absence of standardization that U.S.-based descriptive epidemiologic research could begin to address.

The divergence between Bloemendal et al. (2023) — where higher RI tertiles predicted significantly worse graft and patient survival — and Nguyen et al. (2023) — where RI did not predict graft survival in a living-donor cohort — illustrates how profoundly cohort composition influences RI-outcome associations. Living vs. deceased donors, recipient age, comorbidity burden, racial demographics, and immunosuppression protocols all modify the relationship between RI and outcomes. Without U.S.-specific epidemiologic data reflecting the American transplant population's distinct characteristics, clinicians at U.S. academic centers are applying thresholds derived from populations with fundamentally different risk profiles.

The PSV and EDV literature presents a parallel gap. Despite being mandated parameters under AIUM/ACR standards, population-level reference distributions for PSV and EDV in contemporary U.S. transplant cohorts are absent from the published literature. The sole U.S. PSV-focused study (Mirza et al., 2025) in this review was a single-center retrospective study that itself called for multicenter prospective validation of diagnostic thresholds. This is particularly consequential for TRAS detection, where PSV-based criteria derived from non-transplant native renal artery studies may not apply to the unique anastomotic anatomy of the renal allograft.

The national epidemiologic context amplifies the urgency of this gap. The USRDS 2025 Annual Data Report documents 273,041 individuals living with a kidney transplant in the United States, and federal data confirm that racial and ethnic disparities in graft outcomes persist as a national public health concern. The U.S. donor pool is simultaneously shifting toward higher-risk profiles with DCD donors comprising nearly 50% of deceased donors by 2025, increasing the prevalence of DGF and heightening the clinical importance of early, reliable ultrasound-based complication detection.

The calls for U.S.-based research from Mirza et al. (2026) and Chen and Sanyal (2020) — both published from U.S. transplant centers — are direct acknowledgments from the field itself that domestic epidemiologic evidence is needed. These researchers identified what this systematic review confirms: the evidence base is geographically misaligned with the epidemiologic reality of kidney transplantation in the United States.

Limitations

Several limitations of this systematic review should be acknowledged. First, although Embase and CINAHL were included in the database search, language restrictions to English-language publications may have introduced selection bias by excluding relevant studies published in other languages. Second, the decision to include federal surveillance reports and practice guidelines alongside primary research studies while providing essential national context introduces

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methodological heterogeneity that was addressed by presenting these sources in separate evidence tables. Third, the NOS was applied only to observational research studies; systematic reviews, meta-analyses, and narrative reviews received a N/A designation, as these require different quality assessment tools (e.g., AMSTAR-2). Fourth, the rapidly evolving U.S. transplant landscape (including the expansion of DCD donation and novel immunosuppression protocols) means that studies conducted at the beginning of the 2016–2026 review window may not fully reflect current U.S. clinical practice.

Conclusion

A decade of published epidemiologic evidence (2016–2026) establishes that ultrasound-derived parameters, particularly the resistive index, are associated with adverse post-kidney transplant outcomes including delayed graft function, graft loss, and patient mortality. However, the evidence is methodologically heterogeneous, predominantly non-U.S. in origin, and insufficient to support population-specific surveillance benchmarks applicable to the American transplant population. Evidence on PSV and EDV including TRAS diagnostic thresholds is similarly concentrated in non-U.S. settings and derived from populations with distinct risk profiles.

A critical, well-documented gap exists in U.S.-based descriptive epidemiologic evidence characterizing the full spectrum and frequency of early post-transplant ultrasound findings within the United States healthcare system. Future research priorities should include: (1) a comprehensive descriptive epidemiologic study of early post-transplant ultrasound findings at a U.S. academic transplant center, generating locally valid baseline frequency estimates under AIUM and ACR standards; (2) multicenter prospective investigations to establish standardized RI, PSV, and EDV parameter thresholds applicable across U.S. transplant populations; and (3) longitudinal epidemiologic studies linking ultrasound surveillance patterns to long-term graft survival and patient outcomes using USRDS and OPTN registry data.

The proposed descriptive epidemiologic study at Tufts Medical Center — examining the spectrum and frequency of early post-transplant ultrasound and Doppler findings in a contemporary U.S. academic transplant cohort — represents a direct, scientifically justified, and nationally necessary response to the evidence gap documented in this systematic review.

Declaration

The authors used Claude (Anthropic), an AI-assisted writing tool, to support manuscript drafting and language refinement during the preparation of this manuscript. All scientific research content, data interpretation, conclusions, and final editorial decisions were made by human authors, who take full responsibility for the integrity and accuracy of this work.

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ISSN: 2581-3366

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