

Estimating the causal effect of the Medicaid expansion on heart transplant volume with a differences-in-differences model



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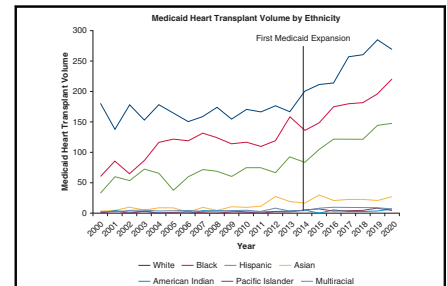
ABSTRACT

Objective: Recent health policy changes have prioritized providing insurance for more Americans, often through Medicaid expansion (ME). The effectiveness of ME as it relates to expanding access to heart transplantation can be gauged by comparing the volume of Medicaid beneficiaries undergoing heart transplantation volume in states with and without ME. Our objective is to determine whether or not ME increased access to heart transplantation.

Methods: The Organ Procurement and Transplantation Network database was used for US transplant data. Difference-in-differences (DiD), an econometric method to estimate causality, was performed between states with ME and bordering states without ME, to minimize geographic variability. For states with multiple bordering nonexpanded states, DiD values were averaged. Unpaired 2-tailed *t* tests, Mann-Whitney *U* test, 1-way-analysis of variance, and Poisson regressions, where appropriate, compared insurance cohorts, sexes, and ethnicities.

Results: Although publicly insured patients comprised only 36.7% of heart transplant volume in 2000, they comprised 53.4% of heart transplant volume in 2020 ($P = .229$); significant differences did not exist between public and private transplant volume ($P = .583$), but exist among forms of public insurance ($P < .001$). ME yielded 1.028 more transplants per state per year, and a total of 113.9 more transplants. Transplant volume was significantly different between ME states and non-ME states (31.4% vs 58.4%; $P < .001$). ME yielded 106 more heart transplants in men cumulatively (DiD = 0.956), compared with 10.23 more transplants in women cumulatively (DiD = 0.090); this sex DiD difference was not significant ($P = .749$). Heart transplant volumes were significantly different for both men and women across ME and non-ME states ($P < .001$ for both). Since 2014, ME yielded 25.67 more transplants in Whites (DiD = 0.079), 55.78 more transplants in Blacks (DiD = 0.510), 2.85 fewer transplants in Hispanics (DiD = -0.038), 37.33 more transplants in Asians (DiD = 0.316), 14.5 fewer transplants in Native Americans (DiD = -0.105), 17.38 fewer transplants in Pacific Islanders (DiD = -0.131), and 12.85 more transplants in multiracial individuals (DiD = 0.134); these ethnic DiD differences were not significant ($P = .957$).

Conclusions: Heart transplant volume is no longer skewed toward patients with private insurance, suggesting expanding public insurance increased access to heart transplantation, according to the Organ Procurement and Transplantation Network database. Through a national DiD model, ME increased heart transplant volume for Medicaid beneficiaries, largely through male, Black, and Asian patients. These benefits were dissimilar across demographic characteristics and do not benefit all groups, suggesting ME should be remodeled if the policy aim is to equitably increase volume across sexes and ethnicities. (JTCVS Open 2022;11:200-13)



Black and Asian patients experienced the greatest increase in heart transplantation.

CENTRAL MESSAGE

Using a differences-in-differences approach, Medicaid expansion increased national heart transplant volume, but the increase was dissimilar across sex and ethnic demographic groups.

PERSPECTIVE STATEMENT

Patients receiving heart transplants have shifted from majority privately insured to publicly insured. One form of public insurance, Medicaid, grew through Medicaid expansion. Medicaid expansion increased Medicaid heart transplant volume, with the greatest benefits for male, Black, and Asian patients.

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Read at the 102nd Annual Meeting of The American Association for Thoracic Surgery, Boston, Massachusetts, May 14-17, 2022.

Received for publication Dec 8, 2021; revisions received May 25, 2022; accepted for publication June 10, 2022; available ahead of print July 8, 2022.

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Abbreviations and Acronyms

BBBA	= Build Back Better Act
DiD	= difference-in-differences
ME	= Medicaid expansion
OPTN	= Organ Procurement and Transplantation Network

The 2010 Patient Protection and Affordable Care Act aimed to reduce the uninsured population in America, through vehicles such as Medicaid expansion (ME), which sought to address health care coverage disparities and increase access across demographic groups.¹⁻³ A paucity of evidence outlines ME's stratified efficacy across states and demographic groups for patients undergoing cardiothoracic surgery. This may be due to difficulties in identifying a tenable model that captures the effects of ME and controls for other parameters. We aimed to investigate ME's influence on heart transplant volume and determine whether or not volume increased due to ME and whether or not ME achieved its stated aim of narrowing disparities in health care access. Elucidating the influence of ME will help physicians and policymakers form approaches that yield the greatest value for patients, especially when there is discussion about ME in current non-ME states.

MATERIALS AND METHODS

A differences-in-differences (DiD) model was used to analyze ME's influence on transplant volume. DiD is an econometric model that became popularized in social sciences research after Card and Krueger investigated the effects of increasing minimum wage on unemployment.⁴⁻⁶ DiD, an empirical framework using a linear regression model estimated with ordinary least squares, utilize longitudinal data of control and treatment groups for a given intervention, combining the advantages of cross-sectional analyses and before-after studies.⁷ DiD estimates causal effects of interventions and control for unobservable variables to isolate the intervention's influence on treatment groups. Similar to randomized control trials, the DiD model assumes treatment groups behave similarly to control groups in the absence of intervention, satisfying a parallel trend assumption (Figure E1). Additionally, the DiD model controls for postintervention biases from spatial differences and temporal biases from external trends. DiD values are the annual change in transplant volume in a given state for a given demographic due to ME, and represent ME's influence.

Heart transplant volume data were extracted from the Organ Procurement and Transplant Network (OPTN), which is publically available and the consequent analysis was considered exempt from institutional review board review. The OPTN database is capable of stratifying transplants by recipient payment modality, including 7 public insurance subcategories: Children's Health Insurance Program, Medicaid, Medicare Fee-for-Service, Other Government, Department of Veterans Affairs, Medicare & Choice, and Medicare Unspecified. For our study, the treatment group consisted of US states that underwent ME. Data from the year before ME and the first full year after ME populated the DiD model. Next, we followed the Card and Krueger approach of using adjacent states that did not expand Medicaid as counterfactuals, which controlled for geographic variability.^{5,6} For states with

multiple bordering non-ME states, DiD values were averaged across these states.⁶ The DiD model, *Medicaid Heart Transplant Volume* = $\beta_0 + \beta_1 \times [\text{Year After ME}] + \beta_2 \times [\text{ME Implementation}] + \beta_3 [\text{Year After ME} \times \text{ME Implementation}] + \epsilon$, used dummy variables for time (pre- and post-ME) and intervention (ME implementation). The outcome variable was Medicaid heart transplant volume, which facilitates analyses of associations between ME status and transplant volume. For sex-stratified DiD, *Medicaid Heart Transplant Volume* = $\beta_0 + \beta_1 \times [\text{Year After ME}] + \beta_2 \times [\text{ME Implementation}] + \beta_3 \times [\text{Female Sex}] + \beta_4 [\text{Year After ME} \times \text{ME Implementation}] + \beta_5 \times [\text{Year After ME} \times \text{Female Sex}] + \beta_6 \times [\text{ME Implementation} \times \text{Female Sex}] + \beta_7 \times [\text{Year After ME} \times \text{ME Implementation} \times \text{Female Sex}] + \epsilon$, was employed. For ethnicity-stratified DiD, the regression model replaced sex dummy variables for ethnicity dummy variables and their respective interactions with the variables year after ME and ME implementation. Exclusion criteria consisted of ME states without geographically adjacent non-ME states, which lacked valid counterfactuals ($n = 15$), or expanded Medicaid after 2020 due to incomplete data 1 year after ME implementation ($n = 5$) (Figure E2).

Unpaired 2-tailed t tests compared sexes, Mann-Whitney tests compared public and private insurance cohorts, 1-way analysis of variance assessed differences across ethnicities, and Poisson regressions analyzed Medicaid states nationally. Statistical analyses were performed in STATA/SE version 15.0 (StataCorp) and the package *statsmodels* in Python version 3.9.0 (Python Software Foundation).

RESULTS

Total heart transplantation volume increased from 2098 transplants in 2000 to 3607 transplants in 2020, alongside the proportion of transplants funded by public health insurance (Figure 1). Publically insured heart transplants increased from 770 in 2000 (36.7%) to 1927 in 2020 (53.4%) ($P = .229$). In 2000, Medicare Unspecified ($n = 456$) and Medicaid ($n = 283$) were the leading payment forms. Following the Balanced Budget Act of 1997, Medicare Unspecified became Medicare Fee-for-Service and Medicare & Choice. Transplant volume proportions changed, with Medicaid ($n = 684$), Medicare & Choice ($n = 569$), and Medicare Fee-for-Service ($n = 522$) underwriting the most public heart transplants in 2020. Significant volume changes exist between public health insurance subcategories from 2000 to 2020 ($P < .001$). From 2014 to 2020, Medicaid volume increased by 50.99%, Medicare & Choice volume increased by 63.51%, and Medicare Fee-for-Service volume increased by 7.63%. Similarly, privately insured volume increased by 32.39%. Medicaid volume increased from 2000 ($n = 283$) to 2020 ($n = 684$), but did not increase significantly differently from total non-Medicaid volume ($P = .190$) (Figure 2).

Using a Poisson regression from 2014 to 2020 across Medicaid transplants nationally, for each additional transplant, Medicaid transplants in men increased by 0.159% annually (95% CI, 0.012-0.30; $P = .033$) and Medicaid transplants in women increase by 0.202% annually (95% CI, -0.038-0.44; $P = .100$). The Poisson model goodness-of-fit χ^2 test had a value of 0.9926, validating this model (Table E1). Using a Poisson regression with

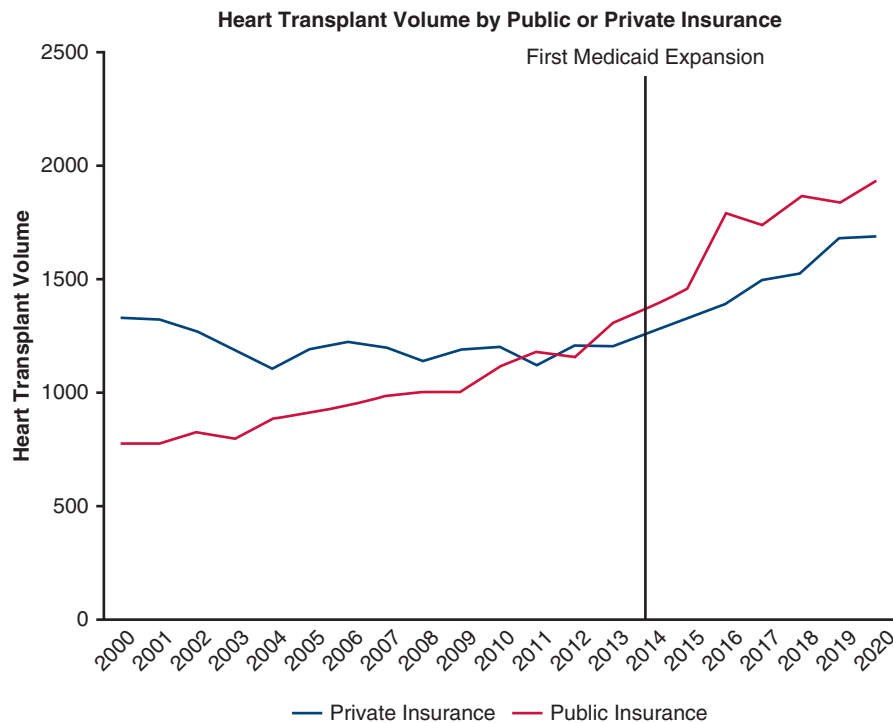


FIGURE 1. Heart transplant volume by private or public insurance. Before 2010, privately insured heart transplant volume consistently exceeded the volume of publicly insured heart transplant volume. The proportion of publicly insured heart transplant volume increased from 36.7% in 2000 to 53.4% in 2020.

Medicaid transplants stratified by ethnicity, for each additional transplant, White patients' transplants were associated with an increase of 0.028% annually (95% CI, -0.535 - 0.592 ; $P = .921$), Black patients' transplants were associated with an increase of 0.383% annually (95% CI, -0.669 - 1.434 ; $P = .476$), Hispanic patients' transplants were associated with an increase of 0.212% (95% CI, -0.448 - 0.872 ; $P = .529$), Asian patients' transplants were associated with a decrease of 0.359% (95% CI, -2.593 - 1.876 ; $P = .753$), and Native American patients' transplants were associated with a decrease of 1.787% (95% CI, -8.325 - 4.750 ; $P = .592$). This model's goodness-of-fit χ^2 test had a value of 0.9604, validating this model. Pacific Islander and multiracial patients reduced the goodness-of-fit test's validity, precluding us from including them in the Poisson regression.

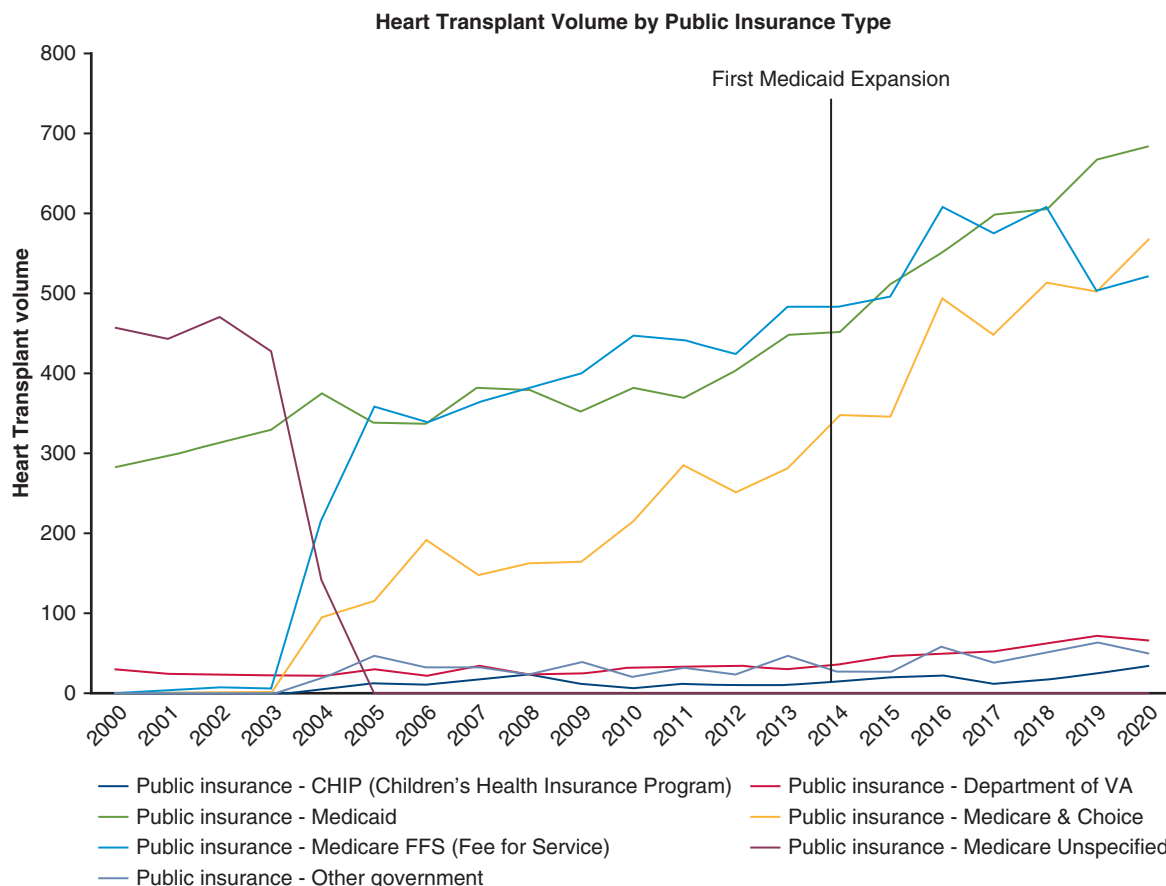
DiD Model

For our study, 19 states met inclusion criteria (Table 1). Transplant volumes grew differently between ME and non-ME states (Figure E3). Nationally, ME yielded a 1.028 increase in heart transplant volume per ME state annually ($P < .001$). Different states experienced different ME effects (Table 2 and Figure 3). The ME state with the greatest volume increase following ME was Arizona ($n = 20$ transplants annually) and the ME state with the greatest volume decrease following ME was Arkansas

($n = -6.167$ transplants annually). Cumulatively, there are 113.9 more transplants (2.80% of Medicaid transplant volume) nationally due to ME, from 2014 to 2020. Volume increase was initially 14.8 additional transplants annually in 2015 (2.89% of total 2015 Medicaid volume) to 19.5 additional transplants annually in 2020 (2.85% of total 2020 Medicaid volume).

Next, ME effects were sex-stratified. Men had consistently more Medicaid heart transplants from 2000 to 2020 ($P < .00001$). Men experienced a 170.06% transplant volume increase from 2000 ($n = 167$) to 2020 ($n = 451$). Women experienced a 100.96% transplant volume increase from 2000 ($n = 116$) to 2020 ($n = 233$) (Figure 4, A). Sex transplant volume differences similarly exist following ME Medicaid heart transplants per state annually ($P = .749$). ME cumulatively yielded 106 more male Medicaid heart transplants in women and 10.23 more Medicaid heart transplants in women from 2014 to 2020 (Figure 4, B and C, and Table 2). Medicaid transplant volumes in men and women also differed significantly between ME and non-ME states (both P values $< .001$).

Lastly, ME effects were stratified by ethnicity, using the OPTN's definitions. Figure 5 shows the largest DiD values were observed in Black and Asian patients (DiD = 0.510 and 0.316, respectively). From 2014 to 2020, ME yielded 25.67 more transplants in White patients



A

FIGURE 2. Heart transplant volume by public insurance type. A, Medicaid transplants increased from 2000 (n = 283) to 2020 (n = 684), but did not increase significantly differently from total non-Medicaid volume (P = .190). Volume increases were significantly different between subcategories of public insurance from 2000 to 2020 (P < .001). B, From 2014 to 2020, there was a 50.99% increase in Medicaid transplant volume, a 63.51% increase in Medicare & Choice transplant volume, and a 7.63% increase in Medicare Fee-for-Service (FFS). CHIP, Children’s Health Insurance Program; VA, Veterans Affairs.

(DiD = 0.079), 55.78 more transplants in Black patients (DiD = 0.510), 2.85 fewer transplants in Hispanic patients (DiD = -0.038), 37.33 more transplants in Asian patients (DiD = 0.316), 14.5 fewer transplants in Native American patients (DiD = -0.105), 17.38 fewer transplants in Pacific Islander patients (DiD = -0.131), and 12.85 more transplants in multiracial patients (DiD = 0.134). Therefore, ME accounts for 1.5% of White Medicaid transplants, 4.5% of Black Medicaid transplants, -0.33% of Hispanic Medicaid transplants, 22.9% of Asian Medicaid transplants, -50% of Native American Medicaid transplants, -44.6% of Pacific Islander Medicaid transplants, and 22.9% multiracial Medicaid transplants. Ethnic DiD differences following ME were not significant (P = .957).

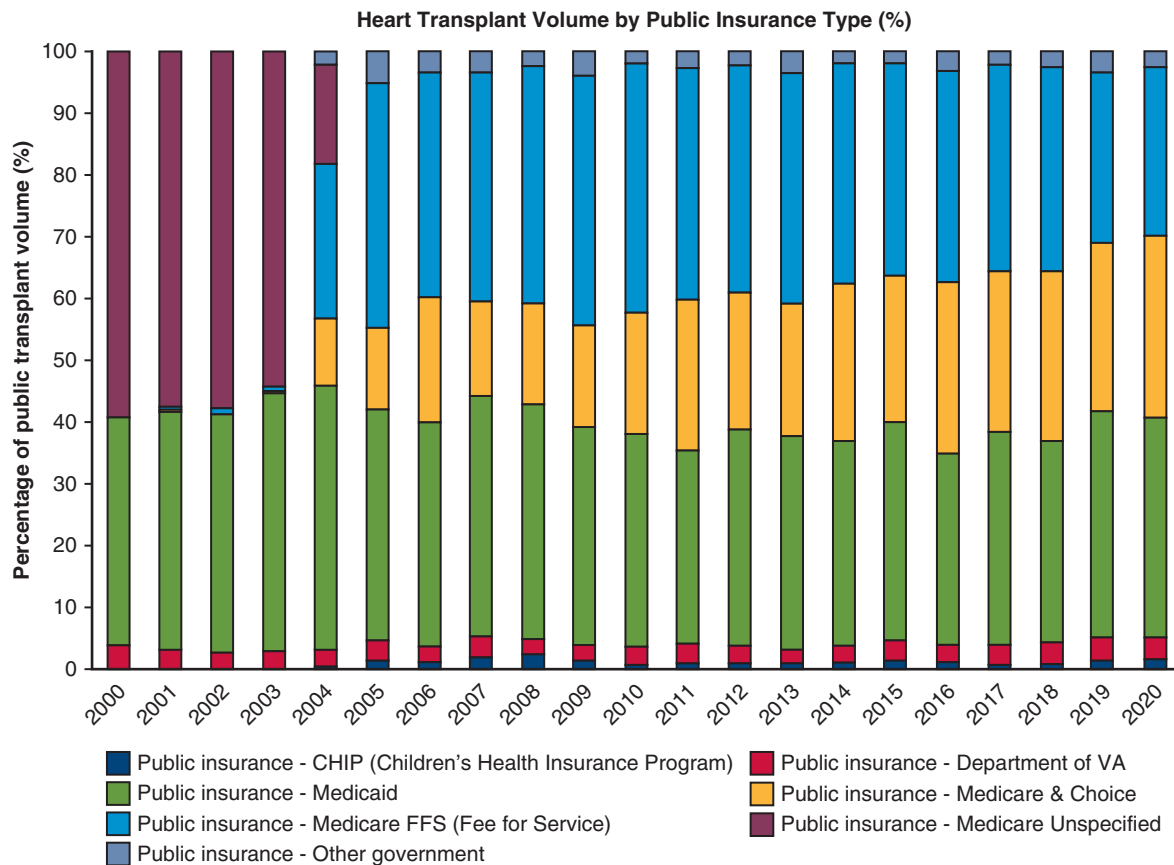
Waiting List Dynamics

Using the OPTN database, we analyzed transplant waitlist dynamics from 2014 to 2020 to contextualize our DiD findings. For waiting list removals due to death, there

were 23.88% fewer deaths for White patients, 2.51% fewer deaths for Black patients, 15.82% more deaths for Hispanic patients, 23.29% more deaths for Asian patients, 11.54% fewer deaths for Native American patients, a 0.00% change in deaths for Pacific Islander patients, and 40.00% more deaths for multiracial patients. Additionally, waiting list addition’s volumes changed by -0.892% for White patients, 16.552% for Black patients, 15.741% for Hispanic patients, 29.771% for Asian patients, -21.739% for Native American patients, -9.091% for Pacific Islander patients, and 100.000% for multiracial patients.

DISCUSSION

ME is among the largest health policy efforts increasing health care access, but limited research assesses its effects on transplantation, especially heart transplant. By building a DiD model, we found ME increased Medicaid heart transplant volume nationally. However, that increase only amounted to 1.028 more heart transplants per ME state



B

FIGURE 2. Continued.

annually, with a cumulative increase of 113.9 heart transplants from 2014 to 2020. ME accounts for 2.80% of total Medicaid heart transplants from 2014 to 2020. However, ME constitutes 16% of total Medicaid spending dollars, markedly higher than the 2.80% transplant volume increase caused by ME.⁸ Therefore, ME may facilitate different areas of care dissimilarly, beyond transplantations, to individuals who require greater investments to reach.^{9,10} Hsiang and colleagues¹¹ similarly showed Medicaid patients face more obstacles to scheduling appointments compared with privately insured patients. Thus, reaching these patients may require greater investment than other patients, and ME reflecting 16% of the total Medicaid budget does not imply ME similarly increased heart transplant volume by 16%.

ME's correlation with increased heart transplant volume nationally supports a theme of ME driving an increase in organ transplant volume, as captured by Harhay and colleagues,¹² who found ME is correlated with increased kidney transplant volume. Harhay and colleagues¹² used a multinomial logistic regression model with the United Network of Organ Sharing database. They demonstrated

ME was associated with an increase in the proportion of new-preemptive listings for kidney transplantations with Medicaid coverage and found ME increased transplant listings in ME states compared with non-ME states, complementing our DiD findings. In a granular state analysis, Arizona experienced the greatest increase in heart transplant volume following ME (n = 20 heart transplants annually) and Arkansas experienced the greatest decrease in heart transplant volume following ME (-6.167 heart transplants annually), which may suggest ME coincidentally targeted a more vulnerable end-stage heart failure population in Arizona compared with Arkansas because ME would benefit a state with a larger population of vulnerable end-stage heart failure patients more than a state with a smaller population of vulnerable end-stage heart failure patients in the filled coverage gap. This suggests geographical variations exist, and these variations are accentuated during policy implementation.

To date, this is the first study in the cardiothoracic surgery literature to repurpose the DiD model for analyzing the influence of national health policy. A recent study in cardiothoracic surgery, performed by Amabile and colleagues¹³

TABLE 1. Medicaid expansion (ME) state and corresponding non-ME counterfactuals

ME state	Pre-ME	Post-ME	Difference	Valid counterfactuals (non-ME state)		Pre-ME	Post-ME	Difference	DiD*
Arizona	5	23	18	Utah		6	4	-2	20
Arkansas	9	6	-3	Oklahoma		3	5	2	-5
			-3	Texas		25	34	9	-12
			-3	Louisiana		10	4	-6	3
			-3	Mississippi		0	3	3	-6
			-3	Tennessee		7	14	7	-10
Colorado	5	10	-3	Missouri		12	4	-8	5
			5	Wyoming		1	0	-1	6
			5	Utah		6	4	-2	7
			5	Oklahoma		3	5	2	3
			5	Kansas		6	2	-4	9
Illinois	29	22	-4	Nebraska		7	8	1	4
			-7	Missouri		12	4	-8	1
			-7	Wisconsin		13	17	4	-11
			1	Wisconsin		13	17	4	-3
			1	South Dakota		0	3	3	-2
Iowa	6	7	1	Nebraska		7	8	1	0
			1	Missouri		12	4	-8	9
			8	Virginia		12	12	0	8
			8	Tennessee		7	14	7	1
Kentucky	7	15	8	Missouri		12	4	-8	16
			6	Texas		34	42	8	-2
			6	Mississippi		3	10	7	-1
Louisiana	4	10	6	Virginia		12	12	0	1
Maryland	8	9	1	Wisconsin		13	17	4	2
			6	Michigan		8	14	6	2
Minnesota	4	9	5	South Dakota		0	3	3	2
			5	Wisconsin		13	17	4	1
Montana	0	0	0	Idaho		4	1	-3	3
			0	Wyoming		0	0	0	0
			0	South Dakota		3	1	-2	2
Nevada	2	0	-2	Idaho		0	4	4	-6
			-2	Utah		6	4	-2	0
New Hampshire	0	1	1	Maine		0	3	3	-2
New Mexico	0	2	2	Texas		25	34	9	-7
			2	Oklahoma		3	5	2	0
			2	Utah		6	4	-2	4
North Dakota	0	0	0	Montana		3	0	-3	3
			0	South Dakota		0	3	3	-3
Oregon	8	6	-2	Idaho		0	4	4	-6
Virginia	12	23	11	Tennessee		21	31	10	1
			11	North Carolina		23	26	3	8
Washington	4	8	4	Idaho		0	4	4	0
West Virginia	1	1	0	Virginia		12	12	0	0

DiD, Difference in difference. *DiD values for ME states with multiple non-ME states were averaged to yield 1 DiD value for the ME state.

TABLE 2. State specific difference-in-difference (DiD) values

State	Statewide DiD value	DiD value for men	DiD value for women	Ethnicity DiD values						
				White	Black	Hispanic	Asian	Native american	Pacific islander	Multiracial
Arizona	20.0	8.0	8.0	12.0	0.0	5.0	4.0	0.0	-1.0	0.0
Arkansas	-6.2	0.5	-1.7	-4.0	2.3	-1.7	0.2	0.0	0.0	-1.0
Colorado	4.2	7.0	-2.8	1.0	1.6	-0.8	2.0	0.0	-0.4	0.8
Illinois	-5.0	-6.0	1.0	-7.0	1.5	-1.0	1.5	0.0	0.0	0.0
Iowa	1.0	-2.5	3.5	-1.0	1.8	0.8	0.0	0.0	-0.3	-0.3
Kentucky	8.3	5.7	2.7	6.3	0.7	1.3	0.0	0.0	0.0	0.0
Louisiana	-1.5	0.5	-2.0	-3.0	1.0	-4.5	-0.5	0.0	0.0	0.0
Maryland	1.0	7.0	-6.0	-4.0	2.0	4.0	-1.0	0.0	0.0	0.0
Michigan	2.0	0.0	2.0	2.0	1.0	-1.0	0.0	0.0	0.0	0.0
Minnesota	1.5	-2.0	3.5	5.0	-0.5	-0.5	-0.5	-2.0	0.0	0.0
Montana	1.7	1.3	0.3	1.7	0.0	-0.3	0.3	-1.0	0.0	0.0
Nevada	-3.0	-1.5	-1.5	0.0	0.0	-2.5	0.0	0.0	-0.5	0.0
New Hampshire	-2.0	-3.0	1.0	-1.0	-1.0	0.0	0.0	0.0	0.0	0.0
New Mexico	-1.0	-0.3	-1.3	3.0	-0.7	-3.0	0.0	0.0	-0.3	0.0
North Dakota	0.0	-1.0	1.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
Oregon	-6.0	-1.0	-5.0	-6.0	0.0	-1.0	0.0	0.0	0.0	0.0
Virginia	4.5	3.5	1.0	-2.5	2.0	1.5	1.0	0.5	0.0	1.0
Washington	0.0	-3.0	3.0	1.0	-1.0	0.0	0.0	0.0	0.0	1.0
West Virginia	0.0	5.0	-5.0	-2.0	-1.0	3.0	-1.0	0.0	0.0	1.0

used the DiD model for analyzing the influence of a policy change for New York residents. Amabile and colleagues¹³ used the New York State Cardiac Surgery Reporting System data to determine whether or not trainee duty hour regulations were associated with poorer short-term coronary artery bypass grafting and valve surgery outcomes, and found no evidence of a negative effect. DiD analyses are

rarely performed in cardiothoracic surgery, but have been utilized in public health research to analyze policy effects.¹⁴ For instance, Stuart and colleagues¹⁴ performed a DiD analysis to control confounding variables when analyzing a new payment and delivery system, by using Massachusetts' Blue Cross Blue Shield. They concluded "Alternate quality contracts," where insurers give care providers fixed prepayments to cover most of patient care, had no effect on out-of-pocket expenditures by plan enrollees.¹⁴ There are limited DiD analyses on ME, and to the best of our knowledge, no utilization in cardiothoracic surgery. In the context of ME, DiD analyses found higher uninsured rates for persons with disabilities, greater health care utilization in women of reproductive age, significant decline in infant mortality rate in Hispanic patients, and increases in primary care physician visits without a concomitant increase in emergency department visits.¹⁵⁻¹⁸ These studies highlight the capacity of DiD analyses to estimate national health policy effects, where it is often infeasible to perform randomized controlled trials.

State-Specific Medicaid Expansion DiD Values

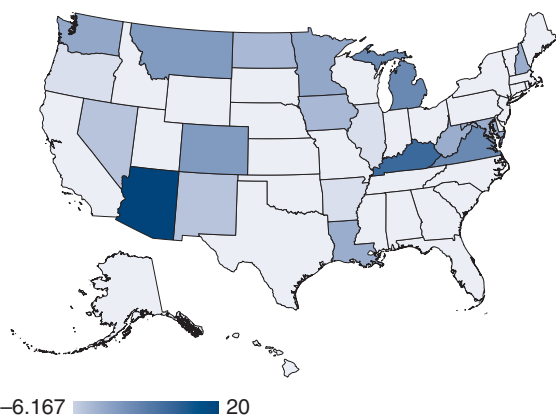
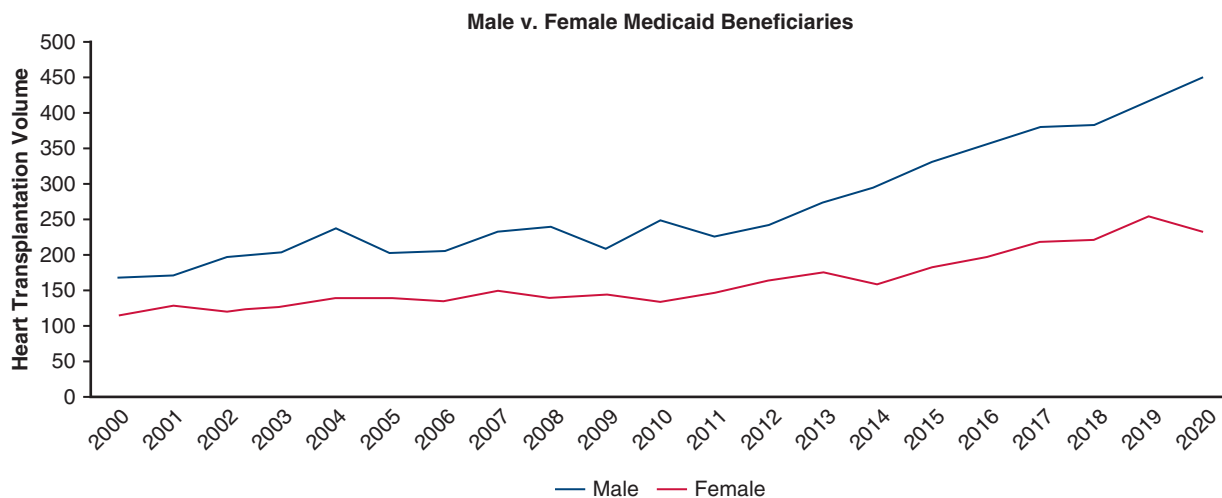
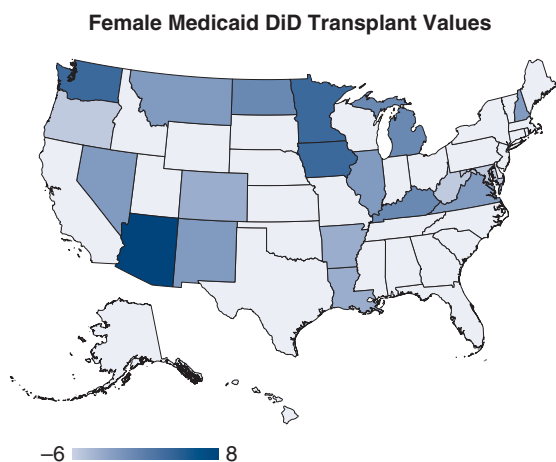


FIGURE 3. State-specific effects of Medicaid expansion (ME). Arizona had the greatest increase in transplant volume due to ME (n = 20 heart transplants annually) and Arkansas had the greatest decrease in transplant volume due to ME (n = -6.167 heart transplants annually). DiD, Difference-in-differences.

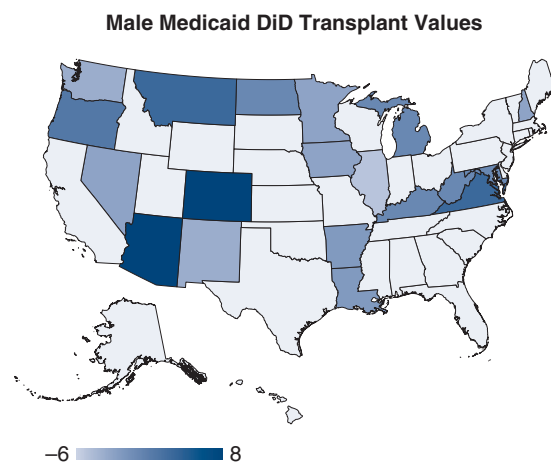
Next, ME analyses were stratified by certain demographic groups, either sex- or ethnicity-based. These analyses found ME did not benefit all demographic groups equally. ME had the highest increases in heart transplant volume in men (DiD = 0.956), Blacks (DiD = 0.510), and Asians (DiD = 0.316). However, when comparing ME's effects between sexes, male beneficiaries experienced



A



B



C

FIGURE 4. Male versus female Medicaid beneficiaries. A, Medicaid heart transplants in men increased from 2000 (n = 167) to 2020 (n = 451), a 170.06% transplant volume increase. Medicaid heart transplants in women increased from 2000 (n = 116) to 2020 (n = 233), a 100.96% transplant volume increase. B and C, Medicaid expansion yielded an estimated 106 more Medicaid heart transplants in men and 10.23 more Medicaid heart transplants in women. *DiD*, Difference-in-differences.

over a 10-fold larger increase ($DiD = 0.956$). These sex differences likely exist because ME expanded health care coverage to more men than women.¹⁹ For instance, the Minnesota ME, which covered individuals earning up to 250% of the federal poverty level, benefited more men.¹⁹ The trend observed by ME states differed from Medicaid transplants nationally, as demonstrated by the Poisson regression, which showed a larger increase in Medicaid heart transplants in women from 2014 to 2020. This suggests ME resulted in a different trend of sex-stratified heart transplant volume than the trend observed by Medicaid states as a whole.

In the context of ethnic analyses, ME had a negative influence on transplant volume for Medicaid beneficiaries who were Hispanic ($DiD = -0.038$), Native American

($DiD = -0.105$), and Pacific Islander ($DiD = -0.131$). Our findings highlight how ME does not benefit all ethnicities, and complement findings by Breathett and colleagues,²⁰ who found Medicaid expansion is associated with increased heart transplant listings for Black patients, but not in Hispanic patients. Breathett and colleagues²⁰ used the Scientific Registry of Transplant Recipients to analyze transplant listings in states expanding Medicaid early, and suggested negative ME effects for Hispanics could be attributed to a lower prevalence of end-stage heart failure compared with ethnicities experiencing positive ME effects. This can be investigated through future studies analyzing diagnoses across different demographic groups before and after ME. Similar to the study performed by Breathett and colleagues,²⁰ our study found

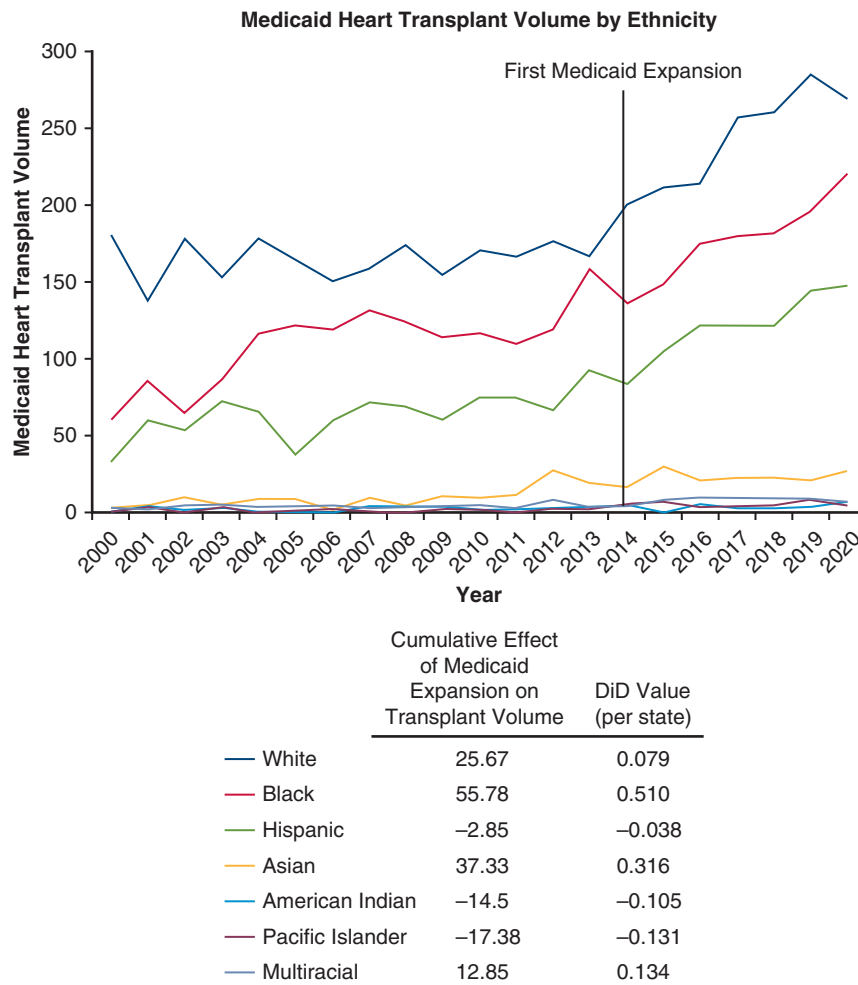


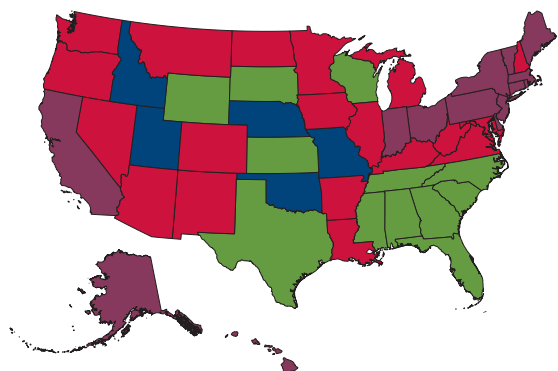
FIGURE 5. Medicaid ethnicity transplant volumes and difference-in-difference (*DiD*) model values by ethnicity. Largest *DiD* values were in Black patients and Asian patients (*DiD* = 0.510 and 0.316, respectively). ME had a negative influence on Hispanic patients (*DiD* = -0.038), Native American patients (*DiD* = -0.105), and Pacific Islander patients (*DiD* = -0.131).

ME did not translate to equal increases in transplant volume across ethnic groups. Historically, ethnic minorities are the highest uninsured groups, suggesting ME would benefit these groups the most.²¹ This notion is supported by Harhay and colleagues¹² finding ME being associated with greater absolute increases in minority listings compared with White listings. However, we found ME benefited White patients more than minority demographic groups. The trend observed by ME states differed from all Medicaid transplants in the United States from 2014 to 2020, as demonstrated by the Poisson regression, which showed increases in Medicaid transplant volume for White patients, Black patients, and Hispanic patients; and showed decreases in Medicaid transplant volume for Asian patients and Native American patients. This suggests ME may result in a different trend of ethnicity-stratified heart transplant volume than the trend observed by Medicaid states as a whole. Contextualized in the larger dynamics of heart transplant waiting lists, from 2014 to

2020, waiting list additions increased for Black, Hispanic, Asian, and multiracial patients. Conversely, waiting list additions decreased for White, Native American, and Pacific Islander patients. For the same timeframe, fewer White, Black, and Native American patients were removed from the waiting list due to waiting list mortality. Conversely, waiting list mortality increased for Hispanic, Asian, and multiracial patients. The findings of our *DiD* model exist within this dynamic environment of the transplant waiting list.

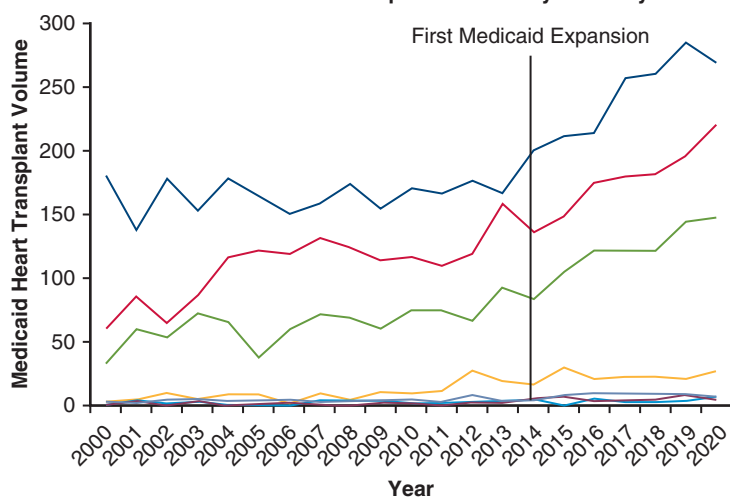
Contextualizing the findings of our study, ME is associated with increased national transplant volumes, but did not increase volume uniformly for minority groups. This mirrored another study by Breathett and colleagues,²² which found ME's increase in ventricular assist device (VAD) implantation for Blacks was not significantly different between ME and non-ME states. Breathett and colleagues²² used the Healthcare Cost and Utilization Project Data State Inpatient Databases to compile data for 19

Estimating the Causal Effect of Medicaid Expansion on Heart Transplant Volume with a Differences-in-Differences Model



A national Differences-in-Differences (DiD) model of 19 U.S. states evaluated Medicaid expansion's (ME) effect on Medicaid heart transplant volume.

Medicaid Heart Transplant Volume by Ethnicity



From 2014-2020, ME yielded:

- 106 additional male heart transplants
- 10.23 additional female heart transplants

ME increased heart transplant volume most for **male, Black, and Asian patients.**

ME's effects are dissimilar across demographics and does not significantly benefit historically vulnerable populations, suggesting ME should be remodeled if the aim is to prioritize transplant access for minority demographics.

Cumulative Effect of Medicaid Expansion on Transplant Volume DiD Value

White	25.67	0.079
Black	55.78	0.51
Hispanic	-2.85	-0.038
Asian	37.33	0.316
American Indian	-14.5	-0.105
Pacific Islander	-17.38	-0.131
Multiracial	12.85	0.134

FIGURE 6. Estimating the causal effect of Medicaid expansion (ME) on heart transplant volume with a differences-in-differences (DiD) model.

states, and performed a piecewise Poisson regression to estimate changes experienced by ME states. Our study arrived at a similar conclusion using a different approach for a slightly different population in cardiothoracic surgery, but for a similar time frame and cohort. We also highlighted different minority groups experiencing different trends following ME, complementing a finding by Nephew and colleagues,²³ who performed a Poisson regression with the United Network for Organ Sharing database and

concluded Black patients with hepatitis C virus experienced decreased liver transplant waitlist times, whereas Hispanic patients without hepatitis C virus experienced increased liver transplant waitlist times following ME.

ME may increase heart transplant volume, but it does not increase volume for all minorities. ME reduced the population of uninsured patients, but it reduced it differently amongst minority groups, which may explain the discrepancies in heart transplant volumes among ME states.^{20,24}

Although ME targets underinsured or low socioeconomic status patients, who are associated with poorer outcomes following heart transplantation, Medicaid patients are not associated with increased risk of severe cellular rejection requiring hospitalization following heart transplantation.²⁵⁻²⁸ To address these discrepancies, ME's specific mechanics should be reevaluated to ensure the most vulnerable and underinsured populations benefit equitably (Figure 6). This is relevant because the current draft of the Build Back Better Act (BBBA) aims to increase health insurance coverage in the 12 states that have yet to expand Medicaid under the Affordable Care Act.²⁹ The BBBA outlines approaches to disseminate marketplace subsidies to individuals in the current Medicaid gap, and it is imperative the gap is addressed equitably.^{20,27,30} Looking beyond the BBBA, there will likely be future policies filling uninsured gaps and it is crucial that before policy implementation, we are cognizant of efficacious policy attributes in cardiothoracic surgery. Highlighting less commonly realized characteristics of ME allows policymakers and physicians to constructively advocate for proper insurance coverage augmentation that equitably increases healthcare access for vulnerable populations.

Limitations

This study is subject to several limitations. Firstly, the DiD model assumes in the absence of intervention, treatment groups mimic the behavior of counterfactuals. We upheld this assumption by using geographically adjacent states as counterfactuals. The confounding variables our DiD model does not control for are events transpiring exactly in ME states and absent in non-ME states, in the same year as ME in the ME states, which we were unable to identify. This extends to events disproportionately affecting ME states, which have not yet been documented such as donation after cardiac death expansion and center-specific initiatives regarding transplant volume. Our model does not analyze national events' influence on different United Network for Organ Sharing transplant regions because it was built state by state, not region by region. Using geographically adjacent localities is the standard for DiD; however, adjacent states may vary.³⁰ For instance, states on borders of allocation regions may behave differently following ME compared with states in the center of allocation regions because of increased organ transport distance. Several counterfactual states were in a different allocation region than their associated ME state because a single counterfactual state can border multiple ME states. However, these differences were controlled using the difference in groups clause of DiD. This inclusion criteria of having geographically adjacent non-ME states allowed 19 states to be included; therefore, we do not make any claims of all-inclusiveness. Included ME states comprise 27.877% of total Medicaid transplant volume and excluded ME states

comprise 37.677% of total Medicaid transplant volume as of February 2022. The non-White Medicaid transplant population comprised 21.937% of total transplants in the included ME cohort, 26.986% in the excluded ME cohort, 26.583% in states that refused Medicaid expansion, and 15.340% in ME states that expanded during or after 2020. No significant ethnic differences exist between included and excluded ME cohorts, suggesting the possibility of ethnic differences arising by chance. We believe the included 19 states and their respective counterfactuals offer our DiD model the largest sample size possible while satisfying the parallel trends assumption, which allows us to derive meaningful conclusions. Including more ME states would diminish the validity of our parallel trends assumption, which would compromise the credibility of our conclusions. Secondly, the database is subject to limitations because patient demographic characteristics may be improperly recorded in acute situations, such as emergency heart transplants. Additionally, the OPTN database may report data differently from other transplant databases because databases may employ different definitions. Thirdly, Medicaid beneficiaries comprise a small portion of the overall transplant population, limiting the degree of analysis that can be performed. There is also a possibility Medicaid patients gained coverage unrelated to ME, which is unlikely because Medicaid is an entitlement program. However, our study optimizes OPTN transplant data, and builds a national DiD model controlling for as many unobservable and confounding variables as possible.

CONCLUSIONS

Heart transplant volume is no longer skewed toward private insurance, suggesting policy increased public insurance beneficiaries' access to health care. Employing a national DiD model, ME increased Medicaid heart transplant volume nationally, with greatest benefits for men, Black patients, and Asian patients. However, this increase is dissimilar across demographic characteristics and does not uniformly benefit historically vulnerable populations, suggesting ME should be remodeled if the aim is to prioritize transplant access for minority groups.

Conflict of Interest Statement

The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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Key Words: Medicaid, heart transplantation, ethnic differences, sex differences

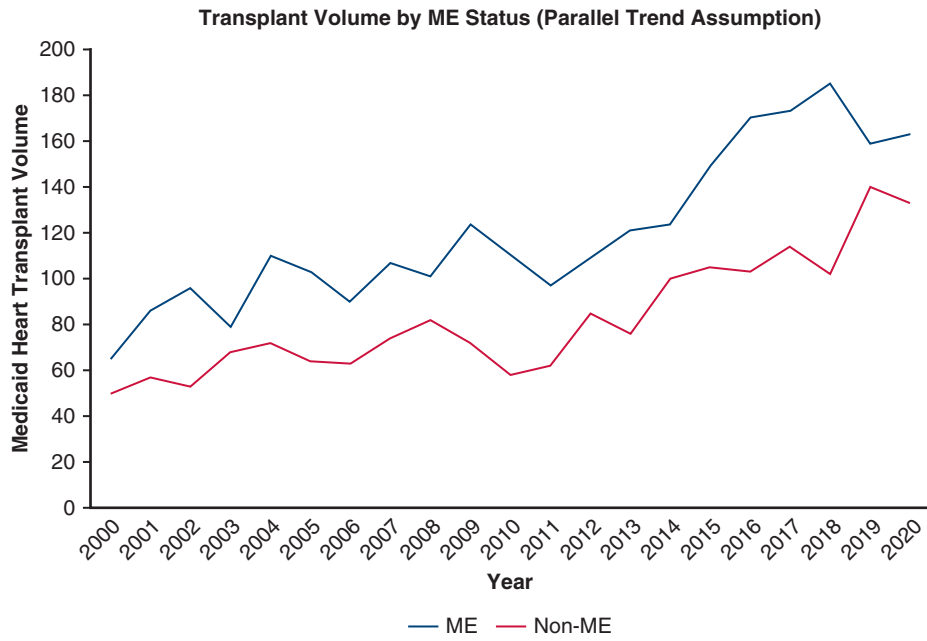


FIGURE E1. Transplant volume by Medicaid expansion (*ME*) status. Before the first *ME* in 2014, the *ME* group and non-*ME* group followed a similar trend. Therefore, the parallel trend assumption needed for the difference-in-difference model is satisfied.

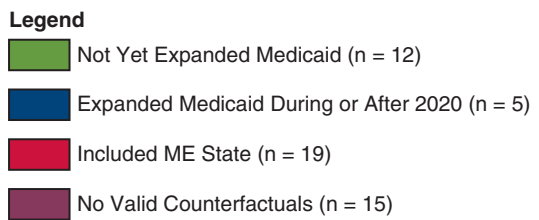
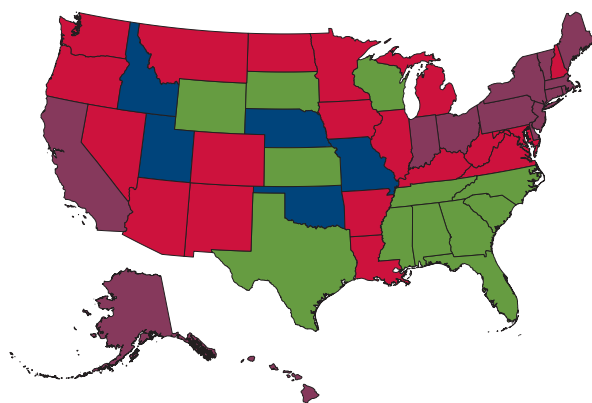


FIGURE E2. US states included as Medicaid expansion (*ME*) states and corresponding rationale for US states excluded from this study.

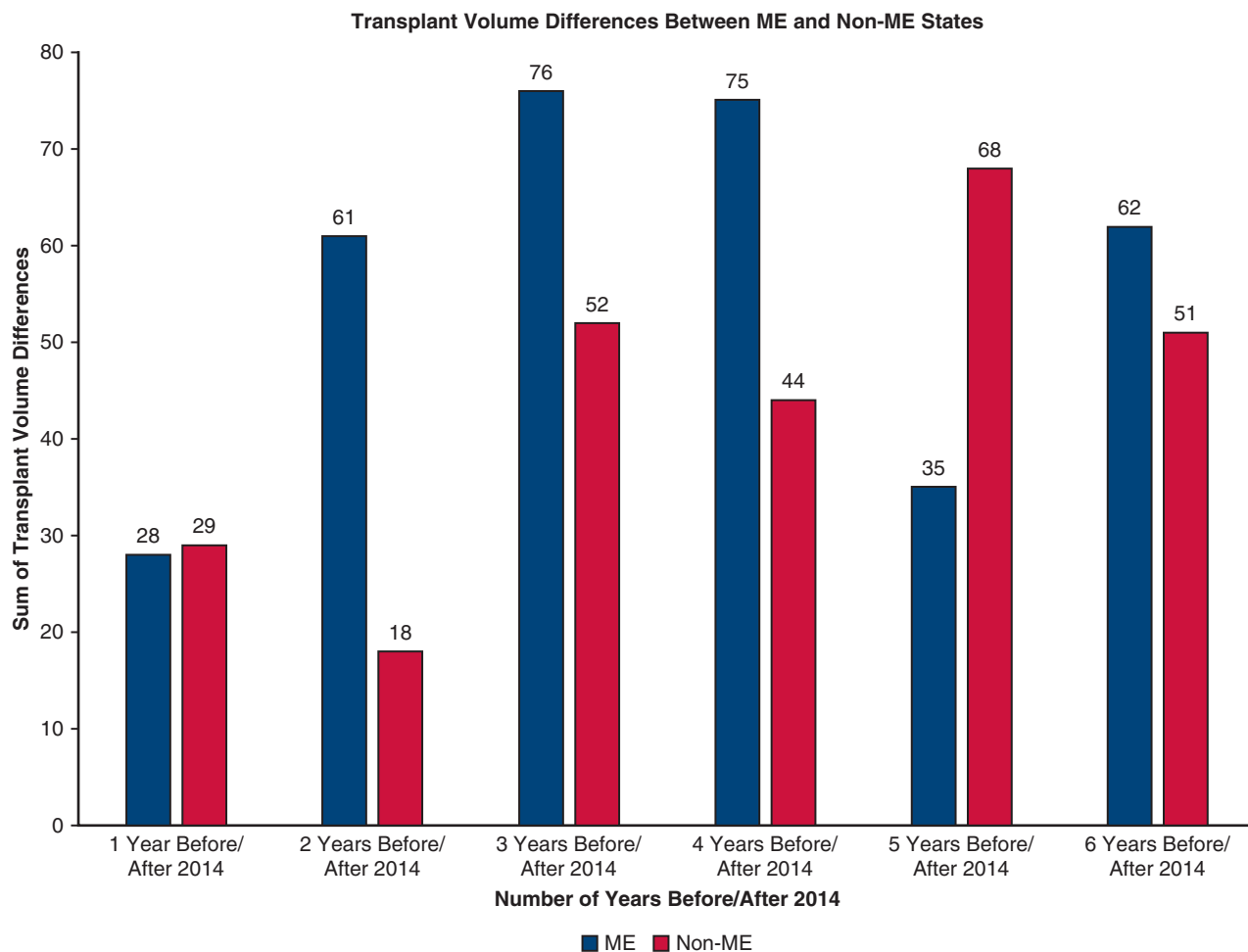


FIGURE E3. Transplant volume differences by Medicaid expansion (ME) status across all US states and without the geographical inclusion criteria requirement for non-ME states. Volume differences increased gradually by ME states to their maximum at 3 and 4 years pre- and post-ME.

TABLE E1. Outputs of the Poisson regression models

Variable	Poisson regression model output			
	β coefficient (%)	95% CI	P value	Goodness-of-fit χ^2 test
Male	0.159	0.012 to 0.30	.033	0.9926
Female	0.202	-0.038 to 0.44	.100	0.9926
White	0.028	-0.535 to 0.592	.921	0.9604
Black	0.383	-0.669 to 1.434	.476	0.9604
Hispanic	0.212	-0.448 to 0.872	.529	0.9604
Asian	-0.359	-2.593 to 1.876	.753	0.9604
Native American	-1.787	-8.325 to 4.75	.592	0.9604