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Wasted Potential: Decoding the Trifecta of Donor Kidney Shortage, Underutilization, and Rising Discard Rates

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Abstract: Kidney transplantation is a life-saving intervention for end-stage renal disease; yet, the persistent gap between organ demand and supply remains a significant challenge. This paper explores the escalating discard rates of deceased donor kidneys in the United States to assess trends, discard reasons, demographical differences, and preservation techniques. Data from the Scientific Registry of Transplant Recipients from 2010 to 2021 was analyzed using chi-squared tests for trend significance and logistic regression to estimate odds ratios for kidney discard. Over the last decade, discard rates have risen to 25% in 2021. Most discarded kidneys came from extended criteria donor (ECD) donors and elevated kidney donor profile index (KDPI) scores. Kidney biopsy status was a significant factor and predictor of discard. Discard rates varied greatly between Organ Procurement and Transplantation Network regions. Of reasons for discard, "no recipient located" reached a high of 60%. Additionally, there has been a twofold increase in hypothermic machine perfusion (HMP) since 2010, with transportation difficulties being the main reason for the discard of perfused kidneys. Our findings suggest a need to recalibrate organ utilization strategies, optimize the use of lower-quality kidneys through advanced preservation methods, and address the evolving landscape of organ allocation policies to reduce kidney discard rates.

Keywords: kidney transplantation; organ donation; organ discard; donation after circulatory death; organ procurement organization; hypothermic machine perfusion; kidney donor profile index; organ procurement and transplantation network

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1. Introduction

Kidney transplantation remains a cornerstone in the treatment of end-stage renal disease, offering patients freedom from dialysis and an improved quality of life. With nearly 89,000 waitlist candidates, the demand for kidneys far exceeds the available supply, creating a critical disparity in organ availability [1]. In 2021, pretransplant waitlist mortality rose to 6.0 deaths per 100 patient–years, the highest value since 2010 [2]. A significant contributor to this problem is the high rate of kidney discard, defined as donated organs that are procured but deemed unsuitable for transplantation.

Due to the high discard rates, concerted efforts have been undertaken to address the organ deficit in the U.S. Initiatives taken to expand the deceased donor pool have included utilizing grafts from older or hepatitis C-positive donors and those with acute injuries, alongside an increasing reliance on donors declared dead based on cardiovascular criteria, i.e., donation after circulatory death (DCD) [3,4]. Moreover, the introduction of hypothermic machine perfusion (HMP) has been designed to expand the donor pool by enabling extended periods of cold ischemia. Continuous reforms in allocation policies have aimed to tackle the high discard rate and inequity within the allocation system. In 2021, the newest iteration of the Kidney Allocation System (KAS), termed KAS 250, was implemented with the aim of reducing geographic disparities in kidney transplantation [5]. KAS 250 replaced the donation service area (DSA) and Organ Procurement and Transplantation Network (OPTN) region distribution system with a distance-based system, offering kidneys first to candidates listed at transplant hospitals within 250 nautical miles of the donor hospital [6]. Unfortunately, these efforts have not created the significant shift that is needed to move the needle on national organ discard rates.

Globally, kidney discard rates vary between 12 and 20% [7]. The United States surpasses global averages for the highest proportion of discarded deceased donor kidneys, with rates as high as 25% in 2022 [2,8]. Although the discard of a small fraction of procured organs from deceased donors is warranted, many of these kidneys may be suitable for transplantation. In a 2019 study conducted by Aubert et al., a French-based allocation model was employed for the population of deceased donor kidneys in the United States and revealed that 62% of the kidneys discarded in the U.S. could have been successfully transplanted under the French system [9]. The magnitude of these differences raises the following question: What factors contribute to the extremely high discard rates in the United States?

In this manuscript, our objective was to investigate how variations in preservation techniques and regional practices influence the discard rates of deceased donor kidneys and what strategies can be implemented to optimize organ utilization and reduce disparities in organ allocation in the United States.

2. Materials and Methods

This study utilized data from the Scientific Registry of Transplant Recipients (SRTR), which includes information on all U.S. donors, candidates on the waitlist, and transplant recipients. For this analysis, the "Deceased Donor" file within the SRTR was used, including donors who had one or more organs recovered for transplantation.

Data were extracted from donors who had one or more kidneys recovered for transplant between 2010 and 2021. Each kidney was analyzed independently, and not in pairs, except for the donor demographics stated in Table 1. Kidneys were classified as not recovered for transplant, recovered for transplant and discarded, or recovered for transplant and transplanted. Kidneys that were recovered and discarded were separated into "left kidney discard" and "right kidney discard" for data analysis to account for variables that were categorized by laterality.

The donor demographics analyzed include age, sex, body mass index (BMI), terminal creatinine, and kidney donor profile index (KDPI). The stratification of kidneys by KDPI consisted of 5 groups (KDPI: 0–20%, 21–40%, 41–60%, 61–80%, 81–100%). Donors were classified as a standard criteria donor (SCD), extended criteria donor (ECD), or donor after cardiac death (DCD).

Variables that were noted in the database as separate "left" and "right" variables included the use of machine perfusion, the use of a kidney biopsy, the glomerulosclerosis score, and the reason for discard. For the preservation technique, when the use of machine perfusion was not employed—the current standard—static cold storage (SCS) was assumed. Discard reasons extracted from the SRTR database were grouped into the following categories: donor factors, procurement factors, organ factors, biopsy findings, transport, recipient factors, no recipient located, or other. Other variables of interest included year, OPTN region, and graft sharing between centers. Shared kidneys refer to kidneys that were not allocated within their transplant region. These kidneys were either transplanted or discarded after becoming an open offer. For comparisons of kidney utilization within the Eurotransplant region (Austria, Belgium, Croatia, Germany, Hungary, Luxembourg, the Netherlands, and Slovenia), data on kidney utilization were obtained from the 2010–2021 annual Eurotransplant reports [10]. Missing data were not imputed.

Table 1. Donor demographics of deceased kidney donors in the United States from 2010 to 2021.

Donor Demographics	Total Donors = 105,472
Age mean ± std	40.4 ± 15.9
BMI mean ± std	28.2 ± 7.1
Terminal SCr (mg/dL) mean ± std	1.36 ± 1.3
KDPI Grouped *n* (%)	
0–20	24,564 (23.3)
21–40	21,807 (20.7)
41–60	20,804 (19.7)
61–80	19,326 (18.3)
81–100	18,828 (17.9)
Donor Type *n* (%)	
SCD	65,508 (62.1)
ECD	18,242 (17.3)
DCD	21,722 (20.6)
DCD donor WIT mean ± std (minutes)	21.6 ± 15.4

SCr: serum creatinine levels; KDPI: kidney donor profile index; SCD: standard criteria donor; ECD: extended criteria donor; DCD: donation after circulatory death; WIT: warm ischemia time; BMI: body mass index.

Descriptive statistics were used to evaluate trends in discard by year to evaluate trends over time and by OPTN region. For descriptive data on discarded kidneys, the variables "left kidney discard" and "right kidney discard" were extracted separately and then combined for analysis. Categorical variables are presented as counts and percentages, while normally distributed continuous variables are presented as mean ± standard deviation. The discard rate trends per year were tested by the Cochran–Armitage chi-square test for ordinal trend, with a p-value < 0.05 considered significant.

We performed two separate binary logistic regression analyses to identify factors predicting kidney discard with the dependent variables "left kidney discarded" and "right kidney discarded". Independent variables for both analyses included KDPI group, donor type, biopsy status, and machine perfusion status. For the analysis of left discarded kidneys, "Left kidney Biopsy" and "Left kidney Machine Perfusion" variables were used. For the analysis of right discarded kidneys, the variables "Right kidney Biopsy" and "Right kidney Machine Perfusion" were used. Variables were entered into the model using the 'Enter' method, where "KDPI group 1" and "SCD" were constants. We calculated odds ratios (Exp (B)), Wald statistics, and confidence intervals for each predictor. Model fit was assessed using the Omnibus Tests of Model Coefficients, and model explanatory power was evaluated with Nagelkerke R Square values. Receiver Operating Characteristic (ROC) curve analyses were conducted to determine the discriminative ability of the logistic regression models. We calculated the area under the ROC curve (AUC) for each predictor to assess their performance in correctly classifying kidneys as discarded or not discarded. An AUC of 0.5 indicated no discriminative ability and an AUC of 1.0 indicated perfect positive discrimination.

Statistical analysis was performed using SPSS 15.0 for Mac. Statistical significance was defined at the $\alpha = 0.05$ level. Graphs were generated using GraphPad Prism 8.0.1.

3. Results

3.1. Donor Demographics

First, we identified the demographics of the national kidney donor cohort. Table 1 presents the demographic characteristics of kidney donors from 2010 to 2021. The mean age was 40.4 years and the average BMI was 28.2 kg/m^2. The predominant source of procured kidneys over the past decade was SCD, accounting for 62.2%. ECD and DCD constituted less than half of the total donors—17.3% and 20.6%, respectively. On average, the warm ischemia time was 21.6 min.

3.2. Donor Kidney Availability and Discard Rate

Next, we examined kidney discard rates. Figure 1 vividly illustrates the trend of escalating discard rates for recovered kidneys over the past decade. In 2010, 2641 recovered kidneys were unused, representing an 18% discard rate, compared to 6500 kidneys representing a nearly 25% discard rate in 2022 (Figure 1a,d). The discard rate significantly increased over time ($p < 0.0001$). Per donor type, ECD kidneys had the largest increase in discard rate, reaching a high of 55% in 2021 compared to 44% in 2010. The discard rate of DCD kidneys has also risen steadily from 21% to 30% over the last decade. The discard rate of SCD donor kidneys has remained stable between 10 and 12% (Figure 1b). Elevated KDPI scores consistently comprised the highest rate of kidney discard, with KDPI scores of 85–100% contributing to the highest proportion of discard rates, averaging 55% over the past decade (Figure 1c). To evaluate potential trends of discard per region, we analyzed the annual discard rate across OPTN regions. The OPTN regions with the largest increases in discard rates since 2010 include regions 2, 9, 10, and 11, which are largely the East Coast areas (Figure 1d). We analyzed kidney sharing between transplanted and discarded kidneys across regions to find trends suggesting if dispersion could correlate with discard. While the majority of kidneys were shared locally, transplanted kidneys were more frequently shared than discarded kidneys but did not differ substantially per OPTN region (Figure 1e,f). Discarded kidneys were also shared for research purposes.

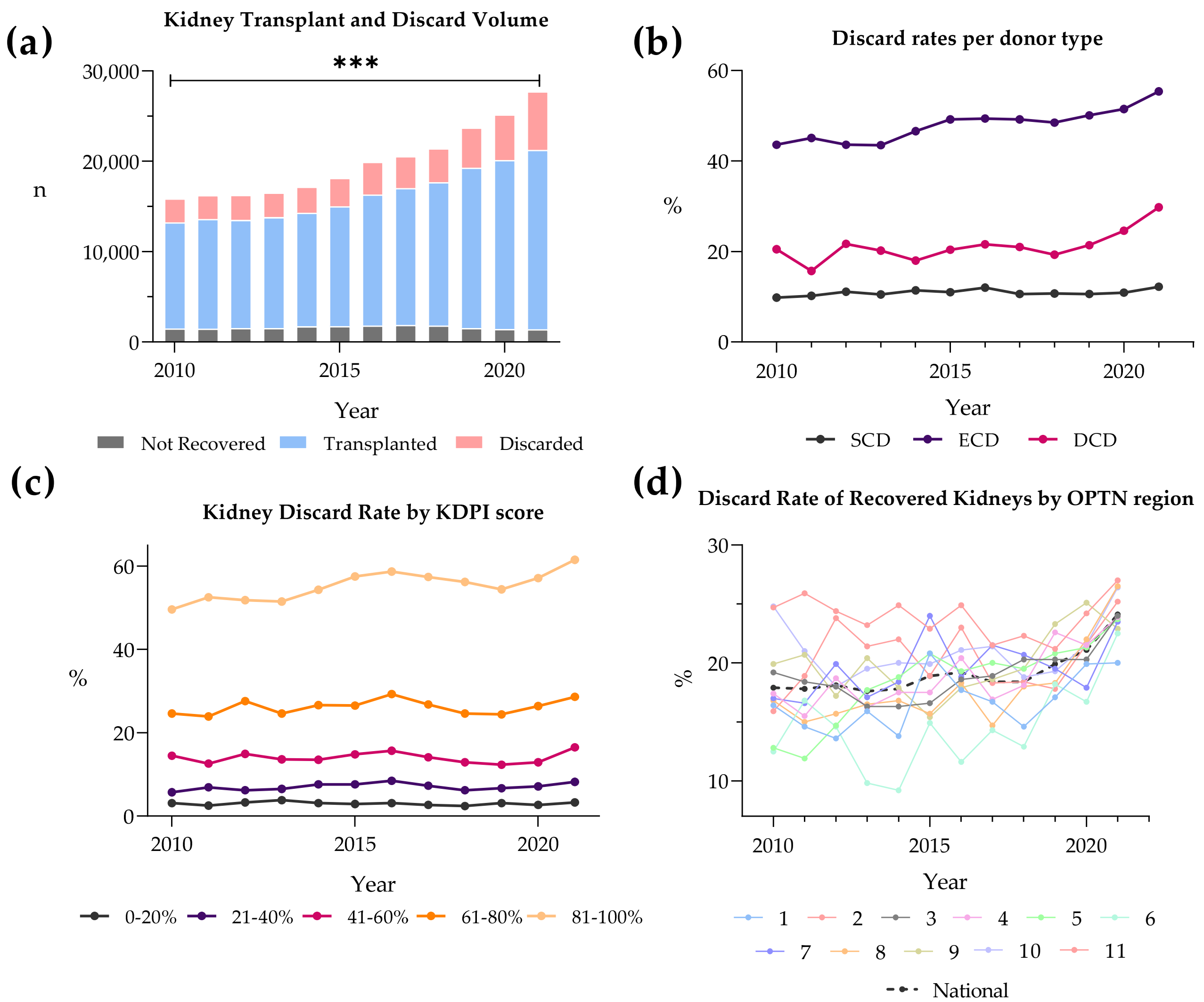

Figure 1. *Cont.*

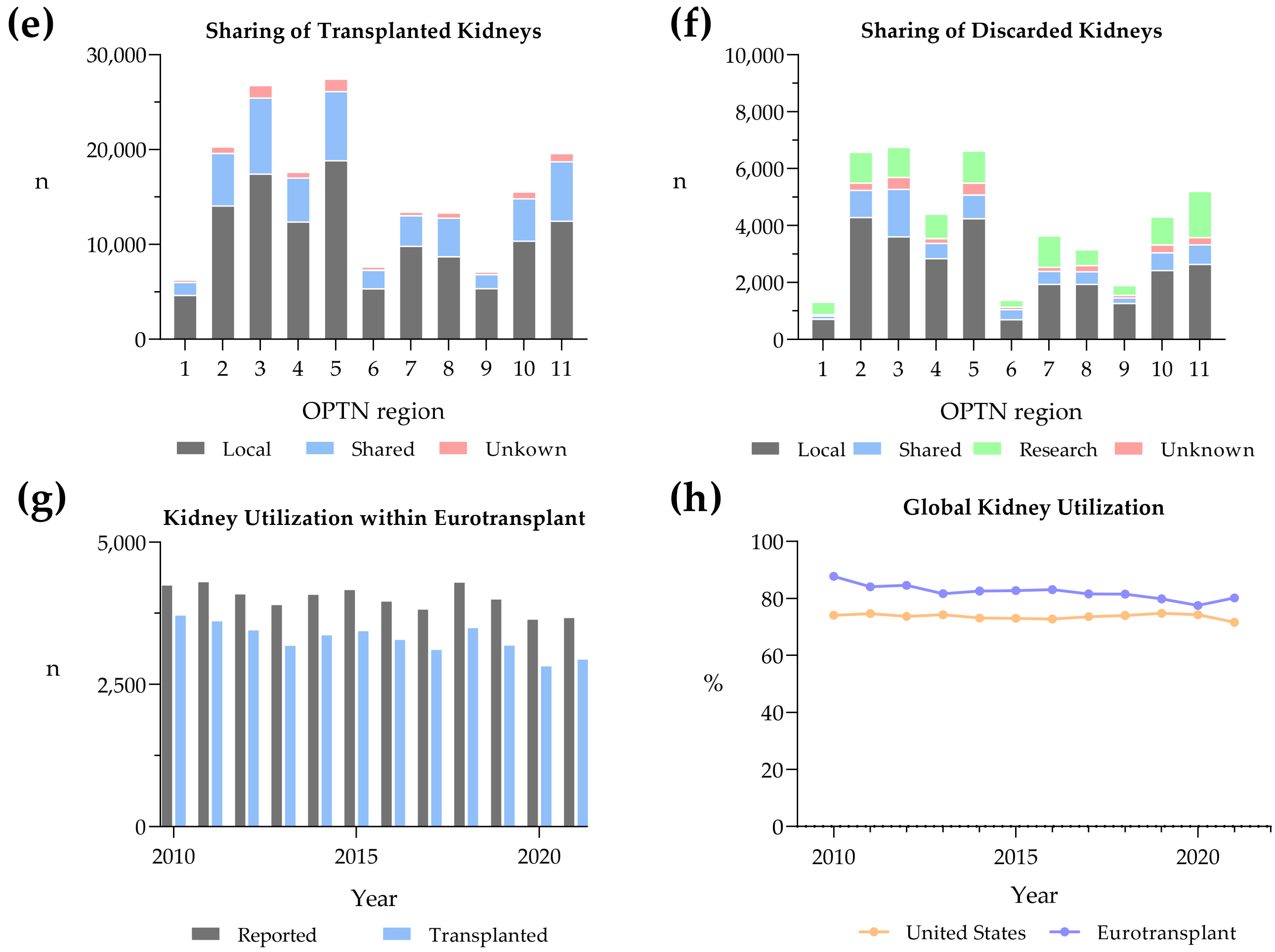

Figure 1. Kidney transplant volume and discard rate from 2010 to 2021. (**a**) All potential deceased donor kidneys and outcomes of non-recovery, discard, or transplant. (**b**) The discard rate per donor type. (**c**) The kidney discard rate based on Kidney Donor Profile Index (KDPI) scores. (**d**) The discard rate per Organ Procurement and Transplantation Network (OPTN) region. (**e**) The sharing of transplanted kidneys per OPTN region. (**f**) The sharing of discarded kidneys per OPTN region. (**g**) The number of reported and transplanted deceased donor kidneys within the Eurotransplant region. (**h**) The kidney utilization rate between the United States and the Eurotransplant region. The discard rate trends per year were tested by the Cochran–Armitage chi-square test for ordinal trend (*** represents a p-value < 0.0001). SCD: standard criteria donor; ECD: extended criteria donor; DCD: donation after circulatory death.

To compare kidney utilization rates on an international level, we compared the deceased donor kidneys reported for transplant and transplanted within the Eurotransplant region. The total number of reported deceased donor kidneys within the Eurotransplant region was around 4000 over the past ten years compared to 20,000–30,000 in the United States (Figure 1a,g). The deceased donor kidney utilization rate within the Eurotransplant region was between 77 and 89% over the past ten years, whereas the American utilization rate ranged between 71 and 75% (Figure 1h).

3.3. Reasons for Discard

Subsequently, we looked at the reasons for kidney discard. Figure 2 shows the annual reasons for kidney discard and provides further stratification by OPTN region. The predominant factors behind discard over the entire period were "No recipient located-list exhausted" (35%) and "biopsy findings" (29%) (Figure 2a). From 2010 to 2021, the contribution of biopsy findings to discard rates progressively diminished, dropping from

38% in 2010 to 15% in 2021 (Figure 2a and Table S1). In contrast, the category of "No recipient located- list exhausted" has consistently seen an annual increase, reaching a peak of 61% in 2021 from 19% in 2010. The other factors for discard have either contributed the same percentage or experienced a slight decrease since 2010. Interestingly, the reasons for discard vary greatly among the different OPTN regions (Figure 2b).

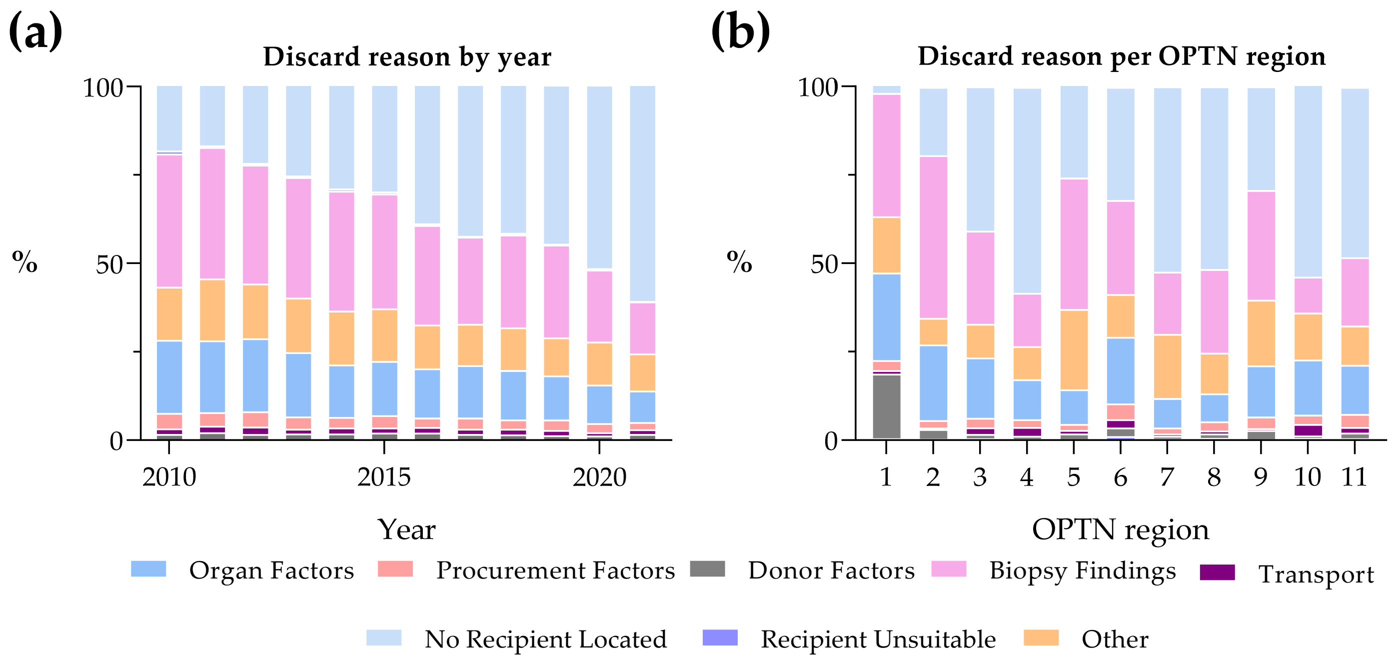

Figure 2. Reasons for kidney discard (**a**) per year (**b**) and per Organ Procurement and Transplantation Network (OPTN) region.

3.4. Discard per Preservation Technique

Additionally, we conducted a comparison of preservation techniques. Although static cold storage (SCS) remains the primary technique employed, the adoption of HMP has more than doubled since 2010 (Figure 3a). In 2021, there was nearly an equal number of discarded kidneys between HMP and SCS (Figure 3a). Noteworthy differences in donor demographics were observed based on the preservation technique (Table S2). When looking at the different OPTN regions, the utilization of HMP varied, showing a higher prevalence in regions 1, 9, 10, and 4, while regions 2, 3, and 5, characterized by the highest kidney volume, tended to favor SCS more frequently (Figure 3b). When categorized by donor type, SCS was used most frequently for SCD and ECD compared to HMP (45.43% and 11.03% vs. 16.46% and 6.53%; Figure 3c), while HMP was used more frequently among DCD donors. When looking at KDPI scores, there were fewer kidneys with a low (0–20%) KDPI score placed on HMP (27% on HMP vs. 73% SCS; Table S2). Of the reasons for discard, "transport" played a major role for kidneys preserved on HMP. In contrast, "biopsy findings" emerged as the primary contributing factor for discard among kidneys preserved on SCS (Figure 3d).

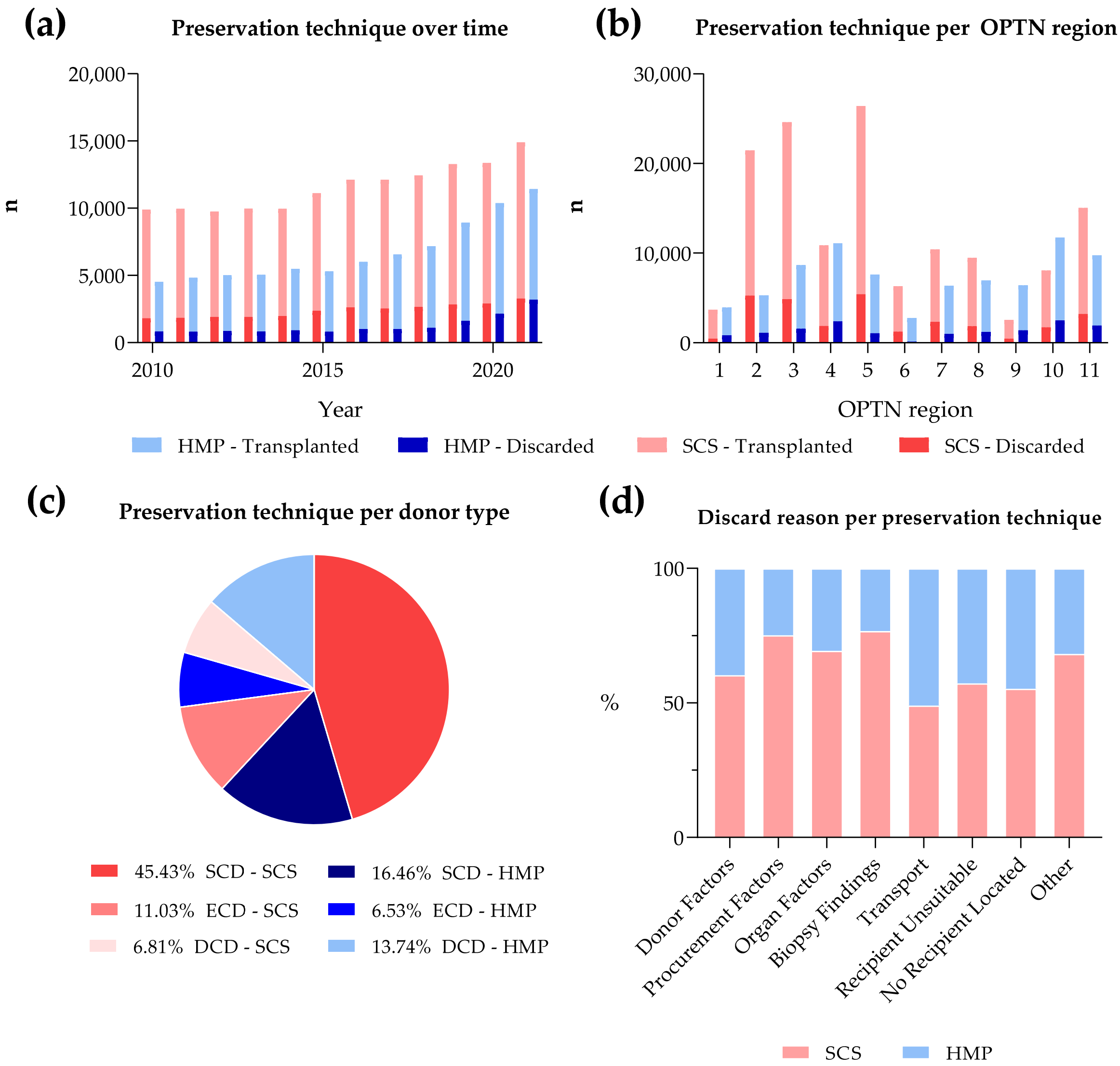

Figure 3. Discarded versus transplanted kidneys per preservation technique (**a**) shown over time (**b**) and per Organ Procurement and Transplantation Network (OPTN) region. (**c**) Preservation technique per donor type (**d**) and per reason for discard. SCD: standard criteria donor; ECD: extended criteria donor; DCD: donation after circulatory death.

3.5. Discard Based on Biopsy Rates

Figure 4 demonstrates the kidney biopsy rate over time and average glomerulosclerosis score of discarded and transplanted kidneys. The biopsy rate of all kidneys has gradually increased to nearly 58%, with discarded kidneys continuing to have the highest biopsy rate (Figure 4a). Kidneys preserved using HMP also had a higher biopsy rate versus kidneys preserved using SCS (72% vs. 45%) (Table S2). The results of kidney biopsy were reported as the glomerulosclerosis score (GS). A higher GS score is associated with more severe sclerotic glomeruli. The majority of biopsied kidneys had a GS score of 1, most of which were transplanted (Figure 4b).

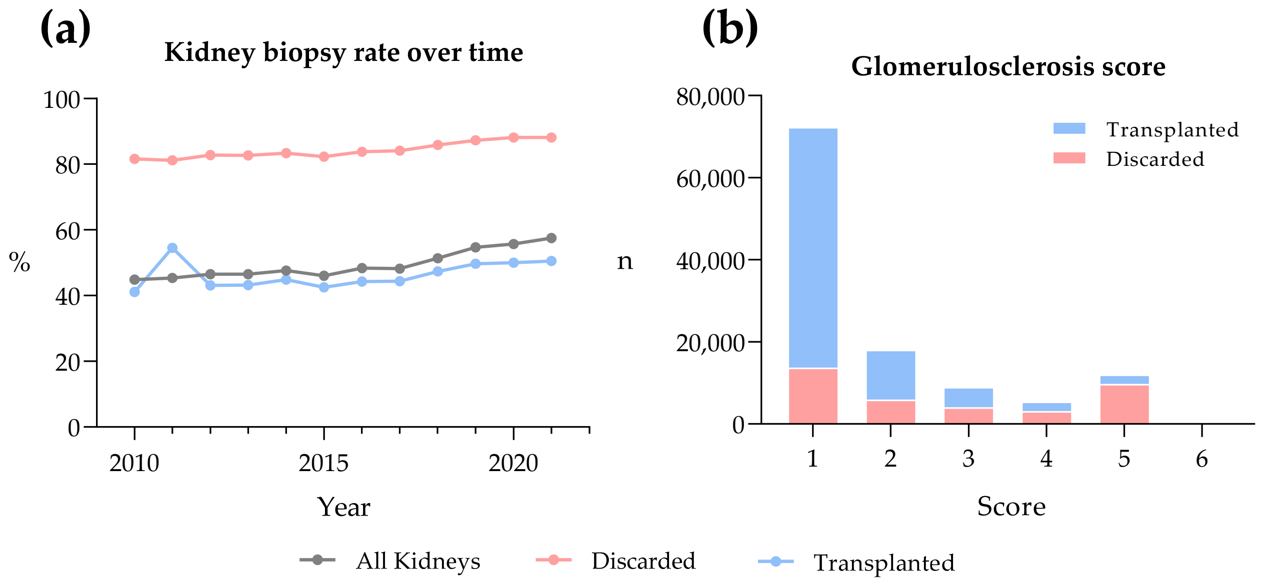

Figure 4. (**a**) Kidney biopsy rate over time (**b**) and glomerulosclerosis score per biopsy, with 1 representing a low glomerulosclerosis score and 6 representing severe glomerulosclerosis.

3.6. Logistic Regression Analysis and ROC Curves

The logistic regression analysis examined how different factors like the condition of the kidney, the type of donor, whether the kidney underwent biopsy, and if machine perfusion was used affected the likelihood of the kidney being discarded (Table 2). The results showed that the condition of the kidney (measured by KDPI score) and whether it was biopsied were the largest significant predictors of discard. Kidneys with higher KDPI scores and those that were biopsied were more likely to be discarded.

Table 2. Summary of binary logistic regression results and ROC curve results for left and right discarded kidneys.

	Left Discarded Kidneys		Right Discarded Kidneys			ROC Curves	
Predictor	**(B)**	**Exp (B)**	**(B)**	**Exp (B)**	**Sig.**	**Left Kidney AUC**	**Right Kidney AUC**
KDPI Grouped							
0–20% (Constant)						0.383	0.384
21–40%	0.482	1.619	0.505	1.658	<0.001	0.424	0.428
41–60%	0.966	2.628	0.969	2.635	<0.001	0.465	0.469
61–80%	1.573	4.821	1.518	4.563	<0.001	0.538	0.537
81–100%	2.536	12.631	2.478	11.915	<0.001	0.69	0.682
Donor Type							
SCD (Constant)						0.33	0.338
ECD	0.107	1.112	0.068	1.07	<0.001	0.648	0.64
DCD	0.362	1.437	0.377	1.459	<0.001	0.522	0.522
HMP	−0.575	0.563	−0.636	0.53	<0.001	0.503	0.495
Biopsied	1.638	5.146	1.554	4.729	<0.001	0.715	0.706
Constant	−3.902	0.02	−3.688	0.025	<0.001		

Specifically, kidneys with KDPI scores of 81–100% had the highest likelihood of being discarded, with odds ratios of 12.631 for the left kidney and 11.915 for the right. Biopsied kidneys also had significantly higher odds of discard, with odds ratios of 5.146 for the left kidney and 4.729 for the right.

ROC curve analysis was performed to evaluate how well the predictor variables could forecast kidney discard, with the AUC values showing how effectively they could distinguish between kidneys that were discarded and those that were not (Table 2). A positive biopsy status demonstrated fair predictive abilities (left AUC: 0.715; right AUC: 0.706).

4. Discussion

With 89,000 patients awaiting kidney transplants, an increase in available donor kidneys is essential. In this study, we analyzed the primary factors contributing to kidney discards over the past decade within the United States, emphasizing the role of allocation disparities between OPTN regions, the incorporation of HMP, and insights derived from biopsy findings.

The findings of our study indicate a notable escalation in the national kidney discard rate over the past decade, culminating in a 25% discard rate in 2021 (Figure 1d). This rate stands in stark contrast to several European nations, including the United Kingdom, France, and The Netherlands, where kidney discard rates are reported to be 10–12%, 9–10%, and 7–8%, respectively [9,11,12]. Moreover, our comparison of deceased donor kidney utilization between the United States and the Eurotransplant region shows that over the last decade, the utilization rate of reported kidneys has been 10% lower in the United States (Figure 1h). These variations may be attributed to distinctions in data reports, national donation programs, ethical considerations, logistical frameworks, and population health profiles. The quality of a 65-year-old DCD kidney may differ between an American and a European donor [13]. Furthermore, variations in DCD policies, the adoption of preservation techniques such as HMP and normothermic regional perfusion (NRP), and disparities in organ allocation distances may contribute to the observed differences in discard rates.

Of the reasons for kidney discard, the most reported and most concerning is “no recipient located”. As seen in our data, “no recipient located” has risen to a record high of 60%, more than doubling since 2015 (Figure 2a,b). This phenomenon may be attributed to a range of factors. To start, OPOs could be adopting a more assertive stance in recovering marginal kidneys for transplant. Secondly, the procured kidneys themselves may exhibit low quality, leading transplant centers to hesitate in utilizing them. This trend is seen within our data, with rising discard rates in ECD, and DCD donors and kidneys with high KDPIs (Figure 1b,c). In the U.S., transplant centers face significant regulatory oversight and pressure to achieve favorable one-year post-transplant outcomes as healthcare insurers and payers heavily rely on these metrics to gauge the success of their insured patients within transplant programs. This scrutiny influences decisions on accepting organs with higher associated risks.

Considerable variations in discard rates were observed among the 11 OPTN regions, underscoring a complex landscape. While discard rates have risen across all regions, regions 2, 9, 10, and 11 have experienced a remarkable 10% increase since 2010 (Figure 1d). Not only do discard rates differ across OPTN regions but also the reasons for discard and the utilization of HMP (Figures 2b and 3b). These differences may be due to several factors including differences in organizational practices and protocols, donor population characteristics, transplant center preferences, public awareness, economic factors, and geographic variations [14]. Additionally, these differences could be explained by the major discrepancies between the 11 regions when looking at population, donors, members, recipients, transplants, and land area [15]. Interestingly, regions 2, 9, 10, and 11 have a much lower percentage of land area yet meet or nearly meet the average percentages of population, donors, members, recipients, and transplants of the other regions. Establishing more balanced regions considering these factors might potentially enhance organ allocation.

Moreover, the growing number of potentially transplantable kidneys and variations between OPTN regions could be due to shortcomings in the allocation system’s effectiveness in assigning kidneys to centers. Kidney allocation policies have undergone a series of changes, most recently with the introduction of KAS 250 [1]. The added complexity of broader distribution impacts the volume of organ offers transplant centers must process and the efficiency with which they are allocated. Transplant centers now have a median of nine OPOs whom they receive organ offers from and OPOs have a tenfold increase in the median number of transplant centers within their local jurisdiction [16]. The massive influx of organ offers substantially impacts a center's ability to process offers, necessitating additional staffing and third-party collaborators, adding to the complexity and perhaps adversely impacting organ utilization [17]. Concepcion et al. (2023) conducted a national survey investigating factors influencing efficient organ placement [18]. The survey highlighted that a majority of OPOs encountered obstacles in obtaining kidney biopsies or faced shortages of available pathologists. Additionally, challenges to utilizing HMP were reported related to organ transportation or staffing shortages. Furthermore, OPOs indicated that the implementation of the new allocation system exacerbated transportation difficulties, amplified communication hurdles with transplant centers, and diminished organ allocation efficiency.

The shift toward kidneys with higher KDPIs, elevated donor terminal serum creatinine, and CIT has underscored the trend of increased donor offers involving organs of perceived lower quality [19–21]. These organs, frequently bypassed by multiple transplantation centers, face delayed acceptance, exacerbating the prolongation of CIT. This delay not only heightens the risk of delayed graft function (DGF) and primary non-function (PNF) but also escalates the tendency among transplant centers to refuse such offers, culminating in a higher incidence of organ discards [17]. Our findings corroborate the pivotal role of elevated KDPI scores as a critical determinant in kidney discard decisions (Figure 1c). Specifically, kidneys with the highest KDPI score (81–100%) were significantly more likely to be non-utilized (Table 2). This pattern may primarily stem from the understanding that kidneys with KDPI scores above 85% possess a diminished prospective functional duration relative to those with lower scores [19]. Nonetheless, numerous studies suggest that for elderly patients, accepting kidneys with KDPI scores greater than 85% can provide survival benefits equal to or greater than remaining or starting on dialysis, reduce waitlist duration, and improve overall quality of life [20–24]. This insight argues for a recalibration of organ utilization strategies, particularly for the elderly demographic. Such strategies have been employed within Eurotransplant and other countries by age-matching donors and recipients, which was an effective approach to expanding the donor pool while maximizing graft survival in older recipients [25,26]. Such an approach incorporating KDPI could significantly lower the rate of kidney discard, presenting a pragmatic resolution to the existing inefficiencies in organ allocation and utilization in the United States.

Biopsy status was shown to be the most significant factor contributing to kidney discard. Biopsied kidneys had significantly increased odds of being discarded and displayed the most substantial predictive strength (Table 2). In the evaluation of discard trends, "biopsy findings" was a leading reason for discard and discarded kidneys had the highest biopsy rate, while the majority of biopsy results consisted of a GS score of 1 (Figures 2a and 4a,b). This suggests that kidney biopsy may be relied on for evaluating transplant suitability. However, kidney biopsies do not consistently predict the potential for early graft failure, and their reproducibility as a tool for organ acceptance is often questionable [27]. Machine perfusion offers the ability to monitor organ function in real time and may be a suitable alternative to biopsy. Our data revealed that while kidneys undergoing HMP were biopsied more frequently, they were less likely to be discarded due to "biopsy findings" compared to those preserved on SCS (Figure 3d). The additional functional insights provided by machine perfusion might reduce the reliance on biopsy status. Consequently, machine perfusion could offer a more accurate assessment of organ viability, potentially making biopsy results less relevant in the decision-making process.

Data reported from the analysis of the SRTR database suggest that transplant centers are reluctant to accept more marginal kidneys, specifically DCD kidneys with extended CIT. Apart from acknowledging the increased risk associated with transplanting these kidneys, which may lead to less-than-ideal one-year post-transplant outcomes, they also come with an elevated risk of DGF. DGF poses significant implications for transplant centers, manifesting in a roughly 10% increase in costs, prolonged hospitalization, and extended intensive care unit (ICU) stays [28]. Given the fixed reimbursement for transplant hospitalization, the escalating costs associated with managing DGF become a substantial financial burden for hospitals. A recent cost–benefit analysis of government compensation showed that increasing the kidney compensation rate could enhance kidney utilization, thereby increasing transplant numbers [29]. This not only has the potential to save thousands of lives annually but also yields substantial savings by mitigating dialysis costs.

While an increased kidney compensation rate would be beneficial, optimal outcomes for recipients necessitate a reduction in the risk of DGF. Ischemia–reperfusion injury (IRI) stands out as a principal contributor to DGF, characterized by an altered Ca^{2+} efflux, compromised Na/K ATPase function, anaerobic glycolysis, and increased reactive oxygen species (ROS) production [30]. While HMP enhances kidney preservation by reducing IRI and thus DGF during allocation [31], the elevated rate of discarded pumped kidneys is notable. This phenomenon is unsurprising given that some OPOs are more inclined to perfuse marginal kidneys. Nevertheless, the predominant kidneys that underwent perfusion were, in fact, from SCD (Figure 3c). Pump-related parameters like intra-renal resistance (IRR) present clinicians with grounds for rejecting a kidney. However, controversial studies have emerged regarding the predictive value of IRR on transplant outcomes [32–34].

Crucially, disparities between oxygenated HMP and non-oxygenated HMP are pivotal, with the latter still categorized as cold ischemia. Adopting portable oxygenated HMP as a national standard can substantially reduce discard rates. Not only will it improve kidney preservation by restoring the kidney its ATP levels [35] but it will also minimize the static cold time, allowing OPOs more time for allocation. A significant drawback to HMP lies in its restriction from commercial plane transport, posing challenges for allocating kidneys to distant locations and necessitating expensive charter flights. Hence, it is not surprising to observe a decline in the number of pumped kidneys following the introduction of KAS 250 as the allocation distances increased. Revising the policy to permit the transportation of portable machines or developing a machine without a lithium battery could yield substantial benefits in reducing kidney discard.

Finally, the implementation of normothermic machine perfusion (NMP) can enhance kidney utilization rates, especially given the trend of increasing marginal kidney recovery. A recent large UK randomized controlled trial has established the safety and feasibility of implementing NMP prior to transplantation [36]. By perfusing kidneys with a blood-based perfusate at physiological temperatures, complete metabolic restoration is achieved [37], allowing clinicians to assess kidney function, which could help decide whether to proceed with kidney transplantation. Furthermore, NMP can serve as a preservation platform, reducing cold ischemia time and potentially alleviating IRI. Ultimately, NMP presents itself as a treatment platform, offering a unique avenue for targeted drug delivery [38,39]. Biopsy findings, such as glomerular sclerosis and fibrosis, can guide the application of compounds tailored to address specific pathologies, representing a personalized medicine approach to kidney treatment.

5. Conclusions

In conclusion, our analysis underscores a concerning increase in kidney discard rates in the United States, significantly surpassing those in European countries. A large proportion of the recovered kidneys are simply discarded due to poor quality. Our results showed that biopsy status was a significant predictor of discard, while elevated KDPI scores and donor type were also important factors in the decision to discard. In recent years, the leading reason for kidney discard has shifted to the inability to find a suitable recipient, implying that factors beyond organ quality contribute to the rising discard rates. Our findings suggest a need for the recalibration of organ utilization strategies, particularly in assessing and optimizing the use of lower-quality kidneys. By incorporating advanced preservation methods like HMP and NMP, there is potential to expand the donor pool while ensuring optimal graft survival. Moreover, addressing logistical and regulatory challenges that contribute to organ underutilization, such as the complexities introduced by broader distribution and the need for enhanced transportation and communication systems, could significantly improve the efficiency of kidney allocation. Ultimately, tackling the multifaceted challenges contributing to high kidney discard rates requires a collaborative effort among policymakers, transplant centers, OPOs, and the broader medical community. By focusing on data-driven policies, leveraging technological advancements in organ preservation, and refining allocation practices, we can make significant strides toward reducing kidney discards, optimizing the utilization of available organs, and improving outcomes for thousands of patients on the transplant waitlist.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/transplantology5020006/s1: Table S1: Reasons for kidney discard in the United States from 2010 to 2021. Table S2: Donor demographics for kidneys preserved using hypothermic machine perfusion (HMP) versus static cold storage (SCS).

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