



Standardized Transplantation Referral Ratio to Assess Performance of Transplant Referral among Dialysis Facilities

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Abstract

Background and objectives For patients with ESRD, referral from a dialysis facility to a transplant center for evaluation is an important step toward kidney transplantation. However, a standardized measure for assessing clinical performance of dialysis facilities transplant access is lacking. We describe methodology for a new dialysis facility measure: the Standardized Transplantation Referral Ratio.

Design, setting, participants, & measurements Transplant referral data from 8308 patients with incident ESRD within 249 dialysis facilities in the United States state of Georgia were linked with US Renal Data System data from January of 2008 to December of 2011, with follow-up through December of 2012. Facility-level expected referrals were computed from a two-stage Cox proportional hazards model after patient case mix risk adjustment including demographics and comorbidities. The Standardized Transplantation Referral Ratio (95% confidence interval) was calculated as a ratio of observed to expected referrals. Measure validity and reliability were assessed.

Results Over 2008–2011, facility Standardized Transplantation Referral Ratios in Georgia ranged from 0 to 4.87 (mean = 1.16, SD = 0.76). Most (77%) facilities had observed referrals as expected, whereas 11% and 12% had Standardized Transplantation Referral Ratios significantly greater than and less than expected, respectively. Age, race, sex, and comorbid conditions were significantly associated with the likelihood of referral, and they were included in risk adjustment for Standardized Transplantation Referral Ratio calculations. The Standardized Transplantation Referral Ratios were positively associated with evaluation, waitlisting, and transplantation ($r=0.46, 0.35, \text{ and } 0.20$, respectively; $P<0.01$). On average, approximately 33% of the variability in Standardized Transplantation Referral Ratios was attributed to between-facility variation, and 67% of the variability in Standardized Transplantation Referral Ratios was attributed to within-facility variation.

Conclusions The majority of observed variation in dialysis facility referral performance was due to characteristics within a dialysis facility rather than patient factors included in risk adjustment models. Our study shows a method for computing a facility-level standardized measure for transplant referral on the basis of a pilot sample of Georgia dialysis facilities that could be used to monitor transplant referral performance of dialysis facilities.

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Introduction

Although kidney transplantation is the optimal treatment for most of nearly 700,000 patients with ESRD in the United States, approximately 13% are waitlisted for transplantation, and of those, <20% get transplanted each year (1). Prior research has attributed poor access to kidney transplantation to gaps along the continuum of care for patients with ESRD (2,3). Although the effects of dialysis facility- and patient-level factors on waitlisting and transplantation have been studied (2–9), their effects on earlier steps, such as receiving education about the benefits of transplantation and referral from dialysis facilities to a transplant center for evaluation, have been understudied. With statewide data collection on transplant referral through the Southeastern Kidney Transplant

Coalition, we previously reported wide variation in facility referral for kidney transplantation in the state of Georgia, where some facilities referred no patients and others referred up to 76% of their patient population (3). This wide variation suggests a need to examine referral as a quality metric for dialysis facilities, because no dialysis facility-based quality metrics for transplant access currently exist.

The Centers for Medicare and Medicaid Services (CMS) plays a primary role in the development of new quality measures for dialysis facilities pertaining to their care of patients with ESRD. In 2015, the ESRD Access to Kidney Transplantation Technical Expert Panel identified several important quality gaps and considered development of several dialysis facility-level measures at the early steps, including transplant

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referral and waitlisting, for overall improved access (10). In addition, the kidney community has called for national collection of transplant referral data for use as a clinical measure to improve performance and equity in access to kidney transplantation (11,12).

Referral to a transplant center is an essential first step for patients to be considered candidates for kidney transplantation. Although national transplant referral data are unavailable, we recently collected patient referral data from all Georgia transplant centers as part of the Reducing Disparities in Access to Kidney Transplantation Community Study, and an extension of this data collection in other states is underway (13). The few studies that have examined transplant performance using transplant referral have used facility-level absolute referral rate to measure facility performance (3,14,15). In a recent study, we examined whether absolute facility referral was associated with other quality metrics within dialysis facilities and found that referral was not associated with other metrics, such as anemia management, morbidity, or mortality, and although referral was associated with waitlisting and transplantation, it was not entirely correspondent with these other measures of transplant access. These results suggest a need for a quality metric for transplant referral rather than waitlisting and transplantation, which may be more driven by organ supply or transplant center practices than dialysis facility attributes, whereas referral is more directly tied to the dialysis facility. Finally, because variation in referrals can be attributable to patient case mix within facilities, a risk-adjusted transplant referral measure is essential to effectively assess dialysis facility performance. The purpose of this study was to present a risk-adjusted quality metric, the Standardized Transplantation Referral Ratio (STReR), to evaluate dialysis facility performance in transplantation referrals relative to a regional average with similar patient case mix. We expect that this metric could be adapted in a larger, national population if national data on transplant referral are collected in the future.

Materials and Methods

Data Sources and Study Population

Patient-level data on transplant referrals between 2008 and 2012 were collected from all three transplant centers in the state of Georgia (Emory Transplant Center [Atlanta], Augusta University Medical Center [Augusta], and Piedmont Transplant Institute [Atlanta]) as previously described (3,16). ESRD Network 6 served as the data coordinating center and linked patient-level referral data with dialysis facility data by unique provider number.

To ensure complete patient follow-up and identify a cohort of nonreferred patients with ESRD in Georgia during the same time period, referral data were linked to the 2015 US Renal Data System (USRDS) standard analytic files, resulting in complete follow-up on patients with ESRD through December 31, 2012. The USRDS is a national surveillance data system that aggregates demographic, diagnosis, treatment, and facility information on nearly 2.5 million patients with ESRD from various data sources, including the Medical Evidence Report (CMS-2728), which is completed for all patients with ESRD at the start of ESRD, as well as United Network for Organ Sharing files on waitlisting and transplantation events.

Patients above 70 years old and those without an ESRD start date were excluded. Facilities with extremely low volumes can unduly influence the estimation of expected risk of referrals. Because the STReR provides little information about the underlying relative rates of these facilities, we limited our analysis to facilities with at least five incident patients per year. In sensitivity analyses, we calculated STReR for the 72 Georgia facilities excluded due to annual incidence of less than five.

Our final cohort included 8308 patients with incident ESRD receiving services at 249 Georgia facilities between January 1, 2008 and December 31, 2011 who were followed through December 31, 2012.

Study Variables

Analogous to existing CMS standardized quality measures (*e.g.*, Standardized Mortality Ratio and Standardized Hospitalization Ratio), the STReR measure compares the observed number of referrals among patients with incident ESRD within a facility (numerator) with an expected number of patients with ESRD in Georgia adjusted for the patient characteristics (case mix) in that facility (denominator).

Outcome Definition

The outcome for this measure is the risk-adjusted dialysis facility-level count of adult Georgia patients on dialysis referred for transplant evaluation to one of the three Georgia transplant centers.

Referral for kidney transplantation was defined as the date on which the transplant center received a transplant referral form from a dialysis facility or referring provider. Only a patient's first referral was counted in the event of multiple referrals.

The sample of patients with incident ESRD between January 1, 2008 and December 31, 2011 was followed for 1 year (last date of follow-up was December 31, 2012) or until their first referral, transplant, or death, whichever occurred first. Patients were assigned to a facility immediately after they started dialysis therapy at that facility. Facility transitions within the first year were accounted for to accurately calculate at-risk time of patients at each facility. For example, for a patient who received services at facility A for 8 months and then facility B for 4 months, the patient was considered to have an at-risk period of 0.67 years in facility A and 0.33 years in facility B.

Risk Adjustment Using Cox Proportional Hazards Model

To compute expected referrals at the facility level, we adjusted for risk factors of age, race, sex, body mass index (BMI), calendar year of incidence, and other comorbidities at ESRD start (*e.g.*, congestive heart failure, atherosclerotic heart disease, cardiovascular disease, peripheral vascular disease, chronic obstructive pulmonary disease, hypertension, diabetes, tobacco use, cancer, and nursing home status) in alignment with the CMS's existing dialysis facility measures of hospitalization and mortality.

A two-stage Cox proportional hazards model was used to compute the expected number of first year referrals at a facility (details are in Supplemental Material). The facility STReRs were obtained as a ratio of observed to expected referrals. Model fit was tested by comparing the risk-adjusted

Table 1. Referrals to kidney transplantation among Georgia patients on incident dialysis for data years 2008–2011

Incident Year	Dialysis Facilities	Patients on Dialysis	Transplant Referrals within 1 yr of ESRD Start	Crude Transplant Referral Proportion ^a
2008	177	2058	557	0.27
2009	194	2147	626	0.29
2010	189	2040	651	0.32
2011	200	2063	708	0.34
Total	249	8308	2542	0.31

^aThe crude referral proportion was defined as the total number of transplant referrals divided by the total number of patients with incident ESRD.

model with an unadjusted model using the Akaike information criterion (AIC).

STReR and 95% Confidence Intervals

By definition, an STReR value close to one indicates perfect agreement between observed referrals and those expected on the basis of facility case mix, whereas an STReR of less than one indicates that the facility's transplant referral rate is lower than expected. Because of low first year observed referrals (approximately 75% of facilities had <15 referrals), exact 95% confidence intervals (95% CIs) were calculated for observed referrals and divided by the expected referrals to obtain the exact 95% CI of STReR (17). Patients with missing data were not excluded from the STReR calculation. Around 3% of the patients ($n=257$) had missing BMI, and <1% ($n=32$) had missing comorbidities. No patients were missing age, race, sex, or date of first ESRD treatment. For the purposes of calculation, missing values of BMI were replaced with mean values for patients of similar age and identical race and sex. Indicator variables identifying patients with missing values for comorbidities were included as covariates in the model.

Reliability

The reliability of STReR was assessed using interunit reliability (IUR) (18). A higher IUR (close to one) indicated that the variation between the STReRs was due to real facility-level differences and was not driven by random noise.

Validity

To assess predictive validity of the metric, we examined how well the STReR predicted downstream kidney transplant outcomes. Of those referred, facility proportions of evaluation, waitlisting, and transplantation within 6, 12, and 24 months of referral, respectively, were computed. Associations with STReRs were examined using Spearman rank correlations.

Data management and statistical analyses were performed in STATA 14.2 and SAS 9.3. SAS code for the calculation of STReR is included in Supplemental Material.

Results

Study Population

The study population included 9067 adult patients with incident ESRD receiving services at 321 Georgia dialysis facilities between January 1, 2008 and December 31, 2011, with follow-up through December 31, 2012. Of those

facilities, 72 had fewer than five incident patients per year between 2008 and 2011 and were excluded from the analysis. Of the remaining 8308 incident patients in 249 facilities included in the final study population (Table 1), a total of 2542 (31%) had first referrals within 1 year of dialysis start. The median time to referral from assignment to the first dialysis facility was 115 days (interquartile range, 60–200 days). There were two first transplants and 940 deaths among patients within the first year of ESRD incidence over the study course. Population characteristics of Georgia patients on incident dialysis between 2008 and 2011 are summarized in Table 1. The crude number of first year referrals varied between 557 in 2008 and 708 in 2011 (*i.e.*, crude referral proportions of 0.27–0.34 over the 4 years). The 4-year crude referral proportion for Georgia dialysis facilities was 0.31.

Referral Counts by Patient Case Mix. Table 2 shows the differences in referral proportions by levels of the patient case mix. Older age, nonblack race, and women were consistently associated with lower referral counts over the study years, and patients with comorbid conditions (except hypertension) were less likely to be referred.

Risk-Adjusted Model for Referrals. The stage 1 model of the two-stage Cox proportional hazards model indicated that age, race, sex, and patient comorbid conditions (except atherosclerotic heart disease and diabetes) were significantly associated with an increased likelihood of referral within 1 year of starting dialysis (Table 3). Blacks were 1.12 times more likely to be referred than whites in the first year (hazard ratio, 1.12; 95% CI, 1.02 to 1.24). Patients of older age, women, and those with the presence of comorbid conditions had a significantly lower referral. Additionally, there was a positive time trend, and the incidence of referral was significantly higher in 2011 compared with 2008 and 2009. Model AIC indicated that the adjusted model was a better fit than the crude model (AIC of 16,611.0 versus 17,297.7). In sensitivity analyses examining an extended 2-year follow-up, the model estimates of risk factors were not statistically different compared with the original model, and the Pearson correlation coefficient ($r=0.96$) indicated high agreement between the facility STReRs from both models (Supplemental Table 1). In sensitivity analyses including insurance status as an additional risk adjustment factor, patients with employer-based health insurance were more likely to be referred than patients with Medicare insurance (hazard ratio, 1.76; 95% CI, 1.55 to 2.00) (Supplemental Table 2), but facility STReRs were highly consistent ($r=0.98$).

Table 2. Kidney transplant referrals (percentages) by levels of patient case mix (risk factors) at the time of ESRD start among Georgia patients on dialysis from 2008 to 2011

Case Mix Variables	2008, n=557 (27%)	2009, n=626 (29%)	2010, n=651 (32%)	2011, n=708 (34%)
Age (yr) group (%)				
19–30	47 (50)	54 (45)	63 (62)	34 (43)
31–40	102 (47)	95 (49)	102 (53)	125 (58)
41–50	138 (33)	153 (36)	158 (42)	174 (42)
51–60	167 (24)	192 (28)	211 (31)	234 (36)
60+	103 (16)	132 (19)	117 (17)	141 (20)
Race (%)				
Black	387 (28)	428 (30)	455 (34)	488 (37)
White	157 (24)	186 (26)	179 (27)	201 (29)
Other	13 (38)	12 (36)	17 (53)	19 (40)
Sex (%)				
Men	344 (30)	340 (29)	388 (33)	413 (36)
Women	213 (23)	286 (29)	263 (31)	295 (33)
BMI\geq35 kg/m² (%)				
Yes	112 (24)	148 (28)	178 (35)	197 (37)
No	445 (28)	478 (30)	473 (31)	511 (33)
Congestive heart failure (%)				
Yes	121 (20)	118 (21)	132 (25)	150 (27)
No	436 (30)	508 (32)	519 (34)	558 (37)
Atherosclerotic heart disease (%)				
Yes	46 (19)	50 (21)	48 (22)	37 (22)
No	511 (28)	576 (30)	603 (33)	671 (36)
Other cardiac disease (%)				
Yes	57 (20)	62 (25)	59 (21)	74 (25)
No	500 (28)	564 (30)	592 (34)	634 (36)
Cerebrovascular disease (%)				
Yes	37 (16)	39 (22)	37 (20)	34 (22)
No	520 (28)	587 (30)	614 (33)	674 (35)
Peripheral vascular disease (%)				
Yes	35 (17)	37 (18)	29 (18)	38 (23)
No	522 (28)	589 (30)	622 (33)	670 (35)
COPD (%)				
Yes	21 (17)	24 (16)	19 (13)	31 (22)
No	536 (28)	602 (30)	632 (33)	677 (35)
Hypertension (%)				
Yes	495 (28)	583 (30)	583 (33)	641 (35)
No	62 (24)	43 (20)	68 (27)	67 (28)
Diabetes (%)				
Yes	295 (25)	327 (27)	346 (31)	384 (32)
No	262 (30)	299 (32)	305 (33)	324 (37)
Tobacco use (%)				
Yes	41 (21)	48 (24)	50 (29)	62 (30)
No	516 (28)	578 (30)	601 (32)	646 (35)
Cancer (%)				
Yes	11 (11)	11 (10)	15 (15)	19 (17)
No	546 (28)	615 (30)	636 (33)	689 (35)
Nursing home status (%)				
No	556 (28)	625 (30)	647 (34)	701 (36)
Yes	1 (1)	0 (0)	3 (3)	6 (8)

BMI, body mass index; COPD, chronic obstructive pulmonary disease.

Sensitivity Analyses Calculating STReR among Small Dialysis Facilities. Among the 72 facilities excluded due to annual incident $n < 5$, classification of facilities was almost identical, except for small differences in the better/worse than expected category (Supplemental Table 3).

Rankings of facility-level STReRs (95% CI) over the 4-year period (2008–2011) are shown in Figure 1. Of the 249 facilities, 191 (77%) had STReRs not significantly different from one, 27 (11%) had STReRs significantly higher than one, and 31 (12%) had STReRs lower than one (Table 4). Compared with the remaining facilities, we found that the facilities with STReRs lower than expected were less likely to be for profit, were free standing, and were farther

from the nearest transplant center. However, they were not different in terms of size or urban/rural classification (Supplemental Table 4).

Comparison of Adjusted Versus Unadjusted Facility STReRs. The estimated STReRs were classified into either the “as expected” category (*i.e.*, not significantly different from one) or the “worse (better) than expected” category (*i.e.*, significantly lower [higher] than one). A crossclassification table indicated 6% ($n=16$) disagreement between the STReRs from the two models (Table 4). Of those, seven facilities (3%) showed better performance after risk adjustment, and nine (3%) showed worse performance after risk adjustment.

Table 3. Stage 1 Cox proportional hazard model estimates of patient case mix factors on referral for transplantation for data years 2008–2011

Parameters	Referent Group	Coefficient	SEM	Hazard Ratio (95% CI)
Age (yr) group				
19–30		0.34	0.09	1.40 (1.18 to 1.66)
31–40		0.34	0.07	1.40 (1.23 to 1.59)
51–60		–0.22	0.06	0.80 (0.72 to 0.89)
60+	41–50	–0.75	0.06	0.47 (0.42 to 0.53)
Race group				
Black	White	0.12	0.05	1.12 (1.02 to 1.24)
Other		0.22	0.14	1.25 (0.95 to 1.65)
Men	Women	0.13	0.04	1.14 (1.05 to 1.24)
Incident ESRD year				
2008		–0.30	0.06	0.74 (0.66 to 0.84)
2009		–0.18	0.06	0.84 (0.75 to 0.94)
2010	2011	–0.05	0.06	0.95 (0.85 to 1.07)
BMI \geq 35 kg/m ²		–0.06	0.05	0.94 (0.86 to 1.04)
BMI unknown	BMI $<$ 35 kg/m ²	–0.51	0.15	0.60 (0.45 to 0.81)
Comorbidities				
Congestive heart failure	None	–0.16	0.05	0.85 (0.77 to 0.94)
Congestive heart failure unknown	None	–0.92	0.60	0.40 (0.12 to 1.30)
Atherosclerotic heart disease	None	0.00	0.09	1.00 (0.85 to 1.18)
Other cardiac disease	None	–0.14	0.07	0.87 (0.76 to 1.00)
Cerebrovascular disease	None	–0.27	0.09	0.77 (0.64 to 0.91)
Peripheral vascular disease	None	–0.24	0.09	0.79 (0.66 to 0.95)
COPD	None	–0.28	0.11	0.76 (0.61 to 0.94)
Hypertension	None	0.23	0.07	1.25 (1.09 to 1.44)
Diabetes	None	–0.02	0.04	0.98 (0.90 to 1.07)
Tobacco use	None	–0.21	0.08	0.81 (0.70 to 0.95)
Cancer	None	–0.71	0.14	0.49 (0.37 to 0.64)
Nursing home status	None	–2.14	0.32	0.12 (0.06 to 0.22)

95% CI, 95% confidence interval; BMI, body mass index; COPD, chronic obstructive pulmonary disease.

Reliability

We found that the IUR values for the STReR range from 22% to 45% across the years 2008–2011. On average, this indicates a moderate degree of reliability (*i.e.*, around 33% of the variability in STReRs can be attributed to between-facility variation, and 67% of the variability in STReRs can be attributed to within-facility variation).

Validity

Of the 2147 Georgia patients on incident dialysis in 2009, 626 (29%) were referred within 1 year, 341 (16%) were evaluated within 6 months, 238 (11%) were waitlisted within 1 year, and 50 (2%) were transplanted within 2 years of referral. The first year STReRs had significant positive correlations with crude facility referral proportions ($r=0.96$; $P<0.001$), transplant evaluation ($r=0.46$; $P<0.001$), waitlisting ($r=0.35$; $P<0.001$), and transplantation ($r=0.20$; $P=0.004$) proportions. Because a small percentage of transplants occurred within 2 years of referral (end of study period), computing the standardized transplant ratio was not feasible.

Discussion

The CMS and the kidney community have called for the development of quality measures for dialysis facility–based metrics to monitor quality, reduce variability in transplant access, and ultimately, improve equity in kidney transplantation (11,12,14). To date, dialysis facilities have only been evaluated on crude measures of transplant referral,

such as in ESRD Network quality improvement projects to increase equitability in kidney transplantation (15), and no national quality metrics for dialysis facility transplant access currently exist. Our study shows that a risk-adjusted measure, the STReR, is a potentially valid and reliable metric that could be used as a clinical performance metric to evaluate kidney transplant access among dialysis facilities. These results underscore the importance of collecting national data on referral for transplantation to calculate quality metrics, such as the STReR.

We found that variation in referrals could be partially attributed to differences in baseline patient characteristics (*e.g.*, demographic and clinical factors). However, after adjusting for patient case mix, considerable variance in STReRs persisted. Although we did not account for all patient characteristics, it is highly unlikely that patient case mix alone explains the total variation in transplant referrals. This suggests that a large part of observed variance in facility performance is due to dialysis facility–level factors versus variation in the patient pool. In addition, STReRs (versus crude measures of referrals) may be more effective when targeting lower-performing facilities for quality improvement initiatives. When targeting facilities with a specific patient pool (*e.g.*, age/sex/race/comorbidity groups), the STReRs could also help identify and compare performances of dialysis facilities not performing as expected and inform where to target additional interventions.

Although the majority of dialysis facilities in Georgia seem to be performing as expected relative to the state, the current STReRs are not indicative of facility performance

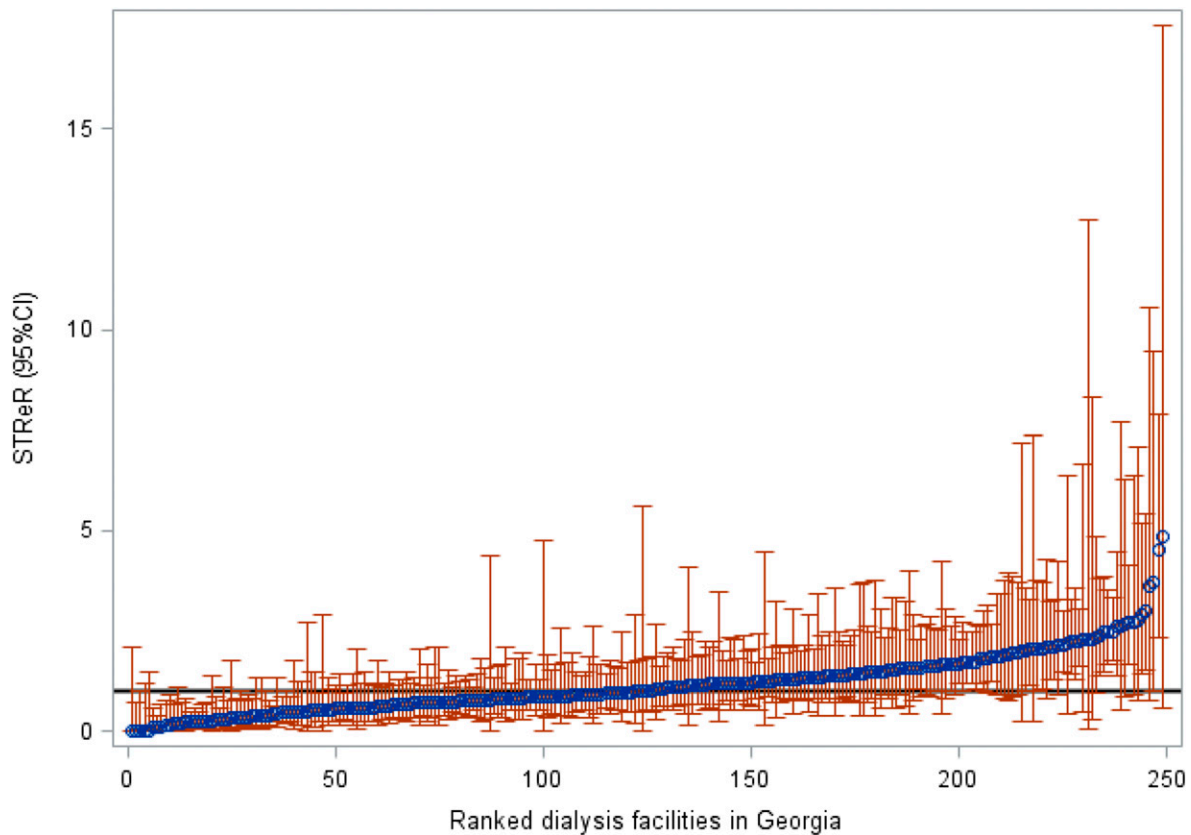


Figure 1. | Ranked Standardized Transplant Ratios (STReRs) and 95% confidence intervals (95% CIs) show actual referrals at Georgia dialysis facilities in reference to those expected for data years 2008–2011 (perfect agreement of observed and expected i.e. STReR=1 indicated in black).

relative to the nation. On the basis of prior research findings that have reported substantial geographic variability in waitlisting and transplantation (2,19–23), we posit that facility STReRs are likely to substantially differ in other regions, which may have different patient characteristics and better transplantation outcomes. Although no other study has looked at a standardized measure of transplant referrals before, one study examining early steps to transplantation (*e.g.*, facility-level medical suitability, interest in transplantation, and pretransplantation workup at dialysis facilities in the Midwest [Indiana, Ohio, and Kentucky]) found a similar distribution of facility performances (4). However, the scope of comparison is limited due to

geographic differences. Likewise, because the STReRs are on the basis of pilot data, providing recommendations for official flagging of facilities by the CMS or other government or payer entities is challenging. Recommending a flagging criteria for facilities on the basis of the STReR will require a nationally representative cohort and a detailed methodology of classification with perhaps an extension to a Bayesian inferential framework, which is important future work.

To use STReR as a standardized measure of dialysis facility performance in a national setting, collection of national surveillance data on transplant referrals from the >5000 dialysis facilities in the United States is essential.

Table 4. Comparisons of the Standardized Transplant Referral Ratio classifications in an unadjusted model and a model adjusted for case mix for data years 2008–2011

Model 1 (Unadjusted)	Model 2 ^a (Adjusted for Case Mix)			Total
	Better than Expected	As Expected	Worse than Expected	
Better than expected (%)	21 (8)	5 (2)	0 (0)	26 (10)
As expected (%)	6 (2)	185 (74)	4 (2)	195 (78)
Worse than expected (%)	0 (0)	1 (0.4)	27 (11)	28 (11)
Total (%)	27 (11)	191 (77)	31 (12)	249

^aAdjusted for patient case mix variables age, race, sex, incident year of ESRD, and comorbidities.

Although a CMS expert review panel recommended collection of these data a decade ago, a national benchmark for collecting referral data on a national level has yet to be established (24). Most recently, development of other kidney transplant access measures, such as the Standardized First Kidney Transplant Waitlist Ratio for Incident Dialysis Patients and the Percentage of Prevalent Patients Waitlisted, were proposed by a CMS Technical Expert Panel but have not yet been submitted to the National Quality Forum (10). Although waitlisting outcomes are more attributable to dialysis facilities compared with transplantation, the use of waitlisting as a performance metric may still be problematic due to geographic variability in waitlisting practices across the United States that is beyond the control of dialysis facilities. Thus, the inclusion of referral for kidney transplantation evaluation as a quality metric may have more face validity and relevance to the dialysis facility leadership and staff responsible for educating patients and referring them to a kidney transplant center for medical evaluation.

There are a number of limitations to our study that should be noted when interpreting the proposed STReR measure. Similar to other indirectly standardized measures (e.g., Standardized Mortality Ratio and Standardized Hospitalization Ratio), the STReR compares the facility-level referrals with those adjusted for patient characteristics within the facility. Thus, one should be cautious about comparing performances of facilities, unless the underlying patient populations are similar. Our restriction of facility size to five or more patients with incident ESRD resulted in an exclusion of 72 smaller facilities, thereby limiting generalizability. Although a sensitivity analysis indicated minimal effects of exclusion on the other facility STReRs, new methodologic research is warranted on how to evaluate performance of small dialysis centers, and it is an important topic of future research. Also, although we risk adjusted for patients' sociodemographic factors (e.g., race and sex) when calculating STReRs, we do acknowledge that their inclusion may mask disparities and inequalities in care (25,26). A sensitivity analysis indicated that exclusion of race and sex from patient case mix had minimal effect on the STReR estimates, and the classification of STReRs from the two models agreed in 99% of cases. We decided *a priori* not to consider any socioeconomic indicators, such as health insurance or neighborhood poverty, in the risk adjustment, because we did not believe that dialysis facilities should restrict access to referral on the basis of social factors that are associated with widespread disparities in transplant access (27). Our sensitivity analyses showed that patients with employer-based health insurance are more likely to be referred than those with Medicare, suggesting that socioeconomic status factors do play a role in referral for transplantation at dialysis facilities. A national conversation may be warranted to discuss whether it is appropriate to risk adjust for these variables before they are applied in practice. The STReR calculation does not account for referrals (<1% of all referrals) made to centers outside Georgia and is likely to be slightly underestimated. Finally, because our study is limited to Georgia, the case mix adjustment is relative to a regional patient population instead of the national ESRD population. National data collection on transplant referral data is needed to ensure generalizability of the STReR to all United States dialysis facilities.

We showed the potential of a new standardized quality measure of dialysis facility transplant performance, the STReR, on the basis of a pilot sample of >8000 patients on dialysis receiving treatment within 249 dialysis facilities in Georgia. Future implementation of transplant referral as a quality metric among dialysis facilities could allow ESRD policymakers and clinical providers to identify gaps in quality and access of care, encourage and/or incentivize dialysis providers to refer appropriate candidates for transplantation, and target evidence-based guidelines and interventions to increase access to kidney transplantation for patients receiving treatment within the dialysis facilities with the lowest performance.

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Disclosures

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Supplemental Material

Definition of Crude referral proportions: Overall crude referral ratios were defined as the total number of referrals divided by the total number of incident ESRD patients in a year. A 4 year crude facility performance measure, facility-specific referral proportions, was calculated as the number of referrals over the study years per incident patients within the facility.

Determining Days at risk for the Cox Proportional Hazard Model: A patient-record began each time the patient was determined to be at a different facility within the first year of ESRD incidence. For example, a patient who was in the same facility for the entire year will result in one patient record, however, when a patient received services at different facilities during the year, the days at risk at the facilities generated one patient record per facility for that year. End of follow-up for each patient/facility for that year was defined as either the day of the event (referral), transplantation, death or the 365th day after ESRD incidence if the event had not yet occurred. Time at risk for each record was calculated as the fraction of the year the patient was in a facility until end of follow-up.

Details of Cox Proportional Hazards Model and STReR computation: A 2-stage Cox proportional hazards (CPH) model was used to compute the expected number of first-time referrals at a facility. Each patient/facility record included a censor indicator of whether a referral was made within that period. Patients were censored for transplant, death or end of 1 year follow up without referral. Stage 1 of the CPH model was stratified by facility and adjusted for patient case-mix. Stratifying by facility ensured that facility-level heterogeneity is accounted for in the baseline survival probabilities. Separate incident year intercepts were included to test for time effects. The predicted values from the stage 1 Cox model were used as offset term in the stage 2 of CPH model, which estimated a common baseline hazard function and included an adjustment for the covariate-adjusted population referral rates. Expected number of referrals per person at each facility were obtained by aggregating the Martingale residuals from stage 2 of the CPH model. The STReRs were obtained as a ratio of observed to expected referrals at the facility level.

Definition of evaluation, waitlisting and transplantation proportions: The evaluation, waitlisting and transplantation proportions was calculated at the facility level and were defined as the number of events within 6, 12 and 24 months respectively over all referred patients in that facility.

Details of Reliability calculation: An inter-unit reliability (IUR) measure was computed for each year using a bootstrap approach. Because STReR is not a simple average across patients in a facility, a resampling scheme was used to estimate the within facility variation (19). Based on 1000 bootstrap samples the proportion of measure variability attributable to the between-facility variance was computed.

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SAS code for STReR calculation:

```
/** define study cohort**/  
data one; set radiant.usrds_referral_facility_1;  
  by USRDS_ID FIRST_SE;  
  format esrddate MMDDYY10.;  
  
  esrddate=FIRST_SE;  
  followup_lyr=intnx('day', FIRST_SE, 365);  
  inc_year=YEAR(esrddate);  
  followup_end= min(died, followup_lyr, txldate);  
  format followup_lyr followup_end mmddyy10.;  
  if (FIRST.USRDS_ID) AND (FIRST_SE ne .) AND  
    (MDY(1,1,2008) <=FIRST_SE <=MDY(12,31,2011)) AND ((referral_date >=  
FIRST_SE) or referral_date=.) ;  
  
run;  
  
/**get treatment history of patients; record facility transitions**/  
data Phistory; set radiant.Treatment_history;  
data Phistory_long; set Phistory;  
array bdate{11} begdatel-begdatell;  
array endate{11} enddatel-enddatell;  
array rx{11} $ rxgroup1-rxgroup11;  
array fac{11} provusrd1-provusrd11;  
do time=1 to 11;  
  begdate=bdate{time};  
  enddate=endate{time};  
  rxgrp=rx{time};  
  facility=fac{time};  
  if (facility ne .) and (begdate ne .) and (rxgrp in  
( '1', '2', '3', '5', '7', '9')) then output;  
end;  
format begdate mmddyy10. enddate mmddyy10.;  
keep USRDS_ID begdate enddate rxgrp time facility;  
run;  
  
/**Merge patient history with the study cohort****/  
  
proc sql;  
  create table two as  
  select *  
  from one, Phistory_long  
  where one.USRDS_ID=Phistory_long.USRDS_ID  
  order by one.USRDS_ID, Phistory_long.begdate, Phistory_long.enddate;  
quit;  
  
/**set the start and followup end date /patient/facility**/  
data three; set two;  
by USRDS_ID;  
retain startbegdate;  
  
if first.USRDS_ID then do;  
tempbegdate=begdate;  
startbegdate=begdate;  
end;
```

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```
if facility = lag1(facility) then tempbegdate=startbegdate;
else do ;
tempbegdate=begdate;
startbegdate=tempbegdate;
end;

timediff=DATDIF(begdate,tempbegdate, 'ACT/ACT');
analysis_start= MAX(esrddate, tempbegdate);
start_year=YEAR(analysis_start);

followup_end_indfac= min(died, followup_end, txldate, referral_date,
enddate);

format analysis_start MMDDYY10. tempbegdate startbegdate mmdyy10.
followup_end_indfac MMDDYY10. ;

pdays=DATDIF(analysis_start, followup_end_indfac, 'ACT/ACT');
if (pdays > 0) then output;
run;

/****keep unique facilities/patients****/

proc sort data=three out=foursorted;
by USRDS_ID facility analysis_start descending followup_end_indfac;

run;
proc sort data=foursorted out=four nodupkey;
by USRDS_ID facility analysis_start ;
run;

/**calculate number of patients/facility and apply >=5 incident patients/year rule*/
proc sql;
create table patsum as
select facility,inc_year, count(distinct USRDS_ID) as numpatients
from four
group by facility, inc_year;
quit;
proc univariate data=patsum;
class inc_year;
var numpatients;
run;

proc sort data=four; by facility inc_year; run;
data four_up; merge four patsum;
by facility inc_year;
run;
data five; set four_up;
if numpatients >=5;
run;

/*****define the risk-adjustment factors*****/

data temp; set five;
ind_ref=0;/**indicator of referral in each interval***/
if referral_date ne . then do;
```

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```
if (referral_date >= analysis_start) and (referral_date <=
followup_end_indfac) then ind_ref=1;
end;
agenum=inc_age;
if agenum ne . then do;
if 18<agenum<=30 then agecat2=1;
else if 30<agenum<=40 then agecat2=2;
else if 40<agenum<=50 then agecat2=3;
else if 50<agenum<=60 then agecat2=4;
else agecat2=5;
end;
else agecat2=99;

yr2008=(inc_year=2008);
yr2009=(inc_year=2009);
yr2010=(inc_year=2010);
yr2011=(inc_year=2011);

if race=3 then race_cat='Black';
else if race=4 then race_cat='White';
else race_cat='Other';

*Ischemic heart disease, cardiac arrest, and MI are all
categorized as atherosclerotic heart disease in 2005
med evidence form;

if carfail ne ' ' or como_chf ne ' ' then do;

if carfail = 'Y' or como_chf = 'Y' then
chf = 1;
else chf = 0;
end;
else chf=99;

if cararr ne ' ' or mi ne ' ' or ihd ne ' ' or como_ashd ne ' '
then do;
if cararr = 'Y' or mi = 'Y' or ihd = 'Y' or como_ashd = 'Y' then
ashd_new = 1;
else ashd_new = 0;
end;
else ashd_new=99;

if como_copd ne ' ' or pulmon ne ' ' then do;
if como_copd = 'Y' or pulmon = 'Y' then copd_new = 1;
else copd_new = 0;
end;
else copd_new=99;

if como_othcard ne ' ' then do;
if como_othcard = 'Y' then como_othcardnew = 1;
else como_othcardnew = 0;
end;
else como_othcardnew = 99;
```

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```
if pvasc ne ' ' or como_pvd ne ' ' then do;
if pvasc = 'Y' or como_pvd = 'Y' then pvasc_new = 1;
    else pvasc_new = 0;
end;
else pvasc_new = 99;

    if cva ne ' ' or COMO_CVATIA ne ' ' then do;
if cva = 'Y' or COMO_CVATIA = 'Y' then cva_new = 1;
    else cva_new = 0;
end;
else cva_new=99;

*Combine cardiac diseases (and other cardiac) to create an
indicator variable of CVD;
if ashd_new ne 99 or pvasc_new ne 99 or cva_new ne 99 or copd_new
ne 99 or COMO_OTHCARD ne ' ' then do;
    if ashd_new = 1 or pvasc_new = 1 or cva_new = 1 or copd_new = 1
or COMO_OTHCARD='Y'
        then CVD = 1;
        else CVD = 0;
    end;
else CVD = 99;

if hyper ne ' ' or como_htn ne ' ' then do;
if hyper = 'Y' or como_htn = 'Y' then hypertension = 1;
    else hypertension = 0;
end;
else hypertension = 99;

if diabins ne ' ' or COMO_DM_INS ne ' ' or COMO_DM_NOMEDS ne ' ' or
COMO_DM_ORAL ne ' ' or COMO_DM_RET ne ' ' then do;
    if diabins = 'Y' or COMO_DM_INS = 'Y' or COMO_DM_NOMEDS = 'Y'
or COMO_DM_ORAL = 'Y' or COMO_DM_RET = 'Y' then diabetes =
1;
        else diabetes = 0;
    end;
else diabetes=99;

if smoke ne ' ' or COMO_TOBAC ne ' ' then do;
if smoke = 'Y' or COMO_TOBAC = 'Y' then smoke_new = 1;
    else smoke_new = 0;
end;
else smoke_new = 99;

if drug ne ' ' or como_drug ne ' ' then do;
    if drug = 'Y' or como_drug = 'Y' then drug_new = 1;
        else drug_new = 0;
    end;
else drug_new=99;

if cancer ne ' ' or como_canc ne ' ' then do;
if cancer = 'Y' or como_canc='Y' then cancer_new=1;
    else cancer_new=0;
```

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```
        end;
        else cancer_new=99;

    **Impossible BMI values - set to missing;
    if bmi > 60 then bmi = .;
        else bmi=bmi;

    ** BMI > 35;
    if bmi ne . then do;
        if bmi >= 35 then bmi_35 = 1;
        else bmi_35 = 0;
    end;
    else bmi_35=99;

    ***history of nursing home status;

    if como_inst_nurs=' ' then hist_nursing_home= 'MISS';
    else hist_nursing_home= como_inst_nurs;

run;

/*****Calculate STReR: stages 1-2 of the Cox PH model ***/

proc phreg data=temp;
class race_cat(ref='White') male(ref='0') agecat2(ref='3') bmi_35(ref='0')
  chf(ref='0') ashd_new(ref='0') como_othcardnew(ref='0') cva_new(ref='0')
pvasc_new(ref='0') copd_new(ref='0') hypertension (ref='0') diabetes
(ref='0') cancer_new(ref='0') smoke_new (ref='0')
hist_nursing_home(ref='N');
strata facility;
model pdays*ind_ref(0)= agecat2 race_cat male yr2008 yr2009 yr2010 bmi_35
chf ashd_new como_othcardnew cva_new pvasc_new copd_new hypertension diabetes
smoke_new cancer_new hist_nursing_home/ties=breslow rl;
id USRDS_ID inc_year;
output out=stagel_srr resmart=marting resdev=rdev xbeta= xbeta_srr;
run;

proc phreg data=stagel_srr noprint;
model pdays*ind_ref(0)=/offset=xbeta_srr ties=breslow;
id USRDS_ID facility inc_year;
output out=srr resmart=res_srr;
run;

data srr_2 (keep=USRDS_ID inc_year facility expectref res_srr pdays ind_ref
);
set srr;
expectref=ind_ref-res_srr;
run;

/****calculate facility STReR****/
proc sql;
create table srr_out as
  select facility, count(unique USRDS_ID) as patients, sum(ind_ref) as
obs_ref, sum(expectref) as expected_ref, sum(ind_ref)/sum(expectref) as STReR
  from srr_2
```

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```
    group by facility;
quit;

/****calculate exact confidence intervals for STReRs****/

data srr_out; set srr_out;

FORMAT LCL UCL 8.2;
IF obs_ref=0 THEN LCL=0;
IF obs_ref>0 THEN
LCL=(quantile('CHISQ', .025, 2*obs_ref)*0.5)/expected_ref;
UCL=(quantile('CHISQ', .975, 2*(obs_ref+1))*0.5)/expected_ref;

cont=0;
if (LCL < 1) AND (UCL >= 1) then cont=1;
else if (LCL > 1) then cont=2;

keep facility patients obs_ref expected_ref log_exp STReR LCL UCL cont;
run;
```

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Supplementary Table A1. Stage 1 Cox Proportional Hazard model estimates of patient case-mix factors on referral for transplantation within 2-year follow up period.

Parameters	Referent Group	Coefficient	Standard error	Hazard Ratio (95% CI)
Age group				
19-30		0.38	0.08	1.46 (1.25, 1.71)
31-40		0.33	0.06	1.39 (1.23, 1.56)
51-60		-0.20	0.05	0.82 (0.74, 0.91)
60+	41-50	-0.73	0.06	0.48 (0.43, 0.54)
Race group				
African-American	White	0.11	0.05	1.12 (1.02, 1.23)
Other		0.23	0.13	1.26 (0.98, 1.64)
Male	female	0.13	0.04	1.14 (1.06, 1.23)
Incident ESRD Year				
2008		-0.26	0.06	0.77 (0.69, 0.86)
2009		-0.16	0.06	0.85 (0.76, 0.95)
2010	2011	-0.04	0.05	0.97 (0.87, 1.07)
BMI \geq 35 kg/m ²	BMI < 35 kg/m ²	-0.02	0.04	0.98 (0.90, 1.07)
Comorbidities				
Congestive heart failure	None	-0.15	0.05	0.86 (0.78, 0.94)
Atherosclerotic heart disease	None	0.03	0.08	1.03 (0.89, 1.21)
Other cardiac disease	None	-0.14	0.07	0.87 (0.76, 0.99)
Cerebrovascular disease	None	-0.31	0.08	0.73 (0.62, 0.86)
Peripheral vascular disease	None	-0.20	0.08	0.82 (0.69, 0.97)
COPD	None	-0.32	0.10	0.72 (0.59, 0.89)
Hypertension	None	0.18	0.06	1.20 (1.06, 1.36)
Diabetes	None	-0.03	0.04	0.97 (0.90, 1.05)
Tobacco use	None	-0.22	0.07	0.80 (0.69, 0.92)
Cancer	None	-0.59	0.12	0.56 (0.44, 0.70)
Nursing home status	None	-1.63	0.23	0.20 (0.13, 0.31)

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Supplementary Table A2: Stage 1 Cox Proportional Hazard model estimates of insurance status on referral for transplantation

A sensitivity analysis was performed to compare the STReRs obtained after risk adjusting for insurance type at start of dialysis. While patients insured by employer groups were more likely to be referred compared to patients with Medicare, the other insurance categories (e.g. Medicaid, other coverage and no coverage) were not statistically significantly different from Medicare (estimates shown below) in this cohort. The results were very similar for the original casemix variables and the facility STReRs calculated w/ and w/o insurance type as a risk adjustment factor had a correlation of 0.98, indicating high agreement.

Parameters	Referent Group	Coefficient	Standard error	Hazard Ratio (95% CI)
Insurance status				
Medicaid	Medicare	-0.13	0.07	0.88 (0.76, 1.01)
Employer group		0.57	0.06	1.76 (1.55, 2.00)
Other coverage		0.19	0.11	1.21 (0.97, 1.51)
No coverage		-0.05	0.07	0.95 (0.82, 1.09)

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Supplementary Table A3: Facility performance for small facilities (<5 incidents patients/ year)

A sensitivity analysis was performed to compare the STReR measure based on all 321 GA dialysis facilities and those excluding the facilities with <5 incident patients/year (N=72). The results are almost identical in terms of model estimates, however, the STReR estimates for the small facilities, especially for those with 0 observed referral, had very high uncertainty resulting in very wide confidence intervals. Among the 72 excluded facilities, 67(94%) were as expected, and 1 in each better/worse than expected categories (please refer to the table below). The STReR measure could not be calculated for 3 (4.2%) facilities due to lack of variability in the data. The classification of the bigger facilities were almost identical except for small differences in the better/worse than expected category.

Facility size	Better than expected	As expected	Worse than expected
≥5 incident patients/year (N=249)	27 (11%)	191 (77%)	31(12%)
<5 incident patients/year (N=72)	1 (1%)	67 (93%)	1 (1%)

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Supplementary Table A4. Characteristics of facilities that performed better than expected, as expected and worse than expected based on the STReR measure

Facility characteristics	Better than expected (N=27)	As expected (N=192)	Worse than expected (N=30)	P-value
For-profit status, n (%)	26 (96%)	154 (82%)	19 (63%)	0.01
Urban, n (%)	23 (92%)	152 (83%)	23 (77%)	0.32
Freestanding, n (%)	27 (100%)	185 (96%)	25 (83%)	0.01
Distance from nearest Tx center (miles): mean(sd)	34.1 (32)	50.6 (48)	99.5 (79)	<0.01
Average # of patients in a year: mean (sd)	68 (15)	62 (23)	70 (15)	0.14