Supplementary Online Content

Nguyen OK, Vazquez MA, Charles L, et al. Association of Scheduled vs Emergency Dialysis With Health Outcomes and Costs in Undocumented Immigrants With End-Stage Renal Disease. Published online December 21, 2018. *JAMA Intern Med*. doi:10.1001/jamainternmed.2018.5866

eMethods: Approach for Cost Analysis

Cost Analysis Inputs

To compare overall costs of care between patients in the scheduled vs. emergency-only dialysis groups, we considered costs related to 1) hospitalizations and observation stays, 2) emergency department visits, 3) scheduled dialysis, and 4) vascular access placement and associated vascular access complications. We defined costs using the average Medicare reimbursement rate in 2015 for encounters and procedures as per eTable 1. Across all settings, we did not include physician professional fees, pharmaceutical costs, or other outpatient costs not otherwise specified. However, these are not major drivers of costs and likely would not be different between groups since both groups were already highly engaged with the healthcare system.[1] Healthcare utilization and presence of vascular access were obtained directly from our source data as described in the Methods section of the manuscript.

For costs associated with outpatient dialysis, we assumed 100% adherence to thrice-weekly hemodialysis since we did not have outpatient claims data for individuals enrolled in scheduled dialysis. We adjusted the base payment rate for scheduled dialysis using adult case-mix adjusters as listed in eTable 1. We included costs associated with establishing vascular access for patients in both groups who had newly placed arteriovenous fistulae (AVF; n=57) or arteriovenous grafts (AVG; n=9) during the 12-month follow-up time period.

Estimating Costs Due to Vascular Access Complications

'Best-Case' vs. 'Worst-Case' Scenarios: Vascular access complications are an important cost driver in dialysis care, and many vascular access complications are treated in outpatient settings.[2,3] Because we did not have outpatient claims data for the scheduled dialysis group, we estimated a range of costs based on high (worst-case) vs. low (best-case) vascular complication rates for individuals with either existing or newly placed arteriovenous access according to the published literature. For the worst-case scenario, we used complication rates observed during the first year after initial AVF placement in a cohort of older Medicare beneficiaries.[4] The per-person-per-year rates for the worst-case scenario are shown in eTable 1. For the best-case scenario, we used complication rates observed in the late dialysis initiation arm of a randomized controlled trial of early vs late dialysis initiation,[5] which included a need for access revision at a rate of 0.124 events per-person-per-year, placement of a temporary tunneled catheter placement at a rate of 0.097 events per-person-per-year, and vascular access related infections treated as an outpatient at a rate of 0.035 events per-person-per-year. Since specific procedure types for access revision were not explicitly delineated in the trial, we applied costs for the most expensive access revision procedure, which was stent placement in an AVF at $9,627.86 per event. Under both scenarios, we rescaled the per-person-per-year complication rates to the actual duration of time observed for each patient during the follow-up period. Given the low number of AVGs in our cohort, we assumed one-year complication rates equivalent to those for AVF. For both scenarios, we did not impute complication rates for central venous catheters since these typically result in hospitalization.

Assumptions for Vascular Access Complication Rates: For costs related to vascular access complications, we made several assumptions that could lead to underestimates of cost differences between groups (i.e. bias to the null) by systematically overestimating costs in the scheduled dialysis group and/or underestimating costs in the emergency-only group. The net result would bias our difference-in-differences (DiD) estimate towards zero. The first assumption that could underestimate costs in the emergency-only group was that all costs associated with vascular access complications among individuals in the emergency-only group were already captured in our inpatient, observation, and emergency department visit costs – that is, we did not apply the vascular complication rates discussed above to the emergency-only group. This would result in an underestimate of complication costs if individuals in the emergency-only group also received non-emergent procedures as outpatients, which is plausible in our health system. The second assumption we made was to apply vascular access complication rates to individuals in the scheduled dialysis group uniformly across the follow-up period even though there was a lag of several months for most individuals between enrollment and vascular access creation. This was a necessary assumption because we did not know the exact dates of vascular access creation, but this means that our estimated AVF complication rates are higher than the actual rates for the scheduled group under both best and worst-case scenarios, resulting in a net overestimate of expected costs for this group. Finally, for vascular complications where there were multiple potential treatment options, we applied the cost for the most expensive treatment option. This could overestimate expected costs for the scheduled dialysis group. The net effect of these three assumptions would be a differential overestimate of vascular access complications and associated costs in the scheduled group in the follow-up period compared to the emergency-only group, which consequently would bias our cost-analysis to finding that differences in the changes in costs of care between groups would be closer to zero (i.e., bias towards finding no difference in costs).

Statistical Analyses for Cost Comparisons

We compared costs between individuals enrolled in scheduled dialysis to those remaining on emergency-only dialysis using a regression-adjusted difference-in-differences approach. We estimated costs for each group in the baseline and post-periods using a generalized linear model (GLM) with a log link function assuming a gamma distribution. A GLM is preferred over a log-linear model to deal with skewed expenditures and avoid transformation/re-transformation biases. Thus, this analytic approach uses the scheduled dialysis group's baseline period as its own historical control, and changes in the emergency-only group as a concurrent control to account for potential secular trends in costs. Our model therefore included time period (baseline versus follow-up), group assignment (scheduled vs. emergency-only), and the interaction between them as predictors, where the coefficient on the interaction was the difference-in-differences term and the primary predictor of interest.

In adjusted analyses, we also included a term for the propensity score to be enrolled in scheduled dialysis (see Methods in manuscript, eTable 2 and eFigure 1). For each individual, costs were averaged and scaled to 30-day increments. We conducted sensitivity analyses using ordinary least squares linear regression models and our findings were qualitatively similar.

We computed marginal effects after model estimation to generate predicted mean per-person per-month expenditures for each period for both groups. We also calculated contrasts for the first differences and the differences-in-differences and robust standard errors using the delta method. All the tests were two-sided, and we considered a P value $\leq$0.05 to indicate a statistically significant difference. All the analyses were performed with Stata 12.0 (StataCorp, College Station, Texas).

eTable 1. Inputs for Cost Analyses

Cost Type	Occurrence	Payment, Method, and Source
Hospitalizations	As observed in data	Average Medicare total payments for the MS-DRG in fiscal year 2015,[6] which includes the MS-DRG amount, teaching, disproportionate share, capital, and outlier payments for all cases. Also, included in the in total payments are co-payment and deductible amounts that the patient is responsible for and any additional payments by third parties for coordination of benefits.
Emergency Department Visits and Observation Stays	As observed in data	Sum of the CY 2015 final Medicare OPPS payment for all submitted APC & HCPCS claims eligible for reimbursement.[7] These include facility fees and separately billed procedures, tests, and medications, including provision of emergent hemodialysis (HCPCS G0257, $613.57).
Scheduled Dialysis	Assumed 100% adherence to thrice weekly dialysis for patients in the scheduled dialysis group during the follow-up period	The base rate of $239.43 under the CY 2015 ESRD PPS was adjusted using the following adult case-mix adjusters implemented in calendar year 2011: age, body surface area, underweight (BMI<18.5), and onset of dialysis.[8,9] Payments were not adjusted for hospital wage index or facility characteristics. Payment includes the 20% patient deductible.
Vascular Access Creation (AVF or AVG)	As observed in data	$3,220.68/event; HCPCS codes 36818-21, 36825, 36830 under CY15 final Medicare ASC rates
Vascular Access Complications[a]	Rates for worst-case scenario	
New surgical AVF for failed access	0.387 events per person year	$3,220.68/event; HCPCS codes 36818-21 under CY 2015 final Medicare ASC rates
AVG creation for failed access	0.113 events per person year	$3,220.68/event; HCPCS codes 36825, 36830 under CY 2015 final Medicare ASC rates
Revision of AVF	0.293 events per person year	$3,220.68/event; HCPCS codes 36832, 36833 under CY 2015 final Medicare ASC rates
Angioplasty	0.987 events per person year	$4,539.22/event; HCPCS codes 35475-76, 37224 under CY 2015 final Medicare ASC rates
Thrombectomy	0.193 events per person year	$4,539.22/event; HCPCS code 36870 under CY 2015 final Medicare ASC rates
Embolization/ligation	0.112 events per person year	$9,627.86/event; HCPCS code 37241 under CY 2015 final Medicare ASC rates
Stent placement	0.067 events per person year	$9,627.86/event; HCPCS codes 37236, 37238 under CY 2015 final Medicare ASC rates
Thrombolysis	0.013 events per person year	$195.20/event; HCPCS code 36593 under CY 2015 final Medicare ASC rates
Distal revascularization (DRIL)	0.020 events per person year	$3,220.86/event; HCPCS code 36838 under CY 2015 final Medicare ASC rates
Tunneled catheter placement	0.540 events per person year	$2,236.28/event; HCPCS codes 36558, 36565 under CY 2015 final Medicare ASC rates
Vascular access related infection treated as outpatient	0.860 events per person year	$1,612.58/event; average estimated Medicare payment for outpatient infections using Medicare Outpatient and Part B files for ICD-9-CM codes 996.62, 999.31, and 999.33.[4]

Abbreviations: APC, Ambulatory Payment Classification; ASC, Ambulatory Surgery Center; AVF, arteriovenous fistula; AVG, arteriovenous graft; BMI, body mass index; CY, calendar year; ESRD, end-stage renal disease; HCPCS, Healthcare Common Procedure Coding System; ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification; MS-DRG, Medicare Severity-Diagnosis Related Group; OPPS, Outpatient Prospective Payment System; PPS, Prospective Payment System

[a]Vascular access complication rates are shown for the worst-case scenario, using observed complication rates in a cohort of Medicare beneficiaries in the first year after AVF creation.[4] For the best-case scenario, we used complication rates observed in the late initiation of dialysis arm of the randomized controlled trial of early vs late dialysis initiation,[5] which included a need for access revision at a rate of 0.124 events per person year, placement of a temporary tunneled catheter placement at a rate of 0.097 events per person year, and vascular access related infections treated as an outpatient at a rate of 0.035 events per person year. Since the need for access revision was not further delineated in the trial, we applied the most expensive cost, which was $9,627.86 per event (the rate for stent placement of an AVF).

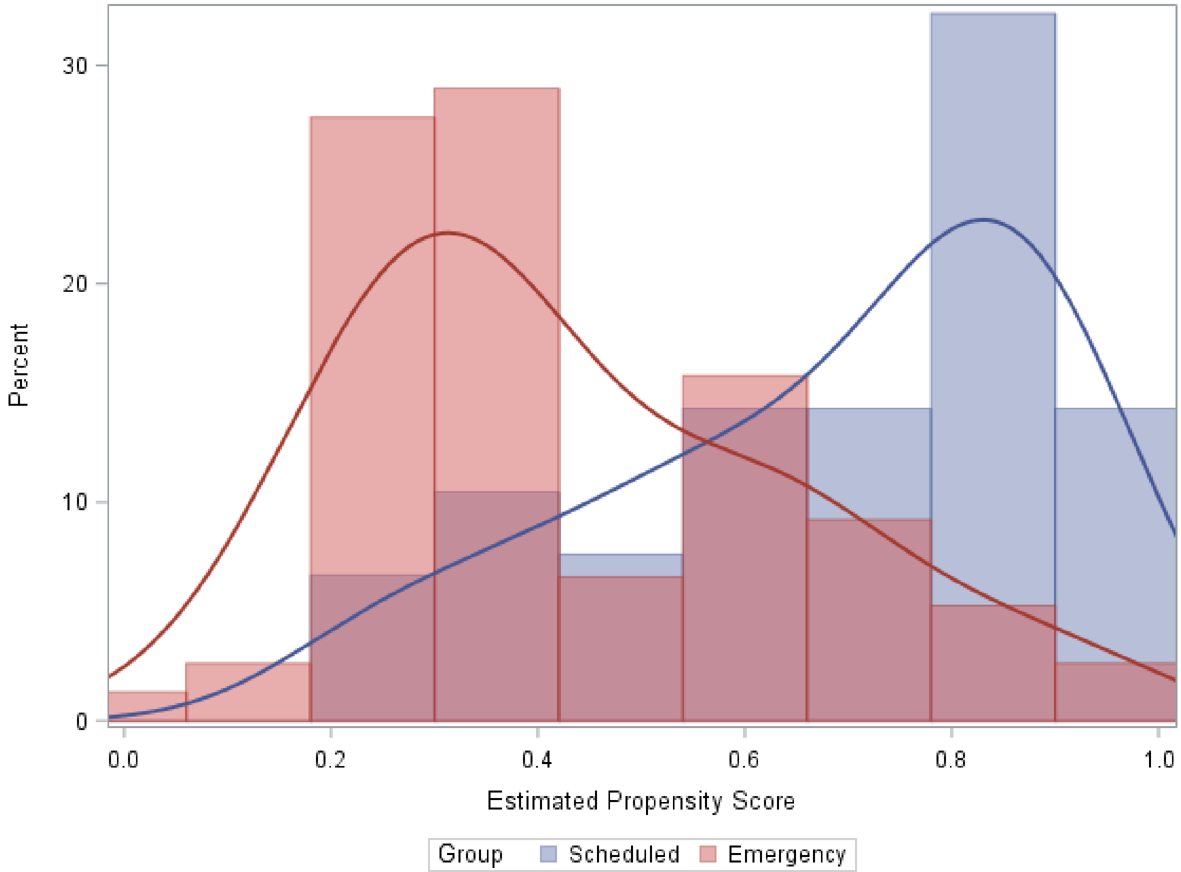
eTable 2. Predictors for Propensity Score Model[a]

Predictors	Adjusted OR (95% CI)	p-value
Male sex	0.87 (0.43-1.79)	0.13
Dialysis access at baseline		
Arteriovenous fistula/graft	[Reference]	
Central venous catheter	1.11 (0.38-3.24)	0.84
Age, per year	0.97 (0.95-1.000)	0.05
Dialysis vintage, per month	0.98 (0.97-0.999)	0.03
Serum albumin, per 1 g/dL	1.82 (0.90-3.68)	0.10
Baseline ED visits, per visit/month	1.55 (1.29-1.87)	<0.001
Baseline hospital days, per day/6 months	1.01 (0.99-1.02)	0.44

Abbreviations: CI, confidence interval; ED, emergency department; OR, odds ratio

[a] We estimated the propensity to receive scheduled dialysis using a logistic regression model including all predictors listed above. The model was well fit: C-statistic=0.79, Hosmer-Lemeshow goodness-of-fit p=0.49, McFadden's R^2=0.20, Wald chi-square=35.2, p<0.001, and likelihood ratio chi-square=49.4, p<0.001.

eFigure. Distribution of Propensity Scores by Group



For the emergency-only group, the median estimated propensity score was 0.38 (IQR, 0.26-0.59) and ranged from 0.04-0.97. For the scheduled dialysis group, the median estimated propensity score was 0.75 (IQR, 0.55-0.87) and ranged from 0.20-0.98.

eTable 3. Ten Most Common Principal Hospital Diagnoses

	Baseline Period	N=266	Follow-up Period	N=425
Emergency-Only Dialysis	Disorders of nutrition, metabolism, fluids, electrolytes w/ MCC	58 (21.8%)	Other circulatory system diagnoses w/ MCC	105 (24.7%)
	Other circulatory system diagnoses w/ MCC	57 (21.4%)	Disorders of nutrition, metabolism, fluids, electrolytes w/ MCC	61 (14.3%)
	Simple pneumonia & pleurisy w/ MCC	23 (8.6%)	Other vascular procedures w/ MCC	34 (8.0%)
	Renal failure w/ MCC	23 (8.6%)	Renal failure w/ MCC	26 (6.1%)
	Heart failure & shock w/ MCC	12 (4.5%)	Septicemia or severe sepsis w/o MV 96+ hours w/ MCC	26 (6.1%)
	Septicemia or severe sepsis w/o MV 96+ hours w/ MCC	9 (3.3%)	Pulmonary edema & respiratory failure	15 (3.5%)
	Cellulitis w/ MCC	7 (2.6%)	Simple pneumonia & pleurisy w/ MCC	14 (3.3%)
	Respiratory system diagnosis w/ MV 96+ hours	6 (2.2%)	Heart failure & shock w/ MCC	11 (2.6%)
	Major GI disorders & peritoneal infections w/ MCC	6 (2.2%)	Septicemia or severe sepsis w/ MV 96+ hours	11 (2.6%)
	Pulmonary edema & respiratory failure	4 (1.5%)	GI hemorrhage w/ MCC	10 (2.4%)
	Baseline Period	**N=391**	**Follow-up Period**	**N=242**
Scheduled Dialysis	Disorders of nutrition, metabolism, fluids, electrolytes w/ MCC	87 (22.3%)	Other circulatory system diagnoses w/ MCC	61 (25.2%)
	Other circulatory system diagnoses w/ MCC	61 (15.6%)	Disorders of nutrition, metabolism, fluids, electrolytes w/ MCC	21 (8.9%)
	Renal failure w/ MCC	60 (15.4%)	Other vascular procedures w/ MCC	16 (6.6%)
	Simple pneumonia & pleurisy w/ MCC	36 (9.2%)	Simple pneumonia & pleurisy w/ MCC	12 (5.0%)
	Septicemia or severe sepsis w/o MV 96+ hours w/ MCC	27 (6.9%)	Heart failure & shock w/ MCC	8 (3.3%)
	Signs & Symptoms w/ MCC	14 (3.6%)	GI hemorrhage w/ MCC	8 (3.3%)
	Cellulitis w/ MCC	10 (2.6%)	Chest pain	8 (3.3%)
	Respiratory system diagnosis w/ MV < 96 hours	7 (1.8%)	Renal failure w/ MCC	7 (2.9%)
	Heart failure & shock w/ MCC	6 (1.5%)	Cellulitis w/ MCC	7 (2.9%)
	Esophagitis, GI, & Misc Digestive Disorders w/ MCC	6 (1.5%)	Fever	6 (2.5%)

Abbreviations: GI, gastrointestinal; MCC, major complication or comorbidity; MV, mechanical ventilation

eTable 4. Effect of Scheduled Dialysis on Adjusted Costs by Health Service Type

	Emergency-Only Dialysis (n=76)			Scheduled Dialysis (n=105)			Difference-in-Differences (95% CI)[b]	p-value
Average costs per month	Baseline	Follow-Up	Net Change[a]	Baseline	Follow-Up	Net Change[a]		
Emergency department[c]	$5,673	$7,918	+$2,245	$5,467	$270	-$5,197	-$7,442 (-$13,876 to -$1,008)	0.02
Dialysis-related ED[c]	$5,562	$7,958	+$2,395	$5,259	$215	-$5,043	-$7,439 (-$15,346 to +$468)	0.07
Non-dialysis-related ED[c]	$229	$165	-$64	$219	$53	-$166	-$101 (-$210 to +$8)	0.07
Hospitalization[c]	$3,931	$4,051	+$120	$5,131	$2,064	-$3,066	-$3,186 (-$5,611 to -$761)	0.01
Scheduled hemodialysis[d]	$0	$0	$0	$0	$3,881	+$3,881	+$3,881	--
Vascular access and complications[d,e]								
Best-case scenario	$0	$27	+$27	$0	$156	+$156	+$129	<0.001
Worst-case scenario	$0	$27	+$27	$0	$565	+$565	+$538	<0.001

Abbreviations: CI, confidence interval; ED, emergency department; PPPM, per person per month

[a]Values may not equal the exact difference in baseline and follow-up values due to rounding.
[b]Difference-in-differences (DiD) calculated as difference in net change in scheduled dialysis group minus net change in emergency-only group.
[c]Adjusted for propensity of being enrolled in scheduled dialysis (age, sex, emergency dialysis vintage, baseline ED visits, baseline hospital days, baseline serum albumin, baseline vascular access type).
[d]Results shown are mean observed costs per person per month during the follow-up period only.
[e]In emergency-only dialysis group, costs estimated only for access creation (arteriovenous fistula) in 14 individuals. In scheduled dialysis group, costs estimated for both access creation and access complications. P-values shown are for Wilcoxon rank-sum test. Please see eMethods page ii for details on ‘best-case’ versus ‘worst-case’ scenarios.

eTable 5. Sensitivity Analysis: Effect of Scheduled Dialysis on Acute Health Care Utilization and Costs at 9 Months

Outcome	Emergency-Only Dialysis (n=76)			Scheduled Dialysis (n=105)			Difference-in-Differences (95% CI)[†]	p-value
	Baseline	Follow-Up	Net Change[*]	Baseline	Follow-Up	Net Change[*]		
Unadjusted average utilization rates								
ED visits per month	4.0	5.0	+1.0	6.3	0.2	-6.1	-7.2 (-7.9 to -6.5)	<0.001
Dialysis ED visits per month	3.5	4.7	+1.2	5.6	0.0	-5.5	-6.8 (-7.4 to -6.1)	<0.001
Non-dialysis ED visits per month	0.5	0.3	-0.2	0.8	0.2	-0.6	-0.4 (-0.6 to -0.2)	<0.001
Hospitalizations per 6 months	3.0	2.5	-0.5	3.0	1.0	-2.0	-1.6 (-2.3 to -0.8)	<0.001
Hospital days per 6 months	22.4	24.8	+2.3	14.8	6.7	-8.2	-10.6 (-18.5 to -2.7)	0.009
Adjusted average utilization rates[‡]								
ED visits per month	5.0	6.7	+1.7	5.3	0.2	-5.2	-6.9 (7.7 to -6.0)	<0.001
Dialysis ED visits per month	4.4	6.2	+1.8	4.8	0.0	-4.7	-6.5 (-7.3 to -5.8)	<0.001
Non-dialysis ED visits per month	0.6	0.4	-0.2	0.6	0.1	-0.5	-0.3 (-0.5 to -0.1)	0.006
Hospitalizations per 6 months	2.9	2.4	-0.5	3.1	1.0	-2.1	-1.6 (-2.4 to -0.9)	<0.001
Hospital days per 6 months	19.3	20.4	+1.1	16.6	7.9	-8.7	-9.9 (-17.2 to -2.4)	0.01
Costs: Best-case scenario								
Unadjusted costs PPPM	$8,317	$10,089	+$1,772	$11,223	$6,478	-$4,745	-$6,517 (-$9,020 to -$4,013)	<0.001
Adjusted costs PPPM[‡]	$8,735	$10,741	+$2,007	$10,768	$6,251	-$4,517	-$6,523 (-$9,153 to -$3,894)	<0.001
Costs: Worst-case scenario								
Unadjusted costs PPPM	$8,317	$10,089	+$1,772	$11,223	$6,856	-$4,367	-$6,138 (-$8,624 to -$3,653)	<0.001
Adjusted costs PPPM[‡]	$8,727	$10,729	+$2,003	$10,774	$6,621	-$4,153	-$6,155 (-$8,764 to -$3,546)	<0.001

Abbreviations: CI, confidence interval; ED, emergency department; PPPM, per person per month

[*]Values may not equal the exact difference in baseline and follow-up values due to rounding.
[†]Difference-in-differences (DiD) calculated as difference in net change in scheduled dialysis group minus net change in emergency-only group.
[‡]Adjusted for propensity of being enrolled in scheduled dialysis (age, sex, and emergency dialysis vintage, baseline serum albumin, baseline vascular access type.

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