

Accountable Care Organizations and HPV Vaccine Uptake: A Multilevel Analysis

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National rates of human papillomavirus (HPV) vaccination remain below national benchmarks.¹ The Advisory Committee on Immunization Practices (ACIP) of the CDC has recommended the HPV vaccine—which is effective in preventing cancer-causing infections of the cervix, vulva, vagina, penis, oropharynx, and anus—for adolescent girls and boys since 2006 and 2011, respectively.²⁻⁴ Multilevel models are increasingly used to guide the development of interventions to improve HPV vaccination.^{5,6} These models recognize the complex, dynamic factors that occur within and across different levels that influence HPV vaccine uptake, including providers, patients, policies, communities, and organizations.

Implemented with the passage of the Affordable Care Act,⁷ accountable care organizations (ACOs) offer the opportunity to evaluate an existing multilevel intervention on HPV vaccine uptake. An ACO is a group of clinicians, health care providers, and/or hospitals that voluntarily come together to coordinate the care of patients and to be held jointly responsible for the total quality and costs of the care rendered,⁸ thus offering a financial incentive to promote HPV vaccination uptake. Although ACOs have experienced tremendous growth in the past decade that coincides with national efforts to improve HPV vaccine uptake,⁹ to the best of our knowledge, no study has evaluated the relationship between ACO membership and HPV vaccination.

Connecticut is among the states with the highest proportion of residents enrolled in ACOs, and its HPV vaccination rate is consistently above the national average.^{10,11} In its first State Health Improvement Plan that outlined goals for 2020, Connecticut aimed to increase its HPV vaccination rate by 20% for male and female adolescents, translating to a male target of 10.2% (from a baseline of 8.5%) and a female target of 52.3% (from a baseline of 43.6%).¹² Data from the 2020 National Immunization Survey show that Connecticut surpassed its goals, achieving a completed HPV vaccination rate of 63.9% among male adolescents and 70% among female adolescents.¹¹ An awareness of the role of ACOs in HPV vaccine uptake may draw attention to unique multilevel, structural factors that influence HPV vaccination and inform HPV

ABSTRACT

OBJECTIVES: To examine associations between accountable care organization (ACO) membership and human papillomavirus (HPV) vaccination and to evaluate variation in HPV vaccination across ACO providers.

STUDY DESIGN: Retrospective cohort study.

METHODS: We analyzed the records of commercially insured children and adolescents aged 11 to 14 years using Connecticut's All-Payer Claims Database from January 2012 to December 2017.

RESULTS: A total of 23,911 adolescents receiving care from 933 ACO-attributable providers and 923 non-ACO-attributable providers were included. The mean rate of HPV vaccine initiation was 53% overall (51% among boys, 55% among girls). Among those who initiated the vaccine, the mean rate of HPV vaccine completion was 69% (67% among boys, 70% among girls). Adolescents receiving care at ACOs vs non-ACO were significantly more likely to receive initial HPV vaccination (OR, 1.80; 95% CI, 1.69-1.91) and to complete the HPV vaccine series (OR, 1.12; 95% CI, 1.01-1.23). Among adolescents receiving care in ACOs, providers were responsible for 14% of variability in HPV vaccine initiation and 10% of variability in HPV vaccine completion and ACOs were responsible for less than 1% of variability in HPV vaccine initiation and completion.

CONCLUSIONS: Adolescents receiving care from ACOs were significantly more likely to initiate and complete HPV vaccination than were adolescents receiving care in non-ACO settings. Variation in HPV vaccine uptake attributable to providers within ACOs dwarfed variation attributable to ACOs, indicating that vaccine uptake was more dependent on the provider irrespective of the ACO with which they were affiliated. Efforts to improve HPV vaccination rates may require provider-focused interventions regardless of the overall performance of their health care system or provider organization.

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vaccination improvement efforts. The primary aim of our study was to examine the impact of ACO status on the initiation and completion of the HPV vaccination series. The secondary aim of our study was to examine variability in HPV vaccine performance attributable to ACOs and providers within an ACO.

TAKEAWAY POINTS

We found that adolescents receiving care at accountable care organizations (ACOs) vs non-ACOs were more likely to initiate and complete the human papillomavirus (HPV) vaccine series.

- ▶ Factors unique to ACOs, including the tracking of HPV vaccination performance that is linked to payment contracts, may support higher rates of HPV vaccine uptake.
- ▶ In ACOs, vaccine uptake was more dependent on the provider than the ACO with which they were affiliated.
- ▶ Future interventions are needed to target provider variability in HPV vaccination.

METHODS

We conducted a retrospective cohort study using Connecticut's All-Payer Claims Database (APCD) of fully insured adolescents in the state of Connecticut from January 2012 to December 2017. We included boys and girls aged 11 years in 2012, 2013, and 2014 and observed them until they turned 14 years old in 2015, 2016, and 2017, respectively. (These children and adolescents aged 11 to 14 years will hereafter be referred to as adolescents.) This observation period accounted for the ACIP recommendation of routine HPV vaccination at age 11 or 12 years using a 2-dose schedule.¹³ Although the HPV vaccine can be administered as early as age 9 years, HPV vaccination among commercially insured children younger than 11 years is highly rare.¹⁴ To minimize participant attrition due to transient care, we included only adolescents with at least 1 medical claim with a valid National Provider Identifier (NPI) during our observation window. We also included only those with continuous commercial insurance (no more than one 45-day gap in insurance coverage) over a 24-month period. We excluded adolescents receiving care from federally qualified health centers because our data set was limited to commercial claims.

We performed a 2-step attribution process to match adolescents to their respective primary care provider and then to match primary care providers to their respective ACO. Among adolescents who received an HPV vaccine, we designated the provider who administered the initial HPV vaccine as the adolescent's primary care provider. Among adolescents who did not receive an HPV vaccine, the provider visited the most by these adolescents at age 14 years was designated as the adolescent's primary care provider. ACOs provided lists of their affiliated providers, and we aggregated patients to providers using NPIs. Providers not associated with an ACO were deemed non-ACO-attributable providers and grouped together in the analysis. We categorized the profession (physicians, advanced practice registered nurses, physician assistants) and specialty (family medicine, internal medicine, pediatrics, general practice, or obstetrics-gynecology) of providers using the NPI. Our primary outcomes of interest were HPV vaccine initiation (yes/no) and HPV vaccine completion (yes/no). We used the most recent ACIP HPV vaccination recommendations to operationalize study outcomes.¹³ Recipients of at least 1 dose were considered to have initiated the series. Recipients of at least 2 doses of HPV vaccination were considered to have completed the series.

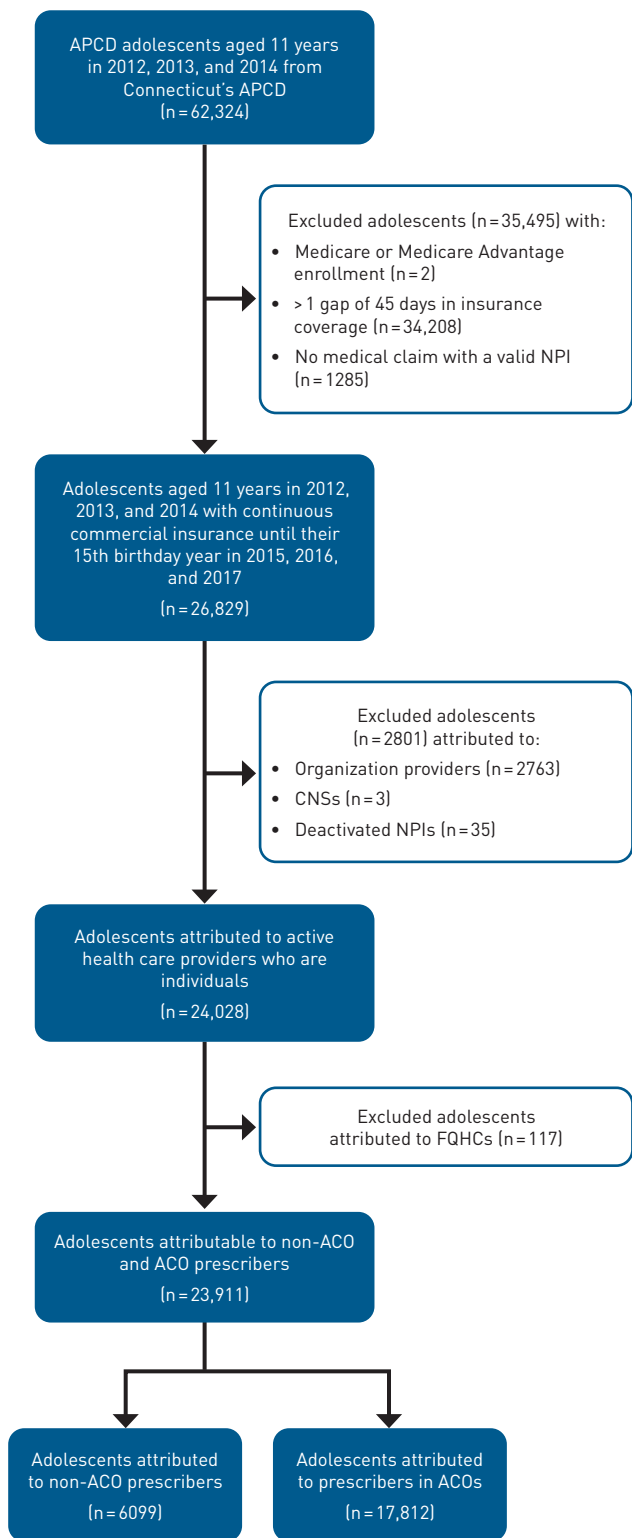
We compared the baseline demographics of adolescents and providers by ACO status using χ^2 and *t* tests. We used logistic regression

models to examine the impact of ACO status on the initiation and completion of the HPV vaccination series (primary aim). We used the intraclass correlation coefficient (ICC) from a multilevel logistic regression model to examine variability in HPV vaccine performance attributable to ACOs and providers within ACOs (secondary aim). The multilevel model accounted for the hierarchical structure of data, in which providers and ACOs were treated as random effects. After fitting the multilevel model, we tested for random effects to determine the appropriateness of including random effects in the model. We used the ICC, which is calculated as the proportion of random effect variance in the total model variance, to quantify the variations in ACOs and providers within ACOs. Models controlled for the following known confounders of HPV vaccination at the patient and practice levels: patient sex, patient mean number of medical claims, provider sex, provider specialty, provider type, and provider years of experience.^{15,16} Because concordance between patient and provider gender may influence HPV vaccination,¹⁷ we included an interaction term for patient and provider sex. In our multilevel model, ACO covariates included a hospital-based indicator and number of providers. All statistical tests were 2-sided, and *P* values less than .05 were considered statistically significant. The R package lme4 was used to perform the statistical analyses.¹⁸ This study was deemed non-human subjects research by the institutional review board of UConn Health and approved by the Connecticut APCD Data Release Committee. We used the Strengthening the Reporting of Observational Studies in Epidemiology Statement to guide the reporting of this study.¹⁹

RESULTS

A total of 23,911 adolescents receiving care from 1856 providers met study inclusion criteria. We depict our study flow diagram in **Figure 1**. These adolescents had a mean of 8 medical claims annually, and most were male (*n* = 12,281; 51%). No significant differences were found among adolescents by ACO status. Among providers, most were female (*n* = 1146; 62%), were physicians (*n* = 1389; 75%), specialized in pediatrics (*n* = 990; 53%), and had 9 or more years of experience (*n* = 1402; 76%) in the 2017 cohort year. Providers differed by ACO status with respect to provider discipline, specialty, and years of experience. Compared with the nonattributable provider group, the ACO provider group included higher proportions of physicians,

FIGURE 1. Study Inclusion/Exclusion Flowchart



ACO, accountable care organization; APCD, All-Payer Claims Database; CNS, clinical nurse specialist; FQHC, federally qualified health center; NPI, National Provider Identifier.

TABLE 1. Characteristics of Adolescents and Providers by ACO Status^a

Characteristic and level	ACO	Non-ACO	Overall
	Adolescents		
Total	17,812 (74.5)	6099 (25.5)	23,911 (100)
Sex			
Female	8620 (48.4)	3010 (49.4)	11,630 (48.6)
Male	9192 (51.6)	3089 (50.6)	12,281 (51.4)
Annual medical visits, mean (SD)	7.7 (8.3)	7.8 (8.1)	7.7 (8.2)
Providers			
Total	933 (50.3)	923 (49.7)	1856 (100)
Sex			
Female	567 (60.8)	579 (62.7)	1146 (61.7)
Male	366 (39.2)	344 (37.3)	710 (38.3)
Type ^b			
MD	730 (78.2)	659 (71.4)	1389 (74.8)
NP	141 (15.1)	144 (15.6)	285 (15.4)
PA	62 (6.6)	120 (13.0)	182 (9.8)
Specialty ^b			
Pediatrics	486 (52.1)	504 (54.6)	990 (53.3)
Family	274 (29.4)	184 (19.9)	458 (24.7)
No specialty provided	82 (8.8)	143 (15.5)	225 (12.1)
Other specialty	91 (9.8)	92 (10.0)	183 (9.9)
Experience (years) ^b			
≥ 9	708 (75.9)	694 (75.2)	1402 (75.5)
0-4	96 (10.3)	100 (10.8)	196 (10.6)
5-8	129 (13.8)	129 (14.0)	258 (13.9)

ACO, accountable care organization; MD, doctor of medicine; NP, nurse practitioner; PA, physician assistant.

^aData are shown as n (%) unless otherwise noted.

^bSignificant differences between ACO and non-ACO groups at 5% significance level. Each categorical variable was tested via a χ^2 test to determine whether there was an association between the characteristic and ACO status, and each continuous variable was tested via a 2-sample *t* test to determine whether there was a significant difference in the sample means between the ACO and non-ACO groups.

providers specializing in family medicine, and providers with 5 or more years of experience. Compared with the ACO provider group, the nonattributable provider group included a higher proportion of nurse practitioners, physician assistants, providers with no specialization listed, and providers with less than 5 years of experience. We provide adolescent and provider characteristics by ACO status in **Table 1**. Demographics of adolescents and their providers excluded from the study by ACO status are provided in the **eAppendix** (available at ajmc.com).

Mean rates of HPV vaccination initiation and completion over the study period were 53% and 69%, respectively (51% and 67% among boys and 55% and 70% among girls). In **Table 2**, we present the logistic regression results modeling initial HPV vaccination and HPV vaccine completion. Adolescents in the 2016 and 2017 cohorts were more likely to receive an initial HPV vaccination compared with adolescents in the 2015 cohort. Male adolescents were less

likely to receive an initial HPV vaccination (OR, 0.79; 95% CI, 0.73-0.85). Adolescents who initiated the series in the 2016 and 2017 cohorts were less likely to receive additional vaccination compared with adolescents in the 2015 cohort. Female adolescents with male providers were more likely to complete the vaccination series (OR, 1.22; 95% CI, 1.08-1.37) compared with female adolescents attributed to female providers. Male adolescents with male providers were less likely to complete the vaccination series (OR, 0.78; 95% CI, 0.66-0.92) compared with female adolescents attributed to male providers. Adolescents receiving care from nonpediatric providers were less likely to receive an initial HPV vaccination. Adolescents receiving care from nurse practitioners vs physicians were less likely to receive an initial HPV vaccination (OR, 0.60; 95% CI, 0.53-0.68). Adolescents receiving care from a provider with 4 or less years of experience vs 9 or more years of experience were less likely to complete the HPV vaccination series (OR, 0.69; 95% CI, 0.56-0.86). Adolescents with higher numbers of medical claims were more likely to receive initial HPV vaccination and to complete the HPV vaccine series. Adolescents receiving care at ACOs vs non-ACOs were more likely to receive the initial HPV vaccination (OR, 1.80; 95% CI, 1.69-1.91) and to receive 2 or more HPV vaccinations (OR, 1.12; 95% CI, 1.01-1.23).

In a multilevel model in which ACO-attributable providers were nested under their ACO, the ICC of the ACO random effect was less than 1%, indicating that the random effects of ACOs were negligible and that the nesting design of ACOs was unnecessary. In the final multilevel logistic model evaluating HPV vaccination performance among providers within ACOs, providers were included in the model as the random effect. Providers accounted for 14.0% of the variance in HPV vaccine initiation and 10.4% of the variance in HPV vaccine completion (Table 3). We depict provider HPV vaccine performance variation within ACOs in Figure 2.

DISCUSSION

In this large retrospective analysis of commercial medical claims in Connecticut, we found that adolescents who received care at ACOs were significantly more likely to initiate and complete the HPV vaccination series than adolescents receiving care in non-ACO settings. To the best of our knowledge, this is the first study to evaluate

TABLE 2. Logistic Regression Analyses of the Association Between ACO Status and HPV Vaccine Status^a

Characteristic	HPV vaccine initiation			HPV vaccine completion		
	OR	95% CI	P	OR	95% CI	P
Adolescent sex						
Female	—	—	—	—	—	—
Male	0.79	0.73-0.85	<.001	0.94	0.84-1.05	.3
Network						
Non-ACO	—	—	—	—	—	—
ACO	1.80	1.69-1.91	<.001	1.12	1.01-1.23	.024
Provider specialty						
Pediatrics	—	—	—	—	—	—
Family	0.62	0.55-0.69	<.001	1.07	0.90-1.28	.4
No specialty provided	0.42	0.26-0.65	<.001	0.49	0.21-1.10	.083
Other specialty	0.49	0.41-0.57	<.001	0.82	0.63-1.07	.14
Provider type						
MD	—	—	—	—	—	—
NP	0.60	0.53-0.68	<.001	0.84	0.69-1.03	.1
PA	1.05	0.65-1.74	.8	2.01	0.85-4.83	.11
Provider experience						
≥9 years	—	—	—	—	—	—
0-4 years	0.92	0.80-1.05	.2	0.69	0.56-0.86	<.001
5-8 years	0.97	0.89-1.05	.5	0.99	0.88-1.13	>.9
Provider sex						
Female	—	—	—	—	—	—
Male	1.00	0.92-1.08	>.9	1.22	1.08-1.37	.001
Annual medical visits (standardized)	1.03	1.00-1.06	.032	1.16	1.11-1.21	<.001
Year						
2015	—	—	—	—	—	—
2016	1.13	1.04-1.23	.005	0.80	0.70-0.91	<.001
2017	1.73	1.58-1.89	<.001	0.53	0.46-0.60	<.001
Adolescent sex*prescriber sex (reference: female*female)						
Male*male	1.04	0.94-1.17	.4	0.78	0.66-0.92	.002

ACO, accountable care organization; HPV, human papillomavirus; MD, doctor of medicine; NP, nurse practitioner; PA, physician assistant.

^aTwo logistic models are presented above that model HPV vaccine initiation and completion as the outcome variable. The main risk factor is the network variable, which indicates the ACO status of the prescriber. The significant P values suggest that adolescents receiving care from ACOs were significantly more likely to initiate and complete HPV vaccination than were adolescents receiving care in non-ACO settings.

associations between ACO status and HPV vaccination. Our study findings are aligned with results from previous studies that found positive associations between ACOs and health care quality. A recent systematic review evaluating ACOs on health care utilization, care, and outcomes found consistent associations between ACOs and reduced inpatient use, reduced visits to emergency departments, and improved preventive care metrics.²⁰

It is possible that mechanisms internal to ACOs may foster improved HPV vaccination uptake. Global performance tracking is an inherent component of ACOs that are contractually obligated to meet performance metrics, inclusive of HPV vaccination. Used by

CLINICAL

TABLE 3. Multilevel Logistic Models Evaluating HPV Vaccine Performance Among Prescribers Within ACOs by Treating the Provider Effect as the Random Effect*

Characteristic	HPV vaccine initiation			HPV vaccine completion		
	OR	95% CI	P	OR	95% CI	P
Intraclass correlation coefficient		14.0%			10.4%	
Adolescent sex						
Female	—	—	—	—	—	—
Male	0.77	0.72-0.83	<.001	0.82	0.74-0.90	<.001
Average medical visits (standardized)	1.04	1.01-1.08	.010	1.17	1.11-1.23	<.001
Provider sex						
Female	—	—	—	—	—	—
Male	1.01	0.87-1.17	>.9	0.98	0.83-1.15	.8
Provider specialty						
Pediatrics	—	—	—	—	—	—
Family	0.68	0.56-0.83	<.001	1.14	0.88-1.47	.3
No specialty provided	0.44	0.20-0.96	.040	0.33	0.10-1.08	.067
Other specialty	0.44	0.31-0.61	<.001	0.86	0.56-1.33	.5
Provider experience						
≥9 years	—	—	—	—	—	—
0-4 years	0.81	0.62-1.05	.11	0.60	0.43-0.83	.003
5-8 years	0.94	0.83-1.07	.4	0.99	0.83-1.18	>.9
Provider type						
MD	—	—	—	—	—	—
NP	0.59	0.45-0.75	<.001	0.86	0.63-1.17	.3
PA	0.83	0.34-2.01	.7	3.50	0.93-13.1	.063
Year						
2015	—	—	—	—	—	—
2016	1.13	1.00-1.27	.053	0.75	0.63-0.90	.001
2017	1.77	1.56-2.01	<.001	0.53	0.44-0.63	<.001
Number of providers (standardized)	1.05	0.98-1.12	.2	0.96	0.89-1.03	.3
Hospital-based indicator						
No	—	—	—	—	—	—
Yes	0.96	0.82-1.11	.6	1.35	1.15-1.59	<.001

ACO, accountable care organization; HPV, human papillomavirus; MD, doctor of medicine; NP, nurse practitioner; PA, physician assistant.

*Two multilevel models are presented above that include the HPV vaccine initiation and completion as the outcome variable. The intraclass correlation coefficient explains the proportion of random effect variance in the total model variance to quantify the providers within ACOs. Based on the model output, providers with ACOs explained 14.0% of the variance for HPV initiation and 10.4% of the variance for HPV completion.

more than 90% of managed care plans to assess care quality and direct reimbursement, the Healthcare Effectiveness Data and Information Set includes 2 measures of HPV vaccination performance: an overall completion rate for HPV vaccination among adolescents and an immunization combination rate that includes meningococcal meningitis, tetanus, diphtheria, pertussis, and HPV.^{21,22} The tracking of HPV vaccination performance by ACOs as part of value-based payment arrangements may foster a greater awareness of HPV vaccine improvement opportunities and efforts. In an analysis of the National Survey of Healthcare Organizations and Systems and the National Survey of ACOs, Rosenthal et al found that providers in

ACOs were significantly more likely to report that their organization provided individual performance feedback to clinicians, shared peer-comparison data, and used performance data to guide quality improvement efforts.²³ Thus, it is possible that HPV vaccine surveillance and resulting HPV vaccination improvement efforts differ systematically between ACOs and non-ACOs, influencing differences in the initiation and completion of the HPV vaccination series. Additional research is needed to evaluate how ACOs are encouraging HPV vaccination in their member practices.

We found variable HPV vaccination performance among providers in ACOs, consistent with previous studies finding that provider-level characteristics influence HPV vaccination.²⁴⁻²⁶ A recent meta-analysis found that interventions targeting providers resulted in significant improvements in initial HPV vaccination and the completion of the HPV vaccine series.²⁷ Effective interventions to change behavior among primary care providers include education, training, and audit and feedback.²⁸ Indeed, a multifaceted intervention including interprofessional provider education, communication training, data feedback, and action plans resulted in significant increases in the initiation and completion of the HPV vaccination series across several primary care and/or family medicine practices in Massachusetts.²⁹ Education and training on communication strategies such as motivational interviewing have been shown to effectively improve providers' communication of the HPV vaccine and HPV vaccine uptake.³⁰⁻³² Such communication strategies include presumptive HPV vaccine recommendations and the use of open-ended questions to address vaccine hesitancy among parents.^{33,34}

Connecticut has a history of including providers in its strategy to improve HPV vaccination uptake, which may provide insight into its HPV vaccination coverage that is above the national average.¹¹ Healthy Connecticut 2020 encouraged provider education and training on vaccine availability, delivery, cost, practice guidelines, and the benefits of HPV vaccination, and funding for provider education on HPV vaccination was passed under Public Act 17-2.^{12,35} National strategies to improve HPV vaccination uptake described in Healthy People 2030 include vaccination information systems, patient reminders, and school-based vaccination programs.³⁶ Policies are needed to secure funding for provider education and training on HPV vaccination and to support the dissemination and implementation

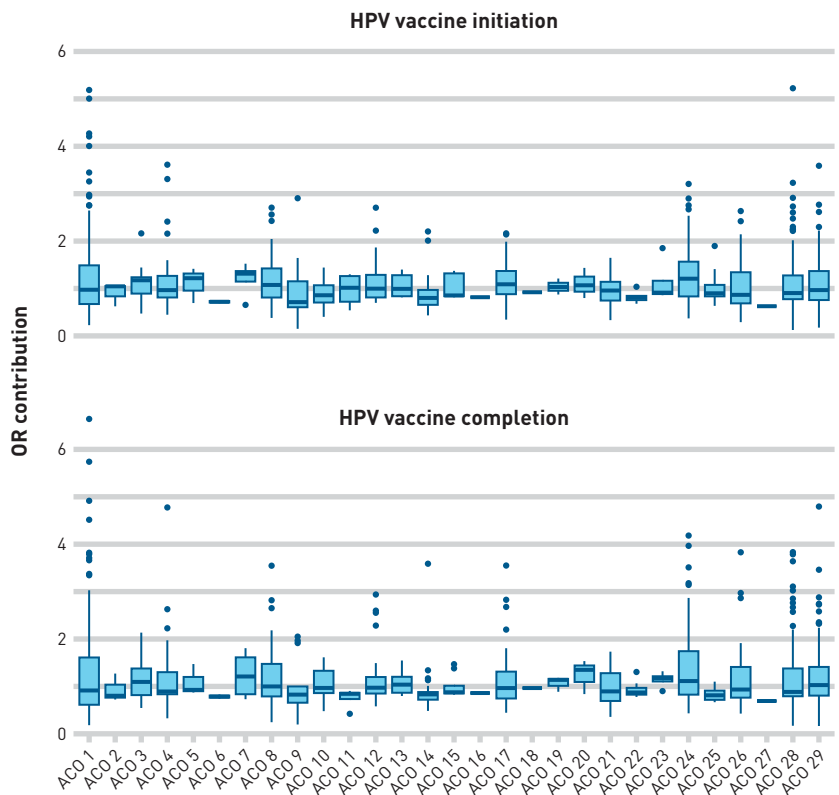
of provider-facing interventions shown to improve HPV vaccine uptake.

Consistent with others,²⁴⁻²⁶ we found differences in the initiation and completion of the HPV vaccine by patient and provider demographics. We found that physicians and those specializing in pediatrics had higher rates of HPV vaccine performance than nurse practitioners and nonpediatric specialties. A national survey of HPV vaccination behaviors among primary care physicians found that routine discussion of HPV vaccination was more common among pediatricians than family physicians.³⁷ We also found that male patients were less likely to initiate the HPV vaccination, which may be because the HPV vaccine had only recently been recommended for boys. Interestingly, we found that female adolescents were more likely to complete the HPV vaccination series if they had a male provider and male adolescents were less likely to complete the HPV vaccination series if they had a male provider. These findings may provide insight into factors that influence providers' recommendation for the HPV vaccination and warrant further study.

Strengths and Limitations

This study has several strengths. We examined trends in HPV vaccine uptake across 3 cohorts of commercially insured adolescents using Connecticut's APCD. Our use of data from one state avoids the impact of state-level policies that confound HPV vaccination, including school requirements for HPV vaccination (absent in Connecticut).³⁸ This study also has important limitations. We analyzed HPV vaccination coverage in Connecticut from 2012 to 2017, and the state has made important gains in HPV vaccination coverage since the study period (achieving 70% coverage among adolescent boys and 74% coverage among adolescent girls in 2022).¹¹ Because of our observational study design that used claims data, we were unable to control for confounders that influence HPV vaccination and may differ between ACO and non-ACO clinics, including patient and family socioeconomic factors, neighborhood socioeconomic factors, parental attitudes toward vaccine uptake, maternal health-seeking behavior, and the race/ethnicity of parents, patients, and providers.^{15,39,40} Also, our observation window could have resulted in underestimates of the HPV vaccine initiation and completion rates. We were interested in the extent to which the HPV vaccination was administered at age 11 or 12 years (as recommended) to maximize the effectiveness of the vaccine, especially because 20% of adolescents are sexually active by age 15 years.⁴¹ Because our study was limited to adolescents with

FIGURE 2. Prescriber HPV Vaccine Performance Variation Within ACOs*



ACO, accountable care organization; HPV, human papillomavirus.

*Each box plot summarizes the distribution of prescribers' effect on an adolescent's odds of vaccine initiation and completion by ACO, given that other characteristics are the same. The y-axis is the magnitude of each prescriber's contribution to odds in a multiplicative scale, so a magnitude below 1 decreases the odds and magnitude above 1 increases the odds. The points are outliers, and the boxes present the middle 50% of the data. The central tendency of prescribers' contribution to odds is quite similar across ACOs, but the shape of prescribers' contribution to odds varies by ACO, suggesting that variation among prescribers within ACOs is greater than variation among ACOs.

continuous commercial insurance in Connecticut, our findings are not generalizable to non-commercially insured adolescents and those with no insurance or with gaps in coverage. Lastly, our statistical models reflected the attribution of patients to providers and providers to organizations at one point in time, although we found little change in attribution over study years.

CONCLUSIONS

We found that adolescents receiving care at ACOs vs non-ACOs were significantly more likely to initiate and complete HPV vaccination. Factors unique to ACOs, including the tracking of HPV vaccination performance that is linked to payment contracts, may support the higher rates of HPV vaccine uptake in ACOs vs non-ACOs. Among adolescents receiving care at ACOs, HPV vaccine uptake attributable to providers dwarfed variability between ACOs, suggesting that provider-level interventions may be more impactful than

interventions at the ACO level. Future research may seek to leverage existing ACO information technology infrastructure to target provider-level HPV vaccination variability. ■

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eAppendix. Characteristics of adolescents who were excluded from the study and their providers by ACO status.*

	Characteristic	Level	ACO N(%)	Non-ACO N(%)	Overall
Adolescent			4796 (65.0)	2585 (35.0)	7381 (100)
	Sex				
		F	2321 (48.4)	1296 (50.1)	3617 (49.0)
		M	2475 (51.6)	1289 (49.9)	3764 (51.0)
	Annual Medical Visits [Mean(SD)]		4.0 (4.8)	4.1 (5.3)	4.0 (5.0)
Provider			703 (48.1)	758 (51.9)	1461 (100)
	Sex [‡]				
		F	424 (60.3)	505 (66.6)	929 (63.6)
		M	279 (39.7)	253 (33.4)	532 (36.4)
	Type [‡]				
		MD	577 (82.1)	515 (67.9)	1092 (74.7)
		NP	90 (12.8)	145 (19.1)	235 (16.1)
		PA	36 (5.1)	98 (12.9)	134 (9.2)
	Specialty [‡]				
		Pediatrics	436 (62.0)	418 (55.1)	854 (58.5)
		Family	172 (24.5)	147 (19.4)	319 (21.8)
		No Specialty Provided	42 (6.0)	127 (16.8)	169 (11.6)
		Other Specialty	53 (7.5)	66 (8.7)	119 (8.1)
	Experience (Years) [‡]				
		9+	503 (48.4)	442 (48.7)	945 (48.5)
		0-4	75 (7.2)	128 (14.1)	203 (10.4)
		5-8	462 (44.4)	337 (37.2)	799 (41.0)

*Includes 7,381 adolescents for whom demographic data were available.

[‡]Significant differences between ACO and non-ACO groups at 5% significance level. Each categorical variable was tested via a Chi-squared test to determine if there is an association between the characteristic and ACO status, and each continuous variable was tested via a two-sample t-test to determine if there is a significance difference in the sample means between the ACO and non-ACO groups.