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# Radical hysterectomy case volume and cervical cancer treatment in the era of COVID-19: A multi-site analysis of National Cancer Institute-designated Comprehensive Cancer Centers

Natalie E. Wickenheisser [a], Mairead Dillon [b], Gloria Broadwater [b], Kathleen Zacherl [a], Kristin Bixel [c], Monica Levine [c], Meredith Newton [d], Hannah Thel [e], Katherine Tucker [d], Paola Gehrig [f], Varun U. Khetan [g], Laurie L. Brunette-Masi [g], Koji Matsuo [g], Olivia R. Khouri [h], Ashley Duhon [h], Divya Gowthaman [h], Matthew Cowan [h], Rachel Mojdehbakhsh [i], Stephen Rose [i], Alexander Olawaiye [j], Brittany A. Davidson [k], Haley A. Moss [k], Laura J. Havrilesky [k,*]

[a] *Department of Obstetrics & Gynecology, Duke University Health System, Durham, NC, United States of America*
[b] *Biostatistics Shared Resources, Duke Cancer Institute, Durham, NC, United States of America*
[c] *Division of Gynecologic Oncology, Department of Obstetrics & Gynecology, Ohio State University Wexner Medical Center, Columbus, OH, United States of America*
[d] *Divison of Gynecologic Oncology, Department of Obstetrics & Gynecology, University of North Carolina Medical Center, Chapel Hill, NC, United States of America*
[e] *University of North Carolina School of Medicine, Chapel Hill, NC, United States of America*
[f] *Division of Gynecologic Oncology, Department of Obstetrics & Gynecology, University of Virginia School of Medicine, Charlottesville, VA, United States of America*
[g] *Divison of Gynecologic Oncology, Department of Obstetrics & Gynecology, Keck School of Medicine of University of Southern California, Los Angeles, CA, United States of America*
[h] *Division of Gynecologic Oncology, Department of Obstetrics & Gynecology, Montefiore Medical Center, Bronx, NY, United States of America*
[i] *Divison of Gynecologic Oncology, Department of Obstetrics & Gynecology, University of Wisconsin Health, Madison, WI, United States of America*
[j] *Division of Gynecologic Oncology, Department of Obstetrics & Gynecology, University of Pittsburgh Medical Center, Pittsburgh, PA, United States of America*
[k] *Division of Gynecologic Oncology, Department of Obstetrics & Gynecology, Duke University Health System, Durham, NC, United States of America*

## HIGHLIGHTS

- A decline in monthly radical hysterectomy case volume was observed after the outbreak of the COVID-19 pandemic
- After the outbreak of the COVID-19 pandemic, a shift to higher stages at the time of cervical cancer diagnosis was observed
- Delays in delivery of surgical and radiation-based therapy were seen for patients with cervical cancer after the pandemic
- There may be long-term implications of these findings on patient outcomes and quality of surgical training post-pandemic

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## ABSTRACT

*Objective.* To compare radical hysterectomy case volume, cancer stage, and biopsy-to-treatment time of invasive cervical cancer diagnosed before and after onset of the COVID-19 pandemic.

*Methods.* In a multi-institution retrospective cohort study conducted at 6 large, geographically diverse National Cancer Institute-designated cancer centers, patients treated for newly diagnosed invasive cervical cancer were classified into 2 temporal cohorts based on date of first gynecologic oncology encounter: (1) Pre-Pandemic: 3/1/2018–2/28/2020; (2) Pandemic & Recovery: 4/1/2020–12/31/2021. The primary outcome was total monthly radical hysterectomy case volume. Secondary outcomes were stage at diagnosis and diagnosis-to-treatment time. Statistical analyses used chi-squared and two sample *t*-tests.

*Results.* Between 3/1/2018–12/31/2021, 561 patients were diagnosed with cervical cancer. The Pre-Pandemic and Pandemic & Recovery cohorts had similar age, race, ethnicity, smoking status, and Body Mass Index (BMI). During Pandemic & Recovery, the mean monthly radical hysterectomy case volume decreased from 7[SD 2.8] to 5[SD 2.0] ($p = 0.001$), the proportion of patients diagnosed with Stage I disease dropped from 278/561 (49.5%) to 155/381 (40.7%), and diagnosis of stage II-IV disease increased from 281/561 (50.1%) to 224/381 (58.8%). Primary surgical management was less frequent (38.3% Pandemic & Recovery versus 46.7% Pre-Pandemic, $p = 0.013$) and fewer surgically-treated patients received surgery within 6 weeks of diagnosis (27.4% versus 38.9%; $p = 0.025$).

* Corresponding author at: Box 3079 DUMC, Durham, NC 27710, United States of America.
*E-mail address:* havri001@mc.duke.edu (L.J. Havrilesky).

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*Conclusions.* Lower radical hysterectomy case volume, a shift to higher cervical cancer stage, and delay in surgical therapy were observed across the United States following the COVID-19 outbreak. Decreased surgical volume may result from lower detection of early-stage disease or other factors.



## 1. Introduction

Since 2000, the incidence of cervical cancer in the United States has declined due to screening and preventive HPV vaccination [1–3]. With fewer cases of cervical cancer diagnosed, imaging resulting in findings of nodal metastasis at diagnosis, and the availability of curative primary chemoradiation for both bulky stage I and locally advanced disease, it is likely that primary surgical treatment with radical hysterectomy is decreasing over time. While national data on radical hysterectomy case volume are lacking, one high volume center reported a significant drop in radical hysterectomy case volume between 1999 and 2018 [4]. Radical hysterectomy case volume decreased by 26% from 2000 to 2017 in the U.S. tumor registry [5].

Despite these trends, radical hysterectomy remains a surgical cornerstone of gynecologic oncology training and practice [6]. Radical hysterectomy with lymphadenectomy is a standard of care treatment option for early stage cervical cancer (stages stage 1A1 with lymph vascular invasion, 1A2, 1B1, and 1B2), making it a mandatory skill that a gynecologic oncologist should be able to routinely perform [7,8]. Sufficient radical hysterectomy case volume is considered a key to successful gynecologic oncology fellowship training. However, one study in the United Kingdom found that gynecologic oncology fellows were performing fewer radical hysterectomies than required by the European Society of Gynecologic Oncology [8]. Additionally, low surgical case volume, defined as <1 case per month for gynecologic surgeons, has been associated with increased intra- and postoperative complication rates as well as higher patient mortality [9]. Thus, a decline in radical hysterectomy case volume has the potential to negatively impact the quality of training for gynecologic oncology fellows and contribute to poor patient outcomes at low volume institutions.

According to the Center for Disease Control (CDC), the COVID-19 pandemic caused an estimated 77–85% drop in screening for cervical cancer in the first 6 months of 2020, which likely impacted detection of early stage disease [10]. Diversion of non-emergent care and avoidance of healthcare centers due to fear of contracting COVID-19 could also have contributed to delays in diagnosis and treatment of cervical cancer during the pandemic. A recent systematic review demonstrated that fewer cases of cervical cancer were diagnosed after the outbreak of the pandemic across multiple countries, although the extent of this decline varied significantly among studies [11]. International studies have documented a shift to later stage of disease at time of diagnosis as well as a decline in the rate of surgical procedures for patients undergoing cervical cancer treatment [12,13]. Determining the extent to which these factors impacted cervical cancer care delivery in the United States is critically important, as it is well documented that advanced stage and delays in delivery of treatment can drastically impact patient outcomes [14–16].

Thus, we wished to evaluate trends in cervical cancer treatment, specifically radical hysterectomy case volume, in a longitudinal multicenter study covering the periods immediately preceding and following the outbreak of COVID-19. Additionally, we wished to study stage at diagnosis, treatment modality, and treatment timeliness. We hypothesized that the volume of radical hysterectomy declined at many institutions in the COVID-19 pandemic and recovery period and that the pandemic also adversely affected other aspects of cervical cancer treatment.

## 2. Methods

### 2.1. IRB approval and patient population

This is a retrospective, multicenter cohort study of patients diagnosed with cervical cancer from 2018 to 2021. Approval to conduct the study was obtained from the Duke University Medical Center (Durham, NC), Ohio State University (Columbus, OH), Montefiore Medical Center (Bronx, NY), University of North Carolina (Chapel Hill, NC), University of Southern California (Los Angeles, CA) and University of Wisconsin (Madison, WI) Institutional Review Boards.

Two patient cohorts were retrospectively created based on date of first gynecologic oncology encounter for a new diagnosis of cervical cancer: (1) Pre-Pandemic- March 1, 2018 to February 28, 2020; (2) Pandemic & Recovery- April 1, 2020 to December 31, 2021. Patients diagnosed in March 2020 were excluded from cohort assignment, as there were no uniform guidelines for hospital policies in response to COVID-19 during this time; however, all patients who underwent radical hysterectomy were included in the longitudinal data display of radical hysterectomy case volume, regardless of cohort exclusion criteria. Patients were identified from the electronic medical records via ICD-9 (180) and ICD-10 codes (C53) for cervical cancer or via institutional pathology databases. Exclusion criteria were diagnosis with (1) cervical cancer prior to March 1st 2018, (2) recurrent cervical cancer at first gynecologic oncology encounter, (3) another primary gynecologic malignancy, or (4) patients without complete treatment records or who were lost to follow up prior to completing treatment.

### 2.2. Data collection

Data were manually extracted from the electronic health record, deidentified and stored in a HIPAA compliant REDCap (Fort Lauderdale, FL) database accessible only to study personnel. Each site had a unique data access group within the database to identify the cohort from their institution. Demographic variables included age at diagnosis, race/ethnicity, smoking status, and social vulnerability index (SVI). The Center for Disease Control SVI is derived from census data and includes social factors such as vehicle access, crowded housing and poverty, and can be used to determine the potential negative effects on communities caused by external stresses on human health such as disease outbreaks [17]. Race and ethnicity data were collected as this factor is important for cervical cancer characteristics and outcomes.

Disease characteristics included histopathologic type, stage at diagnosis, date of antecedent pap smear, date of biopsy-proven diagnosis, and date of initial gynecologic oncology visit. All patients were retrospectively re-assigned a stage at the time of review based on the International Federation of Gynecologic Oncology (FIGO) 2018 criteria to limit discrepancies in staging during the study period [18]. Surgical eligibility variables included body mass index (BMI), Charlson comorbidity index, and any documentation of the provider's opinion on surgical candidacy. Treatment characteristics included type of treatment, date of initiation and date of completion. The number of radical hysterectomies was tabulated by manual chart review of the electronic health record. Radical trachelectomy was considered the surgical equivalent of radical hysterectomy for the purposes of this study. Variables related to COVID-19 included evidence of testing positive during the period between diagnosis and completion of treatment, documentation of delay of care, and documentation of patient concern due to COVID-19, if present.

### 2.3. Statistical analysis

The primary outcome of this study was radical hysterectomy monthly case volume, defined as total number of radical hysterectomies performed at all 6 participating institutions per month, during the Pre-Pandemic and Pandemic & Recovery time periods. Secondary outcomes were stage of cervical cancer at diagnosis, interval between preceding abnormal pap smear and diagnostic biopsy, interval between diagnostic biopsy and primary treatment, interval between initial gynecologic oncology visit and primary treatment, type of treatment performed, and interval between treatment initiation and completion for each cohort.

Patient characteristics were compared between cohorts using the Wilcoxon rank sum test for continuous variables and the Fisher's exact test or chi-squared test for categorical variables. Monthly radical hysterectomy case volume was calculated by summing cases across all institutions for a given month. Mean monthly case volumes were compared between cohorts and displayed longitudinally using statistical process control charts; standard rules for a statistically significant shift were applied (QI Macros for Excel 2022) [19,20]. Annual case volume per academic year was calculated in aggregate and for each institution and compared between years. Time to treatment was compared between groups using the Wilcoxon rank sum test. All statistical analyses were conducted by the study statistician in the R language and environment. A nominal significance level of 0.05 was considered statistically significant.

## 3. Results

### 3.1. Cohort selection

In total, 1005 patients diagnosed with cervical cancer were included in the analysis: 561 in the Pre-Pandemic group, 381 in the Pandemic & Recovery group, 38 diagnosed prior to March 2018, and 25 diagnosed in March of 2020 (Fig. 1). Institutional distribution was as follows: University of North Carolina — 212 patients (22.5%), University of Southern California —131 (13.9%), Ohio State University — 274 (29.1%), University of Wisconsin —169 (17.1%), Albert Einstein School of Medicine - 21 patients (2.2%), Duke University —135 (14.3%). Across institutions, 38 patients who were diagnosed prior to March 1st of 2018 and 25 patients diagnosed during March of 2020 had surgical management during the study period and thus were included in the monthly radical hysterectomy case volume calculations but excluded from cohort analyses.

### 3.2. Patient characteristics

Demographic and clinical characteristics were similar between cohorts (Table 1). The median [range] age at diagnosis was 47.0 [16.0–89.0] for the Pre-Pandemic cohort and 47.0 [20.0–88.0] for the Pandemic & Recovery cohort ($p = 0.322$). The majority of patients in each cohort identified as White (75.8% Pre-Pandemic versus 74.3% Pandemic & Recovery, $p = 0.504$) and non- Hispanic/Latinx (81.5% Pre-Pandemic versus 82.2% Pandemic & Recovery, $p = 0.926$). Nearly half of each cohort had a tobacco use history (46.0% Pre-Pandemic and 48.8% Pandemic & Recovery $p = 0.431$). Predictors of surgical candidacy included BMI and Charlson comorbidity score. Median [Q1,Q3] BMI was similar for both groups (28.3 [23.9, 33.7] Pre-Pandemic versus 28.9 [23.4, 34.7] Pandemic & Recovery, $p = 0.566$). Median [Min, Max] Charlson comorbidity score was higher for the Pandemic & Recovery group (4.0 [2.0,6.0]) compared to the Pre-Pandemic group (3.0 [2.0, 6.0]) ($p = 0.022$) indicating this group had more medical comorbidities than the pre-pandemic group. Median social vulnerability index and NCCN distress scores were similar between groups.

### 3.3. Radical hysterectomy case volume

The aggregate monthly radical hysterectomy case volume dropped from 12 cases to 3 cases between February and April 2020. There was a significant decrease in the mean monthly radical hysterectomy case volume after the outbreak of pandemic from 7.0 [SD 2.8] to 5.0 [SD 2.0] radical hysterectomy cases (Fig. 2b $p = 0.001$). This is further illustrated in Fig. 2a, which depicts a significant shift in monthly radical hysterectomy case volume after the pandemic began (March 2020). In order to measure how the decline in case volume may have affected trainees, the data were also grouped by academic year (i.e. July 2019 to June 2020). No statistically significant differences in annual radical hysterectomy case volume were observed for any institution or in sum when grouped by academic year (88 in 2018–19 versus 78 in 2019–20 versus 90 in 2020–21; $p = 0.591$) (Fig. S1).

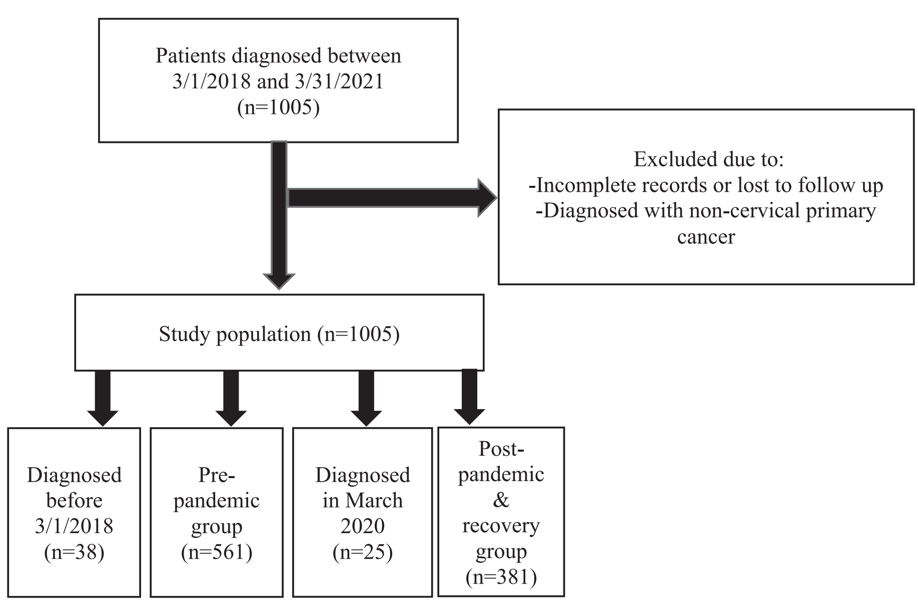


**Fig. 1.** Cohort flowchart.

**Table 1**
Baseline characteristics.

| Patient Characteristics | Pre-Pandemic | Pandemic & Recovery | Overall | *P*-Value |
|---|---|---|---|---|
| | (*N* = 561) | (*N* = 381) | (*N* = 942) | |
| Overall cohort totals | | | | 0.117[1] |
| University of North Carolina | 126 (22.5%) | 86 (22.6%) | 212 (22.5%) | |
| University of Southern California | 72 (12.8%) | 59 (15.5%) | 131 (13.9%) | |
| Ohio State University | 166 (29.6%) | 108 (28.3%) | 274 (29.1%) | |
| University of Wisconsin | 91 (16.2%) | 78 (20.5%) | 169 (17.9%) | |
| Albert Einstein School of Medicine | 16 (2.9%) | 5 (1.3%) | 21 (2.2%) | |
| Duke University | 90 (16.0%) | 45 (11.8%) | 135 (14.3%) | |
| Age | | | | |
| Median [Min, Max] | 47.0 [16.0, 89.0] | 47.0 [20.0, 88.0] | 47.0 [16.0, 89.0] | 0.322[2] |
| Mean (SD) | 48.3 (13.5) | 49.5 (14.2) | 48.8 (13.8) | |
| Race | | | | 0.504[3] |
| American Indian or Alaska Native | 4 (0.7%) | 1 (0.3%) | 5 (0.5%) | |
| Asian | 19 (3.4%) | 13 (3.4%) | 32 (3.4%) | |
| Black or African American | 77 (13.7%) | 49 (12.9%) | 126 (13.4%) | |
| Native Hawaiian or other Pacific Islander | 0 (0%) | 1 (0.3%) | 1 (0.1%) | |
| White | | | | |
| Other | 425 (75.8%) | 283 (74.3%) | 708 (75.2%) | |
| Unknown | 24 (4.3%) | 25 (6.6%) | 49 (5.2%) | |
| Missing | 9 (1.6%) | 9 (2.4%) | 18 (1.9%) | |
| | 3 (0.5%) | 0 (0%) | 3 (0.3%) | |
| Ethnicity | | | | |
| Hispanic/Latinx | 89 (15.9%) | 63 (16.5%) | 152 (16.1%) | 0.926[1] |
| Not Hispanic/Latinx | 457 (81.5%) | 313 (82.2%) | 770 (81.7%) | |
| Missing | 15 (2.7%) | 5 (1.3%) | 20 (2.1%) | |
| Smoking status | | | | |
| Smoker | 258 (46.0%) | 186 (48.8%) | 444 (47.1%) | 0.431[1] |
| Non-smoker | 300 (53.5%) | 193 (50.7%) | 493 (52.3%) | |
| Missing | 3 (0.5%) | 2 (0.5%) | 5 (0.5%) | |
| BMI | | | | |
| Median [1st Quartile, 3rd Quartile] | 28.3 [23.9, 33.7] | 28.9 [23.4, 34.7] | 28.6 [23.8, 34.0] | 0.566[2] |
| Missing | 5 (0.9%) | 1 (0.3%) | 6 (0.6%) | |
| Charlson comorbidity score | | | | |
| Median [1st Quartile, 3rd Quartile] | 3.0 [2.00, 6.00] | 4.0 [2.0, 6.0] | 4.0 [2.0, 6.0] | 0.022[2] |
| Missing | 2 (0.4%) | 1 (0.3%) | 3 (0.3%) | |
| SVI | | | | |
| Median [1st Quartile, 3rd Quartile] | 0.6 [0.4, 0.8] | 0.60 [0.3, 0.8] | 0.6 [0.3, 0.8] | 0.395[2] |
| Missing | 1 (0.2%) | 2 (0.5%) | 3 (0.3%) | |

BMI = body mass index.
SVI = social vulnerability index.
NCCN = National Comprehensive Care Network.
[1] Chi-squared test.
[2] Wilcoxon rank sum test.
[3] Fisher's exact test.

### *3.4. Tumor histology, stage & diagnosis*

Histologic tumor types were similar between cohorts ($p = 0.423$), with squamous cell carcinoma being most common (68.3% Pre-Pandemic versus 63.8% Pandemic & Recovery), followed by adenocarcinoma (26.6% Pre-Pandemic versus 29.7% Pandemic & Recovery). Stage and substage of cervical cancer at diagnosis are described in Table 2. Stage at diagnosis was significantly different between groups ($p = 0.019$), with a shift toward later stage disease during the Pandemic & Recovery period. Fewer patients were diagnosed with Stage I disease during the Pandemic & Recovery period (155/381, 40.7%) compared to the Pre-Pandemic period (278/561, 49.5%). A corresponding increase in diagnosis of later stage disease (Stage II-IV) was observed during the Pandemic & Recovery period (224/381, 58.8%) compared to the Pre-Pandemic period (281/561, 50.1%). Sub-stage analysis was not done due to sample size.

### *3.5. Treatment type*

Primary treatment type, including surgical procedures, chemoradiation, and palliative care, are outlined in Table 3. After the start of the pandemic, primary surgical management was less frequent (38.3% versus 46.7%, $p = 0.013$). 32.4% of patients with newly diagnosed cervical cancer underwent radical hysterectomy Pre-Pandemic, compared to 24.9% in the Pandemic & Recovery cohort (p = 0.013). In the Pandemic & Recovery period, patients more commonly underwent primary treatment with radiation-based therapy (51.7% versus 44.0%, $p = 0.138$), with fewer primary surgically-treated patients receiving surgery within 6 weeks of diagnosis (27.4% Pandemic & Recovery versus 38.9% Pre-Pandemic $p = 0.025$).

### *3.6. Intervals to evaluation and treatment*

The interval from biopsy to initiation of cervical cancer treatment was significantly longer in the Pandemic and Recovery group, compared to the Pre-Pandemic group (54.0 days versus 46.0 days, respectively; p = 0.025; Table 4). There was no significant difference in the time interval from the preceding pap smear to biopsy (43.0 days Pre-Pandemic versus 34.5 days Pandemic & Recovery, $p = 0.516$); however, 46.4% of patients were missing the date of the last pap smear at chart review. There was no significant difference in the time interval from biopsy to first gynecologic oncology evaluation (18.0 for both cohorts; $p = 0.416$).

During the pandemic, a smaller proportion of patients with early-stage disease (stage 1A1 to IIA2) received initial treatment within

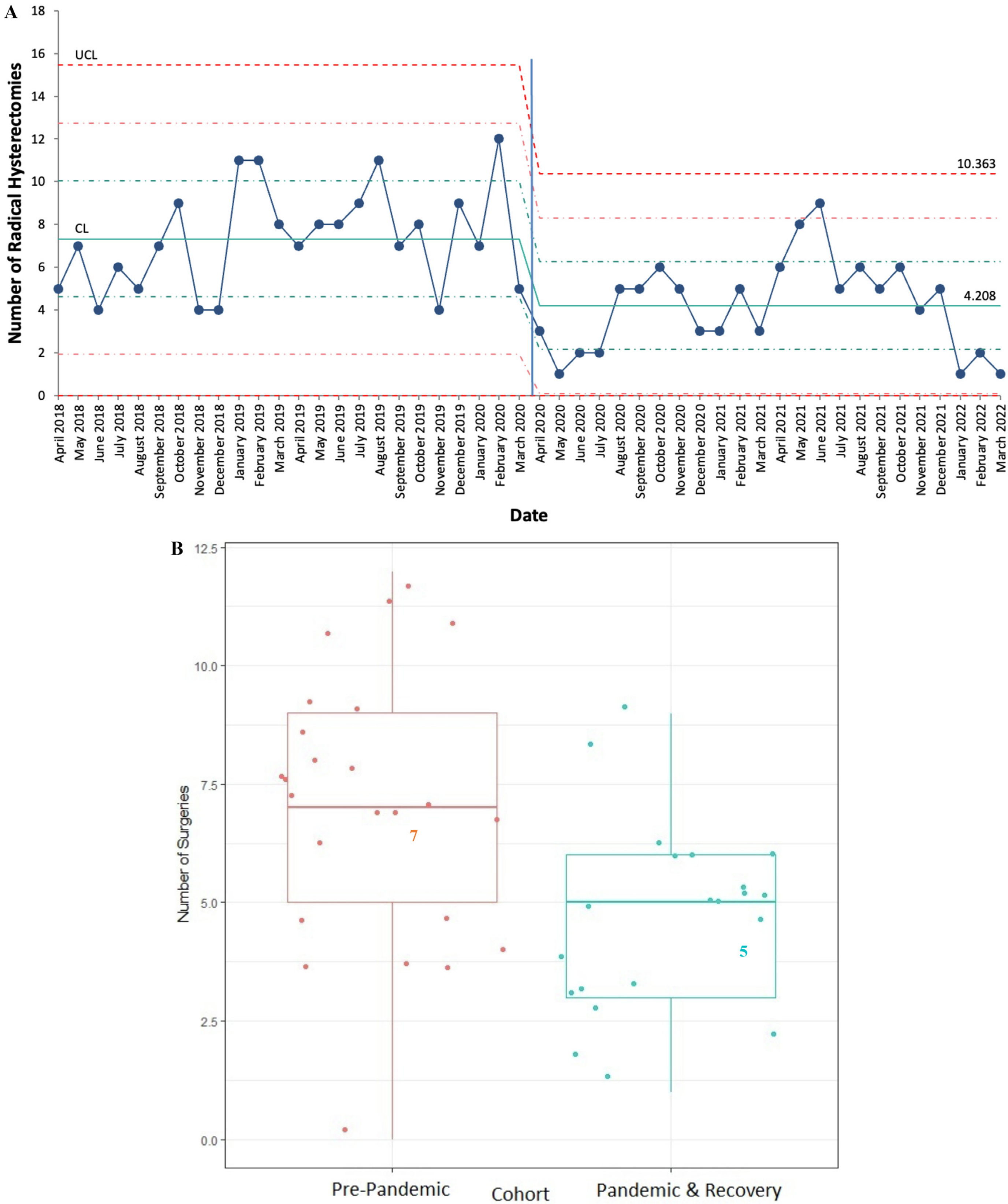


**Fig. 2.** a. Statistical process control chart showing special cause variation with a shift in monthly aggregate radical hysterectomy volume after the March 2020 onset of COVID pandemic. The data meet criteria for a process shift as defined by 8 points in a row (post-intervention) below the mean of the pre-COVID time period. The vertical blue line represents onset of COVID pandemic. UCL = upper control limit, CL = control limit. Fig. 2b Each point represents the aggregate monthly case volume of radical hysterectomy prior to the pandemic (red) and after the onset of the pandemic (green). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

**Table 2**
Tumor histology and stage at diagnosis.

| | Pre-Pandemic (N = 561) | Pandemic & Recovery (N = 381) | Overall (N = 942) | P-Value |
|---|---|---|---|---|
| Stage | | | | 0.019[1,*] |
| Stage I | 278 (49.6%) | 155 (40.7%) | 433 (46.0%) | |
| Stage II | 77 (13.7%) | 62 (16.3%) | 139 (14.8%) | |
| Stage III | 140 (25.0%) | 124 (32.5%) | 264 (28.0%) | |
| Stage IV | 64 (11.4%) | 38 (10.0%) | 102 (10.8%) | |
| Missing | 2 (0.4%) | 2 (0.5%) | 4 (0.4%) | |
| Stage I | | | | |
| 1A1 | 79 (28.4%) | 38 (24.5%) | 117 (27.0%) | |
| 1A2 | 30 (10.8%) | 28 (18.1%) | 58 (13.4%) | |
| 1B1 | 103 (37.1%) | 46 (29.7%) | 149 (34.4%) | |
| 1B2 | 44 (15.8%) | 27 (17.4%) | 71 (16.4%) | |
| 1B3 | 22 (7.9%) | 16 (10.3%) | 38 (8.8%) | |
| Stage II | | | | |
| 2A1 | 6 (7.8%) | 9 (14.5%) | 15 (10.8%) | |
| 2A2 | 9 (11.7%) | 12 (19.4%) | 21 (15.1%) | |
| 2B | 62 (80.5%) | 41 (66.1%) | 103 (74.1%) | |
| Stage III | | | | |
| 3A | 7 (5%) | 6 (4.8%) | 13 (4.9%) | |
| 3B | 39 (27.9%) | 18 (14.5%) | 57 (21.6%) | |
| 3C1 | 67 (47.9%) | 77 (62.1%) | 144 (54.5%) | |
| 3C2 | 27 (19.3%) | 23 (18.5%) | 50 (18.9%) | |
| Stage IV | | | | |
| 4A | 19 (29.7%) | 7 (18.4%) | 26 (25.5%) | |
| 4B | 45 (70.3%) | 31 (81.6%) | 76 (74.5%) | |
| Histology | | | | 0.423[1] |
| Squamous cell carcinoma | 383 (68.3%) | 243 (63.8%) | 626 (66.5%) | |
| Adenocarcinoma | 149 (26.6%) | 113 (29.7%) | 262 (27.8%) | |
| Small cell neuroendocrine carcinoma of the cervix (NECC) | 7 (1.2%) | 4 (1.0%) | 11 (1.2%) | |
| Other | 22 (3.9%) | 21 (5.5%) | 43 (4.6%) | |

[1] Chi-squared test.
* comparison of major stage classification and histology between study cohorts.

6 weeks of diagnosis (38.1% Pre-Pandemic versus 23.4% Pandemic & Recovery; $p = 0.002$), which corresponds to the longer interval from diagnosis to treatment discussed above. This was true for both patients who had primary surgical treatment (38.9% Pre-Pandemic versus 27.4% Pandemic & Recovery; $p = 0.025$) and for those who had chemoradiation (47.4% versus 37.4%, respectively; $p = 0.035$). There was no significant difference in the percent of patients who completed radiation within 60 days (Pre-Pandemic 74.8% vs. 82.1% Pandemic & Recovery, $p = 0.65$).

### 3.7. Delays in treatment during the COVID-19 pandemic

Table S1 displays all documented COVID-19 infections, delays in care due to COVID-19, and documented patient concerns about COVID-19. Overall, 19 patients (2.0%) had documented COVID-19 infection during their cervical cancer treatment course. 11 (1.2%) of all patients, or 58% of those with known COVID infection, had a documented delay in care due to COVID-19, with a mean delay of 28.7 days.

## 4. Discussion

The COVID-19 pandemic has drastically impacted healthcare delivery in the United States; however, its full impact is still unknown. Our study identified major shifts in the diagnosis and management of cervical cancer after the pandemic's onset, including a decline in radical hysterectomy case volume, a shift to later stage at diagnosis, and delays in surgical and radiation-based therapy. Lower overall surgical volume may be the result of a decline in the detection of early-stage disease. Other factors, such as barriers to performing surgery during the pandemic, may have contributed to this change. A large retrospective, population-based study by Algera et al. found that surgical volume for cervical cancer decreased by 16.2% during the COVID-19 pandemic in the Netherlands [13]. Importantly, Algera et al. found that surgical volume for cervical cancer remained lower than expected, whereas other gynecologic malignancies returned to baseline surgical rates shortly after the pandemic's onset [13]. Similarly, our data demonstrate that monthly radical hysterectomy volume remained lower than the pre-

**Table 3**
Details of primary treatment for cervical cancer.

| | Pre-Pandemic (N = 561) | Pandemic & Recovery (N = 381) | Overall (N = 942) | P-Value |
|---|---|---|---|---|
| Surgical | 262 (46.7%) | 146 (38.3%) | 408 (43.3%) | 0.013[1] |
| CKC | 16 (6.1%) | 10 (6.8%) | 26 (6.4%) | 0.570[1] |
| LEEP | 4 (1.5%) | 0 (0%) | 4 (0.98%) | |
| Radical hysterectomy* | 182 (69.5%) | 95 (65.1%) | 277 (67.9%) | |
| Simple hysterectomy | 49 (18.7%) | 32 (21.9%) | 81 (19.9%) | |
| Other | 9 (3.4%) | 7 (4.8%) | 16 (3.9%) | |
| Missing | 2 (0.8%) | 2 (1.4%) | 4 (0.98%) | |
| Neoadjuvant chemotherapy (before hyst) | 4 (1.5%) | 4 (2.7%) | 8 (2.0%) | 0.836[1] |
| Adjuvant chemotherapy (after hyst) | 42 (16.0%) | 34 (23.3%) | 76 (18.6%) | |
| Adjuvant radiation (after hyst) | 54 (20.6%) | 38 (26.0%) | 92 (22.5%) | |
| Radiation-based therapy | 247 (44.0%) | 197 (51.7%) | 444 (47.1%) | 0.014[1] |
| Chemoradiation | 236 (95.5%) | 192 (97.5%) | 428 (96.4%) | 0.571 |
| Brachytherapy only | 2 (0.8%) | 0 (0%) | 2 (0.5%) | |
| External beam radiation only | 1 (0.4%) | 2 (1.0%) | 3 (0.7%) | |
| Both brachytherapy and external beam radiation (no chemotherapy) | 8 (3.2%) | 3 (1.5%) | 11 (2.5%) | |
| Palliative care | 42 (7.5%) | 30 (7.9%) | 72 (7.6%) | 0.925[1] |
| No treatment | 10 (1.8%) | 8 (2.1%) | 18 (1.9%) | 0.602[1] |

CKC-Cold knife cone.
LEEP- Loop electrosurgery execisional procedure.
[1] Chi-squared Test.
* Including radical trachelectomy.

**Table 4**
Interval from diagnosis to treatment initiation & completion.

| | Pre-Pandemic | Pandemic & Recovery | Overall | P-Value |
|---|---|---|---|---|
| Interval from pap smear to biopsy<br>Median [1st Quartile, 3rd Quartile] | 43.0 [16, 89]<br>($N = 317$) | 34.5 [12, 84]<br>($N = 188$) | 41.0 [15, 89]<br>($N = 505$) | 0.516[1] |
| Interval from biopsy to gyn onc visit<br>Median [1st Quartile, 3rd Quartile] | 18.0 [9, 29]<br>($N = 466$) | 18.0 [12, 84]<br>($N = 318$) | 18.0 [7, 29]<br>($N = 784$) | 0.416[1] |
| Interval from biopsy to primary treatment<br>Median [1st Quartile, 3rd Quartile] | 46.0 [32, 66]<br>($N = 519$) | 54.0 [35.8, 72.00]<br>($N = 348$) | 49.0 [34, 69]<br>($N = 867$) | 0.025[1] |
| % receiving surgery who had time from diagnosis to initial treatment <6 weeks | $N = 262$<br>102 (38.9%) | $N = 146$<br>40 (27.4%) | $N = 408$<br>142 (34.8%) | 0.025[2] |
| % receiving chemoradiation who had time from diagnosis to initial treatment <6 weeks | $N = 268$<br>127 (47.4%) | $N = 214$<br>80 (37.4%) | $N = 482$<br>207 (42.9%) | 0.035[2] |
| % who completed radiation within 60 days of starting therapy | $N = 202$<br>151 (74.8%) | $N = 151$<br>124 (82.1%) | $N = 353$<br>275 (77.9%) | 0.654[2] |
| Median time to completion of radiation | 52.5<br>(N = 202) | 50<br>(N = 151) | 51<br>(N = 353) | 0.143[2] |
| <66 days | 170 (84.2%) | 134 (88.7%) | 304 (86.1%) | 0.283[2] |
| ≥66 days | 32 (15.8%) | 17 (11.3%) | 49 (13.9%) | |

[1] Wilcoxon Rank Sum Test.
[2] Chi-squared Test.

pandemic time period through 2021. These data suggest that the COVID delays resulted in missed opportunities for surgical cure.

With regard to the impact of pandemic era surgical volumes on clinical training, we found no statistically significant differences in annual radical hysterectomy case volume by academic year from 2018 to 2021, offering reassurance that, despite the major impacts that the COVID-19 pandemic had on trainees, gynecologic oncology fellows had similar opportunities to learn this critically important procedure throughout their training. Nonetheless, the implications of lower radical hysterectomy case volume on the quality of gynecologic oncology fellow training may extend well beyond the immediate pandemic and recovery period. Our observed aggregate average of 5 cases per month across 6 institutions during pandemic & recovery meets Mowat's definition of low case volume (<1 case per month) [8]. Thus, not only did rates of radical hysterectomy case volume drop after the pandemic, but they may also have reached a critically low volume at which the likelihood of surgical complications is higher. While the collection of operative outcomes was outside of the scope of this study, it is reasonable for institutions to monitor surgical morbidity in the ongoing setting of lower radical hysterectomy case volumes.

Our Pandemic & Recovery cohort included a larger proportion of patients who were diagnosed at later stages; thus, it is plausible that some early stage disease was missed due to the sharp decline in cervical cancer screening during the 6 months following the pandemic [10]. Bonadio et al. similarly reported significantly decreased rates of cervical cancer diagnosis after the pandemic at a single center in Brazil [12]. Multiple factors could have contributed to missing screening or early evaluation appointments, including fear of contracting the virus, encouraged isolation and quarantining for infection.

A larger proportion of patients underwent radiation-based therapy during Pandemic & Recovery, regardless of stage at diagnosis. This might have been expected, given that at the height of the pandemic, expert recommendations were published in the *International Journal of Gynecologic Cancer* and the *British Journal of Radiology* to consider delaying surgery for early-stage cervical cancer and to consider chemoradiation as primary therapy if surgical procedures were delayed [21,22]. The greater proportion of patients diagnosed at a later stage of disease in the Pandemic & Recovery group was another reason to expect the observed increase in radiation-based therapy over primary surgical therapy.

We observed significant delays from cervical cancer diagnosis to primary treatment after the pandemic for both surgical and radiation-based therapy. Matsuo et al. found that patients with early-stage cervical cancer who had longer wait times (>6 weeks) to primary surgical treatment had similar disease-free and overall survival to those who had shorter wait times (<6 weeks); this is reassuring given the higher proportion of patients who had surgery >6 weeks after diagnosis in the Pandemic & Recovery cohort [23]. Shen et al. found that one- and five-year survival rates were worse for patients who received delayed treatment for cervical cancer, however, their definition of delayed treatment was >4 months from diagnosis, compared to 6 weeks in the current study [14]. A 2020 analysis of National Cancer Database found that longer surgical wait time is associated with increased risk of parametrial tumor involvement [24]. Additionally, longer wait time for definitive radiotherapy or adjuvant radiotherapy following radical hysterectomy have been associated with diminished survival outcomes [16,25,26]. Although collection of survival data was outside of the scope of this study, prompt treatment after diagnosis should remain a cornerstone of cancer treatment.

### *4.1. Strengths and limitations*

A major strength of this study was the inclusion of 6 large, geographically diverse sites to create our cohort. "Restaging" of all patients at time of review using standard criteria to account for changing guidelines over time strengthened our study. Additionally, we collected data on both medical and surgical management of cervical cancer, which helped provide a comprehensive analysis of the full scope of treatment of during this major upheaval in healthcare.

This study is limited by its retrospective design, which was necessary due to the unpredictable nature of COVID-19 outbreak. Moreover, it is not possible to establish causation between the COVID-19 pandemic and the observed changes, as other factors may also have impacted treatment type. In particular, the 2021 ConCerv trial, first presented in late 2019, likely resulted in consideration of less radical surgical procedures for some patients with lower risk early stage disease during this same time period. However, if the effects of ConCerv were contributing to lower radical hysterectomy case volume, we would have expected to see a lower percentage of surgically treated patients undergoing radical hysterectomy in the pandemic & recovery group, which was not observed in our study [27]. The more recent SHAPE trial, presenteded after the conclusion of our study period, demonstrated that pelvic recurrence rate with simple hysterectomy was not inferior to radical hysterectomy in selected early stage low-risk cervical cancer [28]. A movement away from radical surgery as a result of these recent trials may result in a sustained decline in radical hysterectomy case volume that persists beyond the pandemic and recovery periods.

There are inherent limitations to using chart review as the method of data collection. For this study, there was incomplete information for some patients and we were limited by provider documentation behaviors. We were also limited by the accuracy of the electronic medical record database that we used to create our patient cohort. While most clinical characteristics remained similar between groups, the Pandemic & Recovery cohort had higher Charlson comorbidity scores, indicating higher chance of mortality over 10 years. These scores were used as an objective proxy for surgical candidacy, but it is important to note that spread of malignancy is included in this index. Thus, the larger proportion of patients with advanced disease in the Pandemic & Recovery cohort may have contributed to the higher Charlson scores. Additionally, our study did not account for radical hysterectomy performed outside the context of cervical cancer; however, the indications for this procedure for other gynecologic malignancies is variable and therefore difficult to track. Last, lack of survival analysis is another limitation in this study that is unavoidable given short term follow up in the Pandemic & Recovery cohort.

## 5. Future directions

In April 2023, the World Health Organization declared the COVID-19 pandemic over [29]. While healthcare systems have largely recovered from the pandemic, the long-term effects of earlier disruptions to care delivery may persist and are still unknown. These effects are especially important for cancers that are often diagnosed through asymptomatic screening. From the perspective of gynecologic oncology practice and training, it is also important that we continue to track radical hysterectomy case volume and its implications for trainees and patient care.

## CRediT author statement

The authors contributions are as follows: Dr. Natalie Wickenheisser: conceptualization, methodology, investigation, project administration, writing-original draft; Dr. Laura Havrilesky: supervision, conceptualization, methodology, formal analysis, writing- original draft, review & editing; Dr. Brittany Davidson, Dr. Hayley Moss: conceptualization, methodology, review & editing manuscript; Mairead Dillon, Gloria Broadwater and Dr. Kathleen Zacherl: formal analysis, visualization, review & editing manuscript; Dr. Meredith Newton, Hannah Thel, Dr. Varun Khetan, Dr. Ashely Duhon, Dr. Divya Gowthaman, and Dr. Rachel Mojdehbakhsh: investigation, data curation; Dr. Kristin Bixel, Dr. Monica Levine, Dr. Paola Gehrig, Dr. Laurie Brunette-Masi, Dr. Olivia Khouri, Dr. Matthew Cowan, Dr. Stephen Rose, and Dr. Alexander Olawaiye: project administration, review & editing.

## Declaration of Competing Interest

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ygyno.2023.10.010.

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