Human Papillomavirus Vaccine Completion by 13: A Quality Improvement Initiative in a Large Primary Care Network

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Abstract

Objective: Fewer than 40% of U.S. children complete the human papillomavirus (HPV) vaccine series before their 13th birthday. In our large pediatric primary care network, HPV vaccine completion rate by age 13 was 30%. We hypothesized that a phased quality improvement (QI) initiative would increase rates of HPV vaccine completion by age 13 across our network.
Methods: This QI initiative was conducted in a network of 30 practices located across two states, in urban and suburban settings, consisting of teaching and non-teaching clinics, and ranging in size from three to 50 providers per office. We used a phased approach incorporating multicomponent network-wide and iterative practice-specific interventions. Key interventions included: updating clinical decision support to default order HPV vaccine due at preventive visits starting at age nine instead of 11, data audit and feedback to providers and practices, encouraging use of a strong provider recommendation, and standing orders.
Results: From April 2019 to October 2022, HPV vaccine completion by age 13 across our network increased from 30% to 55% and met criteria for special cause variation on statistical process control charts. A gap in median HPV vaccine completion by age 13 between patients with public insurance and patients with private or commercial insurance decreased from 9% to 1%.
Conclusion: A QI initiative was associated with a sustained increase in HPV vaccine series completion by age 13 and reduced variation in care across a large network of 30 primary care practices.

Keywords: human papillomavirus vaccine; papillomavirus Infections; primary care; quality improvement

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What's New

Interprofessional quality improvement (QI) can improve human papillomavirus vaccine series completion rates. Phased QI interventions rooted in clinical decision support, feedback, education, and standing orders fostered interprofessional collaboration and reduced practice variation across a diverse primary care network.

Human papillomavirus (HPV) causes > 90% of cervical and anal cancers, > 70% of oropharyngeal cancers and > 60% of vulvar and penile cancers.[1] An HPV vaccine that is safe and effective in reducing the incidence of these cancers has been available in the United States since 2006 for girls and since 2011 for boys. The Centers for Disease Control and Prevention routinely recommends HPV vaccination at age 11 or 12 years[2]; per the Advisory Committee on Immunization Practices (ACIP), vaccination can be given starting at age nine.[3] However, in 2019, only 27–32% of children with commercial insurance and 40% with public insurance completed the series by age 13,[4] a Healthcare Effectiveness Data and Information Set (HEDIS) measure. Moreover, there has been a widening gap over the last decade between initiation and completion before age 13.[5]

Drivers of successful HPV vaccination include a strong provider recommendation,[6] patient reminders that vaccination is due,[7] effective clinical decision support (CDS) in the electronic health record (EHR) to prompt providers to order vaccine,[8,9] data audit and feedback,[10,11] and standing orders.[12] The American Academy of Pediatrics (AAP)[13] and American Cancer Society[14] recommend starting HPV vaccination at age 9. Earlier initiation of HPV vaccine has multiple benefits, including increased immunogenicity,[15] higher completion rate of the vaccine series,[16] and improved prevention by completing vaccination before HPV exposure through sexual activity.[17–19] Multicomponent interventions that combine both patient-

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focused and provider-focused strategies demonstrate the greatest increase in HPV vaccination rates.[20,21]

Examining data from April 2017 to April 2019 in our large pediatric primary care network of 30 practices, we found that only 30% of patients had completed HPV vaccination by age 13, with tremendous variation in rates across practices, ranging from 10%–65%. We hypothesized that a phased approach incorporating both multicomponent network-wide and iterative practice-specific interventions would be an effective strategy to enact change and improve outcomes. Applying our institution's quality improvement (QI) framework, which combines elements of multiple improvement methodologies (Lean,[22] Six Sigma,[23] Model for Improvement),[24] our Specific, Measureable, Achievable, Relevant, Time-bound (SMART) aim was to increase the proportion of patients across our network who complete HPV vaccination by their 13th birthday by 15% above the two-year baseline (from 30% to 45%) by December 2020. In parallel with our primary aim, a corresponding goal was to increase HPV vaccine initiation rates for patients between nine and 12.99 years old by 15% above baseline (from 10% to 25%). Due to the COVID-19 pandemic, we extended this timeframe to December 2021.

METHODS

CONTEXT

This initiative was conducted in a large pediatric primary care network of 30 practices located across 2 states in both urban and suburban settings, consisting of teaching and non-teaching clinics, ranging in size from three to 50 providers per office (Table 1). Primary care providers included approximately 235 physicians, 75 nurse practitioners and 160 residents. The network serves over 300,000 patients and conducts more than 745,000 visits yearly. Approximately 1300–1400 patients turn 13 years old each month in our network. Thirty-four percent of patients have public insurance, 65% have commercial or private insurance, and 1% have military insurance or are self-pay. Although there are a range of quality incentive metrics from the insurance companies we work with, including some insurance companies incentivizing immunizations for adolescents, this was not one of the motivating factors for this improvement initiative.

Table 1. Practice Characteristics

Characteristic	Value
	Total N = 30 practices
	n (%)
Location*	
Urban	7 (23)
Resident teaching clinic	3 (43)
Non-teaching clinic	4 (57)
Suburban	23 (77)
Volume (visits per year)	
10,000–20,000	13 (43)
> 20,000–40,000	13 (43)
> 40,000–70,000	4 (14)
Predominant insurance type†	
Public	7 (23)
Commercial	23 (77)

MSA indicates metropolitan statistical area.
* Urban = MSA, principal city; Suburban = MSA, non-principal city.
† Insurance type for ≥50% of patients in the practice.

INTERVENTIONS

In January 2019, we assembled an interprofessional QI Leadership team that included directors of quality, education, value-based care, regional practice director, senior manager of value-based care and regional medical director with extensive experience with network vaccination initiatives. This team met regularly to engage key stakeholders, review literature to identify evidence-based strategies, brainstorm network-wide interventions, and develop a plan for data collection and visualization. Additional stakeholders with significant involvement in project planning and implementation included the medical director of informatics, lead nurse manager for the network and a data analyst. The QI Leadership team identified key drivers for increasing HPV vaccination rates (Fig. 1) and used an impact-effort matrix to guide selection of network-wide interventions (high potential impact/feasible degree of effort) for the initial phase of the project. The following phase would incorporate iterative practice-specific interventions identified by and implemented within individual offices.

In April 2019, the QI initiative was announced via email and at leadership meetings to the entire network, including providers, practice managers and lead nurses. With this announcement, we introduced the network recommendation to initiate HPV vaccination at age nine. Network-wide interventions began in June 2019, with the exception of the standing order for nurses which was implemented in April 2020. Each practice identified an HPV QI Champion (a physician or nurse practitioner), lead nurse and practice manager who facilitated implementation of interventions and helped to determine additional practice-specific interventions as the project evolved, using Plan-Do-Study-Act (PDSA) cycles.

NETWORK-WIDE INTERVENTIONS

Clinical Decision Support Tool. All practices in the network use a single EHR (Epic, Verona, WI). Our institution had previously developed and embedded a tool that integrates with our EHR to support ordering of vaccines that are due at each preventive visit using a default/opt-out order-set.[10] That is, a provider must "unselect" and opt out of the order if they do not give a vaccine that the patient is due for at that visit. Previously, this tool was programmed to order HPV vaccine starting at age 11; we updated it to default order HPV vaccine starting at age 9. We chose to implement this first because it had the highest leverage in the hierarchy of intervention effectiveness;[25] it is standardized, automated, systems-based and uses a forcing function. For patients 9–12.99 years old, we also added an element to the preventive visit note template to capture reasons why HPV vaccine was declined (concerns

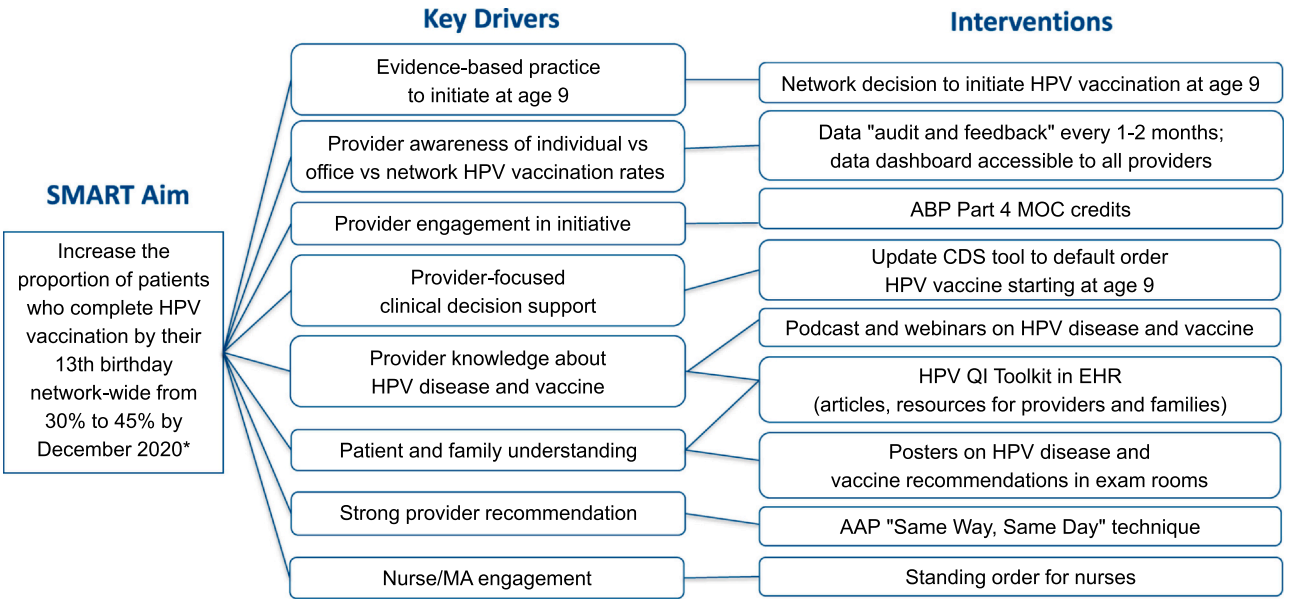


Figure 1. *Key driver diagram of network-wide interventions. AAP indicates American Academy of Pediatrics; ABP, American Board of Pediatrics; CPOE, computerized provider order entry; EHR, electronic health record; HPV, human papillomavirus virus; MA, medical assistant; MOC, maintenance of certification; and QI, quality improvement.*

about safety, concerns about effectiveness, perceived as not necessary at this time, or need more time/information to decide). For sick and follow-up visits, vaccines are not a default part of the order-set. To optimize vaccination at these visits, a Best Practice Alert (BPA) informs the clinical team which vaccines are due. This BPA was also updated to notify providers that HPV vaccine was due starting at age nine.

Audit and Feedback. Using the evidence-based strategy of "audit and feedback",[26] we provided data summaries to providers and practice managers. This technique had been used effectively in our network to sustain antimicrobial stewardship[27] and over the last decade has become part of our network's improvement culture. Summaries included a run chart of overall network rates as well as initiation and completion rates for individual practices, highlighting practices that had increased by ≥15% above their baseline rates.

Maintenance of Certification. To optimize provider engagement, we obtained approval for Maintenance of Certification (MOC) credit under our institution's American Board of Pediatrics MOC portfolio. To attest for credit, providers had to complete online QI educational modules[28] and demonstrate meaningful participation: attend ≥4 project meetings over 6 months, review HPV vaccination data for their practice and submit completed PDSA worksheets to the QI Leadership team.

Provider and Patient Education. Educational interventions for providers and staff included two webinars on HPV disease and HPV vaccine held in July 2019, and a podcast on the same topics. Webinar recordings and a link to the podcast were also made available for asynchronous learning. We provided project updates via email every 1–2 months to QI champions and every 3–6 months to all providers and practice managers; these updates included the data summaries, links to recent HPV-related research, and a synopsis of evidence that HPV vaccine initiation at age nine is safe and effective. We also repeatedly highlighted the compelling research supporting a strong provider recommendation for HPV vaccine and encouraged providers to practice this technique using scripted motivational interviewing role-play scenarios via the AAP's interactive *HPV Vaccine: Same Way, Same Day* application ("app").[29]

For patient education, we selected one standard poster about HPV disease and vaccine to be displayed in all examination rooms in each office. This poster was chosen because it highlights HPV vaccine as cancer prevention, emphasizes the importance of HPV vaccination before age 13, and relays this information via simple infographics and vocabulary.[30] We also embedded an HPV QI toolkit in our EHR with links to articles and resources for providers, the poster, and additional handouts for patients.

Standing Order for Nurses. In April 2020, we implemented a standing order for nurses to administer HPV vaccine dose 1 once a physician or nurse practitioner provides vaccine counseling. Standing orders for HPV vaccine doses 2 and 3 had been approved several years before our QI initiative began, but no standing order had ever been approved by our network for the *initial* dose of any vaccine. We collaborated with nursing leadership to design and streamline CDS in the EHR to enable nurses to order any dose of HPV vaccine. With the announcement of this new standing order, our QI Leadership Team shared links and resources[31] from national and regional HPV organizations with nurses and medical assistants across the network.

Practice-Specific Interventions

With the project launch in Spring 2019, an HPV QI Champion, lead nurse and manager from each practice participated in virtual collaborative learning discussions with the QI Leadership team every 1–2 months. In Fall 2019, these Champions and leaders selected specific interventions to implement at their individual practices. To help inform this process, we shared reasons caregivers refused HPV vaccine during a visit, as captured in the preventive visit note during the first 3 months of our project. To further inform interventions, through an online survey and emails, we also collected barriers to HPV vaccination that providers and staff had experienced during the QI initiative thus far.

During this practice-specific phase, HPV QI Champions submitted PDSA worksheets (Appendix 1) prior to each collaborative learning discussion in which they summarized their interventions and impact on vaccination rates and identified next steps. The QI Leadership team shared successes from these worksheets to help other Champions improve HPV vaccination at their practices. During the COVID-19 pandemic, we scaled back meeting frequency and continued sharing data and successes with Champions, lead nurses and practice managers via email.

Additional Interventions

As we entered the initiative's second year, we implemented an additional intervention – identifying practices that were experiencing significant barriers to HPV vaccination and required more substantial change management to address an issue of culture, rather than of process. We reached out to Champions and managers at these practices with feedback regarding which providers had the highest and lowest rates of HPV vaccination. We packaged data visualizations and peer comparisons and coached Champions to review these data with their colleagues. Some of these Champions also asked our QI Leadership team to visit their practice in-person to discuss the QI initiative at a regularly scheduled staff meeting. Prior to visits, we worked with Champions to identify providers with the lowest HPV vaccination rates, and the specific nurses and providers that demonstrated the greatest resistance to HPV vaccination. During and after each large-group meeting, we strategically engaged these individuals in discussions to elicit and address their specific concerns about the HPV vaccine.

Study of the Interventions

We extracted HPV vaccination data from our institution's data warehouse and conducted chart reviews to validate these data before displaying them in a QlikView dashboard (Qlik Technologies, King of Prussia, PA) that automatically updated weekly. The dashboard facilitated visualization of initiation and completion rates for the entire network, filtered by individual practice or provider, and viewable by month, quarter, or year. The QI Leadership team reviewed these data regularly and Champions, lead nurses and practice managers reviewed the dashboard with colleagues after each practice-specific intervention.

Measures

The outcome measure was HEDIS-consistent[4] HPV vaccine completion, defined as the proportion of patients in the network turning 13 years old each month who received two doses of HPV vaccine between their 9th and 13th birthdays, at least 5 months apart. Because most patients received HPV vaccine at an annual preventive visit, typically one year elapsed between initiation and completion of the series. Therefore, our outcome measure is a "lagging indicator." Our key process measure was the proportion of patients 9–12.99 years old eligible for an *initial* dose of HPV vaccine at the time of a visit who received it at that visit; this measure is a "leading indicator." An additional process measure was the number of physicians who received MOC credits. For our balancing measure, we measured whether our initiative would increase or decrease completion rates of other pre-teen vaccinations included in the HEDIS measure (tetanus, diphtheria, acellular pertussis vaccine (TdaP) and meningococcal conjugate vaccine) among patients 9–12.99 years old.

Analysis

Our baseline HPV vaccine initiation and completion rates were calculated from April 2017 to March 2019. Monthly data for our outcome and process measures were plotted on statistical process control (SPC) charts[32] using Minitab (Minitab Limited Liability Company (LLC), State College, PA). Special cause variation was noted when eight consecutive data points were on the same side of the centerline (a shift). The population included in our dataset were all patients 9–12.99 years old who had ≥1 office visit in our network in the previous 2 years. We excluded patients with severe allergy to a component of the HPV vaccine and patients with documented refusal of all vaccines (International Classification of Diseases (ICD) codes on problem list Code Z28.82, Z28.89). For HPV vaccine initiation rates, sample sizes ranged from ~3000 to > 7000 patients per month; we used a Laney's p-chart[33] to correct for overdispersion.

To examine whether our interventions disproportionately affected completion rates among patients with public insurance or patients with commercial insurance, we plotted data on run charts[34] stratified by insurance type. For our balancing measure, we used a t-test to compare rates of Tdap and meningococcal vaccine completion by age 13 between baseline (April 2017 to March 2019) and the first year of our intervention period (April 2019 to March 2020).

Ethical Considerations

This quality improvement initiative was reviewed and determined to not meet criteria for human subjects research by our institution's Institutional Review Board.

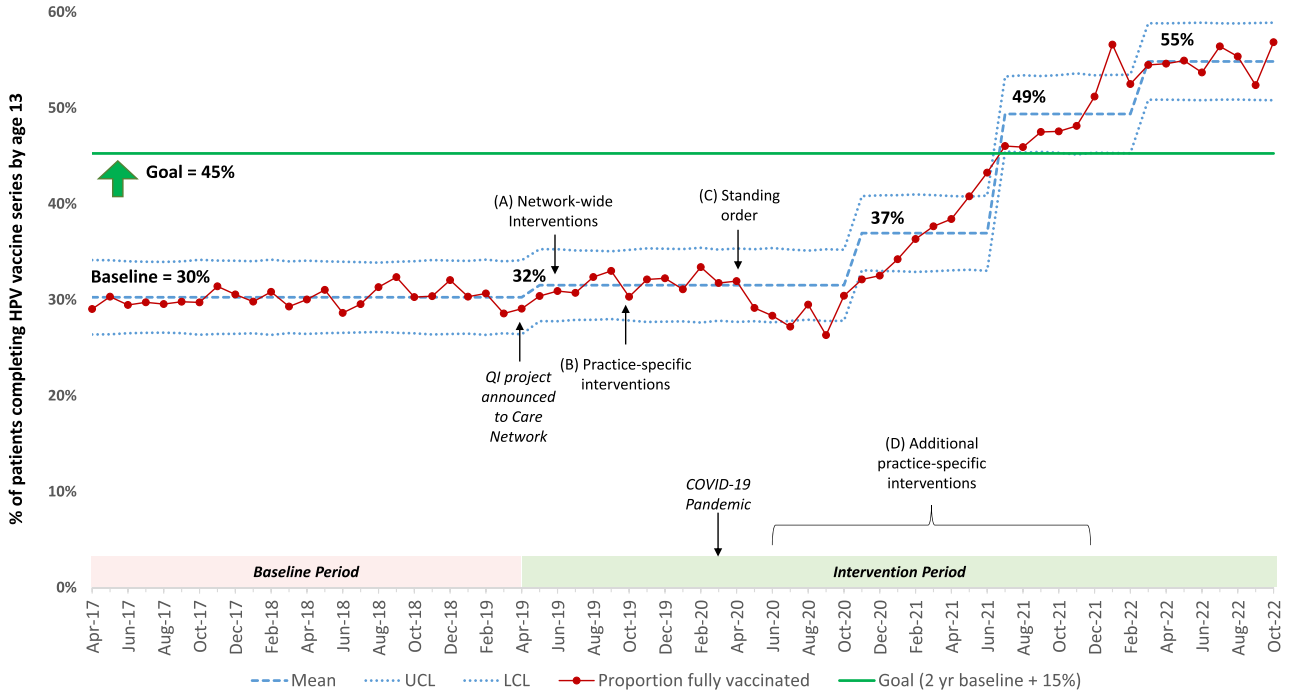


Figure 2. *P-chart showing percentage of patients completing HPV vaccine series by age 13 (lagging indicator). The denominator is all patients in our primary care network turning 13 years old each month. (A) Network-wide interventions included: initiation of HPV vaccine at age 9, data audit and feedback to practices, MOC credit for provider participation, CDS tool updated to default order HPV vaccine at age 9, provider and patient educational interventions, encouraging use of strong provider recommendation for HPV vaccine; (B) Practice-specific interventions included: anticipatory counseling about HPV vaccine at 7 and 8-year-old preventive visits, interprofessional pre-clinic huddles to identify patients scheduled that day who were due for HPV vaccine, use of population health tools to contact patients due for HPV vaccine and/or preventive visit and schedule appointment; (C) Standing order for nurses and MAs to give HPV vaccine; (D) Additional practice-specific interventions included: change management strategies at practices encountering significant resistance from providers and staff regarding HPV vaccination, sharing powerful stories with families and staff about HPV disease. CDS indicates clinical decision support; HPV, human papillomavirus virus; LCL, lower control limit; MOC, maintenance of certification; and UCL, upper control limit.*

RESULTS

Improvement in our outcome measure, HPV vaccine completion by 13th birthday, met criteria for special cause variation with four upward centerline shifts in May 2019, November 2020, July 2021, and March 2022 (Fig. 2). As expected with this "lagging indicator," we observed steady improvement starting about one year into the initiative – after a slight decline in spring of 2020 corresponding with the COVID-19 pandemic. We met our SMART aim of 45% by July 2021 and rates increased to 55% by October 2022.

During the baseline period, 1.9% of all eligible patients (647 patients over 24 months) were excluded from the analysis due to documented refusal of all vaccines; from April 2019 (project initiation) to October 2022 (completion of data collection), this proportion was 1.2% of all eligible patients (614 patients).

The frequencies of reasons for caregiver refusal (captured in the preventive visit note) were as follows: "perceived as not necessary at this time" (48%); "need more time/information to decide" (38%), "concerns about safety" (6%) and "vaccine effectiveness" (< 1%). Based on the provider/staff survey, the top barriers to HPV vaccination at age nine included: parents and patients were unprepared for a vaccine at the 9-year visit and lack of alignment with CDC publications and vaccine advertisements that recommend HPV vaccine at 11–12 years old. Top barriers to HPV vaccination *at any age* were: lack of school mandate for HPV vaccine, negative connotation between HPV and sexual activity, and misinformation and mistrust regarding HPV vaccine. All 30 offices selected practice-specific interventions, informed by these barriers, to implement over at least two PDSA cycles (Table 2).

The process measure, HPV vaccine initiation, rose quickly after project launch, rising above baseline by July 2019 and meeting criteria for special cause variation (Fig. 3).

One unanticipated network-wide strategy that arose during the early pandemic involved pre-visit counseling via phone. Pre-visit counseling occurred as a broad approach (not specific to this initiative) to decrease the time families would need to spend in the office. This was a novel opportunity to address a barrier we identified at the start of the project: prepare families for vaccines and other preventive care that would occur during the visit. These unusual circumstances corresponded with a brief but sharp increase in initiation rates from 27% to 53% (March to May 2020). Standing orders for HPV vaccine were also approved during this time and may have accentuated this peak. However, pre-visit calls were not sustainable when practices returned to typical

Table 2. Most Common Practice-Specific Interventions (PDSA Cycles)

Practice-Specific Intervention	% of Practices that Selected the Intervention
	Total N = 30 practices
	n (%)
Anticipatory counseling at 7- and 8-year-old preventive visits to prepare families for a vaccine at the 9- and 10-year-old visits	17 (57)
Framing the HPV vaccine specifically as cancer prevention	14 (47)
Use of a strong provider recommendation with "Same Way, Same Day" messaging for HPV vaccine	13 (43)
Interprofessional engagement to identify and educate patients eligible for HPV vaccine and their caregivers	12 (40)
Use of population health tools to contact and schedule patients due for HPV vaccine	8 (27)

HPV indicates human papillomavirus; PDSA, plan-do-study-act.

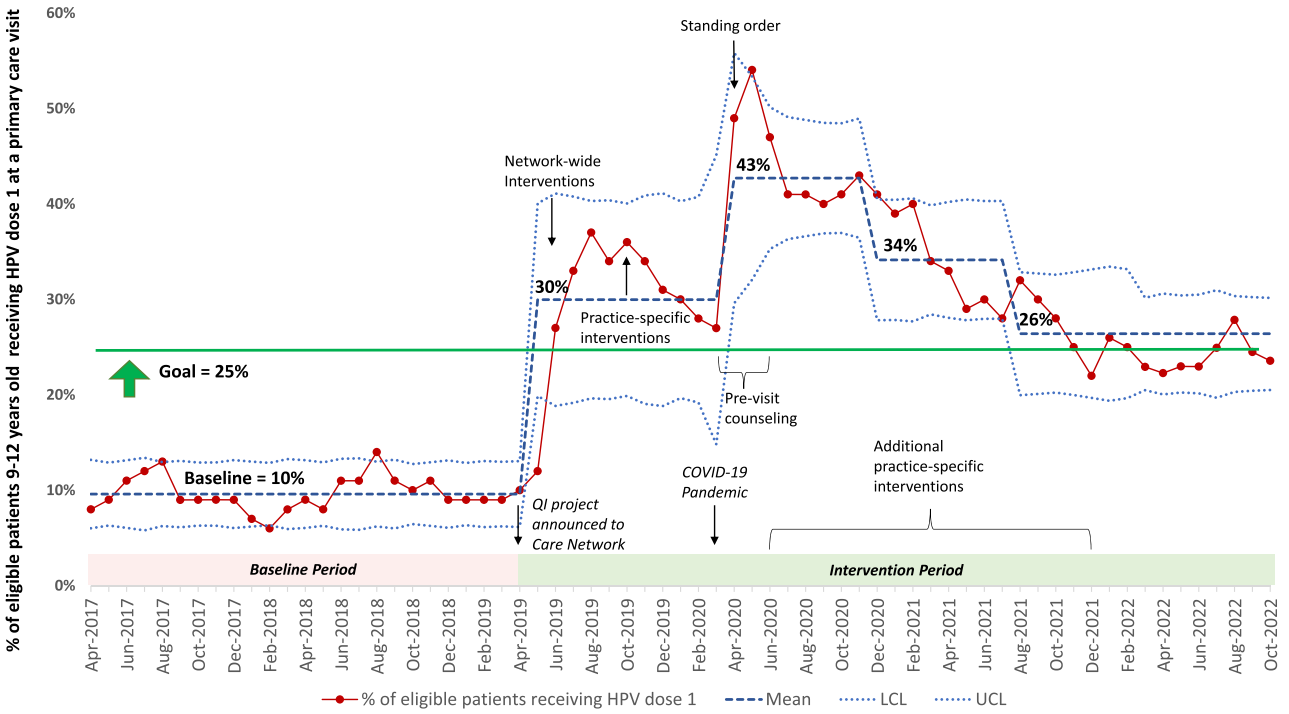


Figure 3. *Laney's P-chart showing percentage of eligible patients 9–12 years old receiving HPV dose 1 at a primary care visit (leading indicator). The denominator is all patients 9–12 years old eligible for first dose of HPV vaccine at the time of a primary care visit. See Figure 2 for additional information regarding interventions. HPV indicates human papillomavirus.*

workload and staff were no longer working remotely, and initiation rates drifted to a new plateau just above our goal of 25%. Physician engagement was robust, with 40% of network physicians (93/232) attesting for MOC credit. There was no statistically significant change in the balancing measure, Tdap and meningococcal vaccine completion by age 13 (baseline = 90%, post = 89%, $P = .33$).

During the baseline period, patients with public insurance had higher rates of HPV vaccine completion by age 13 (37%) than patients with private or commercial insurance (28%), similar to national rates.[4] During the intervention period, this difference was nearly eliminated and rates in both groups increased (Fig. 4). By October 2022, median completion reached 57% (public insurance) and 56% (commercial insurance).

DISCUSSION

Over three and a half years, our QI initiative improved HPV vaccine completion by age 13 from 30% to 55% across a large network of 30 pediatric primary care offices. With our network volumes, approximately 200 *more* patients per month are meeting the HEDIS-metric for HPV vaccine completion compared to baseline, without negatively impacting other routine vaccines for this age group. Our network's rate of HPV vaccine completion by age 13 was negatively impacted by the COVID-19 pandemic and dipped below the centerline from May to October 2020. This is similar to the pandemic's impact on HPV vaccination[35] and other routine pediatric vaccination rates nationally.[36] However, our HPV vaccine completion rates rebounded above the centerline and have continued to rise.

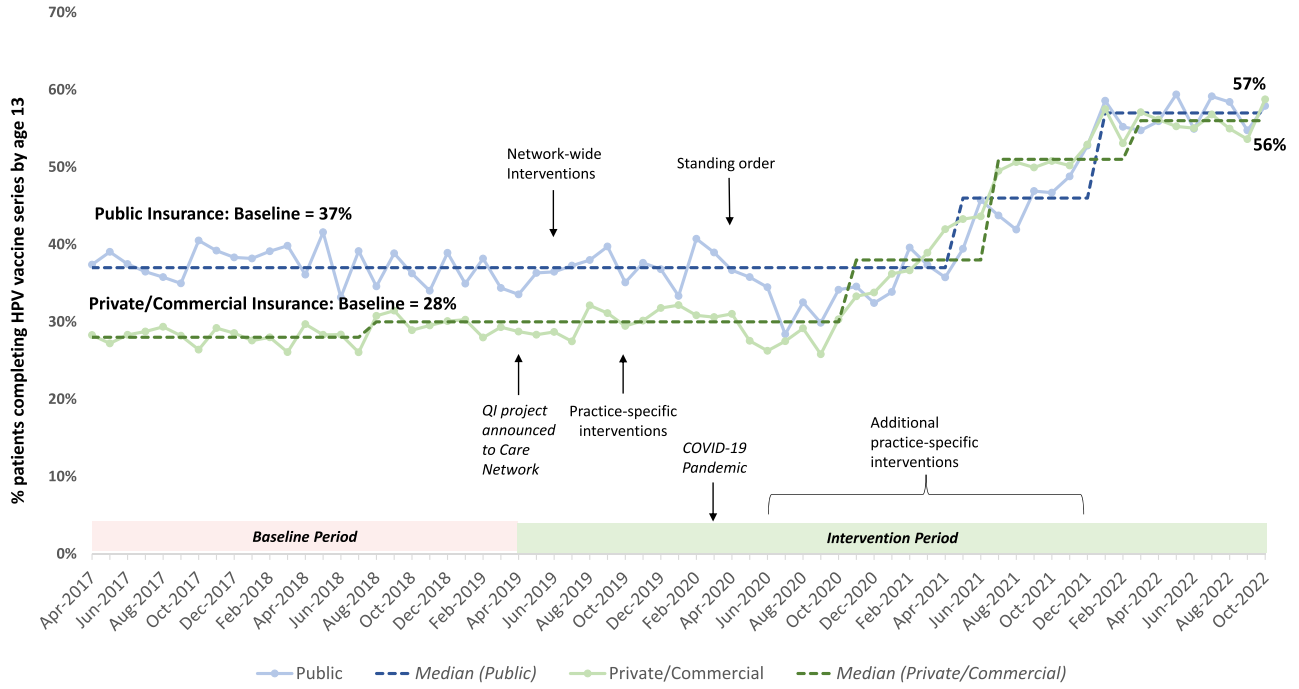


Figure 4. *Run chart showing percentage of patients completing HPV vaccine series by age 13, stratified by insurance type. HPV indicates human papillomavirus.*

Our QI initiative reduced the gap in HEDIS-consistent HPV vaccination between patients with public insurance and those with private or commercial insurance from 9% to 1%. National HPV vaccination rates are consistently higher among adolescents at or above the poverty level compared to adolescents below the poverty level.[4,37] Factors contributing to this difference are unclear, but may include variation in provider recommendation, as well as patient confidence in and access to vaccines.

Our phased approach with multicomponent network-wide and iterative practice-specific interventions was effective in increasing HPV vaccination rates across practices of varying sizes, settings and predominant insurance types. Partnering with clinical, nursing, and administrative leaders from each practice was essential for successful implementation of network-wide interventions at the practice-level and identification and implementation of practice-specific interventions that worked best for each practice's culture and processes. Among practices that improved their HPV vaccine initiation and/or completion rates, there were no clear associations with suburban vs urban location, teaching vs non-teaching, or patient volumes.

Soon after launching network-wide interventions, we observed an increase in our process measure, HPV vaccine initiation. Of these interventions, updating our CDS tool to default-order HPV vaccine due at preventive visits starting at age nine had the highest order forcing function and may have played a key role in increasing and sustaining our HPV vaccine completion rates. Although other QI initiatives also changed their EHR HPV vaccine alert from age 11 to age nine,[8,9] we believe ours may be the first initiative where CDS default orders the vaccine, rather than a simple provider prompt that could easily be ignored.

The sharp increase in HPV vaccine initiation rates during Spring 2020 (from 27% in March to 53% in May) corresponded with drastic changes during the COVID-19 pandemic, including intensive pre-visit counseling and fewer patients coming into the office. Towards the second half of 2020, patient volumes began to normalize and pre-visit counseling was phased out. As a result, HPV vaccine initiation returned to pre-pandemic rates (centerline = 26%), but they remain above our original SMART goal of a 15% increase from our pre-intervention baseline (10%).

One surprising practice-specific intervention emerged from conversations with vaccine-hesitant families and with the aforementioned primary care providers and staff who had concerns about the HPV vaccine, in particular regarding its safety and its association with sexual activity. We discovered that a strong provider recommendation and scientific evidence were not enough to combat vaccine misinformation and mistrust. Instead, numerous Champions asked our QI Leadership Team for powerful stories about the tragic impact of HPV disease to share with their staff and patients. We included these stories in our QI project updates and noted that other practices chose to incorporate story-telling as an intervention in subsequent PDSA cycles. As Dr. David Robert Grimes states in his compelling New York Times video opinion article, "…you never change minds without changing hearts."[38]

Limitations of our improvement initiative include lack of a randomized controlled design, the potential impact of external factors on HPV vaccine acceptance, exclusion of patients with documented refusal of all vaccines, and

geographic homogeneity. Although it is possible that secular trends could have accounted for some of the increase in our rates, national rates remained under 40% from 2019 to 2021, increasing by only ~4% from 2019 to 2021 among commercially-insured patients and actually decreasing by 2.3% among publicly-insured patients.[4] In addition, our project benefitted from existing QI and data resources at our institution, possibly limiting the generalizability of our findings. Finally, since we implemented multiple network-wide interventions simultaneously, we cannot discern the relative contributions of each of the individual interventions. Our QI Leadership Team had weighed using a stepped wedge design; however, we decided not to withhold any potentially impactful interventions, even for a few months, to enable patients at all our practices to benefit from successful HPV vaccine completion as early as possible. Other quasi-experimental methods, such as interrupted time series analysis, were also beyond the scope of this project. Our focus was on quality improvement and change management at the practice level.

CONCLUSIONS

Our QI initiative demonstrated increased rates of HPV vaccine completion by age 13 through a phased approach with multicomponent network-wide and iterative practice-specific interventions. Key interventions included: updating clinical decision support to default order HPV vaccine due at preventive visits starting at age nine instead of 11, data audit and feedback to providers and practices, encouraging use of a strong provider recommendation, and standing orders. We effectively increased HPV vaccination rates across a large primary care network with practices of varying sizes, settings, and predominant insurance types. Future research should also examine whether default opt-out vaccine orders integrated in the EHR can be a sustainable and cost-effective tool to overcome barriers to vaccination.

DECLARATION OF COMPETING INTEREST

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Dr. Huang received an honorarium to present this work at the 26th Annual Pennsylvania Immunization Conference (June 2022).

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SUPPORTING MATERIAL

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