Impact of Affordable Care Act Insurance Expansion on Pre-Hospital Access to Care: Changes in Adult Perforated Appendix Admission Rates after Medicaid Expansion and the Dependent Coverage Provision

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BACKGROUND: The Affordable Care Act (ACA) changed the landscape of insurance coverage, allowing young adults to remain on their parents' insurance until age 26 (Dependent Coverage Provision [DCP]) and states to optionally expand Medicaid up to 133% of the federal poverty level. Although both improved insurance coverage, little is known about the ACA's impact on observed receipt of timely access to acute care. The objective of this study was to compare changes in insurance coverage and perforation rates among hospitalized adults with acute appendicitis "after vs before" Medicaid expansion and the DCP using an Agency for Healthcare Research and Quality (AHRQ)-certified metric designed to measure pre-hospital access to care.

STUDY DESIGN: We performed a quasi-experimental, difference-in-difference (DID) analysis of 2008-2015 state-level inpatient claims.

RESULTS: Adults, aged 19 to 64, in expansion states experienced an absolute 7.7 percentage point decline in uninsured (95% CI 7.5 to 7.9) after Medicaid expansion compared with nonexpansion states. This coincided with a 5.4 percentage point drop in admissions for perforated appendicitis (95% CI 5.0 to 5.8) that was most pronounced among young adults, aged 26 to 34, just age-ineligible for the DCP (DID: 11.5 percentage points). Medicaid expansion insurance changes were 4.1 times larger than those encountered under the DCP (DID: 1.9). They affected all population subgroups and significantly reduced access-related disparities in race/ethnicity and lower-income communities. Although both Medicaid expansion and the DCP were associated with significant insurance gains, those attributable to the DCP were more concentrated among more privileged patients. Despite this trend, both policies resulted in larger reductions in perforation rates for historically uninsured and underserved groups.

CONCLUSIONS: Reductions in uninsured after Medicaid expansion and the DCP were associated with significant reductions in perforated appendix admission rates. Improvements in access to acute surgical care suggest that maintained/continued insurance expansion could lead to fewer delays, better patient outcomes, and reductions in disparities among the most at-risk populations. (J Am Coll Surg 2019;228: 29–43. © 2018 by the American College of Surgeons. Published by Elsevier Inc. All rights reserved.)

As the "second most common gastrointestinal diagnosis mandating urgent operation,"[1,2] perforated appendix admission rates have long been used as a disparity-sensitive marker of pre-hospital access to care. Known to associate with patients' decisions of when to seek care and with variations in insurance status,[3-5] income,[3,4] and race/ethnicity[3,4] among adult patients aged 19 to 64 years, the perforated appendix admission rate has been proposed as an "ideal proxy" for ambulatory access to unplanned urgent care because of acute appendicitis' consistent and time-sensitive natural history progressing toward perforation in the absence of treatment and lack of known biological basis for variation among sociodemographic groups.[3,4,6-10] In 2001, the Agency for Healthcare Research and Quality (AHRQ) recognized adult perforated appendix admission rates as 1 of 16 Prevention Quality Indicators (PQI) designed to capture changes in access to care.[9,10] It is the only PQI that deals directly with operative patients and is one of the few to hold relevance for both older and younger adults.

Since its passage in 2010, the Patient Protection and Affordable Care Act (ACA) has sought to improve access to care through improvements in insurance coverage. Although the law and its various provisions, including expansion of parental private insurance coverage to children younger than 26 years, whose parents have employer-sponsored private health insurance plans, establishment of an individual insurance mandate, formation of state health insurance exchanges, expansion of tax support for employer-sponsored health insurance plans, and optional state expansion of Medicaid with temporary federal funding to all citizens with an income <133% of the federal poverty level,[11] are known to have increased insurance coverage and self-reported access to care on a national scale,[12] the ACA's specific effect on observed access to care among adult patients requiring urgent operative management (or operative consultation and medical management) remains less clear. Previous studies of all adult emergency presentations to the Emergency Department (ED)[13-15] and high-acuity trauma patients[11,16,17] suggest significant reductions in the number of uninsured patients and improvements in access to insurance-sensitive markers of post-discharge care, such as discharge to rehabilitation.

The objective of this study was to use rigorous quasi-experimental difference-in-difference (DID) regression techniques[6,11] in order to access the extent of changes in insurance coverage and associated access to pre-hospital care via the assessment of perforated appendix admission rates among hospitalized adult patients with acute appendicitis "after vs before" Medicaid expansion and implementation of the remainder of the ACA in Medicaid expansion vs no-expansion states. As a secondary analysis, the study also looked at earlier ACA-related changes stemming from implementation of the Dependent Coverage Provision (DCP) in September 2010, which enabled young adults aged 19 to 25 to remain on their parents' private health insurance plans. It considered differences in insurance coverage and perforated appendix admission rates among age-, race/ethnicity-, and community income level-stratified subgroups of the adult emergency general surgery population, in which disparities in insurance and access to care are known to exist.[4,6,18-21]

METHODS
Data source and study population
Data from state inpatient databases collected by AHRQ and obtained directly from state departments of health (Fig. 1A) in 4 large, geographically diverse nonexpansion states (Florida, Nebraska, North Carolina, and Texas) and 5 Medicaid expansion states (Colorado, Illinois, Minnesota, New Jersey, New Mexico) were queried for adult patients, aged 19 to 64 years, with diagnoses of acute appendicitis, as defined by the AHRQ Prevention Quality Indicator for adult perforated appendix admission rate[10] (International Classification of Diseases, 9th edition, Clinical Modification [ICD-9-CM] diagnosis codes: 540.0, 540.1, 540.9, and 541.x). Medicaid expansion states were chosen such that each included state expanded Medicaid in January 2014 and was not operating under a Center for Medicare and Medicaid Services' waiver or alternative payment plan. Consistent with AHRQ specifications,[10] patients were excluded if they were admitted as transfers from other hospitals, skilled-nursing facilities, or intermediate-care facilities; presented with a major diagnostic category definition consistent with pregnancy, childbirth, or puerperium; or were missing information for key covariates of interest. Included patients were further required to be admitted to inpatient hospitals in states where they were residents between January 1, 2008 and September 30, 2015 (before introduction of ICD-10-CM diagnosis codes in October, 2015). They were excluded if they were missing information on primary-payer insurance or demographic and clinical covariates used for stratification and population

comparison (<5.0% of the total sample). Exceptions were made for states that universally do not report race/ethnicity: Minnesota and Nebraska. In order to focus our analyses on patients potentially eligible for ACA-related insurance change, patients were also excluded if they had a primary-payer other than private, Medicaid, or uninsured.

Data obtained from state inpatient databases contained patient-level information on hospitalizations for the majority of hospitals within each state, collectively accounting for approximately 29.6% of the total US population.[22] Each state database included information on patient encounters, encompassing 20 or more ICD-9-CM diagnoses and 15 or more ICD-9-CM procedure codes. In order to attain additional information on hospital-level parameters, patient data from each state were matched to hospital data contained within the American Hospital Association Annual Survey Database.[23] State inpatient databases, whether obtained directly from state departments of health or through AHRQ's Healthcare Cost and Utilization Project, represent an ideal population in which to study changes in hospitalized perforated appendix admission rates. The Prevention Quality Indicator (PQI) was designed by AHRQ for use in administrative claims,[9,10] specifically those contained within the National (Nationwide) Inpatient Sample, which is itself derived from state inpatient databases.[24]

In order to address concerns about potential selection bias inherent in the use of an inpatient quality metric for admissions related to acute appendicitis given an increasing prevalence of ambulatory and same-day management in recent years, 2011 to 2015 data meeting the same inclusion/exclusion criteria were also abstracted from the Florida (nonexpansion state) and New Jersey (Medicaid expansion state) AHRQ Healthcare Cost and Utilization Project State Inpatient Database (SID) which contains information on emergency department admissions (and incoming hospital transfers) subsequently admitted as inpatients to the same hospital, and State Emergency Department Database (SEDD), which contains information on noninpatient (and transferred) emergency department admissions. Patients from each of the 4 databases were compared graphically over time in order to explore the data for potential changes in quarterly admission counts and perforation rates (Figs. 2A and 2B). Locally weighted scatterplot smoothing (LOWESS) regression lines were overlain to facilitate visualization.

Time period and variable definitions

Included patients were categorized according to insurance during index hospitalization: uninsured (self-pay), Medicaid, and private. Changes in insurance and presence of "perforation or abscess of the appendix" (ICD-9-CM: 540.0, 540.1)[10] were the primary analyses and outcomes measure. Demographic covariates used in stratification included age, categorized as adults aged 19 to 25 (also eligible for extended parental private insurance coverage under the DCP), 26 to 34, 35 to 49, and 50 to 64 years old; race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, other); and community income level, defined based on state-specific quartiles (Q) of median incomes for patients' residential ZIP codes and categorized as higher (Q3/4)- vs lower (Q1/2)-income communities.

Month and year of admission were used to define the time period of hospitalization. Patients admitted during the 33 months before the DCP (January 2008 to September 2010) were the "pre-DCP" group. Those admitted following extended parental private insurance coverage but before Medicaid expansion were the "pre-expansion" group (January 2011 to September 2013). Those admitted during the 21 months after Medicaid expansion were the "post-expansion" group (January 2014 to September 2015). The first fiscal quarters of fiscal years 2011 (October to December 2010) and 2014 (October to December 2013) were excluded as "wash-in" periods in order to account for anticipatory changes leading up to policy change. State of hospital admission determined Medicaid expansion vs nonexpansion states. For analyses involving the DCP that took effect in all states, included hospitalizations were aggregated across Medicaid expansion and nonexpansion states and restricted to include only policy-eligible patients aged 19 to 25 years and a slightly older, policy-ineligible comparator group aged 26 to 34 years.[6]

Statistical analysis: population comparison

Differences in demographic and clinical covariates were compared across time periods, DCP age groups, and Medicaid expansion vs nonexpansion states, in order to determine the extent of potential underlying differences in study populations. Included covariates are listed in Tables 1 and 2. In each study group, covariate distributions were clinically similar, with subtle, time-consistent differences between Medicaid expansion and nonexpansion states.

Statistical analysis: "after vs before" effects

Changes in insurance "after vs before" DCP (2010) and full ACA (2014) implementation (including Medicaid expansion) in Medicaid expansion and nonexpansion states were first compared graphically in order to visually inspect for changes in insurance and the presence of pre-implementation parallel trends (a requirement of valid DID). Results for patients aged 19 to 64 years are
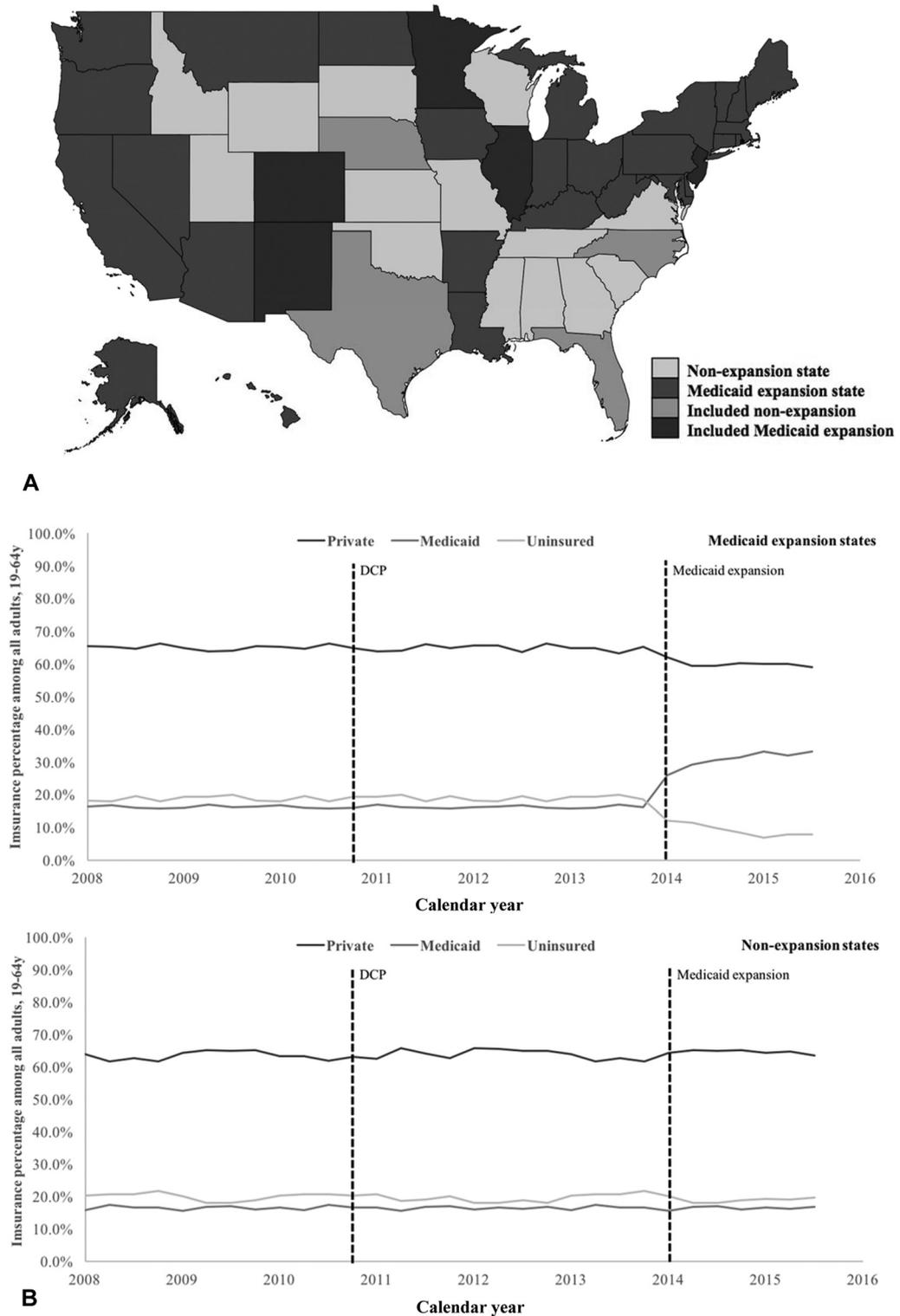
Figure 1. (A) Population: Medicaid expansion in the United States as of 2018 and study included Medicaid expansion vs nonexpansion states. (B) Graphic depiction of Affordable Care Act (ACA)-related insurance change and assessment of pre-implementation parallel trends: Changes in insurance coverage in Medicaid expansion vs nonexpansion states, calendar year: 2008 to 2015. Vertical dashed lines correspond to introduction of the Dependent Coverage Provision (DCP) in September 2010 and full implementation of the ACA in January 2014.
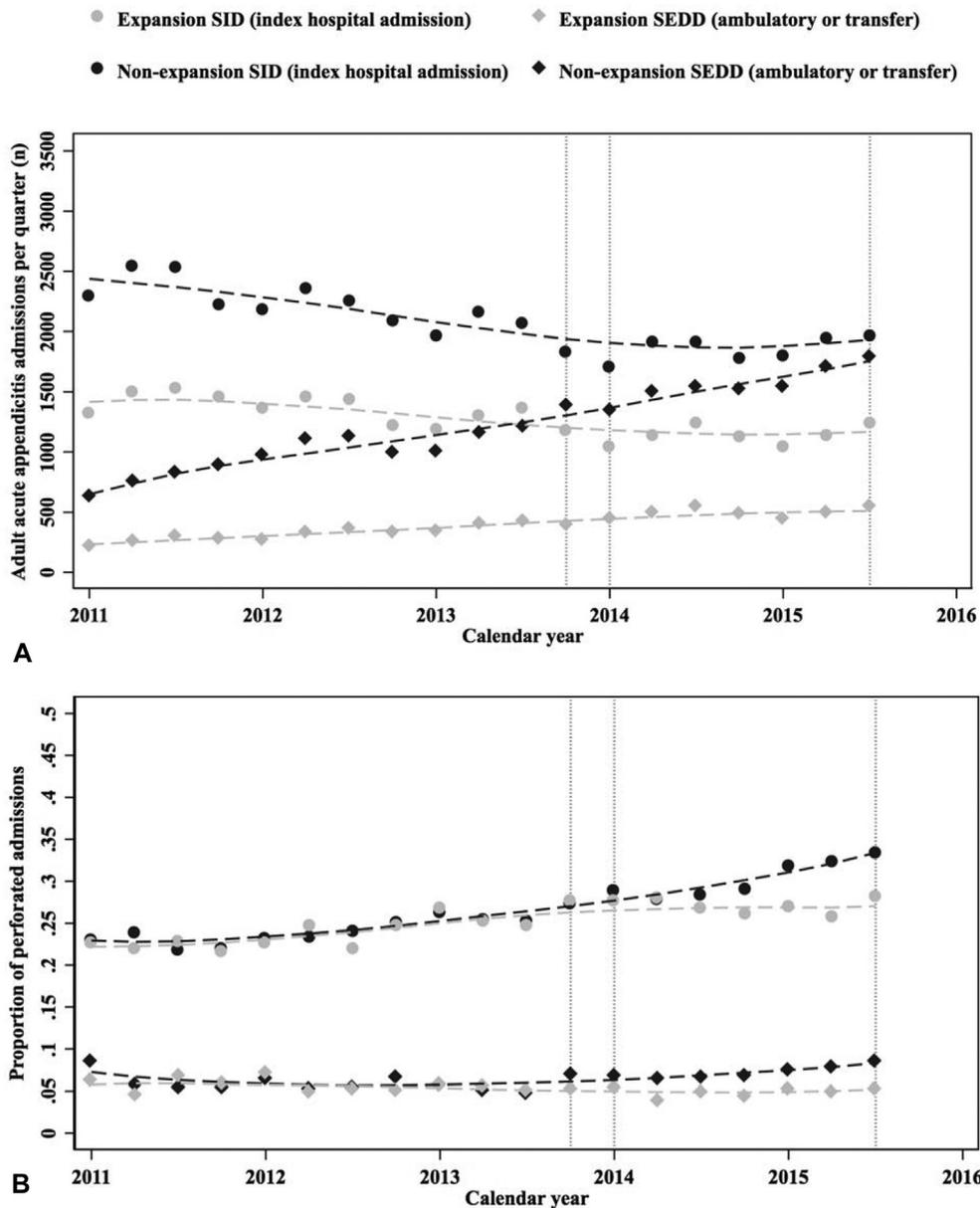
Figure 2. Testing the inpatient quality metric assumption: Unadjusted changes in adult acute appendicitis (A) admission counts and (B) perforation rates are plotted by quarter along with locally weighted scatterplot smoothing regressions to aid in visualization from January 2011 to September 2015 for data abstracted from the Florida (nonexpansion state) and New Jersey (Medicaid expansion state) Agency for Healthcare Research and Quality (AHRQ) State Inpatient Database (SID) and State Emergency Department Database (SEDD). Vertical dashed lines correspond to full implementation of the ACA in January 2014 (and previous wash-in period) and introduction of ICD-10-CM diagnosis codes at the end of September 2015.

presented in Figure 1B. Similar assessment was conducted for perforated appendix admission rates (eFig. 1).

Statistical analysis: difference-in-difference
Differences between Medicaid expansion and nonexpansion states were then compared using DID in order to

ascertain the presumed causal effects of Medicaid separate from the remainder of the ACA. Difference-in-difference models function by fitting linear regressions to data that include parameters for "treatment" (Medicaid expansion vs nonexpansion state), "time period" (before vs after ACA implementation), and an interaction between the

Table 1. Covariate Distributions among Adults Aged 19 to 64 Years, before and after Medicaid Expansion

Variable	Before Medicaid expansion, January 2011 to September 2013		After Medicaid expansion, January 2014 to September 2015	
	Expansion state	Non-expansion state	Expansion state	Non-expansion state
n	177,702	199,784	113,082	127,134
Mean age, y (SD)	38.8 (13.4)	37.7 (13.3)	39.3 (13.5)	38.1 (13.4)
Sex, %				
Male	54.1	50.2	53.9	51.0
Female	45.9	49.8	46.1	49.0
Race/ethnicity. %*				
Non-Hispanic white	57.1	54.8	58.3	55.8
Non-Hispanic black	12.3	9.7	12.2	9.5
Hispanic	22.6	27.6	21.2	28.5
Other	8.0	7.9	8.3	6.3
Pre-existing medical condition, %				
CCI 0	85.9	85.7	83.3	83.3
CCI ≥ 1	14.1	14.3	16.7	16.7
Income of patient's community, %				
Lower-income community	46.2	54.2	51.3	61.5
Higher-income community	53.8	45.8	48.8	38.5
Urbanicity of patient's county, %				
Large metro (>1 million)	56.2	66.1	54.8	68.8
Small metro (<1 million)	35.6	24.4	35.5	24.2
Micropolitan	5.2	4.8	5.2	2.5
Rural	3.0	4.7	4.5	4.4

*Tabulations for race/ethnicity do not include data from Minnesota and Nebraska.
CCI, Charlson Comorbidity Index.

2. Presumed causal effects are calculated as the "difference in the differences" between treated and untreated groups in the post-vs pre-intervention periods (ie by the magnitude and significance of the "treatment by time period" interaction term):

$$Expected\ [Y] = \beta X_{Treatment} + \beta X_{Time\ period} \\ + \beta X_{Treatment * Time\ period}$$

where Y denotes the model outcome, X the indicator variable values, and β the corresponding model coefficients. Analogous DID assessment was conducted in order to study the effects of DCP implementation by comparing "treated" (policy-eligible patients aged 19 to 25 years) vs "untreated" (policy-ineligible patients aged 26 to 34 years) "after vs before" DCP implementation in 2010.

As a sensitivity analysis, differences in risk-adjusted DID changes were also compared using calculated propensity scores and inverse probability of treatment weighting to account for potential confounding associated with the characteristics outlined in Tables 1 and 2. Risk-adjustment did not appreciably change the results. The

DID models are designed to replicate the results of randomized controlled trials in settings, such as national health-policy implementation, where randomization is ethically difficult or pragmatically impossible. They are intended to be unadjusted so as not to alter the magnitude of the presumed casual effect.[25,26] The benefit of the model design is that compared groups do not have to be identical; as long as the assumption of pre-implementation parallel trends holds, unadjusted differences will cancel out. For this reason, and given a lack of meaningful changes in the study's outcomes measures when risk-adjustment was used, unadjusted results are presented throughout this article.[25,26]

Statistical analyses: verifying the presumed association

In order to demonstrate that the presumed association between perforated appendix admission rates and insurance status actually exists within this population, unadjusted perforation rates were compared using generalized linear models with a binomial family and natural log-transformation of aggregate data from all included states

Table 2. Covariate Distributions among Young Adults Aged 19 to 34 Years, Before and After Introduction of the DCP and Medicaid Expansion

Variable	Before the DCP, January 2008 to September 2010		After the DCP, January 2011 to September 2013				After Medicaid expansion, January 2014 to September 2015			
	DCP eligible: 19 to 25 y	DCP ineligible: 26 to 34 y	DCP eligible: expansion state	DCP eligible: non-expansion state	DCP ineligible: expansion state	DCP ineligible: non-expansion state	DCP eligible: expansion state	DCP eligible: non-expansion state	DCP ineligible: expansion state	DCP ineligible: non-expansion state
n	45,697	46,092	22,571	23,026	21,839	23,553	14,680	14,289	14,897	15,347
Mean age, y (SD)	22.3 (2.3)	29.8 (2.6)	22.4 (2.3)	22.4 (2.3)	29.8 (2.6)	29.9 (2.5)	22.4 (2.3)	22.5 (2.3)	29.9 (2.5)	29.9 (2.6)
Sex, %										
Male	54.7	54.2	58.7	53.0	55.7	51.9	56.7	54.3	57.5	52.0
Female	45.3	45.8	41.3	51.0	44.3	48.1	43.3	45.7	42.5	48.0
Race/ethnicity. %*										
Non-Hispanic white	56.9	54.1	54.4	48.2	54.7	49.2	55.7	51.0	56.6	52.4
Non-Hispanic black	10.3	10.4	12.0	11.1	11.8	10.4	13.2	10.6	11.7	9.6
Hispanic	23.5	27.2	25.4	32.6	26.5	30.6	24.0	30.5	25.4	29.2
Other	9.3	8.3	8.3	8.1	7.0	9.8	7.1	7.9	6.3	8.8
Pre-existing medical condition, %										
CCI 0	92.8	92.4	91.3	92.9	91.3	91.4	91.3	91.1	90.1	90.9
CCI ≥1	7.2	7.6	8.7	7.1	8.7	8.6	8.8	8.9	9.9	9.1
Income of patient's community, %										
Lower-income community	49.3	50.1	50.6	55.6	48.0	56.3	51.1	53.0	51.7	54.0
Higher-income community	50.7	49.9	49.4	44.4	52.0	43.7	48.9	47.0	48.3	46.0
Urbanicity of patient's county, %										
Large metro (>1 million)	63.6	62.3	60.3	64.1	60.2	63.7	59.7	61.6	58.3	61.2
Small metro (<1 million)	29.1	30.7	31.4	29.9	29.5	30.3	31.1	31.9	29.4	33.1
Micropolitan	5.0	4.3	5.4	4.3	4.1	4.3	5.1	4.1	5.3	3.6
Rural	2.3	2.7	3.0	1.7	6.2	1.7	4.2	1.4	7.0	1.2

Demographic variables are further stratified by eligibility (age 19 to 25 years) vs ineligibility to for the DCP (age 26 to 34 years) and by admission to inpatient hospitals within Medicaid expansion vs nonexpansion states.

*Tabulations for race/ethnicity do not include data from Minnesota and Nebraska.

CCI, Charlson Comorbidity Index.

between January 2008 and September 2015 in order to yield unadjusted relative risks (RR) and 95% confidence intervals.

Stratified analyses

Age-, race/ethnicity-, and community income level-stratified DID differences in uninsured and perforated appendix admission rates were also assessed in order to determine the extent to which Medicaid expansion and the DCP altered known differences in disparities among at-risk portions of the adult emergency general surgery population.[4,6,18-21] Data were analyzed using Stata Statistical Software: Release 14.2. A 2-sided alpha of 0.05 was considered significant. The Yale Human Investigation Committee approved the study.

RESULTS

Population characteristics

A total of 290,784 patients from Medicaid expansion states and 326,918 patients from nonexpansion states were included (119,684 patients aged 19 to 25 years and 122,307 patients aged 26 to 34 years). Summaries of the distributions of population covariates for each population subgroup are presented in Tables 1 and 2. Consistent with a specified age range of 19 to 64 years, the average age of patients in Medicaid expansion vs nonexpansion states after vs before ACA implementation ranged from 37.7 years (SD 13.3 years) in no-expansion states before ACA implementation to 39.3 years (SD 13.5 years) in Medicaid expansion states after ACA implementation. Approximately one-half (50.2% to 54.1%) of included patients were male, a value which was slightly higher among young adults aged 19 to 34 years (51.9% to 58.7%). Slightly more than one-half (54.8% to 58.3%) identified as non-Hispanic white, while 9.5% to 12.3% identified as non-Hispanic black. An additional 21.1% to 28.5% of patients were ethnically Hispanic. Most (≥83.3%) presented with no pre-existing medical conditions. A total of 46.2% to 61.5% of patients were from lower-income communities (lower half of median income based on residential ZIP code), predominately (≥54.8%) in large metropolitan areas with county populations >1 million people.

Changes in insurance coverage

Overall changes in insurance are presented graphically in Figure 1B. The DID results for DCP implementation and Medicaid expansion are presented overall and stratified by age group in Figure 3A. Before Medicaid expansion and implementation of the remainder of the ACA in Medicaid

expansion states, private insurance was the most common form of insurance among adult patients with acute appendicitis (66.1% of hospitalized patients with uninsured/Medicaid/private). An additional 18.4% of patients were uninsured, and 15.5% were insured through Medicaid. Passage of the DCP among predominately age-ineligible patients had predictably minimal effect. After ACA implementation, the percentage of uninsured dropped by an absolute value of 9.4 percentage points (95% CI 8.7 to 10.1), a relative decline from baseline of 51.1%. Medicaid increased by 13.6 percentage points (95% CI 12.7 to 14.5), a relative increase from baseline of 87.7%, while private insurance decreased by 4.2 percentage points (95% CI 3.8 to 4.6). Over the same time-span in nonexpansion states, the percentage of uninsured declined by 1.7 percentage points (95% CI 1.2 to 2.1), a relative drop from baseline of 8.5%. Medicaid did not significantly change (DID point estimate: decline of 0.4 percentage points), and private insurance increased by 2.1 percentage points (95% CI 1.7 to 2.6), a relative increase from baseline of 3.3%. These changes corresponded to absolute DID differences attributable to Medicaid (above and beyond those attributable to private insurance expansion and the remainder of the ACA detected in both Medicaid expansion and nonexpansion states) of a 7.7 percentage point decline in uninsured (95% CI 7.5 to 7.9), 14.0 percentage-point increase in Medicaid (95% CI 13.7 to 14.3), and a 6.3 percentage point decline in private insurance coverage (95% CI 6.0 to 6.6). Complete results of the DID analysis are presented in eTable 1.

When stratified by age (Fig. 3A), implementation of the DCP among age-eligible patients corresponded to a modest 1.9 percentage point decrease in uninsured for young adults aged 19 to 25 years. The change was dwarfed by a larger additional 12.7 percentage point reduction in uninsured attributable to Medicaid for patients of the same age and a potential 4.4 percentage point reduction in uninsured due to participation in the market exchange observed in nonexpansion states (eTable 1). The extent of declines in uninsured decreased as patients aged, dropping from a decline of 12.7 percentage points among adults aged 19 to 25 years to 4.3 among adults aged 50 to 64 years. Reductions in private insurance coverage increased with age, climbing from a decline of 3.5 percentage points among adults aged 19 to 25 years to upwards of 7.6 among adults aged 26 years or older. In each age group, absolute DID differences for insurance changes were significant for each type of insurance (2-sided p value ≤ 0.001; eTable 1).

Changes in perforated appendix admission rates

Consistent with previous studies that have suggested an association between insurance and perforated appendix admission rates,[3-5] the results in Table 3 show that among adults aged 19 to 64 years, overall and in each age group

there was a significant protective effect of insurance on the risk of presenting with perforated appendicitis. Perforation rates increased with age, while the relationship between different types of insurance remained largely unchanged. Overall, when compared with uninsured
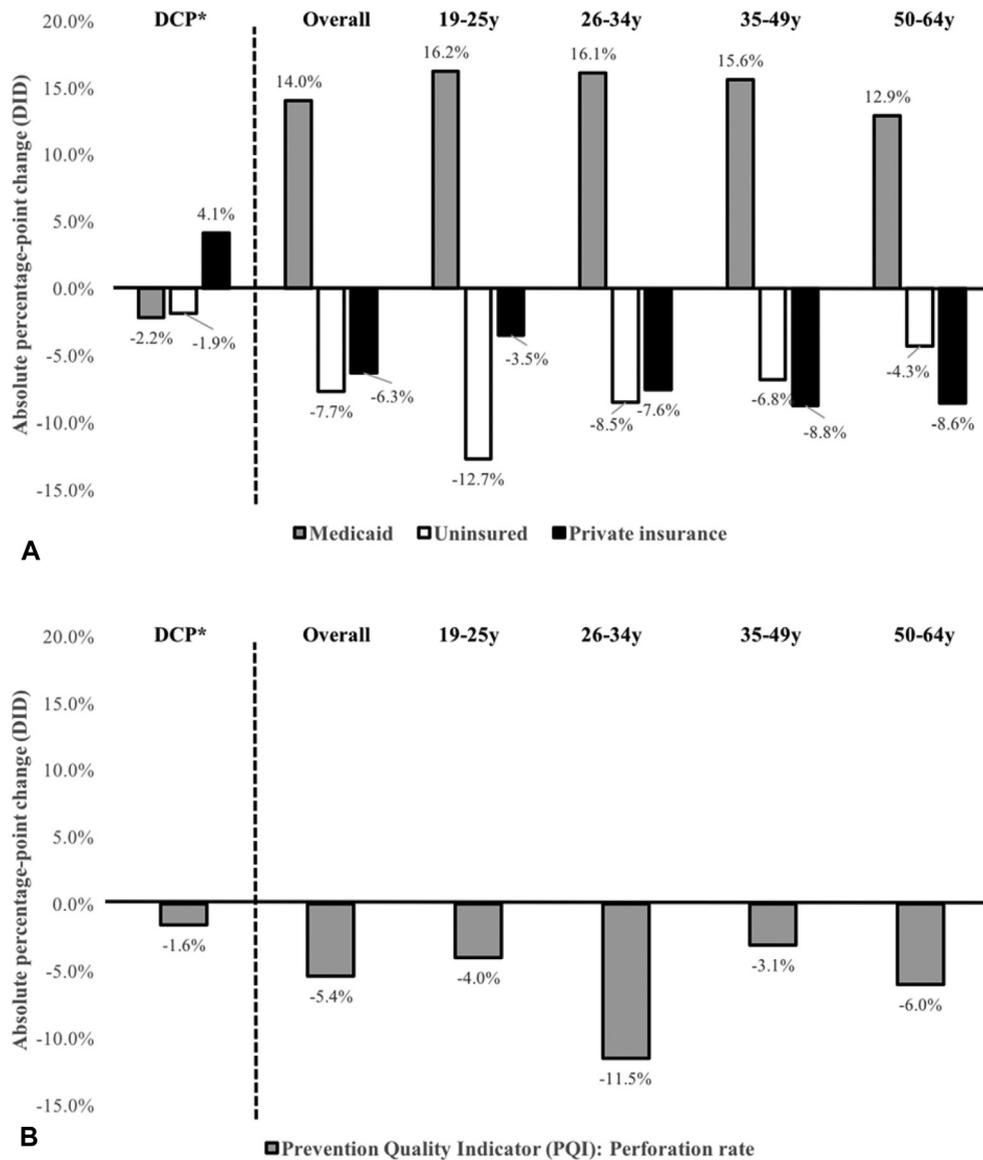
Figure 3. Difference-in-difference results for 2014 Medicaid expansion showing absolute percentage-point changes in (A) insurance coverage (Medicaid, uninsured, private insurance) and (B) perforated appendix admission rates. Difference-in-difference results were taken from linear models comparing the rate of change over time in: (1) experimental group: Medicaid expansion states that also introduced state-level private insurance exchanges along with the remainder of the Affordable Care Act (ACA) vs (2) control group: states that did not expand Medicaid and only implemented the remainder of the ACA before (January 2011 to September 2013) and after (January 2014 to September 2015) Medicaid expansion in January 2014. *Models for the 2010 Dependent Coverage Provision (DCP) compared: (1) experimental group: policy-eligible young adults aged 19 to 25 years vs (2) control group: slightly older, policy-ineligible adults aged 26 to 34 years before (January 2008 to September 2010) and after (January 2011 to September 2013) DCP introduction in September to December 2010.

Table 3. Association Between Insurance Status and Perforated Appendix Admission Rate (Percentage of Perforated Admissions), Total n = 560,773

Insurance	Total, n	January 2008 to September 2015		
		Perforated, %	Unadjusted relative risk	95% CI
Overall: 19 to 64 y				
Uninsured	113,719	28.9	1.00	Reference
Medicaid	96,885	21.6	0.75	0.73, 0.76
Private	350,169	25.3	0.88	0.86, 0.89
Age 19 to 25 y				
Uninsured	32,195	21.6	1.00	Reference
Medicaid	26,211	15.9	0.73	0.72, 0.75
Private	61,278	18.7	0.87	0.85, 0.88
Age 26 to 34 y				
Uninsured	29,439	23.4	1.00	Reference
Medicaid	27,580	14.2	0.61	0.60, 0.62
Private	65,287	18.5	0.79	0.77, 0.81
Age 35 to 49 y				
Uninsured	33,189	32.2	1.00	Reference
Medicaid	30,369	28.6	0.89	0.87, 0.91
Private	118,401	28.7	0.89	0.87, 0.91
Age 50 to 64 y				
Uninsured	18,895	50.0	1.00	Reference
Medicaid	12,724	40.2	0.80	0.79, 0.82
Private	105,203	44.0	0.88	0.86, 0.90

Unadjusted perforation rates were compared using generalized linear models with a binomial family and ln-transformation of aggregate data from all included states in order to yield unadjusted relative risks (RR) and 95% confidence intervals (95% CI).

patients, Medicaid patients had a risk of presenting with perforation that was 7.3 percentage points lower (relative risk [RR] 0.75, 95% CI 0.73 to 0.76). Privately insured patients had a risk of perforation that was 3.6 percentage points lower (RR 0.88, 95% CI 0.86 to 0.89).

When combined with significant ACA-related reductions in uninsured (Figs. 1B and 3A), these associations corresponded to significant absolute reductions in perforated appendix admission rates among policy-eligible hospitalized patients (Fig 3B). Over time in Medicaid expansion states, perforated appendix admission rates increased from an average of 35.2% (PQI: 352 perforated admissions per 1,000 patients) during the pre-expansion period to 39.5% during the post-expansion period. This was contrasted by a more rapid increase in perforated appendix admission rates within nonexpansion states, where average values for adults aged 19 to 64 years increased from 24.1% to 33.8%, resulting in a DID difference of -5.4 percentage points attributable to Medicaid (95% CI 5.0 to 5.8). Complete results of the DID analysis are presented in eTable 1.

When stratified by age (Fig. 3B; eTable 1), the DCP resulted in a more modest -1.6 percentage point reduction in perforation rates for policy-eligible patients aged 19 to 25 years. Medicaid expansion among the same patients in

Medicaid expansion states resulted in an additional 4.0 percentage point reduction in perforation rates. The largest Medicaid-related reductions were observed among young adults just ineligible for DCP coverage due to age (26 to 34 year DID: 11.5) and among nonelderly adults just ineligible for Medicare (50 to 64 year DID: 6.0). Given increases in perforation rates over time in both Medicaid expansion and nonexpansion states, "after vs before" changes associated with the smaller changes in insurance presumably attributable to private insurance expansion and the remainder of the ACA could not be readily assessed. No apparent jumps or sudden changes in trends were observed on visual inspection of time trends within nonexpansion states (eFig. 1).

Disparity-stratified results

Race/ethnicity- and community income level-stratified changes in uninsured and perforated appendix admission rates are presented overall and by age in Figure 4. For all subgroups in expansion states, Medicaid expansion accounted for significant reductions in uninsured and perforated appendix admission rates. Reductions in uninsured were most pronounced among Hispanic (DID 13.8) and non-Hispanic black (DID 11.9) patients aged 19 to 25 years (Fig. 4A)—a marked contrast to the larger
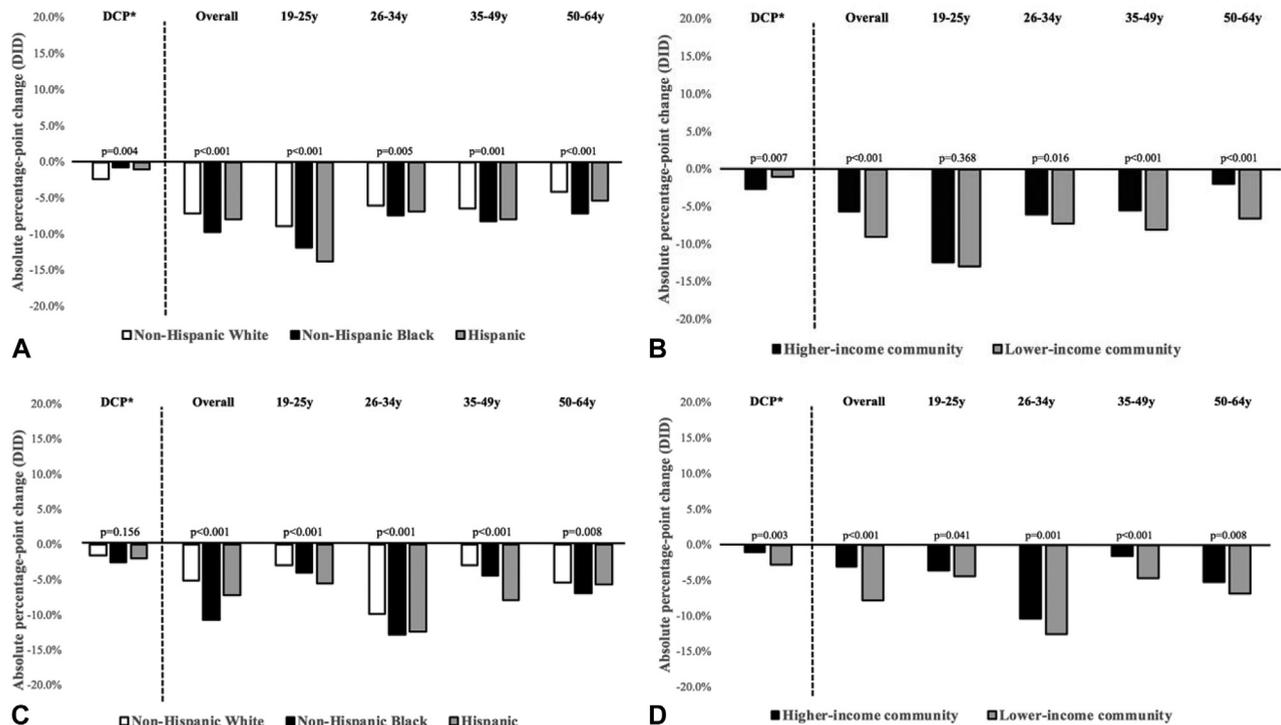
Figure 4. Difference-in-difference results for 2014 Medicaid expansion showing absolute percentage-point changes in (A) uninsured stratified by race/ethnicity; (B) perforated appendix admission rates stratified by race/ethnicity; (C) uninsured stratified by community income level; and (D) perforated appendix admission rates stratified by community income level. Difference-in-difference results were taken from linear models comparing the rate of change over time in: (1) experimental group: Medicaid expansion states that also introduced state-level private insurance exchanges along with the remainder of the Affordable Care Act (ACA) vs (2) control group: states that did not expand Medicaid and only implemented the remainder of the ACA before (January 2011 to September 2013) and after (January 2014 to September 2015) Medicaid expansion in January 2014. *Models for the 2010 Dependent Coverage Provision (DCP) compared: (1) experimental group: policy-eligible young adults aged 19 to 25 years vs (2) control group: slightly older, policy-ineligible adults aged 26 to 34 years before (January 2008 to September 2010) and after (January 2011 to September 2013) DCP introduction in September to December 2010. Two-sided p values indicate the extent of differences between stratified groups.

change seen among non-Hispanic white patients of the same age after implementation of the DCP (DID 2.4 non-Hispanic white, 0.8 non-Hispanic black, and 1.0 Hispanic). For all 3 racial/ethnic groups, changes related to Medicaid expansion were markedly larger than those attributable to the DCP. Among adults aged 26 years or older, reductions in uninsured remained significant for all 3 racial/ethnic groups, with the largest declines in uninsured observed among racial/ethnic minority patients.

Similar patterns emerged based on differences in community income level (Fig. 4C). Although the DCP predominately benefited patients from higher-income communities (reduction in uninsured DID 2.6 vs 1.0), reductions in uninsured related to Medicaid expansion more substantially benefitted patients living in lower-income centers (overall DID 9.0 vs 5.6). Medicaid expansion changes were again larger in magnitude than those

attributable to the DCP for both higher- and lower-income communities.

Changes in perforated appendix admission rates followed a slightly different trend, demonstrating the largest reductions in perforation rates among non-Hispanic black adults aged 26 to 34 years (DID 12.8; Fig. 4B) and among similarly aged patients living in lower-income communities (DID 12.6; Fig. 4D). Perforation rates among Hispanic adults aged 26 to 34 years declined by 12.4 percentage points. Across all age-, race/ethnicity-, and community income level groups, Medicaid expansion-related changes to perforated appendix admission rates were greatest among subsets of the adult emergency general surgery population where disparities are known to exist.[4,6,18-21] Dependent Coverage Provision-related reductions in uninsured were also greatest within lower-income communities (DID 2.8 vs 1.0) and among racial/ethnic minority patients (non-Hispanic black DID

2.5 vs non-Hispanic white DID 1.6), despite larger changes in uninsured among more privileged groups.

Testing the inpatient quality metric assumption

Assessment of changes in adult perforated appendix admissions rates among patients admitted as inpatients vs treated and released from the emergency department in a single Medicaid expansion vs nonexpansion state reveal similar trends. In both sets of databases (Fig. 2B), adult rates of perforation in the Medicaid expansion state (New Jersey) show a marked decrease from anticipated levels in the nonexpansion state (Florida). Despite increasing prevalence of noninpatient management in both states (Fig. 2A), which could challenge the utility of the AHRQ quality metric as written moving forward, comparison of perforation rates in State Inpatient Database (SID) and State Emergency Department Database (SEDD) (as well as a summed total not shown) each suggested a significant reduction in perforated appendix admission rates after Medicaid expansion.

DISCUSSION

This multistate, quasi-experimental assessment of changes in insurance coverage and perforated appendix admission rates demonstrated significant reductions in uninsured and improvements in pre-hospital access to care among adult emergency general surgery patients, attributable to both Medicaid expansion and the DCP. Insurance changes related to Medicaid expansion, including an absolute 7.7 percentage point reduction in uninsured (12.7 percentage points among young adults aged 19 to 25 years), were markedly larger than those attributable to the DCP, which resulted in a more modest 1.9 percentage point reduction in uninsured among policy-eligible patients aged 19 to 25 years. Although DCP-related insurance changes primarily benefited non-Hispanic white patients from higher-income communities, those associated with Medicaid expansion were greatest among racial/ethnic minority patients from lower-income communities. Changes in insurance likely attributable to implementation of the remainder of the ACA were also observed in nonexpansion states, but were not associated with apparent reductions in hospitalized perforation rates or slowing of their rate of increase.

Both Medicaid expansion and the DCP slowed increases in perforated appendix admission rates (DID Medicaid expansion overall: decline of 5.4 percentage points; DCP: decline of 1.6 percentage points), presenting with changes in perforation rates that were greatest among racial/ethnic minority patients and those from lower-income communities. The difference between the

2 programs lay in the magnitude of the extent to which they changed, for although the DCP reduced non-Hispanic black perforated appendix admission rates among patients aged 19 to 25 years by an absolute value of 2.5 percentage points, Medicaid expansion reduced them by an additional 3.9 percentage points (12.8 percentage points from baseline among patients aged 26 to 34 years).

These findings are in keeping with what is known about insurance-based changes to adult perforated appendix admission rates. In a previous national study of DCP-related effects among young adults aged 19 to 34 years, Scott and colleagues[6] reported a risk-adjusted 3.6 absolute percentage point decline in uninsured and a 1.4 percentage point reduction in perforated appendix admission rates among adults aged 19 to 25 vs 26 to 34 years. Our unadjusted findings from a subset of states among adults aged 19 to 25 vs 26 to 34 years yielded similar results. More intriguing was the comparison of both sets of stratified findings with those reported for trauma.[11,16,17,27-29] Among trauma patients, previous studies of the DCP and Medicaid expansion have suggested an inverse association between which population subgroups were most benefitted by the DCP, which targeted patients whose parents were privately insured and correspondingly, most benefitted more privileged groups of previously uninsured patients, and Medicaid expansion, which was designed to assist lower-income US citizens, and correspondingly benefitted more disadvantaged groups of previously uninsured patients. The somewhat predictable result was differential changes in insurance coverage and corresponding outcome measures with consistently greater improvements in outcomes and reductions in disparities when Medicaid was provided to injured patients most in need.[11,16,17,27-29] Among patients with acute appendicitis, similar changes in the extent of insurance coverage were found. However, even under the DCP, where insurance changes favored more historically privileged patients, larger improvements in pre-hospital access to care were observed among racial/ethnic minority and lower-income patients.

The question then becomes, "What distinguishes insurance-sensitive post-discharge outcomes among trauma patients, which follow predictable patterns, from those of pre-hospital acute appendicitis access to care?" Earlier studies of racial/ethnic disparities in perforated appendix admission rates among children[30] and young adults aged 19 to 34 years[4] suggest that variations in insurance explain approximately 12% of differences in children and 22.4% to 39.0% of differences among adults aged 19 to 34 years. The remainder is thought to be a combination of income (estimated to account for an additional 12.2%

to 13.6% of racial/ethnic differences in adults aged 19 to 34 years)[4] and a host of other factors that influence when, where, and how patients choose to seek care.[31] Therein likely lies the critical difference, for when a severe traumatic injury occurs, patients tend to quickly seek care. While insurance has been found to influence what happens to patients after discharge[11,16,17] and where injured patients ultimately receive care,[32,33] as long as life-saving interventions are feasible, trauma care is nearly universally sought. Acute appendicitis, in contrast, involves more of a choice centered around the time at which patients decided to seek and successfully manage to reach appropriate medical care. Previous work conducted among adult patients with acute appendicitis found that time to operation was the single most important predictor of perforation once symptoms occur.[5,6] Delays in the decision to seek care, and in accessing care once the decision to seek care has been made, are thought to underlie differences in the tendency for uninsured patients to have longer durations of symptoms before presentation and correspondingly higher perforation rates.[34] Patients with established primary care physicians and a history of well-patient visits have also been found to have lower perforated appendix admission rates,[35] presumably resulting in more ready access to care and fewer delays in deciding to access care when acute care needs to be sought.

Over the next 2 years, as temporary federal-funding for Medicaid expansion begins to be reduced and changing political wills make the future of health care uncertain, there will be a need for methodologically rigorous assessment of health-policy change that is capable of advocating for the good in existing legislation and promoting evidence-based change to the parts that do not work.[11] This assessment of Medicaid expansion- and DCP-related changes to insurance coverage and pre-hospital access to care suggests that for all of its financial, sustainability, and political challenges, Medicaid expansion uniquely affects pre-hospital care among urgent surgical patients in a way that the DCP was never intended to do. Nevertheless, for all of their inherent differences and admitted variation in the size of their respective effects, both pieces of insurance-promoting legislation reduced disparities in access to care and improved outcomes for patients, providing compelling evidence of a need to ensure insurance coverage, whatever its form, among patients requiring access to acute care. Ultimately, both Medicaid expansion and the DCP offer imperfect solutions, albeit ones that, in conjunction with the remainder of the ACA, did result in an overall -9.4 percentage point reduction in uninsured and marked slowing of the rate of increase of perforated appendix admission rates within Medicaid expansion states.

The results of the study must be interpreted in light of its limitations. Most come from the reliance on administrative claims data, in which completeness of information, the potential for absent or misreporting of events, and a lack of nuanced clinical detail can be concerns. Reliance on a metric consistently reported in administrative claims and designed to measure pre-hospital access to care in such a setting[9,10] helps to allay the majority of these concerns, while use of multistate data facilitated assessment of a large quasi-experimental temporal cohort needed to evaluate health-policy change. However, in relying on combined inpatient data, conclusions might not be nationally representative, and individual data sources might not be the same. Use of inpatient data, while consistent with the AHRQ quality indicator, limits detection of patients with acute appendicitis presenting to outpatient surgical settings and precludes assessment of previous access to primary/specialty care. Although the study was not limited to patients with length of stay $\geq$ 48 hours (inpatient hospitalization), it is possible that some observational hospital stays with LOS < 48 hours were not as robustly reported. Available data are limited to a follow-up period post-implementation of 2 years.

CONCLUSIONS

In summary, this multistate, quasi-experimental assessment of ACA-related changes to insurance coverage and perforated appendix admission rates demonstrated significant reductions in uninsured and slowed increases in the rate of perforated presentations that were greater in Medicaid expansion states than in nonexpansion states. Although changes in expansion states were driven primarily by increased enrollment in Medicaid, significant, albeit smaller, increases in private coverage were also detected within nonexpansion states. Changes attributable to Medicaid expansion were larger in magnitude than those resulting from the DCP and more directly targeted patients most in need. However, both pieces of insurance-promoting legislation led to reductions in perforated appendix admission rate disparities and improvements in outcomes for all patients. Such a change, acting as an AHRQ-certified metric of pre-hospital access to care, suggests that ACA insurance expansion led to fewer delays in seeking and accessing urgent surgical care—most notably among racial/ethnic minorities and patients from lower-income communities, who might otherwise remain uninsured. Observed improvements in timely access to acute surgical care suggest that maintained/continued insurance expansion could lead to fewer delays, better patient outcomes, and reductions in disparities among the most at-risk populations.

Author Contributions

Study conception and design: Zogg, Scott

Acquisition of data: Zogg

Analysis and interpretation of data: Zogg, Scott, Bhulani, Gluck, Curfman, Davis, Dimick, Haider

Drafting of manuscript: Zogg, Bhulani

Critical revision: Scott, Gluck, Curfman, Davis, Dimick, Haider

REFERENCES

1. Bliss LA, Yang CJ, Kent TS, et al. Appendicitis in the modern era: universal problem and variable treatment. Surg Endosc 2015;29:1897−1902.
2. Scott JW, Olufajo OA, Brat GA, et al. Use of national burden to define operative emergency general surgery. JAMA Surg 2016;151:e160480.
3. Barrett M, Hines A, Andrews R. Healthcare Cost and Utilization Project Statistical Brief #159: Trends in Rates of Perforated Appendix, 2001-2010. Washington, DC: Agency for Healthcare Research and Quality; 2013.
4. Zogg CK, Scott JW, Jiang W, et al. Differential access to care: the role of age, insurance, and income on race/ethnicity-related disparities in adult perforated appendix admission rates. Surgery 2016;160:1145−1154.
5. Pieracci FM, Eachempati SR, Barie PS, Callahan MA. Insurance status, but not race, predicts perforation in adult patients with acute appendicitis. J Am Coll Surg 2007;205:445−452.
6. Scott JW, Rose JA, Tsai TC, et al. Impact of ACA insurance coverage expansion on perforated appendix rates among young adults. Med Care 2016;54:818−826.
7. Braveman P, Schaaf VM, Egerter S, et al. Insurance-related differences in the risk of ruptured appendix. N Engl J Med 1994;331:444−449.
8. Bickell NA, Siu AL. Why do delays in treatment occur? Lessons learned from ruptured appendicitis. Health Serv Res 2001;36:1−5.
9. Agency for Healthcare Research and Quality. Prevention Quality Indicators Overview. 2018. Available at: http://www.qualityindicators.ahrq.gov/modules/pqi_overview.aspx. Accessed August 21, 2018.
10. Agency for Healthcare Research and Quality. Perforated Appendix Admission Rate Technical Specifications: Prevention Quality Indicators #2. Washington, DC: Agency for Healthcare Research and Quality; 2013.
11. Zogg C, Scott J, Metcalfe D, et al. Association between Medicaid eligibility and gains in access to rehabilitative care: A difference-in-difference assessment of changes to insurance coverage, outcomes, and discharge to rehabilitation among adult trauma patients. JAMA Surg 2018 [In press].
12. Sommers BD, Gunja MZ, Finegold K, Musco T. Changes in self-reported insurance coverage, access to care, and health under the Affordable Care Act. JAMA 2015;314:366−374.
13. Pines JM, Zocchi M, Moghtaderi A, et al. Medicaid expansion in 2014 did not insurace emergency department use but did change insurance payer mix. Health Aff 2016;35:1480−1486.
14. Garthwaite C, Gross T, Notowidigdo M, Graves JA. Insurance expansion and hospital emergency department access: Evidence from the Affordable Care Act. Ann Intern Med 2017;166:172−179.
15. Nikpay S, Freedman S, Levy H, Buchmueller T. Effect of the Affordable Care Act Medicaid expansion on emergency department visits: Evidence from state-level emergency department databases. Ann Emerg Med 2017;70: 215−225.
16. Zogg CK, Payró Chew F, Scott JW, et al. Implications of the Patient Protection and Affordable Care Act on insurance coverage and rehabilitation use among young adult trauma patients. JAMA Surg 2016;151:e163609.
17. Akande M, Minneci PC, Deans KJ, et al. Association of Medicaid expansion under the Affordable Care Act with outcomes and access to rehabilitation in young trauma patients. JAMA Surg 2018;153:e181630.
18. Scott JW, Havens JM, Wolf LL, et al. Insurance status is associated with complex presentation among emergency general surgery patients. Surgery 2017;161:320−328.
19. Zogg CK, Jiang W, Ottesen TD, et al. Racial/ethnic disparities in longer-term outcomes among emergency general surgery patients: the unique experience of universally insured older adults. Ann Surg 2018;268:968−979.
20. Zogg CK, Olufajo OA, Jiang W, et al. The need to consider longer-term outcomes of care: racial/ethnic disparities among adult and older adult emergency general surgery patients at 30, 90, and 180 days. Ann Surg 2017;266:66−75.
21. Zogg CK, Jiang W, Chaudhary MA, et al. Racial disparities in emergency general surgery: Do differences in outcomes persist among universally insured military patients? J Trauma Acute Care Surg 2016;80:764−775.
22. United States Census Bureau. United States Census 2020. 2018. Available at: http://www.census.gov/programs-surveys/decennial-census/2020-census.html. Accessed August 21, 2018.
23. American Hospital Association. AHA Annual Survey Database 2018. Available at: https://www.ahadataviewer.com/additional-data-products/AHA-Survey/. Accessed August 21, 2018.
24. Agency for Healthcare Research and Quality. Overview of the National (Nationwide) Inpatient Sample (NIS) 2018. Available at: http://www.hcup-us.ahrq.gov/nisoverview.jsp. Accessed August 21, 2018.
25. Zhou H, Taber C, Arcona S, Li Y. Difference-in-differences method in comparative effectiveness research: Utility with unbalanced groups. Appl Health Econ Health Policy 2016;14: 419−429.
26. Stuart EA, Huskamp HA, Duckworth K, et al. Using propensity scores in difference-in-differences models to estimate the effects of a policy change. Health Serv Outcomes Res Methodol 2014;14:166−182.
27. Scott JW, Salim A, Sommers BD, et al. Racial and regional disparities in the effect of the Affordable Care Act's Dependent Coverage Provision on young adult trauma patients. J Am Coll Surg 2015;221:495−501.
28. Scott JW, Sommers BD, Tsai TC, et al. Dependent Coverage Provision led to uneven insurance gains and unchanged mortality rates in young adult trauma patients. Health Aff (Millwood) 2015;34:125−133.
29. Akande M, Minneci PC, Deans KJ, et al. Effects of Medicaid expansion on disparities in trauma care and outcomes in young adults. J Surg Res 2018;228:42−53.

30. Livingston EH, Fairlie RW. Little effect of insurance status or socioeconomic condition on disparities in minority appendicitis perforation rates. Arch Surg 2012;147:11—17.

31. Torain MJ, Maragh-Bass AC, Dankwa-Mullen I, et al. Surgical disparities: a comprehensive review and new conceptual framework. J Am Coll Surg 2016;223:408—418.

32. Delgado MK, Yokell MA, Staudenmayer KL, et al. Factors associated with the disposition of severely injured patients initially seen at non-trauma center emergency departments. JAMA Surg 2014;149:422—430.

33. Zogg C, Schuster KM, Maung AA, Davis K. Insurance status biases trauma-system utilization and appropriate interfacility transfer: national and longitudinal results of adult, pediatric, and older adult patients. Ann Surg 2018;268:681—689.

34. O'Toole SJ, Karamanoukian HL, Allen JE, et al. Insurance-related differences in the presentation of pediatric appendicitis. J Pediatr Surg 1996;31:1032—1034.

35. Guagliardo MF, Teach SJ, Huang ZJ, et al. Racial and ethnic disparities in pediatric appendicitis rupture rate. Acad Emerg Med 2003;10:1218—1227.
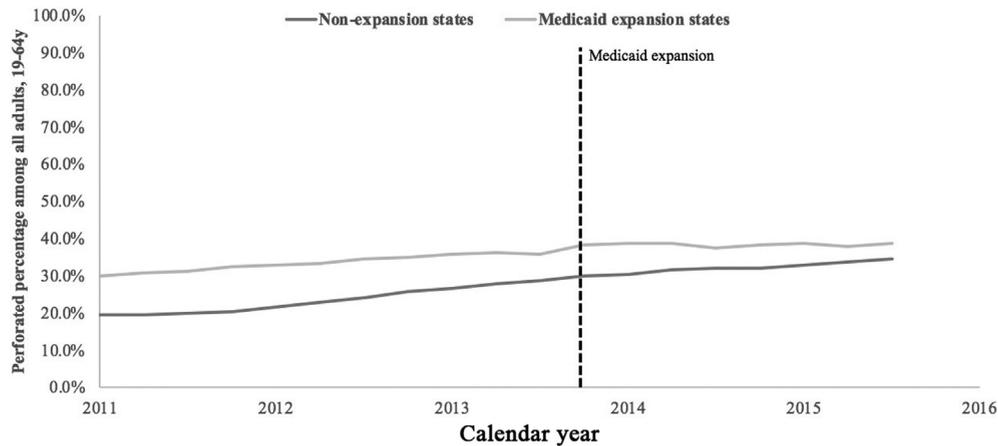
eFigure 1. Affordable Care Act (ACA)-related perforated appendix admission rate change and assessment of pre-implementation parallel trends: Changes in perforated appendix admission rates in Medicaid expansion vs nonexpansion states, calendar year: 2011 to 2015.

eTable 1. Difference-in-Difference Results, Overall and by Age Group, Showing Changes in Insurance and Perforation Rates among Hospitalized Patients with Acute Appendicitis

Age group	Non-expansion state, %		Medicaid expansion state, %		DID	95% CI	p Value
	Pre-ACA	Post-ACA	Pre-ACA	Post-ACA			
Overall							
Uninsured	20.1	18.4	18.4	9.0	−7.7	−7.5 to −7.9	<0.001
Medicaid	16.7	16.3	15.5	29.1	14.0	13.7 to 14.3	<0.001
Private insurance	63.2	65.3	66.1	61.9	−6.3	−6.0 to −6.6	<0.001
PQI: Perforation rate	24.1	33.8	35.2	39.5	−5.4	−5.0 to −5.8	0.001
19 to 25 y							
Uninsured	29.7	25.3	29.0	11.9	−12.7	−13.2 to −12.2	<0.001
Medicaid	22.7	24.7	17.5	35.7	16.2	15.7 to 16.7	<0.001
Private	47.6	50.0	53.5	52.4	−3.5	−4.1 to −2.9	<0.001
PQI: Perforation rate	16.0	24.9	21.8	26.7	−4.0	−4.7 to −3.3	0.001
26 to 34 y							
Uninsured	29.2	27.5	24.3	14.1	−8.5	−8.9 to −8.1	<0.001
Medicaid	24.7	23.6	22.5	37.5	16.1	15.7 to 16.5	<0.001
Private	46.1	48.9	53.2	48.4	−7.6	−8.1 to −7.1	<0.001
PQI: Perforation rate	14.9	25.5	27.0	26.1	−11.5	−12.2 to −10.8	0.001
35 to 49 y							
Uninsured	19.6	17.9	16.9	8.4	−6.8	−7.2 to −6.4	<0.001
Medicaid	17.5	16.4	15.8	30.3	15.6	15.2 to 16.0	<0.001
Private	62.9	65.7	67.3	61.3	−8.8	−9.3 to −8.3	<0.001
PQI: Perforation rate	26.8	34.3	36.5	40.9	−3.1	−3.8 to −2.4	0.001
50 to 64 y							
Uninsured	14.5	12.5	12.6	6.3	−4.3	−4.8 to −3.8	<0.001
Medicaid	7.3	6.6	8.2	20.4	12.9	12.4 to 13.4	<0.001
Private	78.2	80.9	79.2	73.3	−8.6	−9.2 to −8.0	<0.001
PQI: Perforation rate	40.6	48.1	49.7	51.2	−6.0	−6.7 to −5.3	0.001

Two-sided p values taken from the difference-in-difference interaction terms between time period and Medicaid expansion vs non-expansion states.
ACA, Patient Protection and Affordable Care Act; DID, difference-in-difference; PQI, Prevention Quality Indicator.