Preventive Medicine Reports 35 (2023) 102279

Contents lists available at ScienceDirect

Preventive Medicine Reports

journal homepage: www.elsevier.com/locate/pmedr

Factors associated with shorter-interval cervical cancer screening for young women in three United States healthcare systems

Anne Marie McCarthy [a,*], Jasmin A. Tiro [b], Ellen Hu [b], Sarah Ehsan [a], Jessica Chubak [c], Aruna Kamineni [c], Sarah Feldman [d], Steven J. Atlas [e], Michelle I. Silver [f], Sarah Kobrin [g], Jennifer S. Haas [e]

[a] Department of Biostatistics, Epidemiology and Informatics, University of Pennsylvania, Philadelphia, PA, USA
[b] Department of Population & Data Sciences, University of Texas Southwestern Medical Center, Dallas, TX, USA
[c] Kaiser Permanente Washington Health Research Institute, Seattle, WA, USA
[d] Division of Gynecologic Oncology, Brigham and Women's Hospital, Harvard Medical School, Boston, MA, USA
[e] Division of General Internal Medicine, Massachusetts General Hospital, Harvard Medical School, Boston, MA, USA
[f] Division of Public Health Sciences, Department of Surgery, Washington University School of Medicine, Saint Louis, MO, USA
[g] Healthcare Delivery Research Program, Division of Cancer Control and Population Science, National Cancer Institute, Bethesda, MD, USA

ARTICLE INFO

Keywords:
Cervical cancer
Pap screening
Screening interval
Multilevel
Cancer prevention

ABSTRACT

Frequently changing cervical cancer screening guidelines over the past two decades have been inconsistently adopted in the United States. Current guidelines set the recommended screening interval to three years for average-risk women aged 21–29 years. Few studies have evaluated how patient and provider factors are associated with implementation of cervical cancer screening intervals among younger women. This study evaluated multilevel factors associated with screening interval length among 69,939 women aged 21–29 years with an initial negative Pap screen between 2010 and 2015 across three large health systems in the U.S. Shorter-interval screening was defined as a second screening Pap within 2.5 years of an initial negative Pap. Mixed-effects logistic regression was performed for each site to identify provider and patient characteristics associated with shorter-interval screening. The odds of shorter-interval screening decreased over the study period across all sites, though the proportion of patients screened within 2.5 years remained between 7.5% and 20.7% across sites in 2014–2015. Patient factors including insurance, race/ethnicity, and pregnancy were associated with shorter-interval screening, though the patterns differed across sites. At one site, the variation in shorter-interval screening explained by the provider was 10.6%, whereas at the other two sites, the provider accounted for < 2% of the variation in shorter-interval screening. Our results highlight the heterogeneity in factors driving cervical cancer screening interval across health systems and point to the need for tailored approaches targeted to both providers and patients to improve guideline-concordant screening.

1. Introduction

Cervical cancer incidence and mortality in the U.S. have declined substantially over the past several decades due in large part to routine Papanicolaou (Pap) testing (Stat, 2022). While annual screening was historically recommended for all women beginning at age 18, a better understanding of the high prevalence and transient nature of human papillomavirus (HPV) infection (Ho et al., 1998), and the low incidence of cervical cancer in young women led to changes in the recommended age of screening initiation and screening interval. Screening more frequently than every 3 years is particularly concerning for women aged 21–29, as it can lead to more follow-up procedures, associated anxiety, unnecessary complications, and increased costs (Kulasingam et al., 2011). In 2012, the US Preventive Services Task Force (USPSTF), American College of Obstetrics and Gynecology (ACOG), and American Cancer Society (ACS) aligned their cervical cancer screening guidelines to recommend a starting age of 21 years for screening, a 3-year screening interval for average-risk women, and Pap testing alone (i.e., without HPV co-testing) for women aged 21–29 years (Moyer and Force USPST, 2012; Saslow et al., 2012; ACOG Practice Bulletin, 2009). Many women

* Corresponding author at: Blockley Hall, Room 833, 423 Guardian Drive, Philadelphia, PA 19104, USA
E-mail address: annemcc@pennmedicine.upenn.edu (A.M. McCarthy).

https://doi.org/10.1016/j.pmedr.2023.102279
Received 21 February 2023; Received in revised form 16 May 2023; Accepted 7 June 2023
Available online 11 June 2023

continue to be screened more often, with resulting costs incurred at the individual, clinical, and system levels (Wright et al., 2016; Kim et al., 2018). Cervical cancer screening guidelines have continued to evolve over time. With the release of USPSTF's 2018 and ACS's 2020 cervical cancer screening recommendations, guideline-making organizations are no longer aligned. ACS guidelines shifted the age to start screening to 25 (versus 21 years) and expressed a preference for primary HPV testing every 5 years (versus Pap test alone every 3 years through age 29) (Fontham et al., 2020). There will likely be additional changes to screening guidelines for women in this age group in the coming years. While several studies have examined effects of the 2012 guideline change on screening practices and patient factors associated with guideline-concordant screening (Castle et al., 2021; Parekh et al., 2017; Mignot et al., 2021; Qin et al., 2021; Silver et al., 2018), few studies have evaluated the effect of providers and health systems on adoption of new guidelines. Understanding the patient, provider, and health system characteristics associated with variation in the adoption of new recommendations may aid in designing interventions to implement new guidelines for this age group in the future. The purpose of this study was to examine the prevalence of and factors associated with shorter-interval screening, defined as a Pap test within 2.5 years of a prior normal screening Pap test, for women aged 21–29 around the time of the 2012 guideline change in three diverse health care systems. In addition, we examined whether the prevalence of abnormal results differed by shorter versus longer interval.

2. Methods

2.1. Study setting

This study was conducted as part of the National Cancer Institute funded Population-based Research Optimizing Screening through Personalized Regimens (PROSPR II) consortium (Beaber et al., 2022). The cervical PROSPR II Research Center, MultilEvel opTimization of the ceRvIcal Cancer Screening process (METRICS), includes three sites in diverse settings & populations: Kaiser Permanente Washington (KPWA), Parkland Health/University of Texas Southwestern Medical Center (UTSW), and Mass General Brigham (MGB). KPWA is a mixed-model healthcare system providing care and coverage in Washington State. KPWA provides health care coverage for its members through two models—a dominant integrated component in which members receive care from KPWA clinicians and a smaller, contracted component in which KPWA-insured patients receive care from a contracted network of clinicians. Parkland Health is an integrated safety-net system in Dallas, Texas with academic oversight from University of Texas Southwestern Medical Center (PH-UTSW). As a safety net system, PH-UTSW delivers care to a large proportion of uninsured and underinsured patients. Mass General Brigham (MGB), is an integrated delivery system in Massachusetts that includes two academic medical centers—Brigham and Women's Hospital (BWH) and Massachusetts General Hospital (MGH)—and their large affiliated primary care networks. Most patients at MGB are covered by private insurance plans, with some covered by public insurance, as Massachusetts has universal health coverage. This work was approved by the institutional review boards of the participating sites.

2.2. Data collection and study population

The METRICS study cohort included women ages 18–89 years old. MGB and PH-UTSW included women with at least one visit to a primary care or women's health clinic anytime between January 1, 2010 to December 31, 2017. KPWA included women who were enrolled in the health plan and who selected, were assigned, or were attributed to a KPWA primary care provider during this time period. All sites collected cervical cancer screening data on their cohorts at person- and provider-levels using a rich array of electronic clinical information systems and administrative databases (Kamineni et al., 2019).

The study population for this analysis was restricted to cohort members aged 21–29 years with at least one normal screening Pap test (defined as Negative for Intraepithelial Lesion or Malignancy [NILM] and defined as the "**index Pap test**") between 2010 and June 2015, to allow the opportunity for at least 2.5 years of follow-up after index Pap test for all patients. We extracted medical history data prior to the index Pap test and excluded individuals without a cervix, living with HIV, with a prior cervical cancer diagnosis, with a documented history of an abnormal Pap test and/ or HPV result (NILM/HPV + or worse), with a prior cervical procedure or treatment; or those under surveillance for a prior abnormal Pap test. Results from screening tests performed by providers in the health system in the three years prior to index Pap test were extracted when available. The number of exclusions by study site are detailed in Supplemental Table A1.

2.3. Statistical analysis

To describe the distribution of screening intervals, we generated cumulative incidence curves based on Kaplan-Meier estimates of time from index Pap test to the next screening Pap test by year of index Pap test, stratified by site. Patients were censored when they reached age 30, died, or reached administrative cutoff at 3.5 years or December 31, 2017. Patients at KPWA were censored at disenrollment from the health system.

Next, we evaluated predictors of receipt of shorter-interval screening, defined as having a second Pap test within 30 months (2.5 years) after the index Pap test (Rendle et al., 2018). Patients with no record of a second Pap test were considered as not having the test. For each site, we calculated a mixed-effect 2-level multivariable logistic regression model to identify patient characteristics associated with shorter-interval screening. An intra-class correlation coefficient (ICC) was calculated to quantify the proportion of the observed variation in shorter-interval screening attributable to provider clustering.

Covariates measured at time of the index Pap test included age, race and ethnicity (mutually exclusive categories of Hispanic, non-Hispanic (NH) Asian/ Pacific Islander, NH Black, NH White, NH multi-racial/ other/ unknown), insurance status (commercial insurance, national public insurance [Medicare, Medicaid, and other subsidized programs such as Ryan White, Title V, Breast and Cervical Cancer Services program at PH], other insurance [e.g., non-Medicaid, state-subsidized coverage at KPWA or uninsured/missing insurance status; for PH, this category also included medical assistance programs for uninsured such as Parkland HEALTHplus and other Dallas County assistance programs]). If multiple insurance designations were observed within a calendar year, then a single insurance designation was assigned in decreasing priority as follows: Medicaid, Medicare, and Commercial, and Other/Uninsured, which includes other government payers, other insurance, medical assistance charity program for the uninsured, and uninsured. Public Insurance includes Medicaid. Medicare, and other governmental insurance; Uninsured/Unknown includes uninsured, medical assistance or unknown. Characteristics of the index Pap test included: year of performance, type (conventional, liquid, or unknown), time since Pap test prior to index, specialty of the index Pap test performing provider (family, internal, or general medicine, obstetrics and gynecology (OB/GYN), or other/unknown specialty). In addition, pregnancy status was ascertained at time of index Pap test or between index and subsequent Pap test or within 30 months following the index Pap for those with no subsequent Pap test. Cervical cancer risk status at the time of the index Pap test was defined as average risk if there was at least one documented prior normal screen and no documented abnormal results; otherwise, the individual was considered to have an unknown risk. Sensitivity analysis at KPWA excluded patients known to have disenrolled from the health system. Such information was unavailable at MGB and PH/UTSW.

If a second Pap test was received, we compared the proportion of

Table 1
Descriptive characteristics of women aged 21–29 years at time of index Pap test (2010–2015).

	KPWA [i] (N = 25,651)	PH/ UTSW [i] (N = 25,549)	MGB [i] (N = 18,739)	Total (N = 69,939)
Participant Characteristics at Index Pap test				
AGE (YEARS)				
21–24	11,168 (43.5%)	11,116 (43.5%)	7809 (41.7%)	30,093 (43.0%)
25–29	14,483 (56.5%)	14,433 (56.5%)	10,930 (58.3%)	39,846 (57.0%)
RACE/ETHNICITY [ii]				
Asian/Pacific Islander	2944 (11.5%)	404 (1.6%)	1387 (7.4%)	4735 (6.8%)
Non-Hispanic Black	1362 (5.3%)	4193 (16.4%)	1665 (8.9%)	7220 (10.3%)
Hispanic	1864 (7.3%)	19,719 (77.2%)	3479 (18.6%)	25,062 (35.8%)
Non-Hispanic White	15,466 (60.3%)	1139 (4.5%)	11,505 (61.4%)	28,110 (40.2%)
Multi-Racial/Other/ Unknown	4015 (15.7%)	94 (0.4%)	703 (3.8%)	4812 (6.9%)
INSURANCE STATUS/ TYPE [iii]				
Commercial Insurance	24,250 (94.5%)	652 (2.6%)	13,037 (69.6%)	37,939 (54.2%)
Public Insurance	1368 (5.3%)	19,531 (76.4%)	4878 (26.0%)	25,777 (36.9%)
Other Insurance	33 (0.1%)	748 (2.9%)	0 (0%)	781 (1.1%)
Uninsured/Unknown	0 (0%)	4618 (18.1%)	824 (4.4%)	5442 (7.8%)
PREGNANCY STATUS [iv]				
Not Pregnant	21,005 (81.9%)	14,811 (58.0%)	16,537 (88.2%)	52,353 (74.9%)
Pregnant	4646 (18.1%)	10,738 (42.0%)	2202 (11.8%)	17,586 (25.1%)
RISK STATUS PRIOR TO INDEX PAP [v]				
Average	19,353 (75.4%)	12,312 (48.2%)	10,961 (58.5%)	42,626 (60.9%)
Unknown	6298 (24.6%)	13,237 (51.8%)	7778 (41.5%)	27,313 (39.1%)
Index Pap test Characteristics				
YEAR OF THE INDEX PAP TEST				
2010	6607 (25.8%)	6021 (23.6%)	4814 (25.7%)	17,442 (24.9%)
2011	5947 (23.2%)	5713 (22.4%)	3785 (20.2%)	15,445 (22.1%)
2012	4642 (18.1%)	4789 (18.7%)	3096 (16.5%)	12,527 (17.9%)
2013	3385 (13.2%)	4068 15.9%)	2688 (14.3%)	10,141 (14.5%)
2014	3489 (13.6%)	3466 (13.6%)	2880 (15.4%)	9835 (14.1%)
2015	1581 (6.2%)	1492 (5.8%)	1476 (7.9%)	4549 (6.5%)
TIME SINCE LAST PAP TEST PRIOR TO INDEX PAP TEST				
< 1 Yr.	507 (2.0%)	632 (2.5%)	494 (2.6%)	1633 (2.3%)
1 <= Yrs. to < 2 yrs	2514 (9.8%)	5178 (20.3%)	4284 (22.9%)	11,976 (17.1%)
2 <= Yrs. < 3	2424 (9.5%)	4797 (18.8%)	1836 (9.8%)	9057 (12.9%)
3 <= Yrs. < 4	1083 (4.2%)	1778 (7.0%)	759 (4.1%)	3620 (5.2%)
>= 4 Yrs.	343 (1.3%)	1009 (3.9%)	436 (2.3%)	1788 (2.6%)
No Known Prior Pap test	18,780 (73.2%)	12,155 (47.6%)	10,930 (58.3%)	41,865 (59.9%)
PROVIDER SPECIALTY [vi]				
OB/GYN	5132 (20.0%)	20,668 (80.9%)	2953 (15.8%)	28,753 (41.1%)
Family/ Internal Medicine	18,959 (73.9%)	2428 (9.5%)	9218 (49.2%)	30,605 (43.8%)
Other/Unknown	1560 (6.1%)	2453 (9.6%)	6568 (35.0%)	10,581 (15.1%)
CYTOLOGY TYPE				
Conventional	0 (0%)	7509 (29.4%)	0 (0%)	7509 (10.7%)
Liquid	25,629 (99.9%)	18,040 (70.6%)	18,739 (100%)	62,408 (89.2%)
Unknown	22 (0.1%)	0 (0%)	0 (0%)	22 (0.0%)

[i] KPWA = Kaiser Permanente Washington; PH-UTSW = Parkland Health/ University of Texas Southwestern; MGB = Massachusetts General Brigham.

[ii] Race/Ethnicity was categorized into mutually exclusive categories. The Multi-racial/Other/Unknown category includes Native American/Alaskan Native, Other races, persons identified as Multiple Races, and persons with Unknown races.

[iii] Insurance was ascertained at time of index Pap test performed. For PH-UTSW and MGB, when insurance status was unknown at performance of the index Pap test, insurance during the calendar year in which the test occurred was used to impute insurance status at index Pap test. If multiple insurance designations were observed within a calendar year, then a single insurance designation was assigned in decreasing priority as follows: Medicaid, Medicare, and Commercial, and Other/Uninsured, which includes other government payors, other insurance, medical assistance charity program for the uninsured, and uninsured. Public Insurance includes Medicaid. Medicare, and other governmental insurance; Uninsured/Unknown includes uninsured, medical assistance or unknown.

[iv] Pregnancy status was ascertained at time of index Pap test through second Pap test, or during the 30 months following the index Pap test for those with no second Pap test.

[v] Risk status was determined at the time of the index Pap test event. Those with at least one documented prior normal screen were defined as average risk. Those with no documented prior normal screens were considered to have an unknown screening history.

[vi] FM/IM included Family Medicine, Internal Medicine, General Internal Medicine, and other Internal Medicine specialties. Missing (i.e., blank since specialty information is not expected) and Unknown (i.e., blank but specialty information is expected) were both included in the Other/ Unknown category.

abnormal results by screening interval (<2.5 years vs. longer) and by year (2010–2012, 2013–2015) before and after guideline change, stratified by site. Abnormal cytology results warranting follow-up included the following categories: NILM/ HPV_16/18+, ASC-US/ HPV+, LSIL, ASC-H, HSIL, AGC, suspicious for cancer, or cancer. All statistical tests were two-sided ($\alpha \leq 0.05$). Analyses were conducted using SAS version 9.4 (SAS Institute Inc, Cary, NC).

3. Results

The combined study population across all sites included 69,939 women aged 21–29 years at their index Pap test performed between 2010 and 2015 (Table 1). The characteristics of the study population differed by participating sites. KPWA had a larger percentage of Asian/ Pacific Islander individuals compared to PH and MGB, and PH had a larger percentage of Black and Hispanic individuals compared to KPWA and MGB. The majority of individuals at KPWA and MGB had commercial insurance, whereas the majority of individuals at PH had public insurance. Women at KPWA were more likely to have an unknown prior screening history than PH or MGB. More women from PH were pregnant during the study period compared to KPWA or MGB. OB/GYN specialty providers were more likely to be the performing provider for index Pap tests at PH than at KPWA or MGB. In addition, virtually all Pap tests used

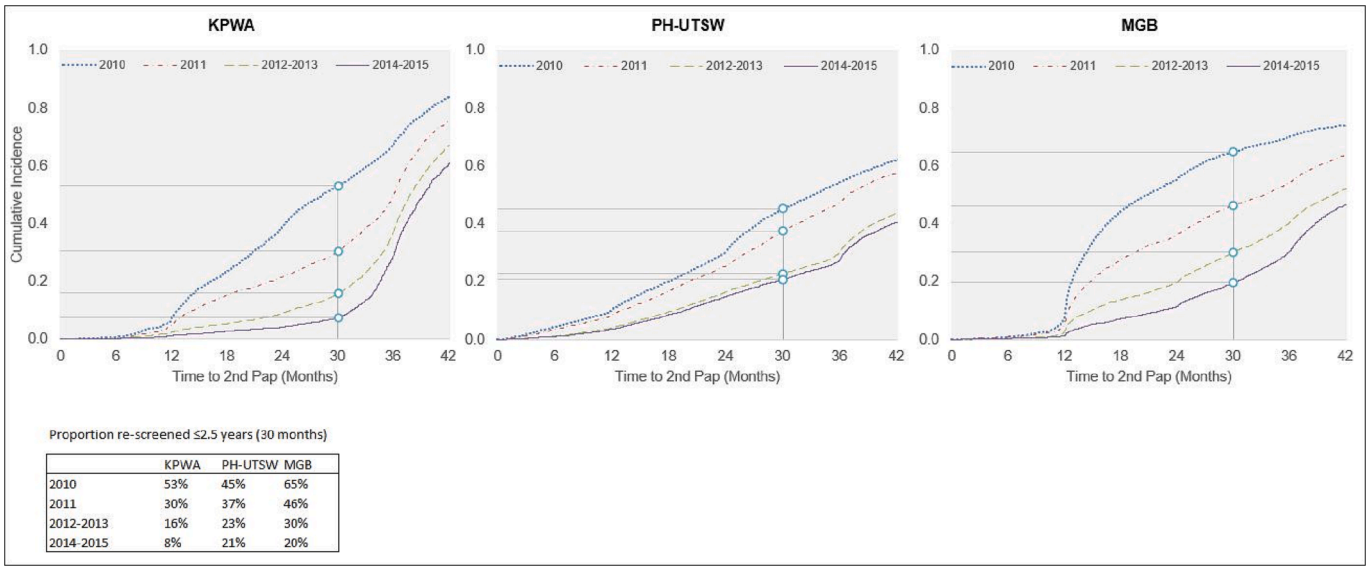

Fig. 1. Cumulative incidence of second Pap test stratified by index Pap test year, by site 2010–2017. KPWA = Kaiser Permanente Washington; PH-UTSW = Parkland Health/University of Texas Southwestern; MGB = Massachusetts General Brigham.

liquid-based cytology at KPWA and MGB, whereas at PH conventional cytology was used in 2010–2011 for patients whose screening test was covered by the Title V maternal and child health program.

Across all sites, the time to next Pap test increased across time periods, with the shortest time to next screen occurring for index Pap tests in 2010, and the longest interval occurring for those in 2014–2015 (Fig. 1). However, there was variation across sites. At KPWA, 53.1% of patients had a second Pap test within 2.5 years of a 2010 index Pap test, compared with 7.5% of persons with an index Pap test in 2014–2015. At PH, 45.2% of patients with an index Pap test in 2010 had a second Pap test within 2.5 years, compared with 20.7% of those with an index Pap test in 2014–2015. At MGB, 64.9% of patients had a second Pap test within 2.5 years of their index Pap test 2010, compared with 19.7% for an index Pap test in 2014–2015.

Shorter-interval screening decreased markedly by year across all sites (Table 2), but additional predictors of shorter-interval screening varied across sites. At KPWA, women aged 25–29 years were less likely to have shorter-interval screening than women aged 21–24 years (OR = 0.91, 95% CI 0.85–0.98). Age was not associated with shorter-interval screening at the other sites. At MGB and KPWA, patients with public insurance were less likely than patients with commercial insurance to have shorter-interval screening (OR = 0.90, 95% CI 0.82–0.98 and OR = 0.71, 95% CI 0.60–0.84, respectively). At PH, those with other insurance were less likely to have shorter-interval screening (OR = 0.75, 95% CI 0.61–0.91) and those who were uninsured or missing insurance status were more likely to have shorter-interval screening (OR = 1.18 95% CI 1.07–1.30) than those with public insurance. At MGB and KPWA, Asian and Pacific Islander women were less likely to have shorter-interval screening than non-Hispanic white women (OR = 0.72, 95% CI 0.63–0.82 and OR = 0.81, 95% CI 0.72–0.92, respectively). At PH, all other racial/ethnic groups were less likely to have shorter-interval screening than Hispanic women. At both KPWA and PH, women who were pregnant during the follow-up period were more likely to have shorter-interval screening. This association was particularly large at PH, as pregnant women had more than 6-fold increase in odds of shorter-interval screening (OR = 6.12, 95% CI 5.73–6.53). At MGB, patients whose index Pap test provider was an OB/GYN were more likely to have shorter-interval screening than patients whose index Pap test was performed by family/internal medicine providers (OR = 1.48, 95% CI 1.26–1.75). In contrast, at PH, patients of family medicine, general internal medicine or other internal medicine providers were more likely to have shorter-interval screening than patients of OB/GYNs (OR = 1.22, 95% CI 1.06–1.41). We observed no association with provider specialty at KPWA. At all sites, the provider random effect was statistically significant, though the proportion of variation in shorter-interval screening attributed to the performing provider was modest, ranging from 1.6% at PH to 10.5% at MGB. Results were, with a few exceptions, similar at KPWA when patients who disenrolled from the health system within 2.5 years were excluded (Supplemental Table A2).

We compared the proportion of abnormal second Pap tests by screening interval (Table 3). Among the 69,939 women with an index Pap test, 36,166 had a second Pap test during the study period (51.7%). Of women with a second Pap test, 19,416 (53.7%) were performed within 2.5 years and 16,750 (46.3%) were performed more than 2.5 years after the index Pap test. The proportion of second Paps that were abnormal was similar for shorter vs. longer interval Pap tests (8.9% and 9.1%, respectively, p = 0.54), and this pattern was consistent across calendar years before and after the new guidelines and across study sites.

We examined whether patients had the same or a different provider between their index and second Pap test (Supplemental Table A3). Among patients with shorter interval screening, 30% had the same provider at both index and second Pap test compared with 21% in the longer interval screening group (p < 0.001). therefore it does not appear that change in provider is associated with shorter interval screening.

4. Conclusions

Overall, our results demonstrate a decline in shorter-interval screening for women aged 21 – 29 years old across three diverse health systems between 2010 and 2015. While this decline is consistent with the adoption of the 2012 consensus guidelines supporting a screening interval for Pap testing every 3 years for average-risk women (Moyer and Force USPST, 2012; Saslow et al., 2012; ACOG Practice Bulletin, 2009), there were important differences in the timing and magnitude of changes between the health systems examined. Even with the decrease over the study period, at two of the three sites, shorter-interval screening remained relatively common, near 20% in 2014–2015. Beyond health system, variation at the provider level was larger at one site than the other two. Pregnant women at two of the three sites were significantly more likely to have shorter-interval screening than women who were not pregnant, though this association was greater

Table 2
Fixed and random effects from multivariable 2-level logistic regression models estimating shorter- vs. longer-interval Pap test screening stratified by site, 2010–2017.

		KPWA (N = 25,651)				PH-UTSW (N = 25,549)				MGB (N = 18,739)			
		Estimate	Std Error	Pr > Z	ICC	Estimate	Std Error	Pr > Z	ICC	Estimate	Std Error	Pr > Z	ICC
Random Effects: Provider-level		0.0606	0.0132	<0.0001	0.0181	0.0525	0.0131	<0.0001	0.0157	0.3846	0.0472	<0.0001	0.1047
Fixed Effects: Patient-level		**OR**	**95% CI**		**Pr > |t|**	**OR**	**95% CI**		**Pr > |t|**	**OR**	**95% CI**		**Pr > |t|**
Performing Provider Specialty [i]	Family/ Internal Med	Reference				Reference				Reference			
	OB/GYN	0.95	(0.85—1.07)		0.3796	0.78	(0.68—0.90)		0.0008	1.48	(1.26—1.75)		<0.0001
	Other/ Unknown	1.09	(0.90—1.31)		0.3932	0.90	(0.73—1.10)		0.3000	0.90	(0.73—1.11)		0.3313
Patient Age (years)	21–24	Reference				Reference				Reference			
	25–29	0.91	(0.85—0.98)		0.0160	1.05	(0.98—1.11)		0.1592	1.05	(0.99—1.13)		0.1292
Insurance type [ii]	Commercial	Reference				Reference				Reference			
	Public	0.71	(0.60—0.84)		0.0001	1.22	(0.97—1.55)		0.0879	0.90	(0.82—0.98)		0.0108
	Uninsured/ Other/ Unknown	1.08	(0.43—2.74)		0.8701	1.34	(1.05—1.69)		0.0171	0.18	(0.15—0.22)		<0.0001
Race/ Ethnicity [iii]	NH White	Reference				Reference				Reference			
	NH Asian/ Pacific Islander	0.81	(0.72—0.92)		0.0007	1.10	(0.81—1.51)		0.5361	0.72	(0.63—0.82)		<0.0001
	NH Black	1.00	(0.85—1.17)		0.9519	1.32	(1.09—1.59)		0.0037	0.92	(0.81—1.04)		0.1868
	Hispanic	1.04	(0.90—1.19)		0.6135	2.00	(1.69—2.38)		<0.0001	1.11	(1.00—1.23)		0.0535
	Multi-Racial/ Other/ Unknown	0.40	(0.36—0.45)		<0.0001	0.74	(0.38—1.43)		0.3667	0.85	(0.71—1.02)		0.0841
Year of Index Pap test	2010	Reference				Reference				Reference			
	2011	0.41	(0.38—0.45)		<0.0001	0.60	(0.55—0.65)		<0.0001	0.45	(0.41—0.49)		<0.0001
	2012	0.20	(0.18—0.23)		<0.0001	0.26	(0.23—0.29)		<0.0001	0.24	(0.21—0.27)		<0.0001
	2013	0.13	(0.12—0.16)		<0.0001	0.24	(0.21—0.26)		<0.0001	0.18	(0.16—0.21)		<0.0001
	2014	0.08	(0.07—0.10)		<0.0001	0.20	(0.18—0.23)		<0.0001	0.13	(0.11—0.14)		<0.0001
	2015	0.05	(0.04—0.07)		<0.0001	0.22	(0.19—0.25)		<0.0001	0.10	(0.08—0.11)		<0.0001
Pregnancy [iv]	No Pregnancy	Reference				Reference				Reference			
	Pregnancy	2.68	(2.45—2.92)		<0.0001	6.09	(5.71—6.50)		<0.0001	1.08	(0.97—1.20)		0.1719

[i]Family/ Internal Med included Family, General Internal Medicine, and other Internal Medicine specialties. Missing (i.e., blank since specialty information is not expected) and Unknown (i.e., blank but specialty information is expected) were both included in the Other/ Unknown category.
[ii]Insurance type was ascertained at time of index Pap test performed. For PH-UTSW, many patients shift between different public payors in a calendar year, so if insurance type was unknown at performance of the index Pap test, insurance during the calendar year in which the test occurred was imputed. For MGB, insurance type during the calendar year in which the test occurred was used. If multiple insurance designations were observed within a calendar year, then designation was assigned in decreasing priority as follows: Medicaid, Medicare, and Commercial, and Other/Uninsured (e.g., other government payors, other insurance, medical assistance charity program), and uninsured. Then, public insurance was classified as Medicaid. Medicare, and other governmental insurance, while uninsured/other/unknown included uninsured, medical assistance, other insurance, or unknown.
[iii]Race and ethnicity were reported in mutually exclusive categories. Patients who reported Hispanic ethnicity were classified as Hispanic, and patients who did not report Hispanic ethnicity were categorized as non-Hispanic (NH) Black, NH White, or NH multi-racial/ other/ unknown. The Multi-racial/Other/Unknown category includes Native American/Alaskan Native, Other races, persons identified as Multiple Races, and persons with Unknown races.
[iv]Pregnancy status was ascertained at time of index Pap test or during the 30 months following the index Pap test for those with no second Pap test.
[v]Insurance type was ascertained at time of index Pap test performed. For PH-UTSW, many patients shift between different public payors in a calendar year, so if insurance type was unknown at performance of the index Pap test, insurance during the calendar year in which the test occurred was imputed. For MGB, insurance type during the calendar year in which the test occurred was used. If multiple insurance designations were observed within a calendar year, then designation was assigned in decreasing priority as follows: Medicaid, Medicare, and Commercial, and Other/Uninsured (e.g., other government payors, other insurance, medical assistance charity program), and uninsured. Then, public insurance was classified as Medicaid. Medicare, and other governmental insurance, while uninsured/unknown included uninsured, medical assistance or unknown.
[vi]Race/Ethnicity was categorized into mutually exclusive categories. The Multi-racial/Other/Unknown category includes Native American/Alaskan Native, Other races, persons identified as Multiple Races, and persons with Unknown races.
[vii]Pregnancy status was ascertained at time of index Pap test or during the 30 months following the index Pap test for those with no second Pap test.

at the one of the three sites. Proportions of second Pap tests that were abnormal did not differ significantly by interval length, and these results were consistent across years and study sites.

The variation in screening intervals for young women and the rate of decline in shorter interval screening across health systems may reflect differences in health system practices and how providers are oriented to changing guidelines as well as the local or state insurance context. Patients at KPWA were most compliant with the new guidelines after 2012, patients at PH experienced the least magnitude of change after the new guidelines, and patients at MGB appeared least compliant with new guidelines. The relatively rapid decline in shorter-interval screening observed at KPWA may reflect that this healthcare system closely follows the USPSTF guidelines as the standard of care and that there is system level implementation of these guidelines. At PH-UTSW, which serves a largely uninsured population, pregnant patients had particularly high likelihood of short interval screening. Eligibility for Medicaid and other public insurance varies widely by state. In Texas, patients are eligible for additional state insurance coverage during pregnancy, which expires after pregnancy. Providers practicing in this context may be more "opportunistic" and offer screening more frequently than recommended because of the concern that their patient population has fragmented access to preventive services after pregnancy (Corley et al., 2016). At MGB, located in Massachusetts which has universal healthcare, younger women and their providers may have fewer constraints in

Table 3
Proportion of abnormal second Pap tests after index Pap test by site, screening interval, and calendar year of index Pap test (N = 36,166).

Site	Year of index Pap test (n 2nd screening Pap test)	Event	2nd Pap test screening interval		*P value*
			≤ 2.5 years	> 2.5 years	
All Sites	All years (n = 36,166)	2nd screening Pap test (row %)[1]	19,416 (53.7%)	16,750 (46.3%)	<0.001
		Abnormal 2nd Pap test (column %)[2]	1723 (8.9%)	1518 (9.1%)	0.544
	2010–12 (n = 27,400)	2nd screening Pap test (row %)[1]	15,506 (56.6%)	11,894 (43.4%)	<0.001
		Abnormal 2nd Pap test (column %)[2]	1332 (8.6%)	1051 (8.8%)	0.487
	2013–15 (n = 8766)	2nd screening Pap test (row %)[1]	3910 (44.6%)	4856 (55.4%)	<0.001
		Abnormal 2nd Pap test (column %)[2]	391 (10.0%)	467 (9.6%)	0.573
KPWA	2010–12 (n = 7272)	2nd screening Pap test (row %)[1]	3698 (50.9%)	3574 (49.1%)	0.041
		Abnormal 2nd Pap test (column %)[2]	238 (6.4%)	258 (7.2%)	0.202
	2013–15 (n = 1761)	2nd screening Pap test (row %)[1]	433 (24.6%)	1328 (75.4%)	<0.001
		Abnormal 2nd Pap test (column %)[2]	48 (11.1%)	121 (9.1%)	0.264
PH-UTSW	2010–12 (n = 11398)	2nd screening Pap test (row %)[1]	5922 (52.0%)	5476 (48.0%)	<0.001
		Abnormal 2nd Pap test (column %)[2]	560 (9.5%)	520 (9.5%)	0.968
	2013–15 (n = 3699)	2nd screening Pap test (row %)[1]	1887 (51.0%)	1812 (49.0%)	0.085
		Abnormal 2nd Pap test (column %)[2]	192 (10.2%)	162 (8.9%)	0.223
MGB	2010–12	2nd screening Pap test (row %)[1]	5886 (67.4%)	2844 (32.6%)	<0.001
	(n = 8730)	Abnormal 2nd Pap test (column %)[2]	534 (9.1%)	273 (9.6%)	0.449
	2013–15	2nd screening Pap test (row %)[1]	1590 (48.1%)	1716 (51.9%)	0.002
	(n = 3306)	Abnormal 2nd Pap test (column %)[2]	151 (9.5%)	184 (10.7%)	0.267

[1]Percentage was calculated based on total number of the study population who received a 2nd screening Pap test.
[2]Percentage was calculated based on the number of 2nd screening Pap test tests classified as abnormal, based on cytology results NILM/ HPV_16/18+, ASC-US/HPV+, LSIL, ASC-H, HSIL, AGC, suspicious for cancer, or cancer.

the choice of Pap test interval than at the other sites, and additionally the fee-for-service structure may incentivize providers toward more screening and more visits rather than less. This idea is consistent with our observation that a much greater proportion of the variation in screening interval was attributed to the provider at MGB than at KPWA or PH-UTSW. A survey of primary care providers at four health systems, including MGB, in 2014 found that 22% recommended annual routine Pap testing for this age group (Haas et al., 2016). Providers were more likely to report cervical cancer screening in excess of guidelines for this age group than any other, and most providers were unaware of the 2012 guideline change (Haas et al., 2016). Providers who reported not changing their screening practices with the new guidelines cited patient concerns about less frequent screening, health system measures based on differing criteria, disagreement with the guidelines, concerns about malpractice risk and lack of time to discuss the benefits and harms of screening (Haas et al., 2016). Shorter interval screening was associated with OB/GYN index Pap test providers at MGB and family medicine/ internal medicine providers at PH-UTSW. At KPWA, there was no significant difference in shorter interval screening by provider specialty. Together, these results suggest that differences in practice patterns by provider specialty are dependent on local context. We hypothesize that factors such as differences in beliefs about the appropriateness of the new guidelines (Haas et al., 2016), patient preferences (Haas et al., 2016), financial incentives, as well as availability of appointments may contribute to differences in screening interval by provider type. System level interventions targeting providers should be considered and evaluated when screening recommendations change in order to increase guideline concordant care.

We observed broad declines in shorter-interval screening over the study period Our findings are consistent with data from a statewide registry in New Mexico that showed a decrease in annual screening from 2013 to 2019 for women age 25–29 years and an increase in the median screening interval (Castle et al., 20222022). We did not observe an increase in the proportion of abnormal second Pap tests for longer screening interval compared with shorter screening interval across these diverse health systems and patient populations. Our findings extend prior work from a single health system (Katki et al., 2013) and we report similar proportions of abnormal Pap tests.

This work is timely given ongoing evolution of screening guidelines for young women. In 2020, the ACS recommended that cervical cancer screening begin at age 25 and that screening every 5 years with primary HPV testing is the preferred strategy, with co-testing every 5 years or Pap testing every 3 years as acceptable alternatives (Fontham et al., 2020), while USPSTF (Moyer and Force USPST, 2012) and ACOG (Updated Cervical Cancer Screening Guidelines Practice Advisory, 2021) have not recommended such changes. This lack of alignment across recommending organizations may lead to confusion among providers as to which guidelines to follow and lead to additional variation in practice patterns within and across health systems; particularly among health systems that do not standardize which guidelines are adopted. Our findings suggest that implementation of these new recommendations; which represent a departure from prior guidelines; will likely require explicit policies and systematic provider education if the goal is to maximize adherence. Given the differences that we observe between health systems, interventions to facilitate implementation could include formal policies and education or electronic health record decision support and "order sets." The effectiveness of such interventions would require evaluation.

Several limitations should be noted when evaluating our results. Pregnancy was defined based on whether a woman was pregnant at any time from index Pap test through second Pap test or the end of follow-up for women without a second Pap test. Though this definition uses pregnancy status after the index Pap test, pregnancy precedes the outcome, and therefore temporality of the association is maintained. In addition, at PH-UTSW and MGB, we lack information on whether patients remained in care through the end of follow-up, and as a result we are likely underestimating the occurrence of second Pap tests among patients who sought care elsewhere. However, our results that excluded women who dis-enrolled from the health system at KPWA yielded similar results to models that included these patients. Our groupings of provider specialties and insurance status may be inadequate, as insurance types and the composition of provider specialties may differ across the sites in ways we are unable to fully detail. Finally, we were unable to distinguish and exclude second Pap tests performed due to symptoms. We were only able to exclude diagnostic Pap tests in which a diagnostic procedure (colposcopy and/or biopsy) was performed during the same visit as a Pap test. However, the proportion of abnormalities was not higher for shorter-interval Pap tests, as would be expected if earlier screening was largely related to symptoms.

To our knowledge this is the first study to examine multi-level predictors of cervical cancer screening interval length among women in their 20 s, detailing patterns of implementation of new screening guidelines across different health systems in different parts of the country. In conclusion, we found that rates of shorter-interval cervical

cancer screening among women 21–29 years old decreased over time following changes in guidelines that recommended a longer screening interval. However, the magnitude of and rate at which change occurred as well as factors associated with shorter screening intervals varied among the three health care systems examined. Cervical cancer screening as practiced may not be optimized with respect to benefits and harms and our work supports the need to improve implementation of screening recommendations.

Disclosure of Funding and Conflicts of Interest

This work was supported by the National Cancer Institute (NCI grant number UM1CA221940). The views expressed here are those of the authors only and do not necessarily represent the views of the National Cancer Institute or National Institutes of Health. None of the authors report a conflict of interest.

CRediT authorship contribution statement

Anne Marie McCarthy: Conceptualization, Investigation, Writing – original draft, Project administration. **Jasmin A. Tiro:** Conceptualization, Investigation, Writing – review & editing, Supervision, Funding acquisition. **Ellen Hu:** Formal analysis, Investigation, Data curation, Writing – review & editing, Visualization. **Sarah Ehsan:** Writing – review & editing. **Jessica Chubak:** Investigation, Writing – review & editing. **Aruna Kamineni:** Conceptualization, Investigation, Writing – review & editing, Supervision, Funding acquisition. **Sarah Feldman:** Conceptualization, Investigation, Writing – review & editing. **Steven J. Atlas:** Conceptualization, Investigation, Writing – review & editing. **Michelle I. Silver:** Conceptualization, Investigation, Writing – review & editing. **Sarah Kobrin:** Conceptualization, Investigation, Writing – review & editing. **Jennifer S. Haas:** Conceptualization, Investigation, Writing – review & editing, Supervision, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgements

Contributors: The authors wish to thank the participating METRICS sites for the data they have provided for this study. A list of the METRICS investigators and contributing research staff is provided at: https://utsouthwestern.edu/labs/prospr-metrics.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2023.102279.

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