Supplemental Online Content

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eTable 1. Clinical Classifications Software[1] Organ System Groups

Clinical Classifications Software Category[a]	Organ System Group
1-9	Nervous system procedures
10-12	Endocrine procedures
13-21, 220	Eye procedures
22-35	ENT and dental procedures
36-42	Thoracic procedures
43-63, 225	Cardiovascular procedures
64-67	Hematologic procedures
68-99, 8	Gastrointestinal and abdominal procedures
100-118	Urologic procedures
119-141	Obstetric and gynecologic procedures
142-164	Orthopedic procedures
165-175	Skin and breast procedures

[a] Individual procedures within Clinical Classifications Software Category 176, Other organ transplantation, were redistributed within their respective organ system grouping.

eTable 2. Current Procedural Terminology Codes for Common Surgical Procedures Subgroup Analysis

Surgical Specialty	Surgical Procedure	CPT Codes
Bariatric	Gastric sleeve	43775, 43843
Bariatric	Roux-en-Y gastric bypass	43644, 43645, 43846, 43847
Cardiac	CABG	33510, 33511, 33512, 33513, 33514, 33515, 33516, 33517, 33518, 33519, 33520, 33521, 33533, 33534, 33535, 33536
Cardiac	Valve repair/ replacement	33400, 33401, 33402, 33403, 33404, 33405, 33406, 33407, 33408, 33409, 33410, 33411, 33412, 33413, 33414, 33415, 33416, 33417, 33420, 33421, 33422, 33423, 33424, 33425, 33426, 33427, 33428, 33429, 33430, 33496
Cardiology	TAVR	33361, 33362, 33363, 33364, 33365, 33366
ENT	Endoscopic sinus surgery	31237, 31240, 31253, 31254, 31255, 31256, 31257, 31259, 31267, 31276, 31287, 31288
ENT	Glossectomy	41135
ENT	Laryngectomy	31360, 31365, 31390, 31395
ENT	Neck dissection	38724
ENT	Parotid	42410, 42415, 42420
ENT	Thyroid and parathyroid	60220, 60225, 60240, 60252, 60260, 60271, 60500
General	Abdominal wall hernia	49560, 49561, 49565, 49566, 49585, 49587, 49652, 49653, 49654, 49655, 49659
General	Appendectomy	44955, 44960, 44970, 44979
General	Breast	19120, 19125, 19160, 19162, 19180, 19240, 19301, 19302, 19303, 19307, 38500, 38525, 38745
General	Cholecystectomy	47562, 47563, 47600, 47605
General	Colorectal	44139, 44140, 44141, 44143, 44144, 44145, 44146, 44147, 44150, 44151, 44155, 44157, 44158, 44160, 44204, 44205, 44206, 44207, 44208, 44210, 44211, 44212, 45110, 45111, 45112, 45113, 45114, 45119, 45123, 45395, 45397
General	Esophagectomy	43107, 43108, 43112, 43113, 43116, 43117, 43118, 43121, 43123, 43124
General	Gastrectomy	43620, 43621, 43622, 43631, 43632, 43633, 43634
General	Hepatectomy	47120, 47122, 47125, 47130
General	Inguinal hernia	49505, 49507, 49520, 49650, 49651
General	Pancreatectomy	48140, 48145, 48146, 48150, 48152, 48153, 48154, 48155
Gynecologic	Hysterectomy or myomectomy	58140, 58150, 58152, 58180, 58200, 58210, 58260, 58262, 58263, 58267, 58270, 58275, 58280, 58285, 58290, 58291, 58292, 58293, 58294, 58541, 58542, 58543, 58544, 58548, 58550, 58552, 58553, 58554, 58570, 58571, 58572, 58573, 58951, 58953, 58954, 58956
Orthopedic	Amputation	61304, 61312, 61313, 61314, 61315, 61320, 61322, 61343, 61500, 61510, 61512, 61518, 61519, 61520, 61521, 61526, 61548, 61697, 61700

Surgical Specialty	Surgical Procedure	CPT Codes
Orthopedic	Amputation	27590, 27592, 27594, 27596, 27598, 27880, 27881, 27882, 27886
Orthopedic	Arthroscopy	29806, 29807, 29822, 29823, 29824, 29825, 29826, 29827, 29828, 29870, 29871, 29873, 29874, 29875, 29876, 29877, 29879, 29880, 29881, 29882, 29883, 29884, 29888, 29891, 29999
Orthopedic	Fracture	23615, 24515, 27236, 27244, 27245, 27488, 27506, 27514, 27535
Orthopedic	Hip replacement	27130, 27125, 27132, 27134, 27137, 27138
Orthopedic	Knee replacement	27447, 27486, 27487
Orthopedic	Shoulder	23470, 23472
Spine	Disc Herniation	22533, 22534, 22551, 22552, 22554, 22558, 22585, 22586, 22590, 22595, 22600, 22612, 22614, 22630, 22632, 22633, 22634, 22856, 63001, 63005, 63012, 63015, 63017, 63020, 63030, 63035, 63045, 63047, 63048, 63050, 63051
Thoracic	Lung surgery	32440, 32442, 32445, 32480, 32482, 32484, 32486, 32488, 32500, 32503, 32504
Urology	Adrenalectomy	60540, 60545, 60650
Urology	Cystectomy	51575, 51590, 51595, 51596, 51597, 52000, 52001, 52204, 52287, 52310, 52341, 52354, 52005, 52224, 52234, 52235, 52332, 52344, 52351, 52240, 52353
Urology	Kidney	50220, 50225, 50230, 50234, 50240, 50543, 50544, 50545, 50546, 50548
Urology	Laser vaporization of prostate	52648
Urology	Prostatectomy	55810, 55812, 55815, 55840, 55842, 55845, 55866
Urology	TURP	52601, 52630
Vascular	Endarterectomy	35301, 35390, 37215, 37216, 37217, 37218
Vascular	Endovascular aorta	34800, 34802, 34803, 34804, 34805
Vascular	Endovascular other	37220, 37221, 37224, 37226, 37228
Vascular	Open aortic	33320, 33321, 33322, 33330, 33332, 33335, 33875, 33877, 34830, 34831, 34832, 35081, 35082, 35091, 35092, 35102, 35103, 35331, 35526, 35531, 35541, 35546, 35548, 35549, 35551, 35560, 35626, 35631, 35641, 35646, 35647, 35651
Vascular	Other infra-inguinal bypass	35521, 35533, 35556, 35558, 35563, 35565, 35571, 35621, 35623, 35654, 35656, 35661, 35663, 35665, 35666, 35671, 35681, 35682, 35683

CPT, Current Procedural Terminology

eTable 3. Clinical Classification Software[1] Categories for Minor Eye, Skin, and Vascular Procedures Subgroup Analysis

Minor Procedure Subgroup	Clinical Classification Software	
	Category	Category Description
Eye	15, 16, 17, 20	Lens and cataract procedures; Repair of retinal tear, detachment; Destruction of lesion of retina and choroid; Other intraocular therapeutic procedures
Skin	169, 172	Debridement of wound, infection or burn; Skin graft
Vascular Access	57	Creation, revision and removal of arteriovenous fistula or vessel-to-vessel cannula for dialysis

eTable 4. Supplemental Patient Characteristics by Days Between Last Hemodialysis and Procedure

	Days Between Last Hemodialysis and Procedure		
Characteristic[a]	**1 Day (N = 750,163)**	**2 Days (N = 285,939)**	**3 Days (N = 111,744)**
Patient Characteristics			
Listed for kidney transplant	30,534 (4.1%)	14,240 (5.0%)	5,670 (5.1%)
Years on hemodialysis at time of procedure	3.3 (1.6-5.8) [n=750,163]	3.2 (1.6-5.6) [n=>285,900][b]	3.3 (1.7-5.8) [n=>111,700][b]
Prior procedure within 30 days	161,588 (21.5%)	69,827 (24.4%)	28,936 (25.9%)
Medicare/Medicaid dual eligible	346,124 (46.1%)	134,487 (47.0%)	52,814 (47.3%)
Charlson comorbidities[c]			
Diabetes without complications	462,802 (61.7%)	180,200 (63.0%)	71,923 (64.4%)
Diabetes with complications	436,218 (58.1%)	170,929 (59.8%)	68,356 (61.2%)
Peripheral vascular disease	414,007 (55.2%)	161,362 (56.4%)	64,635 (57.8%)
Congestive heart failure	411,281 (54.8%)	158,471 (55.4%)	63,051 (56.4%)
Chronic pulmonary disease	319,961 (42.7%)	122,857 (43.0%)	48,634 (43.5%)
Cerebrovascular disease	299,411 (39.9%)	115,330 (40.3%)	46,103 (41.3%)
Myocardial infarction	212,347 (28.3%)	83,015 (29.0%)	33,302 (29.8%)
Mild liver disease	199,537 (26.6%)	77,779 (27.2%)	30,544 (27.3%)
Cancer	113,226 (15.1%)	42,841 (15.0%)	16,472 (14.7%)
Dementia	51,592 (6.9%)	20,979 (7.3%)	8,369 (7.5%)
Peptic ulcer disease	73,156 (9.8%)	28,332 (9.9%)	11,673 (10.4%)
Connective tissue disease-rheumatic disease	52,085 (6.9%)	19,625 (6.9%)	7,837 (7.0%)
Paraplegia and hemiplegia	48,816 (6.5%)	19,446 (6.8%)	8,129 (7.3%)
Moderate or severe liver disease	25,427 (3.4%)	10,026 (3.5%)	3,905 (3.5%)
Metastatic carcinoma	20,424 (2.7%)	7,793 (2.7%)	2,975 (2.7%)
AIDS/HIV	12,330 (1.6%)	4,844 (1.7%)	1,983 (1.8%)

[a] All listed characteristics were used for risk-adjustment in multivariable models. Data are presented as n (%) or median (IQR).
[b] Individual cell counts modified or omitted in order to preserve patient privacy.
[c] Charlson comorbidities were determined using published coding algorithms.[2] Kidney disease was not included as the study cohort only consisted of patients with ESKD. For calculation of the Charlson Comorbidity Index, all patients were considered to have kidney disease.
Abbreviations: AIDS, acquired immunodeficiency syndrome; HIV, human immunodeficiency virus.

eTable 5. Common Clinical Classification Software[1] Procedure Categories

Procedure Category	N (%)
Other intraocular therapeutic procedures[a]	224,784 (19.6%)
Creation, revision and removal of arteriovenous fistula or vessel-to-vessel cannula for dialysis	218,179 (19.0%)
Other OR procedures on vessels other than head and neck[b]	145,635 (12.7%)
Lens and cataract procedures	122,293 (10.7%)
Debridement of wound, infection or burn	98,690 (8.6%)
Skin graft	64,238 (5.6%)
Destruction of lesion of retina and choroid	28,284 (2.5%)
Repair of retinal tear, detachment	17,720 (1.5%)
Kidney transplant	16,392 (1.4%)
Excision of skin lesion	14,515 (1.3%)
Glaucoma procedures	14,335 (1.3%)
Other therapeutic procedures on eyelids, conjunctiva, cornea	14,303 (1.2%)
Amputation of lower extremity	13,324 (1.2%)
Laparoscopy	12,347 (1.1%)
Insertion, revision, replacement, removal of cardiac pacemaker or cardioverter/defibrillator	11,499 (1.0%)

[a] The most common procedure codes in this category included intraocular drug injections and fluid removal.
[b] The most common procedure codes in this category included open or percutaneous stent placements, ligation and open thrombectomy of arteriovenous fistula, and open or percutaneous tibial and femoral revascularization procedures.

eTable 6. Patient and Procedure Characteristics, by Presence of an Additional Hemodialysis Session on the Day of Procedure

Characteristic	**No Additional Hemodialysis (n= 954,569)**	**Additional Hemodialysis (n= 193,277)**
Dialysis-to-procedure interval		
1 day	746,840 (78.2%)	3,323 (1.7%)
2 days	170,350 (17.8%)	115,589 (59.8%)
3 days	37,379 (3.9%)	74,365 (38.5%)
Patient Characteristics		
Age	65.0 (56.0-73.0)	65.0 (56.0-73.0)
18-39	38,635 (4.0%)	6,993 (3.6%)
40-59	295,551 (31.0%)	63,815 (33.0%)
60-79	504,446 (52.8%)	101,314 (52.4%)
80+	115,937 (12.1%)	21,155 (10.9%)
Sex		
Male	538,914 (56.5%)	113,806 (58.9%)
Female	415,655 (43.5%)	79,471 (41.1%)
Race[a]		
White	574,660 (60.2%)	124,274 (64.3%)
Black/African American	324,319 (34.0%)	57,446 (29.7%)
American Indian or Alaska Native	12,389 (1.3%)	2,453 (1.3%)
Asian	31,149 (3.3%)	6,672 (3.5%)
Native Hawaiian or Pacific Islander	10,596 (1.1%)	2,122 (1.1%)
Other or Multiracial	1,456 (0.2%)	310 (0.2%)
Hispanic[a]	174,276 (18.3%)	39,969 (20.7%)
Procedure day of the week		
Monday	129,325 (13.5%)	48,482 (25.1%)
Tuesday	270,705 (28.4%)	27,039 (14.0%)
Wednesday	164,251 (17.2%)	53,641 (27.8%)
Thursday	260,950 (27.3%)	26,149 (13.5%)
Friday	129,338 (13.5%)	37,966 (19.6%)
Cause of ESKD		
Diabetes	558,893 (58.6%)	124,372 (64.4%)
Hypertension	238,038 (25.0%)	41,357 (21.4%)
Glomerulonephritis	60,421 (6.3%)	10,108 (5.2%)
Cystic kidney	15,496 (1.6%)	2,495 (1.3%)
Other urologic	10,883 (1.1%)	2,165 (1.1%)
Other/unknown	69,493 (7.3%)	12,535 (6.5%)
Vascular access type[a]		
Catheter	299,568 (31.5%)	46,014 (23.8%)
Graft	156,169 (16.4%)	33,465 (17.3%)
Fistula	496,035 (52.1%)	113,797 (58.9%)
Median household income for patient zip code (dollars)[a]		
0 to 45,999	296,222 (31.4%)	52,952 (27.8%)
46,000 to 58,999	268,437 (28.5%)	54,034 (28.3%)
59,000 to 78,999	213,254 (22.6%)	45,872 (24.0%)
79,000+	165,211 (17.5%)	37,911 (19.9%)

Characteristic	No Additional Hemodialysis (n= 954,569)	Additional Hemodialysis (n= 193,277)
Dialysis schedule		
MWF	578,366 (60.6%)	139,592 (72.2%)
TThS	376,203 (39.4%)	53,685 (27.8%)
Dialysis on the day of the procedure	0 (0.0%)	193,277 (100.0%)
Listed for kidney transplant	41,001 (4.3%)	9,443 (4.9%)
Years on hemodialysis at time of procedure[a]	3.3 (1.6-5.8)	3.3 (1.7-5.6)
Medicare/Medicaid dual eligible	445,507 (46.7%)	87,918 (45.5%)
Myocardial infarction	271,240 (28.4%)	57,424 (29.7%)
Congestive heart failure	524,574 (55.0%)	108,229 (56.0%)
Peripheral vascular disease	528,200 (55.3%)	111,804 (57.8%)
Cerebrovascular disease	381,932 (40.0%)	78,912 (40.8%)
Dementia	66,899 (7.0%)	14,041 (7.3%)
Chronic pulmonary disease	408,913 (42.8%)	82,539 (42.7%)
Connective tissue disease-rheumatic disease	66,493 (7.0%)	13,054 (6.8%)
Peptic ulcer disease	93,488 (9.8%)	19,673 (10.2%)
Mild liver disease	255,720 (26.8%)	52,140 (27.0%)
Diabetes without complications	589,580 (61.8%)	125,345 (64.9%)
Diabetes with complications	555,244 (58.2%)	120,259 (62.2%)
Paraplegia and hemiplegia	62,526 (6.6%)	13,865 (7.2%)
Cancer	144,335 (15.1%)	28,204 (14.6%)
Moderate or severe liver disease	32,734 (3.4%)	6,624 (3.4%)
Metastatic carcinoma	26,142 (2.7%)	5,050 (2.6%)
AIDS/HIV	16,042 (1.7%)	3,115 (1.6%)
Charlson Comorbidity Index	8.0 (2.0-10.0)	8.0 (2.0-10.0)
Procedure Characteristics		
RVU	8.5 (2.7-12.0)	3.4 (1.4-8.5)
Procedure organ system		
Cardiovascular	357,747 (37.5%)	37,622 (19.5%)
ENT and dental	2,392 (0.3%)	341 (0.2%)
Endocrine	7,578 (0.8%)	377 (0.2%)
Eye	335,971 (35.2%)	89,496 (46.3%)
Gastrointestinal and abdominal	39,911 (4.2%)	3,316 (1.7%)
Hematologic	799 (0.1%)	118 (0.1%)
Nervous system	7,696 (0.8%)	1,339 (0.7%)
Obstetric and gynecologic	1,799 (0.2%)	161 (0.1%)
Orthopedic	42,159 (4.4%)	7,521 (3.9%)
Skin and breast	134,908 (14.1%)	49,567 (25.6%)
Thoracic	1,529 (0.2%)	99 (0.1%)
Urologic	22,080 (2.3%)	3,320 (1.7%)
Facility Characteristics		
Procedure facility type		
Office	315,731 (33.1%)	87,700 (45.4%)
Home	2,243 (0.2%)	1,169 (0.6%)
Inpatient Hospital	93,391 (9.8%)	8,777 (4.5%)
Outpatient Hospital	431,207 (45.2%)	62,806 (32.5%)
Ambulatory Surgery Center	90,432 (9.5%)	20,965 (10.8%)

Characteristic	No Additional Hemodialysis (n= 954,569)	Additional Hemodialysis (n= 193,277)
Skilled Nursing Facility	15,038 (1.6%)	10,009 (5.2%)
Other	6,527 (0.7%)	1,851 (1.0%)
For-profit facility	833,206 (88.1%)	166,919 (87.2%)

Data are presented as n (%) or median (IQR).

[a] Missing data not shown.

eTable 7. Primary Outcome Model—Alternative Reference Levels for Same-Day Hemodialysis Subgroup Analysis

Reference Level	Adjusted Hazard Ratio (95% CI)	P Value	P Value for Interaction
1-day dialysis-to-procedure interval, no same-day hemodialysis			
1-day dialysis-to-procedure interval			
No same-day hemodialysis	Reference		
Same-day hemodialysis	1.18 (.98-1.42)	0.086	
2-day dialysis-to-procedure interval			
No same-day hemodialysis	1.14 (1.10-1.18)	< .001	0.004
Same-day hemodialysis	1.01 (.97-1.05)	0.629	
3-day dialysis-to-procedure interval			
No same-day hemodialysis	1.28 (1.21-1.35)	< .001	0.001
Same-day hemodialysis	1.07 (1.01-1.12)	0.017	
1-day dialysis-to-procedure interval with or without same-day dialysis			
1-day dialysis-to-procedure interval			
No same-day hemodialysis	Reference		
Same-day hemodialysis	Reference		
2-day dialysis-to-procedure interval			
No same-day hemodialysis[a]	1.14 (1.10-1.18)	< .001	0.004
Same-day hemodialysis[b]	0.86 (.71-1.04)	0.113	
3-day dialysis-to-procedure interval			
No same-day hemodialysis[a]	1.28 (1.21-1.35)	< .001	0.001
Same-day hemodialysis[b]	0.90 (.74-1.10)	0.308	

[a] Reference is a 1-day procedure-to-dialysis interval without same-day hemodialysis.
[b] Reference is a 1-day procedure-to-dialysis interval with same-day hemodialysis.
HR, hazard ratio; CI, confidence interval

eTable 8. Post Hoc Secondary Outcome and Subdistribution Hazard Models[a]

	Days Between Last Hemodialysis and Procedure			
	2 days (versus 1 day)		3 days (versus 1 day)	
	HR (95% CI)	P value	HR (95% CI)	P value
Post Hoc Secondary Outcomes				
90-day mortality due to stroke	0.89 (0.69-1.15)	0.364	1.17 (0.83-1.63)	0.375
90-day mortality due to sepsis	1.12 (0.98-1.27)	0.099	1.13 (0.94-1.36)	0.196
90-day mortality due to other infectious causes[b]	1.05 (0.83-1.33)	0.677	1.12 (0.79-1.58)	0.528
90-day mortality due to withdrawal of care	1.26 (1.14-1.39)	< .001	1.42 (1.23-1.64)	< .001
90-day readmissions due to infectious causes	1.01 (0.98-1.04)	0.53	0.99 (0.95-1.03)	0.559
Subdistribution hazard models[c]				
90-day cardiovascular mortality	1.07 (1.01-1.13)	0.015	1.14 (1.06-1.23)	0.001
90-day re-admissions	1.08 (1.06-1.09)	< .001	1.13 (1.11-1.15)	< .001
90-day cardiovascular re-admissions	1.00 (0.98-1.03)	0.691	0.98 (0.95-1.02)	0.31

[a] All models include full sample (N = 1,147,846).
[b] Other infectious causes include infections without evidence of sepsis such as peritonitis, central nervous system infections, endocarditis, hepatitis, pneumonia, pyelonephritis, and urinary tract infections.
[c] Subdistribution hazard ratios are displayed.
HR, hazard ratio; CI, confidence interval.

eTable 9. Sensitivity Analyses—Association Between Days Between Last Hemodialysis and Procedure and 90-Day Postoperative Mortality

	Days Between Last Hemodialysis and Procedure			
	2 days (versus 1 day)		3 days (versus 1 day)	
	HR (95% CI)	P value	HR (95% CI)	P value
Study population subgroups[a]				
Expanded population (weekend and prior ED/hospital visits included)[b]	1.18 (1.15-1.22)	< .001	1.31 (1.25-1.36)	< .001
Procedures without preoperative hemodialysis schedule changes[c]	1.12 (1.08-1.17)	< .001	1.22 (1.14-1.30)	< .001
Procedures with preoperative hemodialysis schedule changes[d]	1.22 (1.12-1.33)	< .001	1.23 (1.12-1.35)	< .001
First procedure per patient only, no censoring for subsequent procedures[e]	1.16 (1.10-1.23)	< .001	1.24 (1.15-1.35)	< .001
Outpatient facility, no same-day hemodialysis[f]	1.17 (1.11-1.23)	< .001	1.34 (1.25-1.43)	< .001
Inpatient facility[g]	1.16 (1.09-1.24)	< .001	1.20 (1.10-1.32)	< .001
Inpatient facility, same-day dialysis subgroup analysis[h]				
With same-day dialysis	1.04 (0.95-1.13)	0.375	1.04 (0.95-1.13)	0.763
Without same-day dialysis	1.15 (1.07-1.24)	< .001	1.24 (1.13-1.37)	< .001
Monday-Wednesday-Friday patients[i]	1.18 (1.10-1.26)	< .001	1.30 (1.19-1.42)	< .001
Tuesday-Thursday-Saturday patients[j]	1.28 (1.15-1.42)	< .001	1.27 (1.16-1.40)	< .001
Procedural risk adjustment				
High-volume proceduralists, random effect for proceduralist[a,k]	1.17 (1.06-1.28)	0.001	1.26 (1.11-1.44)	0.001
Full sample, adjusted for individual CCS categories[l]	1.11 (1.07-1.15)	< .001	1.18 (1.12-1.24)	< .001
Common surgical procedures subgroup, adjusted for individual surgical procedure[a,m]	1.19 (1.09-1.30)	< .001	1.20 (1.05-1.38)	0.007
Follow-up period				
1 day	1.67 (1.33-2.10)	< .001	2.02 (1.51-2.70)	< .001
7 days	1.31 (1.17-1.45)	< .001	1.57 (1.36-1.82)	< .001
14 days	1.25 (1.16-1.36)	< .001	1.47 (1.32-1.65)	< .001
30 days	1.21 (1.15-1.29)	< .001	1.42 (1.31-1.54)	< .001
60 days	1.18 (1.13-1.23)	< .001	1.27 (1.19-1.35)	< .001
90 days (primary model)	1.14 (1.10-1.18)	< .001	1.25 (1.18-1.30)	< .001
180 days	1.14 (1.11-1.17)	< .001	1.22 (1.17-1.26)	< .001
365 days	1.12 (1.10-1.14)	< .001	1.18 (1.15-1.22)	< .001
Alternative model specifications				
Primary model, hemodialysis schedule variable removed	1.14 (1.10-1.18)	< .001	1.25 (1.19-1.31)	< .001
Primary model, procedure day of the week variable removed	1.09 (1.06-1.12)	< .001	1.17 (1.12-1.22)	< .001

	Days Between Last Hemodialysis and Procedure			
	2 days (versus 1 day)		3 days (versus 1 day)	
	HR (95% CI)	P value	HR (95% CI)	P value
Propensity score overlap-weighted models				
Multinomial logistic regression				
Including all primary model covariates	1.09 (0.99-1.21)	0.073	1.22 (1.12-1.32)	< .001
Excluding same-day hemodialysis as a covariate	1.16 (1.08-1.24)	0.006	1.25 (1.16-1.35)	< .001
Including interaction terms[n]	1.09 (0.98-1.20)	0.125	1.26 (1.13-1.40)	< .001
Random forest				
Including all model covariates	1.10 (1.03-1.17)	0.005	1.18 (1.09-1.27)	< .001
Excluding same-day hemodialysis as a covariate	1.14 (1.07-1.20)	< .001	1.21 (1.12-1.30)	< .001

[a] Models presented here are restrictive subgroup analyses, in which the primary model specification was run on either an expanded or restricted study population without a specific test for interaction. The size of the study population is noted in a footnote for each model.
[b] n = 1,248,849.
[c] n = 1,002,173.
[d] n = 145,673.
[e] n = 346,828.
[f] n = 837,370.
[g] n = 139,005.
[h] n = 139,005. The study population was restricted to inpatient procedures and then the model specification for "Examining Heterogeneity by Same Day Dialysis" as described in eMethods was used.
[i] n = 717,958.
[j] n = 429,888.
[k] n = 201,090.
[l] n = 1,147,846 (primary study population).
[m] n = 76,992. See eTable 2 for the list of procedures.
[n] The model to estimate the propensity score contained multiplicative interaction terms between day of the week, dialysis schedule, same-day hemodialysis, and vascular access type.
HR, hazard ratio; CI, confidence interval; CCS, Clinical Classification Software.

eTable 10. Secondary Outcome Models—Alternative Reference Levels for Same-Day Hemodialysis Subgroup Analysis[a]

Secondary Outcome	Adjusted Hazard Ratio (95% CI)	P Value	P Value for Interaction
90-day cardiovascular mortality			
1-day dialysis-to-procedure interval	Reference		
2-day dialysis-to-procedure interval			
No same-day hemodialysis	1.08 (1.01-1.14)	0.015	0.003
Same-day hemodialysis	0.95 (0.89-1.01)	0.127	
3-day dialysis-to-procedure interval			
No same-day hemodialysis	1.14 (1.04-1.24)	0.003	0.049
Same-day hemodialysis	1.03 (0.95-1.10)	0.499	
90-day re-admissions			
1-day dialysis-to-procedure interval	Reference		
2-day dialysis-to-procedure interval			
No same-day hemodialysis	1.07 (1.06-1.09)	< .001	< .001
Same-day hemodialysis	1.03 (1.01-1.05)	0.001	
3-day dialysis-to-procedure interval			
No same-day hemodialysis	1.16 (1.14-1.19)	< .001	< .001
Same-day hemodialysis	1.07 (1.04-1.09)	< .001	
90-day cardiovascular re-admissions			
1-day dialysis-to-procedure interval	Reference		
2-day dialysis-to-procedure interval			
No same-day hemodialysis	1.01 (.98-1.04)	0.634	0.768
Same-day hemodialysis	1.01 (.98-1.05)	0.443	
3-day dialysis-to-procedure interval			
No same-day hemodialysis	.99 (.95-1.04)	0.757	0.839
Same-day hemodialysis	.99 (.95-1.03)	0.577	

[a] Similar to the primary same-day hemodialysis subgroup analysis (Figure 4, eMethods), the one-day interval (with and without same-day dialysis) serves as a single reference category because fewer than 0.5% of patients on a one-day interval received same-day dialysis.
HR, hazard ratio; CI, confidence interval

eMethods

Identification of Outpatient Hemodialysis Claims
Outpatient hemodialysis claims were identified using Revenue Center Code 0821 in outpatient facility claims with a type of bill "72."

Covariates

The Quan modification of the Charlson comorbidities and comorbidity index were determined for all inpatient, outpatient, and physician/supplier claims that occurred prior to the surgical procedure to identify patients' comorbidities at the time of the procedure.[2] The patient zip code (from the dialysis facility for the week or, if this was missing, from the CMS Medical Evidence Report Form) was cross-referenced with the United States Census Bureau American Community Survey 2018 Income Tables to estimate the median income for the zip code.[3]

Secondary Outcomes
Cardiovascular mortality and readmission due to circulatory causes were both defined using algorithms used in the 2020 USRDS Annual Data Report. Cardiovascular mortality was defined using specific cause of death codes from the DEATH file within the USRDS. These death codes come from mandatory forms (CMS-2746: ESRD Death Notification) submitted to Medicare. Readmission due to circulatory causes was defined using the ICD-9 and ICD-10 diagnosis codes listed in the 2020 USRDS Data Annual Report.

Model Specifications

Primary Model

For our primary analysis, we estimated a Cox proportional hazards model for mortality. Specifically, we estimated the following regression for procedure i:

$$h_i(t) = h_0(t) \cdot \exp\left(\sum_{d=2}^{3} Interval_{d,i} \cdot \delta_d + SameDay_i \cdot \theta + X_i \cdot B\right)$$

Where the hazard rate for procedure i is $h_i(t)$, the baseline hazard rate $h_0(t)$, $Interval_{d,i}$ is an indicator variable for whether the dialysis-procedure interval was d days, $SameDay_i$ is an indicator for whether the patient received a same-day dialysis session, X_i is a vector of confounders, and (δ_d, θ, B) is a vector of coefficients.

Examining Heterogeneity by Same-Day Dialysis

We next examined whether a dialysis session performed on the day of the procedure ("same-day dialysis") was associated with lower risk of postoperative mortality in procedures with a 2- or 3-day dialysis-to-procedure interval. We did so by separating patients into five categories: (i) a 1-day interval (this was the reference category); (ii) a 2-day interval without same-day dialysis; (iii) a 2-day interval with same-day dialysis; (iv) a 3-day interval without same-day dialysis; and (v) a 3-day interval with same-day dialysis. We kept the 1-day interval (with and without same-day dialysis) as a single category because fewer than 0.5% of patients on a 1-day interval received same day dialysis. To examine whether same-day dialysis was associated with heterogeneity within the same 2- or 3-day interval, we compared (ii) to (iii) and (iv) to (v), which is analogous to an interaction subgroup analysis. More formally, we estimated the following regression:

$$h_i(t) = h_0(t) \cdot \exp\left(\sum_{d=2}^{3} Interval_{d,i} \cdot \delta_d + \sum_{d=2}^{3} Interval_{d,i} \cdot SameDay_i \cdot \theta_d + X_i \cdot B\right)$$

which is analogous to the primary model except we now incorporate an interaction term between the presence of same-day dialysis and a 2- or 3-day interval. Now the vector of estimated coefficients is (δ_d, θ_d, B). We exclude an indicator variable for same-day dialysis because we combined the 1-day interval (with and without same-day dialysis) into a single reference group.

To estimate the hazard ratio of each subgroup, we take the linear combination of coefficients, using the delta method for standard errors. For instance, the hazard ratio of a 2-day interval with same-day dialysis (compared to the reference of a 1-day interval) is $\exp(\delta_2 + \theta_2)$. To examine whether there is heterogeneity by the presence of same-day dialysis (e.g., whether mortality differed between patients with a 2-day interval *with* same-day dialysis versus *without* same-day dialysis), we examined the p-values on θ_d.

In sensitivity analysis, we included a separate indicator variable for same-day dialysis in addition to the interaction term, which shifts the reference group to patients with a 1-day interval with and without same-day dialysis:

$$h_i(t) = h_0(t) \cdot \exp\left(\sum_{d=2}^{3} Interval_{d,i} \cdot \delta_d + SameDay_i \cdot \theta_1 + \sum_{d=2}^{3} Interval_{d,i} \cdot SameDay_i \cdot \theta_d + X_i \cdot B\right)$$

<u>Subgroup Analysis</u>

We performed subgroup analyses by incorporating an interaction term for the subgroup of interest with the dialysis interval. Specifically, we estimated the following regression:

$$h_i(t) = h_0(t) \cdot \exp\left(\sum_{d=2}^{3} Interval_{d,i} \cdot \delta_d + Subgroup_i \cdot \varphi_1 + \sum_{d=2}^{3} Interval_{d,i} \cdot Subgroup_i \cdot \varphi_d + SameDay_i \cdot \theta + X_i \cdot B\right)$$

To estimate hazard ratios for a specific subgroup, we exponentiated the sum of the relevant coefficients (e.g., the estimate for a 2-day interval is $\exp(\delta_2 + \varphi_2)$ and the p-value for interaction is the p-value on φ_2.

We also performed several restrictive subgroup analyses in which the primary model specification was used on a different study population. These are noted and presented in eTable 9.

<u>Absolute Risk Calculations</u>

We estimated the absolute risk difference of each outcome associated with a change in the dialysis-to-procedure interval. We did so by first estimating the baseline survivor function as a post-estimation procedure following the Cox model (in Stata, this is performed using the post-estimation command "predict" with the "basesurv" option). The post-estimation procedure operationalizes equation 4.34 from Kalbfleisch et al.[4] From here, we estimate the predicted probability of survival at 90 days for each patient under counterfactual scenarios, assuming the patient had a 1-, 2-, or 3-day intervals. For instance, the predicted survival for patient i assuming a 2-day interval is:

$$S_i(90|d = 2) = S_0(90)^{\exp(\delta_2 + SameDay_i \cdot \theta + X_i \cdot B)}$$

The mean difference across all patients is the absolute risk difference. To conduct statistical inference, we conducted a non-parametric bootstrap, where we sampled with replacement a total of 250 samples, with 50 from each multiply imputed dataset.

<u>Propensity Score Overlap-Weighted Models</u>

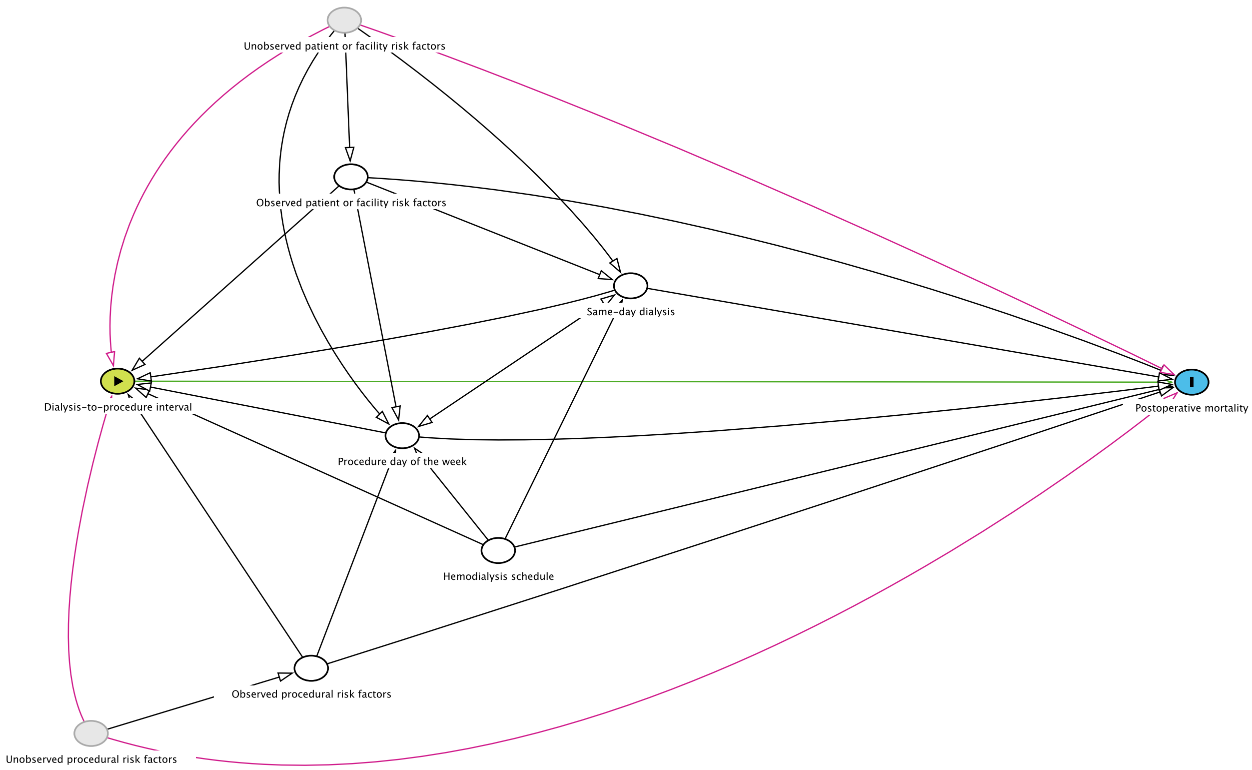
We fitted an overlap-weighted Cox proportional hazards model for the primary outcome. Unlike inverse probability treatment weighting, overlap weighting assigns lower weights to outliers that can bias results.[5] A multinomial logistic regression was used to estimate the propensity score for number of days between last dialysis and procedure for each imputed dataset. Absolute standardized differences were computed for each covariate in the matched sample to assess balance; an absolute standardized difference < .10 was considered acceptable. A doubly robust method using a Cox proportional hazards model containing all primary model covariates and estimated propensity scores was then used to evaluate the association between the dialysis-to-procedure interval and postoperative mortality within each imputed dataset. Estimates were then combined using standard rules from Rubin.

Despite use of overlap-weighting, persistent or exaggerated imbalance was noted across several variables (eFigure 4). Based on examination of the underlying data, we hypothesized that multiple variables including procedure day of the week, additional same-day dialysis sessions, and hemodialysis schedule were related to each other and the dialysis-to-procedure interval in a nonlinear manner. Several exploratory models were used to estimate propensity scores for the dialysis-to-procedure interval: (a) a multinomial logistic regression with multiple interaction terms, (2) a probability forest grown using a random forest algorithm,[6] and (3) all propensity score estimation models were re-fit without additional same-day hemodialysis as a predictor as this variable was felt to be endogenous to the prediction of the dialysis-to-procedure interval. For the random forest algorithm, the minimum node size was 10, unlimited tree depth was allowed, and the Gini index was used as the splitting rule for classification.

Absolute standardized mean differences for adjusted and unadjusted models are shown in eFigure 4. As a propensity score was estimated for a multicategory treatment variable (dialysis-to-procedure interval), the maximum absolute standardized mean difference across treatment levels was calculated for each model characteristic. Absolute standardized mean differences were calculated using the average of standard deviations across all treatment groups and imputed data sets.

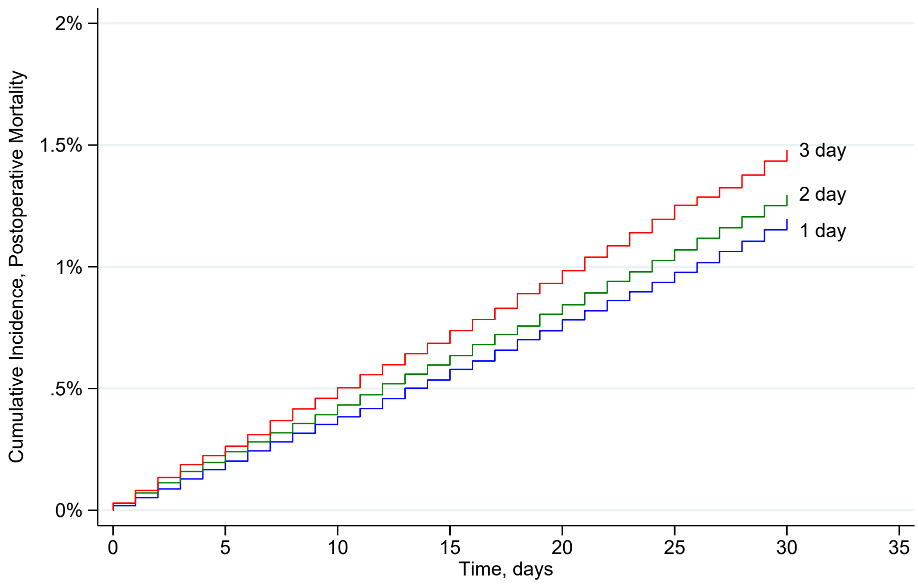
Balance across most covariates improved with random forest propensity score models, although imbalance persisted for procedure day of the week, hemodialysis schedule, additional same-day dialysis, vascular access type, and procedure organ systems categories. All overlap-weighted proportional hazards models were doubly robust and contained these variables as covariates. All models showed consistent evidence of an association between a 3-day dialysis-to-procedure interval and increased hazard of 90-day mortality (eTable 9). Random forest models with better balance across all primary model covariates also showed evidence of an association between a 2-day dialysis-to-procedure interval and increased hazard of 90-day mortality.

eFigure 1. Directed Acyclic Graph of Hypothesized Relationships Between Key Model Variables



This directed acyclic graph depicts hypothesized relationships between key model variables. Groups of variables have been condensed into larger categories in order to facilitate readability. The green circle represents the primary exposure. The blue circle represents the primary outcome. White circles represent adjusted variables. Gray circles represent unobserved (ie, latent) variables. Black and green lines represent causal paths, and pink lines represent biasing paths. Observed patient or facility risk factors included: age, sex, race and ethnicity, cause of end-stage kidney disease, vascular access type, median household income for patient zip code, listed for kidney transplant, years on hemodialysis at time of procedure, prior procedure within 30 days, Medicare/Medicaid dual eligibility, Charlson comorbidities, facility type, and facility profit orientation. Observed procedural risk factors included: procedure relative value units and procedure organ system. Graph created using DAGitty software.[7]

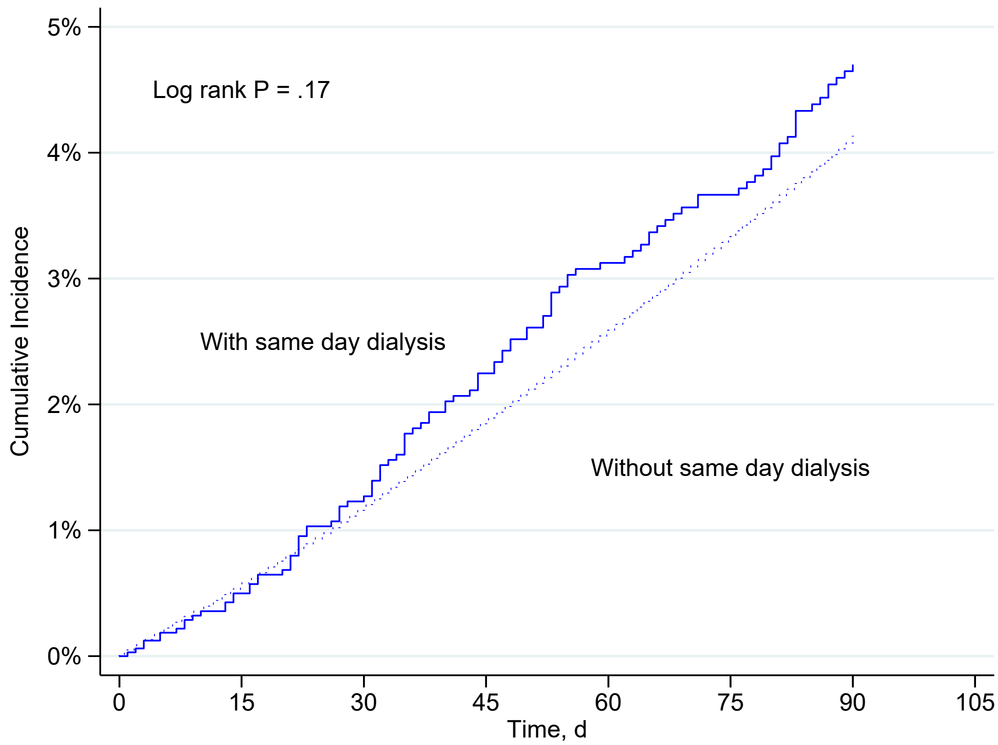
eFigure 2. Cumulative Incidence of 30-Day Postoperative Mortality[a]



No. at risk	0	5	10	15	20	25	30
1 day	750163	738353	677720	642682	631065	609315	579332
2 days	285939	278550	253494	239335	233878	225583	214256
3 days	111744	107961	97123	91750	89212	85533	81759

[a] Median follow up time was 30 days (interquartile range 30-30 days). Log rank for 1-day interval versus 2-day interval p < .001. Log rank for 1-day interval versus 3-day interval p < .001. Log rank for 2-day interval versus 3-day interval p < .001.

eFigure 3. Ninety-Day Postoperative Mortality With and Without an Additional Same-Day Dialysis Session for Patients with 1 Day Between Last Hemodialysis and Surgery[a]



No. at risk							
With same day dialysis	746840	639982	576927	516934	479290	449366	424979
Without same day dialysis	3323	2700	2405	2173	2026	1904	1804

[a] See eTable 7 for a multivariable model evaluating the association between same-day hemodialysis and postoperative mortality for procedures preceded by a 1-day dialysis-to-procedure interval. Median follow up time was 90 days (interquartile range 35-90 days).

eFigure 4. Love Plots for Unadjusted and Overlap-Weighted Models

A. Love Plot Comparing Multinomial Logistic Propensity Score Models With and Without Interaction Terms[a]

[a] The interaction term model to estimate the propensity score contained multiplicative interaction terms between day of the week, dialysis schedule, same-day hemodialysis, and vascular access type.

B. Love Plot Comparing Multinomial Logistic Propensity Score Models With and Without Same-Day Hemodialysis as a Propensity Score Model Covariate

C. Love Plot Comparing Multinomial Logistic and Random Forest Propensity Score Models

D. Love Plot Comparing Random Forest Propensity Score Models With and Without Same-Day Hemodialysis as a Propensity Score Model Covariate

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