# KIPA2022_01 Allocation Simulation Analysis Report: 4 Continuous Distribution Policy Scenarios

Analysis Report for the Data Request from the OPTN Kidney and Pancreas Continuous Distribution Workgroup

## Contents



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## Background

The Organ Procurement and Transplantation Network (OPTN) Kidney and Pancreas Continuous Distribution Workgroup (the workgroup) is currently developing the continuous distribution framework for kidney, pancreas, kidney-pancreas, and pancreatic islets allocation. At the April 29, 2022, workgroup meeting, the workgroup requested simulations for four different scenarios, along with a comparison to a simulation of current policy. Each model, a run of the organ allocation simulation software, represents a different set of weights for each of the attributes that will define continuous distribution.

## Request: Simulation Runs for Four Continuous Distribution Scenarios

The continuous distribution framework for kidney transplant includes five components: medical urgency, posttransplant outcomes, candidate biology, patient access, and placement efficiency. Three of these components—candidate biology, patient access, and placement efficiency—are also included in the continuous distribution framework for pancreas, kidney-pancreas, and pancreatic islets. The workgroup and the OPTN Kidney and Pancreas committees have spent considerable time discussing and evaluating how each component should be prioritized. Their priorities are defined in terms of weights per component and modifiers of those weights based on donor characteristics. They requested simulation runs for the current allocation rules, as well as four different continuous allocation rules. Any components of the allocation system not specified as part of an alternate scenario followed current allocation rules.

## The Continuous Distribution Score

$$Score_i = \sum_j R_j(x_{i,j}(cand_i, don)) * W_j * M_j(don),\ where$$
$$i:\ candidate,$$
$$j:\ metric,$$
$$R_j:\ the\ rating\ scale\ for\ metric,\ j,$$
$$x_{i,j}:\ candidate\ i's\ value\ for\ metric,\ j,$$
$$W_j:\ weight\ for\ metric,\ j,\ and$$
$$M_j:\ donor\ weight\ modifier\ for\ metric,\ j.$$

## Rating Scales

### Kidney

Each component has a rating scale. The committee chose the following rating scales for kidney-alone candidates:

1. Medical urgency: A binary score
    - Candidates meeting the policy definition of medically urgent receive a rating score of 1.
    - All other candidates receive a rating score of 0.
2. Posttransplant outcomes: The posttransplant outcomes component is split into DR mismatch and expected posttransplant survival (EPTS) and kidney donor profile index (KDPI) subcomponents.
    - DR mismatch:
        - Candidates with 0 HLA-DR mismatches to a donor receive a rating score of 1.
        - Candidates with 1 HLA-DR mismatch to a donor receive a rating score of 0.7.
        - Candidates with 2 HLA-DR mismatches to a donor receive a rating score of 0.
    - EPTS/KDPI: Each candidate has a calculated EPTS and each donor has a calculated KDPI.
        - The candidate's EPTS/KDPI rating score is $(0.5 + 2 * (EPTS/100 - 0.5) * (KDPI/100 - 0.5))$.
3. Candidate biology: The candidate biology component is split into blood type and calculated panel reactive antibody (cPRA) subcomponents.
    - Blood type:
        - Candidates with blood type A receive a rating score of 0.00005.
        - Candidates with blood type AB receive a rating score of 0.
        - Candidates with blood type B receive a rating score of 0.00111.
        - Candidates with blood type O receive a rating score of 0.00446.
    - cPRA: Each candidate has a cPRA score for their sensitization.
        - The candidate's rating score for cPRA is $((100000^{cPRA}) - 1)/99999)$.
4. Patient access: The patient access component is split into pediatric, prior living donor, kidney-after-liver safety net, and qualifying time subcomponents.
    - Pediatric: A binary score
        - Candidates younger than 18 years receive a rating score of 1.
        - All other candidates receive a rating score of 0.
    - Prior living donor: A binary score
        - Prior living donors of *any* organ receive a rating score of 1.
        - All other candidates receive a rating score of 0.
    - Kidney-after-liver safety net: A binary score
        - Candidates meeting the policy for kidney-after-liver safety net receive a rating score of 1.
        - All other candidates receive a rating score of 0.
    - Qualifying time: Each candidate has a qualifying time in years on the waiting list.
        - The candidate's qualifying time rating score is calculated as $0.1 * (time\ in\ years)$.
5. Placement efficiency: Candidates receive a score based on a piecewise linear function of the distance in nautical miles (NM) of their listed transplant center from the donor hospital.
    - Candidates 0-50 NM from the donor hospital (inner plateau) receive a rating score of 1.
    - Candidates 51-250 NM from the donor hospital receive a rating score calculated as $1 - 0.15/200 * (NM - 50)$.
    - Candidates 251-500 NM from the donor hospital receive a rating score calculated as $0.85 - 0.6/250 * (NM - 250)$.
    - Candidates 501-5181 NM from the donor hospital receive a rating score calculated as $0.25 - 0.25/4681 * (NM - 500)$.

### Pancreas

The committee chose the following rating scales for pancreas, kidney-pancreas, and pancreatic islets candidates:

1. Candidate biology: The candidate biology component is split into blood type and cPRA subcomponents.
    - Blood type: A binary score
        - Candidates with blood type identical to the donor receive a rating score of 1.
        - Candidates with blood type compatible with the donor receive a rating score of 0.
        - All other candidates are screened off the match run.
    - cPRA: Each candidate has a cPRA score for their sensitization.
        - The candidate's rating score for cPRA is $((100000^{cPRA}) - 1)/99999)$
2. Patient access: The patient access component is split into pediatric, prior living donor, and qualifying time subcomponents.
    - Pediatric: A binary score
        - Candidates younger than 18 years receive a rating score of 1.
        - All other candidates receive a rating score of 0.
    - Prior living donor: A binary score
        - Prior living donors of *any* organ receive a rating score of 1.
        - All other candidates receive a rating score of 0.
    - Qualifying time: Each candidate has a qualifying time in years on the waiting list. The candidate's qualifying time rating score is a piecewise function of qualifying time.
        - Candidates with fewer than 5 years receive a rating score calculated as $0.18 * (time\ in\ years)$.
        - Candidates with more than 5 years receive a rating score calculated as $0.003 * (time\ in\ years) + 0.9$.
3. Placement efficiency: The placement efficiency component is split into proximity efficiency and whole pancreas subcomponents.
    - Proximity efficiency: Candidates receive a score based on a piecewise linear function of the distance in NM of their listed transplant center from the donor hospital.
        - Candidates 0-50 NM from the donor hospital (inner plateau) receive a rating score of 1.
        - Candidates 51-250 NM from the donor hospital receive a rating score calculated as $1 - 0.75/200 * (NM - 50)$.
        - Candidates 251-5181 NM from the donor hospital receive a rating score calculated as $0.25 - 0.25/4931 * (NM - 250)$.
    - Whole pancreas: A binary score
        - Candidates listed for whole pancreas transplant as opposed to pancreatic islets receive a rating score of 1.
        - All other candidates receive a score of 0.

## Weights

**Table 1:** Simulation scenario weights for kidney

| Subcomponent | Scenario 1: Combined AHP Weights | Scenario 2: Increased Longevity Weights | Scenario 3: All Donor Efficiency Weights | Scenario 4: High KDPI Efficiency Weights |
|---|---|---|---|---|
| **Medical Urgency** | | | | |
| Medical Urgency | 15% | 10% | 11.67% | 15% |
| **Posttransplant Outcomes** | | | | |
| DR Mismatch | 5% | 20% | 3.89% | 5% |
| EPTS/KDPI | 5% | 20% | 3.89% | 5% |
| **Candidate Biology** | | | | |
| Blood Type | 5% | 3.30% | 3.30% | 5% |
| CPRA | 15% | 10% | 11.67% | 15% |
| **Patient Access** | | | | |
| Prior Living Donor | 15% | 10% | 11.67% | 15% |
| Pediatrics | 15% | 10% | 11.67% | 15% |
| Kidney-After-Liver Safety Net | 5% | 3.30% | 3.89% | 5% |
| Qualifying Time | 10% | 6.70% | 7.78% | 10% |
| **Placement Efficiency** | | | | |
| Proximity Efficiency | 10% | 6.70% | 30% | 10% |

**Table 2:** Simulation scenario weights for pancreas

| Subcomponent | Scenario 1: Combined AHP Weights | Scenario 2: Increased Longevity Weights | Scenario 3: All Donor Efficiency Weights | Scenario 4: High KDPI Efficiency Weights |
|---|---|---|---|---|
| **Candidate Biology** | | | | |
| Blood Type | 15% | 15% | 11.67% | 15% |
| CPRA | 15% | 15% | 11.67% | 15% |
| **Patient Access** | | | | |
| Prior Living Donor | 20% | 20% | 15.56% | 20% |
| Pediatrics | 20% | 20% | 15.56% | 20% |
| Qualifying Time | 10% | 10% | 7.78% | 10% |
| **Placement Efficiency** | | | | |
| Proximity Efficiency | 10% | 10% | 30% | 10% |
| Whole Pancreas | 10% | 10% | 7.78% | 10% |

**Modifiers**

**Table 3:** Simulation donor weight modifiers for kidney scenarios: Scenario 1, combined AHP; scenario 2, increased longevity; scenario 3, all donor

| Subcomponent | KDPI 0%-20% | KDPI 21%-34% | KDPI 35%-85% & Donor Age < 18 y | KDPI 35%-85% & Donor Age ≥ 18 y | KDPI 86%-100% |
|---|---|---|---|---|---|
| **Medical Urgency** | | | | | |
| Medical Urgency | 1 | 1 | 1 | 1 | 1 |
| **Posttransplant Outcomes** | | | | | |
| DR Mismatch | 1 | 1 | 1 | 1 | 1 |
| EPTS/KDPI | 1 | 1 | 1 | 1 | 1 |
| **Candidate Biology** | | | | | |
| Blood Type | 1 | 1 | 1 | 1 | 1 |
| CPRA | 1 | 1 | 1 | 1 | 1 |
| **Patient Access** | | | | | |
| Prior Living Donor | 1 | 1 | 1 | 1 | 0 |
| Pediatrics | 1 | 1 | 1 | 0 | 0 |
| Kidney-After-Liver Safety Net | 0 | 1 | 1 | 1 | 1 |
| Qualifying Time | 1 | 1 | 1 | 1 | 1 |
| **Placement Efficiency** | | | | | |
| Proximity Efficiency | 1 | 1 | 1 | 1 | 1 |

**Table 4:** Simulation donor weight modifiers for kidney scenario: Scenario 4, high KDPI

| Subcomponent | KDPI 0%-20% | KDPI 21%-34% | KDPI 35%-85% & Donor Age < 18 y | KDPI 35%-85% & Donor Age ≥ 18 y | KDPI 86%-100% |
|---|---|---|---|---|---|
| **Medical Urgency** | | | | | |
| Medical Urgency | 1 | 1 | 1 | 1 | 1 |
| **Posttransplant Outcomes** | | | | | |
| DR Mismatch | 1 | 1 | 1 | 1 | 1 |
| EPTS/KDPI | 1 | 1 | 1 | 1 | 1 |
| **Candidate Biology** | | | | | |
| Blood Type | 1 | 1 | 1 | 1 | 1 |
| CPRA | 1 | 1 | 1 | 1 | 1 |
| **Patient Access** | | | | | |
| Prior Living Donor | 1 | 1 | 1 | 1 | 0 |
| Pediatrics | 1 | 1 | 1 | 0 | 0 |
| Kidney-After-Liver Safety Net | 0 | 1 | 1 | 1 | 1 |
| Qualifying Time | 1 | 1 | 1 | 1 | 1 |
| **Placement Efficiency** | | | | | |
| Proximity Efficiency | 1 | 1 | 1 | 1 | 3 |

**Table 5:** Simulation donor weight modifiers for all pancreas scenarios: Scenario 1, combined AHP; scenario 2, increased longevity; scenario 3, all donor; scenario 4, high KDPI

| Subcomponent | Donor Age ≤ 45 y & Donor BMI ≤ 30 | Donor Age > 45 y or Donor BMI > 30 |
|---|---|---|
| **Candidate Biology** | | |
| Blood Type | 1 | 1 |
| CPRA | 1 | 1 |
| **Patient Access** | | |
| Prior Living Donor | 1 | 1 |
| Pediatrics | 1 | 1 |
| Qualifying Time | 1 | 1 |
| **Placement Efficiency** | | |
| Proximity Efficiency | 1 | 1 |
| Whole Pancreas | 1 | -1 |

## Baseline Scenario

The simulation runs of the current allocation rules will be used as a baseline scenario for all simulation comparisons and as a means of tuning the overall simulation and its sub-models.

The current allocation rules for kidney-pancreas allocation give organ procurement organizations (OPOs) a choice between two pathways for kidney-pancreas donors (OPTN Policy 11.5.A). However, the simulator must follow a deterministic allocation order for all donors. At the March 15, 2022, meeting of the OPTN OPO Committee, OPO representatives indicated that current practice generally follows the pathway of offering both kidney and pancreas to the complete kidney-pancreas match run before offering the kidney to the kidney-alone match run. Accordingly, the baseline and all alternative simulation scenarios for this request will also follow this pathway.

## Cohort

The cohort for all simulation runs was all kidney and pancreas candidates who were active from March 15, 2021, through March 15, 2022, and all transplanted organs (kidney, kidney-pancreas, and pancreas) from the same period. This period was chosen to correspond with the implementation of the current allocation policy, and allow for 1 full year of donated organs from which to sample.

## Analysis Metrics

All metrics, including outcomes and grouping variables, used in the presentation of results will be considered during the verification and validation of the simulation model(s) (ie, the same metrics used for tuning the models will be used for the presentation of the simulated results). For each metric described below, the tuning results will be used to help inform the interpretation of the simulated results of the four continuous distribution scenarios. Because the tuning is specific to this data request, the results are unknown in advance. This means that not all metrics are guaranteed to be included in the analysis; the possibility of describing a metric as not validated will be left open.

### Transplant Rate

Transplant rate, along with time to transplant, was the primary metric used for tuning the simulation models and in turn for analysis. The transplant rate is an average value across the simulation period and the person-time used for the denominator is common across all outcomes (ie, a competing risk framing). Person-time is calculated in days for all candidates from the start of their simulation period (simulation start or listing) to transplant, waitlist removal, or simulation end.

The transplant rate is examined by population and clinical grouping factors.

**Population groups:**

- Sex
- Race
- Ethnicity
- Age
- Rural/urban residence
- Geography

**Clinical groups:**

- Sensitization, or cPRA
- Blood type (ABO)

- EPTS
- Medical urgency, defined for kidney as imminent loss of dialysis access*
- Time on dialysis
- Pancreas-after-kidney transplant or kidney-after-liver safety net*

After validation analysis, medical urgency and pancreas-after-kidney transplant or kidney-after-liver safety net subgroups had too few records to be included for analysis.

### Other Tuning Metrics

In addition to transplant rate, the following metrics and grouping variable combinations were used for tuning and in turn for analysis.

- HLA matches
  - By race
- Posttransplant survival
  - By age
- Kidney donor risk (KDPI)
  - By age
- Donor-recipient distance
  - By geographic area

## Simulation sub-models

Simulation of the organ allocation system requires a number of sub-models, which are described here. All simulated scenarios share the same set of sub-models.

### History Generation

Transplant recipients in the historical cohort do not have a complete history from the standpoint of the simulation. Through simulation we hope to create novel match runs, so transplant recipients require a waitlist history for the simulation period after their transplant: a model of what would have happened had they not received a transplant.

Histories were generated for candidates who underwent transplant with an organ from a deceased donor allocated through the OPTN process. Living donor recipients and those who underwent transplant in another country did not have histories generated; in the simulation they were removed from the list at their time of transplant like any other removal. The availability of living donors and foreign transplants are external to the simulated system.

Each listing for recipients who were listed at multiple centers was treated independently. Each will have a history generated based on the last records available for the listing of each center; though this is the same individual the value for each of their records at the two (or more) centers are not *required* to match.

There are two time-varying fields important for allocation policies in this simulation analysis, EPTS and cPRA.

cPRA is updated when the candidate's transplant center enters new unacceptable antigen information. For this history generation model we assumed that candidates who received a transplant had an already advantageous cPRA value and so their transplant programs did not make any updates to their unacceptable antigen information. That is, the recipients keep their cPRA value at transplant.

Raw EPTS is calculated as:

```
Raw EPTS = 0.047 * max(Age - 25, 0) - 0.015 * Diabetes * max(Age - 25, 0)
+ 0.398 * Prior Solid Organ Transplant - 0.237 * Diabetes * Prior Organ Transplant
+ 0.315 * log(Years on Dialysis + 1) - 0.099 * Diabetes * log(Years on Dialysis + 1)
+ 0.130 * (Years on Dialysis = 0) - 0.348 * Diabetes * (Years on Dialysis = 0) + 1.262 * Diabetes
```

For the purpose of calculating EPTS in a generated patient history, we assumed Diabetes and Prior Organ Transplant statuses do not change. Given this, the only values that changed were Years on Dialysis and Age. The Raw EPTS was simply calculated every day of the simulation period post-transplant.

Waitlist removal was modeled with a matching algorithm. An attempt was made to match each transplant recipient to a candidate who did not receive a transplant during the cohort period; potential candidates were removals from the list or those who were still waiting. The matching was based on:

- Kidney:
  - Gender
  - Age at listing +/- 5 years of transplanted candidate
  - Waitlist organ
  - At least 80% of the waiting time as the transplanted candidate
- Pancreas and Kidney-Pancreas
  - Gender
  - Age at listing +/- 10 years of transplanted candidate
  - Waitlist organ

After matching to create a group of potential candidates and checking that there were at least 10 unique candidates, a single candidate and date on their waitlist history that met the criteria was randomly selected. This sampled waitlist history was then applied to the transplant recipient at their transplant date. If this sampled removal history was:

- still waiting on the list historically, then the transplant recipient did not have a generated removal
- removed historically, but not within the remaining simulation period, then the transplant recipient did not have a generated removal
- removed within the remaining simulation period, then the transplant recipient had a generated removal of the same reason as the selected candidate.

After the matching algorithm there were 31 kidney recipients and 1 kidney-pancreas recipient who could not be matched based on too few matching records. These recipients were assumed to remain on the list for the entire simulation period.

## Donor Arrival Generation

Novel simulated match runs are created in part via randomization of the donated organ arrivals. We used a sampling approach to create different simulation iterations based on donor arrival date. All donors were sampled as follows:

- The donor arrival dates were sampled without replacement; reshuffling the donor arrival dates. This was used for 4 simulation iterations, and was intended to closely match the historical record.
- The donor arrival dates were sampled with replacement. This was used for 3 iterations, and was intended to broaden the range of possible match runs.
- Donor arrival dates were sampled uniformly from the entire cohort period. This was used for 3 iterations, and was intended to create more variability. This sampling scheme may “smooth out” trends for donor arrival.

## Placement Mechanism (Acceptance Model)

The placement mechanism (PM) in a simulation study of the organ allocation system is a sub-model that determines who (if anyone) on a match run will accept a deceased donor organ for transplant. A PM can take many forms. For the KIPA2022_01 data request we used an "accept/decline" style PM; a PM that offers an organ to candidates sequentially on the match run until a candidate accepts the organ, determined by probabilities calculated from one or more logistic regression models along with a random number generator, or until the match run is exhausted, in which case the organ is not utilized.

Note, since only transplanted organs are included in the cohort, non-utilization of organs is not a validation/analysis metric. The "goal" of the placement mechanism is to place all organs somewhere on the match run; however, given the stochastic nature of the acceptance model framing this is not guaranteed. There will always be some probability that an organ may be declined by every candidate; this is a model artifact, not a model result, and may result in fewer transplants performed in the simulation than were actually performed.

The same PM was used for all requested simulations. This framing introduces an important assumption: the accept/decline behavior of candidates is invariant across allocation polices (i.e., probability of acceptance under different allocation systems is reasonably approximated by the same logistic regression model(s)). This assumption is likely not entirely true in practice. However, the degree to which this assumption is violated in our simulations will depend greatly on the degree of allocation change under consideration and on what variables we allow to inform the PM model.

Since offer acceptance behavior depends, at least in part, on the allocation system in effect, the logistic regression model used to calculate the probability that a candidate will accept an organ was trained using match run data for the baseline allocation system. Discards were not be modeled; only match runs that ultimately resulted in an acceptance were included in the model building. Four independent models were fit: kidney and 18 or older at listing, kidney and younger than 18 at listing, kidney-pancreas, and pancreas.

We represented each individual "accept/decline" decision made by a candidate on a match run as a record in a logistic regression model. The probability that a candidate will accept an organ for transplant likely depends on characteristics of both the donor and the candidate. The SRTR database provides a large number of possible donor and candidate characteristics which could have informed our model. However, we need to be very careful given that our simulation framing assumes the same accept/decline behavior across allocation policies.

Too many variables, or variables that are heavily allocation-dependent, may produce better model performance during training, but at the expense of learning idiosyncratic behavior that is specific to *that* allocation system and which may not hold under a proposed allocation system.

To avoid such overfitting, we selected a relatively small number of variables to inform the model. Further variable selection was done via penalized regression.

## Post-Transplant Models

Each simulation produces a unique group of patients that are transplanted, some of whom may not have yet received a transplant in reality. To represent post-transplant outcomes in these simulated groups of transplant recipients, predicted probabilities at 1 year and 10 years post-transplant of all-cause graft-failure and of death after transplant were estimated with Cox proportional hazards survival models.

Patients who underwent transplant between January 1, 2007 and November 2, 2021 were included in the cohort to fit the survival models. Patients were followed until the earliest of graft-failure, death or November 2, 2021. Patients who did not experience death or graft-failure were assumed alive until November 2, 2021 even if their date of last followup was prior to November 2, 2021. Living donor transplants were excluded.

Separate models were fit for four different outcomes:

1. Kidney graft-failure, including patient death. This outcome is defined as the earliest of death, relisting, retransplant, resuming dialysis or center reported graft failure.

2. Kidney recipient death.

3. Pancreas graft-failure, including patient death. This outcome is defined as the earliest of death, relisting or retransplant as there has only recently been a consistent OPTN definition of graft-failure.
4. Pancreas recipient death.

The model cohort was split into an 80% training dataset and a 20% validation dataset. Elastic-net Cox proportional hazard models with alpha of 0.99999 were fit with the 80% training dataset for variable selection. Variables identified from program-specific reports as predicting graft failure or death, and additional variables hypothesized to be associated with these outcomes were included. Models were be stratified on demographic or clinical predictors with evidence of violating the proportional hazards assumption to the extent possible. Continuous variables were transformed with linear splines. After variable selection with the elastic net models, center level random effects were estimated with a Cox proportional hazard frailty model with an offset for the linear predictor from the elastic net model.

The linear predictor from the elastic net models and the center level random effect were used to predict the probability of an outcome at 1-year and 10-years post-transplant. For each model, strata specific baseline cumulative hazards at 1-year and 10-years post-transplant were estimated, multiplied by the patient level linear predictor and center level random effect and transformed to a probability of event at 1-year or 10-years post-transplant for each patient. Using the 20% validation dataset, the sum of the probabilities of events from the models was compared to the observed number of events to estimate a multiplier for adjusting the baseline hazard. For example, if there were 120 predicted events, but only 100 observed events, the multiplier (or divisor) is 1.2, and each individual probability is divided by 1.2 to bring the baseline percents closer to those observed in reality.

For the simulated transplants individual level probabilities were estimated using the model parameters and divided by the multipliers. These individual level probabilities were averaged across population subgroups of interest and multiplied by 100 to get the predicted percent of patients within a subgroup that would experience the event by 1-year or 10 -years post-transplant.

**Table 6:** Summary measure for the entire kidney simulation cohort

| | Current Policy | Combined AHP | Increased Longevity | All Donor Efficiency | High KDPI Efficiency |
|---|---|---|---|---|---|
| Transplant Rate per Patient-Year | 0.19 (0.19,0.19) | 0.19 (0.19,0.19) | 0.19 (0.19,0.19) | 0.19 (0.19,0.19) | 0.19 (0.19,0.19) |
| WL Death Rate per Patient-Year | 0.05 (0.05,0.05) | 0.05 (0.05,0.05) | 0.05 (0.05,0.05) | 0.05 (0.05,0.05) | 0.05 (0.05,0.05) |
| Median Travel Distance (NM) | 110 (108,112) | 269 (261,274) | 347 (335,357) | 128 (125,130) | 260 (255,266) |
| 1-year Graft Failure Percent | 6.73 (6.71,6.75) | 7.64 (7.64,7.65) | 7.35 (7.33,7.36) | 7.41 (7.39,7.43) | 7.63 (7.62,7.64) |

Travel distance is between the donor hospital and the transplant center; NM: nautical miles. Person-time is calculated in days for all candidates from the start of their simulation period (simulation start or listing) to transplant, waitlist removal, or simulation end.

## Simulated Results

All results presented in this report represent the mean value for a given metric across the 10 iterations; each metric is calculated at the scenario/iteration level and the mean across iterations is calculated to apply to the scenario; the minimum and maximum across iterations are also presented as error bars in figures and as a range in tables.

### Kidney

The simulated kidney alone transplant rate was 0.19 transplants per patient-year for all continuous distribution scenarios as well as for the simulation of current policy. Waitlist death rates also remained consistent across the continuous distribution scenarios as well as the simulation of current policy at 0.05 deaths per patient-year. The median travel distance for kidneys was higher under all continuous distribution scenarios: under the "All Donor Efficiency" continuous distribution scenario, at 128 nautical miles (NM), travel distance was closest to the simulation of current policy (110 NM). The simulation percent of kidney recipients experiencing graft-failure at 1-year post-transplant was higher under all continuous distribution scenarios compared to the simulation of current policy, ranging from 7.35 to 7.64% under continuous distribution and 6.73% under the simulation of current policy. (Table 6)

### Pancreas and kidney-pancreas

The simulated pancreas and kidney-pancreas transplant rate was 0.34 transplants per patient-year for all continuous distribution scenarios as well as for the simulation of current policy. Waitlist death rates also remained consistent across the continuous distribution scenarios as well as the simulation of current policy at 0.04 deaths per patient-year. The median travel distance for pancreas and kidney pancreas was stable under all continuous distribution scenarios compared to the simulation of current policy, except under the "All Donor Efficiency" scenario, at 111 nautical miles (NM), in which travel distance was lower than the simulation of current policy (155 NM). The simulation percent of pancreas and kidney-pancreas recipients experiencing graft-failure at 1-year post-transplant was only slightly higher under all continuous distribution scenarios compared to the simulation of current policy, ranging from 4.76 to 4.95% under continuous distribution and 4.67% under the simulation of current policy. (Table 7)

**Table 7:** Summary measure for the entire pancreas and kidney-pancreas simulation cohort

| | Current Policy | Combined AHP | Increased Longevity | All Donor Efficiency | High KDPI Efficiency |
|---|---|---|---|---|---|
| Transplant Rate per Patient-Year | 0.34 (0.34,0.35) | 0.34 (0.34,0.35) | 0.34 (0.34,0.35) | 0.34 (0.34,0.35) | 0.34 (0.34,0.35) |
| WL Death Rate per Patient-Year | 0.04 (0.04,0.04) | 0.04 (0.04,0.04) | 0.04 (0.04,0.04) | 0.04 (0.04,0.04) | 0.04 (0.04,0.04) |
| Median Travel Distance (NM) | 155 (151,159) | 160 (144,169) | 161 (155,168) | 111 (105,119) | 159 (153,173) |
| 1-year Graft Failure Percent | 4.67 (4.46,4.84) | 4.88 (4.62,5) | 4.92 (4.82,5.06) | 4.76 (4.62,4.88) | 4.95 (4.8,5.07) |

Travel distance is between the donor hospital and the transplant center; NM: nautical miles. Person-time is calculated in days for all candidates from the start of their simulation period (simulation start or listing) to transplant, waitlist removal, or simulation end.

## Summary by Organ

Kidney alone transplant rates remained constant at about 0.19 transplants per patient-year across the simulation of all continuous distribution scenarios as well as under the simulation of current policy. Pancreas and kidney-pancreas transplant rates were also stable between the simulation of current policy and the continuous distribution scenarios, with pancreas alone transplant rates only slightly higher under continuous distribution scenarios and kidney-pancreas transplant rates only slightly lower under three of the four continuous distribution scenarios. (Figure 1)

Waitlist death rates, median KDPI, and the percent of recipients receiving low (KDPI $\leq$ 20) or high (KDPI > 85) KDPI kidneys did not differ noticeably for any organ from the simulation of current policy to any of the continuous distribution scenarios. (Figures 2-5)

Median travel distance was notably higher under all continuous distribution scenarios compared to the simulation of current policy for kidney alone and under most continuous distribution scenarios for pancreas alone transplants, with the "All Donor Efficiency" continuous distribution scenario having the lowest median travel distance among all continuous distribution scenarios for kidney and pancreas alone transplants. By contrast, the median travel distance for kidney-pancreas transplants did not differ notably from the simulation of current policy to the continuous distribution scenarios with the exception of the "All Donor Efficiency" scenario, which had the lowest median travel distance of any simulated scenario for kidney-pancreas transplants. (Figure 6) The distributions of travel distance by scenarios show that under the simulation of current policy, the vast majority of transplant take place within 250 nautical miles of the donor hospital. By contrast, all continuous distributions scenarios show notably more transplants occurring beyond 250 nautical miles from the donor hospital, with the "All Donor Efficiency" scenario concentrating more transplants closer to the donor hospital than the other continuous distribution scenarios. (Figure 7)

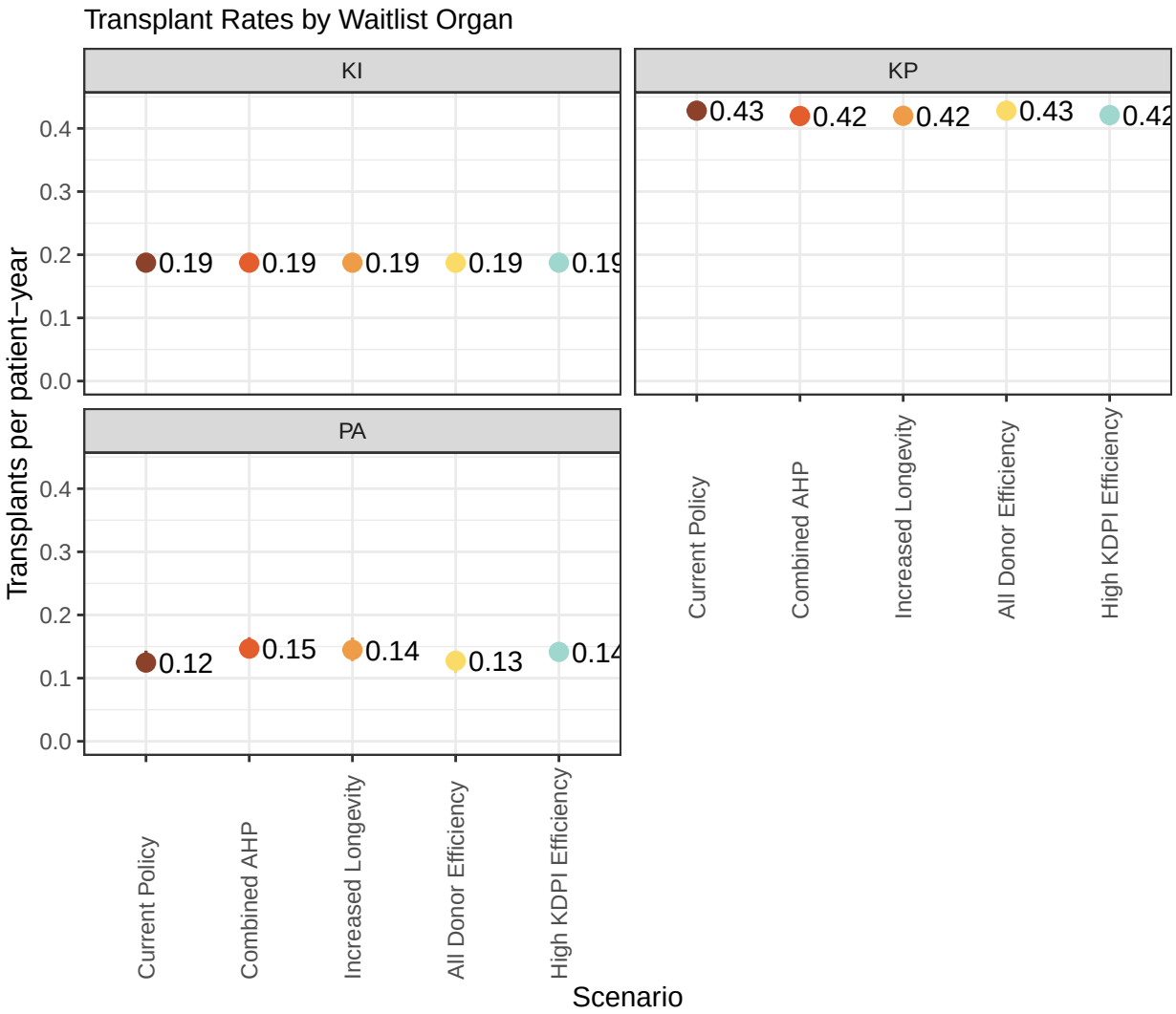


**Figure 1:** Person-time is calculated in days for all candidates from the start of their simulation period (simulation start or listing) to transplant, waitlist removal, or simulation end.

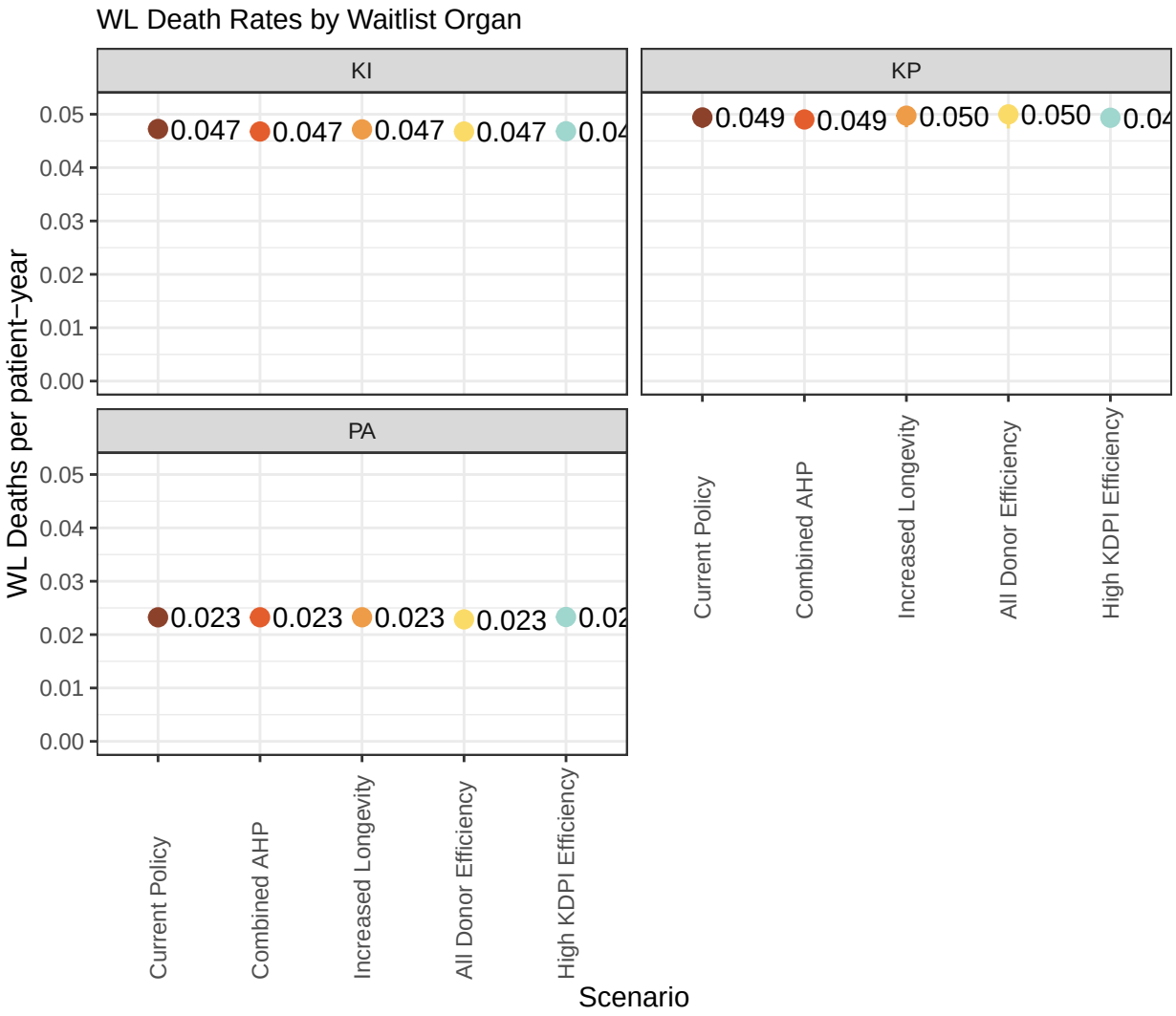


**Figure 2:** Person-time is calculated in days for all candidates from the start of their simulation period (simulation start or listing) to transplant, waitlist removal, or simulation end.

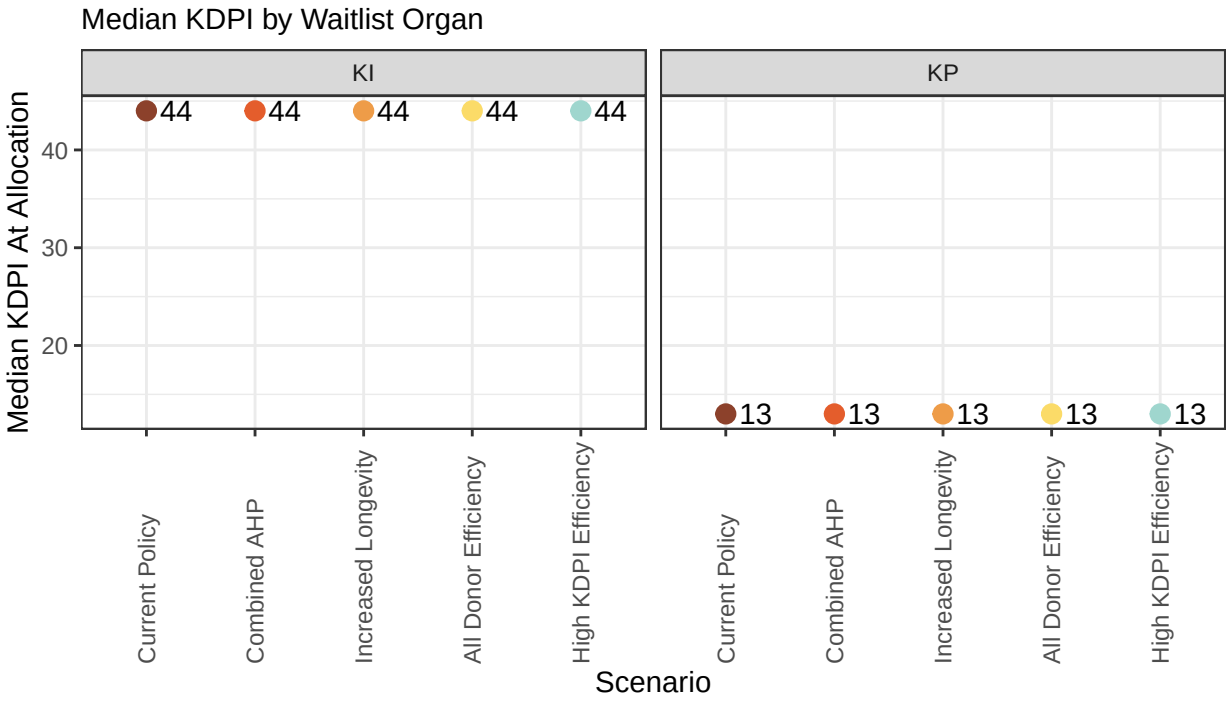


**Figure 3:** Median KDPI. PA recipients are not included.

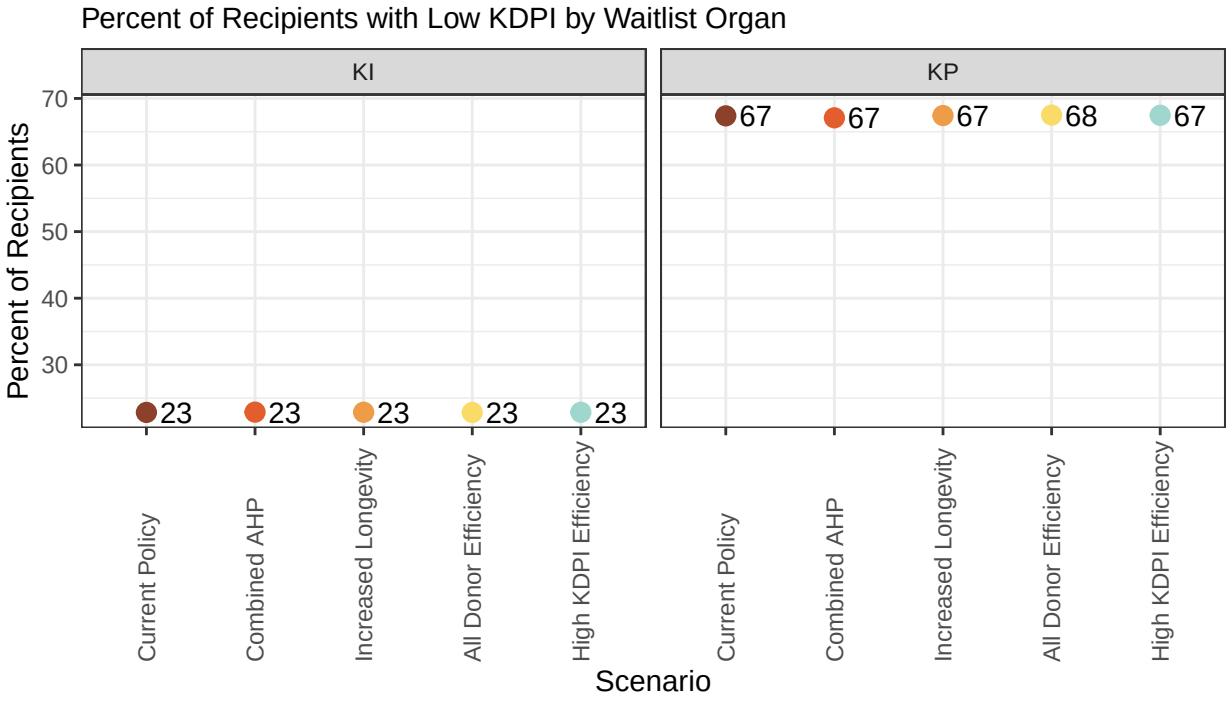


**Figure 4:** Low KDPI are recipients with KDPI in [0, 20]. PA recipients are not included.

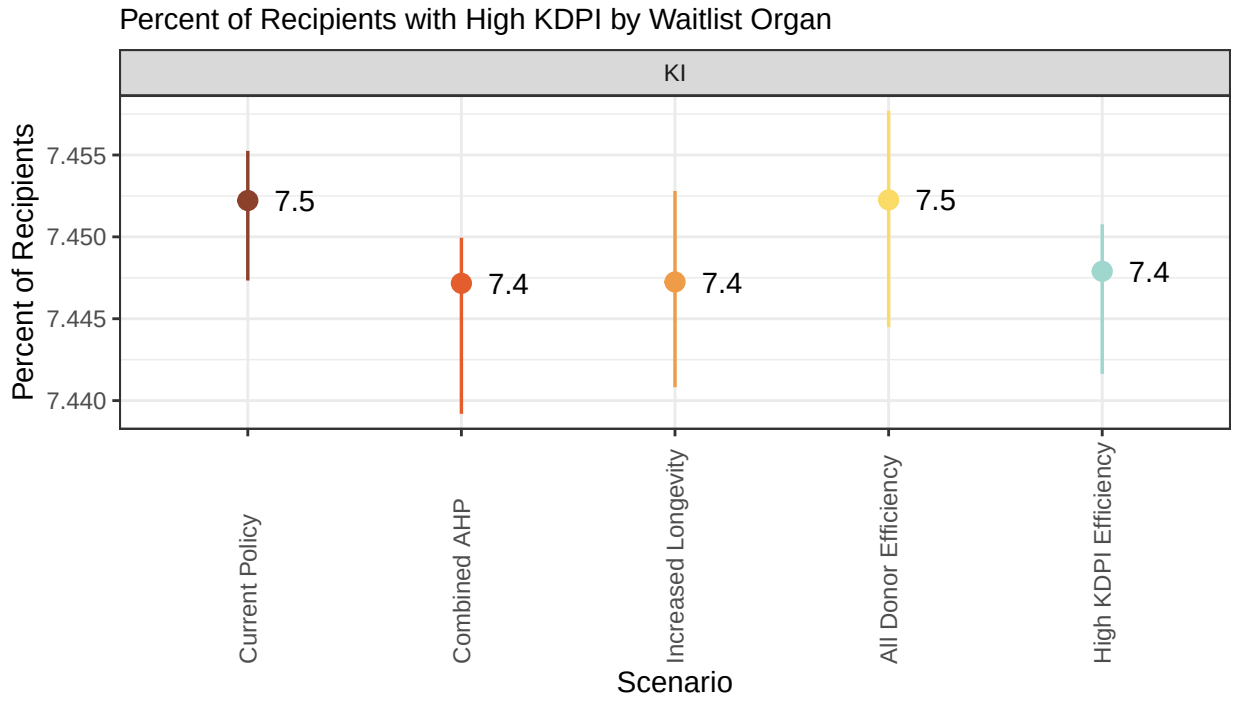


**Figure 5:** High KDPI are recipients with a KDPI in (85, 100]. PA recipients are not included.

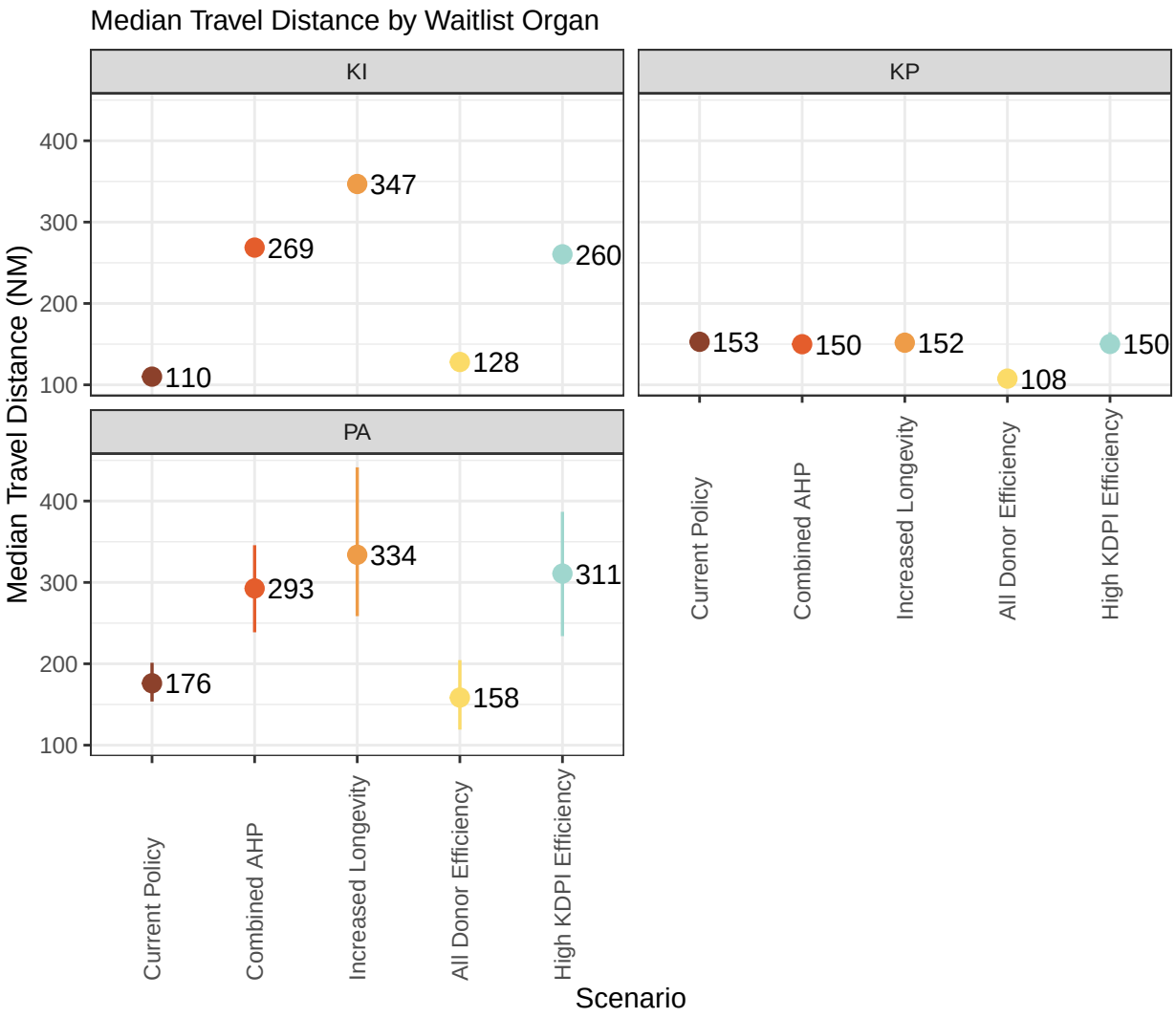


**Figure 6:** Travel distance is between the donor hospital and the transplant center, in nautical miles.

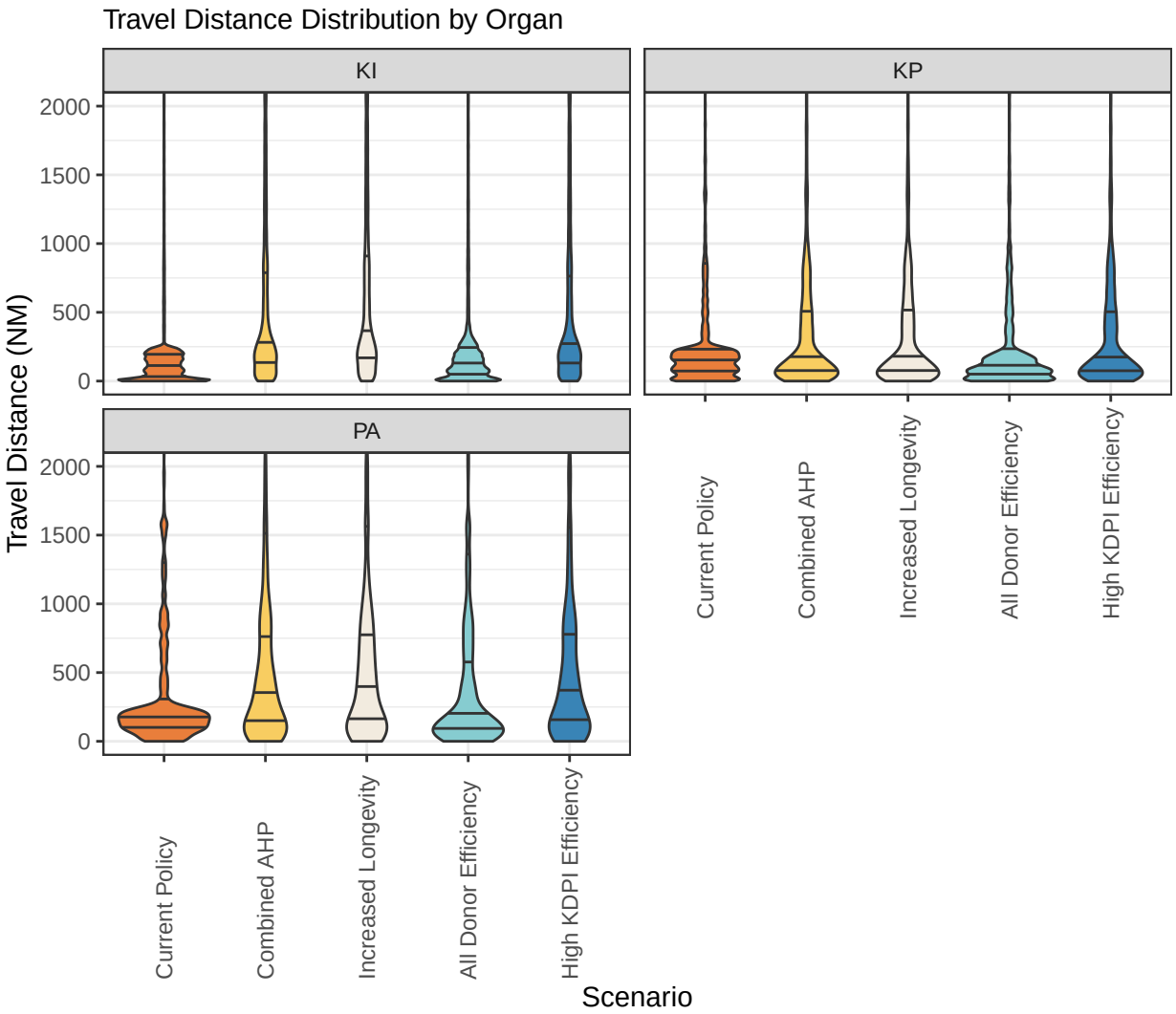


**Figure 7:** Distribution of travel distance. Travel distance is between the donor hospital and the transplant center, in nautical miles.

## Summary by Age

### Kidney

Pediatric kidney transplant rates were higher under all continuous distribution scenarios compared to the simulation of current policy, with the "All Donor Efficiency" scenario being closest to, though still notably higher than, the simulation of current policy. Among patients age 18 to 35, transplant rates were lower under the continuous distribution scenarios compared to the simulation of current policy, with the exception of the "Increased Longevity" scenario, which had slightly higher transplant rates than the simulation of current policy. Among patients age 35 to 50, transplant rates were lower under all continuous distribution scenarios compared to the simulation of current policy, while transplant rates were higher for patients age 65 and older under all continuous distribution scenarios. (Figure 8)

The median KDPI for pediatric kidney recipients remained low across all continuous distribution scenarios and the simulation of current policy. The median KDPI for kidney recipients age 18 to 35 and recipients age 35 to 50 was lower under all continuous distribution scenarios compared to the simulation of current policy, while the median KDPI for kidney recipients age 50 to 65 and recipients age 65 and older was higher under all continuous distribution scenarios. The "Increased Longevity" continuous distribution scenario produced the greatest decrease in median KDPI among recipients age 18 to 35 and the greatest increase in median KDPI among recipients age 50 to 65 compared to the simulation of current policy. (Figure 9)

The percent of pediatric kidney recipients receiving a low (KDPI $\leq$ 20%) KDPI kidney was consistently high across all continuous distribution scenarios and the simulation of current policy. The percent of kidney recipients age 18 to 35 receiving a low KDPI kidney was notably higher under the "Increased Longevity" scenario compared to the simulation of current policy, though under all other continuous distribution scenarios the percent receiving a low KDPI kidney was slightly lower than the simulation of current policy. This trend was reversed in kidney recipients age 50 to 65 with the percent receiving a low KDPI kidney lower under the "Increased Longevity" scenario compared to the simulation of current policy, though all other continuous distribution scenarios had slightly higher percent receiving a low KDPI kidney. The percent of recipients age 35 to 50 receiving a low KDPI kidney was higher under all continuous distribution scenarios compared to the simulation of current policy. The percent of recipients age 65 and older receiving a low KDPI kidney was low across all scenarios, though lowest under the "Increased Longevity" scenario. (Figure 10)

Under the continuous distribution scenarios, no kidney patients age 18 to 35 underwent transplant with high (KDPI > 85%) KDPI kidneys. The percent of kidney recipients age 35 to 50 receiving a high KDPI kidney was lower under every continuous distribution scenario compared to the simulation of current policy, while the percent of kidney recipients age 65 and older receiving a high KDPI kidney was higher under all continuous distribution scenarios. The percent of kidney recipients age 50 to 65 receiving a high KDPI kidney was consistent across scenarios, with the exception of the "Increased Longevity" scenario in which a higher percent received a high KDPI kidney. (Figure 11)

With the exception of the "All Donor Efficiency" scenario, median travel distance of kidneys was higher for every age group under the continuous distribution scenarios compared to the simulation of current policy. The increase in travel distance was most notable for pediatric recipients. Older recipient showed less dramatic increases in median travel distance, though the "Increased Longevity" scenario showed notably increased median travel distances for recipients age 50 and older compared to all other simulated scenarios. The "All Donor Efficiency" scenario was closest to the simulation of current policy for every age group. For recipients age 18 to 50, the median travel distance under the "All Donor Efficiency" scenario was slightly lower than the simulation of current policy; for all other age groups the median travel distance under the "All Donor efficiency scenario was slightly higher. (Figure 12)

The predicted percent of kidney recipients experiencing graft failure by 1-year post-transplant was consistently low across all simulated scenarios for pediatric recipients. Among kidney recipients age 18 to 49, 1-year predicted graft failure rates were lower under the "Increased Longevity" and "All Donor Efficiency" compared to the simulation of current policy, but were not substantially different under other continuous distribution scenarios. Predicted 1-year graft failure percent was higher under all continuous distribution scenarios for kidney recipients age 50 and older. The increased predicted graft failure percent for older recipients was highest under the "Increased Longevity" scenario and was lowest under the "All Donor Efficiency" scenario. (Figure 13)

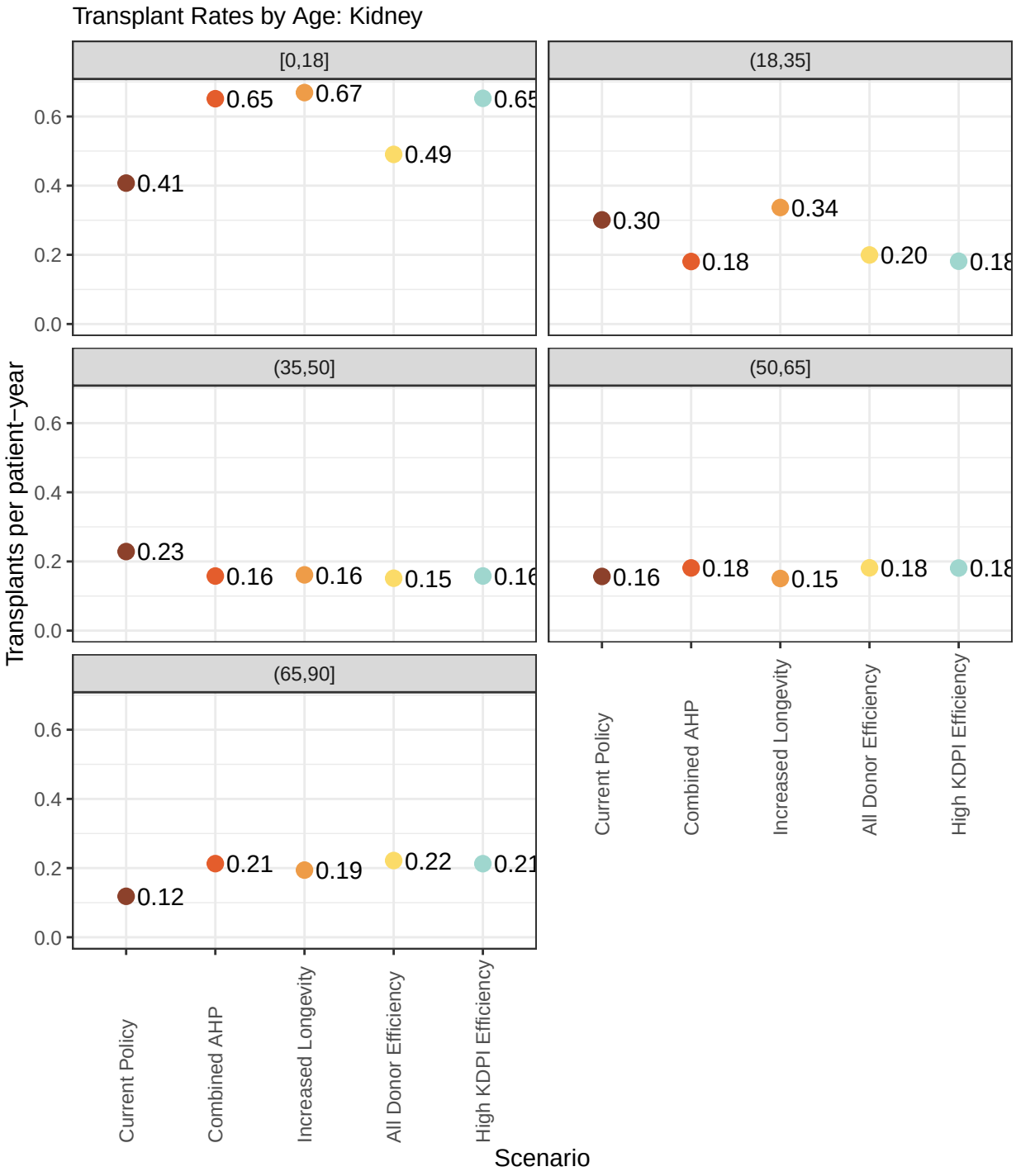


**Figure 8:** Age at listing. Person-time is calculated in days for all candidates from the start of their simulation period (simulation start or listing) to transplant, waitlist removal, or simulation end.

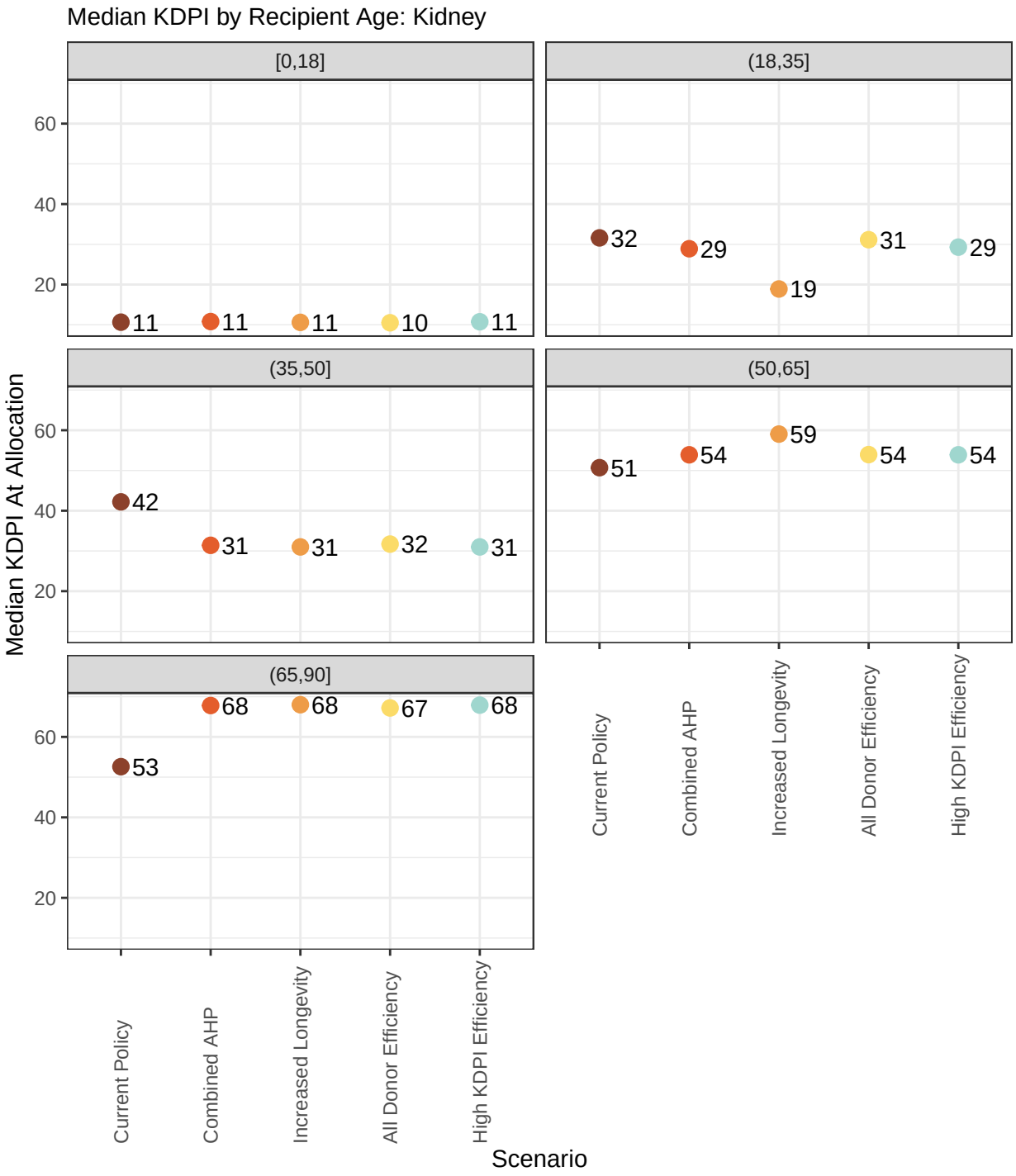


**Figure 9:** Age at transplant.

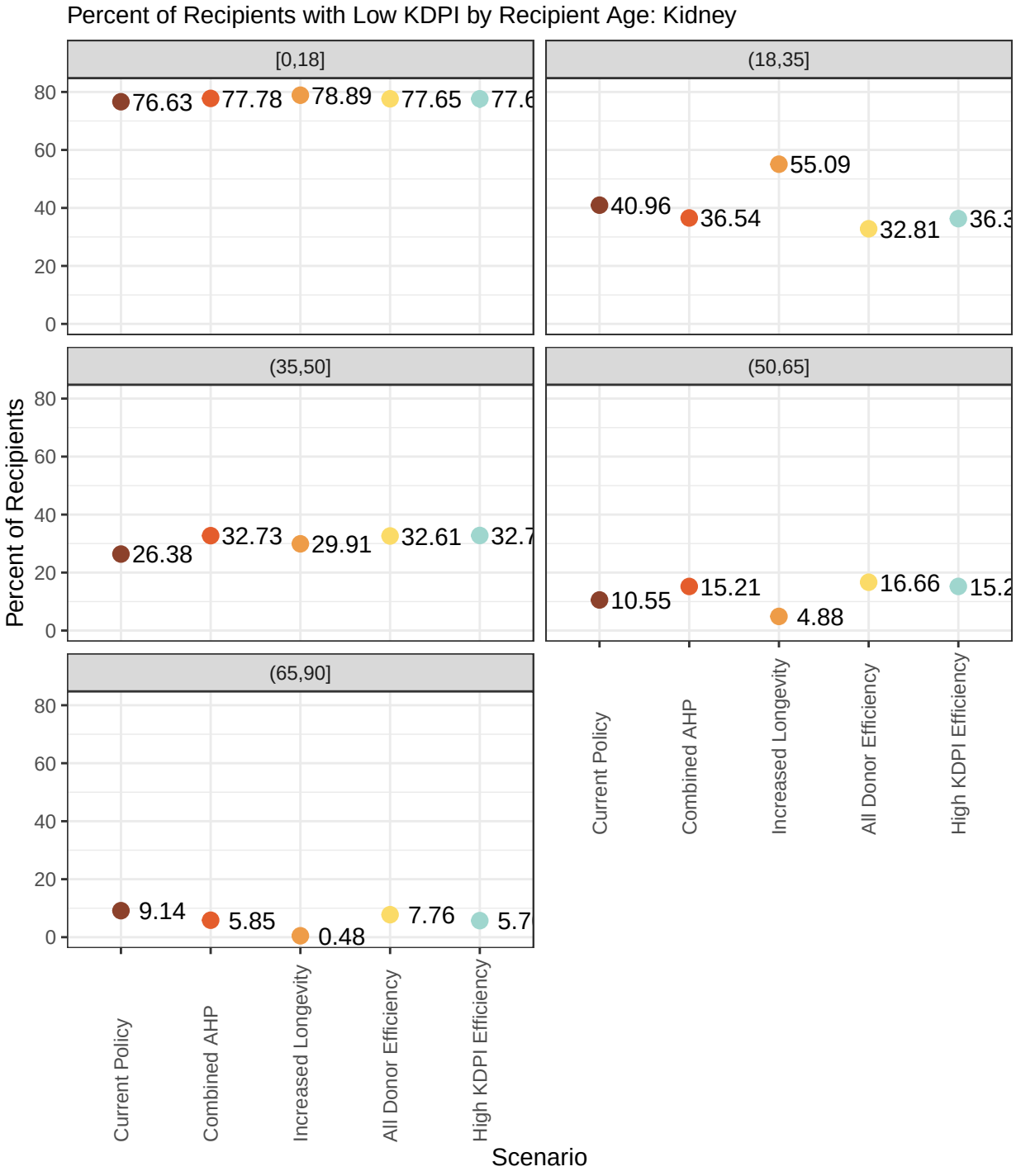


**Figure 10:** Low KDPI are recipients with KDPI in [0, 20].

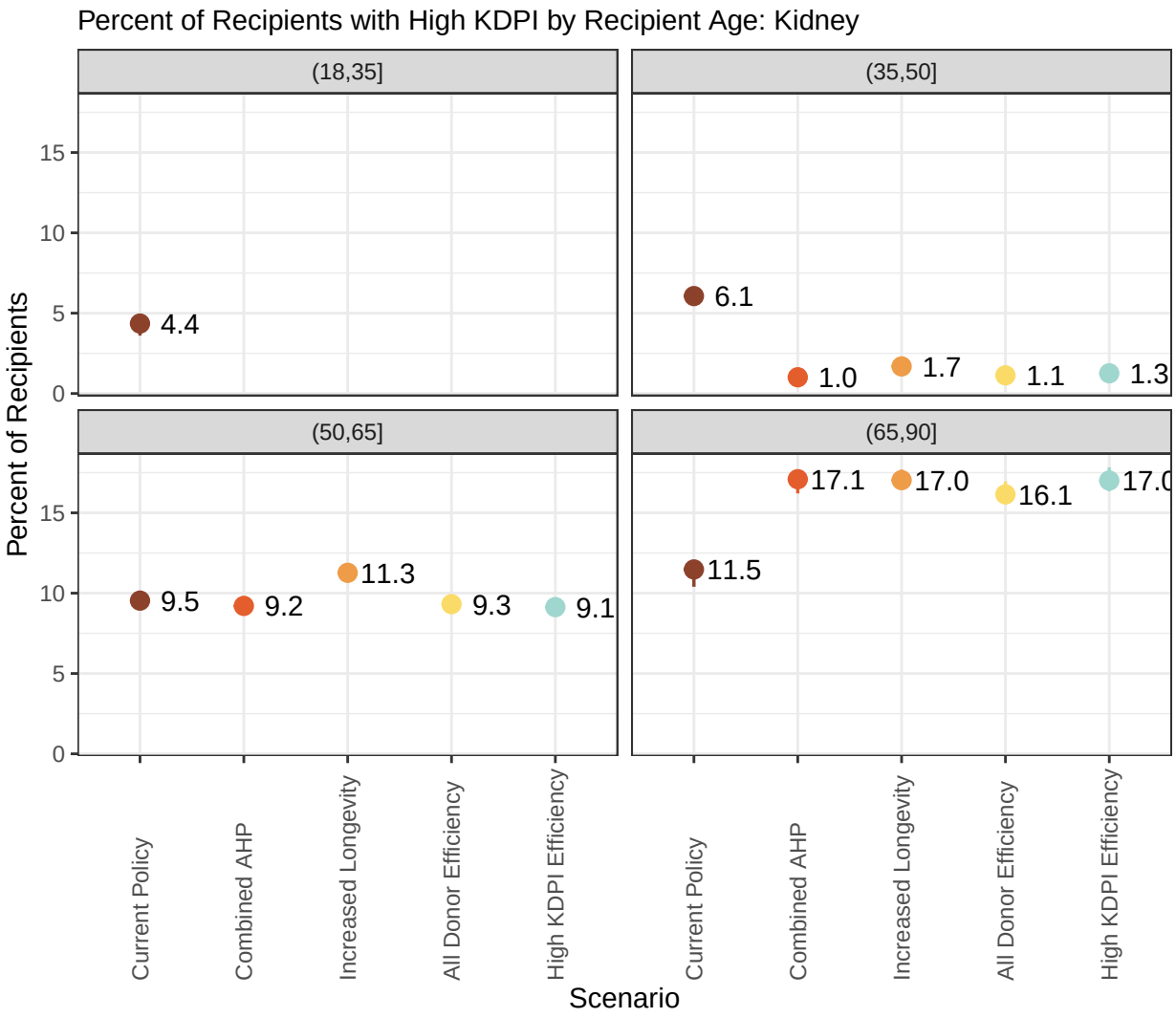


**Figure 11:** High KDPI are recipients with a KDPI in (85, 100].

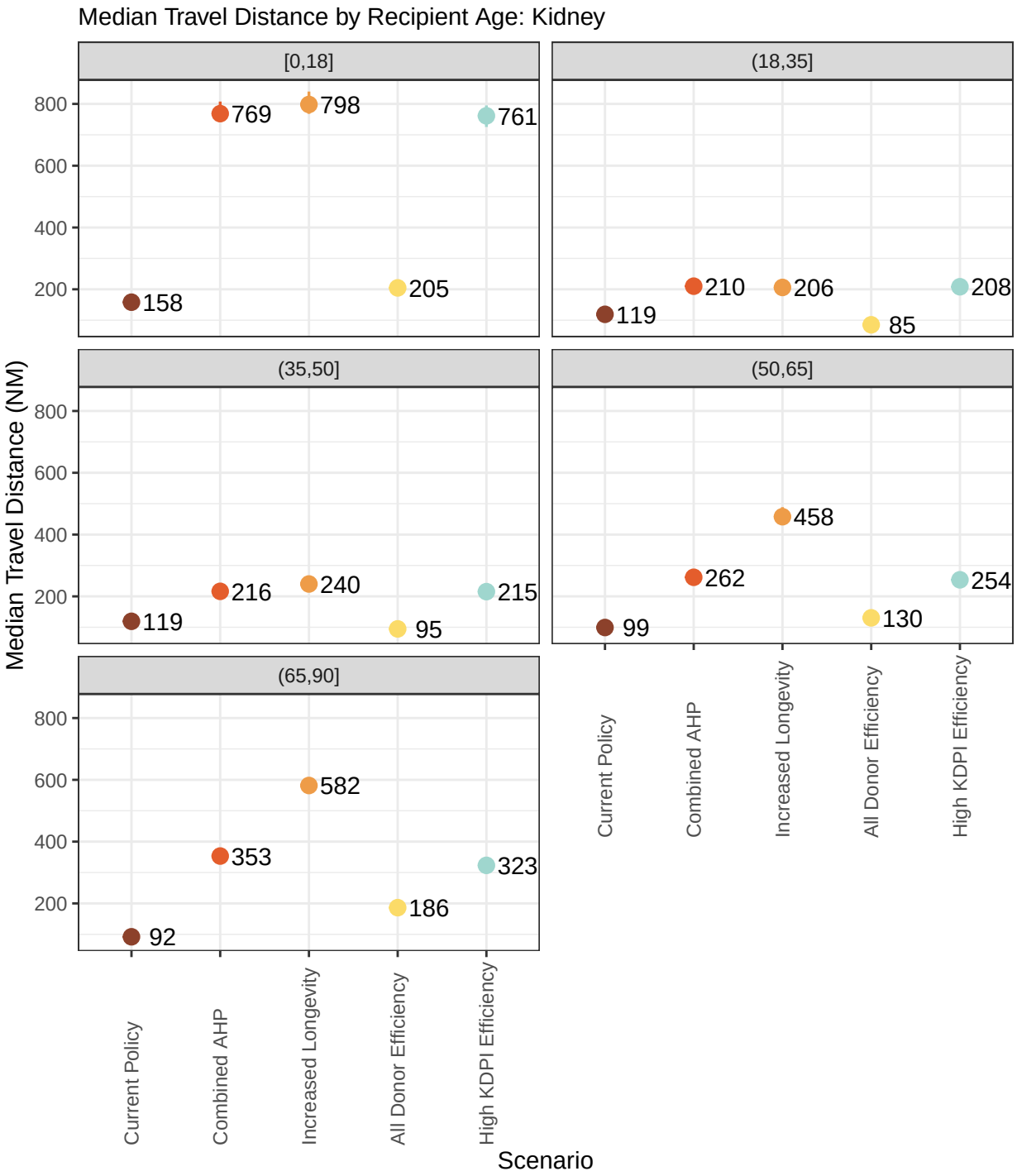


**Figure 12:** Travel distance is between the donor hospital and the transplant center, in nautical miles.

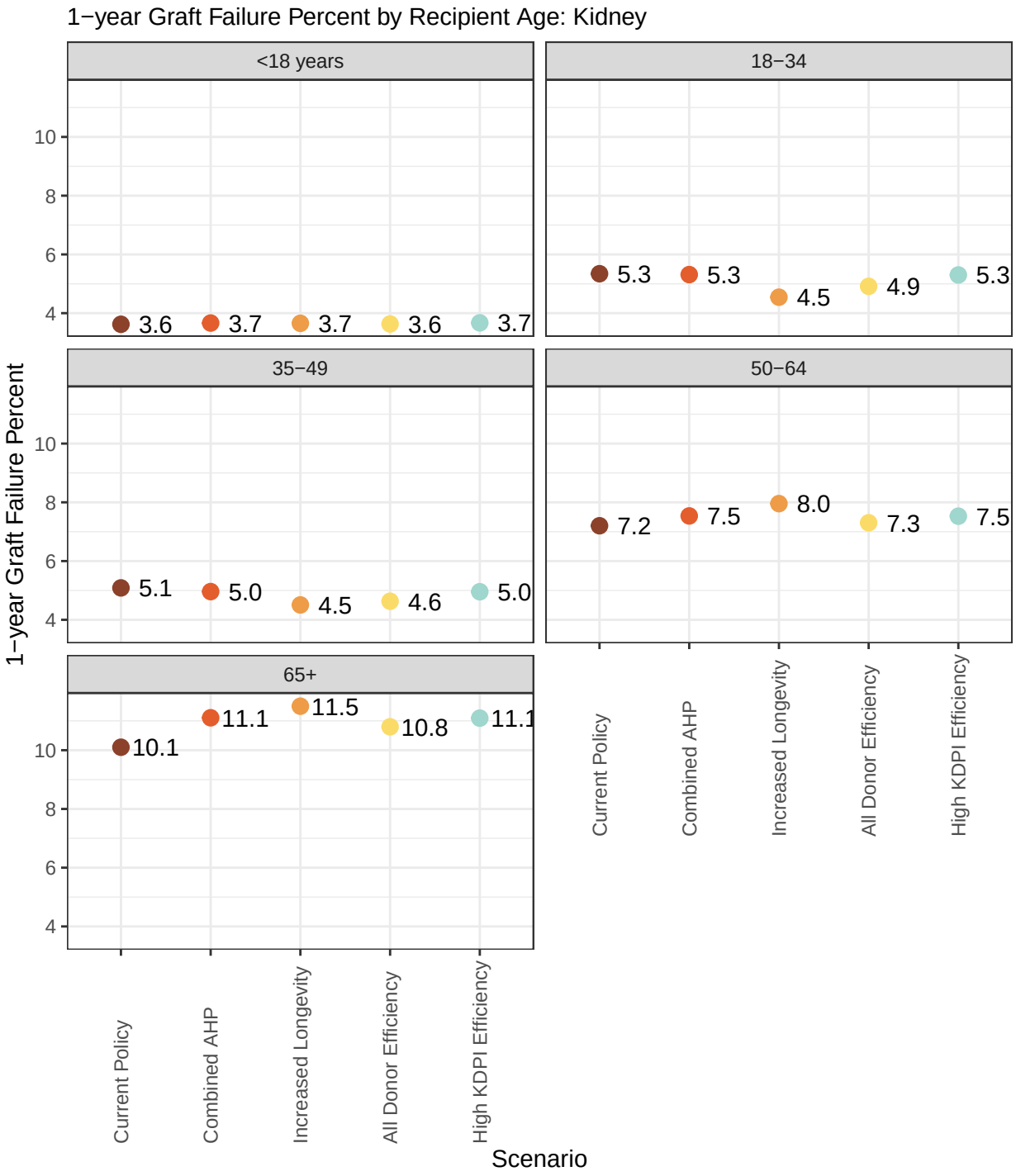


**Figure 13:** Age at transplant. All cause graft failure.

## Pancreas and Kidney-Pancreas

Pancreas and kidney-pancreas transplant rates for pediatric candidates were higher under all continuous distribution scenarios compared to the simulation of current policy. There were wide variations across the iterations of the simulated scenarios for transplant rates for pancreas candidates age 65 and older, though the "Increased Longevity" and "All Donor Efficiency" continuous distribution scenarios had higher transplant rates in this age group than the simulation of current policy. Transplant rates for pancreas candidates age 18 to 65 did not differ noticeably across continuous distribution scenarios or the simulation of current policy. (Figure 14)

Across the iterations of simulated scenarios, there were wide variations in median pancreas and kidney-pancreas travel distance for pediatric recipients, though the median travel distances were greater under continuous distribution scenarios than the simulation of current policy, and notably highest under the "High KDPI Efficiency" scenario. For pancreas and kidney pancreas recipients age 18 and older, the median travel distance did not differ much across continuous distribution scenarios compared to current policy, with the "All Donor Efficiency" scenario having slightly lower median travel distances. Pancreas and kidney-pancreas recipients age 65 and older also had wide variations in median travel distance across iterations of the simulated scenarios, but had lower median travel distances under the "High KDPI Efficiency" scenario as well as the "All Donor Efficiency" scenario. (Figure 15)

The predicted percent of pancreas recipients younger than age 65 who would experience graft failure by 1-year post-transplant was fairly stable across all continuous distribution scenarios and the simulation of current policy. Across the iterations of simulated scenarios, there were wide variations in percent of 1-year pancreas and kidney-pancreas graft-failures for pediatric recipients, though the percent of 1-year post-transplant graft failures was slightly higher under the "High KDPI Efficiency" scenario compared to all other scenarios. For pancreas recipient age 65 and older, the wide variations across iterations of the simulated scenarios for predicted 1-year graft failure percent prevent discerning any notable trend. (Figure 16)

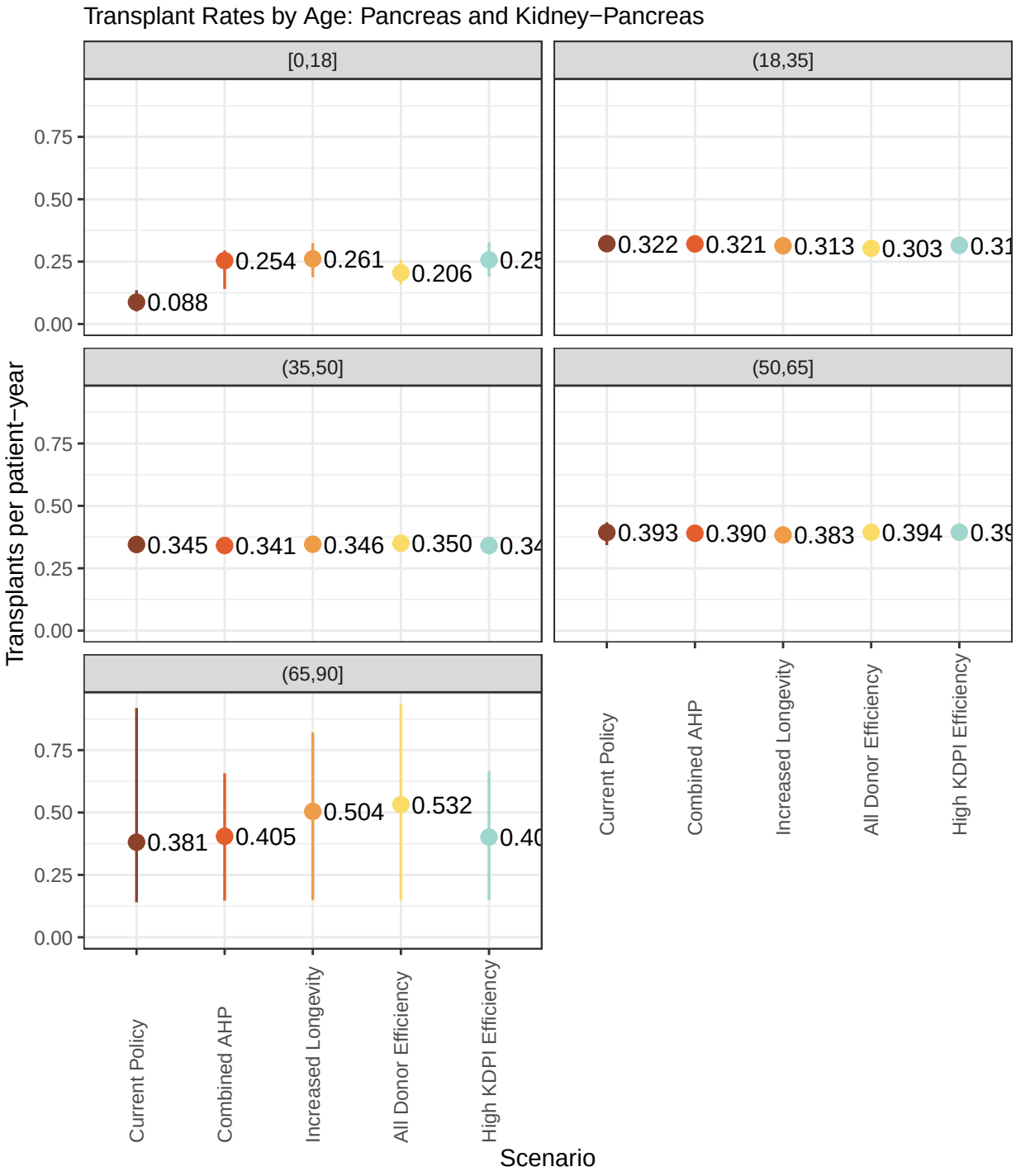


**Figure 14:** Age at listing. Person-time is calculated in days for all candidates from the start of their simulation period (simulation start or listing) to transplant, waitlist removal, or simulation end.

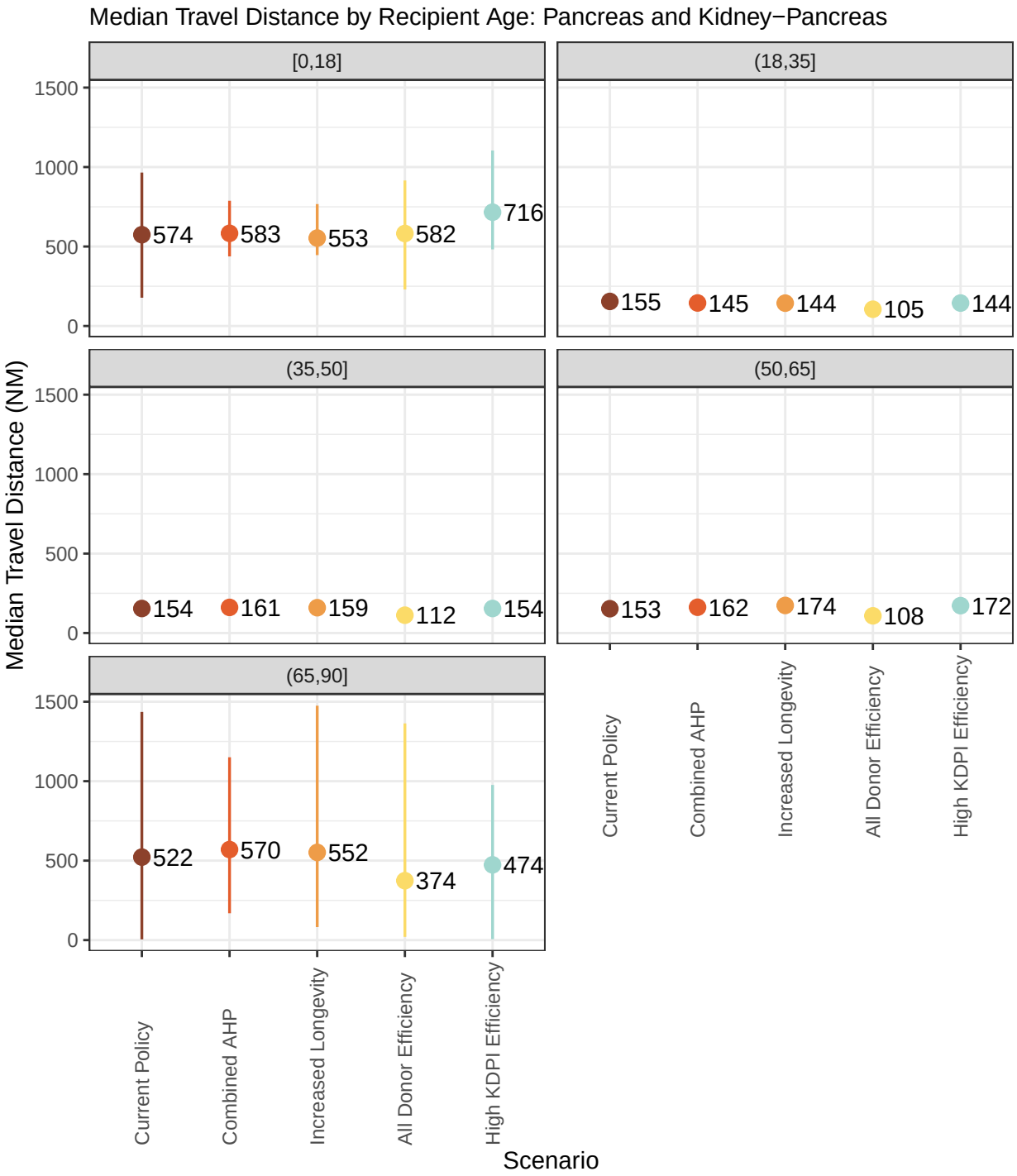


**Figure 15:** Travel distance is between the donor hospital and the transplant center, in nautical miles.

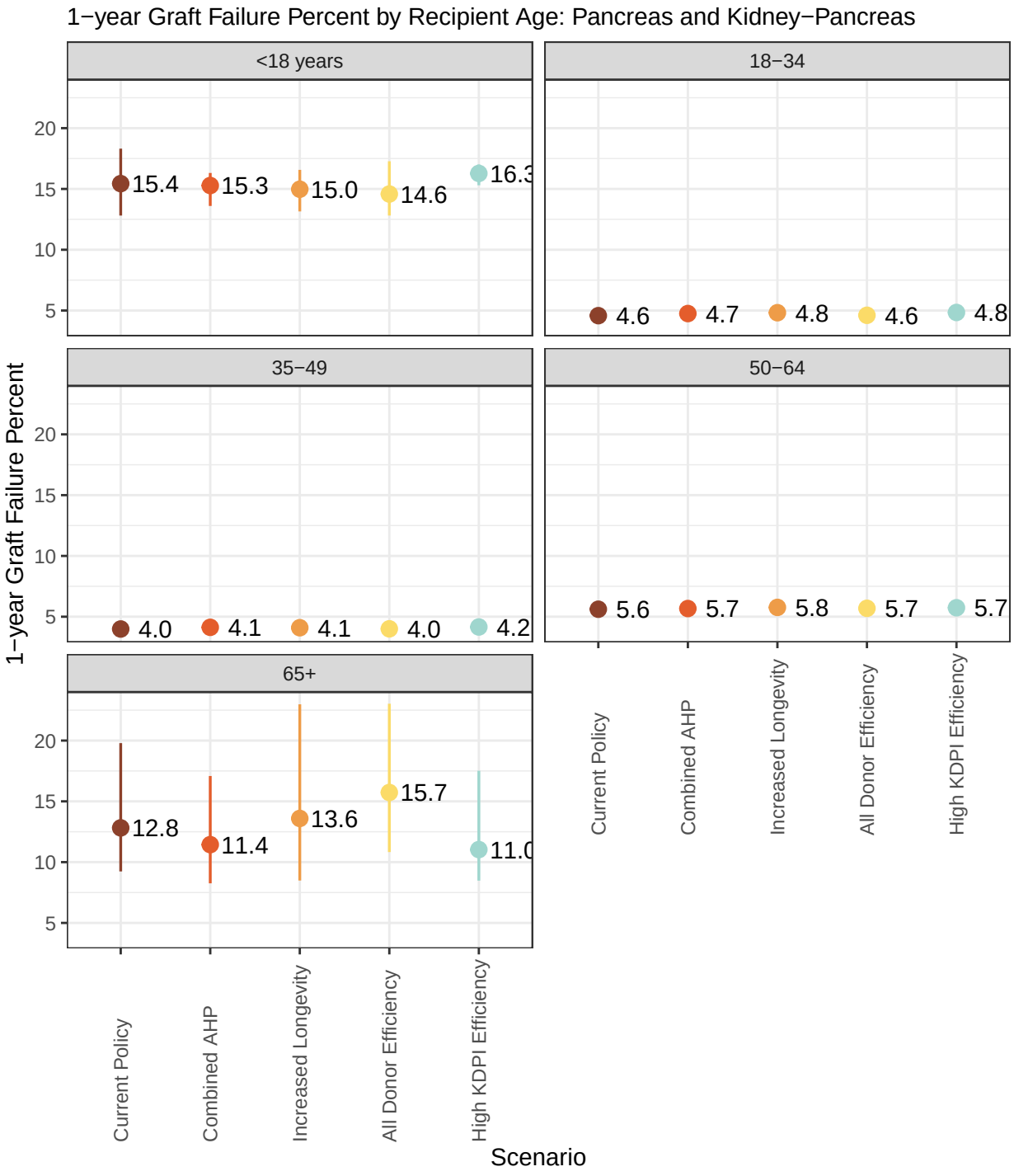


**Figure 16:** Age at transplant. All cause graft failure.

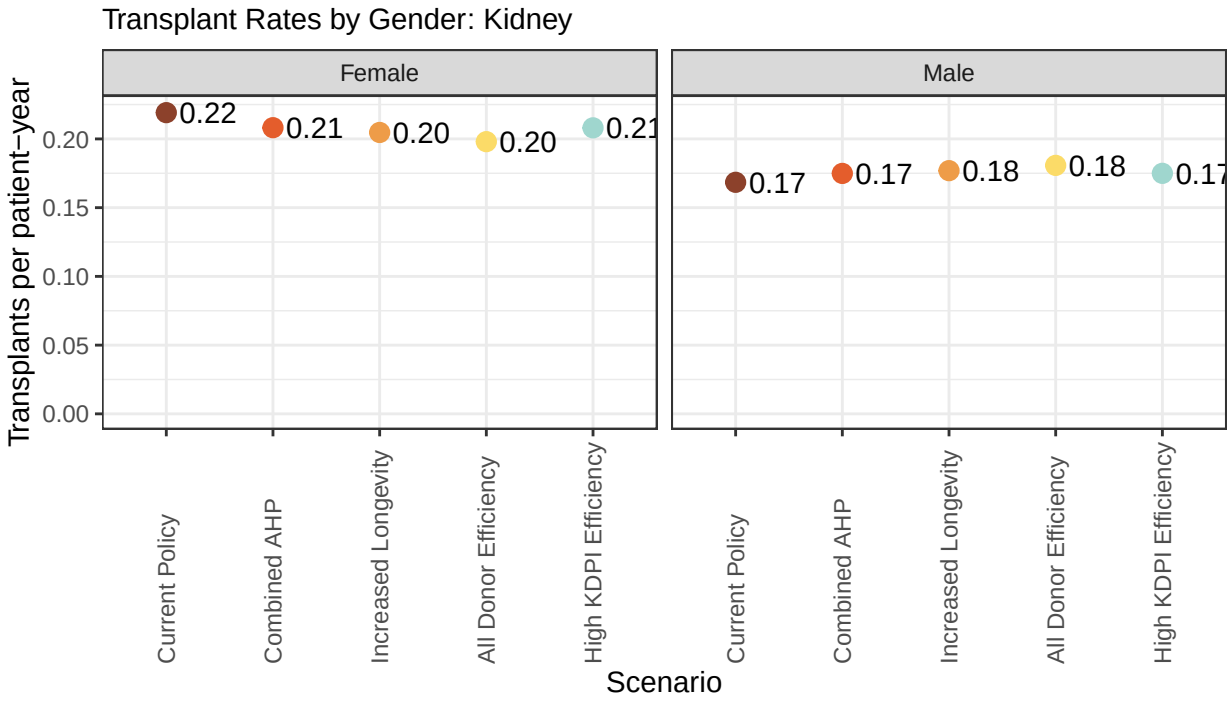


**Figure 17:** Person-time is calculated in days for all candidates from the start of their simulation period (simulation start or listing) to transplant, waitlist removal, or simulation end.

## Transplant Rates by Population Groups

### Kidney

Kidney transplant rates, generally higher among female candidates, did not differ substantially across continuous distribution scenarios for female or male candidates compared to the simulation of current policy. The "All Donor Efficiency" scenario brought the predicted transplant rate for males closest to the predicted transplant rate for females. (Figure 17)

With the exception of Native American and Hawaiian/Pacific Islander candidates, kidney transplant rates did not vary substantially across continuous distribution scenarios compared to current policy, though under the "Increased Longevity" and "All Donor Efficiency" scenarios, the kidney transplant rates were slightly lower for Black candidates compared to other scenarios. Hawaiian/Pacific Islander and Native American candidates had lower transplant rates across all continuous distribution scenarios compared to the simulation of continuous distribution, though the "All Donor Efficiency" scenario had rates closest to the simulation of current policy for these groups. (Figure 18) Between Latino and Not Latino candidates, transplant rates under the continuous distribution scenarios did not substantially differ compared to the simulation of current policy. (Figure 19)

For both urban and rural candidates, kidney transplant rates were quite stable across continuous distribution scenarios and the simulation of current policy. (Figure 20) Across OPTN regions, only Regions 8 (Iowa, Missouri, Nebraska, Kansas, Colorado, Wyoming) and 6 (Montana, Idaho, Oregon, Washington, Alaska, Hawaii), which under the simulation of current policy had notably high transplant rates compared to many other regions, showed marked differences in transplant rates from the simulation of current policy to the continuous distribution scenarios. Both of these regions showed lower transplant rates across all continuous distribution scenarios except for "All Donor Efficiency", which had transplant rates equal to or slightly higher than the simulation of current policy. (Figures 21 & 22)

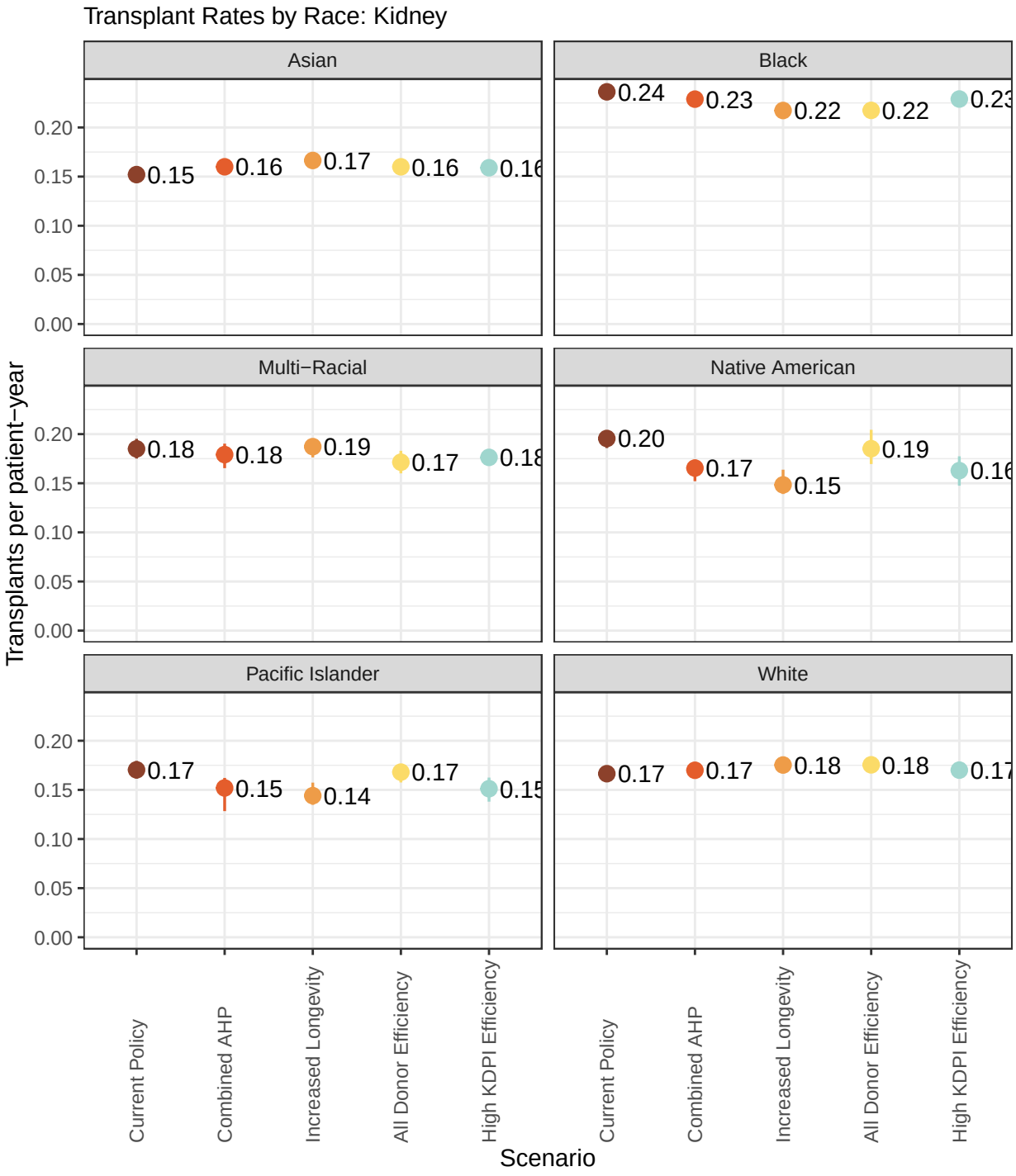


**Figure 18:** Person-time is calculated in days for all candidates from the start of their simulation period (simulation start or listing) to transplant, waitlist removal, or simulation end.

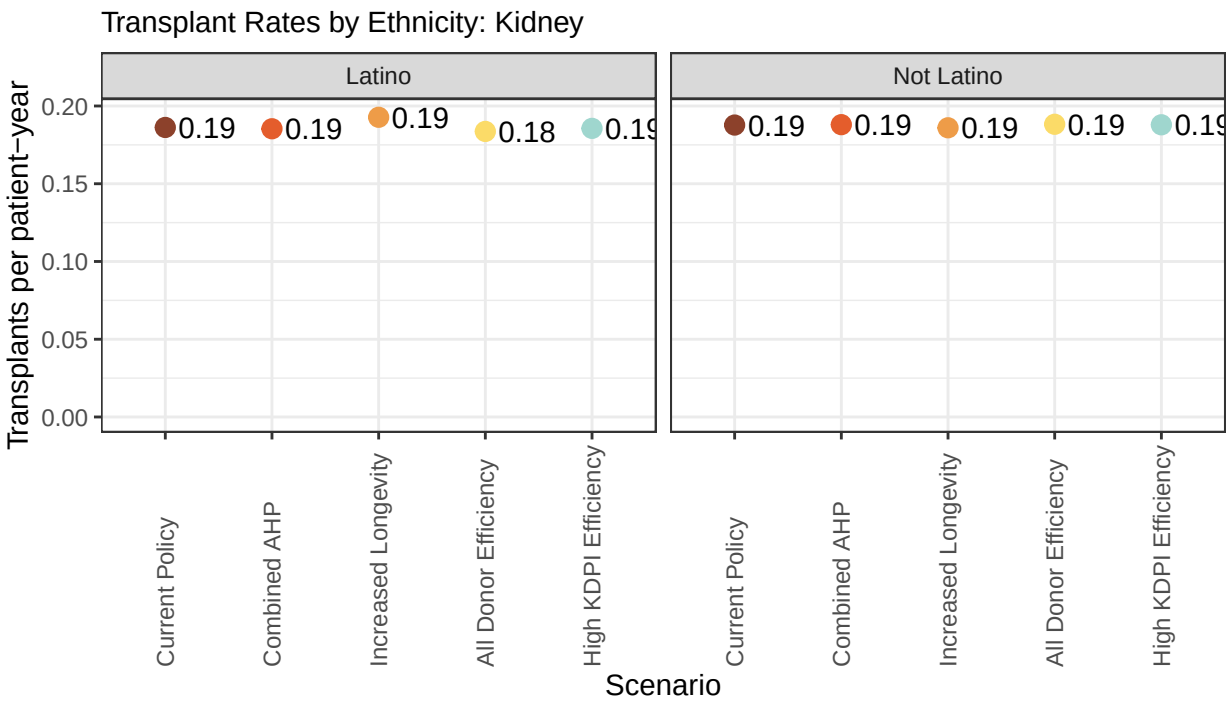


**Figure 19:** Person-time is calculated in days for all candidates from the start of their simulation period (simulation start or listing) to transplant, waitlist removal, or simulation end.

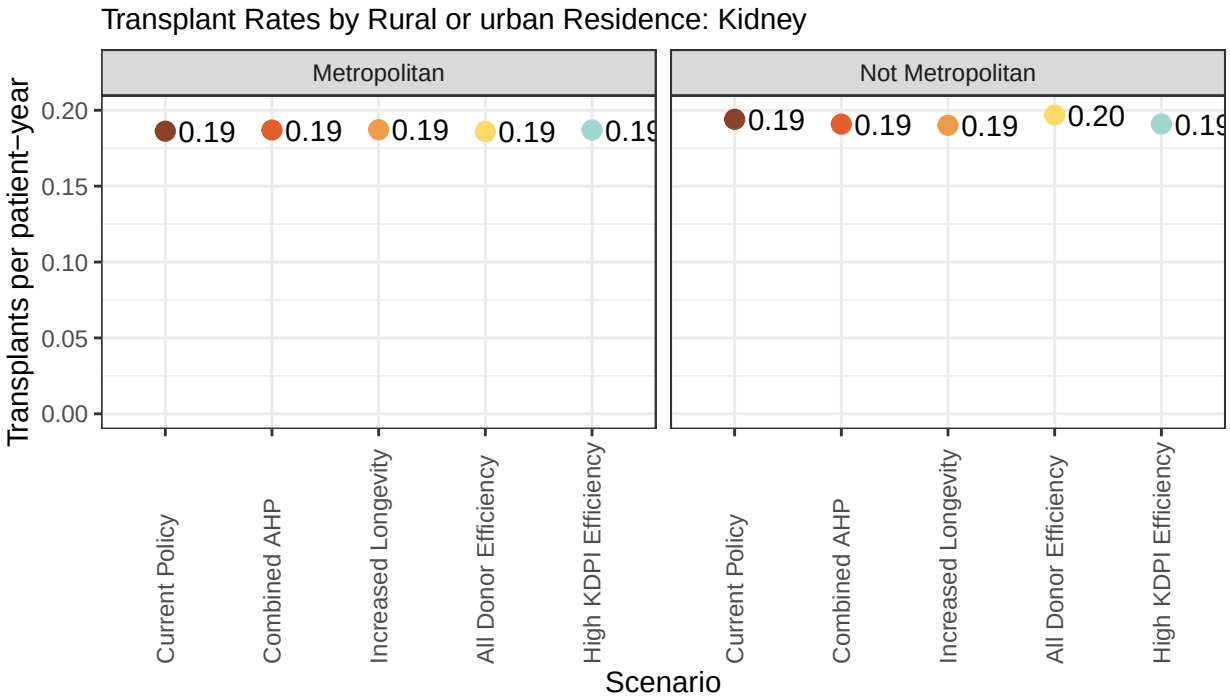


**Figure 20:** Person-time is calculated in days for all candidates from the start of their simulation period (simulation start or listing) to transplant, waitlist removal, or simulation end.

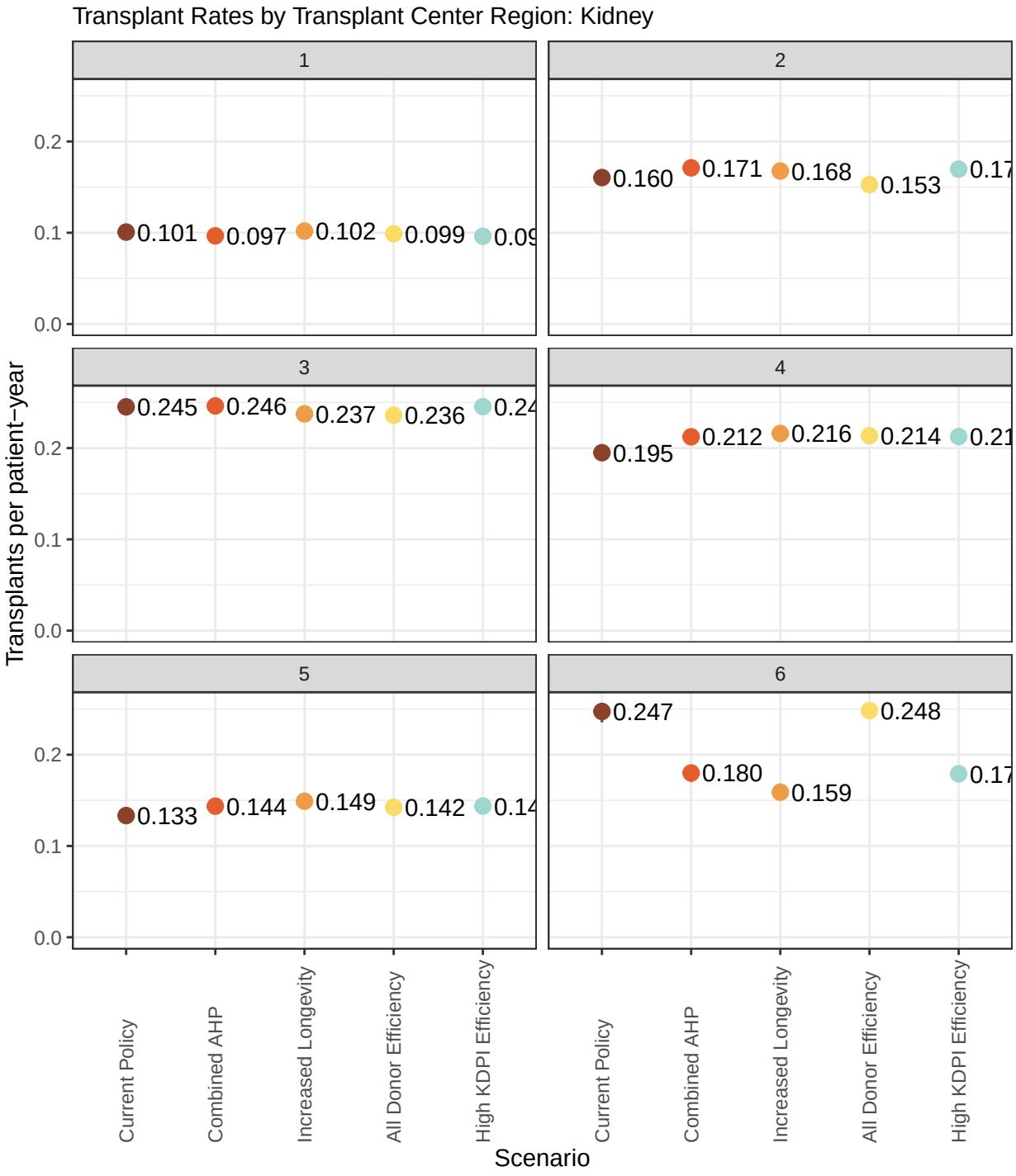


**Figure 21:** Person-time is calculated in days for all candidates from the start of their simulation period (simulation start or listing) to transplant, waitlist removal, or simulation end. OPTN regions numbers 1 to 6.

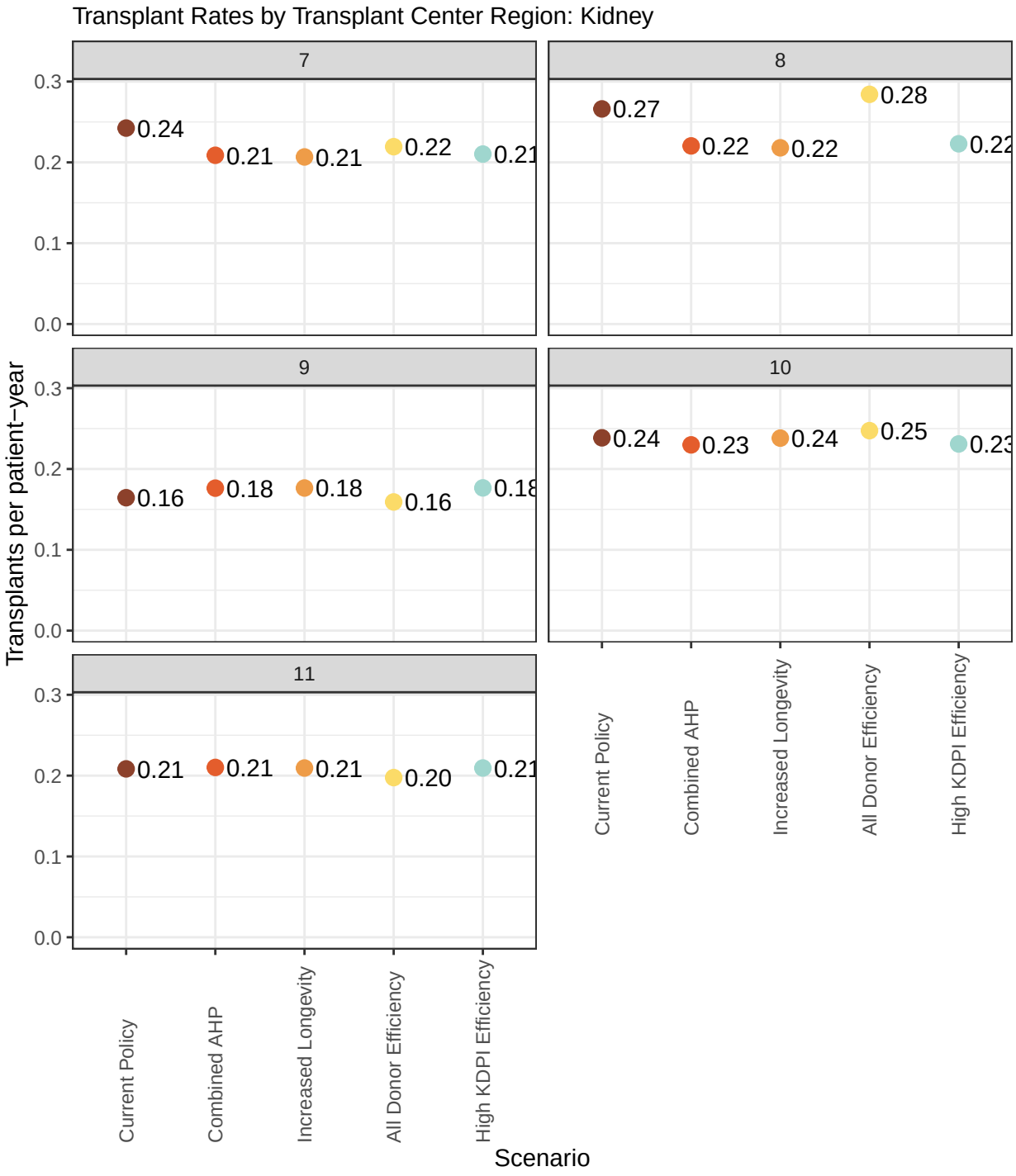


**Figure 22:** Person-time is calculated in days for all candidates from the start of their simulation period (simulation start or listing) to transplant, waitlist removal, or simulation end. OPTN regions numbers 7 to 11.

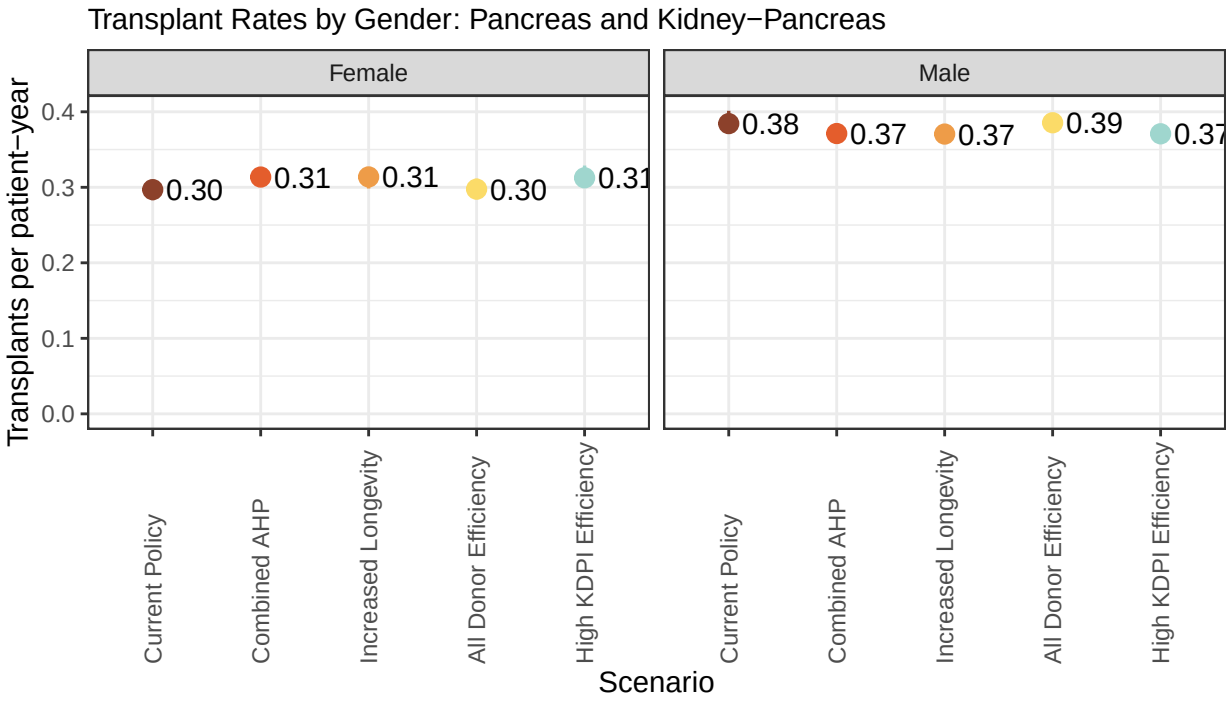


**Figure 23:** Person-time is calculated in days for all candidates from the start of their simulation period (simulation start or listing) to transplant, waitlist removal, or simulation end.

## Pancreas and Kidney-Pancreas

Pancreas and kidney-pancreas transplant rates, generally higher among male candidates, did not differ substantially across continuous distribution scenarios for female or male candidates compared to the simulation of current policy. The predicted transplant rate for females were slightly closer to the predicted transplant rate for males under all continuous distribution scenarios except for the “All Donor Efficiency” Scenario. (Figure 23)

Pancreas and kidney-pancreas transplant rates did not vary substantially by race (Figure 24) or ethnicity (Figure 25) from the simulation of current policy to the continuous distribution: there was only a very slightly higher transplant rate among Latino patients under the continuous distribution scenarios compared to the simulation of current policy and slightly lower, though variable across iterations of the scenarios, transplant rates for Native American candidates under the “Increased Longevity” and “All Donor Efficiency” scenarios.

For both urban and rural candidates, pancreas and kidney-pancreas transplant rates were quite stable across continuous distribution scenarios and the simulation of current policy with a slightly lower transplant rate for rural candidates only under the “High KDPI Efficiency” scenario. (Figure 26) While some OPTN regions showed slightly lower (ie Regions 3 and 4) or slightly higher (i.e. Regions 2 and 6) pancreas and kidney-pancreas transplant rates under continuous distribution scenarios compared to the simulation of current policy, only Region 8, which under the simulation of current policy had notably high transplant rates compared to many other regions, showed marked differences in transplant rates from the simulation of current policy to the continuous distribution scenarios, with lower transplant rates across all continuous distribution scenarios - the “All Donor Efficiency” scenario being closest to the simulation of current policy. (Figures 27 & 28)

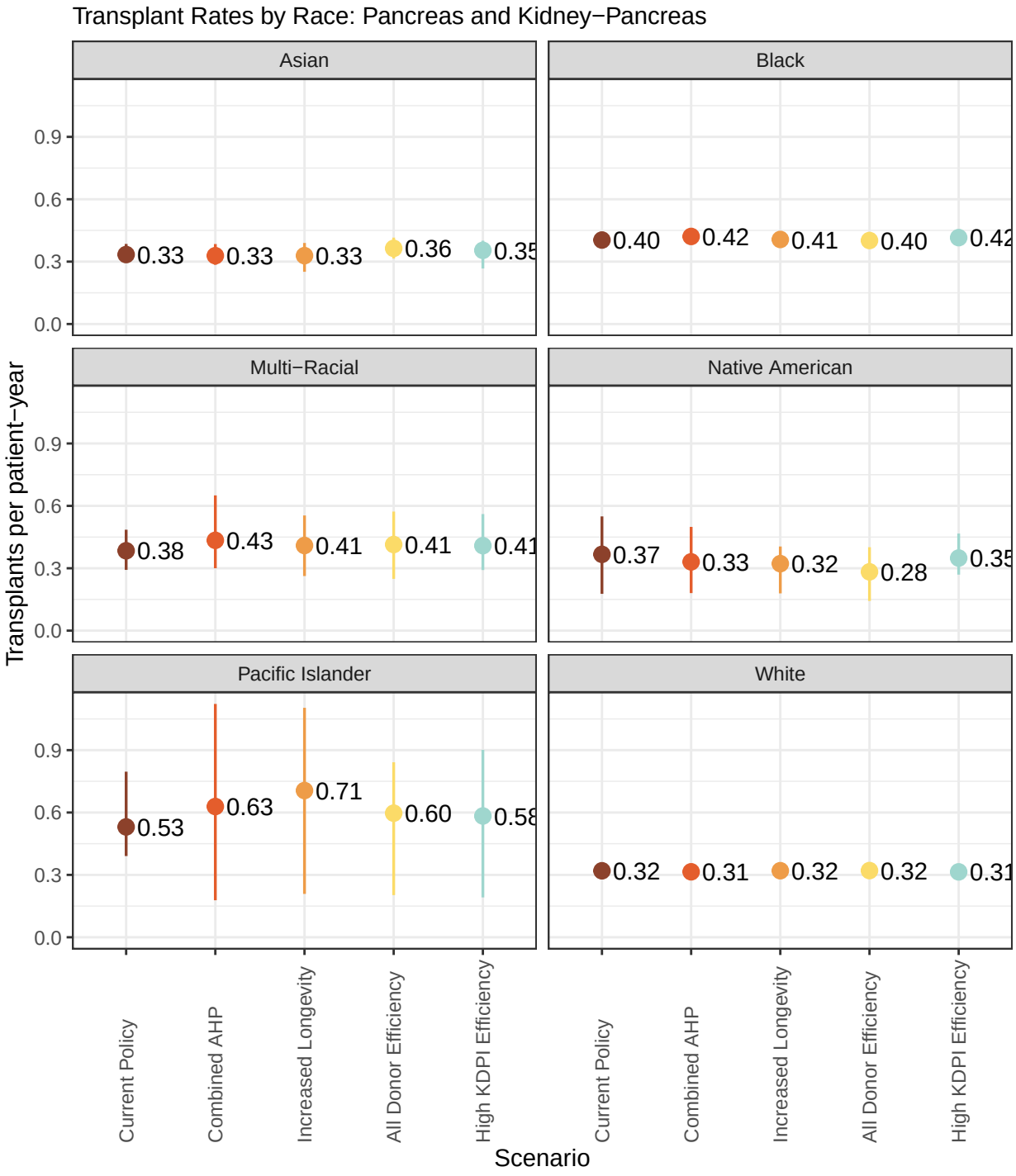


**Figure 24:** Person-time is calculated in days for all candidates from the start of their simulation period (simulation start or listing) to transplant, waitlist removal, or simulation end.

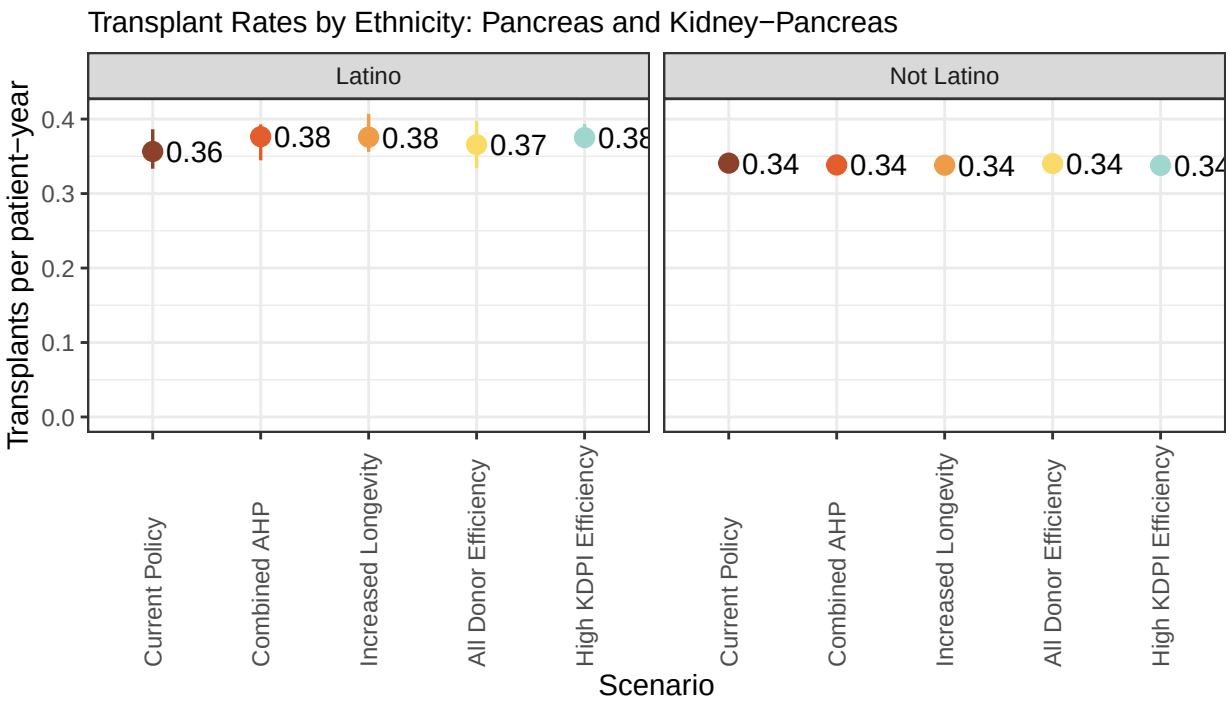


**Figure 25:** Person-time is calculated in days for all candidates from the start of their simulation period (simulation start or listing) to transplant, waitlist removal, or simulation end.

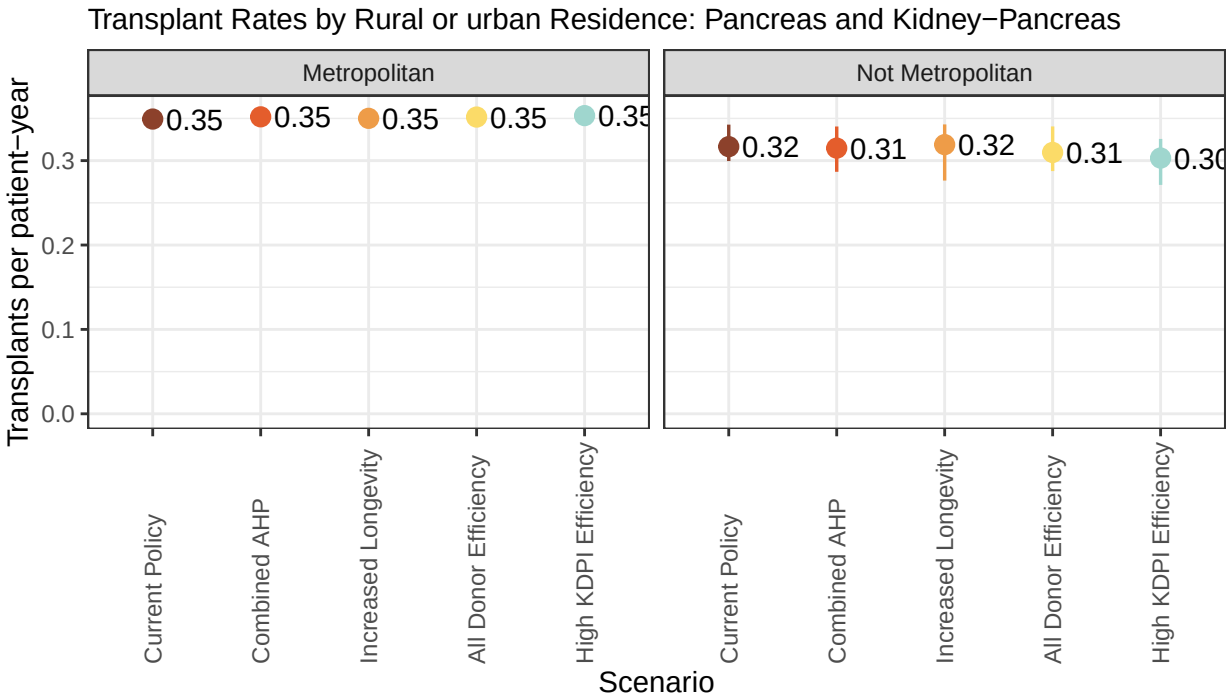


**Figure 26:** Person-time is calculated in days for all candidates from the start of their simulation period (simulation start or listing) to transplant, waitlist removal, or simulation end.

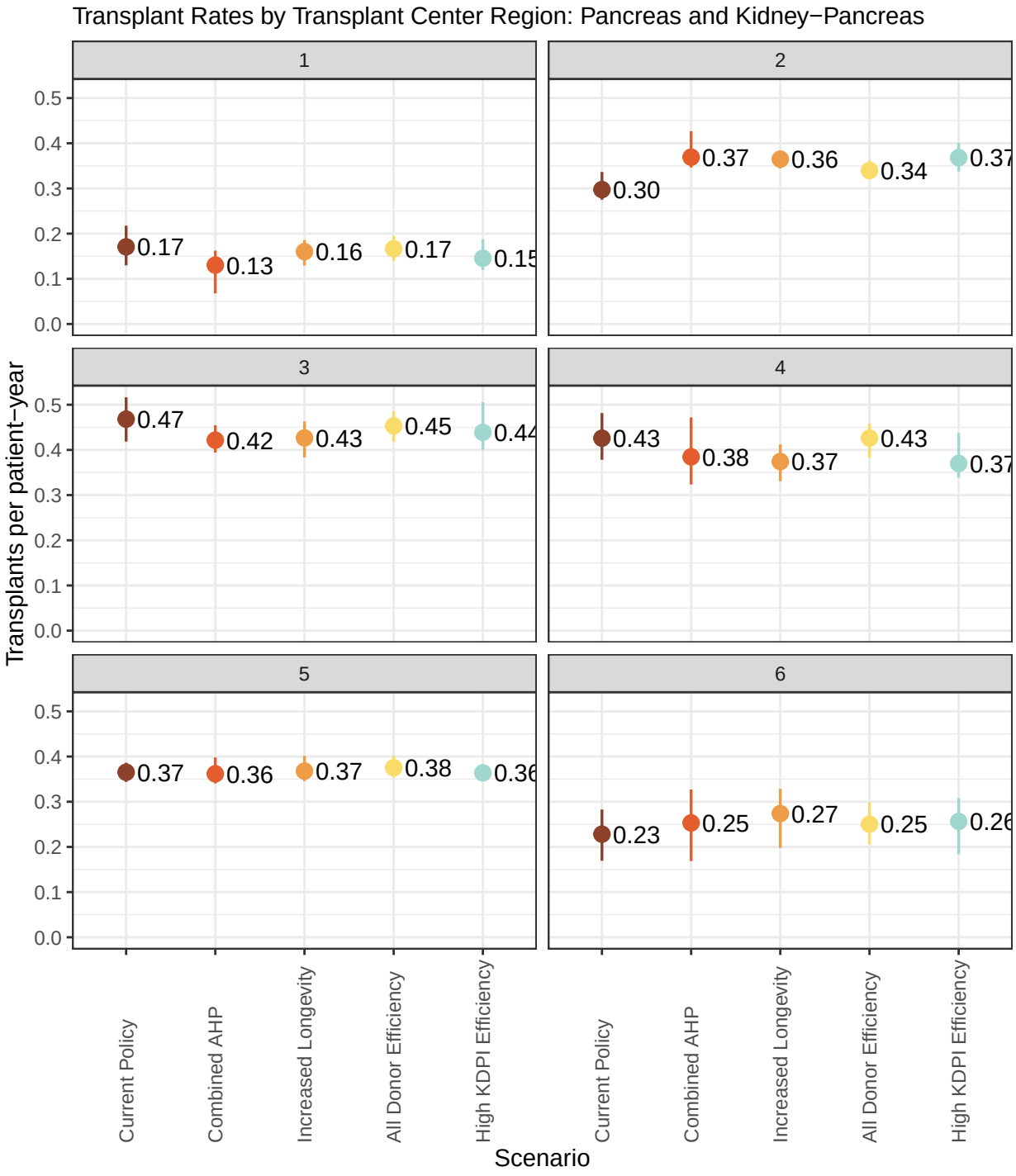


**Figure 27:** Person-time is calculated in days for all candidates from the start of their simulation period (simulation start or listing) to transplant, waitlist removal, or simulation end. OPTN regions numbers 1 to 6.

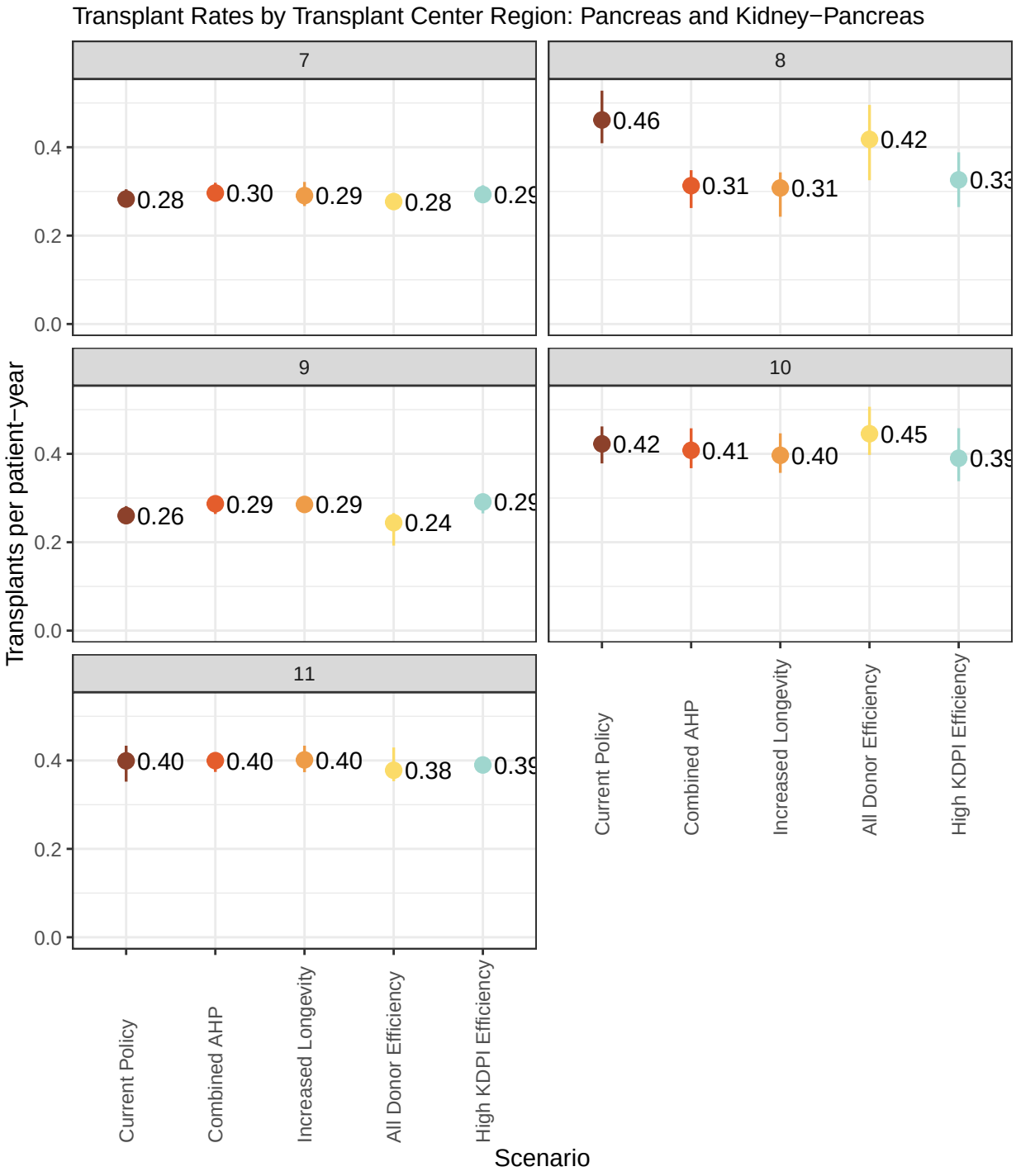


**Figure 28:** Person-time is calculated in days for all candidates from the start of their simulation period (simulation start or listing) to transplant, waitlist removal, or simulation end. OPTN regions numbers 7 to 11.

## Transplant Rates by Clinical Groups

### Kidney

Kidney transplant rates did not differ substantially from the simulation of current policy to the continuous distribution scenarios for patients with cPRA less than 0.6. For patients with cPRA between 0.6 and 0.8 there were slightly lower transplant rates under the continuous distribution scenarios compared to the simulation of current policy. For patients with cPRA greater than 0.8, kidney transplant rates were lower under notably lower under the "Increased Longevity" and "Donor Efficiency" scenarios compared to the simulation of current policy, bringing transplant rates in the high cPRA groups closer to rates in the lower cPRA groups. (Figure 29)

Kidney transplant rates were stable from the simulation of current policy to the continuous distribution scenarios for patients with A, B and O blood types. For patients with AB blood type, kidney transplant rates were slightly higher under all continuous distribution scenarios compared to the simulation of current policy. (Figure 30)

Transplant rates for adult kidney patients with EPTS between 0 and 0.2 were notably lower under the continuous distribution scenarios compared to the simulation of current policy, except for the "Increased Longevity" scenario, which was comparable to the simulation of current policy. For adult kidney patients with EPTS between 0.2 and 0.6, transplant rates were slightly lower under all continuous distribution scenarios compared to the simulation of current policy. By contrast, kidney transplant rates for adult patients with EPTS greater than 0.6 were higher under all continuous distribution scenarios compared to the simulation of current policy, as were transplant rates for pediatric patients, who do not have a defined EPTS. (Figure 31)

For patients on dialysis 5 years or less, kidney transplant rates were slightly higher under all continuous distribution scenarios compared to the simulation of current policy. Only under the "Increased Longevity" scenario were transplant rates notably higher for patients on dialysis 2 years or less. For patients on dialysis 5 to 10 years, transplant rates were lower under all continuous distribution scenarios, and notably lower under the "Increased Longevity" and "All Donor Efficiency" scenarios compared to the simulation of current policy. For patients on dialysis 10 or more years, kidney transplant rates were slightly higher under the "Combined AHP" and "High KDPI Efficiency" scenarios, but notably lower under the "Increased Longevity" and "All Donor Efficiency" scenarios, compared to the simulation of current policy. For patients not on dialysis, transplant rates were consistently low across all continuous distribution scenarios and the simulation of current policy. (Figure 32)

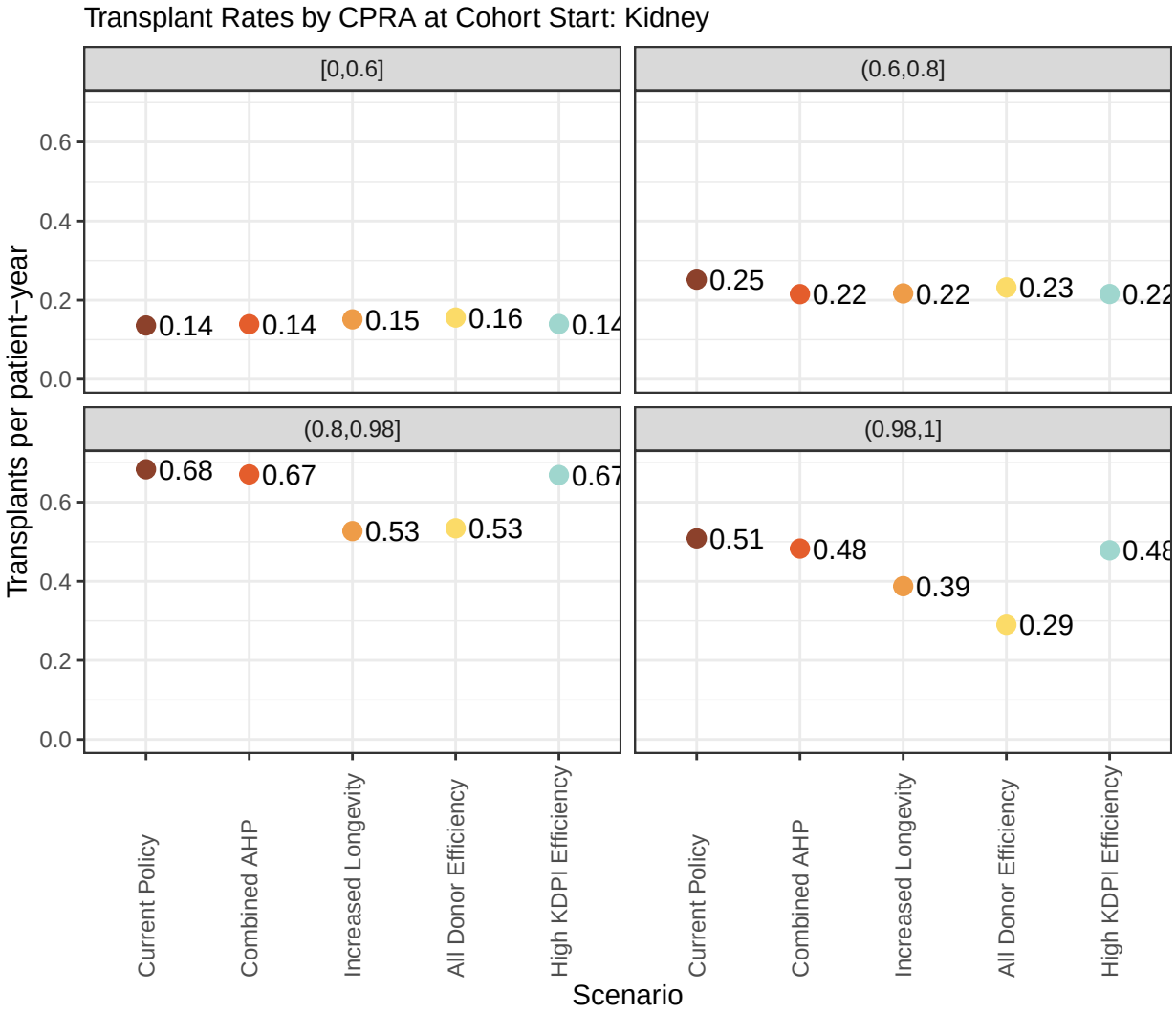


**Figure 29:** CPRA at cohort start is the last value the candidate had prior to the simulation start or their value at listing. Person-time is calculated in days for all candidates from the start of their simulation period (simulation start or listing) to transplant, waitlist removal, or simulation end.

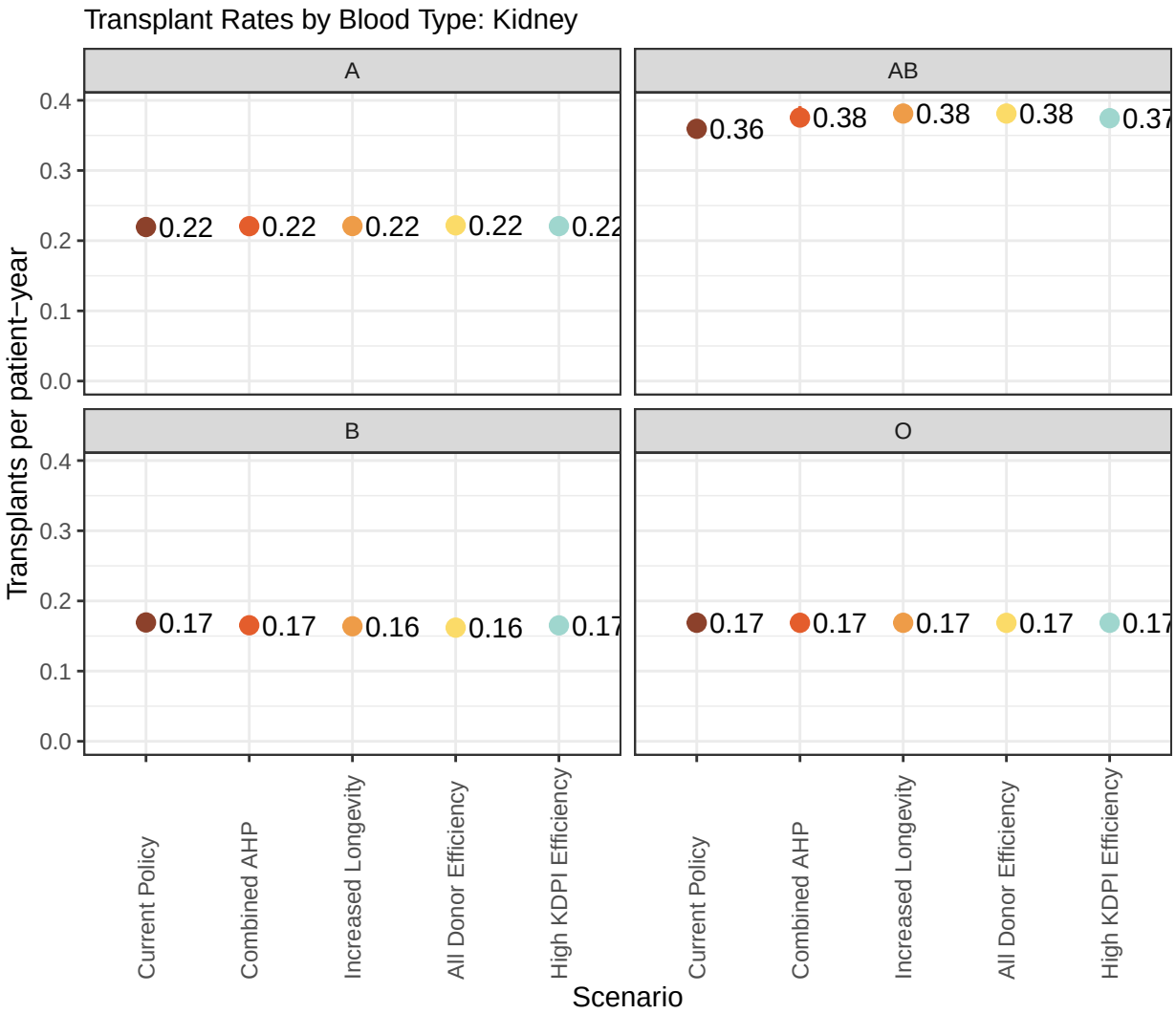


**Figure 30:** Person-time is calculated in days for all candidates from the start of their simulation period (simulation start or listing) to transplant, waitlist removal, or simulation end.

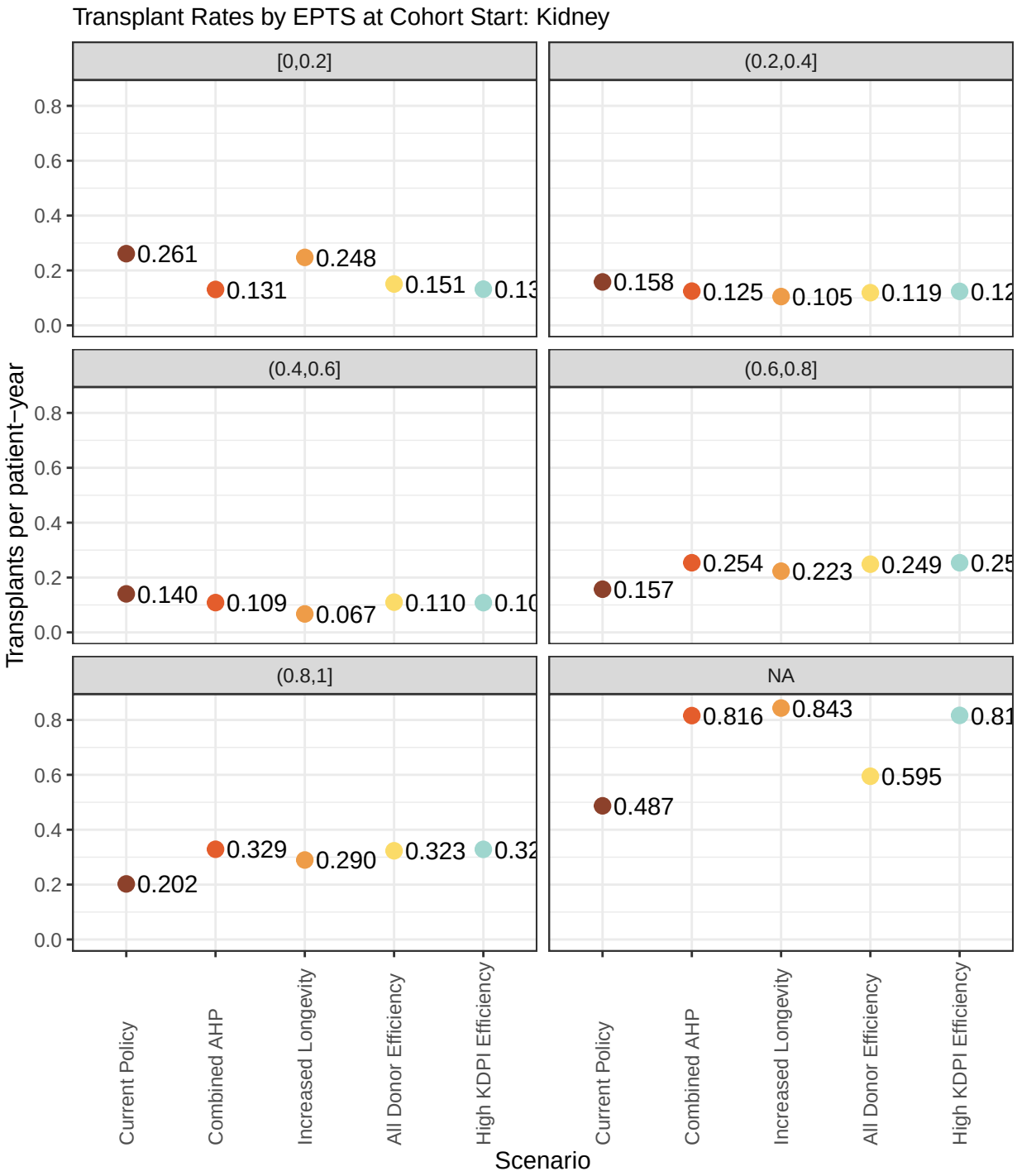


**Figure 31:** EPTS at cohort start is the last value the candidate had prior to the simulation start or their value at listing. Person-time is calculated in days for all candidates from the start of their simulation period (simulation start or listing) to transplant, waitlist removal, or simulation end.

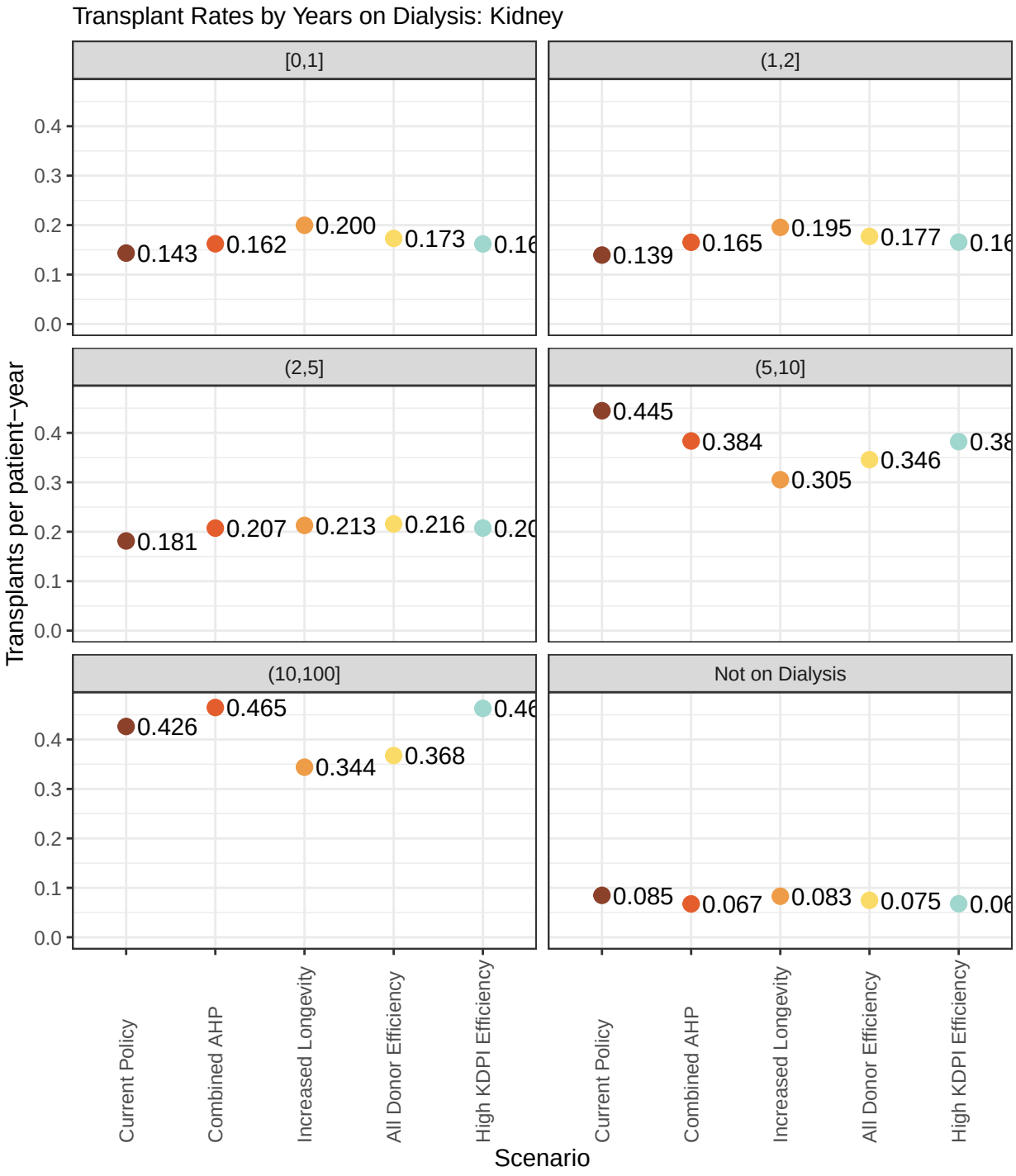


**Figure 32:** Person-time is calculated in days for all candidates from the start of their simulation period (simulation start or listing) to transplant, waitlist removal, or simulation end.

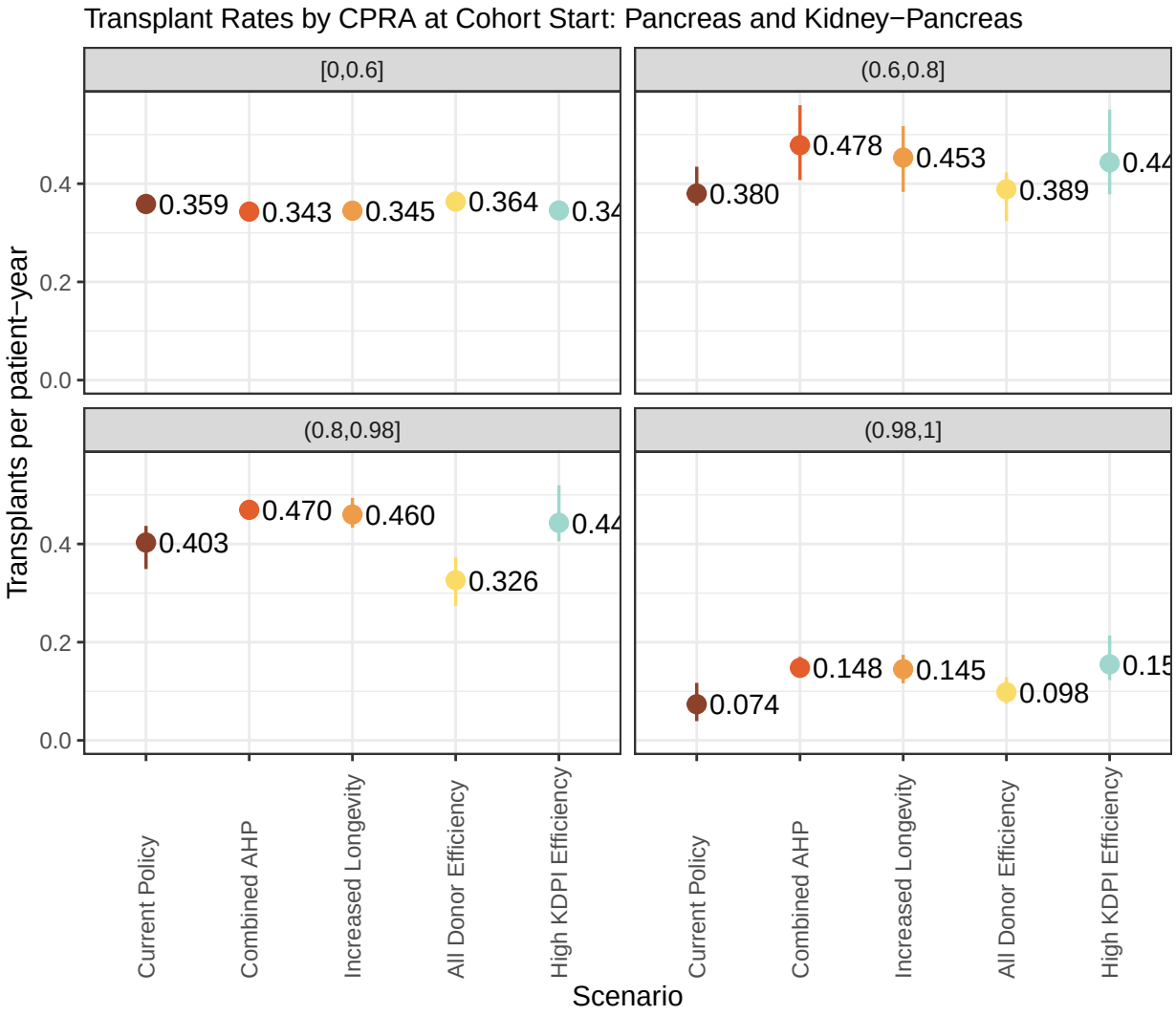


**Figure 33:** CPRA at cohort start is the last value the candidate had prior to the simulation start or their value at listing. Person-time is calculated in days for all candidates from the start of their simulation period (simulation start or listing) to transplant, waitlist removal, or simulation end.

## Pancreas and Kidney-Pancreas

Pancreas and kidney-pancreas transplant rates did not differ substantially from the simulation of current policy to the continuous distribution scenarios for patients with cPRA less than 0.6. For pancreas and kidney-pancreas candidates with cPRA greater than 0.6, transplant rates were higher than the simulation of current policy for the "Combined AHP", "Increased Longevity" and "High KDPI Efficiency" scenarios, but was lower than or consistent with the simulation of current policy for the "All Donor Efficiency" scenario. (Figure 33)

For candidates with blood types B and O, pancreas and kidney-pancreas transplant rates were consistent across all continuous distribution scenarios and the simulation of current policy. Pancreas and kidney-pancreas transplant rates were only slightly higher for candidates with blood type A under all continuous distribution scenarios compared to the simulation of current policy. Pancreas and kidney-pancreas rates were notably lower under all continuous distribution scenarios for candidates with blood-type AB compared to the simulation of current policy. (Figure 34)


**Figure 34:** Person-time is calculated in days for all candidates from the start of their simulation period (simulation start or listing) to transplant, waitlist removal, or simulation end.

## HLA-DR Mis-matches by Race

### Kidney

Compared to other scenarios, the percent of Black, White and Asian recipients that received a zero HLA-DR mismatch kidney was higher under the "Increased Longevity" scenario and lower under the "All Donor Efficiency scenario. Other races had wider variation between iterations of the scenarios, but most showed similar trends. (Figure 35) By contrast, the percent of recipients of most races that received a one or two HLA-DR mismatch kidney was not notably different across the continuous distribution scenarios or the simulation of current policy (Figures 36 and 37).

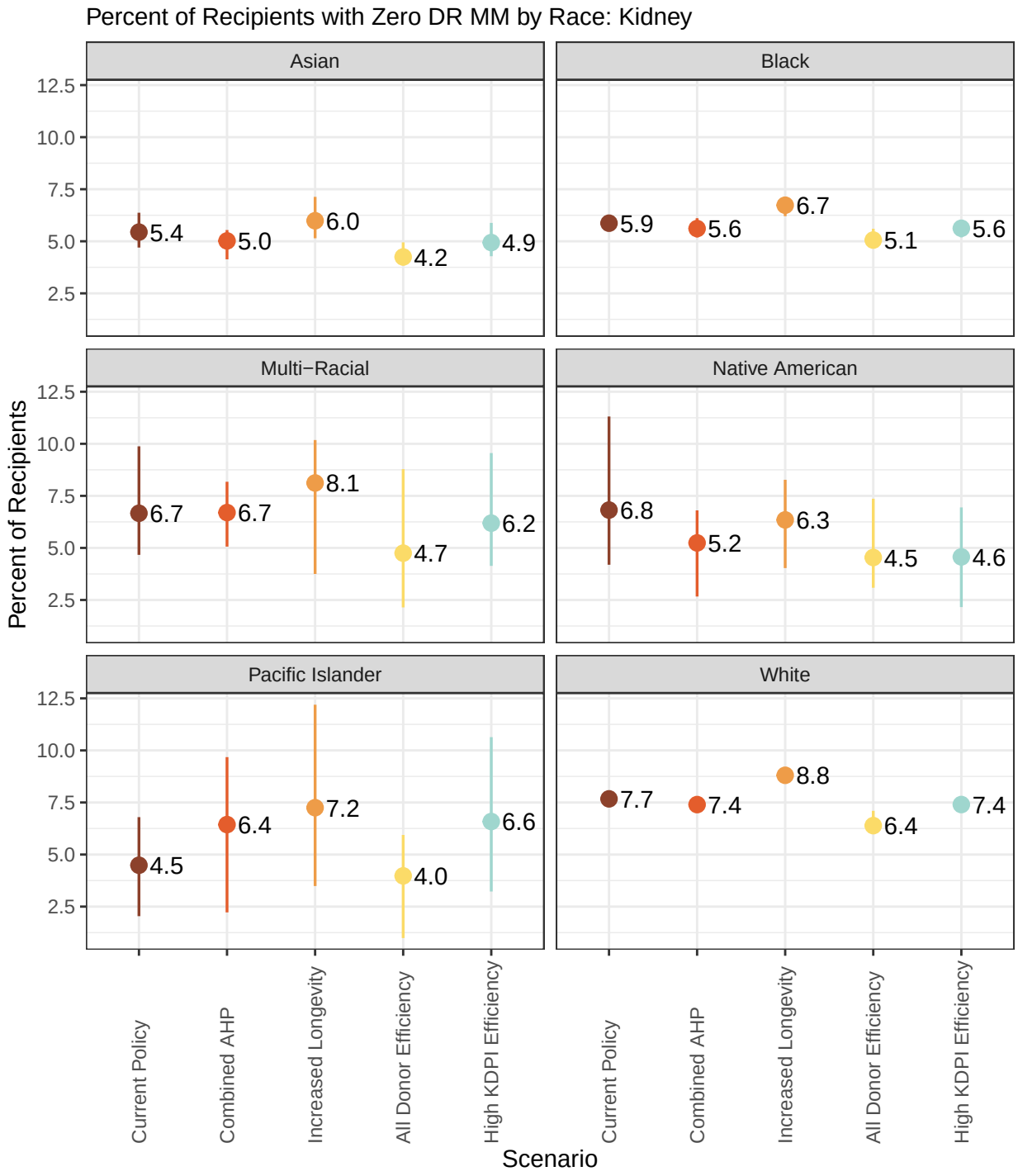


**Figure 35:** HLA-DR mismatches as defined under the current OPTN policy definitions for matched antigens.

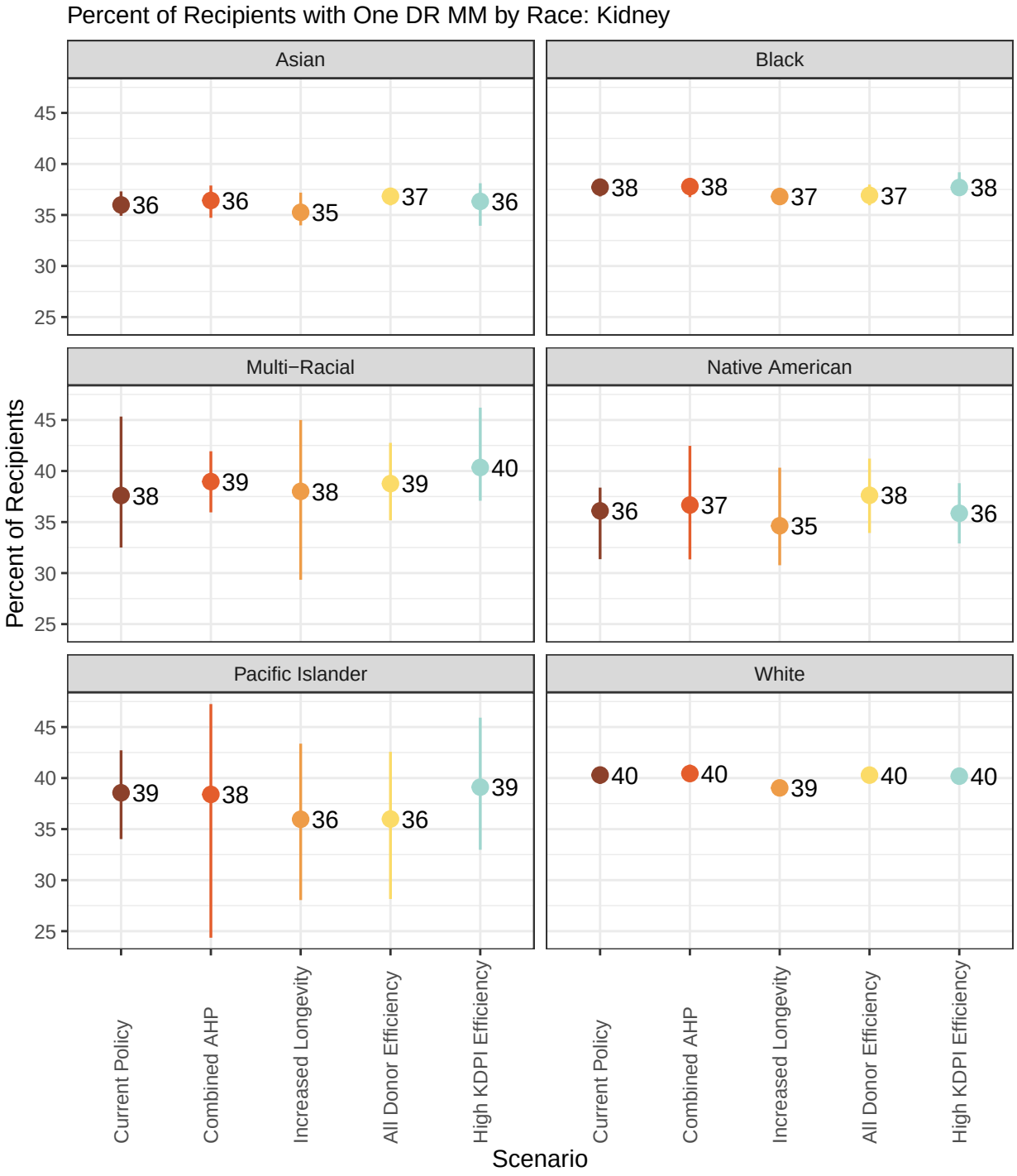


**Figure 36:** HLA-DR mismatches as defined under the current OPTN policy definitions for matched antigens.

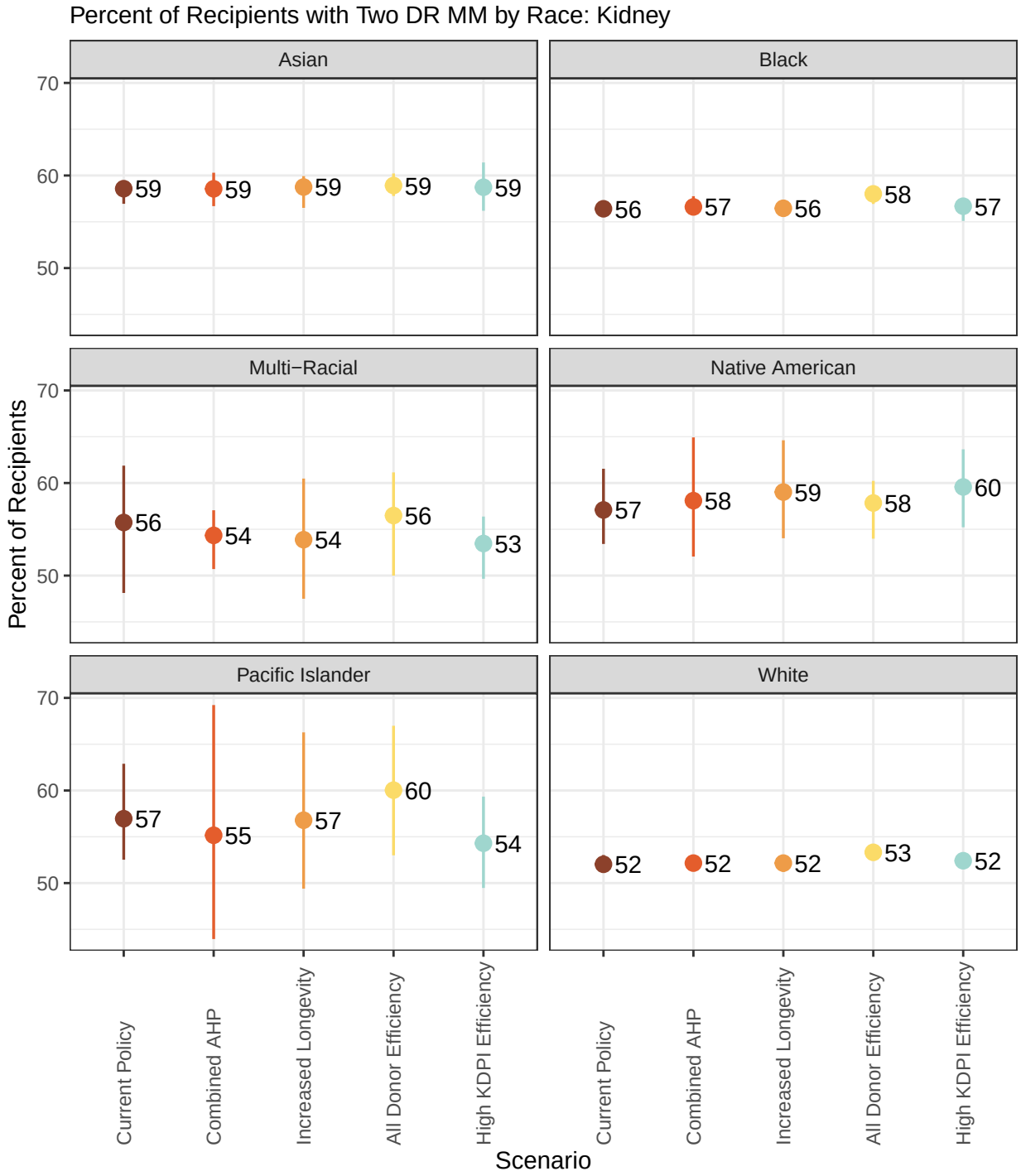


**Figure 37:** HLA-DR mismatches as defined under the current OPTN policy definitions for matched antigens.

## Pancreas and Kidney-Pancreas

The percent of pancreas and kidney-pancreas receiving 0, 1 or 2 HLA-DR mismatch transplants did vary substantially from the simulation of current policy to the continuous distribution scenarios for most races, or the variation across the iterations for the scenarios was too wide to discern any strong trends. (Figures 38-40)

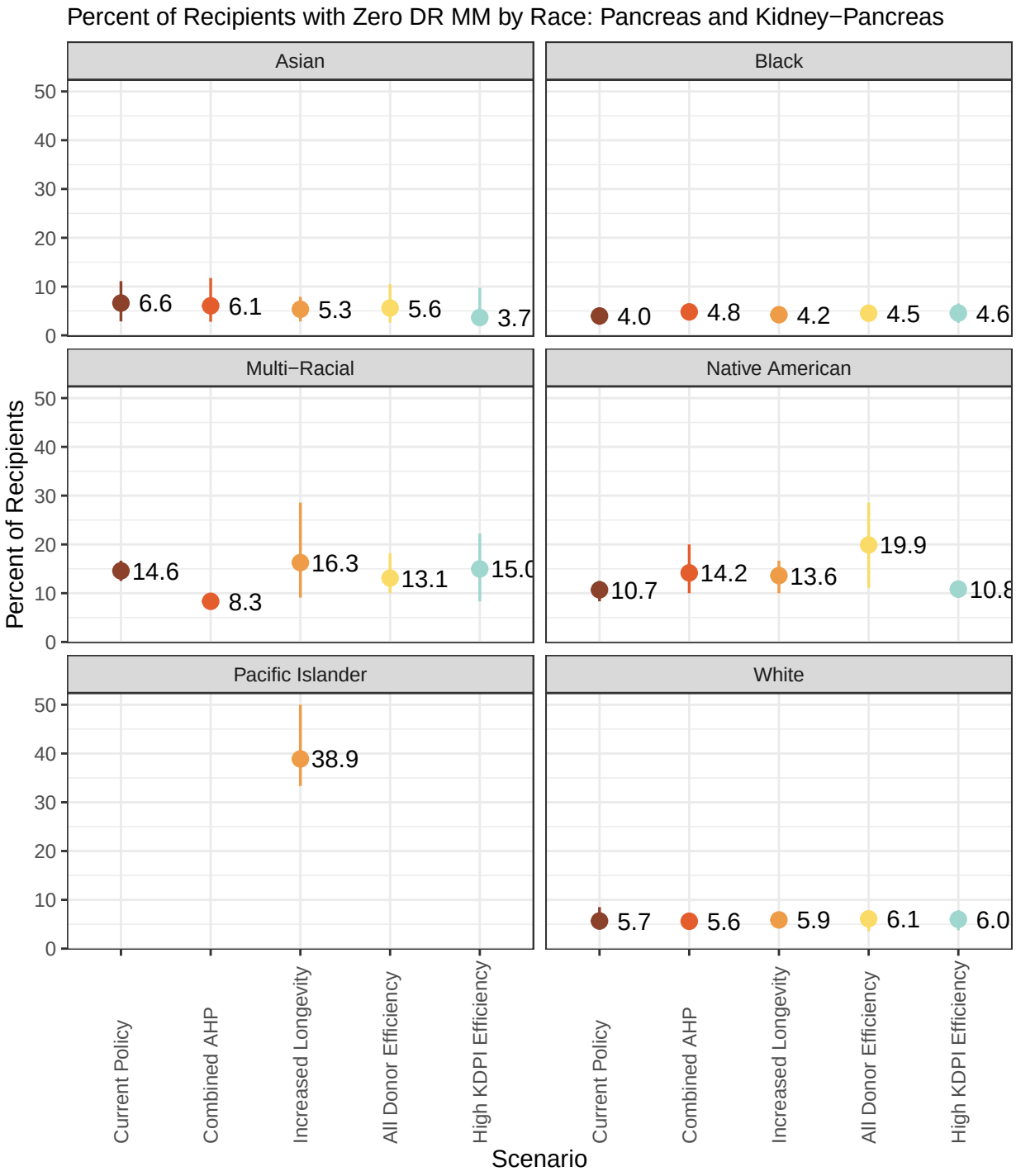


**Figure 38:** HLA-DR mismatches as defined under the current OPTN policy definitions for matched antigens.

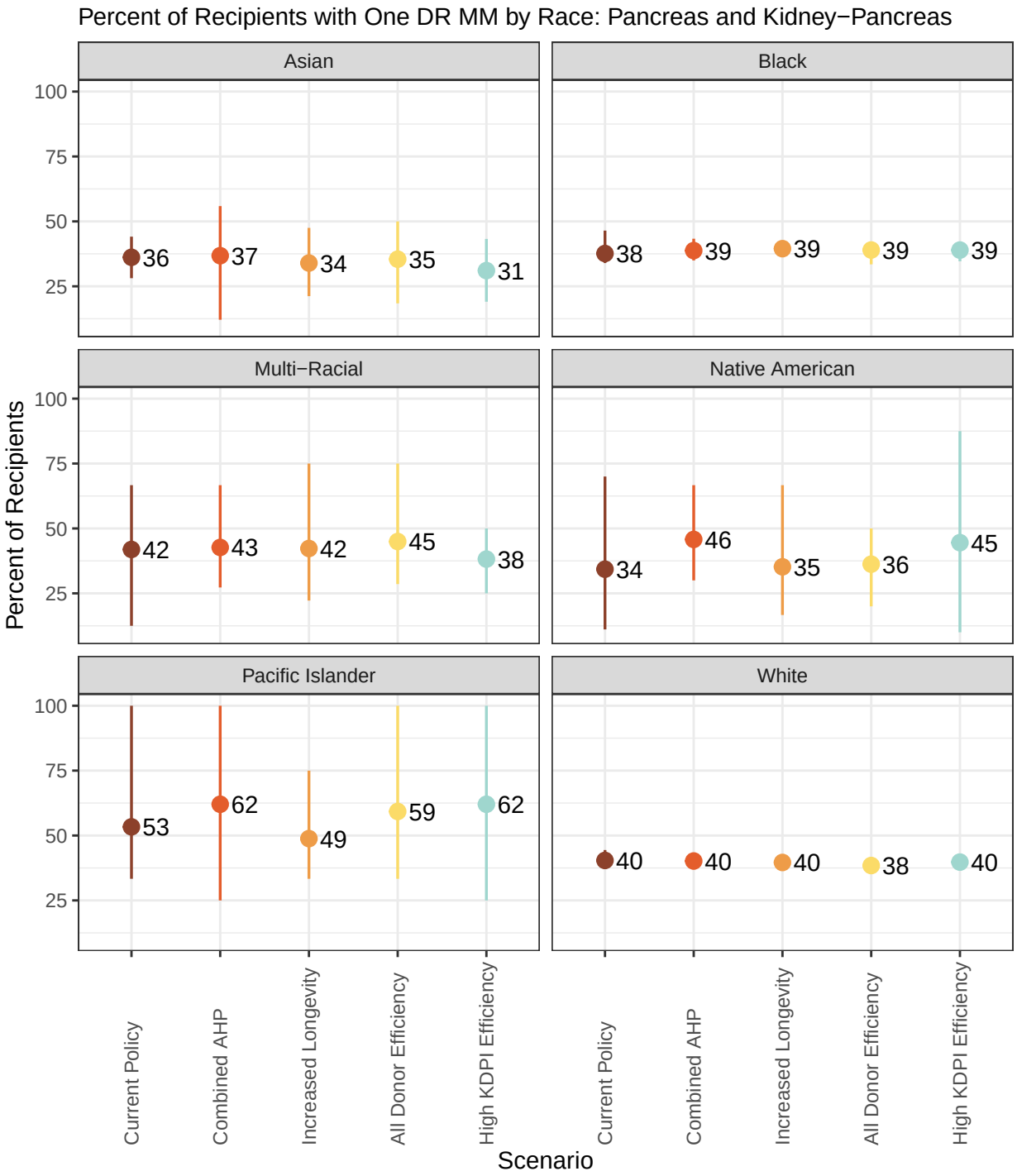


**Figure 39:** HLA-DR mismatches as defined under the current OPTN policy definitions for matched antigens.

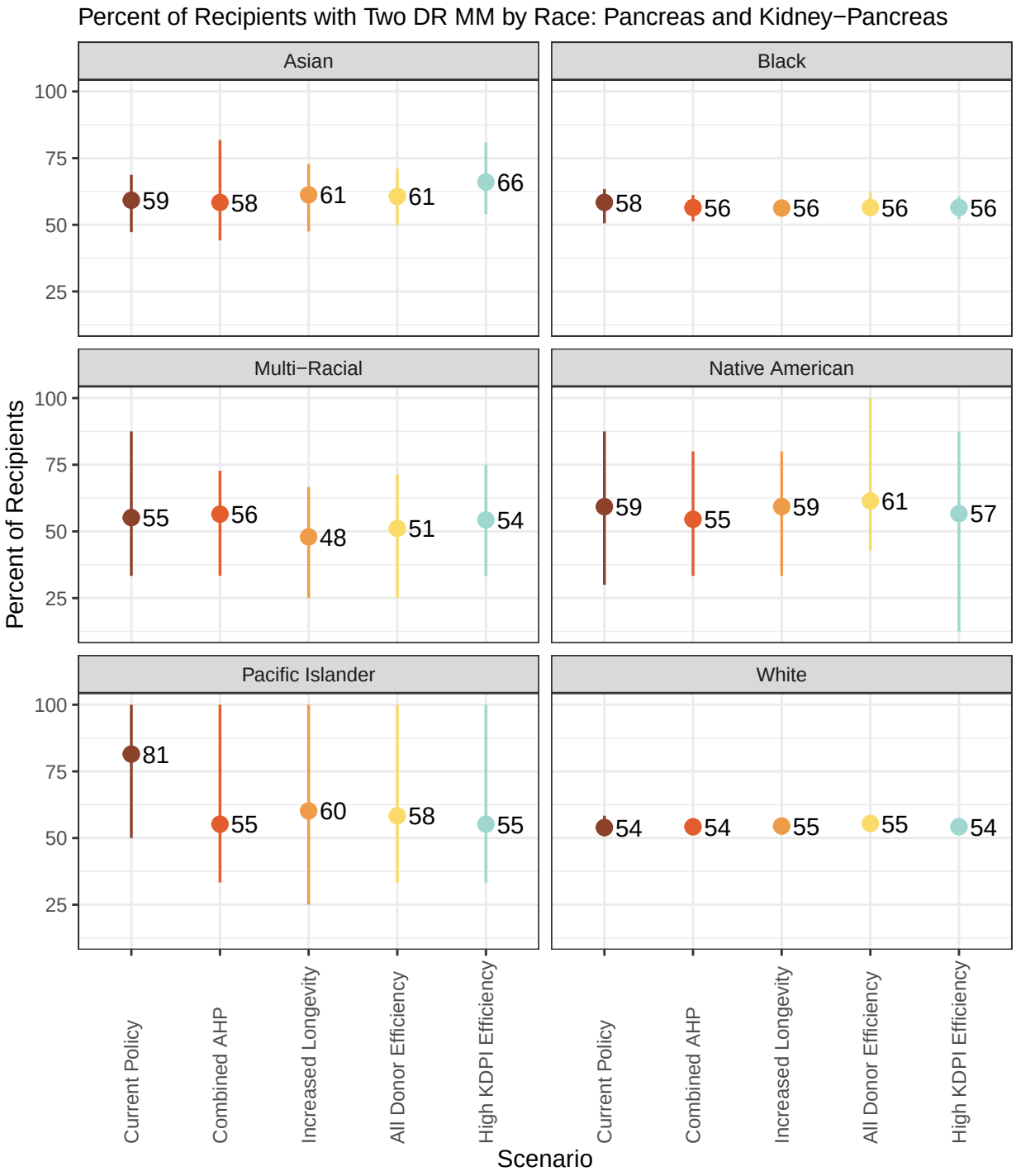


**Figure 40:** HLA-DR mismatches as defined under the current OPTN policy definitions for matched antigens.

## Posttransplant Metrics

### Kidney

Predicted died by 1-year post-transplant for kidney recipients did not differ substantially from the simulation of current policy to any of the continuous distribution scenarios for recipients less than 50 years of age. For kidney recipients age 50 and older, 1-year post-transplant predicted percent died was higher under all continuous distribution scenarios compared to the simulation of current policy, with highest predicted percent died under the “Increased Longevity” scenario. (Figure 41)

For pediatric kidney recipients, predicted all cause graft failure percent by 10-years post-transplant was consistently low across all continuous distribution scenarios and the simulation of current policy. For kidney recipients age 18 to 49, 10-year predicted all cause graft failure percent was lower than the simulation of current policy under the “Increased Longevity” and “All Donor Efficiency” scenarios, though not substantially different under the “Combined AHP” and “High KDPI Efficiency” scenarios. Predicted 10-year all cause graft failure percent for kidney recipients age 50 and older were higher under all continuous distribution scenarios than the simulation of current policy, with the highest predicted percent under the “Increased Longevity” scenario. (Figure 42)

For pediatric kidney recipients and for recipients age 50 and older, predicted percent died by 10-years post-transplant did not differ substantially between the simulation of current policy and any of the continuous distribution scenarios. For kidney recipients age 18 to 49, 10-year predicted percent died was slightly lower under the “Increased Longevity” scenario compared to all other scenarios. (Figure 43)

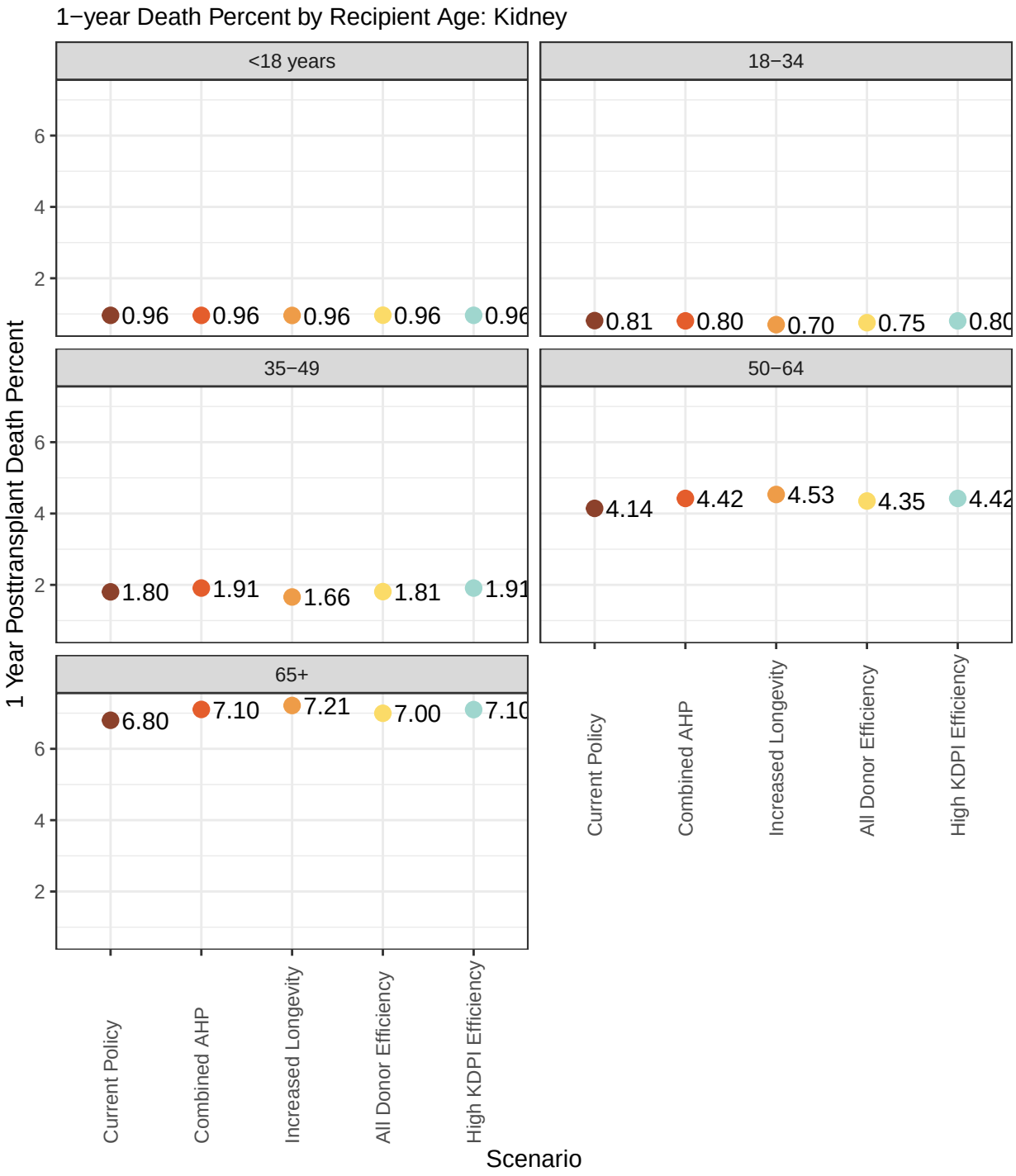


**Figure 41:** Age at transplant.

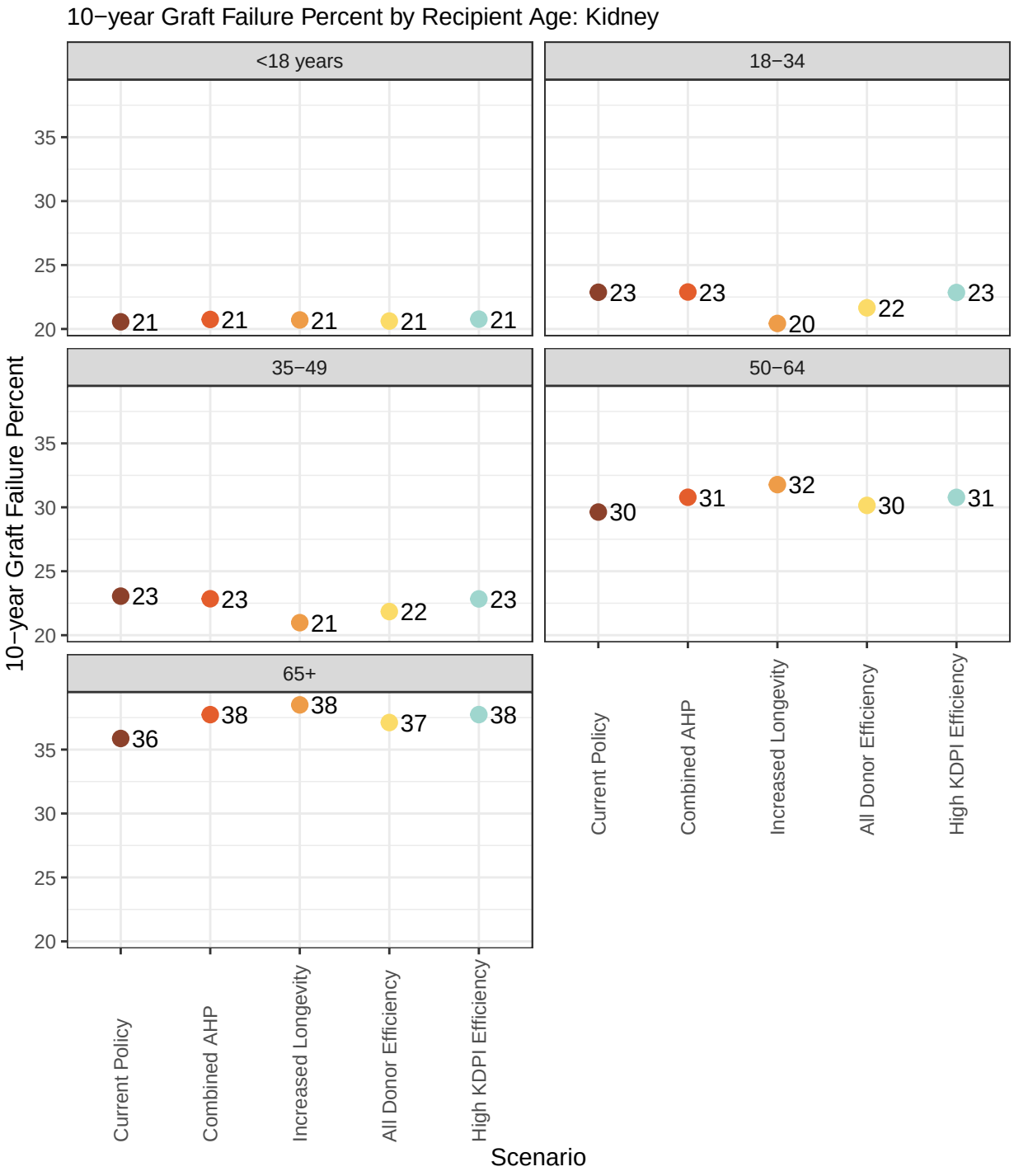


**Figure 42:** Age at transplant. All cause graft failure.

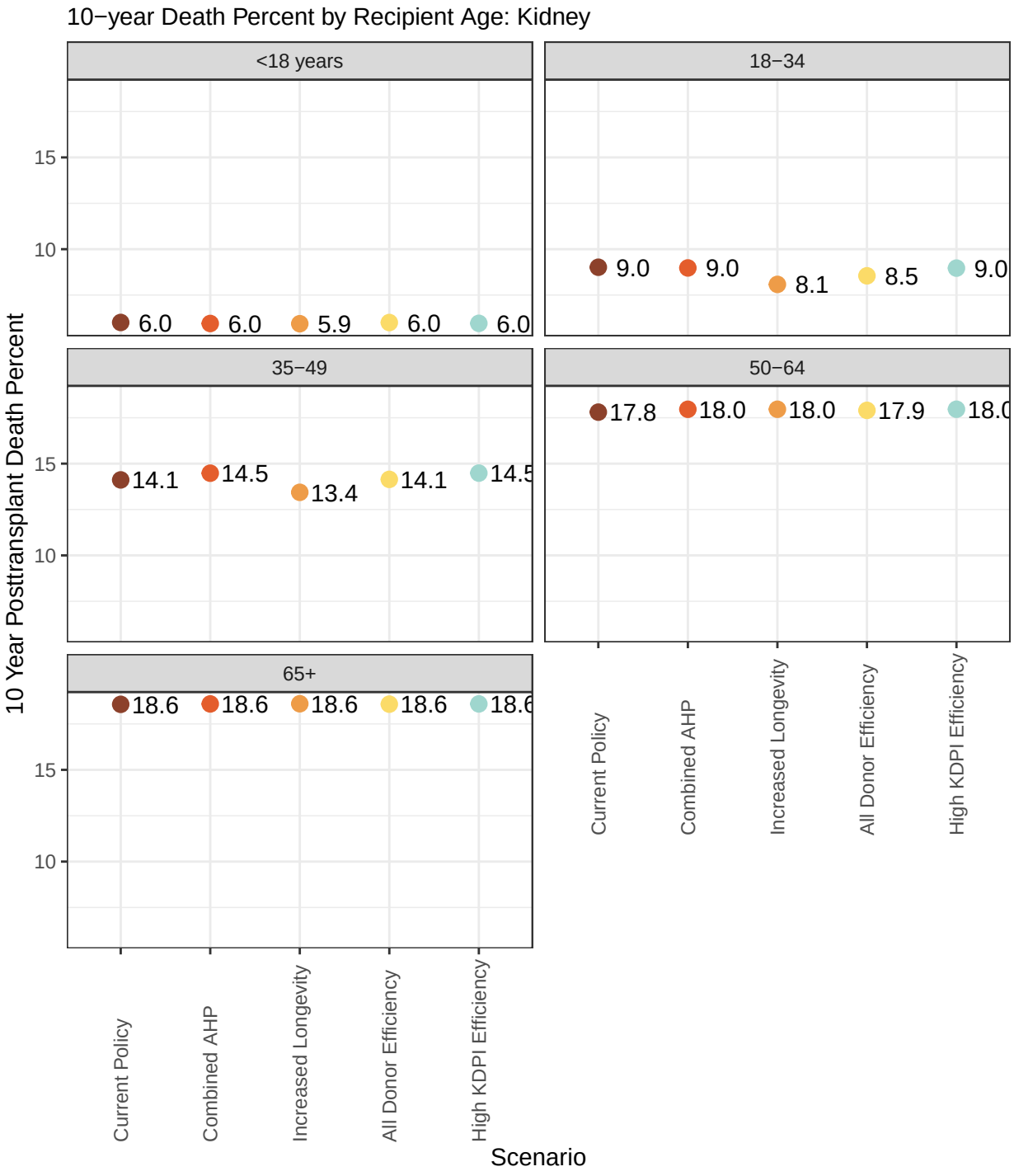


**Figure 43:** Age at transplant.

## Pancreas and Kidney-Pancreas

Among pancreas recipients younger than age 65, the predicted percent died by 1-year post-transplant was fairly stable across all continuous distribution scenarios and the simulation of current policy. Across the iterations of simulated scenarios, there were wide variations in percent died by 1-year post transplant among pediatric pancreas and kidney-pancreas recipients, though the percent died by 1-year post-transplant was slightly higher under the "High KDPI Efficiency" scenario compared to all other scenarios. For pancreas recipient age 65 and older, the wide variations across iterations of the simulated scenarios for predicted percent died by 1-year post-transplant prevent discerning any notable trend. (Figure 44) These same trends by age, seen in the 1-year post-transplant all cause graft failure and percent died, are also seen in the 10-year post-transplant all cause graft failure and percent died outcomes (Figures 45 and 46).

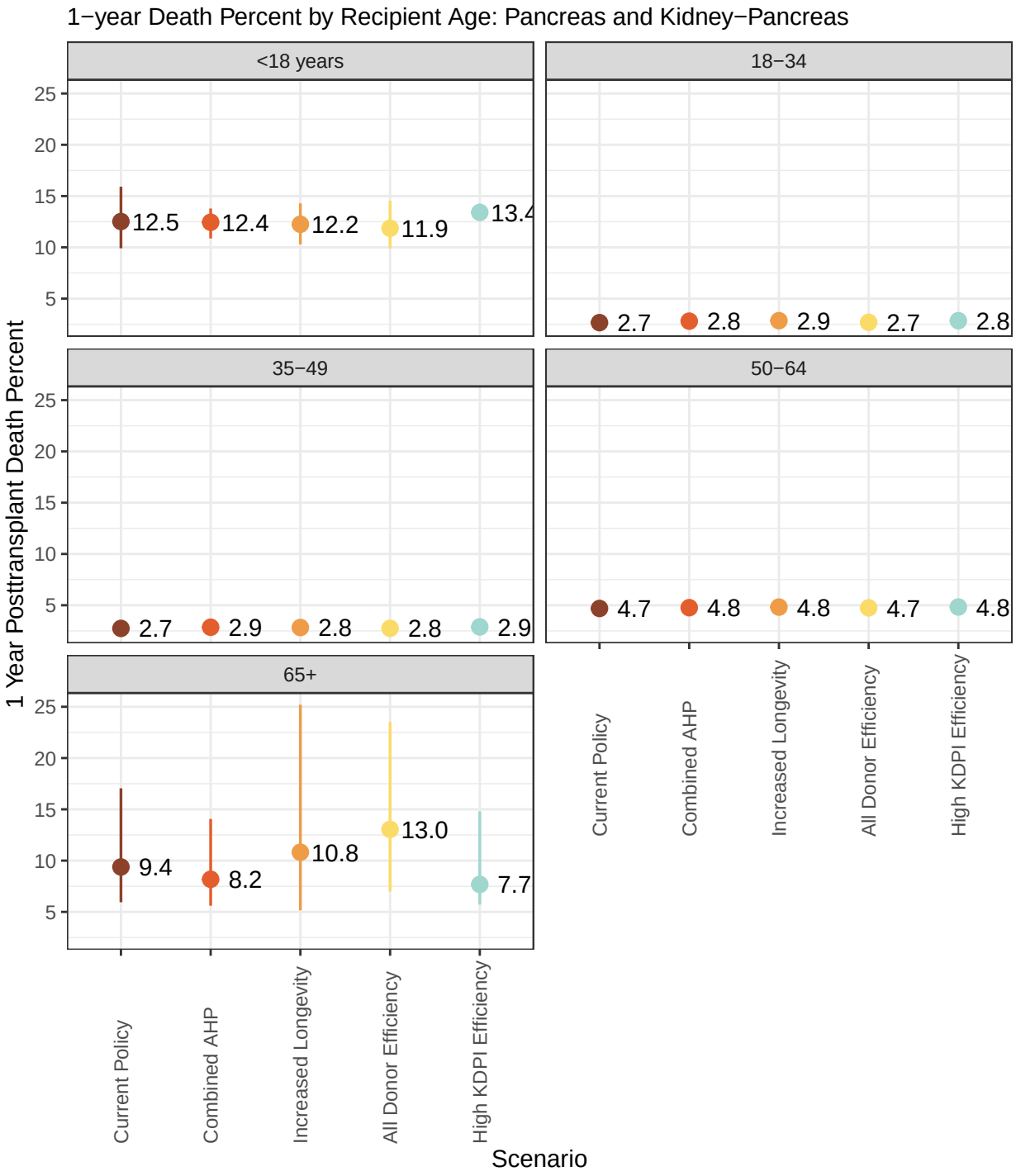


**Figure 44:** Age at transplant.

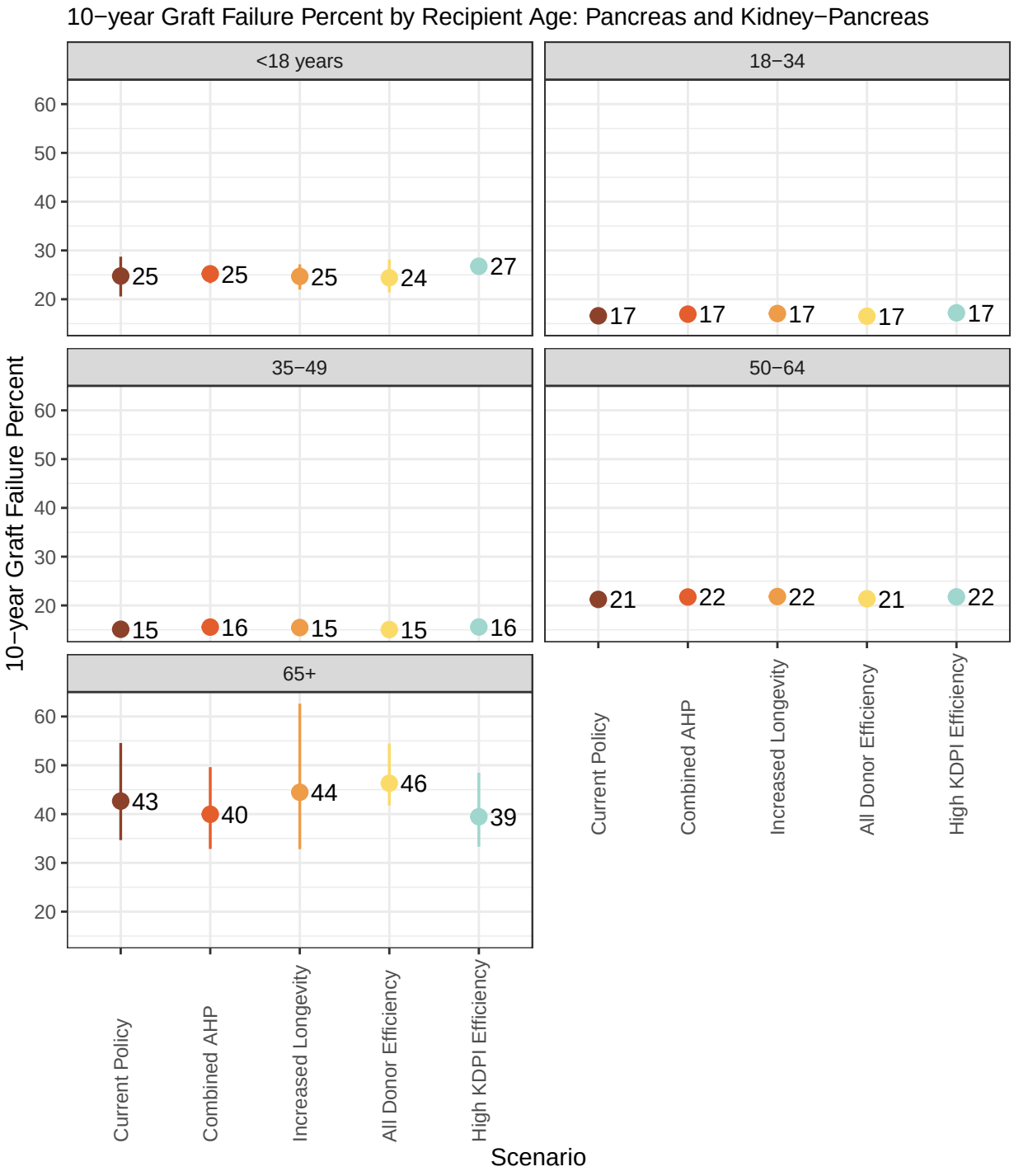


**Figure 45:** Age at transplant. All cause graft failure.

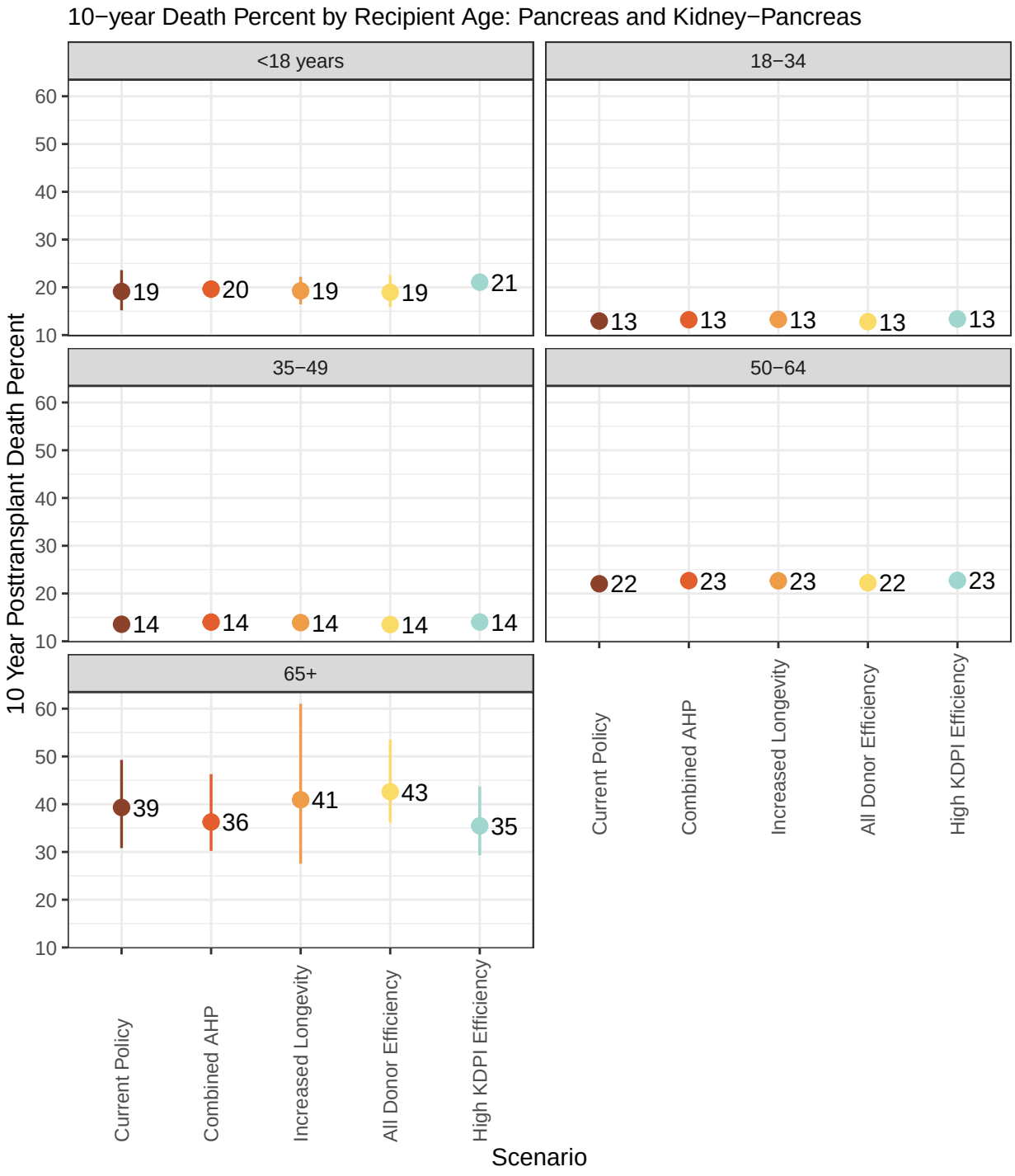


**Figure 46:** Age at transplant.

## Interpretation

Changes observed under continuous distributions scenarios compared to the simulation of current policy should be interpreted as estimates of what would have happened had this historic cohort – candidates and donors from March 15, 2021 to March 14, 2022 – been allocated under a counterfactual continuous distribution allocation system as opposed to the current policy, and assuming no change in transplant center behavior particularly around offer acceptance. Given the strong necessary assumption of no change in transplant center behavior and confounding factors that may occur in the future, these simulation results may not predict future outcomes in the transplant system.

### Kidney

In this simulation study, longevity matching of kidneys seems to be more precise under all continuous distribution scenarios compared to the simulation of current policy, with higher KDPI kidneys going to older recipients. This longevity matching trend was strongest under the "Increased Longevity" scenario. A side-effect of more precise longevity matching seems to be lower transplant rates in kidney candidates age 18-35. This study showed no high KDPI (KDPI > 85) kidneys going to candidates age 18-35 under the continuous distribution scenarios, while about 5% of these candidates were transplanted with high KDPI kidneys under the simulation of the current policy. The continuous distribution longevity matching score gives priority for high EPTS, generally older, patients for high KDPI kidneys, a difference from current policy under which there is no specific mechanism that pushes high EPTS candidates higher on the high KDPI kidney match runs. Though the transplant rates for 18-35 year olds were lower under continuous distribution, consistent with this better longevity matching the post-transplant graft failure rates in this age group at 1-year and 10-years were also particularly lower under the "Increased Longevity" scenario. An additional expected, though undesirable, side-effect of more precise longevity matching seems to be the increased rates of graft failure in older kidney recipients, and in turn overall, predicted by this simulation study.

The continuous distribution scenarios, which remove hard boundaries in allocation, seemed to increase travel distance for kidneys, particularly for pediatric candidates whose priority for national kidneys may have been greater on average under the continuous distribution scenarios compared to the simulation of current policy. However, the "All Donor Efficiency" scenario, which generally had travel distances closest to the simulation of current policy shows that it may be possible to manage travel distances by increasing the weight on proximity efficiency, as expected.

The "Increased Longevity" and "All Donor Efficiency" scenarios, which increased the weight on the "Posttransplant Outcomes" scores and "Placement Efficiency" scores respectively, had lower weights on the "Qualifying Time" score. The lower weight on the qualifying time score under these scenarios may explain lower transplant rates for patients on dialysis 5 years or more under these scenarios, which in turn may be related to slightly lower rates for Black candidates, who tend to have longer time on dialysis. While this is an example of a possible unintended consequence, it is encouraging that continuous distribution allows for relatively simple fixes – transplant rates for both candidates on dialysis 5 years or more and for Black candidates are higher under the scenarios where more weight is given to the "Qualifying Time" score.

Finally, while the continuous distribution scenarios did show lower transplant rates in some OPTN regions, it was among regions with already high transplant rates, bringing these regions closer in transplant rate to many of the other OPTN regions. Additionally, the "All Donor Efficiency" scenario showed that under continuous distribution, the "Placement Efficiency" weights can be adjusted to address concerns about geographic disparities.

### Pancreas and Kidney-Pancreas

The most notable difference under the continuous distribution scenarios compared to the simulation of current policy for pancreas and kidney-pancreas transplant was the lower transplant rates for blood type AB candidates under continuous distribution. This is likely due to the pancreas "Blood Type" score, which gives identical blood type candidates a score of 1 and compatible blood type candidates a score of 0. Again, the continuous distribution framework offers many options for addressing transplant rates among AB candidates – like changing the weight on the "Blood Type" score or changing the underlying rating scale for "Blood Type".