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The Clinical and Financial Burden of Early Dialysis After Deceased Donor Kidney Transplantation

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Abstract

Background: The economic implications of dialysis-requiring allograft dysfunction early after kidney transplantation are not well-described.

Methods: Data for Medicare-insured adult kidney transplant recipients in 1995-2004 who did not develop permanent graft failure in the first 90 days were drawn from the United States Renal Data System. We identified dialysis treatment records from Medicare claims and categorized patients according to frequency and duration of post-transplant dialysis as: first week (delayed graft function, DGF), second week, weeks 3 or 4, second month, or third month.Associations of dialysis requirements with Medicare payments for the transplant hospitalization and over the next three years were estimated with multivariable linear regression. Graft and patient survival according to early dialysis requirements were examined with multivariable survival analysis.

Results: Among 37,533 recipients, 15,314 (41%) experienced DGF and 3,184 (21% of those with DGF) received dialysis beyond the first week. Compared with no dialysis in the first 3 months, adjusted marginal first-year costs associated with early post-transplant dialysis ranged from $6,467 for dialysis requirement limited to first week to $27,606 for dialysis in multiple periods ($p<0.0001$). Patients who experienced DGF and received dialysis in >2 early periods were more than twice as likely to lose their grafts within 3 years as those without early dialysis requirements.

Conclusions: While dialysis in the first week post-transplant is an adverse risk marker, early dialysis in weeks 2 to 12 is associated with similarly adverse, if not worse, costs and clinical consequences. This observation supports a need for broader definition of DGF.

Keywords: Delayed graft function; Economic analysis; Kidney transplantation; Medicare; Allograftsurvival; Outcomes

Introduction

Renal transplantation provides the best clinical outcomes, quality of life and cost-savings among the options for renal replacement therapy [1-3]. From 1997 through 2010 the number of patients on the wait-list for a renal transplant increased more than two-fold, to >80,000 patients [4]. The number of patients awaiting transplant in 2010 was almost five-times the number transplants performed [4]. To improve access to transplant in the context of this organ shortage, many centers have liberalized criteria for organ acceptance. From 1993 to 2008, the relative frequency of expanded criteria donor (ECD) allograft use rose from 7.4% to 22% among U.S. Transplantation of kidneys donated after cardiac death (DCD) also increased from <1% to 12.4% in this period [5].

The increased utilization of ECD and DCD kidneys has resulted in a higher rate of delayed graft function (DGF) [5-7]. In general, DGF is defined as receiving dialysis in the first week post-transplant. However, other investigators have attempt to further categorize the clinical implications of DGF according to the severity and persistence graft dysfunction [8-10]. Typically, DGF results in increased costs in transplant recipients compared to those who do not experience DGF, in part due to a longer length of stay for the transplant hospitalization and need for hemodialysis [11,12]. DGF also increases the risk of rejection, graft failure and death, which can add substantial costs [6,13-15].

Current data on the cost implications of DGF are largely drawn from single center studies focused on the transplant hospitalization, and consider DGF as a binary event [2,6,11,12,16]. To improve understanding of the financial and clinical outcome implications of early post-transplant dialysis requirements after kidney transplantation, we performed a historical cohort study of large sample of Medicare beneficiaries registered in the United States Renal Data System (USRDS). Medicare claims records were used to identify the frequency and duration of dialysis requirements in the first 90 days after transplant. We also quantified associations of early graft function, as defined by the timing and persistence of dialysis requirements, with subsequent Medicare costs, permanent graft failure, and patient death over time.

Methods

Study data and sampling criteria

Study data were drawn from the USRDS [17]. The USRDS is a database that links the Organ Procurement and Transplantation

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network (OPTN) renal transplant registry data with administrative data from the Health Care Financing Administration (HCFA). The OPTN registry contains descriptive and clinical data on all kidney transplants performed in the United States. HCFA administrative data capture billing claims for Medicare-insured renal transplant recipients.

The study sample includes all adult (age >18 year old) deceased-donor renal transplant recipients in the USRDS registry from 1995 to 2004 with Medicare as their primary payer. Medicare primary payer status at transplant was defined by USRDS "Payer History" records and a total Medicare payment for the initial transplant hospitalization exceeding $15,000, as per previous reports [18]. Patients with multiple-organ transplants or previous transplants were excluded. Patients who experienced permanent graft failure, as reported to the OPTN registry, within the first90 days post-transplant were also excluded. In addition, patients with Medicare claims for dialysis within 2 weeks after the initial 90 day assessment period (days 91-104 post-transplant) were also removed from the sample to ensure that patients with permanent early graft failure who return to chronic dialysis were not included in this study of delayed function.

Dialysis records and categorization of early dialysis requirements

Early post-transplant dialysis requirements were categorized using Medicare claims for dialysis within 90 days-post transplant as well as center reports of DGF to the OPTN registry. Medicare claims for dialysis were identified by a service code for dialysis, a place of service code for ESRD treatment, or indicated dialysis treatment modality on a billing claim. Dialysis claims were categorized according to occurrence in the following post-transplant periods: the first week, the second week, weeks 3 or 4, the second month, or the third month post-transplant. We defined DGF as an indication of DGF in the OPTN registry and/or any claims for dialysis in the first week post-transplant. Patients were then categorized into mutually exclusive groups based on DGF and subsequent dialysis claims as follows: 1) DGF with dialysis claims in the first week post-transplant only, 2) DGF and dialysis claims in one additional post-transplant period, 3) DGF and dialysis claims in >1 additional post-transplant periods, 4) no DGF but some claims for dialysis in days 8 to 90 post-transplant, and 5) no DGF and no dialysis claims within 90 days post-transplant.

Outcomes

The primary outcome was post-transplant costs, as defined by all post-transplant Medicare payments for a recipient within specified intervals. The cost measure includes Medicare payments to the recipients' dialysis center, health providers, and treatment centers including hospitals. Payments were adjusted for inflation with the medical component of the consumer price index using the year 2004 as the base year [19]. Claims from the date of transplant until three years post transplant (the time when Medicare coverage after transplant ends in the absence of age >65 or disability), death, or end of study date (December 31, 2004) were captured. The transplant hospitalization costs comprised all claims with a diagnosis-related group (DRG) code of 302, which indicates hospitalization for a kidney transplant. One, two, and three year post transplant costs were computed as the sum of the patient's claims from transplant hospitalization to the indicated follow-up time. Patients who had incomplete follow-up due to loss of Medicare or end of study within an interval of analysis were excluded from that and subsequent intervals. Patients who died within an interval were included in all intervals with payments after date of death set to zero dollars.

Secondary outcomes included: reported creatinine and estimated glomerular filtration rate (eGFR) at discharge and at 6 and 12 months post-transplant, length of transplant hospitalization stay, rejection (within 3 years post transplant), death-censored graft failure, and mortality, as defined by OPTN reports. eGFR was calculated by the 4-variable MDRD equation, that has been demonstrated to perform well in transplant recipients [20]. Patients with missing creatinine values were excluded from the analysis of renal function for the periods in which they had missing data. Rejection was defined as any OPTN reported occurrence of acute or chronic rejection, rejection as a cause of graft failure, or administration of anti-rejection immunosuppression within one, two, or three years post-transplant. At time of discharge, data on length of stay and renal function were available for 22,269 (60%) and 36,867 (98%) of the patients in the study, respectively. At six months and one-year post-transplant there were 35,514 (95% of total) and 33,957 (90.5% of total) patients with renal function data available, respectively.

Covariate data were ascertained from OPTN records including: patient gender, race, ethnicity, age at transplant, body mass index (BMI), primary cause of ESRD, pre-transplant dialysis duration, and peak panel reactive antibody (PRA) percent; donor type (standard criteria donor [SCD], ECD, DCD), gender, race, ethnicity, age, BMI, cause of death, terminal creatinine ≥1.5 mg/dL, history of hypertension, diabetes; donor-recipient cytomegalovirus (CMV) sero-pairing, types and number of ABDR HLA mismatches, cold ischemia time, and year of transplant.

Statistical analysis

Distributions of recipient, donor, and transplant characteristic were compared between the groups defined by dialysis utilization using chi-square and t-tests. Missing baseline data was categorized as missing, other or unknown depending on the type of characteristic.

The unadjusted mean cost of transplant hospitalization, and costs incurred in one, two, and three years post-transplant were compared for all groups using the non-parametric Wilcoxon rank-sum test. Multivariate linear regression analysis was performed to compare costs within the four periods according to dialysis utilization, adjusting for recipient, donor, and transplant characteristics. Secondary outcomes were analyzed using chi-squared and ANOVA tests. Patient and graft survival after transplant were estimated by the Kaplan-Meier method. We used Cox Proportional Hazard analyses to examine the impact of early post-transplant dialysis on graft and patient survival, adjusting for the baseline covariates. An alpha level of 0.05 was used for all significance tests. Analyses were performed using SAS v.9.1 (SAS Institute, Cary, NC).

Results

We identified 37,533 Medicare insured adult renal recipients who met selection criteria. Of these recipients, 15,314 (41%) experienced DGF and 3,184 (21% of those with DGF) received dialysis beyond the first week post-transplant. Patients required varying intensity of post-transplant dialysis treatment: 12,130 (32.2%) patients had DGF but no dialysis beyond the first week post-transplant, 2,144 (5.7%) had DGF and dialysis in 1 additional period (week 1 and either week 2, weeks 3 or 4, the second month, or the third month), 1,040 (2.8%) had DGF and early dialysis in >1 additional period, 1,525 (4.1%) without DGF and but had some early dialysis in days 8 to 90, and 20,694 (55.1%) did not experience DGF or require dialysis in the 90 days after transplant.

The demographic characteristics of the transplant recipients varied

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significantly as a function of the need for and duration of dialysis treatment (Table 1). African Americans experienced more DGF than white recipients and were more likely to require some dialysis after the first week. Obese recipients were the most likely to experience DGF, but the percentage of obese patients requiring dialysis after the first two weeks was similar to non-obese recipients. Recipients of SCD allografts were less likely to experience DGF than patients transplanted with ECD or DCD organs (38.3% compared to 52.1 and 62.8%, respectively, p<0.0001). The percentage of transplants complicated by DGF increased substantially over the years of study, from 26% in 1995 to 54% in 2004 (p<0.0001).

	DGF with early week only, ‡n(%)	DGF and early dialysis in 1 additional period, ‡n(%))	DGF and early dialysis in >1 additional period, ‡n(%)	No DGF but some early dialysis, ‡n(%)*	No DGF and no dialysis, ‡n(%)*	p-value†
Recipient Characteristics						
Female	4349 (29.8)	780 (5.4)	346 (2.4)	572 (3.9)	8546 (58.6)	<0.0001
Race						<0.0001
African American	4193 (34.6)	851 (7.0)	440 (3.6)	542 (4.5)	6099 (50.3)	
White	7129 (31.0)	1165 (5.1)	543 (2.4)	889 (3.9)	13247 (57.7)	
Other	808 (33.2)	128 (5.3)	57 (2.3)	93 (3.8)	1348 (55.8)	
Hispanic	1336 (31.3)	263 (6.2)	135 (3.2)	156 (3.7)	2383 (55.8)	0.08
Age (years)						<0.0001
18-30	900 (27.5)	155 (4.7)	74 (2.3)	135 (4.1)	2015 (61.5)	
31-44	3038 (30.1)	528 (5.2)	263 (2.6)	441 (4.4)	5852 (57.8)	
45-59	4796 (33.1)	875 (6.0)	417 (2.9)	594 (4.1)	7828 (54.0)	
≥ 60	3396 (35.3)	586 (6.1)	286 (3.0)	355 (3.7)	4999 (52.0)	
BMI category (kg/m²)						<0.0001
BMI < 10 or Missing	2673 (28.6)	541 (5.8)	280 (3.0)	420 (4.5)	5423 (58.1)	
BMI ≥10 to <25	3503 (29.0)	582 (4.8)	289 (2.4)	499 (4.1)	7206 (59.7)	
BMI ≥ 25 to <30	3249 (34.8)	544 (5.8)	259 (2.8)	355 (3.8)	4929 (52.8)	
BMI ≥ 30	2705 (39.9)	477 (7.0)	212 (3.1)	251 (3.7)	3136 (46.3)	
Primary cause of ESRD						<0.0001
Diabetes mellitus	3048 (31.8)	561 (5.8)	234 (2.4)	369 (3.8)	5389 (56.1)	
Glomerulonephritis	2155 (30.8)	351 (5.0)	163 (2.3)	277 (4.0)	4049 (57.9)	
Polycystic kidney disease	850 (31.7)	133 (5.0)	58 (2.2)	113 (4.2)	1530 (57.0)	
Hypertension	3001 (32.9)	567 (6.2)	327 (3.6)	410 (4.5)	4821 (52.8)	
Other	1594 (34.3)	241 (5.2)	109 (3.3)	167 (3.6)	2539 (54.6)	
Unknown	1482 (33.1)	291 (6.5)	149 (2.3)	189 (4.2)	2366 (52.9)	
Pre-Transplant Dialysis Duration						<0.0001
None (pre-emptive)	941 (35.9)	159 (6.1)	59 (2.3)	105 (4.0)	1356 (51.8)	
0-12 months	784 (25.9)	94 (3.1)	48 (1.6)	118 (3.9)	1985 (65.5)	
13-24 months	1594 (28.0)	233 (4.1)	104 (1.8)	232 (4.1)	3533 (62.0)	
25-60 months	5905 (32.4)	1074 (5.9)	513 (2.8)	750 (4.1)	9972 (54.8)	
> 60 months	2906 (36.4)	584 (7.3)	316 (4.0)	320 (4.0)	3848 (48.3)	
Donor Characteristics						
Female	5157 (34.0)	842 (5.5)	422 (2.8)	630 (4.2)	8137 (53.6)	<0.0001
Hispanic	1336 (31.3)	263 (6.2)	135 (3.2)	156 (3.7)	2383 (55.8)	0.08
Race						<0.0001
African American	1394 (31.0)	274 (6.1)	138 (3.1)	224 (5.0)	2461 (54.8)	
White	10223 (32.3)	1786 (5.7)	860 (2.7)	1232 (3.9)	17515 (55.4)	
Other	513 (36.0)	84 (5.9)	42 (3.0)	69 (4.8)	718 (50.4)	
Age (years)						<0.0001

< 18	1423 (25.3)	207 (3.7)	95 (1.7)	251 (4.5)	3658 (64.9)	
18-30	2002 (26.5)	321 (4.3)	120 (1.6)	322 (4.3)	4790 (63.4)	
31-44	2392 (31.4)	431 (5.7)	206 (2.7)	313 (4.1)	4274 (56.1)	
45-59	3403 (37.0)	657 (7.1)	339 (3.7)	363 (3.9)	4444 (48.3)	
≥ 60	1337 (39.1)	265 (7.8)	159 (4.7)	141 (4.1)	1518 (44.4)	
BMI category (kg/m²)						<0.0001
BMI < 10 or Missing	326 (22.2)	68 (4.6)	49 (3.3)	86 (5.9)	938 (63.9)	
BMI ≥10 to <25	5701 (29.5)	916 (4.7)	458 (2.4)	803 (4.2)	11480 (59.3)	
BMI ≥ 25 to <30	3574 (34.4)	695 (6.7)	313 (3.0)	400 (3.9)	5405 (52.0)	
BMI ≥ 30	2529 (40.0)	465 (7.4)	220 (3.5)	236 (3.7)	2872 (45.4)	
Death due to stroke	5452 (37.0)	982 (6.7)	535 (3.6)	595 (4.0)	7169 (48.7)	<0.0001
Terminal Creatinine ≥ 1.5	2083 (38.5)	430 (7.9)	234 (4.3)	233 (4.3)	2433 (45.0)	<0.0001
Hypertension history	2929 (40.1)	555 (7.6)	332 (4.5)	587 (3.9)	3203 (43.8)	<0.0001
Diabetes	563 (39.3)	92 (6.4)	71 (5.0)	41 (2.9)	664 (46.4)	<0.0001
CMV sero-positive	7539 (32.7)	1348 (5.9)	683 (3.0)	930 (4.0)	12562 (54.5)	0.002
Transplant Factors						
Donor type						
ECD	2037 (39.4)	402 (7.8)	253 (4.9)	203 (3.9)	2270 (44.0)	<0.0001
DCD	409 (44.3)	121 (13.1)	50 (5.4)	23 (2.5)	320 (34.7)	<0.0001
SCD	9684 (30.8)	1621 (5.2)	737 (2.3)	1299 (4.1)	18104 (57.6)	<0.0001
Peak Panel Reactive Antibody (%)						<0.0001
0-10	8342 (31.6)	1435 (5.4)	728 (2.8)	1088 (4.1)	14814 (56.1)	
11-30	1236 (31.3)	220 (5.6)	106 (2.7)	175 (4.4)	2218 (56.1)	
>30	1688 (32.7)	355 (6.9)	163 (3.2)	198 (3.8)	2756 (53.4)	
Unknown	864 (43.0)	134 (6.7)	43 (2.1)	64 (3.2)	903 (45.1)	
HLA Mismatches						<0.0001
0	1072 (32.8)	145 (5.6)	60 (1.8)	104 (3.2)	1888 (57.8)	
1	673 (28.6)	119 (4.4)	57 (2.4)	78 (3.3)	1424 (60.6)	
2	1237 (30.5)	219 (5.1)	91 (2.2)	192 (4.7)	2318 (57.1)	
3	2528 (31.2)	449 (5.5)	231 (2.9)	354 (4.4)	4547 (56.1)	
4	3108 (33.3)	564 (6.0)	254 (2.7)	384 (4.1)	5036 (53.9)	
5	2324 (33.6)	433 (6.3)	231 (3.3)	270 (3.9)	3653 (52.9)	
6	930 (34.9)	169 (6.4)	92 (3.5)	99 (3.7)	1373 (51.6)	
Unknown	258 (31.2)	46 (5.6)	24 (2.9)	44 (5.3)	455 (55.0)	
CMV sero-pairing						<0.0001
Donor - / Recipient -	1289 (30.7)	209 (5.0)	97 (2.7)	173 (4.1)	2663 (57.5)	
Donor - / Recipient +	2824 (33.1)	502 (5.9)	229 (2.7)	355 (4.2)	4627 (54.2)	
Donor + / Recipient -	1930 (32.9)	313 (6.2)	168 (3.1)	256 (3.9)	3611 (53.8)	
Donor + / Recipient +	4895 (29.1)	918 (4.7)	466 (2.2)	586 (3.9)	7998 (60.1)	
Unknown	1192 (34.8)	202 (5.9)	80 (2.3)	155 (4.5)	1795 (52.4)	
Year						<0.0001
1995	767 (20.1)	148 (3.9)	88 (2.3)	253 (6.6)	2562 (67.1)	
1996	760 (20.5)	187 (5.0)	111 (3.0)	224 (6.0)	2433 (65.5)	
1997	835 (21.4)	183 (4.7)	92 (2.4)	195 (5.0)	2595 (66.5)	
1998	830 (22.0)	207 (5.5)	106 (2.8)	179 (4.8)	2449 (64.9)	
1999	1132 (31.3)	220 (6.1)	90 (2.5)	158 (4.4)	2012 (55.7)	
2000	1405 (38.2)	224 (6.1)	97 (2.6)	118 (3.2)	1837 (49.9)	
2001	1544 (39.5)	239 (6.1)	126 (3.2)	108 (2.8)	1888 (48.4)	

2002	1576 (40.7)	258 (6.7)	127 (3.3)	98 (2.5)	1812 (46.8)	
2003	1845 (46.4)	227 (5.7)	122 (3.1)	82 (2.1)	1698 (42.7)	
2004	1436 (43.7)	251 (7.6)	81 (2.5)	110 (3.4)	1408 (42.9)	
	Mean(std)	Mean(std)	Mean(std)	Mean(std)	Mean(std)	
Cold-time(hours)	20.5 (8.6)	22.3 (8.6)	23.1 (9.8)	19.5 (8.5)	18.6 (8.1)	<0.0001

†P values differences in trait distributions according to dialysis utilization were computed by the Chi-square test for categorical variables and the t-test for continuous variables.
* Percents given are row percents.
‡Periods of early dialysis were defined as first week, the second week, weeks 3 or 4, the second month and the third month post-transplant

Table 1: Characteristics of Medicare-insured renal transplant recipients in 1995-2004 according to early post-transplant dialysis utilization (N = 37,533).

Period	Dialysis Use	N	Mean (std)	p-value*
Transplant hospitalization	DGF with early dialysis first week only†	12,130	$31,451 (23,144)	<0.0001
	DGF with early dialysis in 1 additional period†	2,144	$31,242 (17,649)	
	DGF with early dialysis in >1 additional period†	1,040	$33,280 (20,487)	
	No DGF but some dialysis†	1,525	$33,035 (19,746)	
	No DGF and no early dialysis†	20,694	$30,068 (13,714)	
One year post transplant	DGF with early dialysis first week only†	10,721	$74,081 (51,171)	<0.0001
	DGF with early dialysis in 1 additional period†	1,904	$87,330 (71,645)	
	DGF with early dialysis in >1 additional period†	963	$98,651 (64,521)	
	No DGF but some dialysis†	1,419	$90,590 (67,299)	
	No DGF and no early dialysis†	19,304	$68,089 (41,809)	
Two years post transplant	DGF with early dialysis first week only†	8,964	$98,621 (69,100)	<0.0001
	DGF with early dialysis in 1 additional period†	1,699	$112,002 (85,184)	
	DGF with early dialysis in >1 additional period†	859	$129,105 (83,008)	
	No DGF but some dialysis†	1,340	$114,589 (86,538)	
	No DGF and no early dialysis†	17,571	$90,072 (59,685)	
Three years post transplant	DGF with early dialysis first week only†	7,273	$121,063 (84,526)	<0.0001
	DGF with early dialysis in 1 additional period†	1,408	$136,189 (102,254)	
	DGF with early dialysis in >1 additional period†	710	$156,079 (102,681)	
	No DGF but some dialysis†	1,235	$138,264 (101,836)	
	No DGF and no early dialysis†	15,776	$110,109 (74,650)	

Costs adjusted to 2004 as the base year
* P value for the difference in cost distribution according to early post-transplant dialysis utilization was computed by the Wilcoxon rank-sum test for continuous variables.
†Periods of early dialysis were first week, the second week, weeks 3 or 4, the second month and the third month post-transplant

Table 2: Average accumulated costs for transplant hospitalization and care over 1, 2, and 3 years post transplant among Medicare-insured renal recipients from 1995-2004 according to early post transplant dialysis utilization (in US dollars).

The average cost for patients who did not receive any dialysis in the 90 days post-transplant was less than all of the other groups across all time periods of interest (Table 2). Patients who did not experience DGF but required dialysis between 8 and 9 days were at least as expensive as those who were dialyzed within the first week post transplant. For all time periods the average total cost of medical care in patients who were dialyzed between days 8-90 was higher than that of recipients with DGF and dialysis in two or fewer periods. Compared to patients free of DGF and any early dialysis, those with dialysis in the first week incurred $1,400 in additional costs during the transplant hospitalization and $6,000 more by the end of the first year. Patients who had DGF who received dialysis in more than two periods had approximately $3,200 more in costs for the transplant hospitalization than those without any dialysis utilization.

After multivariate regression analysis, patients who received some dialysis in the 90 days post-transplant are more expensive to care for than those without any early dialysis utilization at each time period (Table 3). Receiving dialysis within the first week after transplant was independently associated with $2,727 in incremental costs compared to patients without DGF. The independent cost differential between these two groups increased over follow-up to $8,742 at three years post-transplant; The need for sustained early dialysis or dialysis which began between 8 to 90 days, was also independently associated with notably increased total costs where compared to no dialysis utilization. After accounting for dialysis utilization, ECD and DCD transplant were still associated with more expenses than SCD grafts in the transplant hospitalization and first year post-transplant, although the difference in cost was only significant only for DCD transplants. After accounting for inflation, dialysis utilization, and recipient and donor factors, Medicare payments for post-transplant care declined over time. By 2004 Medicare reimbursed approximately $15,700 less for the average transplant hospitalization than in 1995.

Both DGF and subsequent dialysis were found to dramatically impact patient survival (Table 4). By one year post-transplant the prevalence of any rejection ranged from 1.9% to 8.5%, and was most frequent in recipients with DGF and dialysis >2 early periods. This

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Variable	Transplant hospitalization†	One year post transplant†	Two years post transplant†	Three years post transplant†
Base Cost (Intercept)	33173 (31410 to 34936)*	57337 (52327 to 62346) *	66255 (59137 to 73373) *	76000 (66675 to 85326) *
DGF with early dialysis in first week only	2727 (2323 to 3131) *	6476 (5299 to 7652) *	7246 (5537 to 8954) *	8742 (6456 to 11029) *
DGF and early dialysis in 1 additional periods‡	1219 (442 to 1997) *	17070 (14794 to 19346) *	18036 (14777 to 21295) *	21481 (17107 to 25855) *
DGF and early dialysis in >1 additional periods‡	2461 (1379 to 3544) *	27606 (24497 to 30716) *	33675 (29221 to 38129) *	39855 (33856 to 45855) *
No DGF but some early dialysis‡	1762 (868 to 2657) *	20013 (17448 to 22578) *	21984 (18408 to 25560) *	24846 (20265 to 29426) *
No DGF and no early dialysis	Reference	Reference	Reference	Reference
Recipient characteristics				
Female	-226 (-599 to 146)	-93 (-1168 to 983)	1207 (-334 to 2748)	3086 (1053 to 5120) *
Race				
African American	1318 (879 to 1757) *	1969 (690 to 3249) *	4532 (2691 to 6374) *	7543 (5112 to 9974) *
White	Reference	Reference	Reference	Reference
Other	391 (-354 to 1136)	-5426 (-7624 to -3228) *	-9224 (-12397 to -6052) *	-13901 (-18094 to -9708) *
Age (years)				
18-30	Reference	Reference	Reference	Reference
31-44	-37 (-722 to 648)	192 (-1764 to 2148)	636 (-2134 to 3405)	329 (-3254 to 3911)
45-59	-597 (-1273 to 79)	976 (-960 to 2911)	1449 (-1298 to 4197)	620 (-2943 to 4182)
≥ 60	-291 (-1010 to 428)	3932 (1869 to 5996) *	4916 (1974 to 7859) *	3835 (-4 to 7675)
BMI category (kg/m²)				
< 10 or Missing	-289 (-769 to 191)	13 (-1358 to 1385)	474 (-1462 to 2411)	1325 (-1176 to 3825)
≥10 to <25	Reference	Reference	Reference	Reference
≥ 25 to <30	-951 (-1421 to -481) *	-2122 (-3485 to -759) *	-1401 (-3370 to 568)	-2438 (-5071 to 196)
≥ 30	-1037 (-1558 to -516) *	266 (-1257 to 1790)	1050 (-1167 to 3267)	2272 (-720 to 5264)
Primary cause of ESRD				
Diabetes mellitus	2535 (1910 to 3160) *	13085 (11248 to 14923) *	22012 (19388 to 24636) *	28111 (24658 to 31563) *
Hypertension	1343 (706 to 1980) *	390 (-1512 to 2291)	1685 (-1042 to 4412)	1715 (-1885 to 5315)
Glomerulonephritis	-480 (-1125 to 164)	-4148 (-6054 to -2241) *	-5515 (-8233 to -2798) *	-7745 (-11317 to -4173) *
Polycystic kidney disease	126 (-704 to 956)	-3593 (-6024 to -1161) *	-5395 (-8883 to -1908) *	-9005 (-13620 to -4389) *
Other	Reference	Reference	Reference	Reference
Unknown	1385 (672 to 2098) *	577 (-1525 to 2680)	1267 (-1752 to 4286)	846 (-3120 to 4812)
Hispanic	507 (-72 to 1086)	3361 (1745 to 4977) *	5217 (2909 to 7525) *	6181 (3123 to 9239) *
Peripheral vascular disease	233 (-668 to 1133)	6601 (4026 to 9176) *	11829 (8152 to 15505) *	14462 (9646 to 19278) *
Pre-Transplant Dialysis				
None (pre-emptive)	1359 (436 to 2283) *	6174 (3503 to 8845) *	6680 (2848 to 10511) *	7769 (2669 to 12869) *
0-12 months	Reference	Reference	Reference	Reference
13-24 months	-1354 (-2111 to -596) *	-2315 (-4464 to -167) *	-2626 (-5650 to 398)	-2150 (-6038 to 1737)
25-60 months	-667 (-1337 to 3)	-858 (-2760 to 1045)	-1989 (-4680 to 702)	-3123 (-6593 to 348)
>60 months	398 (-352 to 1147)	3270 (1122 to 5417) *	3855 (789 to 6921) *	4895 (885 to 8904) *
Donor Characteristics				
Female	-392 (-767 to -18) *	-402 (-1487 to 683)	-229 (-1787 to 1329)	-28 (-2087 to 2031)
Race				
African American	698 (143 to 1253) *	2977 (1368 to 4585) *	4979 (2661 to 7298) *	8448 (5370 to 11527) *
White	Reference	Reference	Reference	Reference
Other	857 (-77 to 1791)	-1 (-2880 to 2879)	303 (-3872 to 4477)	5889 (386 to 11393) *
Age (years)				
< 18	125 (-436 to 686)	561 (-1051 to 2172)	742 (-1549 to 3032)	1729 (-1267 to 4725)
18-30	Reference	Reference	Reference	Reference
31-44	725 (215 to 1236) *	1889 (415 to 3363) *	1495 (-623 to 3612)	2639 (-157 to 5434)
45-59	998 (458 to 1538) *	3703 (2135 to 5271) *	5346 (3076 to 7616) *	7526 (4483 to 10569) *
≥ 60	2127 (1130 to 3124) *	9117 (6215 to 12019) *	13809 (9622 to 17997) *	16626 (11016 to 22236) *
BMI category (kg/m²)				
< 10 or Missing	499 (-484 to 1481)	-82 (-2805 to 2642)	301 (-3401 to 4004)	-1320 (-5896 to 3256)
≥10 to <25	Reference	Reference	Reference	Reference
≥ 25 to <30	-22 (-446 to 402)	-543 (-1773 to 686)	-797 (-2569 to 974)	-337 (-2684 to 2009)
≥ 30	148 (-365 to 661)	-192 (-1686 to 1302)	-1636 (-3797 to 525)	-2869 (-5766 to 27)
Death due to stroke	361 (-73 to 795)	2443 (1184 to 3702) *	3881 (2064 to 5697) *	5822 (3401 to 8244) *
Terminal Creatinine ≥ 1.5mg/dl	967 (458 to 1477) *	586 (-891 to 2063)	1036 (-1089 to 3161)	1796 (-1008 to 4600)
Hypertension history	609 (79 to 1139) *	2759 (1218 to 4300) *	4005 (1774 to 6236) *	5767 (2803 to 8732) *

Diabetes	-123 (-1050 to 804)	376 (-2326 to 3079)	1825 (-2180 to 5831)	4006 (-1447 to 9460)
Transplant Factors				
Donor Type				
SCD	Reference	Reference	Reference	Reference
ECD	750 (-98 to 1598)	2069 (-401 to 4538)	3147 (-418 to 6711)	4494 (-247 to 9235)
DCD	1969 (831 to 3107) *	4453 (947 to 7959) *	5079 (-328 to 10486)	4293 (-3404 to 11989)
Peak Panel Reactive Antibody (%)				
0-10	776 (197 to 1355) *	2547 (889 to 4205) *	3842 (1494 to 6190) *	4924 (1875 to 7972) *
11-30	Reference	Reference	Reference	Reference
>30	2026 (1487 to 2566) *	6482 (4927 to 8037) *	10917 (8684 to 13149) *	12567 (9614 to 15520) *
Unknown	2950 (2054 to 3847) *	7985 (4395 to 11576) *	6113 (750 to 11476) *	4231 (-2866 to 11328)
HLA Mismatches				
0	Reference	Reference	Reference	Reference
1	404 (-508 to 1316)	452 (-2161 to 3065)	-196 (-3910 to 3517)	2010 (-2888 to 6908)
2	-326 (-1126 to 474)	684 (-1608 to 2976)	1147 (-2123 to 4417)	1799 (-2517 to 6116)
3	-387 (-1097 to 322)	1106 (-944 to 3155)	2319 (-620 to 5258)	2181 (-1706 to 6067)
4	391 (-308 to 1089)	2600 (573 to 4628) *	3901 (979 to 6824) *	4697 (819 to 8576) *
5	976 (243 to 1709) *	5956 (3822 to 8090) *	8719 (5628 to 11810) *	10145 (6035 to 14254) *
6	1606 (711 to 2502) *	6829 (4229 to 9429) *	8405 (4633 to 12178) *	10601 (5541 to 15660) *
Unknown	2502 (1163 to 3842) *	7659 (3831 to 11487) *	13312 (7932 to 18691) *	16293 (9370 to 23217) *
CMV sero-pairing				
Donor - / Recipient -	Reference	Reference	Reference	Reference
Donor - / Recipient +	-325 (-961 to 311)	-172 (-2005 to 1662)	-86 (-2706 to 2534)	2471 (-986 to 5928)
Donor + / Recipient -	43 (-621 to 706)	6119 (4209 to 8029) *	8062 (5332 to 10792) *	10371 (6784 to 13959) *
Donor + / Recipient +	-98 (-693 to 497)	1658 (-58 to 3374)	3020 (568 to 5473) *	5880 (2653 to 9108) *
Unknown	64 (-722 to 849)	2877 (609 to 5145) *	5162 (1941 to 8383) *	9235 (5019 to 13450) *
Cold time (hours)				
0 - 14	Reference	Reference	Reference	Reference
15 - 19	-325 (-817 to 167)	-1125 (-2553 to 303)	-1584 (-3637 to 469)	-794 (-3513 to 1924)
20 - 25	890 (386 to 1394) *	648 (-810 to 2106)	704 (-1389 to 2797)	617 (-2143 to 3377)
26+	4037 (3501 to 4573) *	5325 (3784 to 6865) *	5649 (3455 to 7844) *	4429 (1550 to 7308) *
Unknown	2978 (2319 to 3637) *	5036 (3103 to 6970) *	4750 (1896 to 7605) *	6270 (2359 to 10181) *
Year				
1995	Reference	Reference	Reference	Reference
1996	-1458 (-2262 to -654) *	-2277 (-4502 to -53) *	-1673 (-4685 to 1338)	-1819 (-5519 to 1882)
1997	-4418 (-5192 to -3643) *	-6521 (-8664 to -4379) *	-8239 (-11141 to -5336) *	-9645 (-13213 to -6077) *
1998	-5952 (-6736 to -5168) *	-11433 (-13602 to -9264) *	-12815 (-15755 to -9875) *	-13715 (-17332 to -10098) *
1999	-7277 (-8068 to -6485) *	-13947 (-16138 to -11757) *	-14618 (-17588 to -11647) *	-15831 (-19488 to -12173) *
2000	-8297 (-9093 to -7500) *	-11218 (-13426 to -9010) *	-10232 (-13231 to -7233) *	-10798 (-14500 to -7096) *
2001	-9399 (-10188 to -8609) *	-13744 (-15932 to -11555) *	-14396 (-17371 to -11421) *	-15758 (-19434 to -12081) *
2002	-11555 (-12348 to -10761) *	-18870 (-21070 to -16670) *	-19225 (-22216 to -16233) *	-
2003	-13837 (-14632 to -13043) *	-23061 (-25267 to -20854) *	12991 (3764 to 22219) *	-
2004	-15699 (-16600 to -14798) *	15414 (3619 to 27208) *	-7226 (-23593 to 9140)	-

Costs adjusted to 2004 as the base year

†Coefficient Estimates (95% CI).

* P-value < 0.05.

‡ Periods of early dialysis were first week, the second week, weeks 3 or 4, the second month and the third month post-transplant

Table 3: Multivariate regression estimates of adjusted cost drivers at transplant hospitalization and one, two, and three years in Medicare-insured transplant recipients from 1995–2004 (in US dollars).

group continued to have the highest rejection prevalence at 2 and 3 years post-transplant (12.5% and 14.5%, respectively) while those with no early dialysis utilization consistently had the lowest rejection (1.9%, 4.0%, and 5.1% at one, two and three years). The intensity of dialysis was correlated with length of hospital stay, serum creatinine, and eGFR at all time periods. Patients without dialysis requirements had the shortest length of stay, lowest serum creatinine, and highest eGFR at all follow-up points.

Graft survival varied significantly based on post-transplant dialysis utilization (p<0.0001), being best in those with no early dialysis utilization and worst in those with DGF and dialysis in >2 subsequent periods (Figure 1A). Patterns were similar for patient survival, such that patients with DGF and dialysis in >2 early periods had approximately 10% lower survival by one year post-transplant compared to those with no early dialysis utilization (Figure 1B). After adjusting for recipient, donor, and transplant characteristics, post-transplant dialysis utilization was associated with lower graft and patient survival compared to no early dialysis utilization (Table 5). Patients who experienced DGF and received dialysis in >2 early periods were more than twice as likely to lose their grafts within 3 years as those

	N at Risk	DGF and early dialysis in 1 additional period, ‡n(%))	DGF and early dialysis in >1 additional period, ‡n(%)	No DGF but some early dialysis, ‡n(%)*	No DGF and no dialysis, ‡n(%)*	p-value†	p-value*
		n (%)	n (%)	n (%)	n (%)	n (%)	
Rejection††							
1 year post transplant	37,533	314 (2.6)	99 (4.6)	88 (8.5)	71 (4.7)	389 (1.9)	<0.0001
2 year post transplant	37,533	574 (4.7)	173 (8.1)	130 (12.5)	109 (7.2)	817 (4.0)	<0.0001
3 year post transplant	37,533	709 (5.9)	198 (9.3)	151 (14.5)	132 (8.7)	1060 (5.1)	<0.0001
		mean (std)	mean (std)	mean (std)	mean (std)	mean (std)	
Length of stay (days)	22,269	11.6 (31.7)	13.1 (55.4)	17.6 (83.7)	11.3 (31.9)	9.4 (45.9)	<0.0001
Serum Creatinine (mg/dl)							
Discharge	36,867	4.2 (2.9)	6.7 (3.5)	7.3 (3.4)	2.9 (2.4)	2.2 (1.6)	<0.0001
6 months post transplant	35,514	1.7 (0.8)	1.9 (1.0)	2.1 (1.1)	1.7 (0.8)	1.5 (0.7)	<0.0001
1 year post transplant	33,957	1.7 (0.8)	1.9 (1.0)	2.1 (1.0)	1.8 (1.1)	1.5 (0.7)	<0.0001
eGFR (ml/min/1.73 m²)							
Discharge	36,867	27.3 (21.0)	15.4 (16.2)	13.7 (15.9)	40.6 (43.6)	45.9 (35.4)	<0.0001
6 month post transplant	35,514	52.7 (22.9)	48.1 (20.5)	44.7 (21.6)	52.3 (32.9)	57.3 (22.1)	<0.0001
1 year post transplant	33,957	52.5 (21.1)	47.9 (20.1)	44.4 (20.5)	51.9 (21.0)	56.7 (22.7)	<0.0001

*P value for the difference in trait distribution according to early post-transplant dialysis utilization was computed by the Chi-square test for categorical variables and ANOVA F-tests for continuous variables.
†Periods of early dialysis were first week, the second week, weeks 3 or 4, the second month and the third month post-transplant
††Rejection is defined as any OPTN reported rejection with in the indicated period
‡Missing data is excluded from the analysis.

Table 4: Graft outcomes according to early post-transplant dialysis utilization.

who did not receive early dialysis (p<0.0001). Dialysis in the first week only increased the risk of graft failure and death by 24% (p<0.0001 for both comparisons). After adjustment for dialysis utilization and other factors, recipients of ECD transplants were 10% more likely to experience graft failure and 20% more likely to experience death than recipients of SCD transplants (p= 0.04 and p = 0.003 respectively). Year of transplant was not associated with patient or graft survival after accounting for other factors

Discussion

Our study examined the cost of care for the transplant hospitalization and at one, two, and three years post transplant for adult Medicare recipients of deceased donor kidneys in 1995 to 2004 in the United States. We assessed the implications of dialysis utilization early after transplant. A major observation was that patients who receive early post-transplant dialysis are not a homogenous group with respect to costs of care and clinical outcomes. Patients experiencing DGF incurred an additional $1,200 to $2,700 in adjusted costs during the transplant hospitalization. By one year after transplant, there was a graded increase in the incremental cost of care according to the duration of early dialysis utilization, ranging from $6,500 in those with dialysis confined to the first week to $27,600 in those with DGF and dialysis in >2 additional early periods.

In addition to increased cost, dialysis utilization in the first 90 days post transplant is also a marker for poorer clinical outcomes including higher serum creatinine, lower eGFR and longer length of stay. Patients who require dialysis also have more common rejection in the 3 years post transplant, especially those with sustained early dialysis utilization. They also experience worse graft and patient survival. Our results are similar to those of Humar et al. [21,22] who found that both DGF and slow graft function (SGF) are associated with higher acute rejection rates and worse graft survival [21].

Our results show that not only is dialysis in the first week post-transplant a marker for worse clinical and cost outcomes but that early dialysis in the first 8 to 90 days is associated with similarly adverse, if not worse, outcomes. This observation supports a need for a broader definition of DGF that includes graft dysfunction which occurs after the first weekpost transplant. Some studies have explored the concept of SGF in terms of serum creatinine levels in patients who do not require dialysis, but thresholds of elevated creatinine varied across studies [21-23]. Further, most of these definitions consider function only within the first week post-transplant. The need for dialysis beyond the first week, yet still early after transplant needs to be considered. Definitions of DGF and SGF severity that reflect the amount and frequency of early post-transplant dialysis should be formalized. Prospective studies considering eGFR levels and the amount and the amount and frequency of dialysis requirements in relation to outcomes are warranted.

In recent years UNOS has been encouraging the utilization of ECD and DCD kidneys in order to increase the donor supply [24]. While these allografts may remove patients from the wait-list faster than waiting for an SCD kidney, the organs come with additional risk. This includes an increased risk of DGF and graft failure compared to SCD kidneys [23,25]. These outcomes often lead to more frequent and longer hospitalizations which increase the cost of care [16,25]. Merion et al. [26] suggested that given these increased risks, the use of ECD kidneys should be targeted at specific recipient groups including older patients, those with diabetes, and patients who live in areas with very long waiting times.

A number of studies have demonstrated strong associations of

	Patient Death		Graft Failure	
Variable	**Odds Ratio**	**95% CI**	**Odds Ratio**	**95% CI**
DGF with early dialysis in first week only	1.24	(1.17 to 1.32)*	1.24	(1.18 to 1.3) *
DGF and early dialysis in 1 additional periods‡	1.60	(1.45 to 1.78) *	1.66	(1.53 to 1.8) *
DGF and early dialysis in >1 additional periods‡	2.08	(1.83 to 2.36) *	2.23	(2.02 to 2.47) *
No DGF but some early dialysis‡	1.61	(1.44 to 1.8) *	1.54	(1.41 to 1.69) *
No DGF and no early dialysis	Reference		Reference	
Recipient characteristics				
Female	0.92	(0.87 to 0.97) *	0.91	(0.87 to 0.95) *
Race				
African American	0.94	(0.88 to 1.01) *	1.27	(1.21 to 1.33) *
White	Reference		Reference	
Other	0.70	(0.61 to 0.8) *	0.79	(0.71 to 0.88) *
Age (years)				
18-30	Reference		Reference	
31-44	1.41	(1.21 to 1.63) *	0.86	(0.8 to 0.94) *
45-59	2.17	(1.88 to 2.5) *	0.86	(0.79 to 0.93) *
≥ 60	3.38	(2.93 to 3.89) *	1.06	(0.98 to 1.16)
BMI category (kg/m²)				
< 10 or Missing	1.01	(0.95 to 1.08)	1.04	(0.99 to 1.1)
≥10 to <25	Reference		Reference	
≥ 25 to <30	0.91	(0.85 to 0.98) *	0.95	(0.9 to 1.01)
≥ 30	1.02	(0.94 to 1.11)	1.09	(1.02 to 1.16) *
Primary cause of ESRD				
Diabetes mellitus	1.55	(1.41 to 1.7) *	1.19	(1.1 to 1.28) *
Hypertension	1.05	(0.95 to 1.16)	1.07	(0.99 to 1.15)
Glomerulonephritis	0.81	(0.73 to 0.9) *	0.90	(0.83 to 0.98) *
Polycystic kidney disease	0.66	(0.58 to 0.76) *	0.70	(0.63 to 0.78) *
Other	Reference		Reference	
Unknown	1.00	(0.89 to 1.12)	1.02	(0.93 to 1.11)
Hispanic	1.49	(1.36 to 1.63) *	1.24	(1.16 to 1.33) *
Peripheral vascular disease	1.32	(1.19 to 1.46) *	1.24	(1.13 to 1.36) *
Pre-Transplant Dialysis				
None (pre-emptive)	0.96	(0.84 to 1.11)	0.92	(0.83 to 1.03)
0-12 months	Reference		Reference	
13-24 months	1.02	(0.92 to 1.14)	1.00	(0.92 to 1.08)
25-60 months	1.00	(0.92 to 1.1)	0.94	(0.87 to 1.01)
> 60 months	1.15	(1.03 to 1.28) *	1.00	(0.92 to 1.09)
Donor Characteristics				
Female	1.03	(0.98 to 1.09)	1.08	(1.04 to 1.13) *
Race				
African American	1.08	(0.99 to 1.17)	1.18	(1.11 to 1.26) *
White	Reference		Reference	
Other	0.98	(0.84 to 1.14)	1.00	(0.89 to 1.13)
Age (years)				
< 18	1.03	(0.94 to 1.12)	1.03	(0.96 to 1.1)
18-30	Reference		Reference	
31-44	1.05	(0.97 to 1.13)	1.10	(1.03 to 1.17) *
45-59	1.17	(1.07 to 1.26) *	1.25	(1.17 to 1.34) *
≥ 60	1.19	(1.04 to 1.36) *	1.44	(1.29 to 1.6) *
BMI category (kg/m²)				
< 10 or Missing	0.97	(0.86 to 1.1)	1.01	(0.91 to 1.11)
≥10 to <25	Reference		Reference	
≥ 25 to <30	0.94	(0.88 to 1)	0.95	(0.9 to 1)
≥ 30	1.01	(0.94 to 1.09)	0.95	(0.9 to 1.01)
Death due to stroke	1.09	(1.02 to 1.16) *	1.11	(1.05 to 1.17) *
Terminal Creatinine ≥ 1.5mg/dl	0.94	(0.87 to 1.01)	1.01	(0.96 to 1.08)
Hypertension history	1.02	(0.95 to 1.1)	1.06	(1 to 1.13) *
Diabetes	1.14	(1 to 1.29) *	1.16	(1.04 to 1.28) *

Transplant Factors				
Donor Type				
SCD	Reference		Reference	
ECD	1.19	(1.06 to 1.33) *	1.10	(1.01 to 1.2) *
DCD	1.07	(0.88 to 1.3)	1.02	(0.87 to 1.19)
Peak Panel Reactive Antibody (%)				
0-10	Reference		Reference	
11-30	1.02	(0.94 to 1.1)	1.07	(1 to 1.14)
>30	1.19	(1.1 to 1.28) *	1.22	(1.15 to 1.3) *
Unknown	1.19	(1.01 to 1.42) *	1.10	(0.95 to 1.26)
HLA Mismatches				
0	Reference		Reference	
1	1.09	(0.96 to 1.25)	1.08	(0.97 to 1.22)
2	1.10	(0.97 to 1.23)	1.18	(1.07 to 1.3) *
3	1.16	(1.04 to 1.29) *	1.22	(1.11 to 1.33) *
4	1.18	(1.06 to 1.32) *	1.30	(1.19 to 1.42) *
5	1.21	(1.08 to 1.35) *	1.29	(1.17 to 1.41*)
6	1.22	(1.06 to 1.4) *	1.34	(1.2 to 1.5) *
Unknown	1.20	(1 to 1.45) *	1.27	(1.09 to 1.47) *
CMV sero-pairing				
Donor - / Recipient -	Reference		Reference	
Donor - / Recipient +	1.15	(1.04 to 1.27) *	1.12	(1.03 to 1.21) *
Donor + / Recipient -	1.27	(1.15 to 1.42) *	1.24	(1.14 to 1.35) *
Donor + / Recipient +	1.23	(1.11 to 1.35) *	1.16	(1.08 to 1.25) *
Unknown	1.21	(1.07 to 1.36) *	1.17	(1.06 to 1.28) *
Cold time (hours)				
0 - 14	Reference		Reference	
15 - 19	0.99	(0.92 to 1.07)	1.02	(0.96 to 1.08)
20 - 25	1.07	(1 to 1.16)	1.11	(1.05 to 1.18) *
26+	1.05	(0.97 to 1.13)	1.07	(1.01 to 1.14) *
Unknown	1.01	(0.9 to 1.13)	1.03	(0.95 to 1.13)
Year				
1995	Reference		Reference	
1996	0.94	(0.85 to 1.03)	0.94	(0.87 to 1.02)
1997	0.99	(0.9 to 1.09)	0.95	(0.88 to 1.02)
1998	1.01	(0.91 to 1.11)	0.95	(0.88 to 1.02)
1999	0.99	(0.89 to 1.1)	0.92	(0.85 to 1)
2000	1.09	(0.97 to 1.21)	1.02	(0.94 to 1.11)
2001	1.04	(0.92 to 1.17)	0.92	(0.84 to 1.01)
2002	0.96	(0.83 to 1.1)	0.96	(0.86 to 1.06)
2003	0.96	(0.82 to 1.14)	0.90	(0.79 to 1.03)
2004	0.92	(0.7 to 1.22)	0.90	(0.73 to 1.12)

* P-value < 0.05

†Periods of early dialysis were first week, the second week, weeks 3 or 4, the second month and the third month post-transplant

Table 5: Adjusted associations of early post-transplant dialysis utilization with graft failure and patient death.

non-standard deceased-donor organs with increased need for early dialysis after transplant [25,27,28]. For example, one large registry study documented DGF in over 42% of DCD transplants in recent US practice [28]. Another large registry study found DGF occurred in 31% of ECD recipients, compared to 19% in non-ECD recipients [29]. Thus, use of these organs is expected to increase expenditures based on increased risk of early dialysis requirements. Further, we also detected associations of DCD kidneys with significant increase in cost even after adjusting for early post-transplant dialysis utilization. ECD kidneys were associated with a trend towards higher incremental costs after adjusting for early post-transplant dialysis utilization and other covariates. This can have a detrimental effect on the finances of a transplant center, as marginal organs are being used more often and kidney transplantation is reimbursed by Medicare at a fixed rate, regardless of the kidney quality or patient comorbidity [30-32].

Our results also support those of Englesbe et al. [6] who showed that ECD transplants and cases of DGF are associated with a decrease in their institution's profit margin as well as an increase in cost and decrease in Medicare reimbursement over time [6]. We not only found early post transplant dialysis utilization to be costly, but also found that Medicare is paying less per transplant per year. Total payments have been decreasing at a rate of over $1,500 a year. Compared to 1995 Medicare reimbursed almost $16,000 less per transplant in 2004. These results suggest there will be an increasing burden on transplant centers which utilize organs associated with early post transplant dialysis requirements to expand the organ supply.

ECDs and DCDs kidneys have been shown to be associated with an increased risk of DGF, which in turn is associated with increased

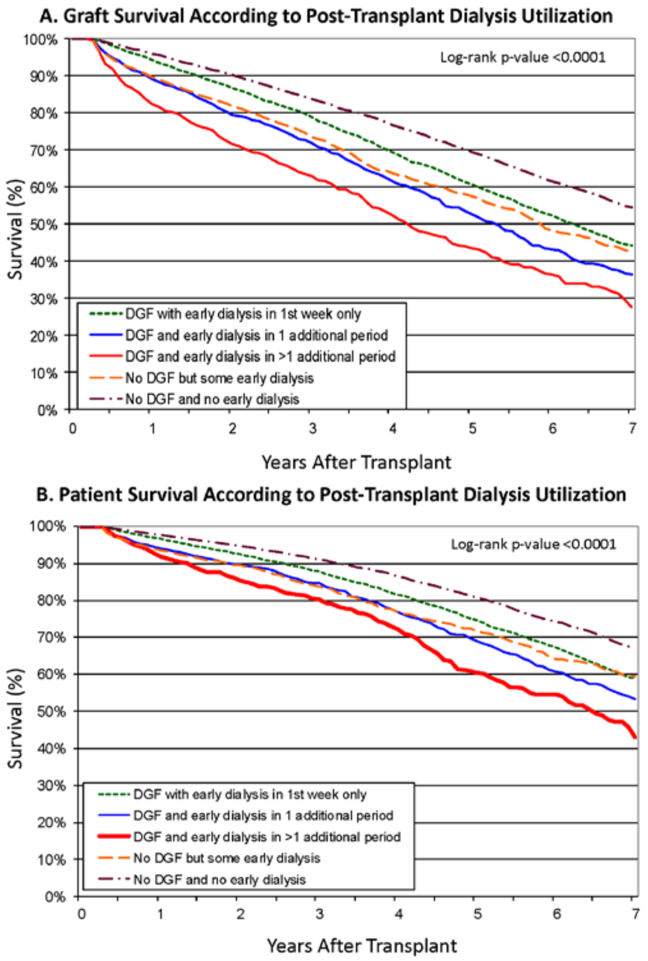

Figure 1: Graft and patient survival of Medicare-insured renal transplant recipients in the USRDS 1995-2004 according to early post-transplant dialysis utilization.

costs [23,32]. In order to minimize the economic impact of these organs and expand the organ supply we propose that the DRG for kidney transplantation should be different for each donor type. Kidneys associated with better outcomes and thus a lower cost (SCD kidneys) should have a DRG associated with a lower reimbursement by Medicare compared to DRGs for kidneys shown to be associated with poorer outcomes, such as ECD and some DCD kidneys. In the future, this reimbursement could be graded based on a donor profile index or another continuous scale.

Our study has several limitations. First, given a retrospective registry design we could not control for variables that were not collected in the USRDS database. Our multivariate models were adjusted for a number of factors associated with costs and clinical outcomes in other studies [27]. However, other clinical factors not recorded in the registry may drive costs. A prospective study is needed to determine if the cost associations we found are due to dialysis utilization and not the characteristics of the population. Secondly, our sample was restricted to patients with Medicare as the primary insurer and our findings may not generalize to beneficiaries of private insurance. We applied strict inclusion criteria to limit the possibility that study participants were using Medicare as a secondary insurer. Third, analyses of serum creatinine/eGFR after transplant may be affected by survivor bias in that patients who died or lost their graft and may have had worse renal function are not represented. Finally not all transplant centers submit separate charges to Medicare for dialysis that occurs in the first week post transplant as some bundle inpatient dialysis charges with the transplant hospitalization charge. Thus we were unable to determine how many sessions of dialysis and how frequently the sessions were occurring for the recipients who experienced DGF. Redefining how DGF is reported to the OPTN can allow for a more detailed study of DGF.

In summary, we found that Medicare is paying less each year for a transplant even as more marginal kidneys are being used to increase the donor supply. These marginal kidneys have an increase rate of DGF and dialysis initiated after the first post transplant week. DGF and additional early post-transplant early dialysis are costly at the time of transplant and result in higher longterm costs. In order to reduce the economic disincentive to use marginal kidneys, Medicare should consider reimbursement rates based on organ quality.

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