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Financial impact of delayed graft function in kidney transplantation

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Abstract

Increased utilization of suboptimal organs in response to organ shortage has resulted in increased incidence of delayed graft function (DGF) after transplantation. Although presumed increased costs associated with DGF are a deterrent to the utilization of these organs, the financial burden of DGF has not been established. We used the Premier Healthcare Database to conduct a retrospective analysis of healthcare resource utilization and costs in kidney transplant patients (n = 12 097) between 1/1/2014 and 12/31/2018. We compared cost and hospital resource utilization for transplants in high-volume (n = 8715) vs low-volume hospitals (n = 3382), DGF (n = 3087) vs non-DGF (n = 9010), and recipients receiving 1 dialysis (n = 1485) vs multiple dialysis (n = 1602). High-volume hospitals costs were lower than low-volume hospitals (\$103 946 vs \$123 571, $P < .0001$). DGF was associated with approximately \$18 000 (10%) increase in mean costs (\$130 492 vs \$112 598, $P < .0001$), 6 additional days of hospitalization (14.7 vs 8.7, $P < .0001$), and 2 additional ICU days (4.3 vs 2.1, $P < .0001$). Multiple dialysis sessions were associated with an additional \$10 000 compared to those with only 1. In conclusion, DGF is associated with increased costs and length of stay for index kidney transplant hospitalizations and payment

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CONFLICT OF INTEREST

Sumit Mohan is an scientific advisory board member for Angion Biomedica Corp.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

schemes taking this into account may reduce clinicians' reluctance to utilize less-than-ideal kidneys.

Keywords

delayed graft function; dialysis; kidney disease; kidney transplant

1 | INTRODUCTION

Kidney transplantation is the treatment of choice for patients with end-stage kidney disease (ESKD), offering survival and quality of life advantages compared to dialysis.¹ Severe ischemic reperfusion injury following allograft implantation can result in significant renal tubular cell dysfunction and continued need for supportive renal replacement therapy in the early postoperative period.^{2–4} Delayed graft function (DGF)—where a transplant recipient continues to require dialysis following transplantation—is a common complication of ischemia reperfusion injuries.^{5,6} DGF is broadly defined as the need for dialysis within the first 7 days of transplantation, regardless of indication, and is associated with several donor and transplant factors including advanced donor age, higher kidney donor profile index (KDPI), stroke/anoxia as cause of death, elevated terminal serum creatinine, and prolonged cold ischemia.^{7–10}

Recent changes in deceased donor allocation in the United States (US) under the new Kidney Allocation System (KAS) implemented in 2014 were associated with an increase in DGF—presumably due to increased cold ischemia time that resulted from increased organ sharing and increased dialysis vintage among recipients.^{11,12} With the increased focus on the use of less-than-ideal organs to lower the currently high discard rate, there is concern of a further increase in the incidence of DGF in the United States—and the attendant costs associated with this complication.^{12,13} Increased costs that are incurred when using less-than-ideal organs that progress to DGF potentially deter transplant centers from accepting these organs despite evidence that this approach would still be cost-effective for the healthcare system vs staying on dialysis, while also providing significant quality of life and mortality benefits.¹³ We attempt, using direct hospital-reported charge data from the Premier Healthcare Database, to estimate the increased financial costs incurred with DGF following kidney transplantation.

2 | MATERIALS AND METHODS

2.1 | Study design and data sources

A retrospective analysis of hospital healthcare resource utilization (HRU) and cost in kidney transplant patients among high- and low-volume transplant centers was conducted using the Premier Healthcare Database (Premier). Premier is a hospital-based, service-level, all-payer database that contains information on inpatient discharges from over 970 US hospitals. Premier data are geographically diverse, capturing over 108 million inpatient encounters and representing 25% of all inpatient US admissions.¹⁴ Premier contains administrative, HRU, financial data (hospital-reported costs and charges) augmented with inpatient records,

prescription claims, and selected laboratory test results. Hospital admission records, including diagnosis and procedures, are coded using the International Classification of Diseases, 9th and 10th Revision Clinical Modification (ICD-9 and ICD-10) classification system. Inpatient admissions and hospital-based outpatient care within the same hospital can be tracked over time, allowing assessment of readmissions and total hospital length of stay for a subset of patients.

2.2 | Study population

We included inpatient admissions for kidney transplant among adults aged ≥ 18 years presenting between 01/01/2014 and 12/31/2018. Kidney transplant admissions were identified by the presence of at least one kidney transplant-related charge code or all of the following: (a) a kidney transplant ICD-9 or ICD-10 procedure code, (b) a charge code for at least one immunosuppressant drug, and (c) a charge code for ≥ 1 kidney procurement within the same admission. Subjects with multiple organ transplants in the same admission were excluded.

2.3 | Study definitions

Hospital kidney transplant volume was characterized as “high” or “low” based on the number of annual transplant procedures. The average annual number of kidney transplant procedures in this dataset was 50. Hospitals performing ≥ 50 kidney transplants per year were classified as high volume and <50 as low volume. DGF was defined by a patient having at least one dialysis procedure within seven days of a qualifying transplant procedure. Given questions about the clinical value of a single dialysis treatment for determining patients who were truly experiencing DGF, patients who received dialysis in this early postoperative period were further categorized into those who received only one dialysis session and those who received multiple sessions.

Given the limitations of coding in the dataset, definitive segregation of all deceased and living donor kidney transplants was not feasible. However, for the subset of cases (n = 357; 3.0%) that were clearly identified as living donor transplants, a sensitivity analysis was performed (Tables S1 and S2).

2.4 | Statistical analysis

Baseline characteristics at the hospital- and patient-level were examined for the overall study population and by hospital volume, DGF, and dialysis utilization. Patient characteristics included age at admission, race, and sex. Characteristics of reporting hospitals included urban/rural status, teaching status, and number of beds.

The primary analyses examined the hospital volume, impact of DGF, and dialysis utilization on HRU and cost within the initial index hospitalization for the transplant admission. HRU endpoints captured in the analysis included total length of stay (LOS), intensive care unit (ICU) admission, and ICU-related LOS. Secondary analyses included all subsequent HRU and costs for readmissions within 90 days that occurred at the original transplant hospital.

Descriptive statistics were provided for the overall population and reported by hospital volume, DGF status, and dialysis utilization. HRU and costs within cohorts of DGF status and by dialysis utilization were compared between high- and low-volume hospitals. Statistical tests of significance for observed differences between groups were conducted using chi-squared test or Fisher's exact test for categorical variables and t tests for continuous variables. For outcomes that were not normally distributed, such as duration of stay or costs, Wilcoxon rank-sum tests were used to compare the medians. ANOVA was performed when comparing three groups (ie, non-DGF (or 0 dialysis), 1 dialysis, and 2+ dialyses). Statistical significance was defined as a 2-sided alpha 0.05.

Due to the skewness of cost data, admissions with costs below the first or above the 99th percentile for the sample were excluded from further analysis. All costs were inflation-adjusted to 2018 US dollars using the medical component of the Consumer Price Index produced by the US Bureau of Labor. All statistical analyses were performed using SAS version 9.4.

3 | RESULTS

3.1 | Demographics and hospital characteristics

A total of 12 097 kidney transplant admissions across 56 unique hospitals were included in the analysis (Figure 1). Patient and hospital characteristics for the total sample and hospital volume, DGF status, and dialysis utilization are presented in Table 1. The mean age across all initial admissions was 51.7 ± 13.4 years, and subjects were predominantly white (53%) and male (61%). Most admissions were to large hospitals (72%), teaching hospitals (81.2%), and/or urban hospitals (95.5%). Patient characteristics were similar across hospital volume practice settings. Roughly 80% of both high- and low-volume hospitals were teaching hospitals. Low-volume hospitals were more often located in rural areas (10% vs 2% of high-volume settings).

Approximately half of the admissions were from the South US census region (50.4%), with approximately 17% of admissions located in the West and Northeast regions, respectively, and 14% in the Midwest. Medicare was the primary insurer for most admissions (67%).

Approximately one-quarter of all kidney transplant admissions in the sample experienced DGF—of whom 52% received multiple dialysis treatments.

3.2 | HRU and cost outcomes by hospital volume

Table 2 summarizes HRU and cost for initial transplant admissions and initial transplant plus 90-day readmissions to the same hospital by hospital volume. After exclusion of the 1% outlier at both ends, mean hospital cost for kidney transplant admissions was $\$109\,425 \pm \$52\,823$, with a maximum observed cost of $\$319\,492$ (Table 2). Average total LOS was 8.6 ± 7.6 days and more than half the patients (57%) were admitted to the ICU for at least part of the initial admission, for an average ICU LOS of 2.5 ± 6.3 days. Approximately one-third of patients (34.1%, $n = 4129$) were readmitted to the same hospital within 90 days.

High-volume hospitals had lower costs (\$103 946 vs \$123 571, $P < .0001$) despite higher rates of ICU admission (58.9% vs 51.2%, $P < .0001$)—perhaps as a result of shorter mean ICU LOS (2.3 vs 3.0 days, $P < .0001$). Total LOS did not vary significantly by transplant volume. 90-day, same-hospital readmissions were marginally higher for higher transplant volume hospitals (35% vs 33%, $P = .031$).

3.3 | Impact of DGF status and hospital volume on HRU and costs

Approximately one-quarter of all kidney transplant recipients at both high and low transplant volume hospitals experienced DGF (Tables 3 and 4). Patients who experienced DGF displayed longer initial LOS (12.1 ± 12.9 vs 7.4 ± 0.8 days, $P < .0001$), more frequent ICU admissions (59% vs 56%, $P = .025$), longer ICU stays, and a significantly higher 90-day readmission rate (46% vs 30%, $P < .0001$). Patients with DGF incurred significantly higher costs over the course of the initial hospitalization and with readmissions over the subsequent 90 days ($\$130\,492 \pm \$56\,701$ vs $\$112\,598 \pm \$57\,675$, $P < .0001$). High-volume transplant centers had lower costs for transplant recipients overall than those at low-volume centers ($\$115\,700 \pm \$43\,759$ vs $\$126\,270 \pm \$57\,310$, $P < .0001$) and costs for recipients without DGF were significantly lower ($\$99\,826 \pm \$50\,628$ vs $\$122\,692 \pm \$58\,728$, $P < .0001$).

There was substantial variation in total LOS and ICU LOS for DGF admissions for both high- and low-volume hospitals (11.7 vs 7.4 days for high volume and 13.2 vs 7.4 for low volume, $P < .0001$). High-volume hospitals had higher 90-day readmission rates to the same hospital for recipients who experienced DGF compared to those at low transplant volume hospitals (46.90% vs 30.50% for high volume and 42.20% vs 29.50% for low volume, $P < .0001$).

3.4 | Impact of dialysis utilization and hospital volume on HRU and costs

Approximately half the transplant recipients in our cohort required multiple dialysis sessions (52%, Figure 1). The initial LOS for individuals needing multiple sessions was significantly longer and while the proportion needing ICU admissions were slightly higher, the duration of ICU LOS was nearly double that of patients with one dialysis session (5.3 ± 14.4 vs 2.6 ± 5.7 , $P < .0001$, Tables 5 and 6). Many more patients (58.8%) needing multiple sessions were readmitted within 90 days, increasing the difference in the cost of managing these patients to nearly \$15 000 per patient.

3.5 | Sensitivity analysis

Only 357 transplant recipients were clearly identifiable as recipients of living donor kidneys in our cohort. After excluding the outliers as previously described, 27 recipients (7.6%) were identified as having experienced DGF. While patients with living donor transplants incurred fewer costs, the differences between those who developed DGF and those did not were larger in absolute terms (\$16 293 vs \$12 239) in comparison with the overall cohort.

4 | DISCUSSION

Currently, DGF impacts more than 1 out of every 5 kidney transplants in the United States, including 10%-40% of deceased donor transplants.^{5,15,16} With fixed reimbursements for

kidney transplantation, the increased costs associated with the occurrence of DGF creates a financial disincentive for the acceptance and transplantation of organs that are at higher risk of developing DGF.^{17,18} These financial disincentives are perhaps greatest for organs with high KDPI and those that accumulate long cold ischemia time during the allocation process despite evidence that would suggest a weak link between organ quality and costs incurred.¹⁹ With the recent changes in KAS and broader organ sharing, there was a notable increase in the incidence of DGF following deceased donor transplantation.^{11,15,17} Further policy changes in how geography is incorporated into kidney allocation are expected.^{20,21} Variation in the organ supply and demand is likely to result in broader sharing of organs which in turn is likely to contribute to further increases in cold ischemia time and thus possible a higher incidence of DGF.^{22,23}

Currently in the United States, fewer than 1 in 5 kidneys is accepted when first offered for transplantation and nearly 1 in 5 kidneys is being discarded annually.^{22,24} The overall reluctance to use any deceased donor kidneys, despite evidence of improved patient survival and quality of life with even less-than-ideal organs and the mounting organ shortage, does not make clinical nor economic sense.^{25–28} While concerns about the transplant center metrics have been frequently cited as an explanation for the lower acceptance of organs particular at the higher KDPI, financial considerations are another potential source of concern.^{29–31} As the incidence of DGF after kidney transplantation increases, a thorough understanding of the financial implications of DGF is needed in order to ensure appropriate resource allocation and remove financial disincentives toward the use of kidneys at higher risk for experiencing DGF.^{17,32,33} Our results clearly demonstrate the increased costs during the incident hospitalization following transplantation as well as the additional burden of 90-day readmissions for those individuals who experience DGF and for the first time provide point estimates of the true hospital financial burden of this complication. Notably, our analysis also demonstrates the increased HRU with more frequent and longer ICU admissions for these individuals. Our analysis also demonstrates the increased financial burden associated with the need for multiple dialysis sessions in the early postoperative period, by demonstrating the HRU and costs differences between those individuals who have one treatment session vs those with multiple sessions. These differences further underscore the need to revisit the current definition of DGF. While the current definition of DGF is convenient and seemingly objective, the initiation of dialysis for patients in the postoperative period is highly subjective without a clear standard, resulting in considerable variation. This is especially true in circumstances where patients receive just a single treatment.

Our results demonstrate that DGF was associated with an approximately \$18 000 increase in mean cost, 6 additional days of hospitalization, and 2 additional days of ICU stay. Notably, the increased cost of transplantation associated with DGF was observed across all settings, including both high- and low-volume hospitals as well as urban and rural settings. This corresponds with the findings where DGF was used as an independent predictor of HRU in kidney transplantation and DGF was expected to result in higher costs and longer LOS than non-DGF.^{34–36} On average, hospitals saw an increase of >10% of total costs when a patient experienced DGF after kidney transplantation. Additionally, ICU LOS and 90-day readmission were almost double for patients with DGF than for those without. However, the differences between high-volume vs low-volume hospital LOS and readmission bear

examination. While high-volume hospitals have shorter LOS, this appears to be offset by higher rates of 90-day readmission. Further exploration of this observation is warranted.

The intensity of the dialysis requirements for recipients who experienced DGF was also associated with cost, and recipients who required multiple dialysis treatments displayed increases of over \$10 000 across settings compared to recipients who experienced DGF with 1 dialysis treatment. Other studies have also identified hospital LOS and the need for dialysis as major factors driving hospital resource consumption.^{37–39} These findings suggest that as a patient requires more dialysis treatments after transplantation, which is likely an indicator of true DGF and not simply fluid overload or hyperkalemia, the greater the LOS and as a result, more HRU. As expected, patients with DGF exhibited greater LOS, dialysis treatments, and ultimately resulted in higher HRU and costs than for patients without DGF.

These findings have significant implications for transplant hospitalization reimbursement. With the transplant hospitalization reimbursement remaining constant, the rising costs of DGF treatments are essentially a financial disincentive for hospitals to transplant deceased donor organs that are perceived to be associated with a higher risk of DGF, thus contributing to more turn downs and a greater likelihood of discard.

Despite the significant cost increase of DGF following kidney transplantation, transplant remains the most cost-effective treatment option for patients with ESKD when compared to staying on dialysis. In addition, there are improvements in the quality of life and mortality benefits that follow transplantation. There is a net overall cost savings when comparing the cost of transplantation, regardless of the development of DGF as compared to staying on dialysis. Therefore, the increased costs from complications with DGF should not discourage transplantation. While ascertaining the true disincentive that results from the increased financial costs of DGF for transplant centers as opposed to other concerns, such as center flagging or poor allograft outcomes for individual patients is not currently feasible, it needs to be acknowledged as a potential concern. Further, given the potential system wide savings associated with transplantation, coupled with the desire to dramatically increase organ utilization rates, policy changes that would remove the financial disincentives to transplantation of organs perceived to be at high risk for developing DGF ought to be considered.

Although this is a large cohort analysis, the study had several limitations. First, Premier is unable to fully distinguish between recipients of living donor vs deceased donor kidneys. The small sub-cohort of individuals who clearly received a living donor transplant experienced a much lower rate of DGF but experienced a similar increase in costs when they experienced DGF. However, it remains possible that the subset of patients without DGF in our cohort may have an overrepresentation of living donor recipients. This would result in lower average costs for this set of patients which in turn may exaggerate the observed differences in the increased costs being attributed to DGF. However, given that our overall DGF rates in our cohort are keeping with nationally reported incidence for both deceased donor and living donor transplant recipients, we believe that the impact of this is likely to be small and do not detract from the specific findings of increased LOS, increased

ICU admission and ICU LOS as well as higher readmission rates among recipients who experienced DGF.

Additionally, since this is a retrospective analysis of HRU and costs, there may be factors that can affect costs including laboratory, radiology, or other testing which are not included in this evaluation. Although Premier is a very extensive database that includes a wide range of hospitals, it is a performance improvement database, which means that the data definitions might not perfectly align among different centers. Furthermore, the study cohort was not geographically diverse, as more than half of the study cohort was located in the southeastern area of the United States which would be consistent with the current geographic variation in the incidence of ESRD which is highest in the southeastern United States. Additional studies are required to confirm that these relationships are consistent throughout the country.

5 | CONCLUSION

In conclusion, we found that the development of DGF after kidney transplantation was associated with significantly increased cost and HRU in both high-volume and low-volume hospitals. While strategies to lower the incidence of DGF would have a positive financial outcome for transplant centers, policy makers should need to consider the financial disincentives in the current system where reimbursement rates do not account for the complexities associated with accepting a less-than-ideal organ for patients.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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FIGURE 1.
Sample attrition and stratification

TABLE 1

Sample demographic and hospital characteristics

	Hospital volume			DGF status	Dialysis utilization		
	All admissions n = 12 097	High volume n = 8715	Low volume n = 3382	DGF n = 3087	Non-DGF n = 9010	1 dialysis n = 1485	2 dialyses n = 1602
Patient age at admission (y)							
Mean (SD)	51.7 (13.4)	51.2 (13.3)	53.0 (13.6)	53.31 (12.5)	51.16 (13.6)	52.63 (12.9)	53.95 (12.2)
Gender, n (%)							
Female	4704 (38.9%)	3413 (39.2%)	1291 (38.2%)	1105 (35.8%)	3599 (39.9%)	572 (38.5%)	533 (33.3%)
Male	7393 (61.1%)	5302 (60.8%)	2091 (61.8%)	1982 (64.2%)	5411 (60.1%)	913 (61.5%)	1069 (66.7%)
Race, n (%)							
Black	2716 (22.5%)	2048 (23.5%)	668 (19.8%)	991 (32.1%)	1725 (19.2%)	446 (30.0%)	545 (34.0%)
White	6468 (53.5%)	4411 (50.6%)	2057 (60.8%)	1360 (44.1%)	5108 (56.7%)	680 (45.8%)	680 (42.5%)
Other	2548 (21.1%)	1986 (22.8%)	562 (16.6%)	659 (21.4%)	1889 (21.0%)	321 (21.6%)	338 (21.1%)
Unknown	365 (3.0%)	270 (3.1%)	95 (2.8%)	77 (2.5%)	288 (3.2%)	38 (2.6%)	39 (2.4%)
DGF status, n (%)							
Yes	3087 (25.5%)	2240 (25.7%)	847 (25.0%)	3087 (100%)	0 (0.0%)	1485 (100%)	1602 (100%)
No	9010 (74.5%)	6475 (74.3%)	2535 (75.0%)	0 (0.0%)	9010 (100%)	0 (0.0%)	0 (0.0%)
Dialysis utilization, n (%)							
1 dialysis	1485 (48.1%)	1062 (47.4%)	423 (49.9%)	1485 (48.1%)	0 (0.0%)	1485 (100%)	0 (0.0%)
2 dialyses	1602 (51.9%)	1178 (52.6%)	424 (50.1%)	1602 (51.9%)	0 (0.0%)	0 (0.0%)	1602 (100%)
Hospital admission by setting, n (%)							
High volume	8715 (72.0%)	8715 (72.0%)	0 (0.0%)	2240 (25.7%)	6475 (74.3%)	1062 (71.5%)	1178 (73.5%)
Low volume	3382 (28.0%)	0 (0.0%)	3382 (28.0%)	847 (25.0%)	2535 (75.0%)	423 (28.5%)	424 (26.5%)
Hospital vicinity to a city center, n (%)							
Rural	539 (4.5%)	198 (2.3%)	341 (10.1%)	117 (3.8%)	422 (4.7%)	67 (4.5%)	50 (3.1%)
Urban	11 558 (95.5%)	8517 (97.7%)	3041 (89.9%)	2970 (96.2%)	8588 (95.3%)	1418 (95.5%)	1552 (96.9%)
Teaching hospital status, n (%)							
Yes	9824 (81.2%)	6970 (80.0%)	2854 (84.4%)	2670 (86.5%)	7154 (79.4%)	1251 (84.2%)	1419 (88.6%)
No	2273 (18.8%)	1745 (20.0%)	528 (15.6%)	417 (13.5%)	1856 (20.6%)	234 (15.8%)	183 (11.4%)
Total number of beds, grouped, n (%)							
Up to 199	3 (0.0%)	0 (0%)	3 (0.0%)	1 (0.0%)	2 (0.0%)	0 (0%)	1 (0.0%)
200–299	13 (0.1%)	0 (0%)	13 (0.4%)	2 (0.0%)	11 (0.0%)	0 (0%)	2 (0.1%)

	Hospital volume		DGF status		Dialysis utilization		
	All admissions n = 12 097	High volume n = 8715	Low volume n = 3382	DGF n = 3087	Non-DGF n = 9010	1 dialysis n = 1485	2 dialyses n = 1602
300–399	2182 (18.0%)	1745 (20.0%)	437 (12.9%)	423 (13.7%)	1759 (19.5%)	222 (15.0%)	201 (12.6%)
400–499	321 (2.7%)	110 (1.3%)	211 (6.2%)	116 (3.8%)	205 (2.3%)	48 (3.2%)	68 (4.2%)
500+	9578 (79.2%)	6860 (78.7%)	2718 (80.4%)	2545 (82.4%)	7033 (78.1%)	1215 (81.8%)	1330 (83.0%)
US census region, n (%)							
Midwest	1760 (14.6%)	731 (8.4%)	1029 (30.4%)	508 (16.5%)	1252 (13.9%)	253 (17.0%)	255 (15.9%)
Northeast	2113 (17.5%)	1171 (13.4%)	942 (27.9%)	606 (19.6%)	1507 (16.7%)	260 (17.5%)	346 (21.6%)
South	6100 (50.4%)	5114 (58.7%)	986 (29.2%)	1517 (49.1%)	4583 (50.9%)	790 (53.2%)	727 (45.4%)
West	2124 (17.6%)	1699 (19.5%)	425 (12.6%)	456 (14.8%)	1668 (18.5%)	182 (12.3%)	274 (17.1%)

TABLE 2

HRU and costs for initial admission and 90-d readmission by hospital volume

Admissions (n, %)	All admissions		High-volume hospital admissions		Low-volume hospital admissions		P-value (high vs low volume)
	12 097	100%	8715	72.0%	3382	28.0%	
Initial transplant							
Cost ^a							
n (%)	11 855	98.0%	8545	98.0%	3310	97.9%	<.0001
Mean (SD)	\$109 425	\$52 823	\$103 946	\$49 427	\$123 571	\$58 394	
Min, Max	\$13 998	\$319 492	\$13 998	\$319 492	\$14 079	\$310 079	
Length of stay (d)							
Mean (SD)	8.6	7.6	8.5	6.9	8.8	9.1	.0854
Min, Max	1	397	1	397	2	176	
ICU admission (n, %)	6866	56.8%	5133	58.9%	1733	51.2%	<.0001
ICU LOS (d)							
Mean (SD)	2.5	6.3	2.3	5.5	3.0	8.0	<.0001
Min, Max	0	376	0	376	0	174	
90-d readmission ^b (n, %)	4129	34.1%	3025	34.7%	1104	32.6%	.0314
Initial transplant plus 90-d readmissions to same hospital							
Cost ^a							
n, %	11 855	98.0%	8539	98.0%	3316	98.0%	<.0001
Mean (SD)	\$117 173	\$57 953	\$111 735	\$55 022	\$131 177	\$62 772	
Min, Max	\$14 062	\$352 702	\$14 062	\$352 702	\$14 690	\$348 270	
Length of stay (d)							
Mean (SD)	10.2	9.4	10.3	9.2	10.1	9.9	.3218
Min, Max	1	209	1	209	2	148	
ICU admission (n, %)	6959	57.5%	5190	59.6%	1769	52.3%	<.0001
ICU LOS (d)							
Mean (SD)	2.7	6.6	2.5	5.8	3.2	8.3	<.0001
Min, Max	0	376	0	376	0	174	

^a After exclusion of outliers.

Includes only readmissions to the same hospital.

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TABLE 3

HRU and costs for initial admission and 90-d readmission by DGF status for all subjects

All admissions n = 12 097						
Admissions (n, %)	DGF		Non-DGF		P-value (DGF vs non-DGF)	
	3087	25.5%	9010	74.5%		
Initial transplant						
Cost ^a						
N, %	3031	98.2%	8824	97.9%		<.0001
Mean (SD)	\$118 535	\$47 992	\$106 296	\$54 033		
Min, Max	\$16 377	\$316 728	\$13 998	\$319 492		
Length of stay (d)						
Mean (SD)	12.1	12.9	7.4	3.8		<.0001
Min, Max	3	397	1	88		
ICU admission (n, %)	1824	59.1%	5042	56.0%		.0025
ICU length of stay (d)						
Mean (SD)	4.0	11.2	2.0	3.2		<.0001
Min, Max	0	376	0	68		
90-d readmission ^b (n, %)	1408	45.6%	2721	30.2%		<.0001
Initial transplant plus 90-d readmissions to same hospital						
Cost ^a						
n, %	3031	98.2%	8824	97.9%		<.0001
Mean (SD)	\$130 492	\$56 701	\$112 598	\$57 675		
Min, Max	\$16 377	\$352 702	\$14 062	\$347 400		
Length of stay (d)						
Mean (SD)	14.7	13.5	8.7	6.9		<.0001
Min, Max	2	209	1	112		
ICU admission (n, %)	1864	60.4%	5095	56.6%		.0002
ICU length of stay (d)						
Mean (SD)	4.3	11.5	2.1	3.4		<.0001
Min, Max	0	376	0	68		

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After exclusion of outliers
Includes only readmissions to the same hospital

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HRU and costs for initial admission and 90-d readmission by DGF status for high and low volume

TABLE 4

High-volume hospital admissions n = 8715					Low-volume hospital admissions n = 3382						
Admissions (n, %)	DGF	25.7%	Non-DGF	74.3%	P-value (HV DGF/non-DGF)	DGF	25.0%	Non-DGF	75.0%	P-value (LV DGF/non-DGF)	HV vs LV
	2240		6475			847		2535			
Cost ^a											
n (%)	2218	98.00%	6327	97.70%	<.0001	813	96.00%	2497	98.50%	.1292	<0.0001
Mean (SD)	\$115 700	\$43 759	\$99 826	\$50 628		\$126 270	\$57 310	\$122 692	\$58 728		
Min, Max	\$16 377	\$316 728	\$13 998	\$319 492		\$17 380	\$310 079	\$14 079	\$305 498		
Length of stay (d)											
Mean (SD)	11.7	11.5	7.4	3.6	<.0001	13.2	15.9	7.4	4.2	<.0001	<0.0001
Min, Max	3	397	1	88		4	176	2	59		
ICU admission (n, %)	1363	60.9%	3770	58.2%	.0295	461	54.4%	1272	50.2%	.0322	<0.0001
ICU length of stay (d)											
Mean (SD)	3.5	9.6	1.9	3	<.0001	5.4	14.5	2.2	3.6	<.0001	<0.0001
Min, Max	0	376	0	0		68	174	0	48		
90-d readmission ^b (n, %)	1051	46.90%	1974	30.50%	<.0001	357	42.20%	747	29.50%	<.0001	<0.0001
Initial transplant plus 90-d readmissions to same hospital											
Cost ^a											
n, %	2215	98.9%	6324	97.7%	<.0001	816	96.3%	2500	98.6%	.0002	<0.0001
Mean (SD)	\$127 523	\$52 111	\$106 205	\$54 947		\$138 552	\$66 985	\$128 770	\$61 155		
Min, Max	\$16 377	\$352 702	\$14 062	\$343 383		\$17 380	\$348 270	\$14 690	\$347 400		
Length of stay (d)											
Mean (SD)	14.6	12.9	8.8	6.9	<.0001	15.0	14.8	8.4	6.8	<.0001	0.3218
Min, Max	2	209	1	112		3	148	2	80		
ICU admission (n, %)	1390	62.1%	3800	58.7%	.0051	474	56.0%	1295	51.1%	.0139	<0.0001
ICU length of stay (d)											
Mean (SD)	3.8	10.0	2.0	3.2	<.0001	5.7	14.8	2.3	3.9	<.0001	<0.0001
Min, Max	0	376	0	68		0	174	0	48		

^a After exclusion of outliers.

Includes only readmissions to the same hospital.

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TABLE 5

HRU and costs for initial admission and 90-d readmission by dialysis utilization

All admissions n = 12 097						
Admissions (n, %)	Non-DGF (0 dialyses)		1 dialyses		2 dialyses	
	9010	74.5%	1485	12.3%	1602	13.2%
<i>Cost^a</i>						
n, %	8824	97.9%	1468	98.9%	1563	97.6%
Mean (SD)	\$106 296	\$54 033	\$113 640	\$47 353	\$123 132	\$48 148
Min, Max	\$13 998	\$319 492	\$17 380	\$316 728	\$16 377	\$310 079
Length of stay (d)						
Mean (SD)	7.4	3.8	9.2	6.7	14.8	16.2
Min, Max	1	88	3	176	4	397
ICU admission (n, %)	5042	56.0%	858	57.8%	966	60.3%
ICU length of stay (d)						
Mean (SD)	2.0	3.2	2.6	5.7	5.3	14.4
Min, Max	0	68	0	174	0	376
90-d readmission ^b (n, %)	2721	30.2%	564	38.0%	844	52.7%
Initial transplant plus 90-d readmissions to same hospital						
<i>Cost^a</i>						
n, %	8824	97.9%	1473	99.2%	1558	97.3%
Mean (SD)	\$112 598	\$57 675	\$122 870	\$54 587	\$137 699	\$57 729
Min, Max	\$14 062	\$347 400	\$17 380	\$334 409	\$16 377	\$352 702
Length of stay (d)						
Mean (SD)	8.7	6.9	11.3	9.4	17.9	15.7
Min, Max	1	112	2	89	3	209
ICU admission (n, %)	5095	56.6%	873	58.8%	991	61.9%
ICU length of stay (d)						
Mean (SD)	2.1	3.4	2.8	6.0	5.7	14.8
Min, Max	0	68	0	174	0	376

^a After exclusion of outliers

Includes only readmissions to the same hospital

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HRU and costs for initial admission and 90-d readmission by dialysis utilization for high and low volume

TABLE 6

High-volume hospital admissions n = 8715							Low-volume hospital admissions n = 3382								
Admissions (n, %)	Non-DGF (0 dialyses)		1 dialysis		2 dialyses		P- value*	Non-DGF (0 dialyses)	1 dialysis		2 dialyses		P- value*	HV vs LV	
	6475	74.3%	1062	12.2%	1178	13.5%			2535	75.0%	423	12.5%			424
Cost ^a															
n (%)	6327	97.7%	1057	99.5%	1161	98.6%	<.0001	2497	98.5%	411	97.2%	402	94.8%	.0140	<0.0001
Mean (SD)	\$99 826	\$50 628	\$110 695	\$42 506	\$120 256	\$44 399		\$122 692	\$58 728	\$121 213	\$57 354	\$131 439	\$56 873		
Min, Max	\$13 998	\$319 492	\$19 674	\$316 728	\$16 377	\$294 707		\$14 079	\$305 498	\$17 380	\$308 008	\$20 717	\$310 079		
Length of stay (d)															
Mean (SD)	7.4	3.6	9.2	4.7	14	14.8	<.0001	7.4	4.2	9.5	10.1	16.8	19.5	<.0001	0.0854
Min, Max	1	88	3	50	4	397		2	59	4	176	4	166		
ICU admission (n, %)	3770	58.2%	653	61.5%	710	60.3%	.0790	1272	50.2%	205	48.5%	256	60.4%	.0002	<0.0001
ICU length of stay (d)															
Mean (SD)	1.9	3	2.4	3.0	4.5	12.9	<.0001	2.2	3.6	3.1	9.6	7.7	17.9	<.0001	<0.0001
Min, Max	0	0	0	32	0	376		0	48	0	174	0	164		
90-d readmission ^b (n, %)	1974	30.50%	424	39.9%	627	53.2%	<.0001	747	29.50%	140	33.1%	217	51.2%	<.0001	0.0314
Initial transplant plus 90-d readmissions to same hospital															
Cost ^a															
n, %	6324	97.7%	1058	99.6%	1157	98.2%	<.0001	2500	98.6%	415	98.1%	401	94.6%	<.0001	<0.0001
Mean (SD)	\$106 205	\$54 947	\$120 067	\$49 767	\$134 342	\$53 280		\$128 770	\$61 155	\$130 018	\$64 806	\$147 384	\$68 130		
Min, Max	\$14 062	\$343 383	\$19 674	\$322 842	\$16 377	\$352 702		\$14 690	\$347 400	\$17 380	\$334 409	\$20 717	\$348 270		
Length of stay (d)															
Mean (SD)	8.8	6.9	11.5	9.0	17.4	15.1	<.0001	8.4	6.8	10.8	10.1	19.2	17.4	<.0001	0.3218
Min, Max	1	112	2	80	3	209		2	80	3	89	4	148		

High-volume hospital admissions n = 8715										Low-volume hospital admissions n = 3382									
Non-DGF (0 dialyses)					P- value*					Non-DGF (0 dialyses)					P- value*				
1 dialysis					2 dialyses					1 dialysis					2 dialyses				
Admissions (n, %)					Admissions (n, %)					Admissions (n, %)					Admissions (n, %)				
ICU admission (n, %)					ICU admission (n, %)					ICU admission (n, %)					ICU admission (n, %)				
3800					3800					3800					3800				
58.7%					58.7%					58.7%					58.7%				
662					662					662					662				
62.3%					62.3%					62.3%					62.3%				
728					728					728					728				
61.8%					61.8%					61.8%					61.8%				
.0193					.0193					.0193					.0193				
ICU length of stay (d)					ICU length of stay (d)					ICU length of stay (d)					ICU length of stay (d)				
2.0					2.0					2.0					2.0				
3.2					3.2					3.2					3.2				
2.6					2.6					2.6					2.6				
3.4					3.4					3.4					3.4				
4.8					4.8					4.8					4.8				
13.3					13.3					13.3					13.3				
<.0001					<.0001					<.0001					<.0001				
2.3					2.3					2.3					2.3				
3.9					3.9					3.9					3.9				
3.3					3.3					3.3					3.3				
9.8					9.8					9.8					9.8				
8.1					8.1					8.1					8.1				
18.1					18.1					18.1					18.1				
<.0001					<.0001					<.0001					<.0001				
0					0					0					0				
68					68					68					68				
32					32					32					32				
0					0					0					0				
376					376					376					376				
0					0					0					0				
48					48					48					48				
174					174					174					174				
0					0					0					0				
164					164					164					164				
<.0001					<.0001					<.0001					<.0001				
263					263					263					263				
62.0%					62.0%					62.0%					62.0%				
.0001					.0001					.0001					.0001				
<.0001					<.0001					<.0001					<.0001				