Research Article

A Population-Based Evaluation of Cervical Screening in the United States: 2008–2011

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Abstract

Background: Cervical screening consumes substantial resources, but little is known about utilization in the United States or compliance with guideline recommendations.

Methods: To describe population screening coverage, utilization, and outcomes and examine time trends from 2008 to 2011, cervical cytology reports from women residing in New Mexico (981,063 tests from 511,381 women) were evaluated.

Results: From 2008 to 2011 cervical screening utilization decreased at all ages, but especially in younger women, with a two-third reduction at ages 15 to 20 years. Ninety-four percent of women ages 25 to 29 years were screened within 48 months but coverage decreased at older ages to 69% at 45 to 49 years and 55% at 60 to 64 years. Intervals between screening tests were significantly longer in 2011 compared with 2008 [HR = 1.23; 95% confidence intervals (CI), 1.22–1.24], although the commonest rescreening interval was 13 months. In 2011, 91.9% of screening tests for women ages 21 to 65 years were negative, 6.6% showed minor abnormalities, and 1.0% high-grade abnormalities. High-grade abnormality rates were relatively constant over time, but minor abnormalities and atypical cells cannot rule out high-grade (ASC-H) were increasing.

Conclusions: This population-based evaluation of cervical screening shows high coverage under the age of 40 years, but lower levels in older women. Screening under age 21 years is becoming less common and screening intervals are lengthening, reflecting updates in national screening guidelines.

Impact: Assessment of cervical screening intervals and population outcomes is essential for accurately estimating the impact and effectiveness of changing recommendations and vaccination against human papilloma virus infections. *Cancer Epidemiol Biomarkers Prev; 23(5); 765–73. ©2013 AACR.*

Introduction

Although cervical cancer screening by cytology has never been subjected to a randomized clinical trial, there is indisputable evidence from disease trend data in whole populations and case–control studies that it has been highly effective in reducing the incidence of and mortality from cervical cancer in parts of the world where adequate infrastructure and program organization exists. The best outcomes have been achieved by organized programs such as those in Finland, Sweden, the Netherlands, and the United Kingdom (1–8), and such programs are also able to regularly monitor performance, not only for cancer reduction, but also in terms of utilization and adherence to guidelines. With this information cost-effectiveness analyses can be performed to evaluate and modify screening recommendations, such as age at starting and stopping screening, screening interval, and appropriate surveillance algorithms.

We believe the New Mexico HPV Pap Registry (NMHPVPR) is the first population-based registry in the United States, which is monitoring the full spectrum of cervical cancer preventive care. Its remit is to document patterns of cervical cancer screening utilization, outcomes, and treatment of precancerous lesions and to facilitate surveillance of the population coverage and effectiveness of prophylactic human papilloma virus (HPV) vaccination. This will enable evaluation of adherence to guidelines and monitoring of changes in disease prevalence as HPV vaccination and HPV-based screening become more widely introduced. In conjunction with the well-established New Mexico Tumor Registry, it will also facilitate cohort and case–control analysis of the impact of screening on cancer incidence and mortality, as has been done elsewhere (2, 8–19).

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Cervical cancer screening recommendations in the United States have undergone steady evolution as new knowledge becomes available. To enable appropriate interpretations of cervical screening surveillance information, an overall understanding of changes in cervical screening guidelines is necessary as clinical practice changes are gradually adopted and outcomes are potentially impacted. As such, we briefly outline those changes that immediately preceded (since the year 2000), were coincident with, or occurred following the population-based evaluations presented in this report.

In 2002, the American Cancer Society (ACS) recommended annual Pap or bi-annual liquid-based cytology (LBC), starting at the age 21 years or 3 years after the age of sexual initiation and stopping at age 70 following 3 negative Pap tests (20). ACS also made a preliminary recommendation for high-risk HPV (HR-HPV) every 3 years for women 30 years and older. In 2003, American College of Obstetricians and Gynecologists (ACOG) and U.S. Preventive Services Task Force (USPSTF) updated their recommendations from the 1990's. ACOG recommended annual cytology (no distinction between Pap or LBC) and extending screening intervals to 2 to 3 years in women 30 years and older following 3 consecutive negative cytology screenings, with the same starting ages as recommended by the ACS and no specific recommendation to stop screening (21). USPSTF recommend cytology screening at least every 3 years, with the same starting ages as recommended by the ACS and stopping at the age of 65 years (22).

The ACS, the American Society for Colposcopy and Cervical Pathology (ASCCP), and the National Institutes of Health/National Cancer Institute (NIH/NCI), in 2004, and following the first U.S. Food and Drug Administration approval of the clinical test for HR-HPV to be used in cervical cancer screening issued an interim guidance (23) for concurrent HR-HPV and cytology testing ("cotesting") every 3 years, with a 12-month follow-up of women with HR-HPV negative and atypical squamous cells of undetermined significance (ASC-US) (HR-HPV-negative ASC-US) and 6- to 12-month follow-up of HR-HPV positive and normal/negative cytology (HR-HPV-positive negative cytology). The ASCCP reiterated these recommendations in 2006 and suggested that when HPV16 and HPV18 testing was available, women with HR-HPV-positive negative cytology who tested positive for either or both HPV16 and HPV18 could be referred immediately to colposcopy (24, 25). In 2009, both ASCCP (26) and ACOG (27) recommended that cervical cancer screening uniformly starts at the age of 21 years.

Finally, based on an even greater body of knowledge, following a lengthy process of carefully consideration by many individuals and organizations, new U.S. screening guidelines by the major organizations that provide recommendations on cervical cancer screening were issued in 2012 (28–30). The 2012 revised recommendations are very briefly summarized as follows: screening for all women should begin at age 21 years; for women 21 to 29 years, cytology alone every 3 years is recommended; for women 30 to 65 years, cotesting every 5 years is recommended, or cytology alone every 3 years may be continued to age 65 years. Most women can discontinue screening at age 65 years or after hysterectomy with removal of the cervix.

This report examines screening utilization and population coverage and time trends in New Mexico to determine the impact of changes associated with these recommendations (20–27), notably initiating cervical cancer screening at the older age of 21 years, extending the interval between screens and stopping screening at age 65 years. Here we document screening utilization and outcome before a high uptake of HPV-vaccination occurs, which provides a baseline for determining the impact of the HPV vaccine on screening practices and disease incidence and allows evaluation of the implementation of more recent national cervical screening recommendations in the United States (28–30).

Materials and Methods

Design and overview

The New Mexico HPV Pap Registry. NMHPVPR is located at the University of New Mexico (Albuquerque, NM) and acts as a designee of the New Mexico Department of Health (NMDOH). The NMHPVPR operates under NMAC 7.4.3, which specifies the list of Notifiable Diseases and Conditions for the state of New Mexico. In 2006, NMAC 7.4.3 specified that laboratories must report to the NMHPVPR all cytology tests and results, cervical pathology, and HPV tests performed on women residing in New Mexico. NMAC 7.4.3 was updated in 2009 to also include vulvar and vaginal pathology (31). Ongoing evaluations of cervical screening, diagnosis, and treatment by the NMHPVPR have been reviewed and approved under exempt status by the University of New Mexico Human Research Review Committee.

Data on cervical cytology were obtained for the period January 1, 2007, to January 1, 2012, from 9 laboratories in New Mexico and 9 out-of-state laboratories (corporate entities operating multiple facilities were counted as one unit). All hospitals and clinical practices in New Mexico report through these laboratories. Probabilistic matching and linking of different tests to the same woman was performed using Registry Plus Link Plus (32) and augmented by manual reviews where linkage (nonlinkage) was uncertain. Manual checking involved checking addresses and near matches for personal identifiers.

Setting and participants

Population and cytologic classification. A total of 981,063 cervical cytology tests performed on women residing in New Mexico were obtained from 2008 to 2011. These were linked to 511,381 distinct women. Here we focus on women ages 21 to 65 years (863,608 tests and 451,255 women), but for completeness provide results for the broader age band 15 to 84 years in the Supplementary material (978,369 tests and 509,488 women;

Supplementary Fig. S1). We defined a "screening test" as a cytology test, which was at least 300 days after any previous cytology test (33) to exclude tests resulting from short-term surveillance following an abnormal result, but to include an "annual" cytology test that may have occurred up to 2 months early. Annual cytology test utilization and screening test rates by year and age group were calculated using U.S. Census data for 2010, intercensal population estimates for years 2008 to 2009 and postcensal estimates for 2011 (34). The estimated New Mexico female population ages 21 to 65 years was 591,413 in 2008, 605,344 in 2010, and 608,943 in 2011.

Outcomes and follow-up

Age-specific screening coverage rates were calculated for 18, 36, and 48 months before the landmark date of January 1, 2012 (using the 2011 census estimate to provide a denominator for that time point) for comparison with 3-year screening rates based on guideline recommendations (20–27) and to parallel estimates of 1- and 3-year coverage reported by the U.S. Centers for Disease Control and Prevention (CDC; ref. 35). For the 1-year estimate, we included a 6-month "grace period" by showing coverage at 18 months, and for the 3-year estimate, we included a 12-month "grace period" by showing coverage at 48 months. This approach incorporates additional time to accommodate for short delays in annual or triennial screening and provides the most favorable estimate of coverage likely achieved. Screening intensity was defined as the number of screening tests per woman in the 4 years from 2008 to 2011. The number of unscreened women was calculated as the difference between the 2008 census population estimate and women with a recorded test during 2008 to 2011. Data collection and handling methods were unchanged throughout the entire evaluation period. All cervical cytology results were included in this study, including cotesting or cytology alone.

Cytologic results were classified according to the 2001 Bethesda System (36) as high-grade squamous intraepithelial lesion (HSIL), atypical squamous cells cannot rule out HSIL (ASC-H), atypical glandular cells (AGC), low-grade squamous intraepithelial lesion (LSIL), atypical squamous cells of undetermined significance (ASC-US), and negative for intraepithelial lesion or malignancy. Tests reported as LSIL cannot rule out HSIL (LSIL-H) were categorized as ASC-H, CIN1 as LSIL, and CIN2, CIN2-3, CIN3, carcinoma *in situ* (CIS), or possible carcinoma as HSIL as previously described (23).

Statistical methods

We primarily have used tabular and graphical methods for proportions and changes in proportions with 95% confidence intervals (CI) based on binomial statistics and a normal approximation where appropriate. Kaplan–Meier analyses and proportional hazard models were used in reverse time to examine intervals between screening tests. Reverse-time intervals were censored on December 31, 2006 or on the 15th birthday if it was later.

Log-linear binomial regression was used to assess trends in cervical screening coverage and abnormality rates over time. The association between age and screening intensity was assessed using a Cochran–Armitage trend test. SAS v9.3 (SAS Institute Inc.) was used to perform analyses.

Results

Cytology utilization, screening intervals, and coverage

In 2011, 219,610 cytology tests were recorded from 210,273 women ages 15 to 84 years (Supplementary Fig. S1). Of these 200,159 tests (91.1%) were considered "screening tests." Screening utilization from 2008 to 2011 by age is shown in Fig. 1 and Supplementary Table S1, indicating a significant decrease in the percent of women screened for all age groups ($P < 0.001$). The decrease was greatest in the 15 to 20 years age group, with a 61% reduction from 22.4% in 2008 to 8.7% in 2011. Reductions in all other age groups during this period were smaller, ranging between 3% and 6% for absolute reductions and 12% to 27% in relative terms.

The time since the previous screening test by year in which the index test was collected is shown in Fig. 2A for women ages 21 to 65 years. It was significantly longer in 2011 compared with 2008 (HR = 1.23; 95% CI, 1.22–1.24). Longer screening intervals imply lower annual screening rates, and this decrease seemed to be largely because of fewer women being screened within 2 years. Coverage within 5 years was around 80%. Figure 2B shows the median time to last screening test by age. For women ages 21 to 65 years, it increased from 1.50 years in 2008 to 1.87 years in 2011.

Figure 3A shows a histogram of number of screening tests or intensity of screening over the 4-year period of 2008 to 2011 by age on January 1, 2008, where those with no tests are inferred from the state population. Overall, 28.9% of women ages 21 to 65 years had no screening tests and this increased with age from 5.3% among women ages
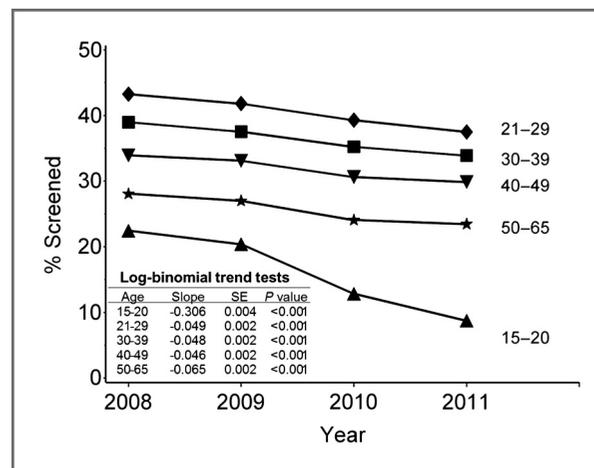

Figure 1. Percent of New Mexico female population with a screening cytology test (Pap test) during a specific year by age group.
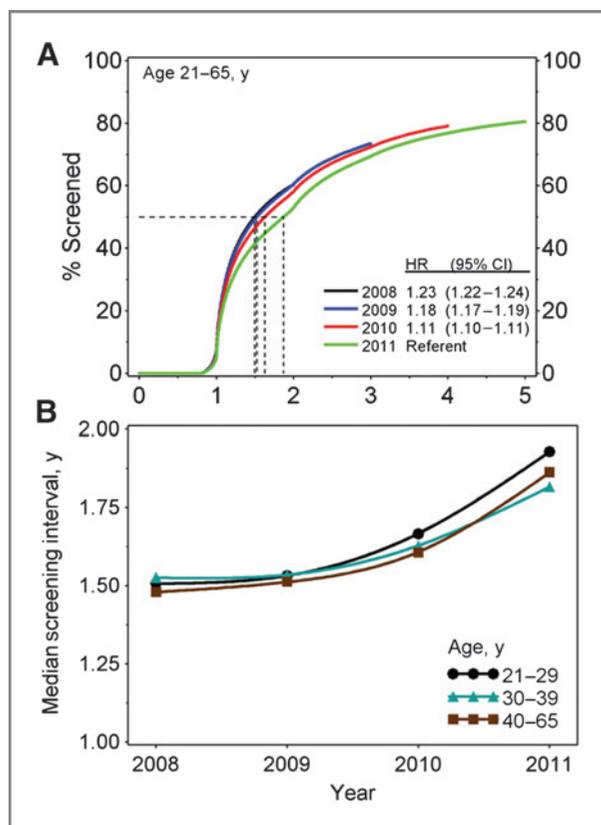
Figure 2. A, Kaplan–Meier estimates for time since previous cervical screening test by year index test was performed with HR and 95% CIs from Cox model regression analyses; B, median time to last screening test by age group in the given year.

21 to 24 years to 45.6% for age 50 to 65 years. Only 15.2% of women ages 21 to 65 years were regularly screening on an annual basis as demonstrated by 3 or more screening tests within this 4-year period. This rate decreased significantly with age ($P < 0.001$). Regular annual screening was practiced by 18.3% of women ages 21 to 24 years, 18.7% at age 25 to 29 years, 17.1% at age 30 to 39 years, 16.2% at age 40 to 49 years, and 11.6% of women ages 50 to 65 years.

Screening at intervals of less than 300 days following a negative result (designated "over screening" below) has been decreasing. For women ages 21 to 65 years, those who had a screening test in 2010 with a negative outcome, the proportion who had their next test within 300 days was 3.6% (95% CI, 3.5–3.7) compared with 4.2% (4.2–4.3) in 2008. Over screening also decreased with age ($P < 0.001$), being 6.9% (95% CI, 6.7–7.1) among women ages 21 to 29 years, 4.3% (4.1–4.4) for women ages 30 to 39 years, and 1.7% (1.7–1.8) for women ages 40 to 65 years screened in 2010.

As of January 1, 2012, 76.7% of the population ages 21 to 65 years had a screening test within the prior 48 months, 64.6% within 36 months, and 42.4% within 18 months (Fig. 3B). Forty-eight–month coverage peaked at 93.6% for women ages 25 to 29 years and then decreased with age.

For women who had a screening test in 2011 and at least 1 previous test, the most common return time was 13 months for women ages 21 to 29 years and women ages 30 to 65 years (Fig. 4A and B).

Screening outcomes

Cytology results in 2011 are shown for different ages in Table 1. Overall, 91.9% of screening tests were negative, 6.6% were minor cytologic abnormalities (ASCUS, LSIL), and 0.9% exhibited higher grade abnormalities [ASC-H, HSIL, AGC, adenocarcinoma *in situ*, adenocarcinoma squamous cell carcinoma, or unspecified cancer (CA)]. Over a quarter of adenocarcinoma (ADCA) or 10 of 38 cases were diagnosed among women beyond the age for which screening is still recommended. Most abnormalities were more common in younger women; ASCUS results were reported in 8.2% of tests for women ages 15 to 20 years, but in only 2.8% of women ages 50 to 65 years. Similarly LSIL dropped from 8.4% to 0.6% for these age groups and ASC-H from 0.6% to 0.2%. Full details of outcome by year are shown in Supplementary Table S2. HSIL was highest in the 21 to 29 years age group (0.5%), whereas AGC peaked in the 40 to 49 years age group (0.4%). ASCUS, LSIL, and ASC-H rates increased from 2008 to 2011 (Table 2), with annual increases of 5.0% for ASCUS, 9.1% for LSIL, and 6.8% for ASC-H.
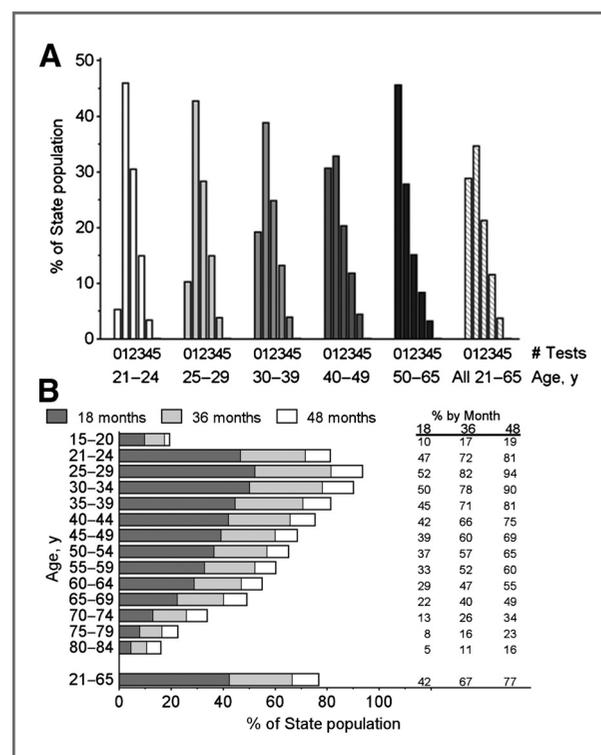

Figure 3. A, percentage of women with different numbers of cervical screening tests by age (on January 1, 2008) between years 2008 and 2011. B, percentage of women with at least one cervical screening test in the previous 18, 36, and 48 months before January 1, 2012, by age on January 1, 2012.
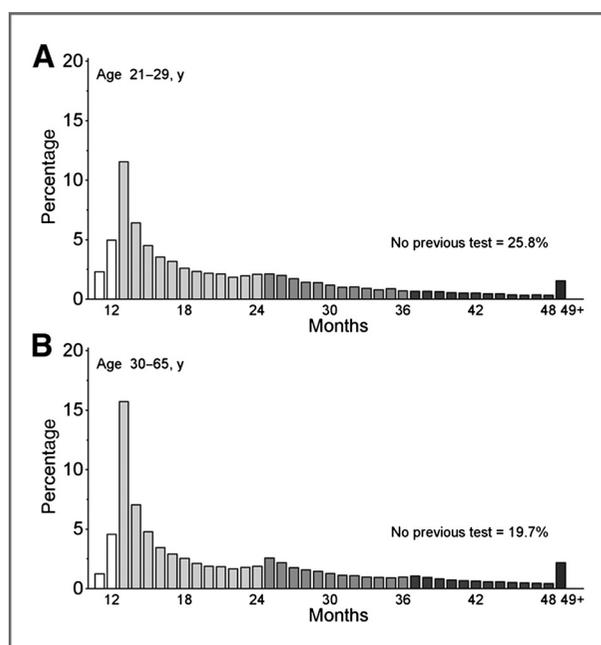
Figure 4. Screening interval distributions (months between cytology tests) among women with a screening test in 2011 and ages 21 to 29 years (A) and 30–65 years (B). The 49+ months category includes women with no previous screening test.

Discussion

The NMHPVPR is the first state wide registry in the United States, and here we provide the first population-based snapshot of cervical screening utilization, coverage, and outcomes across the spectrum of clinical practice care delivery, funding structures, organizational systems, facilities, and practice and provider levels. Not only does the NMHPVPR provide critical basic information, but it also creates an opportunity to evaluate the effectiveness of cervical screening in reducing cancer incidence and to understand in detail the natural history of HPV-related cervical disease. Some countries currently use similar systems more actively to invite women for screening, improve follow up of abnormal screening results, and monitor outcomes on an individual basis (37). Over time data collected from this surveillance system have the potential to pinpoint reasons for cancer development, including lack of attendance for screening, failure to follow up abnormal tests, missed abnormalities present in the sample, inadequate sample, inadequate treatment of abnormal findings, and an apparently adequate sample but negative test result despite disease being present. This information can identify opportunities for improving the delivery of the service under standard care practices, and also monitor the impact of new guidelines such as those related to the age at starting and stopping screening, the introduction of HPV testing—either as an adjunct to cytology or as the sole screening test and extending screening intervals. It is also important to have a baseline measure of screening parameters before HPV vaccination has an impact on women ages 21 years or more. In a 2010 national U.S. survey, very few women of age >26 years had been vaccinated and an estimated 17.5% of those ages

Table 1. Cervical cytology results from screening tests in 2011 overall and by age

	Age group						
	15–20	**21–29**	**30–39**	**40–49**	**50–65**	**66–84**	**21–65**
Test result[a]	***N* (%)**	***N* (%)**	***N* (%)**	***N* (%)**	***N* (%)**	***N* (%)**	***N* (%)**
Negative	6,099 (81.9)	41,162 (87.1)	39,021 (91.8)	37,225 (93.5)	50,113 (95.3)	9,370 (95.4)	167,521 (91.9)
ASC-US	612 (8.2)	3,314 (7.0)	1,983 (4.7)	1,676 (4.2)	1,496 (2.8)	194 (2.0)	8,469 (4.6)
LSIL	628 (8.4)	2,018 (4.3)	850 (2.0)	415 (1.0)	323 (0.6)	44 (0.4)	3,606 (2.0)
ASC-H	42 (0.6)	295 (0.6)	177 (0.4)	72 (0.2)	100 (0.2)	17 (0.2)	644 (0.4)
HSIL	24 (0.3)	247 (0.5)	147 (0.3)	67 (0.2)	43 (0.1)	12 (0.1)	504 (0.3)
SCC	0 (0)	1 (0.0)	4 (0.0)	2 (0.0)	4 (0.0)	2 (0.0)	11 (0.0)
AGC	3 (0.0)	80 (0.2)	126 (0.3)	148 (0.4)	160 (0.3)	28 (0.3)	514 (0.3)
AIS	0 (0)	2 (0.0)	3 (0.0)	1 (0.0)	0 (0)	0 (0)	6 (0.0)
ADCA	0 (0)	2 (0.0)	2 (0.0)	4 (0.0)	20 (0.0)	10 (0.1)	28 (0.0)
CA	0 (0)	1 (0.0)	0 (0)	1 (0.0)	2 (0.0)	2 (0.0)	4 (0.0)
Insufficient/No Dx	43 (0.6)	157 (0.3)	184 (0.4)	219 (0.5)	347 (0.7)	143 (1.5)	907 (0.5)
All	7,451 (100.0)	47,279 (100.0)	42,497 (100.0)	39,830 (100.0)	52,608 (100.0)	9,822 (100.0)	182,214 (100.0)
ASC-US + LSIL	1,240 (16.6)	5,332 (11.3)	2,833 (6.7)	2,091 (5.2)	1,819 (3.5)	238 (2.4)	12,075 (6.6)
ASC-H & HSIL+	69 (0.9)	628 (1.3)	459 (1.1)	295 (0.7)	329 (0.6)	71 (0.7)	1,711 (0.9)

NOTE: Screening tests were performed at least 300 days after any previous cytology test.

[a]ASC-US, atypical squamous cells of undetermined significance; ASC-H, atypical squamous cells cannot rule out HSIL; LSIL, low-grade grade squamous intraepithelial lesion; HSIL, high-grade squamous intraepithelial lesion; SCC, squamous cell carcinoma; AGC, atypical glandular cells; AIS, adenocarcinoma *in situ*; ADCA, adenocarcinoma; CA, carcinoma not otherwise specified; Insufficient/No Dx, insufficient sample for diagnostic test or no diagnosis provided.

Table 2. Annual change (percent) in cervical screening test outcome by age (and overall) from 2008–2011

| | Age group | | | | | | | | | | | | |
| | 15–20 | | 21–29 | | 30–39 | | 40–49 | | 60–65 | | 66–84 | | 21–65 | |
Test result[a]	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI	%	95% CI
Negative	−0.9	(−1.3, −0.6)	−0.6	(−0.7, −0.4)	−0.5	(−0.6, −0.4)	−0.3	(−0.4, −0.1)	−0.1	(−0.1, 0.0)	−0.1	(−0.3, 0.1)	−0.3	(−0.4, −0.3)
ASC-US	2.9	(0.2, 5.7)	4.7	(3.2, 6.3)	5.7	(3.7, 7.8)	5.4	(3.2, 7.6)	4.1	(1.7, 6.5)	3.5	(−2.4, 9.8)	5.0	(4.0,6.0)
LSIL	8.7	(5.6, 12)	6.2	(4.1, 8.3)	14	(10, 18)	10	(5.3, 15)	13	(7.0, 19)	14	(−1.0, 30)	9.1	(7.5,11)
ASC-H	4.0	(−6.9, 16)	7.5	(2.1, 13)	6.9	(0.0, 14)	−1.1	(−9.9, 8.6)	11	(1.2, 22)	4.9	(−15, 29)	6.8	(3.1,11)
HSIL	−7.0	(−19, 6.2)	0.5	(−4.8, 6.1)	3.9	(−3.2, 12)	12	(0.1, 25)	2.5	(−10, 17)	15	(−8.3, 45)	3.2	(−0.7,7.3)
AGC	−8.3	(−32, 24)	0.5	(−8.9, 11)	6.6	(−1.7, 15)	−1.8	(−8.4, 5.4)	2.5	(−4.6, 10)	0.1	(−14, 17)	1.6	(−2.3,5.7)
AIS	—		4.2	(−61, 177)	81	(−42, 461)	6.8	(−73, 325)	—		0.0	(0.0, 0.0)	32	(−32,159)
CA	—		0.0	(0.0, 0.0)	−47	(−95, 481)	6.1	(−57, 163)	−3.4	(−42, 62)	20	(−36, 123)	16	(−26,79)
SCC	—		0.0	(0.0, 0.0)	16	(−32, 97)	0.4	(−48, 95)	−17	(−41, 17)	16	(−30, 92)	−4.2	(−26,24)
ADCA	—		31	(−41,191)	4.5	(−61,178)	18	(−24,82)	24	(−4.6,61)	14	(−14, 53)	25	(1.1,55)
Insufficient/No Dx	−4.4	(−14, 5.8)	−12	(−17,−6.6)	−11	(−16,−5.8)	−8.2	(−13,−3.4)	−13	(−17,−10)	−5.5	(−11, 0.7)	−11	(−14,−9.3)
ASC-US and LSIL	5.5	(3.6, 7.5)	5.2	(4.0, 6.5)	7.9	(6.1, 9.7)	6.2	(4.2,8.2)	5.4	(3.3,7.6)	5.1	(−0.4, 11)	6.1	(5.3, 7.0)
ASC-H and HSIL+	−1.3	(−9.1, 7.1)	3.9	(0.3, 7.6)	6.1	(1.8, 11)	1.5	(−3.4,6.6)	5.3	(0.1,11)	6.8	(−3.2, 18)	4.3	(2.1, 6.6)

NOTE: Annual changes (% and 95% CI) are based on rate ratios for a log-linear model with binomial errors. Cells with too few cases are indicated by a dash.

[a]ASC-US, atypical squamous cells of undetermined significance; ASC-H, atypical squamous cells cannot rule out HSIL; LSIL, low-grade squamous intraepithelial lesions; HSIL, high-grade squamous intraepithelial lesions; SCC, squamous cell carcinoma; AGC, atypical glandular cell; AIS, endocervical adenocarcinoma *in situ*; ADCA, endocervical adenocarcinoma not otherwise specified; CA, carcinoma not otherwise specified; Insufficient/No Dx, insufficient sample for diagnostic test or no diagnosis.

21 to 26 years had at least one dose with <10% having had 3 or more doses (38). In New Mexico, preliminary data indicate women ages 21 to 26 years may have even lower rates of HPV vaccination so this will have had a minimal impact on our current findings (data not shown). As more of the population becomes vaccinated against HPV infections, the primary cause of cervical cancer, reductions in disease prevalence will require attendant adjustments in screening policy.

Our analyses demonstrate a decrease in the proportion of women attending for cervical screening across all age groups, extending a report from CDC's Behavioral Risk Factor Surveillance System (BRFSS) for women ages 18 to 30 years (39). Part of this decrease is almost certainly because of earlier changes in U.S. guidelines (20–27), which recommended a later age at initiating screening and a longer interval between screening episodes, especially when cotesting with HPV is used. However, this may also reflect a general decrease in attendance for preventive health services as a result of the ongoing economic recession. Overall 28.9% of women ages 21 to 65 years had no reported tests during the study period. Our results indicate that screening coverage is still high among women ages 21 to 40 years, but drops substantially above that age. This is a real concern, as the median age for invasive cervical cancer diagnosis in New Mexico (and the United States overall) is 48 years (40, 41). At this stage, it is not possible to assess the extent to which this is because of more women not attending at all for screening or if it is just a small increase in intervals between screens in a larger fraction of the population. The situation will become

clearer as the NMHPVPR database matures, so we can look at trends in proportions screened within the last 3 years and last 5 years. This will also help to assess the impact of the more recent guideline changes on extended intervals and to monitor the extent to which screening under age 21 years will continue to decrease.

A general concern with the BRFSS survey is that coverage estimates were based on landline telephone interviews, and did not include clinical verification (35, 42). For New Mexico, the 2010 BRFSS reported at least one cytology test in the previous 3 years as follows: 89.4% for women ages 25 to 34 years, 88.6% at ages 35 to 44 years, 84.3% at ages 45 to 54 years, and 82.2% for women ages 55 to 64 years. This is substantially higher than our record-based estimates, especially for older women. Previous studies have suggested that self-reported cancer screening can result in inaccurate estimates of time since last screen (43, 44) and these data highlight the importance of laboratory-verified population-based surveillance to accurately measure the true utilization of screening. Among older women, most women with a hysterectomy no longer need screening. We do not currently have this data, but hope to be able to add it in the future as an adjustment to our estimates of population coverage. Adjustments for hysterectomy may have implications for the population-based screening rates reported here, especially for older women.

Although high-grade cytologic abnormality rates were fairly constant over the 5 years of this survey, minor cytologic abnormalities and ASC-H were increasing. These changes could not be explained simply by

cumulative effects of longer average intervals between screens, but could be because of a number of other reasons, including changes in clinical diagnostic practices or changes in sexual behavior or other factors affecting HPV prevalence. This will pose problems for assessing the impact of HPV vaccination on ASC-US and LSIL cytology, one of the earliest indicators of vaccine effectiveness, and it will be important to monitor and adjust for differences in screening intervals when studying these endpoints.

An issue regarding the validity of these data is the accuracy of population ascertainment, including issues of undercount and in- and out- migration during the survey period. In the 2010 census, undercount for age 20 to 64 years was less than 0.5% based on estimates made for the NMDOH (http://ibis.health.state.nm.us/), and net population immigration was 0.4% between 2010 and 2011 for women ages 20 to 64 years (bber.unm.edu/bber_research_demPop.html). These effects are likely to have a minimal impact on our population estimates. However, we do not have information regarding previous screening for women moving into New Mexico, which would lead to underestimates of coverage. Conversely, for women emigrating from the state, their prior screens would be included in our database, but they would not be included in the population denominator, leading to overestimates of coverage. Assuming net in-migration exceeded out-migration by 0.4% per annum at all ages and screening intensity was similar in these women and uniform over time, this could lead to our 3-year coverage estimates being as much as 0.6% too low in relative terms.

Another issue relates to the completeness of the data on screening visits. We estimate a very small percentage (less than 1%) of cytology tests performed on women residing in New Mexico may not be documented in the NMHPVPR.

A further issue is the completeness of linkage of separate cytology reports to individual women. Failure to link records from the same woman would lead to higher estimated overall coverage levels, and longer screening intervals than is truly the case. Extensive efforts indicate that linkage is very complete. For example in other analyses, biopsy reports could be linked to a recent cytology report in 99% of the cases. However, only 1.1% of tests had partial matches that were not taken to be linked, but which had an appreciable probability of linkage to a known record had full information been available.

There is evidence from other countries (1–8) that a centralized registry can improve the overall management of a screening program. Our report provides the first detailed population-based evidence of the extent to which guidelines related to increasing the age at initiating screening and extending the interval between screens are being adhered to. Although cervical screening practices in the New Mexico population may not reflect the situation in other parts of the United States, the methodology developed here is likely to have wider use. The activities of the NMHPVPR program require the collation of information from a wide range of healthcare organizational structures, and the strategies developed here could be used to support not only cervical cancer prevention programs, but also serve as a model for monitoring screening activity at other cancer sites such as the breast, bowel, prostate, and lung. They may also be helpful for programs targeting other sexually transmitted infections (STI; e.g., chlamydia, gonorrhea, trichomonas), because opportunistic screening for non-HPV STIs commonly has occurred at the time of cervical screening, especially for young women (45, 46). Linkage of the NMHPVPR screening data with laboratory-based reporting systems can help to study changes in STIs reporting and associated outcomes potentially related to changes in cervical screening services. Under the U.S. Affordable Care Act implementation, this will become even more important because of the anticipated expansion of health care coverage, including clinical preventive services (47).

As the NMHPVPR program matures, future analyses will include case–control evaluations of the effectiveness of screening and pinpoint deficiencies. Furthermore, it will provide data necessary for making rational choices about screening intervals for women who have received an HPV vaccine. However, even at this early stage, the data have highlighted issues related to poor coverage in older women. We have also identified a continuing proportion of "screening tests" at intervals of less than 1 year and in women ages <21 and >65 years, counter to current screening guidelines. Corrective actions and continued monitoring are needed to minimize these deficiencies.

Disclosure of Potential Conflicts of Interest

Disclaimer

Authors' Contributions

Conception and design: J. Cuzick, P.E. Castle, C.M. Wheeler, V.B. Benard
Development of methodology: J. Cuzick, O. Myers, C.M. Wheeler
Acquisition of data (provided animals, acquired and managed patients, provided facilities, etc.): M. Robertson, N.E. Joste, C.M. Wheeler
Analysis and interpretation of data (e.g., statistical analysis, biostatistics, computational analysis): J. Cuzick, O. Myers, W.C. Hunt, P.E. Castle, C.M. Wheeler, V.B. Benard
Writing, review, and/or revision of the manuscript: J. Cuzick, O. Myers, W.C. Hunt, N.E. Joste, P.E. Castle, C.M. Wheeler, V.B. Benard
Administrative, technical, or material support (i.e., reporting or organizing data, constructing databases): O. Myers, W.C. Hunt, M. Robertson
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