Organ Transplantation

Report on Equity in Access

Deceased Donor Kidney Allocation
November 28, 2016

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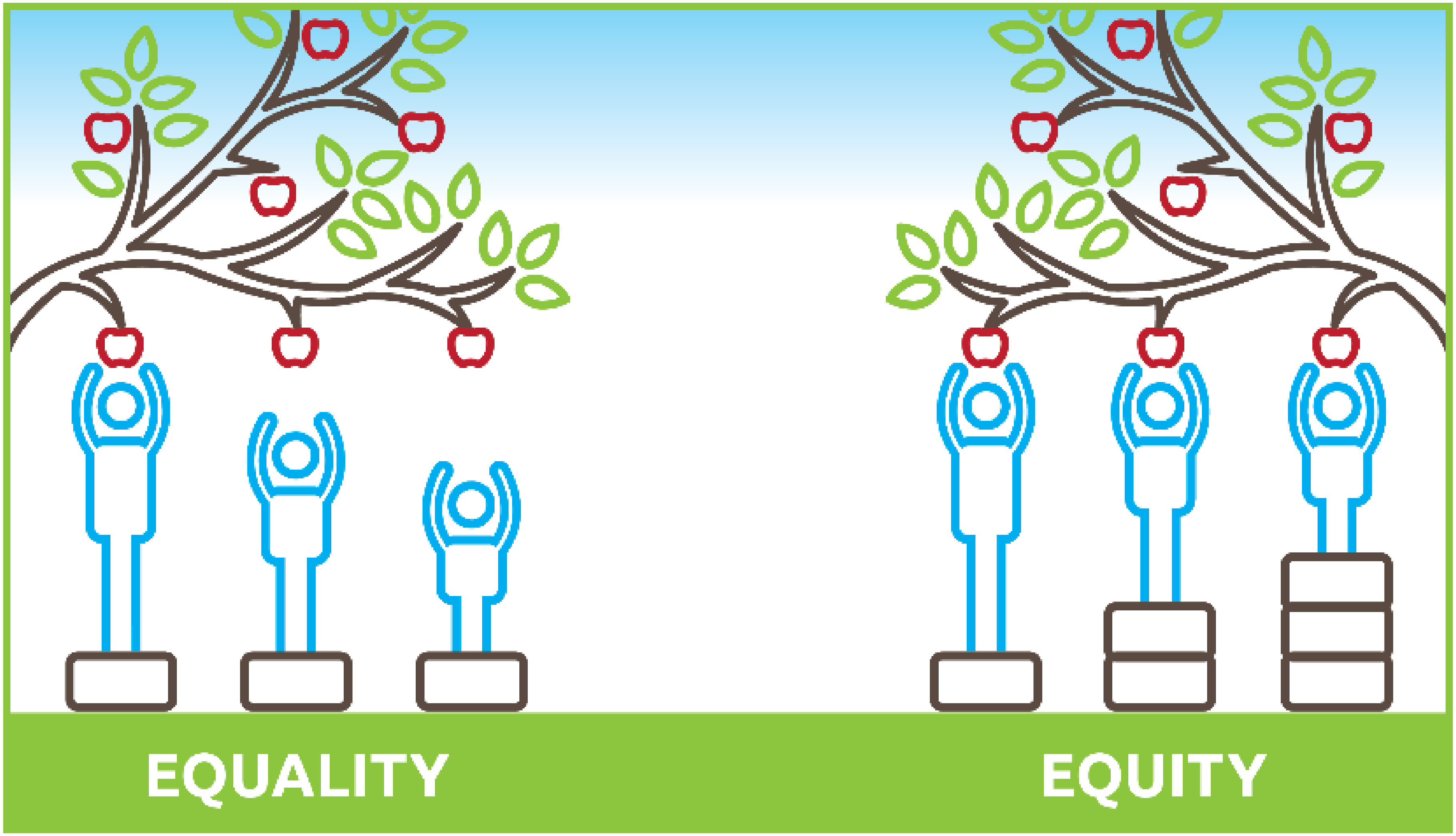

EQUALITY
EQUITY

Standard for Measuring Equity in Deceased Donor Organ Allocation

The OPTN pursues strategic goals of increasing the number of transplants; providing equity in access to transplants; improving outcomes for waitlisted patients, living donors, and transplant recipients; promoting living donor and transplant recipient safety; and promoting the efficient management of the OPTN.

The approach presented in this report measures equity in organ allocation by analyzing disparities in the expected time to deceased donor transplant among candidates on the waiting list. Disparities in timely access to transplantation attributable to the following factors are discounted when measuring the degree to which the system is equitable, since these factors are intentionally used by OPTN policy to increase transplant access for specific groups of patients: medical urgency, pediatric status, previously accumulated waiting time, prior organ donation in the U.S. or its territories (kidney), and net-benefit of transplantation (lung).

Conversely, disparities associated with other candidate factors, including the following, are not considered intentional or desirable and are *not* discounted when measuring the degree to which the system is equitable: ethnicity; age (among adults); age (among pediatrics); blood type; degree of immune sensitization; gender; cause of organ failure; socioeconomic factors such as income level, education, and insurance type (public or private); citizenship status; place of residence or place of listing.

A system with no undesirable disparities in access to transplantation may be unattainable. For example, for some candidates the pool of biologically compatible donors is so limited that equalizing their opportunities for transplant compared to other candidates may be an impossibility. Further, achieving perfect equity may be undesirable if it comes at the expense of other goals, such as optimizing organ utilization and improving recipient outcomes.

The intent of measuring and tracking equity is three-fold: (1) to gauge progress with respect to the OPTN's goal of providing equitable access to transplants, (2) to evaluate the impact on equity of previously implemented policy changes, (3) and to help the OPTN evaluate tradeoffs between equity and other goals when considering the adoption of new policies.

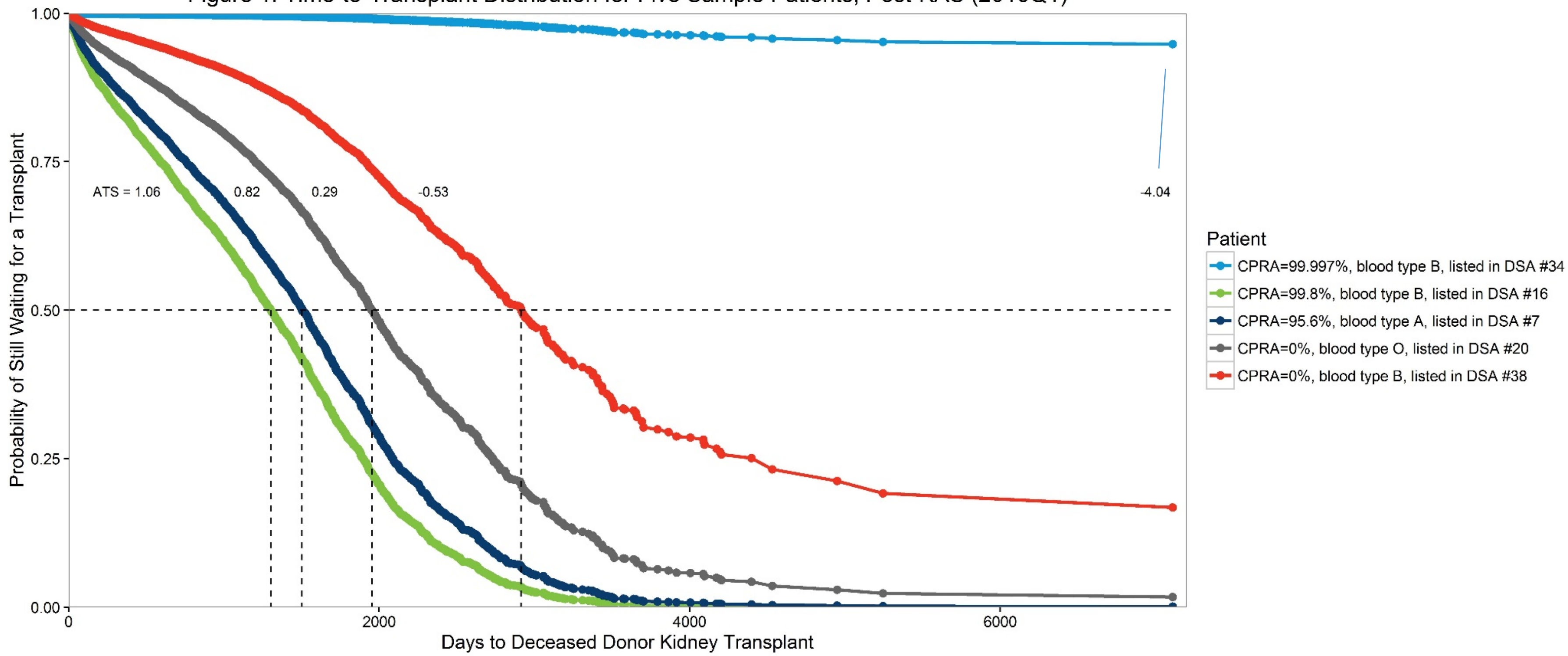
This first report focuses exclusively on equity in access to deceased donor kidney transplants for waitlisted candidates. The feasibility of extending this methodology to the allocation of non-renal organs is being evaluated.

Measuring Equity in Access to Deceased Donor Kidney Transplants

What is an "Access-to-Transplant Score" (ATS)?

An Access-to-Transplant Score, or ATS, is a numerical measure developed to quantify the variability in expected waiting times for receiving a deceased donor kidney transplant among waitlisted patients. It is derived from a Cox proportional hazards regression model that takes into account fifteen patient characteristics such as blood type, CPRA, DSA of listing, age, ethnicity, and other factors considered to potentially impact a candidate's time-to-transplant. The ATS is actually the (discounted) "xbeta" from this statistical model, minus the average xbeta for all active candidates. The "xbeta" shifts the time-to-transplant curve higher or lower depending on candidate factors, as illustrated in **Figure 1** for five sample patients.

Figure 1: Time-to-Transplant Distribution for Five Sample Patients, Post-KAS (2016Q1)



Current Variability among Active WL Candidates in the Timely Access to Deceased Donor Kidney Transplantation

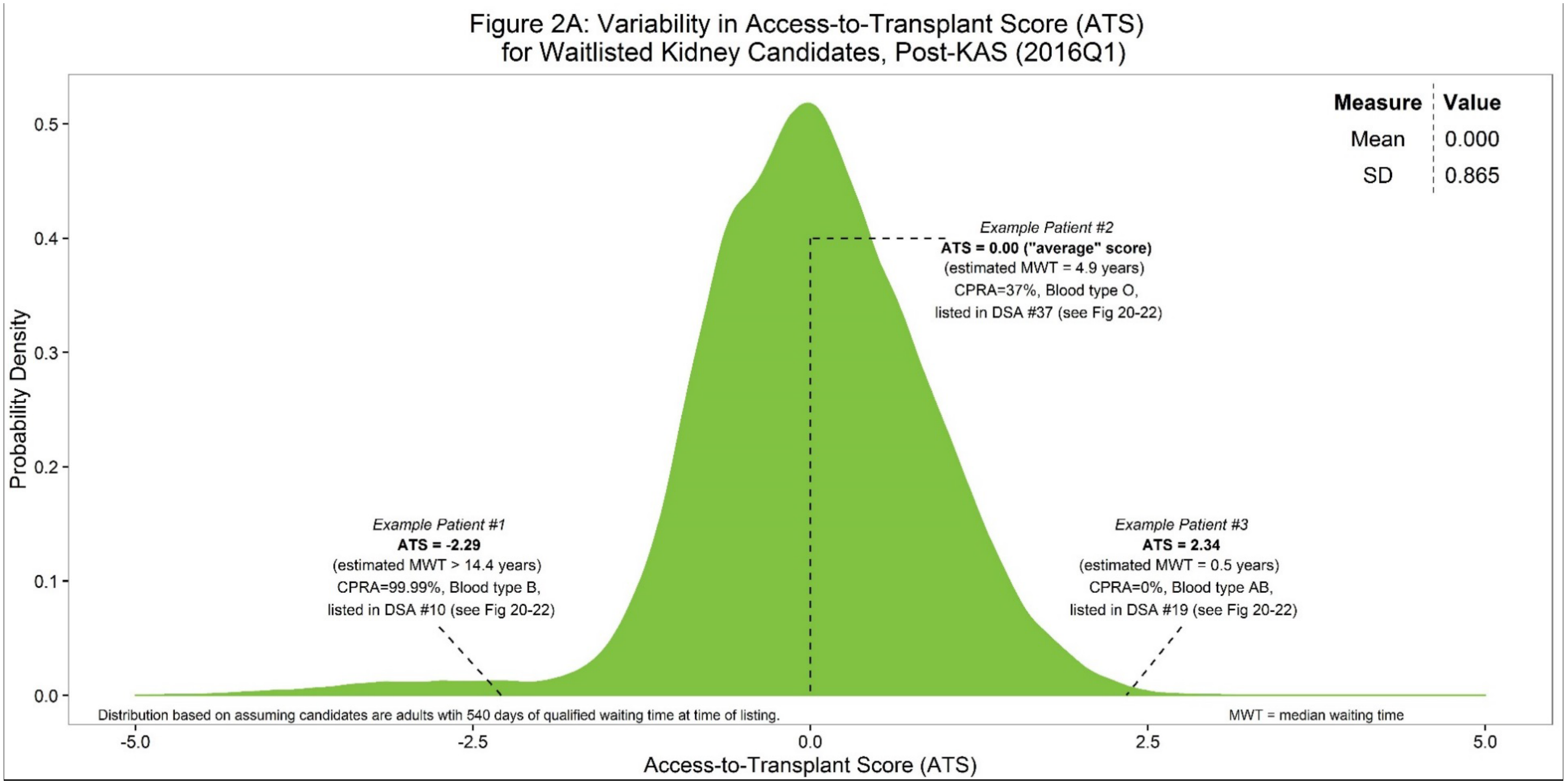
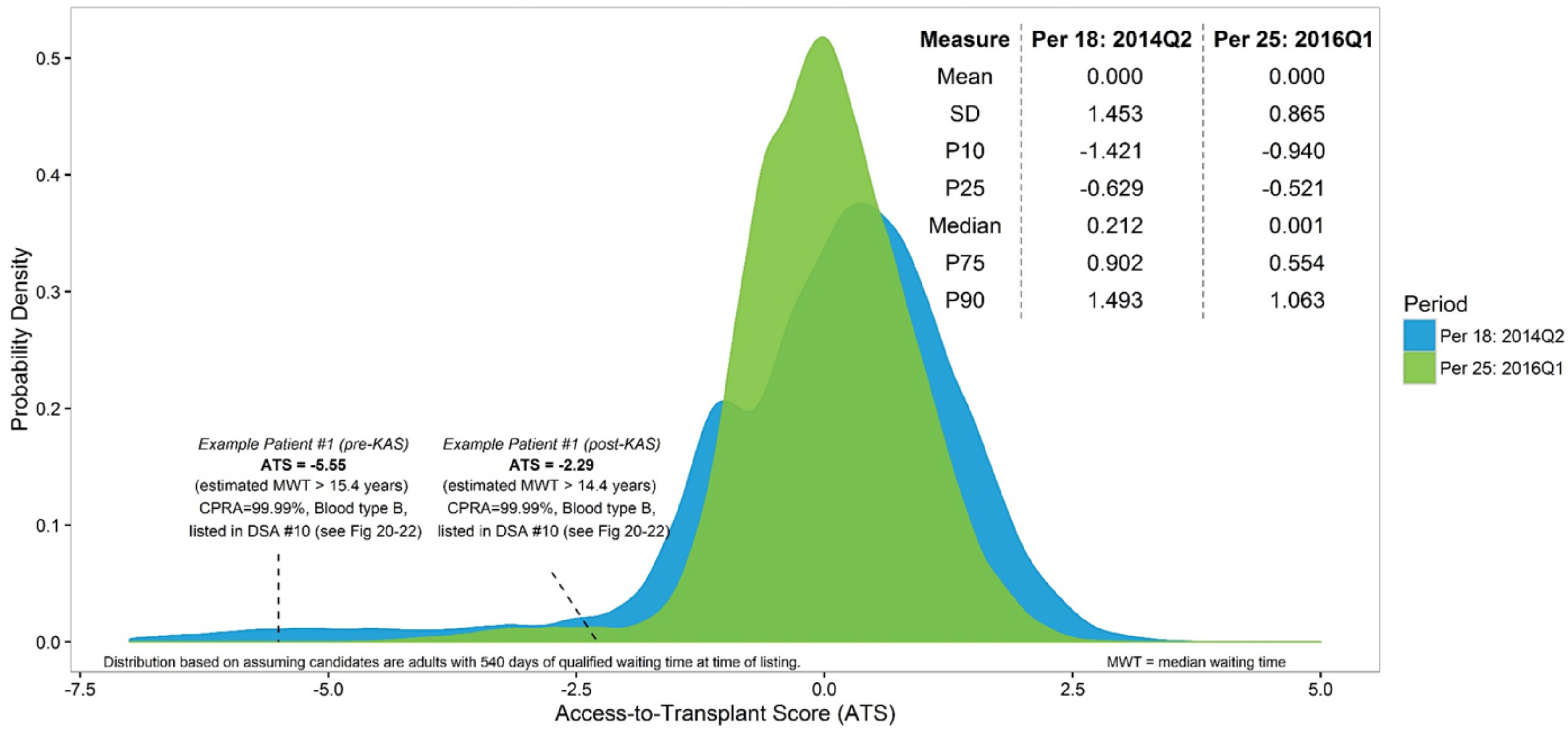


Figure 2A shows the distribution of "Access to Transplant Scores" (ATS) for the 65,619 kidney registrations waiting in active status on January 1, 2016. The standard deviation of 0.865 summarizes the degree of variability among candidates in ATS. ATS is highlighted for three patients, revealing that the estimated median waiting times (MWT) vary from under one year to over 14 years. These differences are *not* due to pediatric priority, differences in previously accumulated waiting time, or other factors in OPTN policy that induce *desired* disparities in time-to-transplant. Rather, the disparities shown in Figure 1 are attributable to other factors, such as blood type, CPRA, and donor service area (DSA) of listing. These scores were estimated based on the allocation of deceased donor transplants during the 1st quarter of 2016 (January 1 – March 31).

Pre vs Post-KAS Variability in the Timely Access to Deceased Donor Kidney Transplantation

The blue distribution curve in **Figure 2B** shows the variability in access to transplant among waitlisted kidney candidates pre-KAS (2[nd] quarter of 2014), with a standard deviation of 1.493. The post-KAS standard deviation of 0.865 represents a 42% decrease in variability in ATS scores compared to pre-KAS. *Example patient #1*, a very highly sensitized candidate, had an ATS of -5.55 pre-KAS. This candidate's ATS was still quite low but increased to -2.29 post-KAS (Figure 1). Percentiles (P10, P25, P75, P90) are shown for comparison.

Figure 2B: Variability in Access-to-Transplant Score (ATS) for Waitlisted Kidney Candidates Pre (2014Q2) vs. Post (2016Q1) KAS



"Period 25" is a 3-month (Jan 1, 2016 – Mar 31, 2016) post-KAS period, while "Period 18" is a 3-month (Apr 1, 2014 – Jun 30, 2014) pre-KAS period chosen for comparison. A complete list of all 25 period start and end dates is included in **Appendix I**.

Tracking Variability in Transplant Access over Time (Jan 1, 2010 – Mar 31, 2016)

Figure 3: Tracking Variability in Access-to-Transplant Score (ATS) Among Waitlisted Kidney Candidates by Quarter (January 2010 - March 2016)

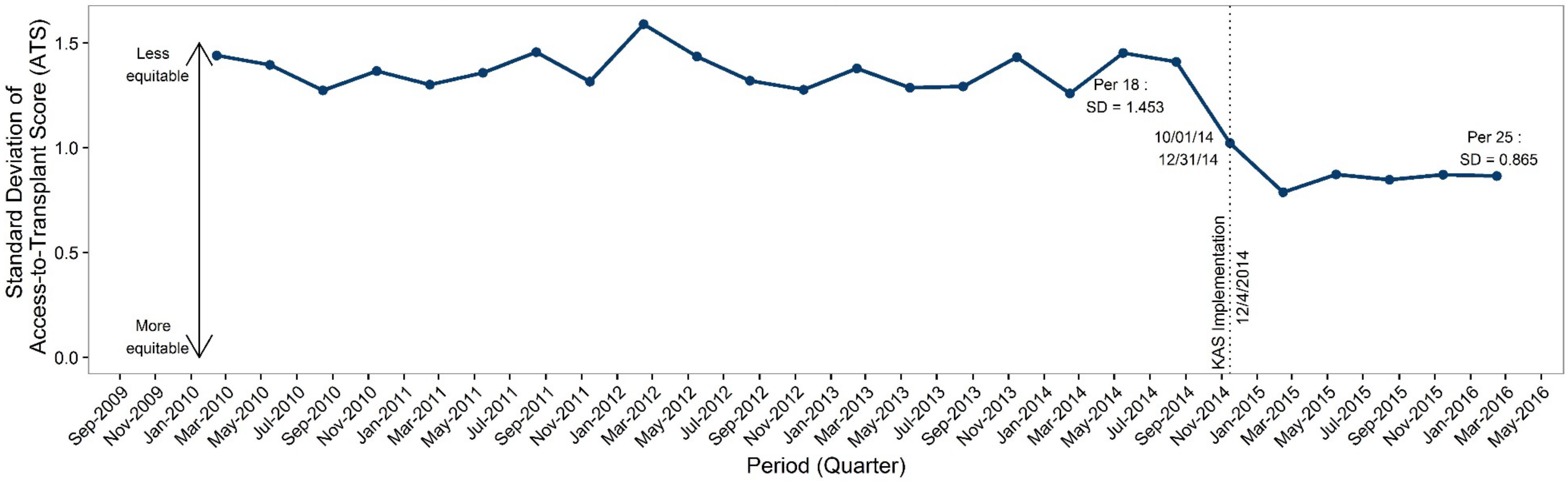


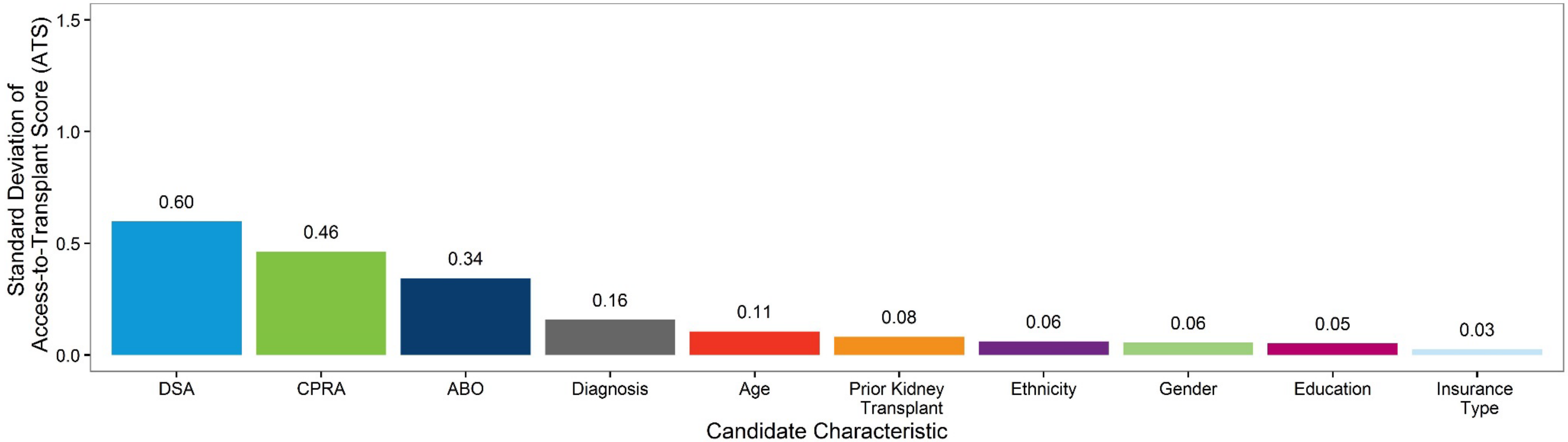
Figure 3 shows quarterly measurements of the variability in ATS scores, as captured by the standard deviation of scores for all active candidates on the waiting list. Twenty-five quarters are shown, starting with January 1, 2010 – March 31, 2010 (Period 1) and extending through January 1, 2016 – March 31, 2016 (Period 25). A complete list of all 25 period start and end dates is included in **Appendix I**. Prior to implementation of the new Kidney Allocation System (KAS) on December 4, 2014, the standard deviation ranged from 1.25 to 1.59. Post-KAS, this standard deviation dropped by approximately 40% to between 0.79 and 0.87. *(Note that the standard deviation of 1.02 for period 20 – Oct 1, 2014 through Dec 31, 2014 – reflects approximately two pre-KAS months together with one post-KAS month.)*

These results suggest that KAS improved equity in access to deceased donor kidney transplants by substantially reducing the variability in the expected time-to-transplant among waitlisted patients. During the five years prior to KAS, the variability in ATS scores remained relatively stable. After decreasing concurrent with KAS, the standard deviation has remained relatively consistent through March 31, 2016.

Measuring Equity in Access by Candidate Characteristics

Identifying Candidate Characteristics Most Associated with Disparities in Access to Transplantation

Figure 4: Variability in Access-to-Transplant Score (ATS) by Candidate Characteristic, 'All Else Equal', Post-KAS: 2016Q1



In **Figure 4**, the standard deviation of *risk-adjusted* ATS scores for the most recent period (25: Jan 1, 2016 – March 31, 2016) are shown for ten candidate characteristics (factors). Risk-adjusted scores isolate the degree to which each factor is associated with candidates' time-to-transplant, *assuming all other factors are equal*, or *ceteris paribus*. For example, the risk-adjusted standard deviation associated with CPRA means that all other factors, such as blood type, donor service area (DSA), age, etc., are assumed to be the same, such that only the variation attributable to differences in CPRA is included.

Figure 4 suggests that though equity has improved with KAS, the remaining disparities in timely access to transplantation are largely attributable to three factors: DSA of the transplant hospital, candidate CPRA, and candidate blood type (i.e., ABO). All else equal, the disparity associated with candidate diagnosis was fourth largest, although the standard deviation was less than half that associated with blood type. The disparity associated with candidate age was fifth largest, though relatively small. The remaining five candidate factors – prior kidney transplant, ethnicity, gender, education level, and insurance type (private vs. public) – were found to contribute very little to differences in candidate ATS scores. The remainder of this report contains information intended to help better understand the association of each of these ten factors with equitable access to kidney transplantation.

Equity in Access by Candidate CPRA

Tracking Equity by CPRA, Jan 2010 – Mar 2016 (ceteris paribus*: "all else equal")*

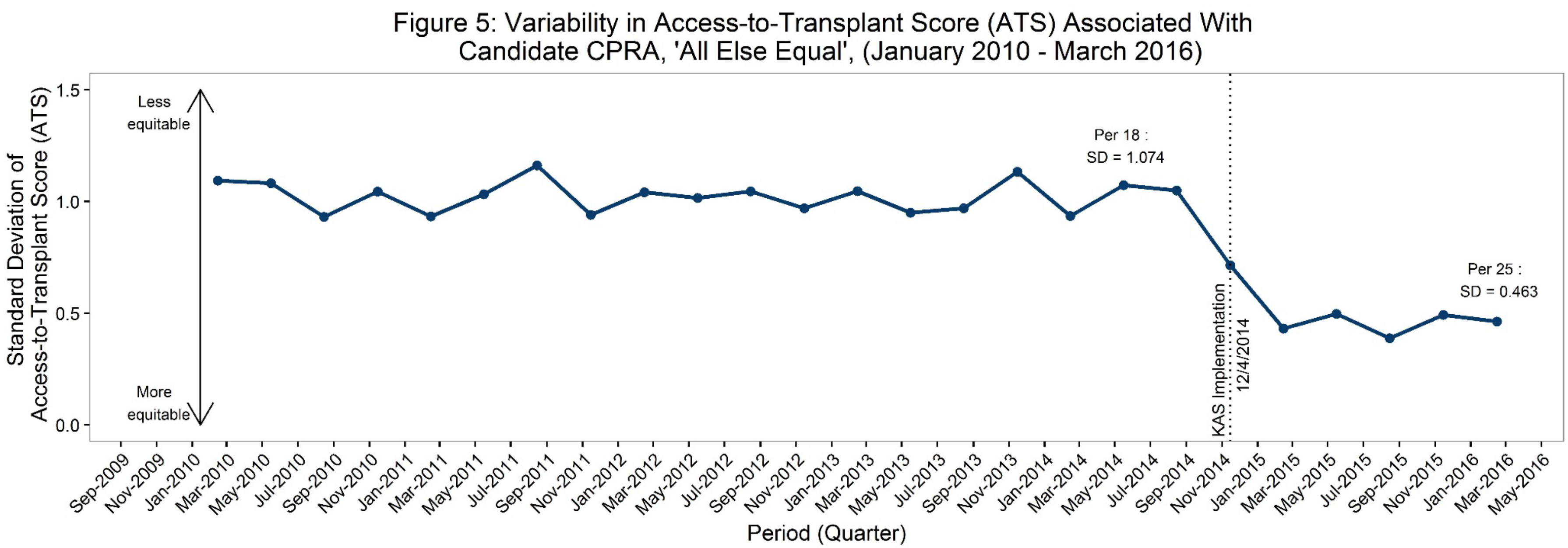


Figure 5 reveals the sharp decrease post-KAS in the variation in ATS scores attributable to differences in patients' degree of immune sensitization, as measured by CPRA. The pre-KAS standard deviation ranged from 0.93 to 1.13, dropping over 50% to between 0.39 and 0.50 post-KAS. This dramatic reduction in the variability in access to transplant associated with sensitization levels was intended, as the new allocation policy expanded opportunities for highly sensitized candidates by increasing their priority on the waiting list.

Risk-adjusted Equity by CPRA, Pre vs. Post-KAS (ceteris paribus: *"all else equal")*

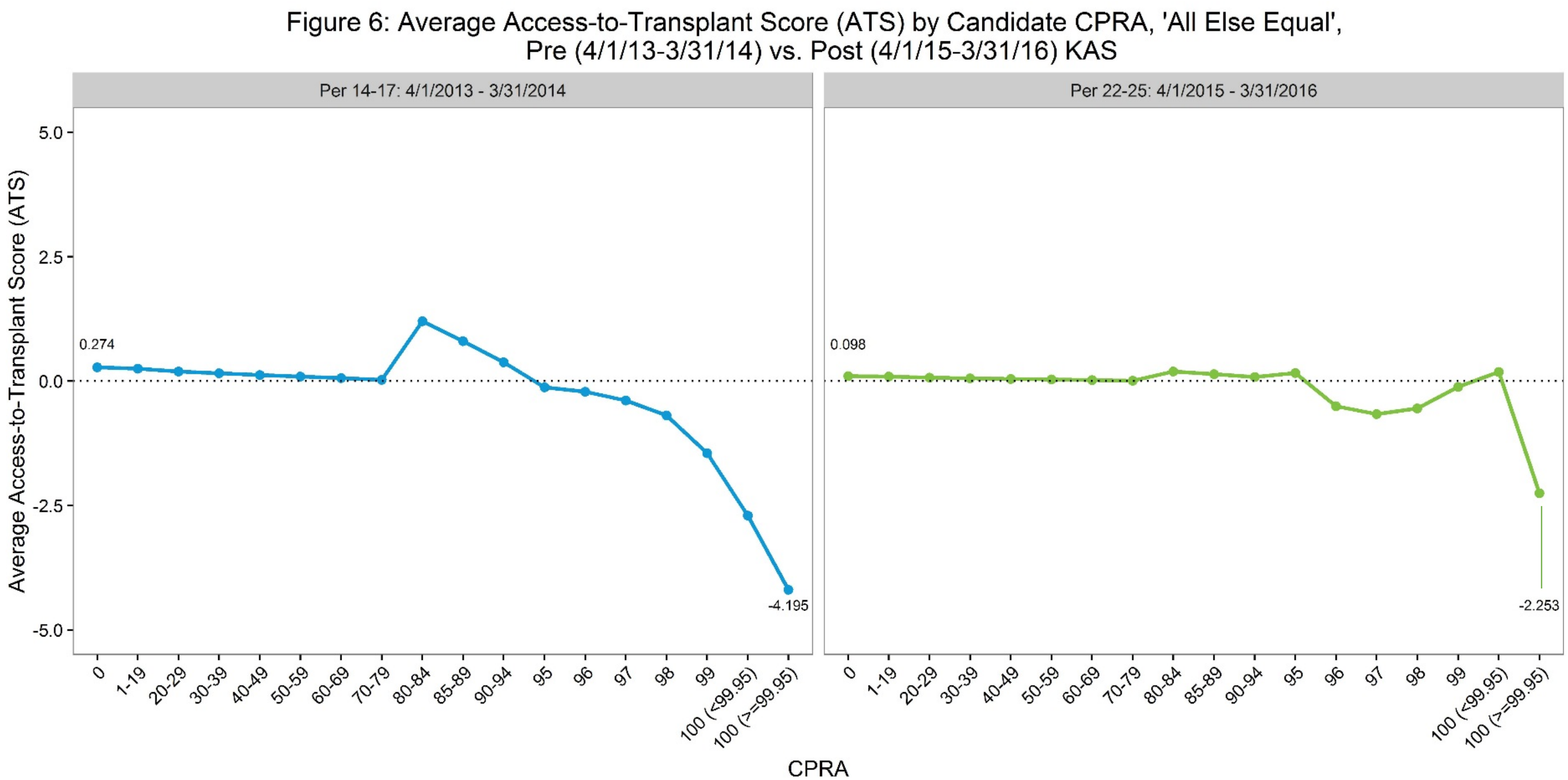
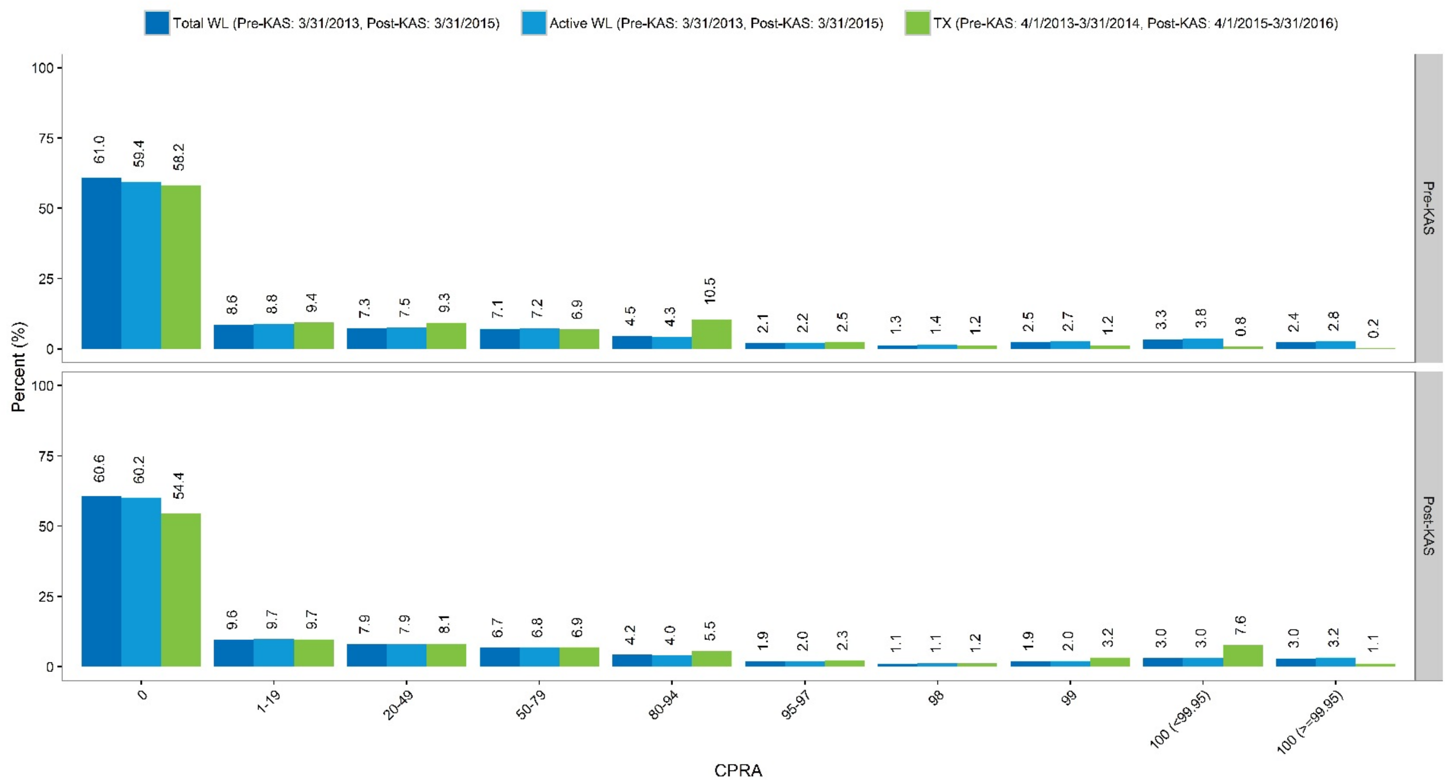


Figure 6 shows the average, risk-adjusted ("all else equal"), ATS scores by candidate CPRA, before and after KAS. The blue curve reveals that the most highly sensitized patients, those with CPRA of 98-100, had extremely low scores prior to KAS, which portends an extremely long expected waiting time to transplant (see Figure 1B). For some of these patients, the expectation was that a compatible kidney donor would likely never be found. Post-KAS, the green curve is much flatter than the blue curve, suggesting a substantial increase in equity in access to transplantation across the sensitization spectrum. Still, these results reveal that patients with CPRA over 99.95% have much lower access to transplant than other candidates, despite receiving national priority under KAS.

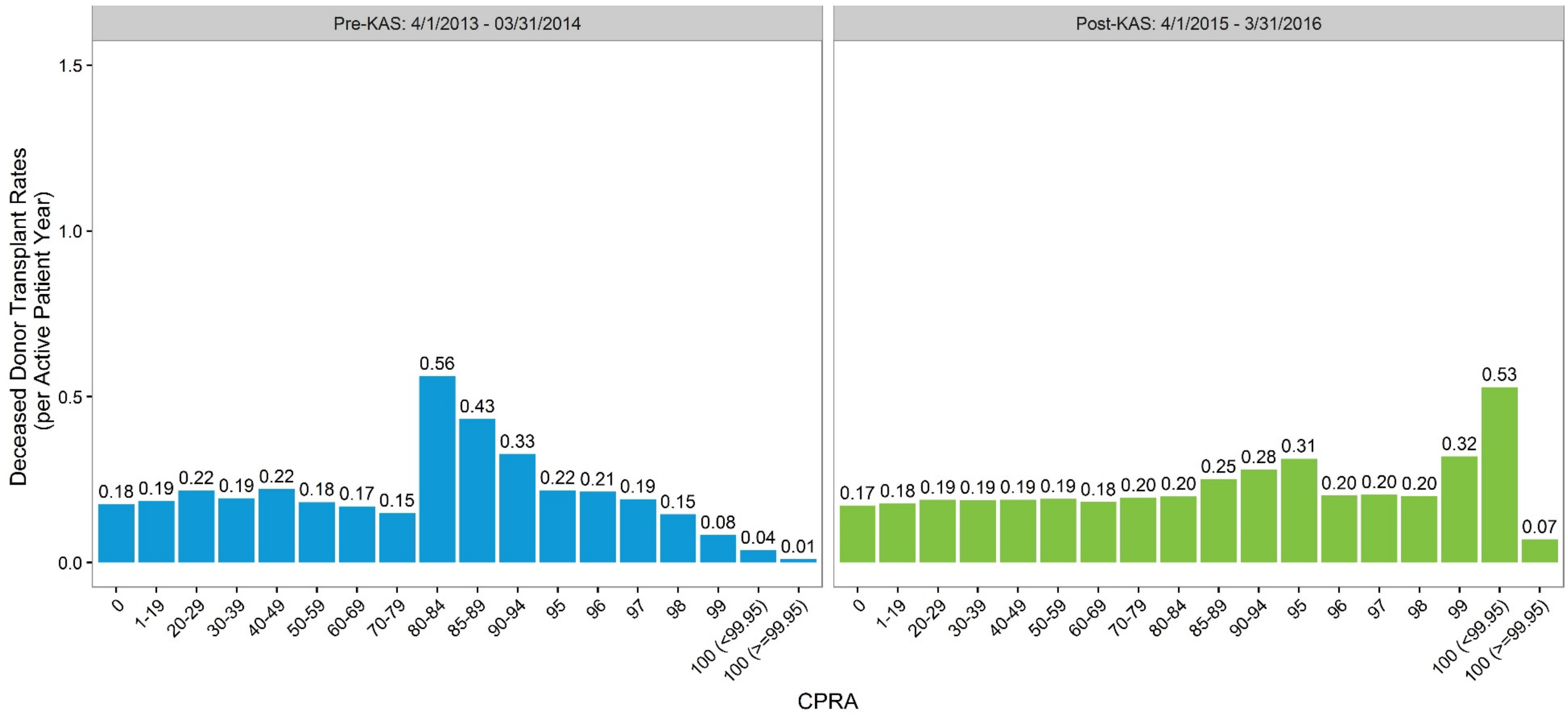
Traditional Ways of Assessing Equity, by CPRA

Figure 7: Waitlist (WL) Percent versus Transplant (TX) Percent by CPRA, Pre- vs. Post-KAS



Comparing the percentage of transplants received by a particular group of patients with the percentage of the waiting list represented by that group is a traditional way of gauging equity in organ allocation. Approximately equal percentages suggest allocation is equitable. **Figure 7** shows that before KAS, CPRA 80-94% patients represented 4.5% of the waiting list (and 4.3% of the *active status* waiting list) but received 10.5% of transplants. After KAS, which replaced the “4 points for CPRA ≥ 80%” policy with a “sliding scale” for assigning allocation points based on CPRA, the CPRA 80-94% group received 5.5% of transplants, closer to their 4.5% representation on the waiting list and suggestive of increased equity. Figure 7 also shows that patients with CPRA of 100% (but less than 99.95%) received far fewer transplants than their waiting list prevalence pre-KAS, but far greater post-KAS. This traditional approach for evaluating equity is useful, however it not risk-adjusted, which means it is possible that apparent inequities could be attributable to correlations with CPRA and other factors.

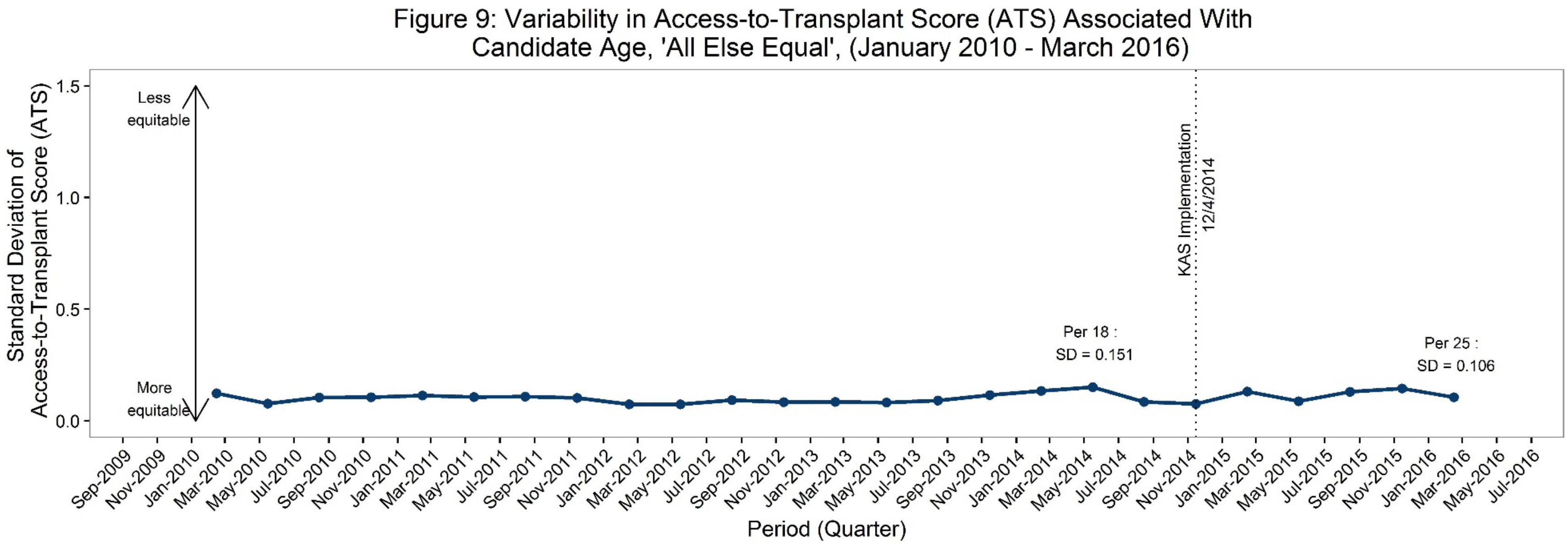
Figure 8: Deceased Donor Transplant Rates Per Active Patient Year by CPRA,
Pre-KAS: 4/1/2013 - 3/31/2014 vs. Post-KAS: 4/1/2015 - 3/31/2016



Transplant rates – the number of deceased donor kidney transplants per "patient-year" on the waiting list – by CPRA are shown in **Figure 8**. Pre-KAS, the sharply higher transplant rate for candidates with CPRA of just over 80% was likely attributable to the pre-KAS policy of assigning four allocation points for these candidates compared to zero points for those with CPRA of 79% or lower. This artificial and disproportionate access to transplants for candidates with CPRA just over 80% disappeared post-KAS, presumably due to the adoption of a sliding scale for assigning points. Figure 8 also shows that transplant rates for patients with CPRA of 99-100% were exceedingly low prior to KAS but rose sharply after implementation of the new policy. However, about half of CPRA 100% candidates (Figure 7) have CPRA 99.95% or greater, and both Figures 7 and 8 suggest that access to these most sensitized patients is still very low, especially compared to CPRA 100% patients below the 99.95% threshold.

Equity in Access by Candidate Age

Tracking Equity by Candidate Age, Jan 2010 – Mar 2016 (ceteris paribus: *"all else equal")*



Relative to the changes seen in variability in access by CPRA, **Figure 9** shows very little change in the variability in access to transplants attributable to differences in candidates' age. The ATS score standard deviation increased slightly from 0.10 pre-KAS to 0.12 post-KAS, still relatively low compared to other factors (Figure 4). Though this aggregate measure of risk-adjusted variability in access to transplants attributable to candidate age changed little and remains low, Figures 10-12 do reveal shifts in the distribution of transplants by age post-KAS.

Risk-adjusted Equity by Candidate Age, Pre vs. Post-KAS (ceteris paribus: *"all else equal")*

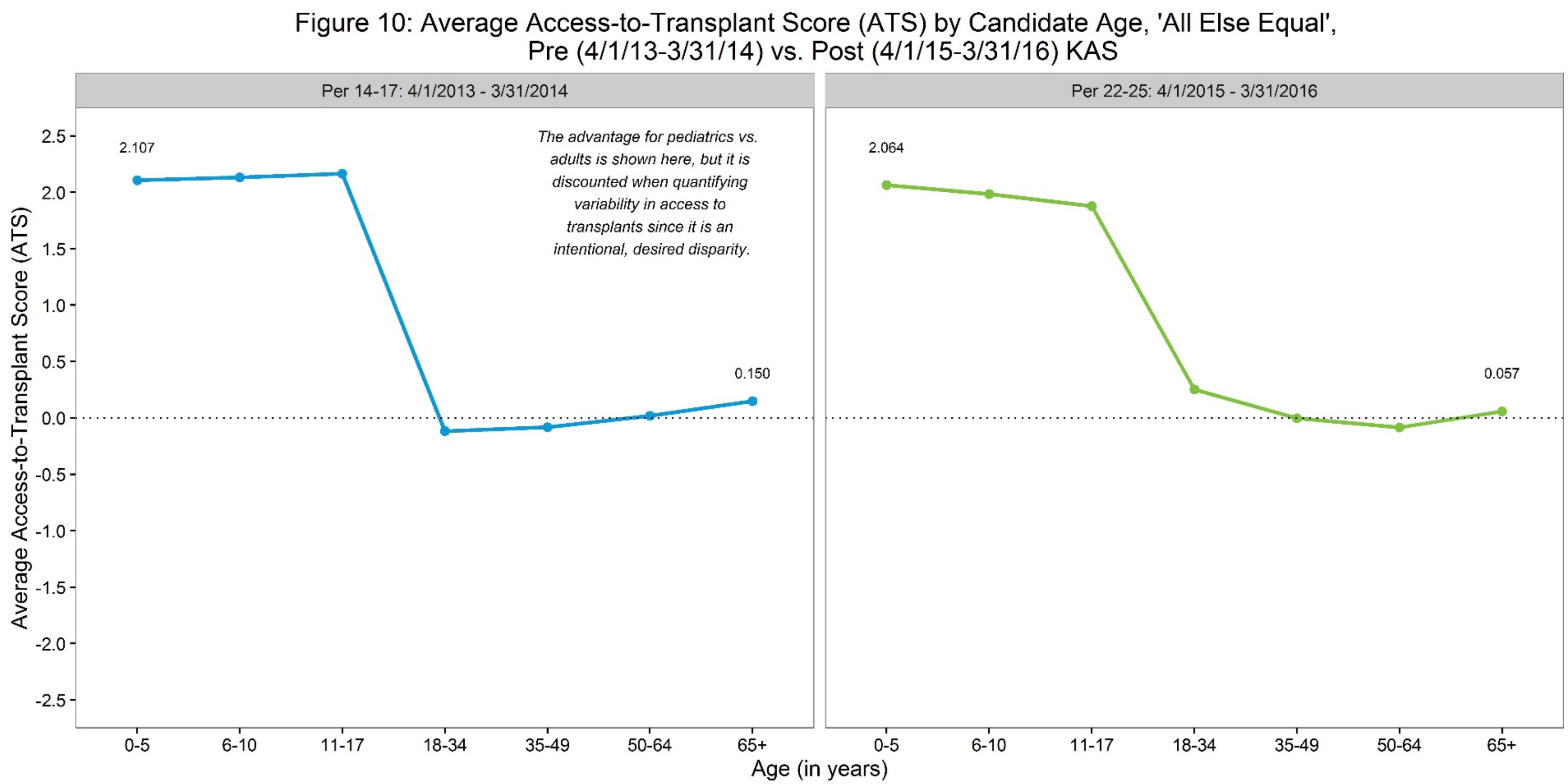


Figure 10 reveals that among adults, prior to KAS older patients had slightly greater access-to-transplant than younger adults, all else equal. This trend reversed post-KAS, with the average ATS score increasing moderately for 18-34 year olds. This shift is likely due to the longevity-matching aspect of the new system, in which kidneys expected to function the longest are preferentially allocated to candidates expected to benefit from a transplant the longest, who tend to be younger.

Pediatric patients still maintain a sizable advantage over adults under KAS, with average scores around 2.0, which translates to an estimated median waiting time of less than one year. Adults, on average, have an estimated MWT of approximately five years.

Traditional Ways of Assessing Equity, by Age

Figure 11: Waitlist (WL) Percent versus Transplant (TX) Percent by Recipient Age, Pre- vs. Post-KAS

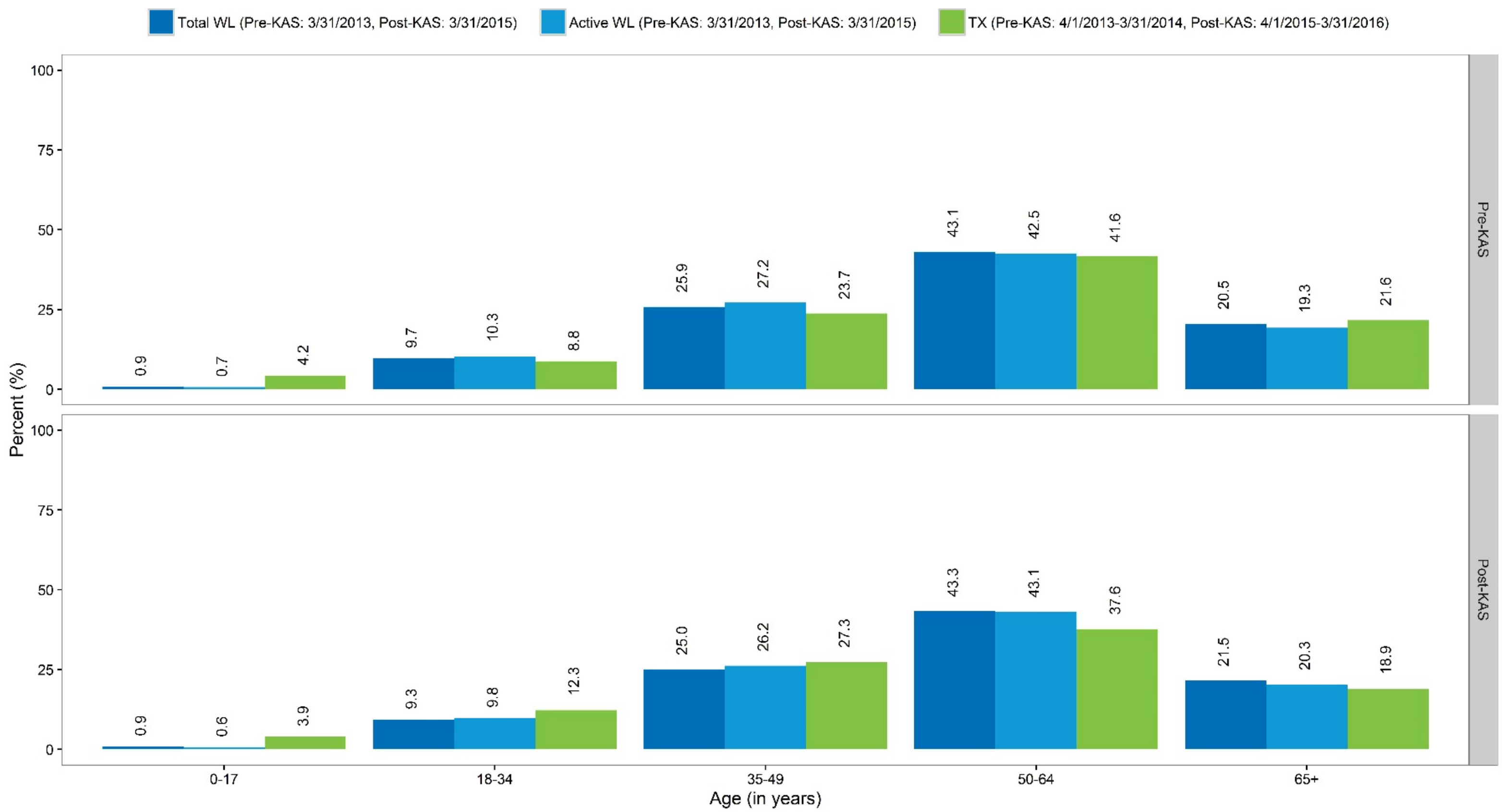
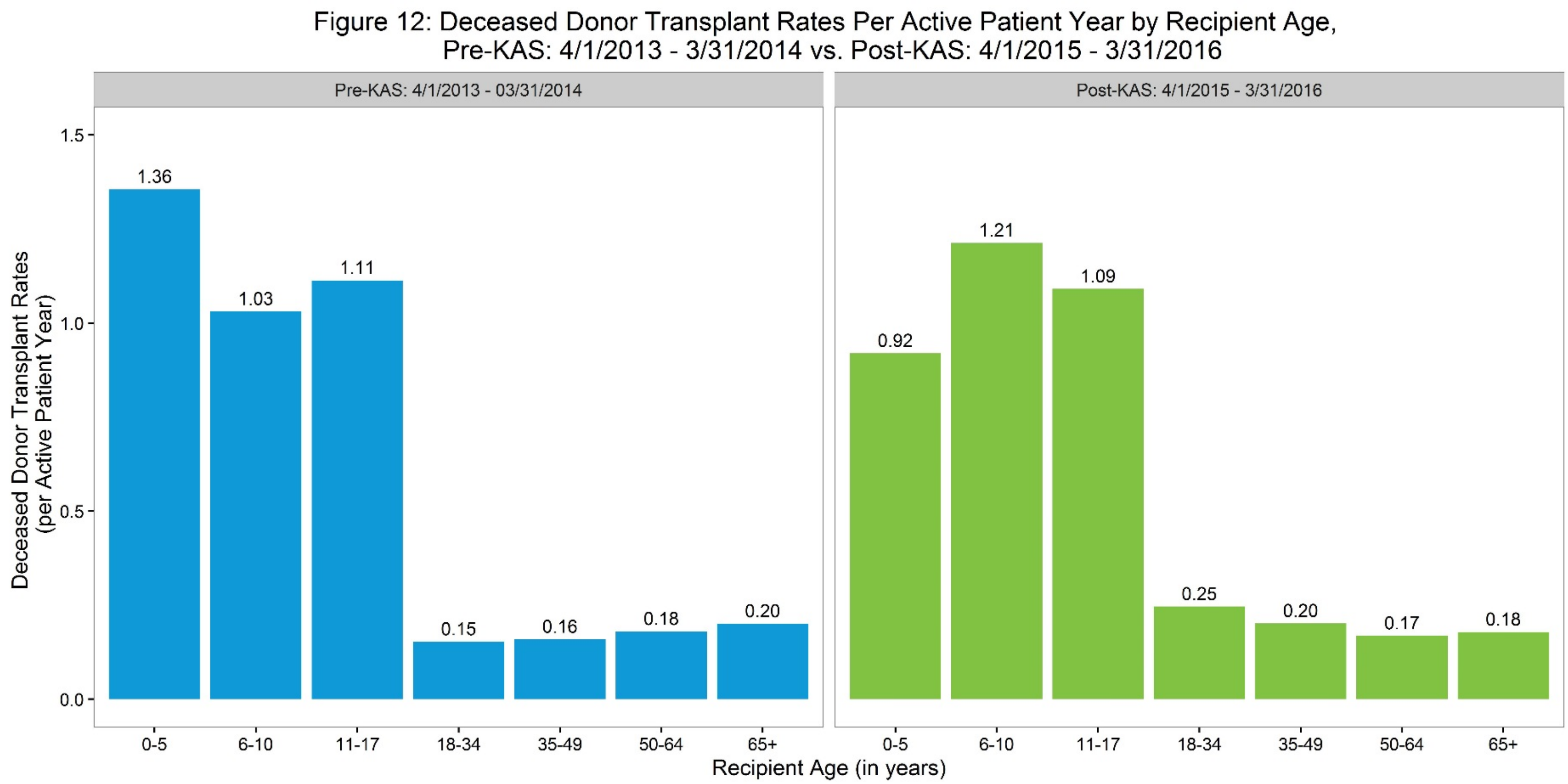


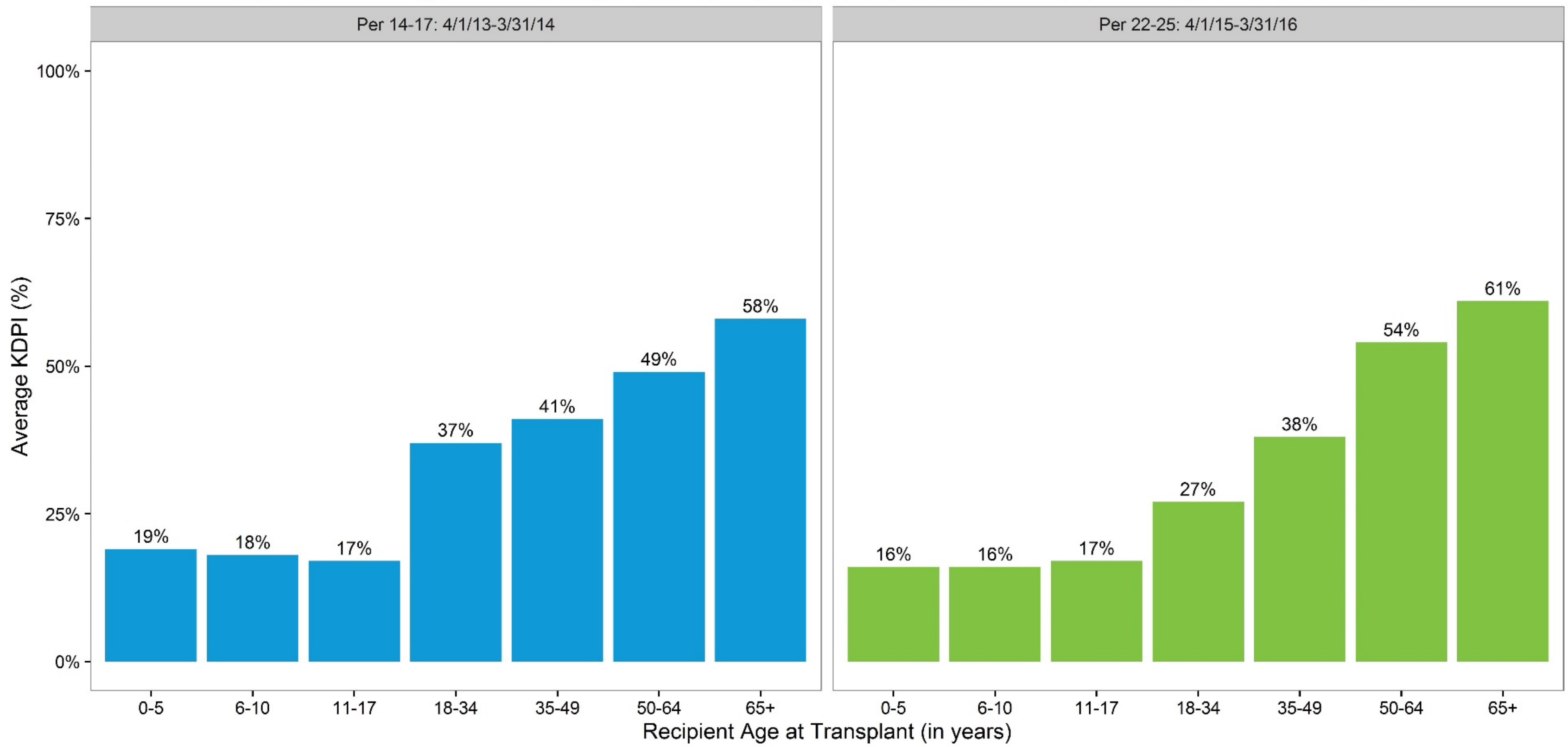
Figure 11 compares the percentage of candidates on the waiting list by age group with the percentage of transplants going to each group. Both pre and post-KAS, less than 1% of candidates were pediatrics, and this group received approximately 4% of transplants. Whereas before KAS the percentage of transplants going to age 18-34 adults (8.8%) was lower than their prevalence on the active waiting list (10.3%), after KAS this group is receiving about 12% of transplants. After KAS, active age 65+ candidates represented about 20% of the waiting list while accounting for about 19% of transplants.



Like Figure 11, **Figure 12** (transplant rates by age group) also shows the advantage in access to transplants afforded pediatric candidates under both the old system and KAS. Before KAS, older adult candidates had higher transplant rates than younger adults, a pattern which reversed after KAS. This traditional approach for evaluating equity is not risk-adjusted, so though useful, it is possible that apparent inequities could be attributable to other factors besides age. The transplant rate by age pattern is very similar to the risk-adjusted approach shown in Figure 10, though, suggesting other factors are not obscuring the patterns observed here. The variation in transplant rates among the three pediatric groups may be attributable to random variation induced by small sample sizes; hence, differences among these three pediatric groups should not be overinterpreted.

Distribution of Kidneys by Expected Longevity and Recipient Age

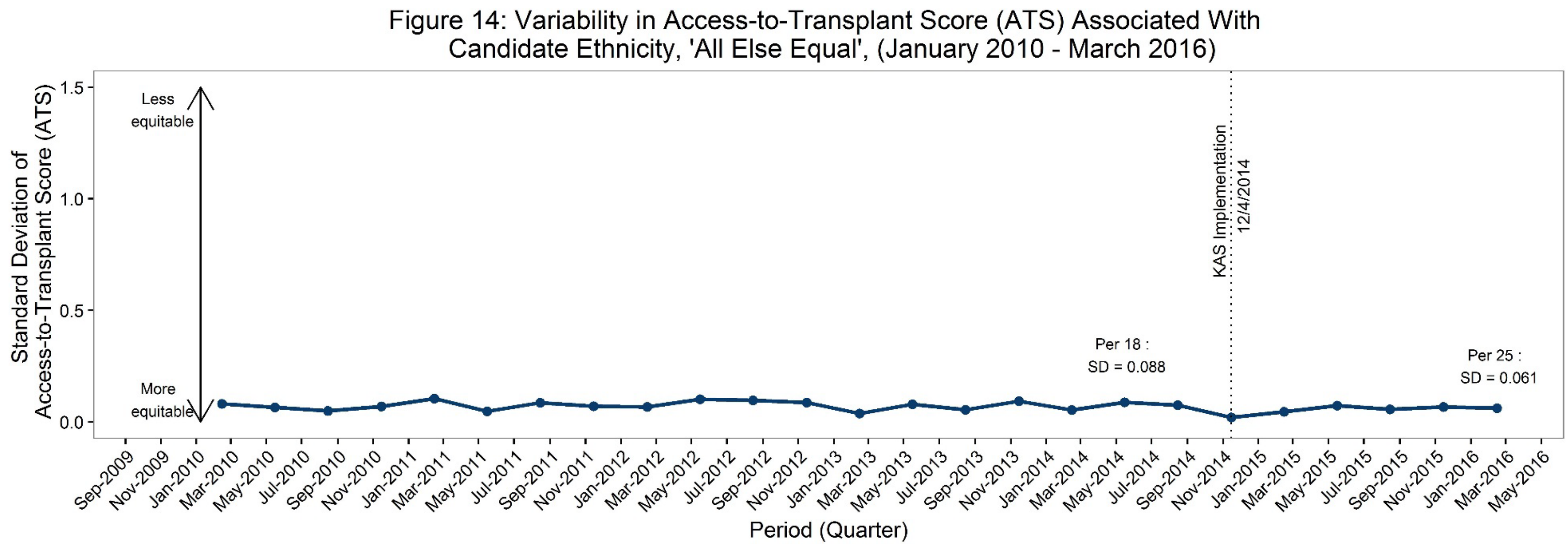
Figure 13: Average KDPI Among Recipents by Age, Pre (4/1/13-3/31/14) vs. Post (4/1/15-3/31/16) KAS



Evaluating equity in access to kidney transplants with respect to candidate age involves more than just variations in the expected waiting time to receiving a transplant. The quality, or expected longevity, of the kidneys received must also be considered. **Figure 13** reveals that the average Kidney Donor Profile Index (KDPI) is much lower for pediatric recipients compared to adults, and decreased further post-KAS. Kidneys from lower KDPI donors are expected to function longer than kidneys from higher KDPI donors. Figure 13 also shows that younger adult recipients have tended to receive lower KDPI kidneys after implementation of KAS, ostensibly due to the longevity-matching element of the new system, which prioritizes EPTS 0-20% candidates to receive KDPI 0-20% kidneys.

Equity in Access by Candidate Ethnicity

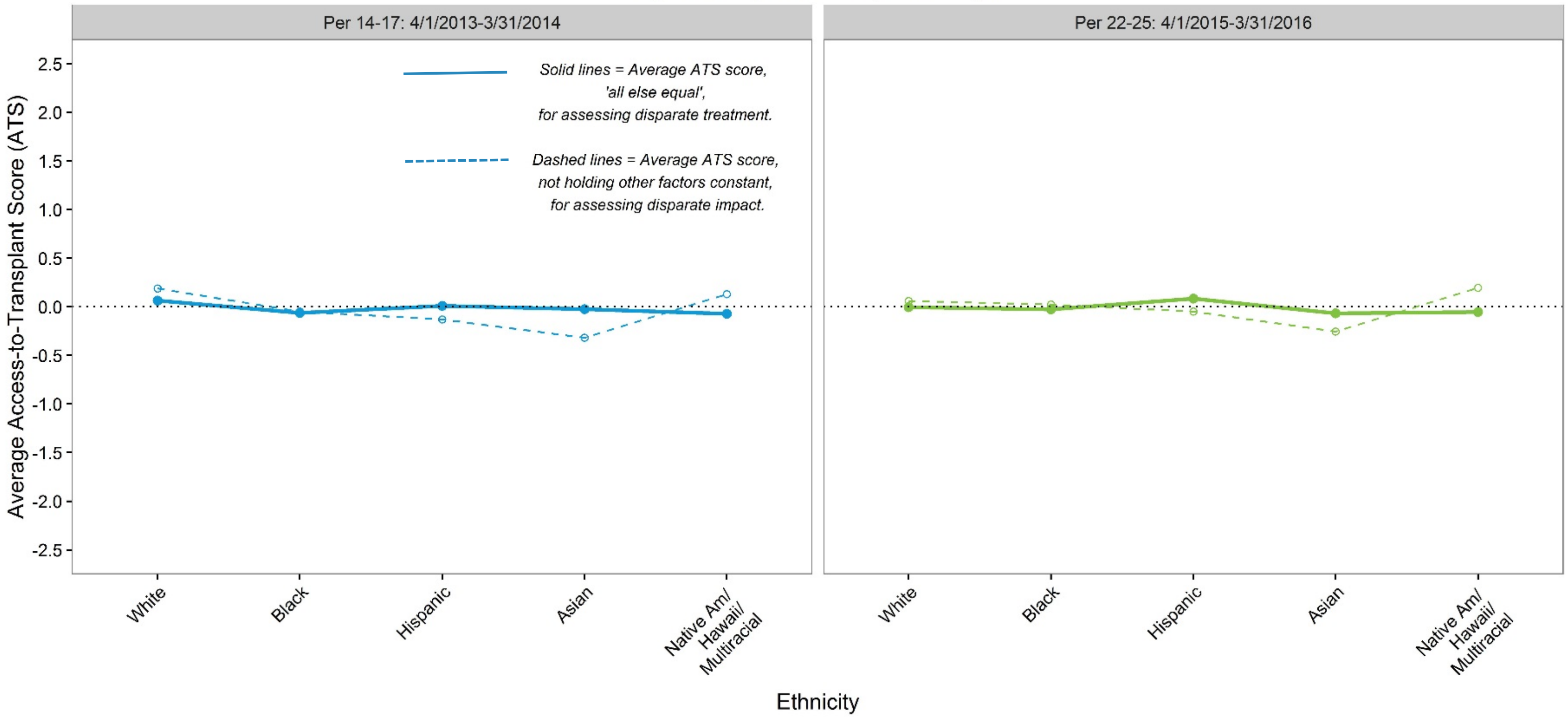
Tracking Equity by Candidate Ethnicity, Jan 2010 – Mar 2016 (ceteris paribus: *“all else equal”)*



As shown in Figure 4, **Figure 14** echoes that relative to other factors, the variability in ATS scores by ethnicity, all else equal, is very small. On average, this measure of variation decreased 18% from 0.074 to 0.061, suggesting a small improvement in equity with respect to allocation of kidneys by ethnicity.

Risk-adjusted Equity by Candidate Ethnicity, Pre vs. Post-KAS (ceteris paribus: *"all else equal")*

Figure 15: Average Access-to-Transplant Score (ATS) by Candidate Ethnicity, Pre (2014Q2) vs. Post (2016Q1) KAS



All else equal, the average ATS scores by candidate ethnicity varied little (**Figure 15**, **solid lines**) both pre and post-KAS. A slight post-KAS increase in ATS was observed for Black candidates, from -0.06 to -0.03, a difference that translates into an expected waiting time change from approximately 5.07 years to 4.97 years (Figure 47), a 30-day reduction. Average ATS decreased slightly for Whites, from 0.06 to -0.003 (60-day MWT increase); and a slight increase for Hispanics, from 0.01 to 0.09 (71 day MWT reduction). The flatness of the solid green line suggests that once listed in active status, the kidney allocation system contains little if any *disparate treatment* of candidates based on ethnicity. However, it is possible that some groups may still experience a *disparate impact* (assessed by **dashed lines**) due to associations between ethnicity and other factors. For example, Asian candidates tend to more often have (difficult-to-match) blood type B, and are also more often registered at transplant centers in DSAs with longer waiting times. When evaluating equity in organ allocation, it is essential to consider risk-adjusted measures that assess potential disparate treatment as well as unadjusted measures to assess potential disparate impact[1].

Traditional Ways of Assessing Equity, by Candidate Ethnicity

Figure 16: Waitlist (WL) Percent versus Transplant (TX) Percent by Recipient Ethnicity, Pre- vs. Post-KAS

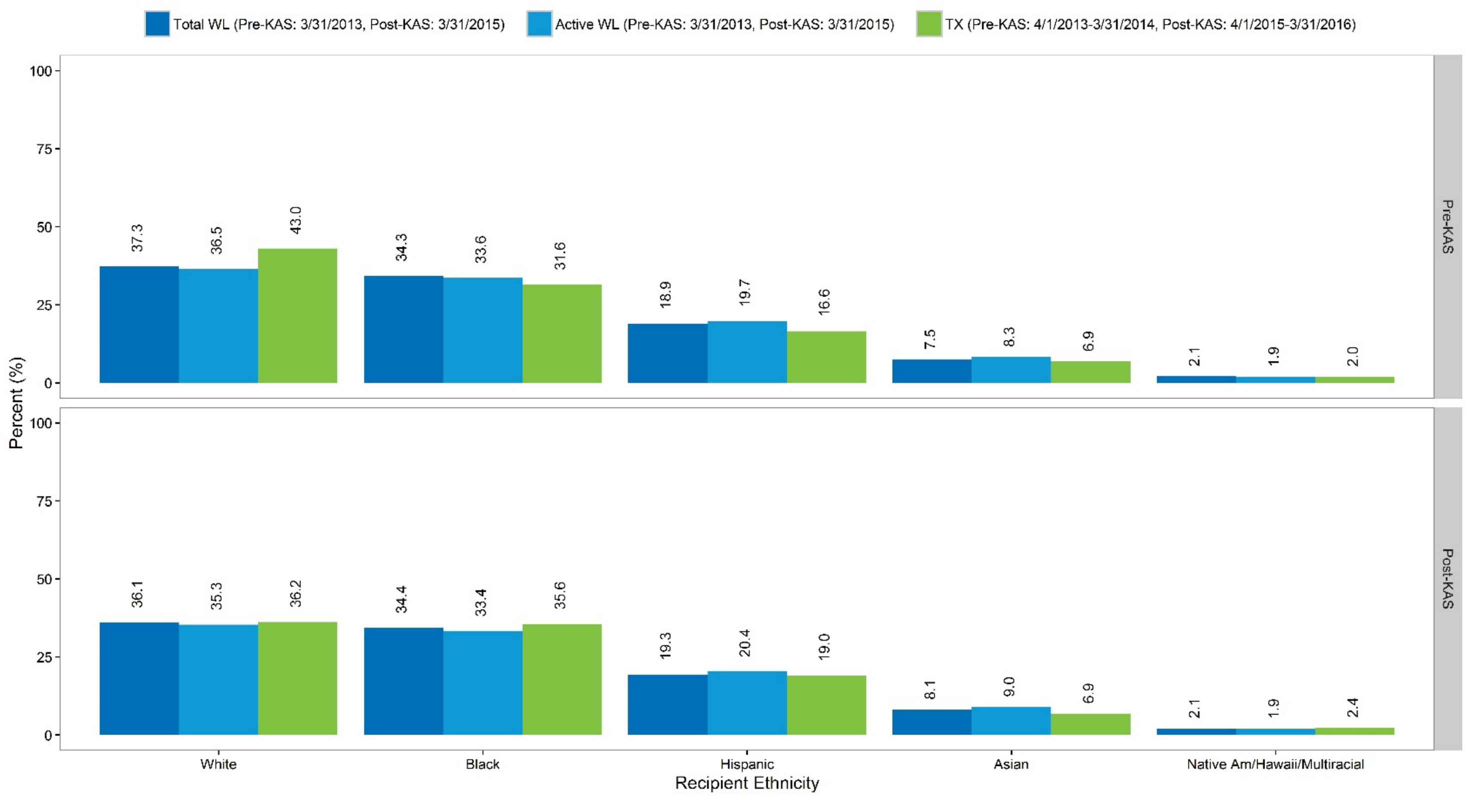
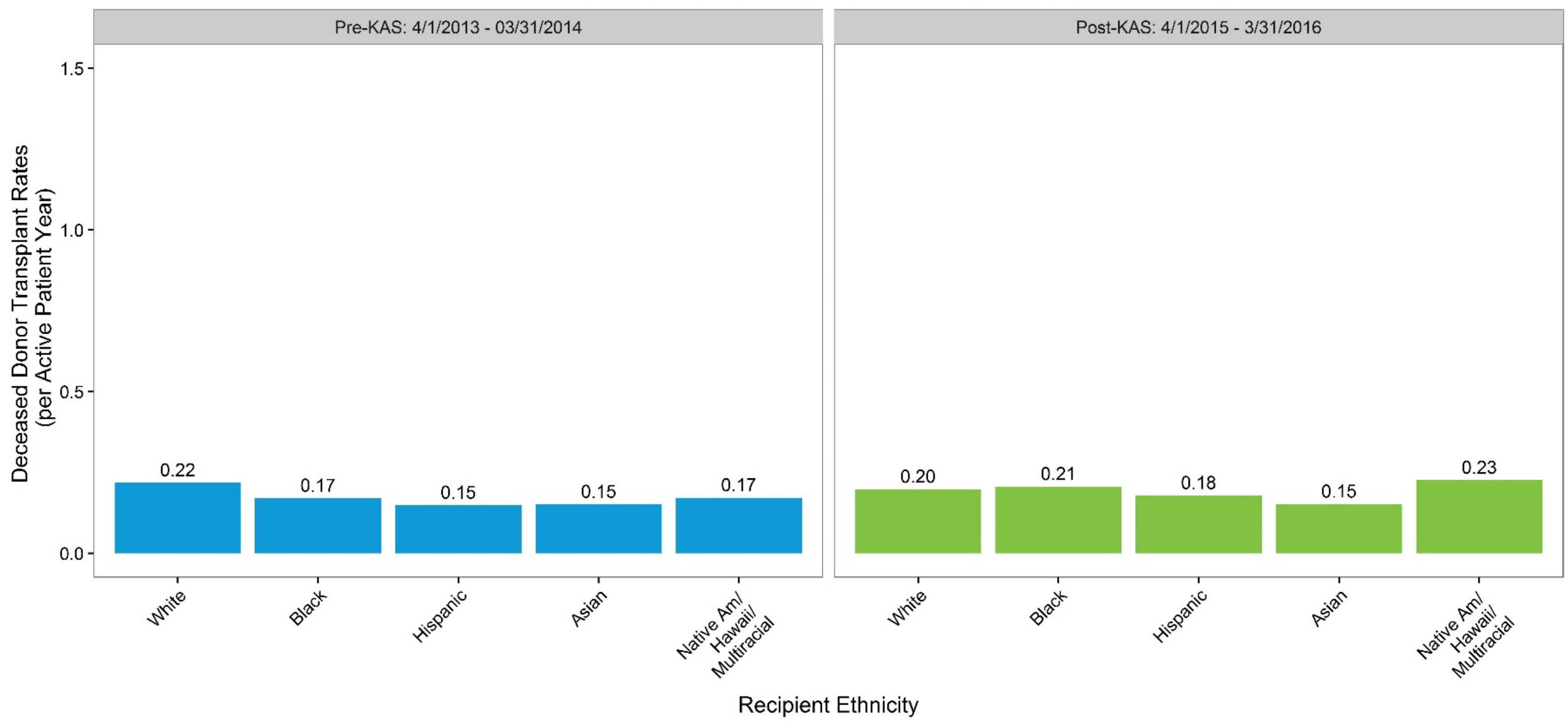


Figure 16 reveals a post-KAS decrease in the percentage of transplants going to White recipients and an increase for both Black and Hispanic patients. After KAS, the proportions of transplants by ethnic groups is more comparable to their proportion of the waiting list, suggesting increased equity and less potential disparate impact. Asians are still slightly underrepresented among recipients compared to their representation on the waiting list, however. These findings, as well as those in Figure 17, highlight the importance of including both risk-adjusted and non-adjusted analyses when tracking equity. For example, the substantial increase in access to Black patients from 31.6% to 35.6%, is observed here but is barely perceptible in the risk-adjusted ("all else equal") approach (Figure 15, solid lines), most likely because that approach excludes variation in transplant access due to waiting time accumulated prior to listing (i.e., time on dialysis), which is a factor responsible for the increase in transplants to Black patients (who tend to have more years of accumulated dialysis time when listed).

Figure 17: Deceased Donor Transplant Rates Per Active Patient Year by Recipient Ethnicity,
Pre-KAS: 4/1/2013 - 3/31/2014 vs. Post-KAS: 4/1/2015 - 3/31/2016



Like Figure 16, **Figure 17** also shows a substantial post-KAS increase in access to transplants, as measured by the deceased donor transplant rate, for Black and Hispanic candidates. Since transplant rates are much more similar between White and Black patients after KAS, these results suggest KAS has improved equity in access by ethnicity, at least to some degree. However, as seen in Figure 16, Asian candidates tend to receive fewer transplants relative to their composition on the waiting list. “All else equal,” access to transplants is very similar for Asians compared to other ethnicities (Figure 15). However, “all else” is not equal, as Asians tend more often to be blood type B and listed in high MWT DSAs, leading to a lower transplant rate of about 0.15 compared to the national average of approximately 0.20.

In summary, Figures 14-17 suggest that among active, waitlisted patients, there is little to no *disparate treatment* under KAS by ethnicity. However, some degree of *disparate impact* by ethnicity – due to associations between ethnicity and other factors, such as blood type – is apparent, in particular for Asian candidates who continue to receive transplants at a lower rate even post-KAS.

Equity in Access by Candidate's Donor Service Area (DSA)

Tracking Equity by Candidate DSA, Jan 2010 – Mar 2016 (ceteris paribus*: "all else equal")*

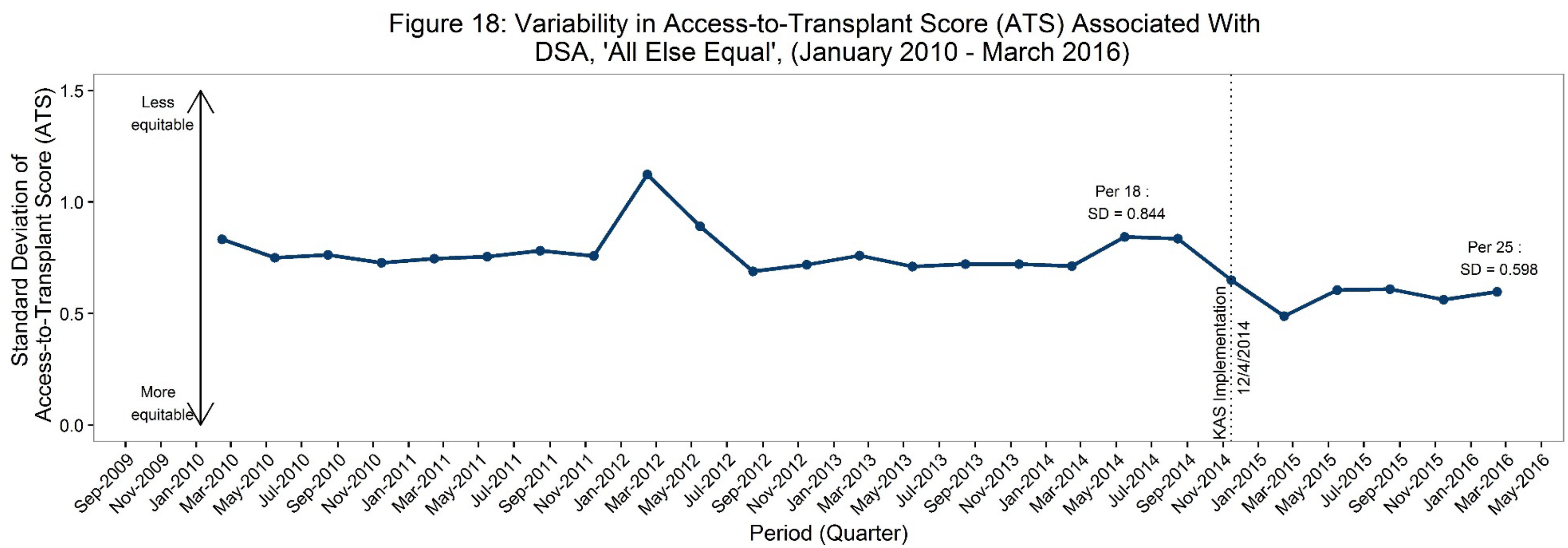


Figure 18 reveals that variation in access-to-transplant by donor service area (DSA) decreased moderately post-KAS, all else equal. On average, the standard deviation dropped 27% from 0.78 to 0.57. Though reducing geographic differences in access to transplantation was not one of KAS's central goals, the new system includes broader sharing of high KDPI kidneys as well as kidneys for highly sensitized patients, which has decreased the percentage of kidneys being transplanted "locally" (in same DSA as recovery) and, in turn, appears to have moderately increased equity by DSA. Still, as shown in Figure 4, the DSA of a patient's transplant center is associated with the highest degree of disparity in access to transplant among all ten factors evaluated.

Risk-adjusted Equity by Candidate DSA, Pre vs. Post-KAS (ceteris paribus: *"all else equal")*

Figure 19: Average Access-to-Transplant Score (ATS) by DSA, 'All Else Equal', Post (4/1/15-3/31/16) KAS

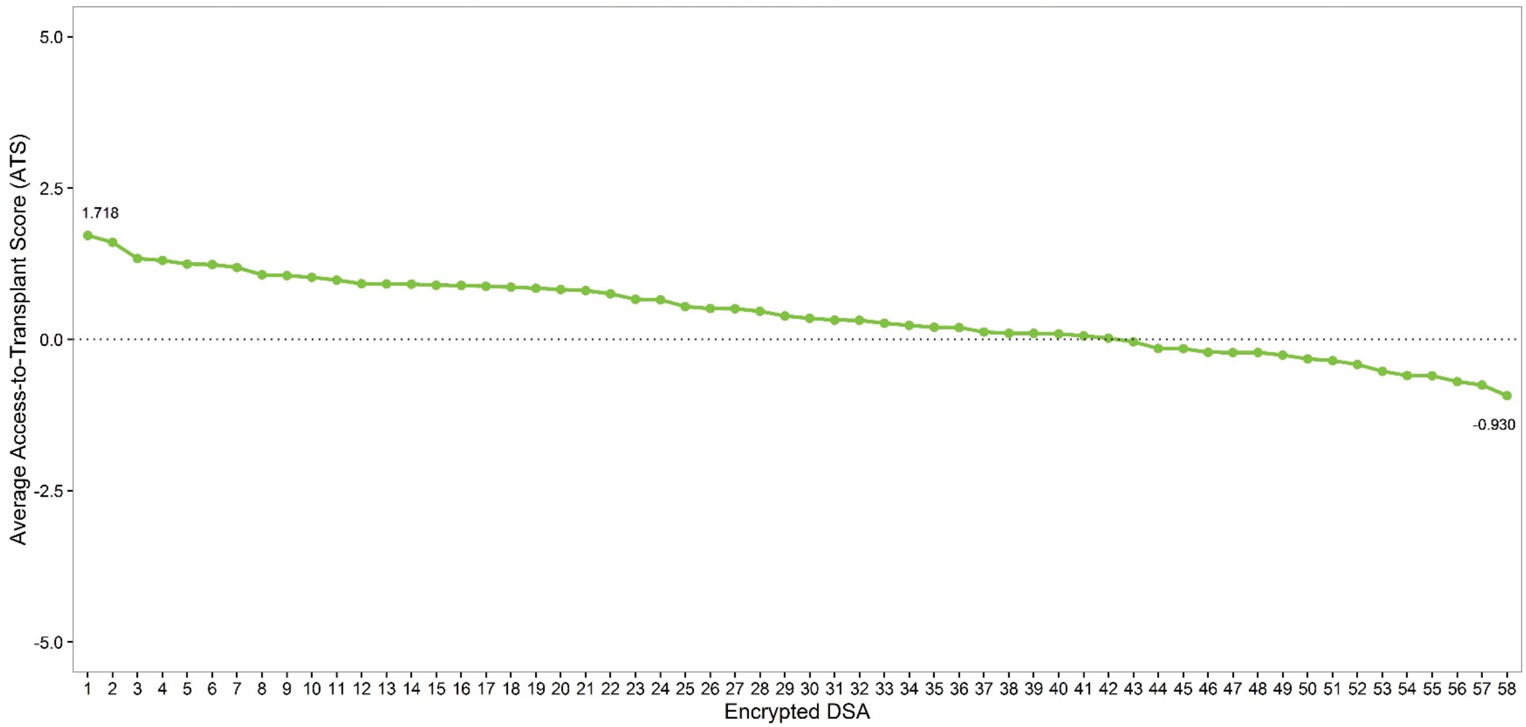


Figure 19 shows that all else equal, the average ATS score for candidates varied from -0.93 to 1.72, reflecting a range in DSA median waiting times of approximately 7.6 years to less than two years (Figure 47). Though Figure 19 reveals substantial DSA-to-DSA variability in average ATS scores, the variability is less than it was prior to KAS.

For reference, DSAs can be identified in **Appendix II**. Since ATS scores take into account transplants of locally recovered kidneys as well as imported kidneys, and are affected by both local supply/demand dynamics and center acceptance practices, they should not be considered a measure of OPO performance. Rather, these scores reflect differential patient experience by DSA due to several underlying factors.

Traditional Ways of Assessing Equity, by Candidate DSA

Figure 20a: Waitlist (WL) Percent versus Transplant (TX) Percent by DSA, Pre- vs. Post-KAS

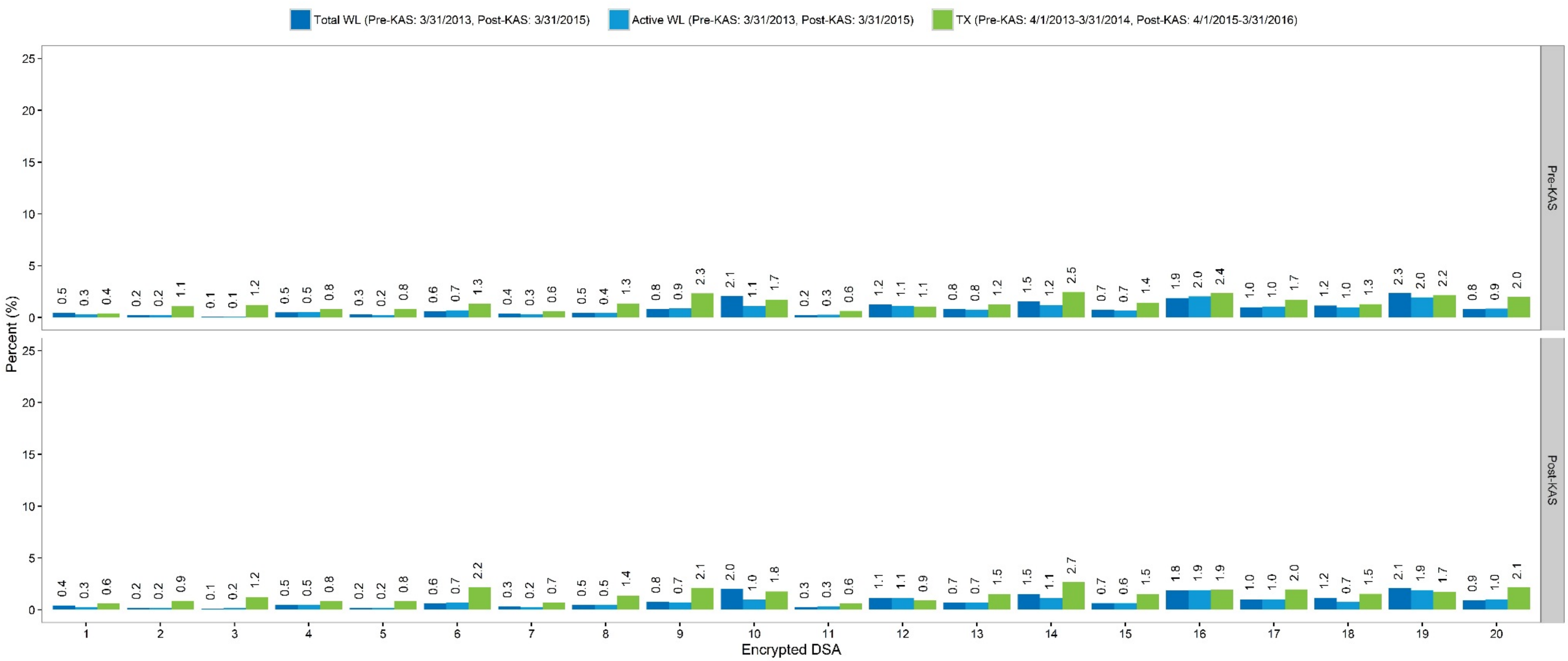


Figure 20a compares the percentage of candidates listed in each DSA with the percentage of deceased donor kidney transplants occurring in each DSA. Transplants include those from kidney donors recovered in the DSA as well as imported kidneys. Figure 20a includes statistics from DSAs numbered 1-20, ordered from highest to lowest in terms of average ATS (Figure 19). It is notable that a comparison of the percentage of the nation's transplants occurring in a DSA might be very comparable to the percentage of the nation's candidates being listed in the DSA, suggesting equity; however, an apparent disparity may emerge when only including active candidates (e.g., encrypted DSA #10). It is important to recognize that this approach for assessing equity by DSA is not "risk-adjusted;" in other words, it does not take into account potential differences in the mix of patients (e.g., by blood type, CPRA, time on dialysis, etc.) registered for transplant in each DSA.

Figure 20b: Waitlist (WL) Percent versus Transplant (TX) Percent by DSA, Pre- vs. Post-KAS

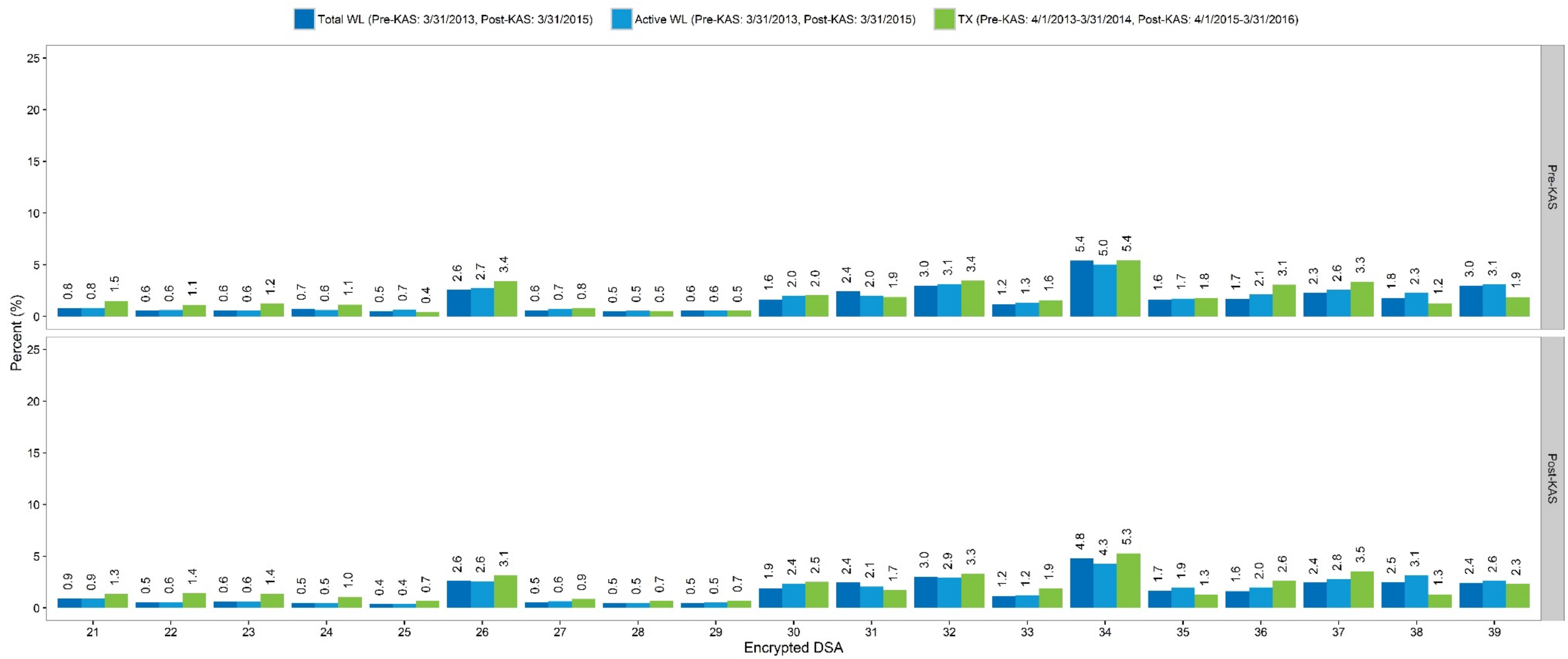


Figure 20b includes statistics from DSAs numbered 21-39, ordered from highest to lowest in terms of average ATS (Figure 19).

Figure 20c: Waitlist (WL) Percent versus Transplant (TX) Percent by DSA, Pre- vs. Post-KAS

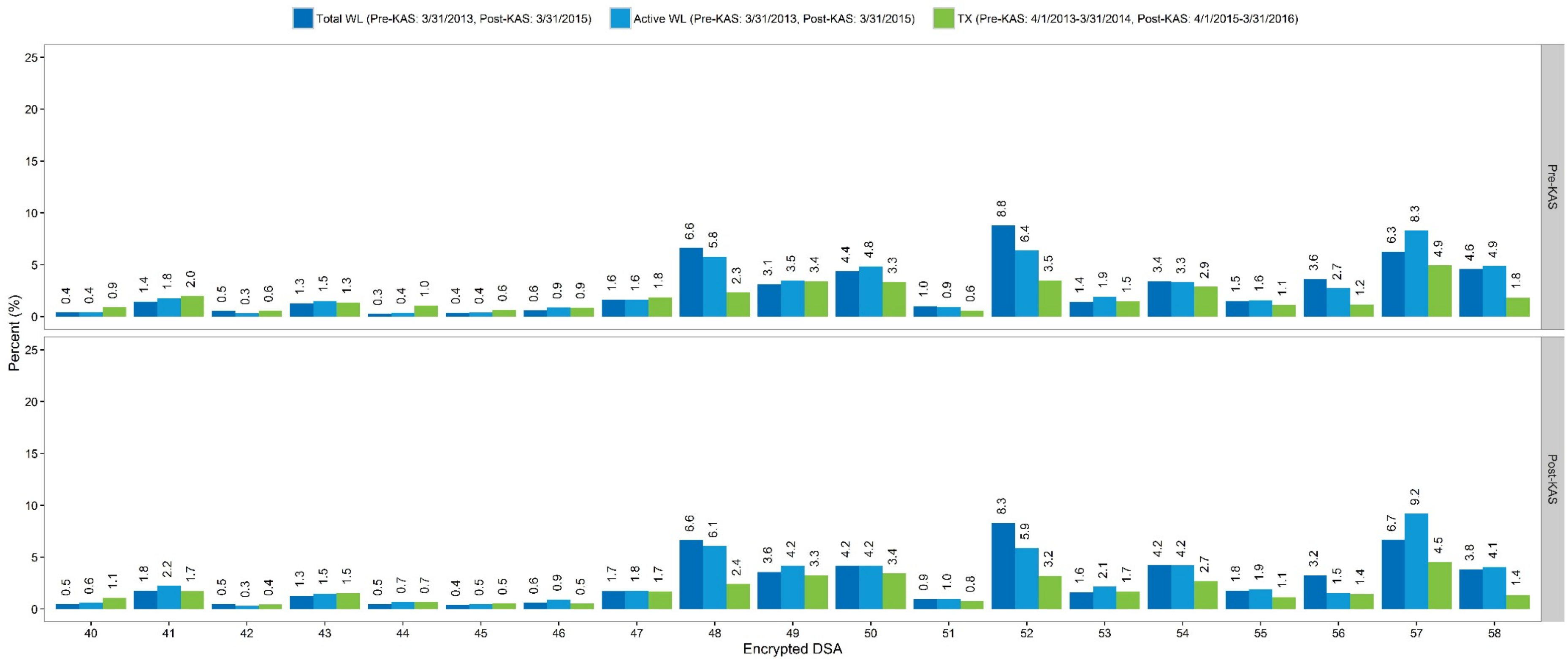


Figure 20c includes statistics from DSAs numbered 40-58, ordered from highest to lowest in terms of average ATS (Figure 19).

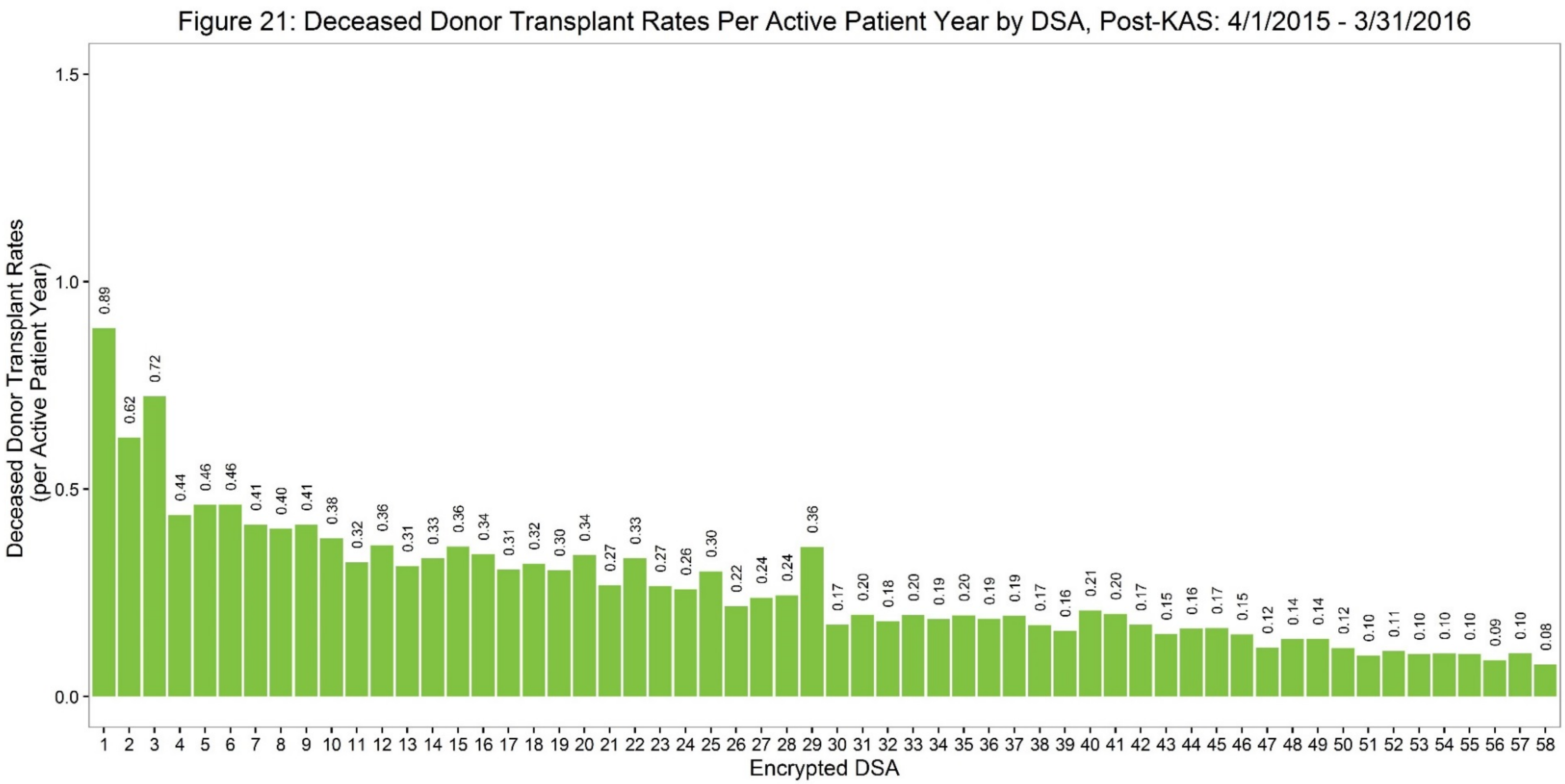


Figure 21 shows the number of deceased donor transplants per active patient-year on the waiting list, by DSA. The DSAs are numbered 1-58, from highest to lowest average ATS score (Figure 19). Figure 21 shows that generally speaking, transplant rates are higher for DSA's with higher average ATS scores, and vice versa. DSAs for which the pattern differs between Figure 19 and Figure 21 are those with disproportionate numbers of candidates having characteristics associated with short or long waiting times (e.g., blood type B; high CPRA). Among the 58 DSAs, the transplant rate ranges from 0.08 to 0.89, an 11-fold difference.

Though geographic variability in access to kidney transplants decreased modestly after KAS (Figure 18), both the risk-adjusted and traditional analyses suggest substantial variability in timeliness of kidney transplant exists across DSAs. Since transplant rates take into account transplants of locally recovered kidneys as well as imported kidneys, and are affected by both local supply/demand dynamics and center acceptance practices, they should not be considered a measure of OPO performance.

Equity in Access by Candidate Blood Type (ABO)

Tracking Equity by Candidate Blood Type, Jan 2010 – Mar 2016 (ceteris paribus: *"all else equal")*

Figure 22: Variability in Access-to-Transplant Score (ATS) Associated With Candidate ABO, 'All Else Equal', (January 2010 - March 2016)

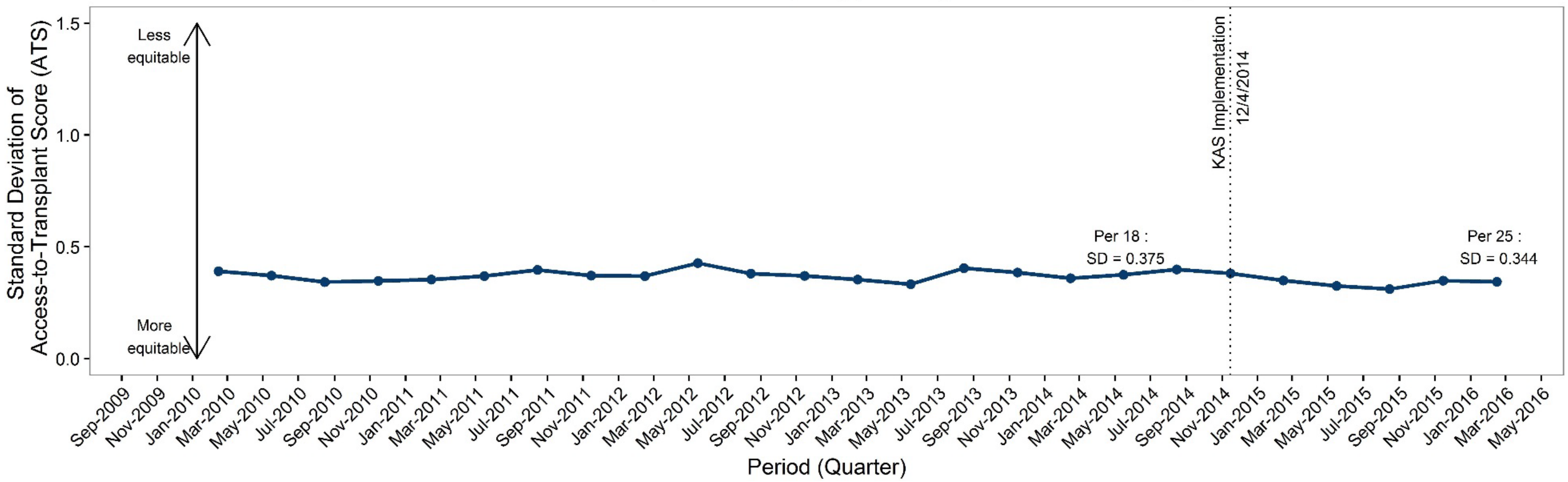


Figure 22 reveals little apparent change over time in the degree of disparity in access to kidney transplantation by blood type, all else equal. The average of the quarterly standard deviations was 0.37 pre-KAS and 0.34 post-KAS, suggesting a slight improvement in equity by blood type with the new policy. This slight improvement may be attributable to the expanded access to A2 or A2B donor subtype kidneys, which are prioritized to eligible blood type B candidates under KAS. However, relatively few centers have identified candidates as eligible for this expanded pool of kidneys, suggesting room for growth that could yield improvements in equity by blood type, the factor associated with the 3rd highest degree of disparities in this study (Figure 4).

Risk-adjusted Equity by Candidate Blood Type, Pre vs. Post-KAS (ceteris paribus: *"all else equal")*

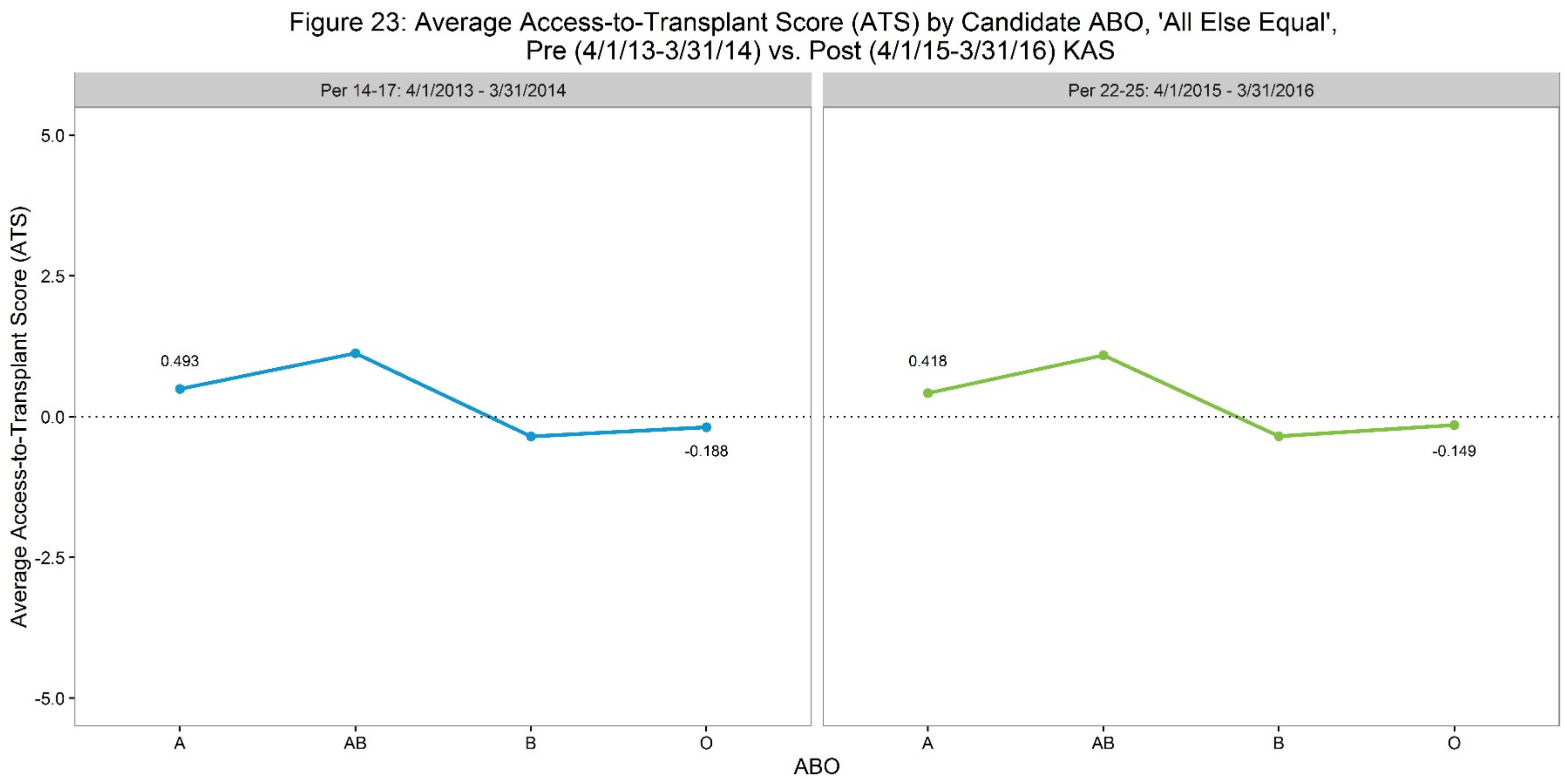


Figure 23 reveals that all else equal, blood type AB candidates have higher average ATS scores, which are associated with shorter expected time to transplant, compared to other blood types. Blood type A patients tend to have above average scores, while blood type B and O candidates tend to have below average scores. Blood type B patients have the lowest access to transplantation according to average ATS score. This average ATS score by blood type relationship changed very little after KAS.

Traditional Ways of Assessing Equity, by Candidate Blood Type

Figure 24: Waitlist (WL) Percent versus Transplant (TX) Percent by Recipient Blood Type, Pre- vs. Post-KAS

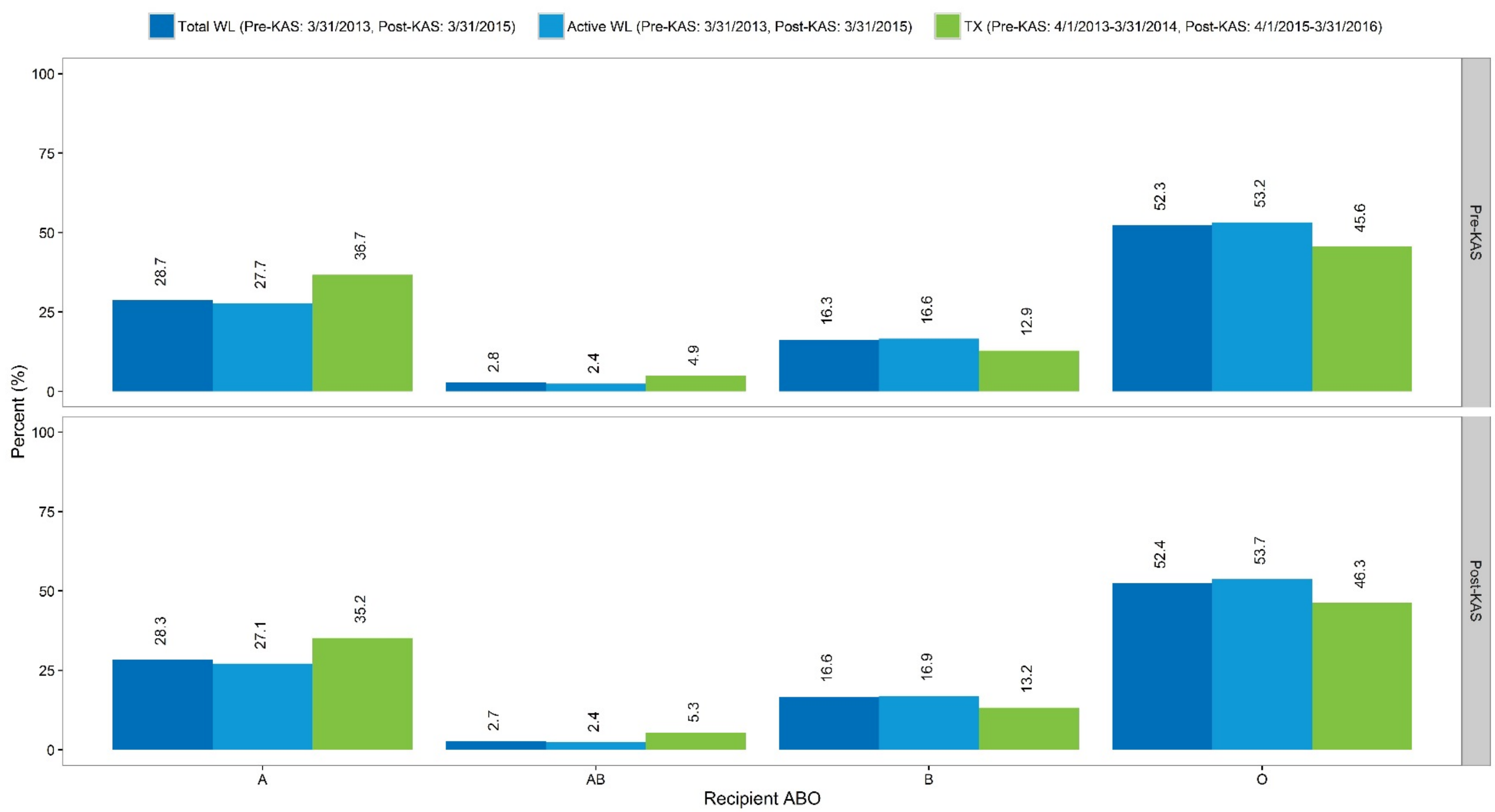
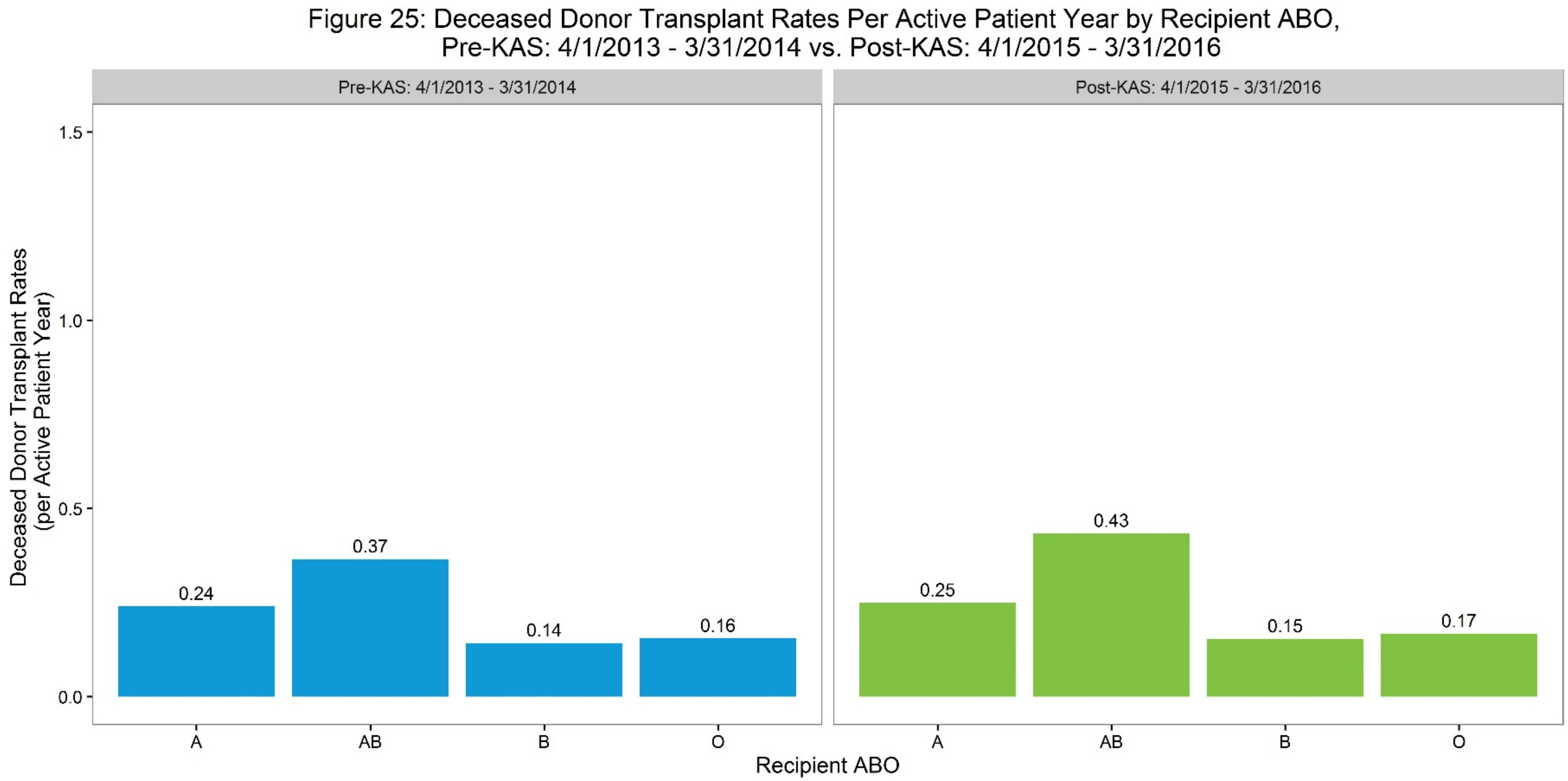


Figure 24 shows that blood type A and AB candidates received a higher proportion of transplants compared to their percentage of the waiting list, and vice versa for blood type B and O candidates. This pattern changed little with KAS.



As in Figures 23-24, transplant rates (Figure 25) show that blood type B and O patients have reduced access to transplants than other blood types. Notably, transplant rates increased post-KAS for all blood types since the number of donors recovered and transplants performed nationally have both been increasing in the past few years.

Equity in Access by Candidate Diagnosis

Tracking Equity by Candidate Diagnosis, Jan 2010 – Mar 2016 (ceteris paribus: *"all else equal")*

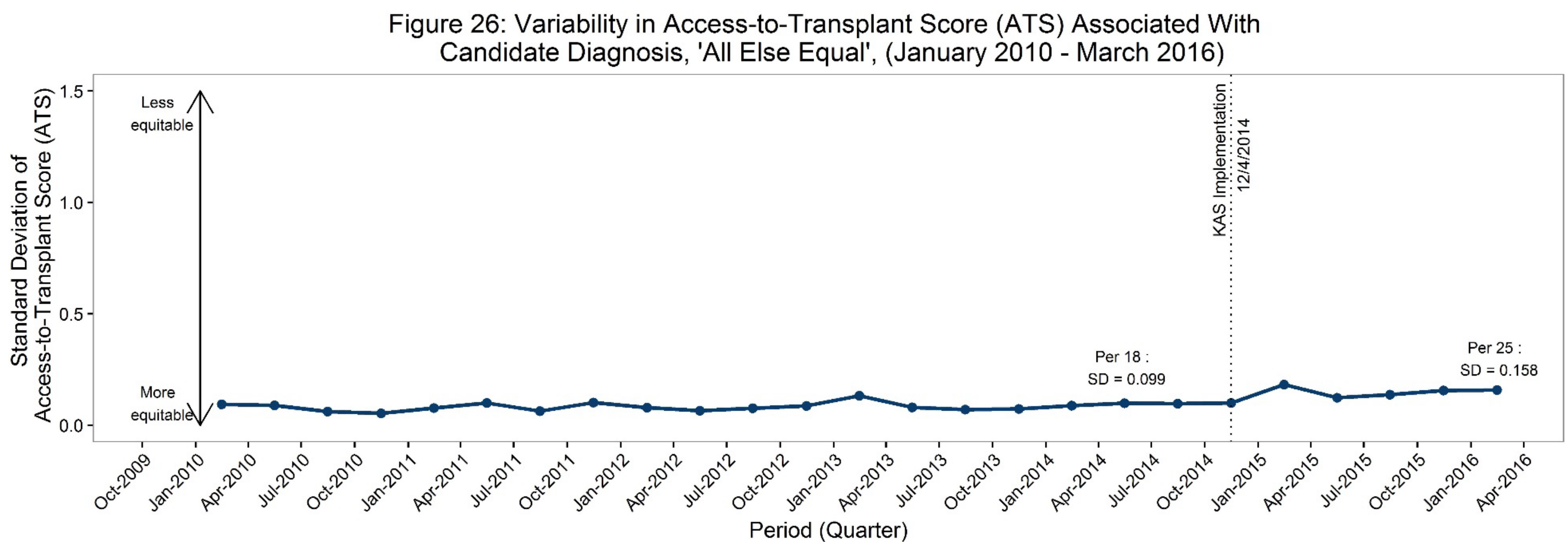
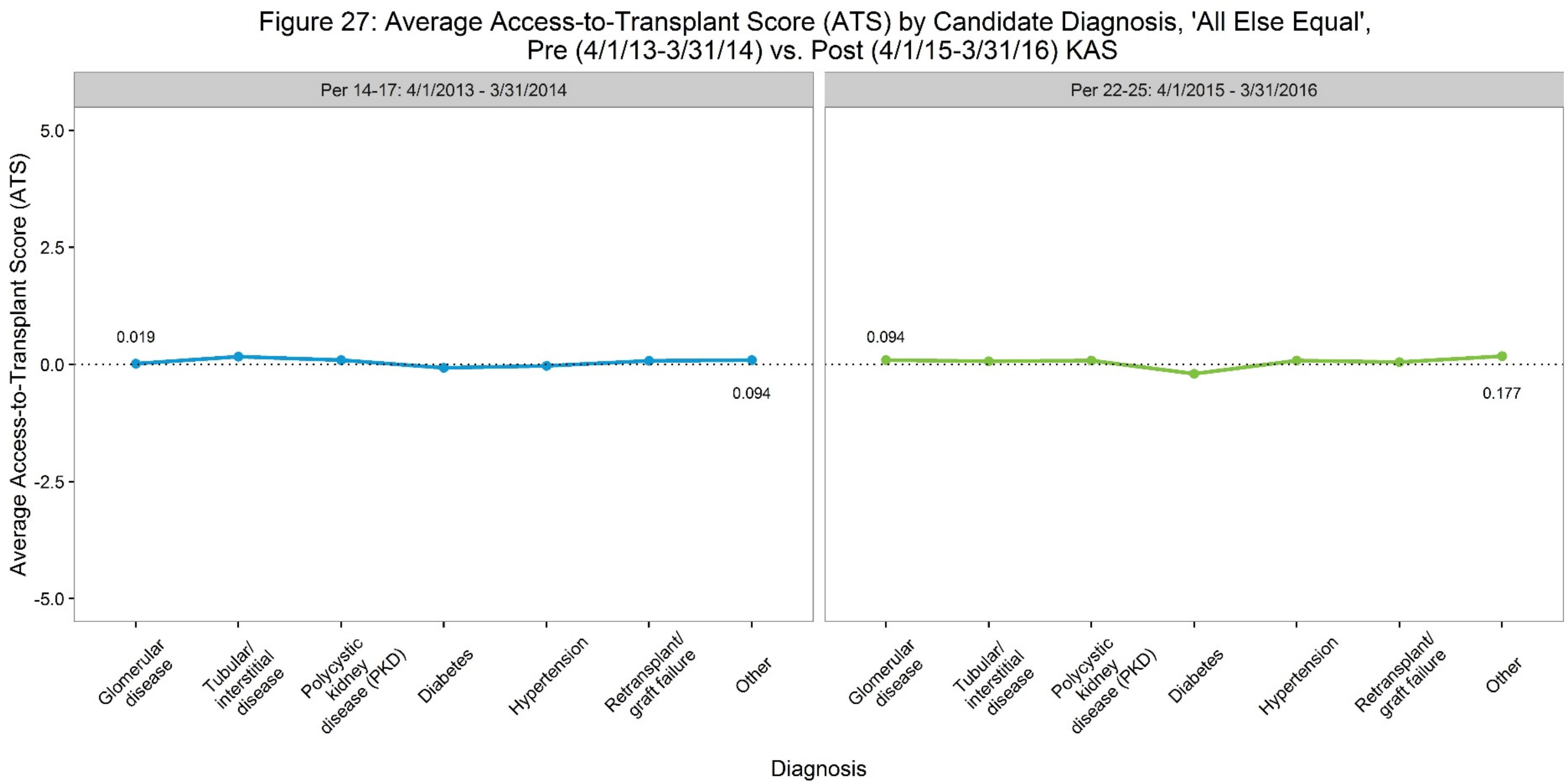


Figure 26 shows an increase in the degree of disparity in access to kidney transplantation by candidates' renal failure diagnosis, all else equal. After KAS, the average of the quarterly standard deviations was 0.15, which is still relatively small compared to DSA, CPRA, and blood type (Figure 4), but greater than 0.08 from before KAS. A decrease in transplants to patients with diabetes as primary diagnosis for renal failure (Figures 27-29) is the likely cause of this increase. Diabetic candidates, whose average post-transplant survival time is lower than for non-diabetics, tend to have higher EPTS scores and hence are less likely under KAS to receive high priority for a KDPI 0-20% kidney.

Risk-adjusted Equity by Candidate Diagnosis, Pre vs. Post-KAS (ceteris paribus: *"all else equal")*



All else equal, differences in access to transplant by candidate diagnosis are very small, both pre and post-KAS. **Figure 27** reveals a moderate decline in access for diabetic patients, whose average score dropped from -0.07 to -0.20, which translates to a relatively small increase in expected waiting time of about 3 months (Figure 47).

Traditional Ways of Assessing Equity, by Candidate Diagnosis

Figure 28: Waitlist (WL) Percent versus Transplant (TX) Percent by Diagnosis, Pre- vs. Post-KAS

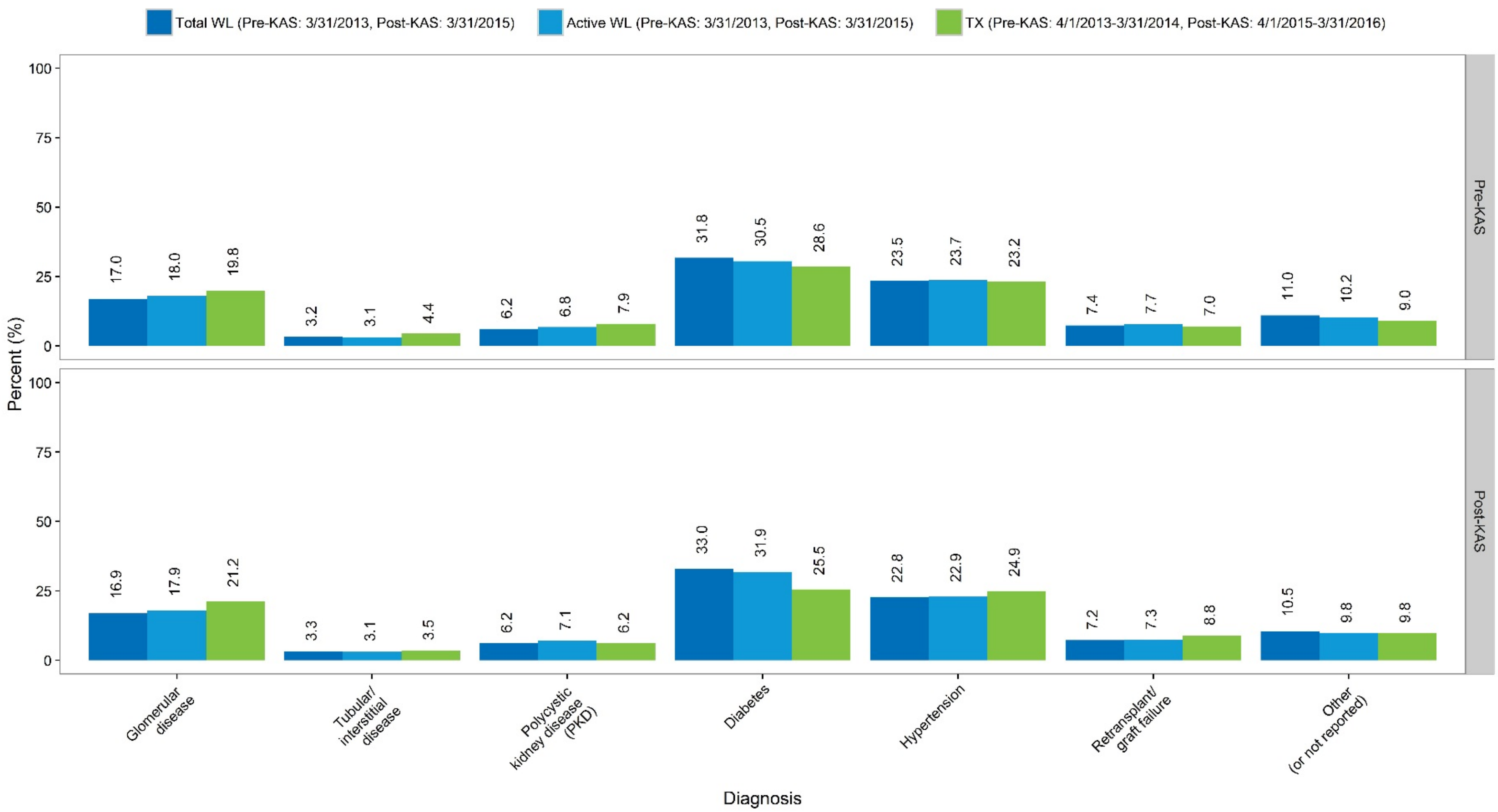
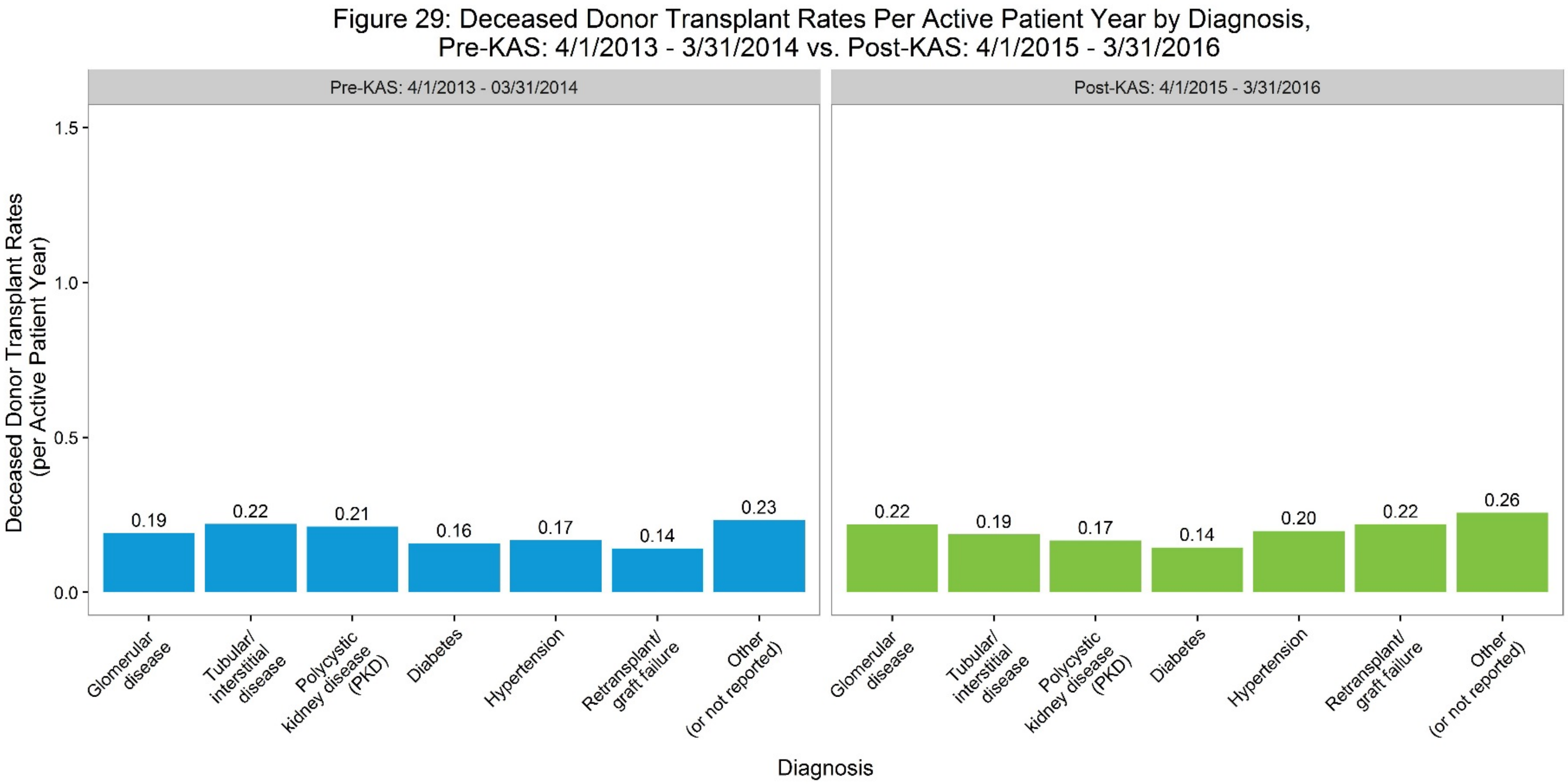


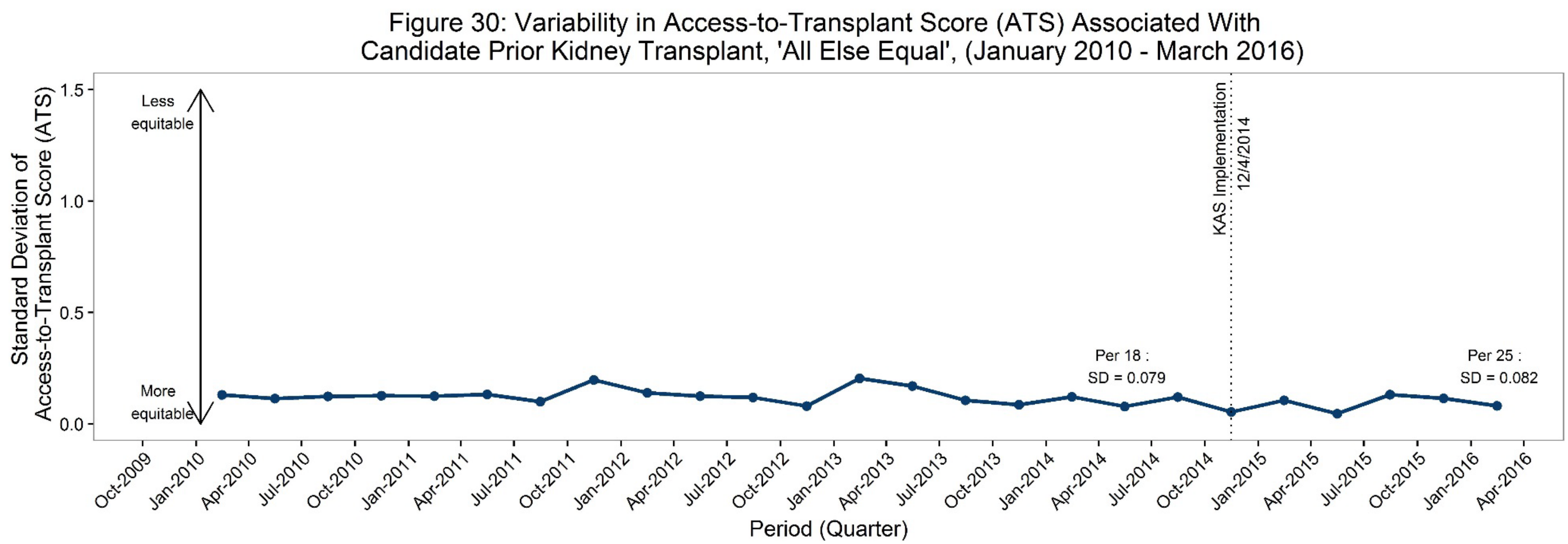
Figure 28 shows that nearly three-fourths of kidney candidates on the waiting list have either glomerular disease, diabetes, or hypertension as cause of renal failure. After KAS, a higher percentage of kidney transplants went to patients diagnosed with glomerular disease, hypertension, or graft failure from a previous transplant; a small percentage of kidney transplants went to patients with tubular/interstitial disease, PKD, or diabetes.



Differences in transplant rates by renal failure diagnosis are shown in **Figure 29**. Patients with glomerular disease receive transplants at a rate (0.22) substantially higher than diabetic (0.14) and PKD (0.17) patients under KAS. However, the very small differences in risk-adjusted ATS scores in Figure 27 suggest that the differences in transplant rates are at least partially attributable to associations between diagnosis and other factors that affect timeliness of transplant.

Equity in Access by Whether Candidate had a Previous Kidney Transplant

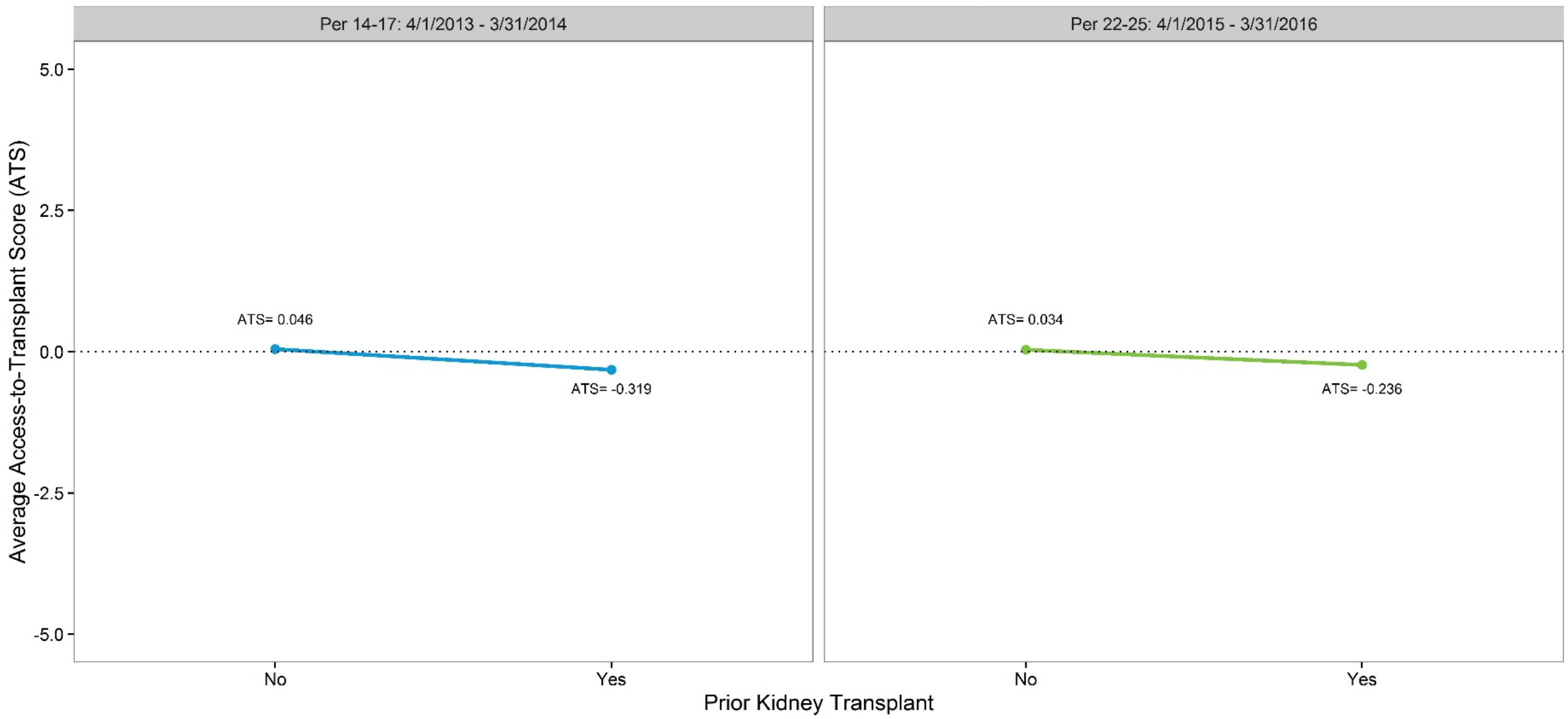
Tracking Equity by Prior Kidney Transplant, Jan 2010 – Mar 2016 (ceteris paribus: *"all else equal")*



All else equal, disparities in access to transplant by whether a candidate had a prior transplant decreased by about 25%, from an average standard deviation of 0.13 pre-KAS to 0.10 post-KAS (**Figure 30**).

Risk-adjusted Equity by Prior Kidney Transplant, Pre vs. Post-KAS (ceteris paribus*: "all else equal")*

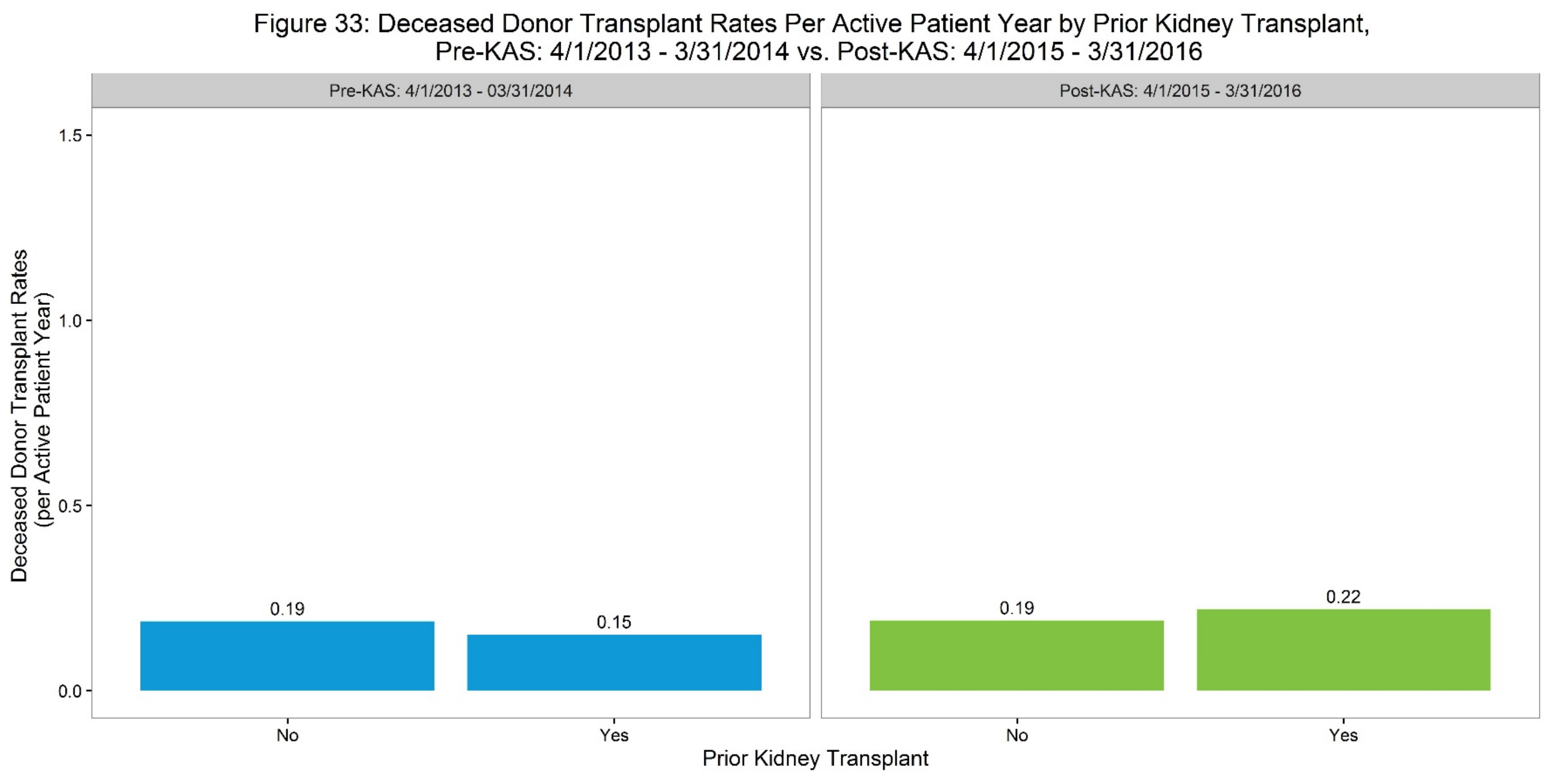
Figure 31: Average Access-to-Transplant Score (ATS) by Candidate Previous Kidney Transplant, 'All Else Equal', Pre (4/1/13-3/31/14) vs. Post (4/1/15-3/31/16) KAS



All else equal, differences in access to transplant by whether a candidate had a prior transplant are relatively small (**Figure 31**). However, both pre and post-KAS, candidates with a prior transplant had less access to transplant compared to patients who had not had a prior transplant. This difference diminished somewhat after KAS. Candidates who have had a prior transplant are more likely to be highly sensitized than candidates without a prior transplant. However, these risk-adjusted results isolate the association between prior transplant and access to transplant, all else equal, including CPRA. For example, for two patients with identical CPRA (e.g., 95%), identical blood type (e.g., A), and all other modeled factors the same, but only differing in that one patient had a prior transplant and the other had not, the patient without having the prior transplant has moderately higher access to transplant. The ATS difference of 0.27 translates into an expected waiting time difference of just over 200 days (Figure 47).

Traditional Ways of Assessing Equity, by Prior Kidney Transplant

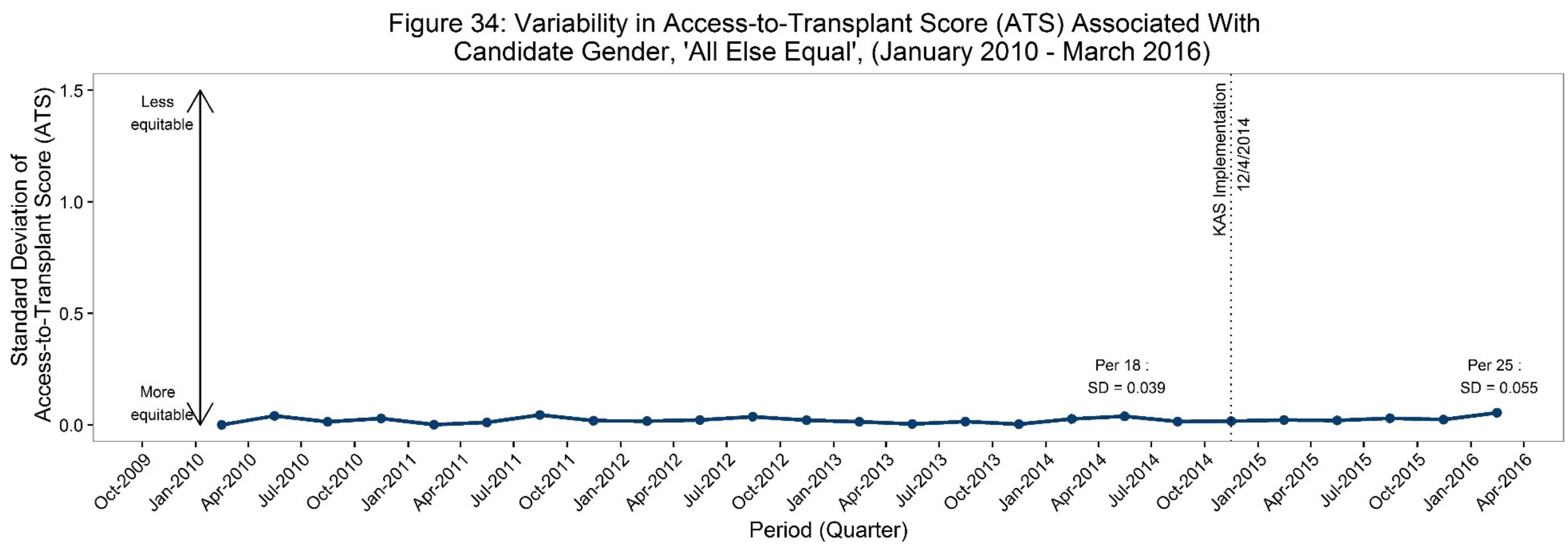
Figure 32 reveals that about 15% of candidates on the kidney waiting list have had a prior kidney transplant. The percentage of transplants going to prior recipients increased after KAS, from 12.5% to 15.2%. This is likely attributable to the increase in transplants to highly sensitized patients under KAS. Post-KAS, the percentage of transplants going to prior recipients (15.2%) is slightly higher than their percentage of the active waiting list (14.6%). Conclusions drawn from these unadjusted, post-KAS results may differ from the risk-adjusted findings in Figure 31, which show that all else equal, prior recipients have lower access to transplant. This discordance in findings highlights the importance of evaluating both traditional (which does not adjust for factors highly associated with prior transplant, like CPRA) and risk-adjusted analyses (which adjusts for CPRA and other factors) for a more holistic understanding of equity with respect to various candidate factors.



Differences in transplant rates by whether candidates had a prior kidney transplant or not are shown in **Figure 33**. Transplant rates increased by about 47% post-KAS for patients with a prior kidney transplant. This is ostensibly due to the increased number of transplants going to highly sensitized patients, since prior transplant is one of the biological mechanisms by which patients get sensitized. However, as shown in Figure 31, all else equal (including CPRA), patients with a prior kidney transplant are actually less likely to receive a transplant than those who have not.

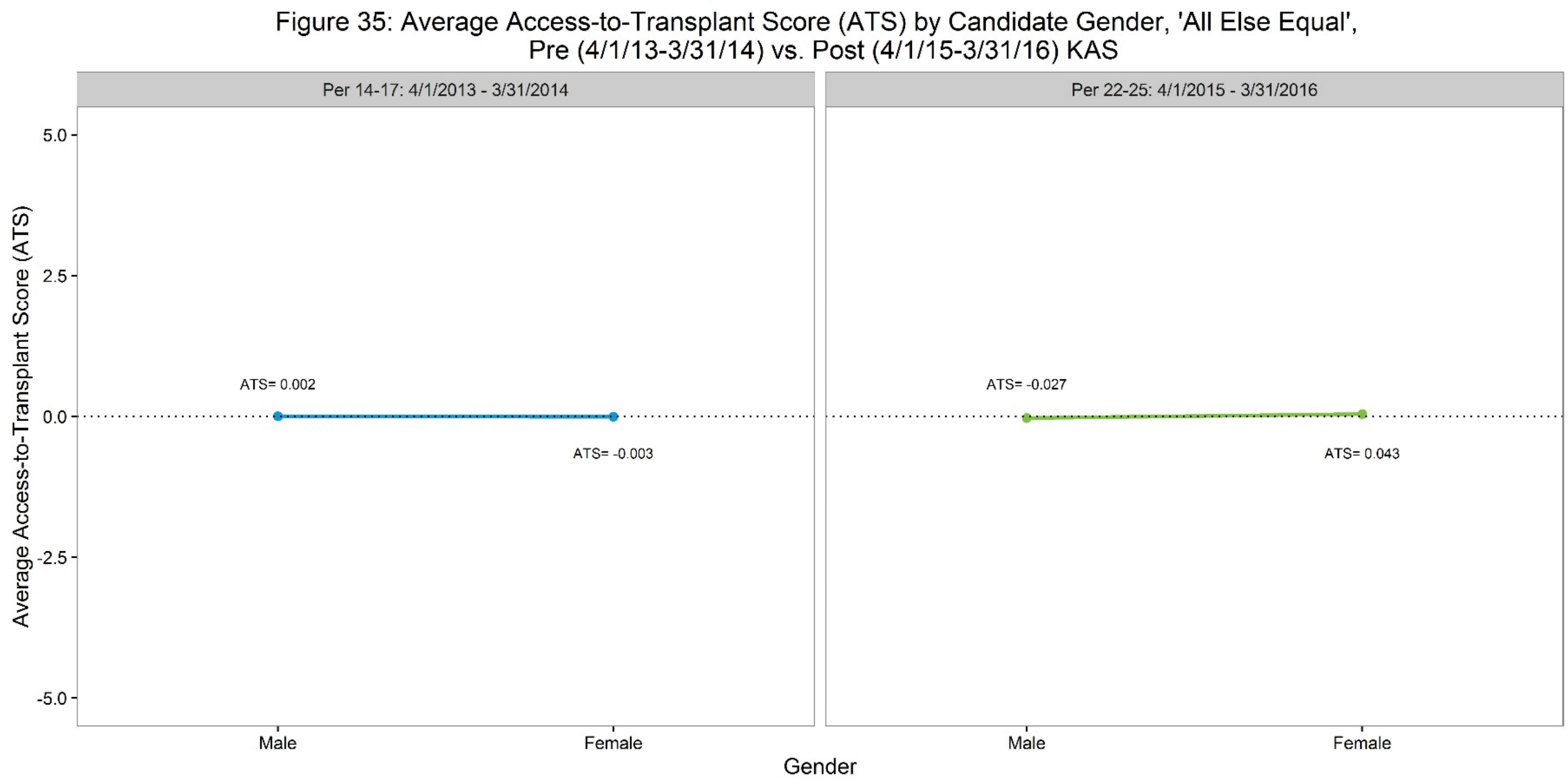
Equity in Access by Candidate Gender

Tracking Equity by Candidate Gender, Jan 2010 – Mar 2016 (ceteris paribus: *"all else equal")*



All else equal, disparities in access to transplant by candidate gender have been very low (standard deviation of between 0.01 and 0.05) and have remained very low after KAS (**Figure 34**). Gender was found to have the third lowest association with disparities in access to transplantation among all ten studied factors (Figure 4).

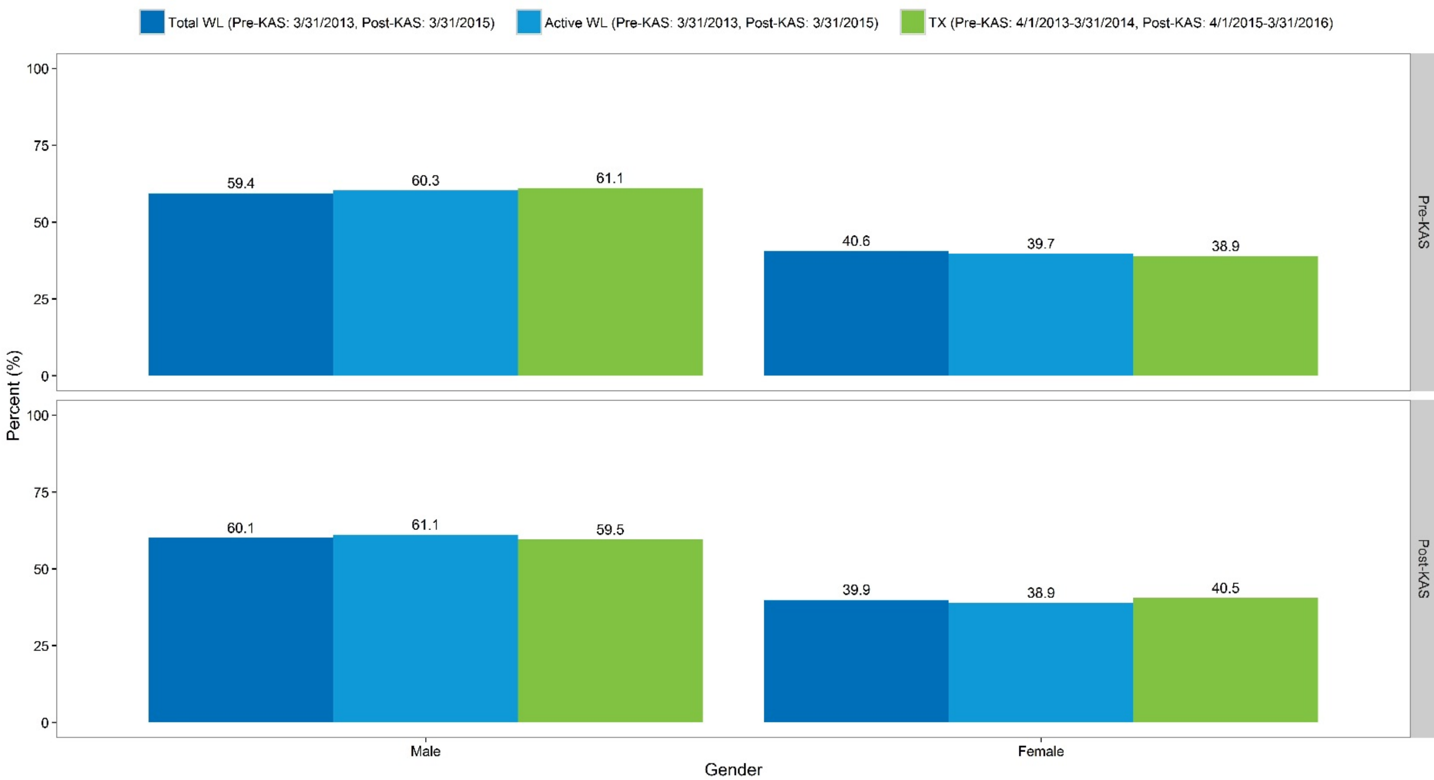
Risk-adjusted Equity by Candidate Gender, Pre vs. Post-KAS (ceteris paribus: *"all else equal")*



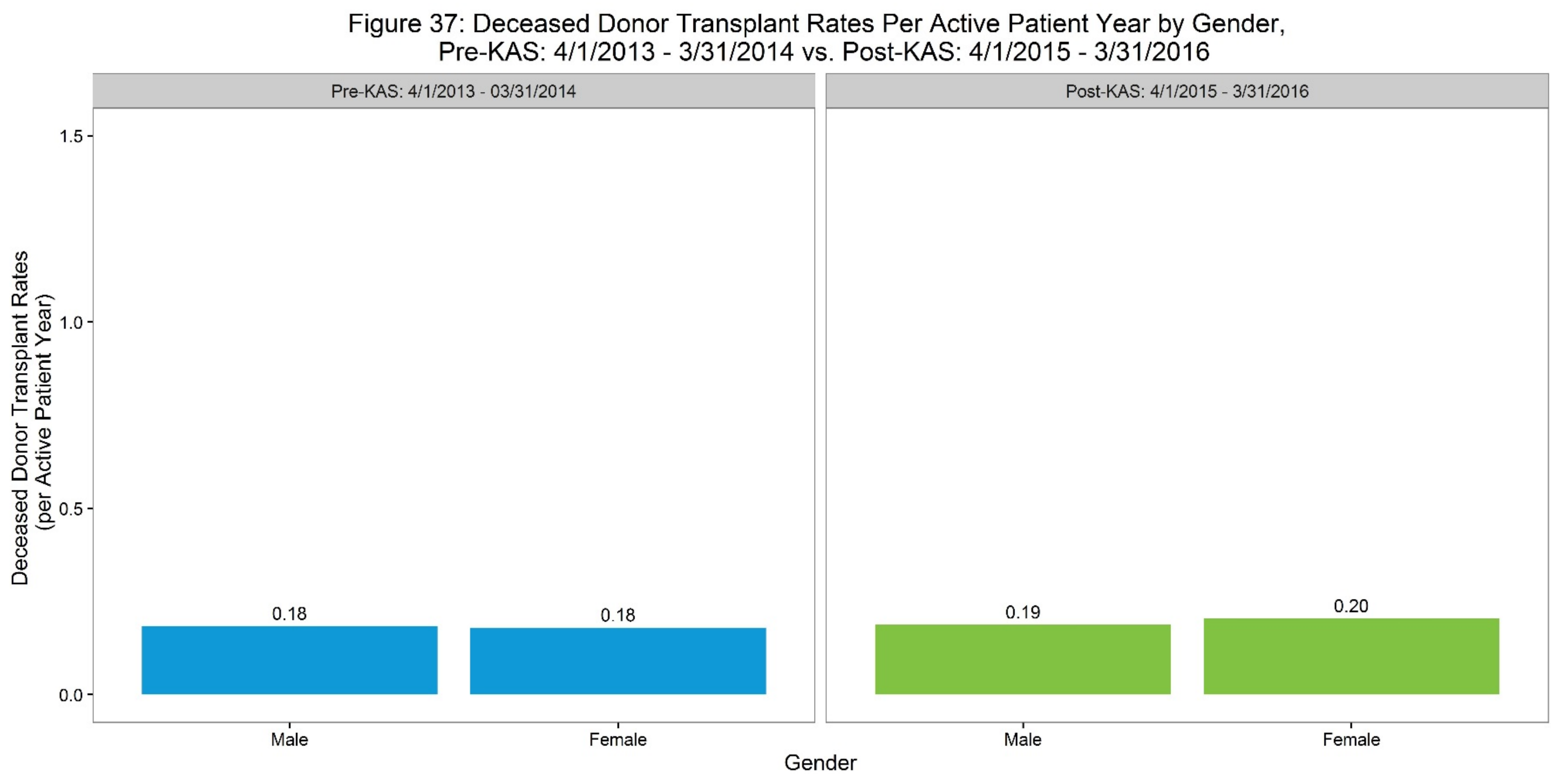
All else equal, differences in access to transplant by candidate gender are extremely small (**Figure 35**). An apparent, slightly elevated access to transplant for females compared to males in Figures 36 & 37 is likely attributable to gender differences in CPRA or other factors, which are adjusted for in Figure 35.

Traditional Ways of Assessing Equity, by Candidate Gender

Figure 36: Waitlist (WL) Percent versus Transplant (TX) Percent by Gender, Pre- vs. Post-KAS



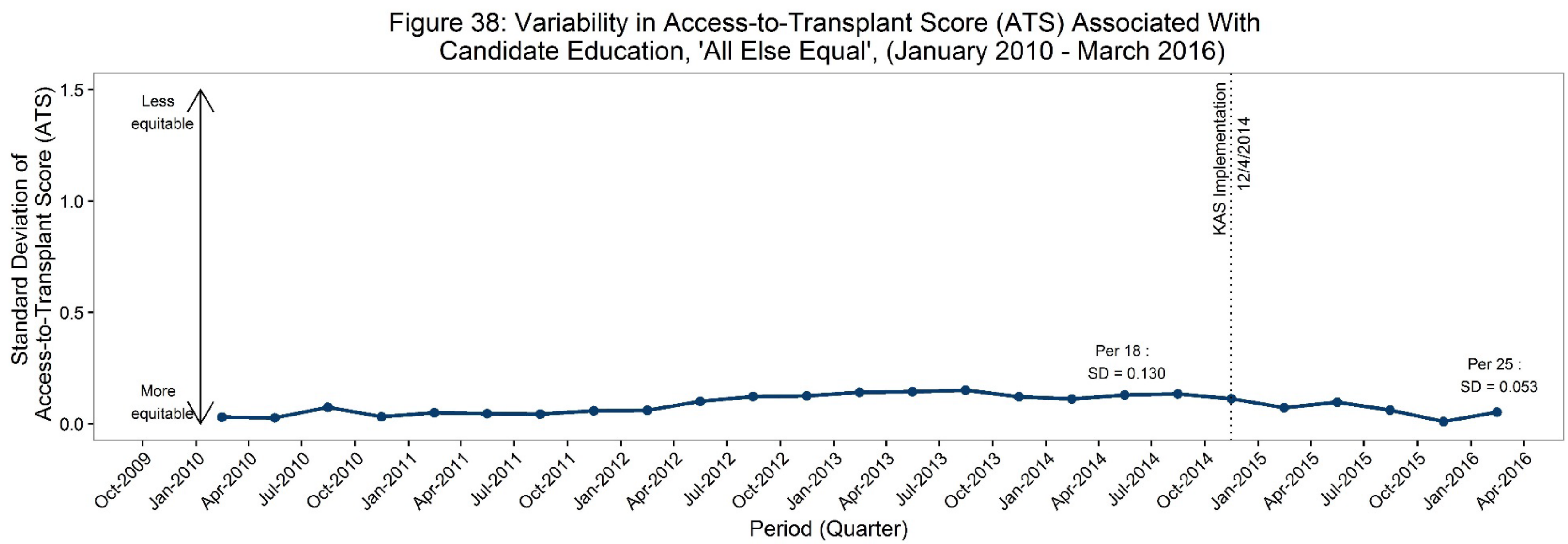
The proportion of kidney transplants received by female recipients increased from 38.9% to 40.5% after KAS (**Figure 36**). This increase may be related to the increase in transplants to highly sensitized patients, since prior pregnancy is a biological mechanism that can cause antibody sensitization.



Transplant rates are slightly higher for females (0.20) compared to males (0.19) post-KAS (**Figure 37**). Transplant rates increased for both groups, since the number of donors recovered and transplants performed nationally has increased over the past few years.

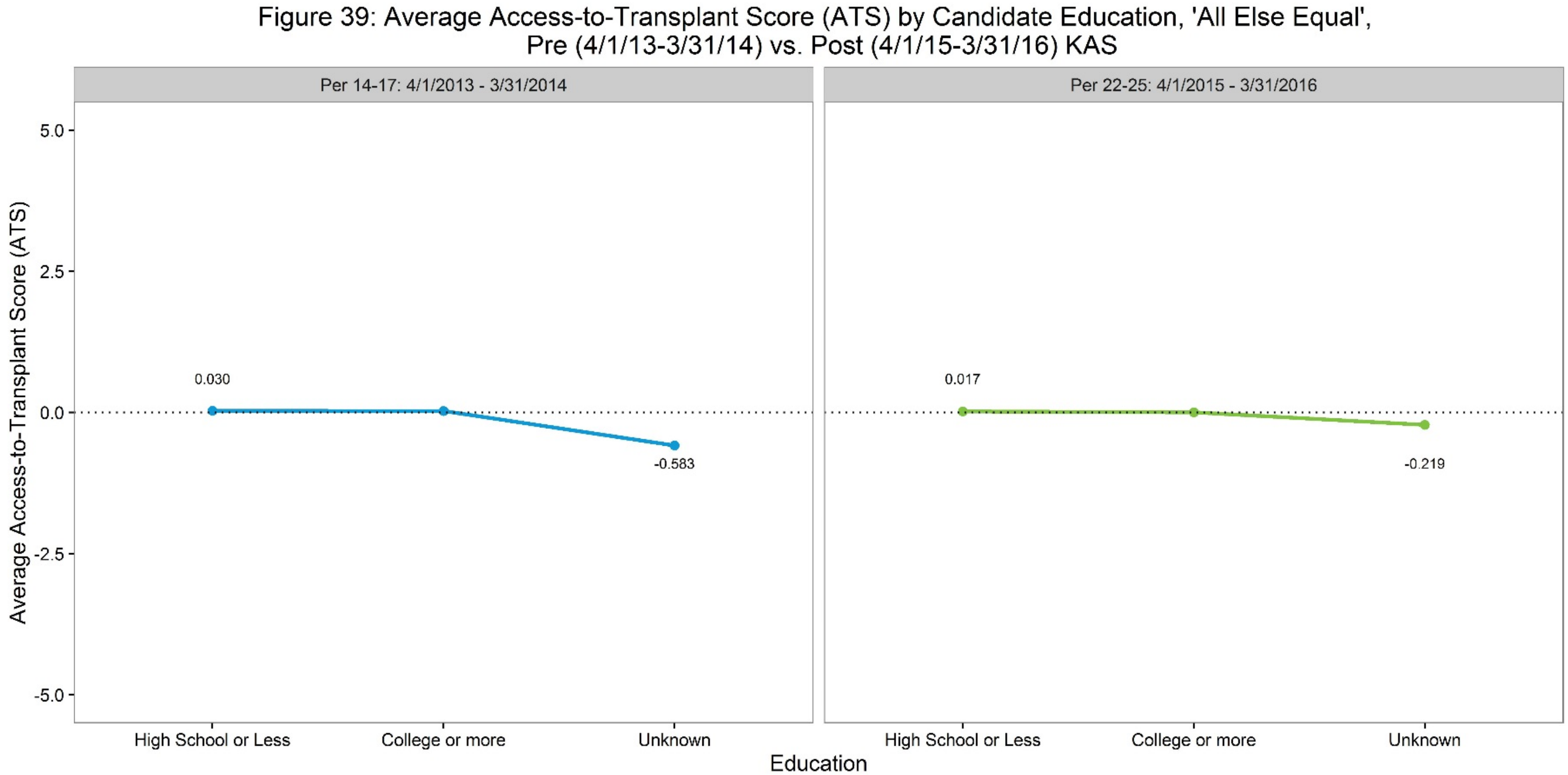
Equity in Access by Candidate Highest Education Level

Tracking Equity by Candidate Education, Jan 2010 – Mar 2016 (ceteris paribus: *"all else equal")*



All else equal, disparities in access to transplant by candidate education level have been relatively low compared to other factors (**Figure 38**). Interestingly, the standard deviation of ATS scores increased in 2012, remained stable through 2014, and decreased post-KAS, suggesting a decrease in equity by education level prior to KAS, followed by a post-KAS equity improvement. Education level was found to have the second lowest association with disparities in access to transplantation among all ten studied factors (Figure 4).

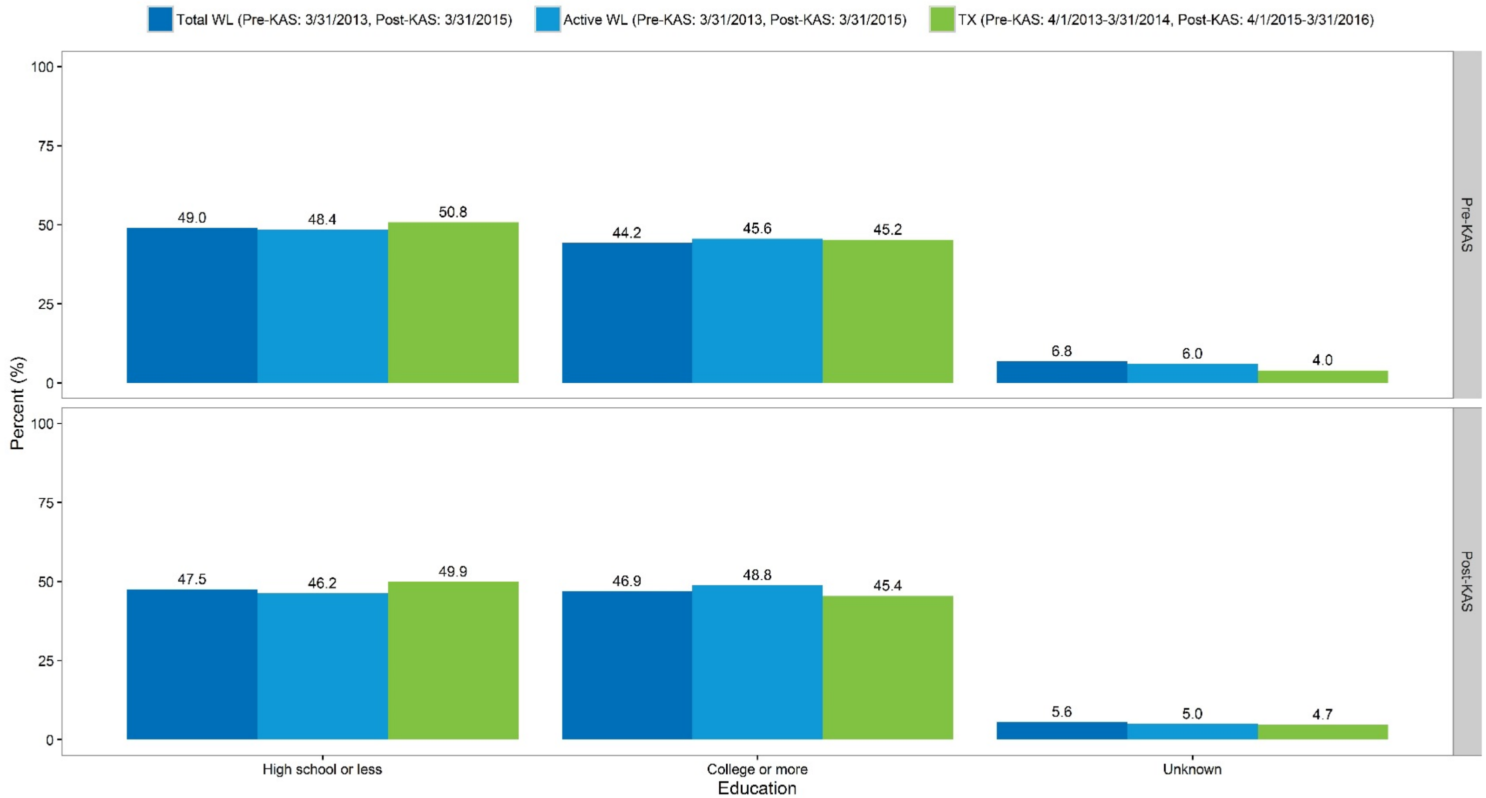
Risk-adjusted Equity by Candidate Education Level, Pre vs. Post-KAS (ceteris paribus: *"all else equal")*



All else equal, differences in access to transplant by candidate education level are small (**Figure 39**), and became substantially smaller post-KAS. Average ATS scores, in fact, were essentially identical for candidates with a high school diploma or less vis-à-vis college-educated candidates. Only 5% (Figure 40) of kidney candidates have "unknown" education level in the OPTN database. Transplant access has increased sharply for this small group of patients post-KAS, although Figure 39 indicates their level of access is still lower than for other candidates.

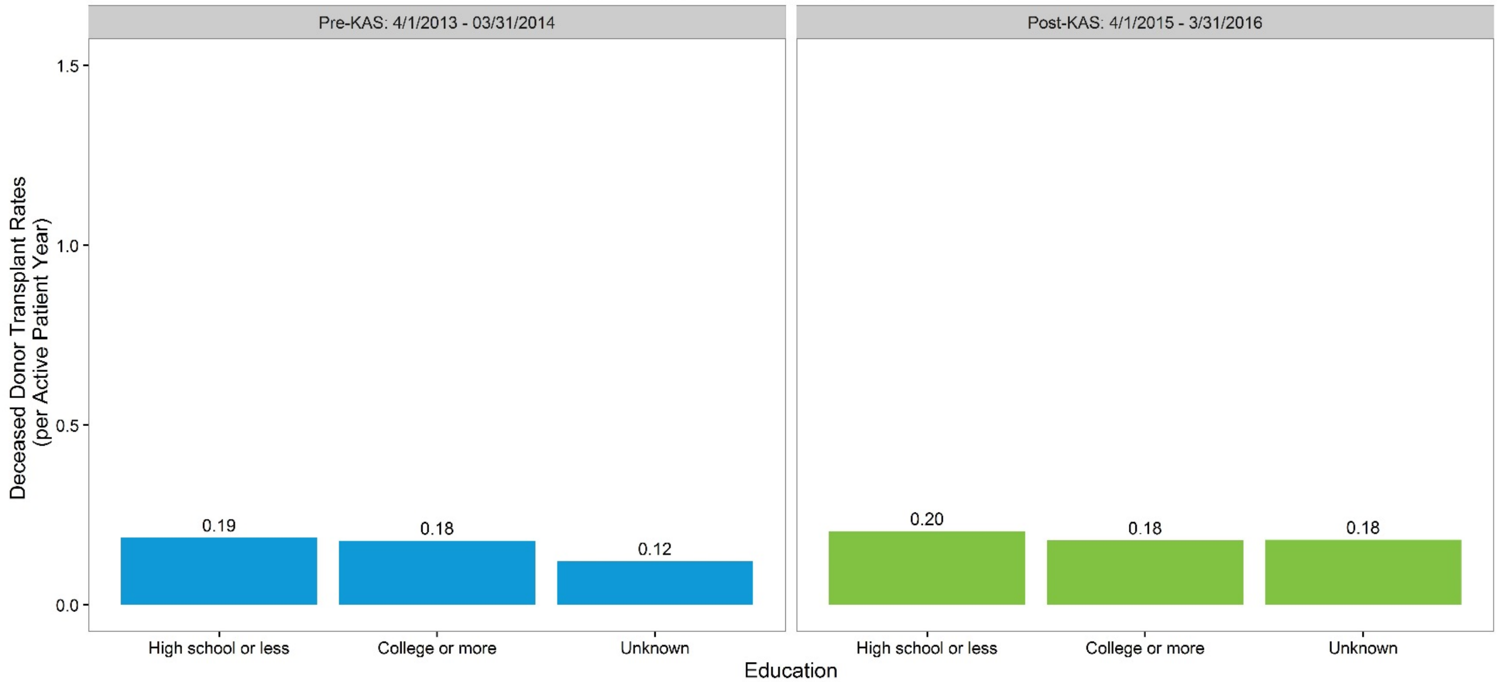
Traditional Ways of Assessing Equity, by Candidate Education Level

Figure 40: Waitlist (WL) Percent versus Transplant (TX) Percent by Education, Pre- vs. Post-KAS



The proportion of kidney transplants received compared with the proportion of the waiting list by education level are both shown in **Figure 40**. The percentage of transplants going to high school educated vs. college educated vs. unknown changed little after KAS.

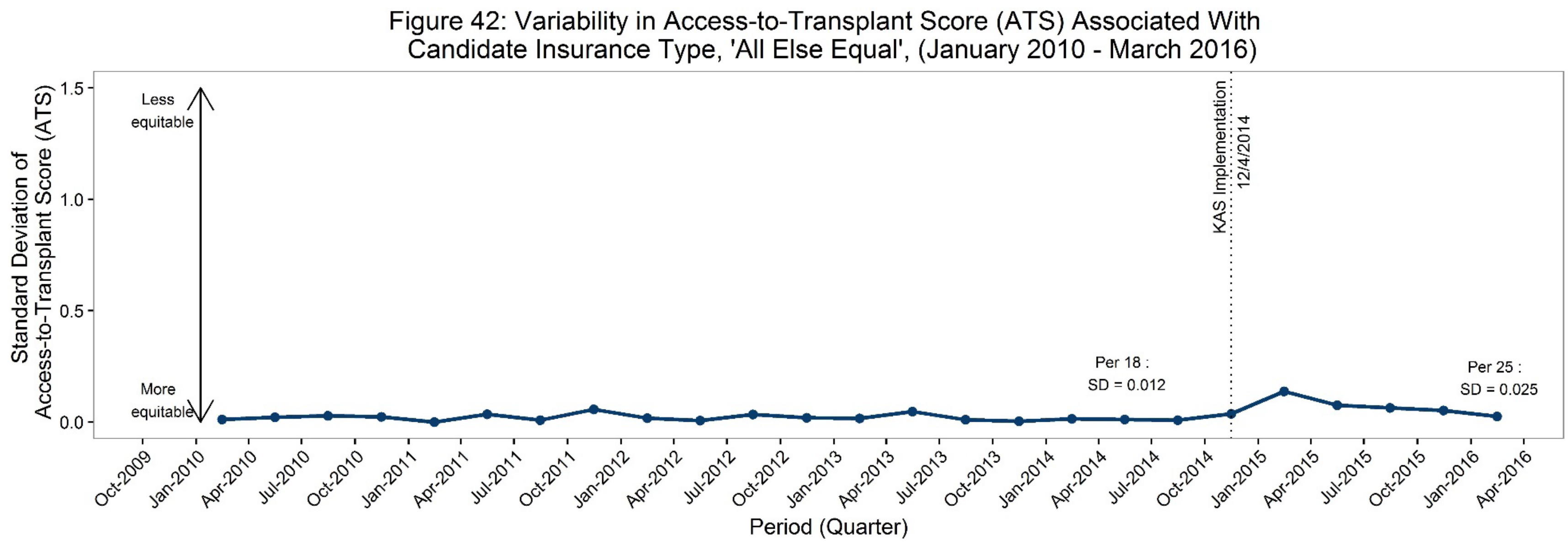
Figure 41: Deceased Donor Transplant Rates Per Active Patient Year by Education,
Pre-KAS: 4/1/2013 - 3/31/2014 vs. Post-KAS: 4/1/2015 - 3/31/2016



Transplant rates increased after KAS for high school (or less) educated candidates and candidates with unknown education level, while remaining stable for college-educated candidates (**Figure 41**).

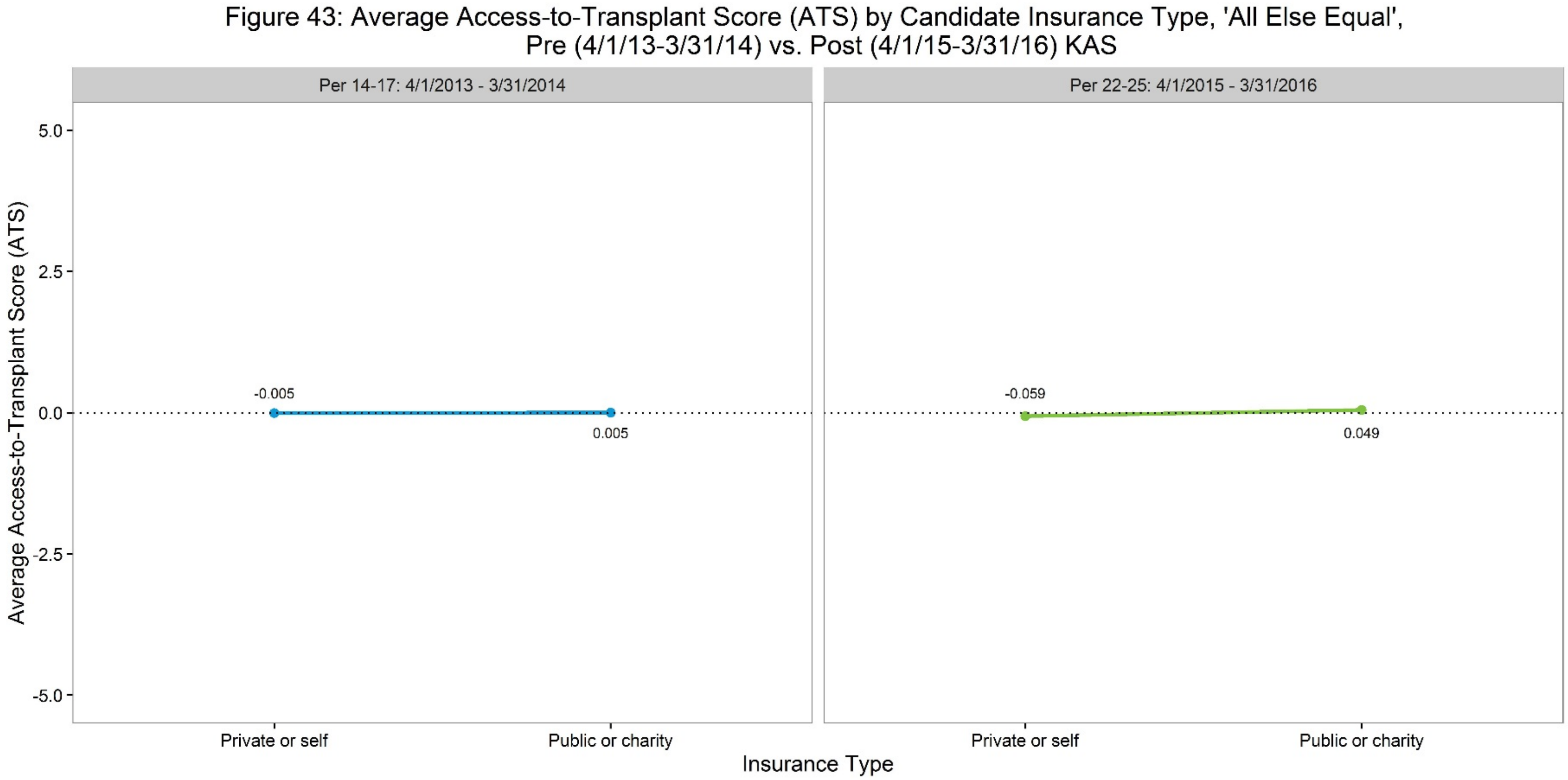
Equity in Access by Candidate Insurance Type (Public vs. Private)

Tracking Equity by Candidate Insurance Type, Jan 2010 – Mar 2016 (ceteris paribus: *"all else equal")*



All else equal, disparities in access to transplant by candidate insurance type (public vs. private) are extremely low (**Figure 42**). After a slight increase in the standard deviation of ATS scores post-KAS implementation, this metric declined to previously observed levels. In the most recent period (Jan 1, 2016 – Mar 31, 2016), insurance type was found to have the lowest association with disparities in access to transplantation among all ten studied factors (Figure 4). However, traditional, non-risk adjusted measures (Figures 44-45) do reveal differences in access to transplant by insurance type due to correlations between insurance type and other factors such as ethnicity, CPRA, and time on dialysis.

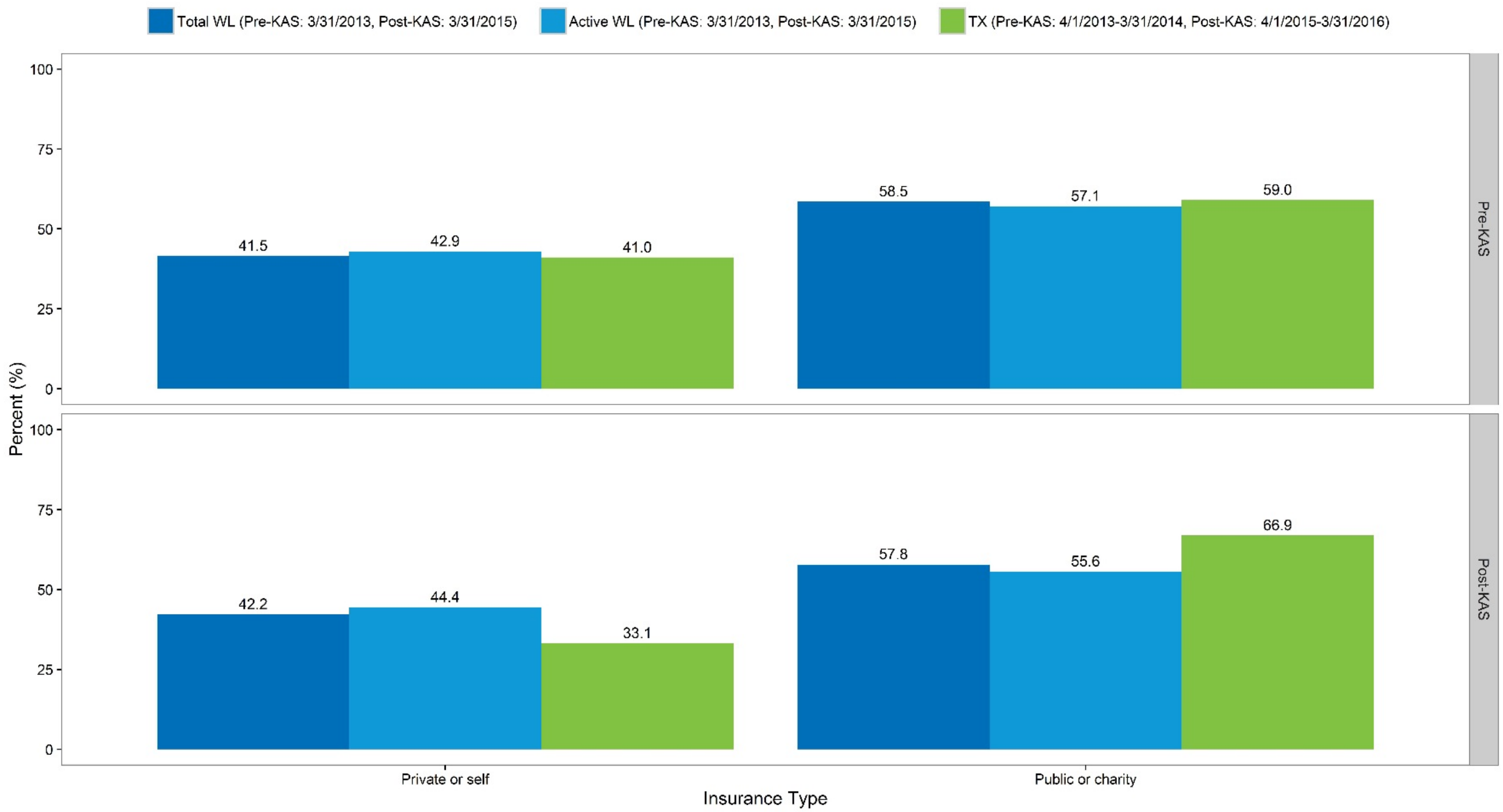
Risk-adjusted Equity by Candidate Insurance Type, Pre vs. Post-KAS (ceteris paribus: *"all else equal")*



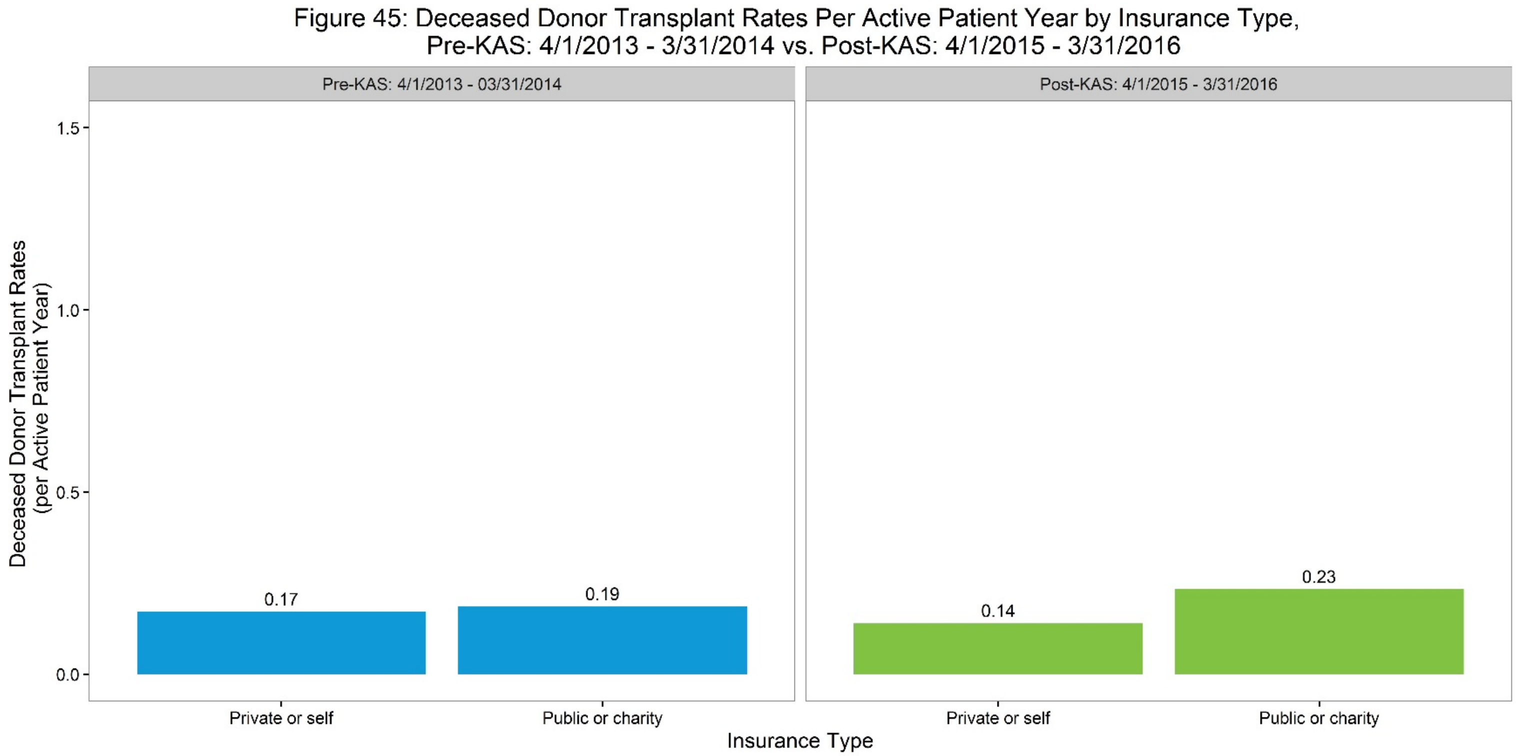
All else equal, differences in access to transplant by candidate insurance type are extremely small (**Figure 43**).

Traditional Ways of Assessing Equity, by Candidate Insurance Type

Figure 44: Waitlist (WL) Percent versus Transplant (TX) Percent by Insurance Type, Pre- vs. Post-KAS



The proportion of kidney transplants received compared with the proportion of the waiting list by insurance type are both shown in **Figure 44**. Post-KAS, the proportion of transplants received by candidates with public insurance (or charity) increased.



Transplant rates increased after KAS for candidates insured by public payers (e.g., CMS) or charity (**Figure 45**). Candidates with public insurance or charity tend to more often be Black or Hispanic, have long durations on dialysis, and have CPRA 99-100%; each of these three characteristics was associated with sharp increases in transplant rates after KAS. All other factors equal, however, Figure 43 suggests that there are little to no disparities in access to transplant based on insurance type.

Discussion

This report on equity in access to deceased donor kidney transplants contains several important findings. First, the variability in access to transplants among active, waitlisted candidates has decreased with the implementation of the new kidney allocation system (KAS). By one measure, the degree of unintentional variability in the system has dropped by about 40%. Much of this decline in variability was driven by improving equity in access to transplants across the CPRA spectrum. Patients with very little access to transplants before KAS due to numerous HLA antibody sensitivities now have much greater access to transplants, while some candidates (for example those with CPRA just over the 80% threshold) arguably had too much access prior to KAS.

Second, while equity in access among the 58 donor service areas (DSAs) has improved, as reflected by a 27% decrease in variability attributable to DSAs post-KAS, substantial variation in expected waiting time remains for patients based on which DSA they are listed in. Of all ten factors evaluated in this report, DSA has the greatest association with disparities in access to kidney transplants, followed by CPRA and blood type (Figure 4).

Third, equitable access to transplants by age (among adults) changed in that pre-KAS, older adults had shorter expected waiting times, all else equal; but post-KAS, younger adults have shorter expected waiting times. However, compared to the variability in access associated with other factors such as DSA, CPRA, and blood type, the differences in expected waiting times by age are relatively small. A modest increase in priority for younger, less sick candidates was an intended goal of the new kidney allocation system in the interest of realizing more life years from each donated kidney, a scarce national resource. However, the OPTN kidney transplantation committee was intent on ensuring that this emphasis on increasing utility did not usher in too great of a detrimental impact on equity. Some may argue that, due to the "fair innings" principle, younger, less sick candidates should have *some degree* of increased access to transplants[2], all else equal. Others have suggested the fair innings rationale is not philosophically justifiable[3], and some have proposed an approach that seeks to incorporate the fair innings principle through organ/recipient longevity matching that is constrained to ensure candidates (regardless of age) have an equal opportunity at receiving an organ[4].

Fourth, access to transplants by candidate diagnosis has changed. Fewer diabetics are receiving transplants under KAS. All else equal, the disparity in access to transplants by diagnosis increased after KAS, though it still remains smaller than the disparities attributable to DSA, CPRA, and ABO.

Fifth, KAS increased access to transplants for Black and Hispanic candidates. This increase is attributable, at least in part, to the back-dating of waiting time priority to begin with the commencement of dialysis, as opposed to time of listing. After adjusting for a number of factors, differences in access to transplant (among active, waitlisted candidates) by ethnicity were extremely small and decreased further after KAS. This finding suggests that the "allocation system" – which consists of a policy that determines the rank-ordering list of compatible candidates; the

OPOs' effort to offer kidneys for candidates on the match list; and transplant clinicians decisions to accept organ offers – does not exhibit *disparate treatment* with respect to candidate ethnicity. All else equal, there is no evidence of systematic bias in this system with respect to kidney transplant access by ethnicity. However, unadjusted analyses suggest there remains a *disparate impact* on candidates by ethnicity. Asians, in particular, experience lower-than-average access to transplants, due at least in part to Asian patients more often having blood type B and being listed in DSAs with longer waiting time.

In totality, KAS has led to a substantial improvement in equity. Gains in equity must, of course, be judged in the context of whether other strategic goals were positively or negatively affected. It is possible that these gains in equity were neutral with respect to other OPTN goals (https://optn.transplant.hrsa.gov/governance/about-the-optn/vision-goals/), for example optimizing utilization of the available supply of kidneys and improving outcomes for transplant recipients. However, though transplant volume has risen significantly over the last few years, the percentage of kidneys recovered for transplant but not utilized (discard rate) has increased post-KAS. Whether this rise is related to elements of KAS that increased equity is unclear. And though early post-KAS outcomes analyses suggest short-term kidney graft survival has remained relatively stable post-KAS[5], some members of the transplant community have expressed concern that the increases in equity ushered in by KAS may lead to poorer long term outcomes. Organ utilization and kidney recipient outcomes must be tracked closely in the coming years to assess whether there indeed have been tradeoffs with respect to these other goals, and if so, whether such tradeoffs are acceptable to the OPTN and transplant community at large.

It must also be recognized that access to deceased donor kidney transplants first requires patients to be aware of transplantation as an option; referred to a transplant center for evaluation; added to the waiting list; and made active on the list to receive offers. The focus of this report is to identify potential disparities in access to transplantation after patients have been added to the active waiting list. Disparities in access to the waiting list have been documented[6] but are outside the scope of this study for several reasons. First, the OPTN has limited hegemony over referral and listing practices but primary control over allocation policies, so tracking equity with respect to allocation is of primary relevance to the OPTN. Secondly, national data identifying candidates in need of transplantation but not added to the waiting list are not immediately available for all organs, in particular non-renal patients with end stage organ failure.

This study is also limited in that it did not address equity concerns related to multiply-listed patients[7] or multi-organ (e.g., simultaneous liver-kidney) allocation. This report is intended to be updated quarterly to include equity measures based on the most recent quarter of data available. As future changes to kidney allocation are implemented, this analytical framework will allow the OPTN to continually measure the current state of equity in kidney allocation. The applicability of this methodology to the allocation of non-renal organs is being explored.

Many other helpful references related to the complex issue of equity in allocation are available[8-24].

Concise Methods

Access to Transplant Scores (ATS) were developed using Cox proportional hazards models to predict the time to deceased donor kidney transplant as a function of 15 candidate covariates: pediatric status; prior living donor status; medically urgent indicator; previously accumulated qualified waiting time; ethnicity; gender; citizenship; renal failure diagnosis; prior kidney transplant; insurance type; education level; age; median income of permanent residence zip code; duration on dialysis; CPRA; donor service area (DSA). Twenty five separate models were built, one for each quarterly, period-prevalent cohort from January 1, 2010-March 31, 2010 (period 1) through January 1, 2016-March 31, 2016 (period 25), including all active, kidney-alone registrations on the waiting list.

Waiting time was left truncated for candidates already on the list at the start of a cohort. The following covariates were treated as time-dependent, to capture changes during the candidate's time on the list: CPRA, prior living donor status, medically urgent indicator. Age, median income, dialysis time, and previously accumulated qualified waiting time were modeling as restricted cubic splines. CPRA was modeled as a piecewise linear function to adequately reflect nonlinearities (especially for CPRA above 99%) and abrupt discontinuities attributable to policy thresholds.

To ensure that the measure of disparities in access to transplants over time are reflective of policy and practice changes in allocation of kidney and not shifts in the characteristics of listed patients, each of the 25 models was applied to the same population of patients: all 65,619 active, kidney-alone registrations on the waiting list on January 1, 2016. "Raw" ATS scores were simply equal to the xbeta – the linear combination of candidate factors times the associated model coefficients – minus the population average xbeta, and can be thought of as a composite score that quantifies differences in expected time to transplant based on differential candidate characteristics. "Discounted" ATS scores were calculated the same way, except that the following factors were set to constant values for all 65,619 registrations: pediatric status (set to "No"); prior living donor status (set to "No"); medically urgent indicator (set to "No"); previously accumulated waiting time prior to listing (set to the mean of 540 days). Normalizing these factors to constant values ensures that the disparity measure does not reflect desired/intentional variability in access to transplant that is reflected in OPTN kidney allocation policy (Figure 46).

The global measure of disparity in access to kidney transplantation (Figure 3) was calculated as the standard deviation of discounted ATS scores for the 65,619 registrations, separately using the statistical model estimated from each quarterly time period. For each of the ten factors closely examined in this study, risk-adjusted variability in ATS scores was calculated as the standard deviation of xbetas with *all other factors* held constant.

This study used data from the Organ Procurement and Transplantation Network (OPTN). The OPTN data system includes data on all donors, wait-listed candidates, and transplant recipients in the US, submitted by the members of the Organ Procurement and Transplantation Network (OPTN), and has been described elsewhere. The Health Resources and Services Administration (HRSA), U.S. Department of Health and Human

Services provides oversight to the activities of the OPTN contractor. Duration on chronic, maintenance dialysis for end stage renal disease (ESRD) was determined using the most recent dialysis start date submitted to the OPTN or on a Centers for Medicare and Medicaid (CMS) ESRD Medical Evidence 2728 form (2nd quarter, 2016 file). Dialysis start dates before a prior transplant were ignored unless the graft was reported to have failed within 90 days. Median income by zip code data were obtained through the U.S. Census Bureau's American Community Census (ACS) 2014 file using 5-year average values.

Figure 46: Variability in Access-to-Transplant Score (ATS) for Waitlisted Kidney Candidates Post (2016Q1) KAS, Raw vs. Discounted

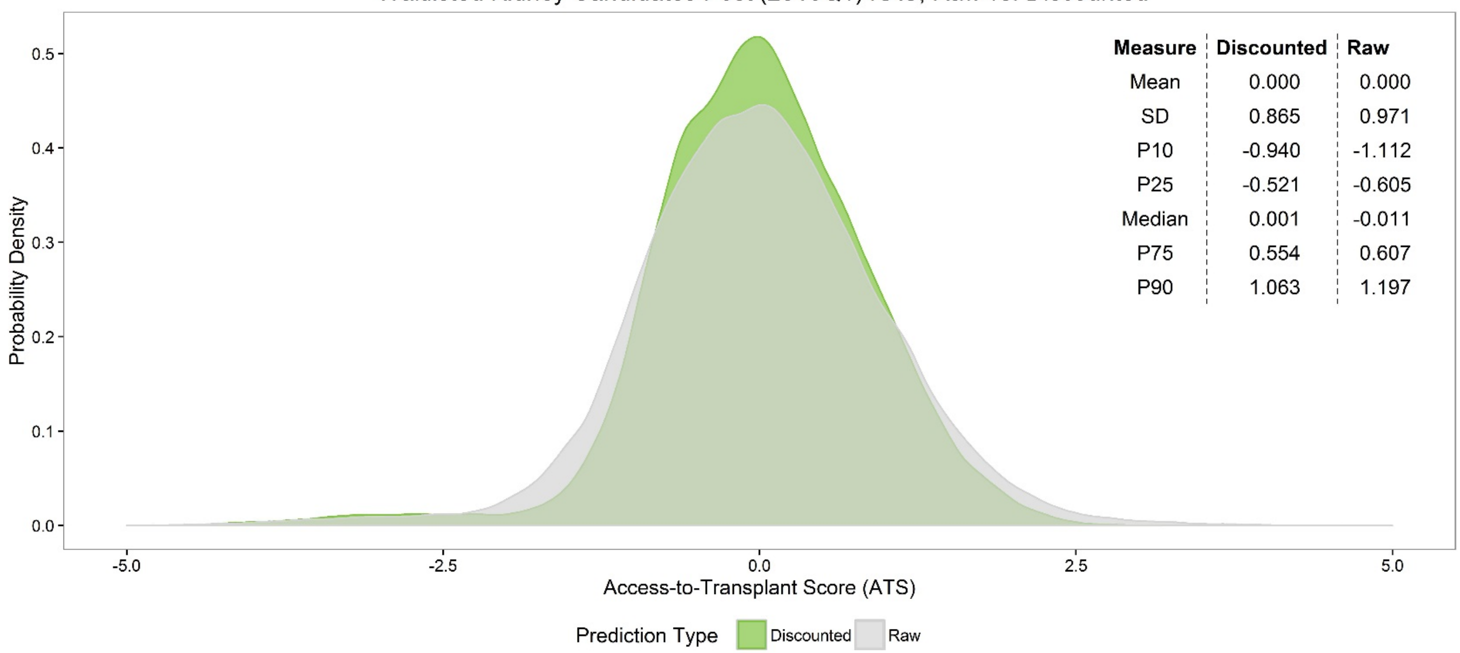


Figure 46 shows the impact of "discounting" ATS scores to omit desired/intentional variability associated with pediatric status, prior living donor status, medical urgency, and previously accumulated qualified waiting time. The distribution of the non-discounted ("raw") scores is wider than the distribution of the discounted scores, as reflected visually and by the standard deviations (0.971 vs. 0.865).

Association between Access to Transplant Scores (ATS) and Median Waiting Time (MWT)

Figure 47: Estimated Median Waiting Times (MWT) by ATS Score
(Post-KAS: Jan. 1, 2016 - Mar. 31, 2016)

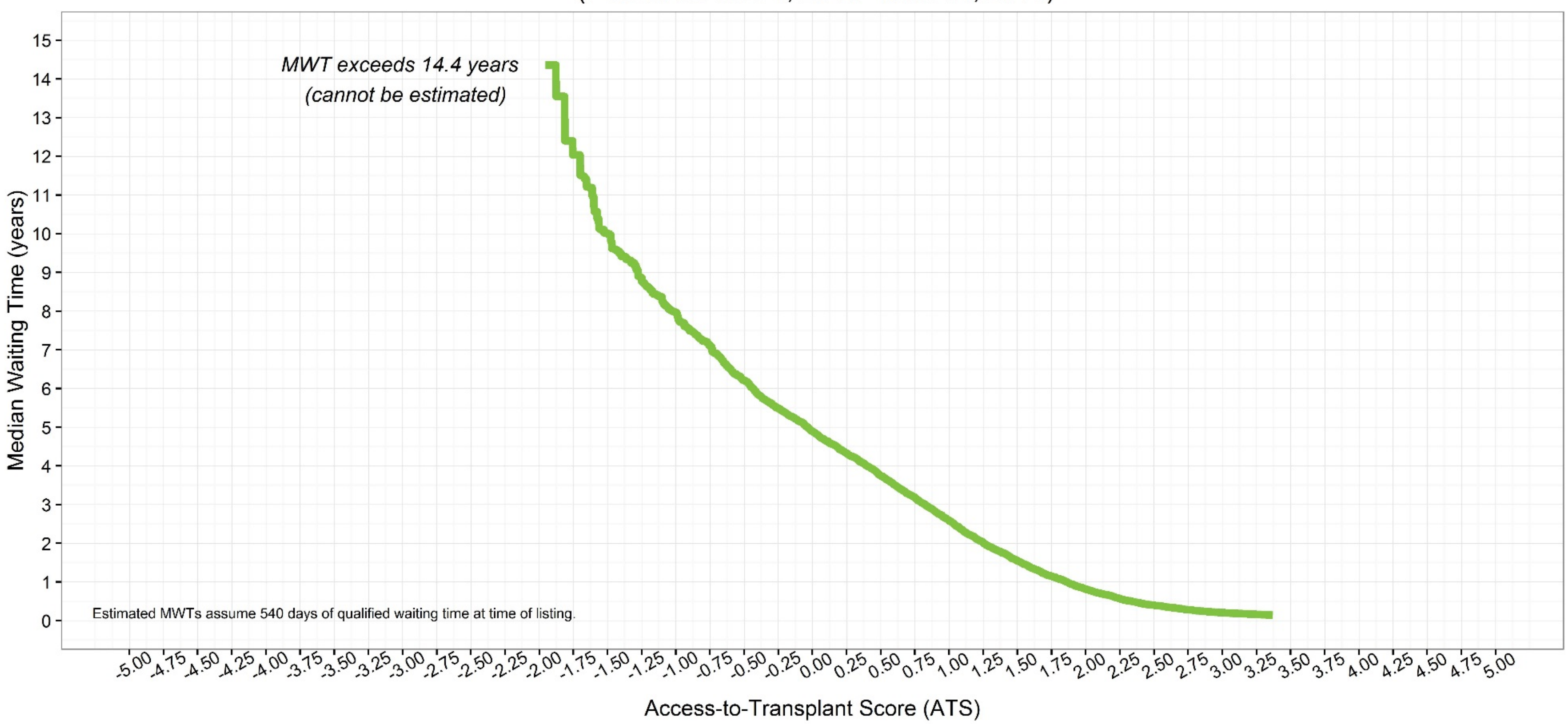


Figure 47 can be used to gauge the approximate impact on the expected (median) waiting time based on differences in average ATS score. A score of 0 is associated with the national average waiting time of about 5 years. A score of -0.23, for example (as seen for prior kidney recipients in Figure 31), is associated with a MWT of about 5.5 years, a difference of approximately one half year.

Appendix I: Period Start and End Dates

This analysis quantified disparities in time to receiving a deceased donor transplant in 25 different quarters. Periods 1-25 are identified below.

Period	Start	End
1	01/01/2010	3/31/2010
2	04/01/2010	6/30/2010
3	07/01/2010	9/30/2010
4	10/01/2010	12/31/2010
5	01/01/2011	3/31/2011
6	04/01/2011	6/30/2011
7	07/01/2011	9/30/2011
8	10/01/2011	12/31/2011
9	01/01/2012	3/31/2012
10	04/01/2012	6/30/2012
11	07/01/2012	9/30/2012
12	10/01/2012	12/31/2012
13	01/01/2013	3/31/2013
14	04/01/2013	6/30/2013
15	07/01/2013	9/30/2013
16	10/01/2013	12/31/2013
17	01/01/2014	3/31/2014
18	04/01/2014	6/30/2014
19	07/01/2014	9/30/2014
20	10/01/2014	12/31/2014
21	01/01/2015	3/31/2015
22	04/01/2015	6/30/2015
23	07/01/2015	9/30/2015
24	10/01/2015	12/31/2015
25	01/01/2016	3/31/2016

Appendix II: Donor Service Area Identification Key

Encrypted DSA	The Donor Service Area (DSA) served by:
1	NYWN-OP1: Upstate New York Transplant Services Inc
2	NEOR-OP1: Nebraska Organ Recovery System
3	NVLV-OP1: Nevada Donor Network
4	IAOP-OP1: Iowa Donor Network
5	OHLC-OP1: Life Connection of Ohio
6	OKOP-OP1: LifeShare Transplant Donor Services of Oklahoma
7	NYAP-OP1: Center for Donation and Transplant
8	UTOP-OP1: Intermountain Donor Services
9	MWOB-OP1: Midwest Transplant Network
10	VATB-OP1: LifeNet Health
11	AROR-OP1: Arkansas Regional Organ Recovery Agency
12	CAGS-OP1: Sierra Donor Services
13	SCOP-OP1: LifePoint
14	WALC-OP1: LifeCenter Northwest
15	ORUO-IO1: Pacific Northwest Transplant Bank
16	AZOB-OP1: Donor Network of Arizona
17	MOMA-OP1: Mid-America Transplant Services
18	FLUF-IO1: LifeQuest Organ Recovery Services
19	NCNC-OP1: Carolina Donor Services
20	FLWC-OP1: LifeLink of Florida
21	WIUW-IO1: UW Health Organ and Tissue Donation
22	FLFH-IO1: TransLife
23	KYDA-OP1: Kentucky Organ Donor Affiliates
24	NCCM-IO1: LifeShare of the Carolinas
25	OHOV-OP1: LifeCenter Organ Donor Network
26	MIOP-OP1: Gift of Life Michigan
27	OHLP-OP1: Lifeline of Ohio
28	NMOP-OP1: New Mexico Donor Services
29	NYFL-IO1: Finger Lakes Donor Recovery Network

Encrypted DSA	The Donor Service Area (DSA) served by:
30	PATF-OP1: Center for Organ Recovery and Education
31	MNOP-OP1: LifeSource Upper Midwest Organ Procurement Organization
32	MAOB-OP1: New England Organ Bank
33	INOP-OP1: Indiana Donor Network
34	PADV-OP1: Gift of Life Donor Program
35	DCTC-OP1: Washington Regional Transplant Community
36	TNDS-OP1: Tennessee Donor Services
37	TXSB-OP1: Southwest Transplant Alliance
38	MDPC-OP1: The Living Legacy Foundation of Maryland
39	NJTO-OP1: New Jersey Organ and Tissue Sharing Network OPO
40	PRLL-OP1: LifeLink of Puerto Rico
41	FLMP-OP1: Life Alliance Organ Recovery Agency
42	CTOP-OP1: LifeChoice Donor Services
43	OHLB-OP1: Lifebanc
44	MSOP-OP1: Mississippi Organ Recovery Agency
45	HIOP-OP1: Legacy of Life Hawaii
46	TNMS-OP1: Mid-South Transplant Foundation
47	CORS-OP1: Donor Alliance
48	NYRT-OP1: LiveOnNY
49	TXGC-OP1: LifeGift Organ Donation Center
50	ILIP-OP1: Gift of Hope Organ & Tissue Donor Network
51	WIDN-OP1: Wisconsin Donor Network
52	CADN-OP1: Donor Network West
53	LAOP-OP1: Louisiana Organ Procurement Agency
54	GALL-OP1: LifeLink of Georgia
55	CASD-IO1: Lifesharing - A Donate Life Organization
56	ALOB-OP1: Alabama Organ Center
57	CAOP-OP1: OneLegacy
58	TXSA-OP1: Texas Organ Sharing Alliance

References

1. Ayres I. Three tests for measuring unjustified disparate impacts in organ transplantation: the problem of "included variable" bias. *Perspectives in biology and medicine.* Winter 2005;48(1 Suppl):S68-87.
2. Ladin K, Hanto DW. Rational rationing or discrimination: balancing equity and efficiency considerations in kidney allocation. *American journal of transplantation : official journal of the American Society of Transplantation and the American Society of Transplant Surgeons.* Nov 2011;11(11):2317-2321.
3. Rivlin MM. Why the fair innings argument is not persuasive. *BMC medical ethics.* 2000;1:E1.
4. Ross LF, Parker W, Veatch RM, Gentry SE, Thistlethwaite JR, Jr. Equal Opportunity Supplemented by Fair Innings: equity and efficiency in allocating deceased donor kidneys. *American journal of transplantation : official journal of the American Society of Transplantation and the American Society of Transplant Surgeons.* Aug 2012;12(8):2115-2124.
5. Stewart DE, Kucheryavaya AY, Klassen DK, Turgeon NA, Formica RN, Aeder MI. Changes in Deceased Donor Kidney Transplantation One Year After KAS Implementation. *American journal of transplantation : official journal of the American Society of Transplantation and the American Society of Transplant Surgeons.* Jun 2016;16(6):1834-1847.
6. Patzer RE, Perryman JP, Schrager JD, et al. The role of race and poverty on steps to kidney transplantation in the Southeastern United States. *American journal of transplantation : official journal of the American Society of Transplantation and the American Society of Transplant Surgeons.* Feb 2012;12(2):358-368.
7. Ankeny RA. Recasting the debate on multiple listing for transplantation through consideration of both principles and practice. *Cambridge quarterly of healthcare ethics : CQ : the international journal of healthcare ethics committees.* Summer 1999;8(3):330-339.
8. Reese, Peter P., et al. "How should we use age to ration health care? Lessons from the case of kidney transplantation." Journal of the American Geriatrics Society 58.10 (2010): 1980-1986.
9. Davis, Daniel F. "The Ethics of Organ Allocation: Policy Questions Concerning Geography, Age, and Net Benefit" The President's Council on Bioethics. February, 2007.

https://bioethicsarchive.georgetown.edu/pcbe/background/ethics_of_organ_allocation.html. Accessed 11/21/2016.

10. Segev DL. Evaluating options for utility-based kidney allocation. *American journal of transplantation : official journal of the American Society of Transplantation and the American Society of Transplant Surgeons.* Jul 2009;9(7):1513-1518.
11. Hoffmaster B, Hooker C. Tragic choices and moral compromise: the ethics of allocating kidneys for transplantation. *The Milbank quarterly.* Sep 2013;91(3):528-557.
12. Organ Procurement and Transplantation Network (OPTN). Ethical Principles in the Allocation of Human Organs (https://optn.transplant.hrsa.gov/resources/ethics/ethical-principles-in-the-allocation-of-human-organs/). Updated 2015.
13. Davis, D., Wolitz, R. The Ethics of Organ Allocation (working paper). Sep 2006. https://bioethicsarchive.georgetown.edu/pcbe/background/davispaper.html Accessed 11/21/2016.
14. Gaston RS. Addressing minority issues in renal transplantation: is more equitable access an achievable goal? *American journal of transplantation : official journal of the American Society of Transplantation and the American Society of Transplant Surgeons.* Jan 2002;2(1):1-3.
15. Braveman P. Health disparities and health equity: concepts and measurement. *Annual review of public health.* 2006;27:167-194.
16. Braveman P, Gruskin S. Defining equity in health. *Journal of epidemiology and community health.* Apr 2003;57(4):254-258.
17. Waters HR. Measuring equity in access to health care. *Social science & medicine.* Aug 2000;51(4):599-612.
18. Norheim OF, Asada Y. The ideal of equal health revisited: definitions and measures of inequity in health should be better integrated with theories of distributive justice. *International journal for equity in health.* Nov 18 2009;8:40.
19. Truman BI, Smith KC, Roy K, et al. Rationale for regular reporting on health disparities and inequalities - United States. *MMWR supplements.* Jan 14 2011;60(1):3-10.
20. Asada Y, Hurley J, Norheim OF, Johri M. A three-stage approach to measuring health inequalities and inequities. *International journal for equity in health.* Nov 01 2014;13:98.

21. Childress JF. Putting patients first in organ allocation: an ethical analysis of the U.S. debate. *Cambridge quarterly of healthcare ethics : CQ : the international journal of healthcare ethics committees.* Fall 2001;10(4):365-376.
22. Graham, Walter. "The UNOS statement of principles and objectives of equitable organ allocation." Seminars in Anesthesia, Perioperative Medicine and Pain. Vol. 14. No. 2. WB Saunders, 1995.
23. Wyatt R, Laderman M, Botwinick L, Mate K, Whittington J. Achieving Health Equity: A Guide for Health Care Organizations. IHI White Paper. Cambridge, Massachusetts: Institute for Healthcare Improvement; 2016. (Available at ihi.org).
24. Persad G, Wertheimer A, Emanuel EJ. Principles for allocation of scarce medical interventions. *Lancet.* Jan 31 2009;373(9661):423-431.