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Underutilization of brachytherapy and disparities in survival for patients with cervical cancer in California

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HIGHLIGHTS

- Brachytherapy after chemoradiation for locally advanced cervical cancer constitutes the standard of care.
- There are declining national trends for the utilization of brachytherapy.
- Patients not treated with a boost after chemoradiation have worse survival outcomes.
- Understanding disparities, access, and interventions to increase the receipt of brachytherapy is needed.

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ABSTRACT

Purpose. The treatment for locally advanced cervical cancer is external beam radiation (EBRT), concurrent chemotherapy, and brachytherapy (BT). We investigated demographic and socioeconomic factors that influence trends in BT utilization and disparities in survival.

Methods. Using the California Cancer Registry, cervical cancer patients FIGO IB2–IVA from 2004 to 2014 were identified. We collected tumor, demographic and socioeconomic (SES) factors. We used multivariable logistic regression analysis to determine predictors of use of BT. Using Cox proportional hazards, we examined the impact of BT vs EBRT boost on cause specific (CSS) and overall survival (OS).

Results. We identified 4783 patients with FIGO stage 11% IB2; 32% II, 54% III, 3% IVA. Nearly half (45%) of patients were treated with BT, 18% were treated with a EBRT boost, and 37% had no boost. Stage II and III were more likely to be treated with BT ($p = 0.002$ and $p = 0.0168$) vs Stage IB2. As patients aged, the use of BT decreased. Using multivariate analysis, BT impacted CCS (HR 1.16, $p = 0.0330$) and OS (HR 1.14, $p = 0.0333$). Worse CSS was observed for black patients ($p = 0.0002$), low SES ($p = 0.0263$), stage III and IVA ($p < 0.0001$). Black patients, low and middle SES had worse OS, ($p = 0.0003$).

Conclusions. The utilization of BT in locally advanced cervical cancer was low at 45%, with a decrease in CSS and OS. Black patients and those in low SES had worse CSS. As we strive for outcome improvement in cervical cancer, we need to target increasing access and disparities for quality and value.

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1. Background

Cervical cancer affects over 12,000 women in the United States with 4200 deaths annually. The standard of care for these patients consists of

radiation, external beam radiation (EBRT) with chemotherapy (CRT) followed by brachytherapy (BT). Furthermore, patterns of care studies established the essential role of BT in the management of cervical cancer, and linked its use to improvements in pelvic control and disease-free survival [1]. Image guided BT is a key component in the treatment of cervical cancer as it allows for dose escalation to the tumor while minimizing dose to surrounding critical organs at risk such as the sigmoid, bladder, and rectum. A typical BT application is shown in Fig. 1, and dose distribution in Fig. 2 [2].

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Fig. 1. A cervical cancer patient with brachytherapy equipment placed into the cervix and uterus. The red arrow points to the cervical tumor on the CT planning image. The black arrows point to the radiation after loading equipment.

There has been decrease in utilization trends of BT, and potential disparities of the use of BT, with detrimental effects on cause specific (CSS) and overall survival (OS) [3–8]. A recent study looking at the Surveillance, Epidemiology, and End Results (SEER) database showed a downward trend in BT usage from 68% in 1988 to 45% in 2010, [3] with a subsequent decline in CSS and OS based on a propensity score matched cohort. A national cancer database (NCDB) report showed a decrease in BT utilization, from 96.7% to 86.1%, with a subsequent survival detriment. Another SEER analysis showed significant geographic disparities in the delivery of brachytherapy in the United States [5]. In addition, elderly cervical cancer patients have

been found to receive BT less than younger patients, with a resulting increase in cancer specific mortality [8]. However, the NCDB is not a population based registry like the CCR, and therefore the percentage of brachytherapy utilization could be underrepresented. Also the SEER is a sampling of the national trends based on 18 registries and could have inherent selection bias.

Given the disparities on the use of BT reported in the literature, and reported adverse effects on outcomes, we used data from the California Cancer Registry to: 1) examine the utilization trends of BT and potential disparities in survival outcomes based on race, socioeconomic status (SES), or age; and 2) investigate the use of BT on cause-specific (CSS) and overall survival (OS). The goal of our study is to help direct California cervical cancer programs, for better utilization of resources and appropriate allocation.

2. Methods

Women diagnosed with cervical cancer were identified through the California Cancer Registry (CCR), a program of the California Department of Public Health's Chronic Disease Surveillance and Research Branch. The CCR contains demographic, diagnostic, treatment, and outcome information on all reportable cancers diagnosed in California residents since January 1988 and is the single largest population-based state cancer registry in the U.S. The registry is also part of the SEER program through contracts to three of the CCR's Regional Registries and meets all of the quality and completeness standards of the National Cancer Institute SEER program as well as those of the National Association of Central Cancer Registries. Data collected by the CCR are used to develop strategies and policies for the prevention, treatment, and control of cancers. To date the CCR has collected detailed information on over 7 million cases of cancer among Californians, and >175,000 new cases are added annually.

Women included in this study were diagnosed with microscopically confirmed stage IB2-IVA cervical cancer in California between 2004 and 2014. Stage at diagnosis was based on the International Federation of Gynecology and Obstetrics (FIGO) system. Only first primary tumor cases were included, and patients diagnosed at autopsy or by death certificate only were excluded from analysis. All patients in the study received EBRT as part of the first course of treatment. We then assessed whether patients were treated with a radiation boost; women were categorized as having received BT, EBRT boost, or no boost. Women with unknown or missing radiation boost information were excluded from the study ($n = 34$).

We examined trends in the use of BT by demographic and tumor characteristics, including age at diagnosis, race/ethnicity, year of diagnosis, SES, stage at diagnosis, histology, and tumor grade. Neighborhood-level SES was based on U.S. Census data, including educational attainment, occupation type, employment rate, median household income, poverty level, median rent, and house values. For cases diagnosed 2004–2005, SES was computed using census-block group data from the Census 2000 Summary File. For patients diagnosed 2006–2014, SES was determined from the 2007–2011 American Community Survey. These two data sources were combined to form quintiles at the block group level across the state [9,10]. Tumor histologic subtype was classified according to the International Classification of Diseases for Oncology, third edition, as squamous cell carcinoma (codes 8050–8130) adenocarcinoma (codes 8140–8490), or other.

Multivariable logistic regression was used to identify predictors of BT compared to no boost. Cox proportional hazards regression was used to estimate the impact of BT on CCS and OS. Follow-up time for mortality was calculated as the number of days between the date of diagnosis and date of death through the end of the follow-up period (December 31, 2014). Censoring was accounted for patients who were alive at the follow-up date or were lost to follow-up. All statistical analyses were performed using SAS version 9.3 (SAS Institute, Cary, NC).

Fig. 2. The dose distribution is overlaying the cervical tumor and radiation equipment, with the isodose lines being the prescribed treatment. The yellow line is the 100% radiation prescription. The bladder, rectum, and sigmoid are spared of the high dose regions with brachytherapy as shown in this figure.

3. Results

A total of 4783 women with cervical cancer were identified. Patient characteristics are displayed in Table 1 and are compared by radiation boost type. Nearly half (47.9%) of all patients were under age 50. More than 40% of patients were Hispanic, and over a third (36.1%) were non-Hispanic white. About half of the women were in the lower SES groups. A majority of the patients (53.5%) were diagnosed at stage III and had squamous cell carcinoma (74.2%). A total of 2144 women (44.8%) received BT, while 862 (18.0%) and 1777 (37.1%) had other EBRT boost, and no radiation boost, respectively. There was little variation in utilization of brachytherapy by race/ethnicity, SES. There was no evidence of a decline in utilization of brachytherapy over the study period.

The results of the analysis of predictors of BT versus no boost are shown in Table 2. Women aged 80 years and older were significantly less likely to receive a brachytherapy boost than women under the age of 50 (OR = 0.62; 95% CI: 0.40, 0.95, $p = 0.0300$). As patients aged, the use of BT decreased, from 46% among patients under age 50 to 33% for patients over age 80. Women diagnosed at stage II or III were significantly more likely to have brachytherapy than those diagnosed at Stage IB2 ($p = 0.0002$ and 0.0168 , respectively). Patients with poorly differentiated and undifferentiated tumors were less likely than those with well differentiated tumors to receive BT (OR = 0.73; 95% CI: 0.54, 1.00, $p = 0.0474$, OR = 0.47, 95% CI 0.29–0.75, $p < 0.0017$), respectively. Neither SES nor histology were statistically significant predictors of BT.

Adjusted cervical cancer-specific and all-cause mortality estimates are presented in Table 3. Compared to those receiving BT, not receiving a radiation boost was significantly associated with both deaths from

Table 1
Characteristics of women who initially received radiation for the treatment of cervical cancer, and distribution by type of boost received, California, 2004–2014.

Variable	Total		% receiving radiation boost		
	N	%	Brachytherapy	Other EBRT	None
Total	4783	100	44.8	18.0	37.2
Age at diagnosis					
<50 years	2289	47.9	45.5	16.6	37.9
50–59 years	1130	23.6	46.2	19.3	34.5
60–69 years	736	15.4	44.7	19.8	35.5
70–79 years	441	9.2	43.3	17.0	39.7
80+ years	187	3.9	32.6	23.0	44.4
Race/ethnicity					
Non-Hispanic White	1729	36.1	45.8	17.8	36.4
Non-Hispanic Black	282	5.9	42.9	17.4	39.7
Hispanic	1962	41.0	43.9	18.8	37.3
Asian/Pacific islander	758	15.8	45.4	16.8	37.9
Other/unknown	52	1.1	48.1	19.2	32.7
Socioeconomic status					
Lowest	1319	27.6	43.3	17.7	39.0
Lower-middle	1046	21.9	44.9	19.9	35.2
Middle	880	18.4	45.3	18.6	36.0
Upper-middle	749	15.7	48.5	14.7	36.8
Highest	507	10.6	43.8	18.3	37.9
Unknown	282	5.9	42.2	19.1	38.7
Stage at diagnosis					
IB2	517	10.8	43.7	12.4	43.9
II	1543	32.3	48.3	16.8	34.9
III	2558	53.5	43.8	19.3	36.9
IVA	165	3.4	31.5	27.3	41.2
Histology					
Squamous cell carcinoma	3547	74.2	45.6	18.1	36.3
Adenocarcinoma	855	17.9	44.8	16.7	38.5
Other	381	8.0	37.5	20.5	42.0
Tumor grade					
Well differentiated	271	5.7	48.7	16.2	35.1
Moderately differentiated	1528	31.9	44.6	18.5	36.9
Poorly differentiated	1771	37.0	43.9	18.0	38.1
Undifferentiated/anaplastic	146	3.1	33.6	15.1	51.4
Unknown	1067	22.3	47.1	18.3	34.6

Table 2

Odds of receiving brachytherapy boost for the treatment of cervical cancer compared to no radiation boost in California, 2004–2014.

Variable	OR (95% CI) ⁺	p-Value
Age at diagnosis		
<50 years	Ref	–
50–59 years	1.09 (0.90, 1.32)	0.3667
60–69 years	1.06 (0.85, 1.33)	0.5914
70–79 years	0.83 (0.63, 1.10)	0.1888
80+ years	0.62 (0.40, 0.95)	0.0300*
Race/ethnicity		
Non-Hispanic White	Ref	–
Non-Hispanic Black	1.03 (0.74, 1.44)	0.8438
Hispanic	1.05 (0.88, 1.26)	0.5982
Asian/Pacific islander	1.06 (0.84, 1.33)	0.6282
Socioeconomic status		
Lowest	0.91 (0.69, 1.19)	0.4991
Lower-middle	1.10 (0.84, 1.44)	0.4692
Middle	1.12 (0.85, 1.48)	0.4064
Upper-middle	1.23 (0.93, 1.64)	0.1519
Highest	Ref	–
Stage at diagnosis		
IB2	Ref	–
II	1.63 (1.27, 2.11)	0.0002*
III	1.33 (1.05, 1.69)	0.0168*
IVA	1.13 (0.69, 1.84)	0.6384
Histology		
Squamous cell carcinoma	Ref	–
Adenocarcinoma	0.88 (0.72, 1.07)	0.2014
Other	0.81 (0.60, 1.08)	0.1512
Tumor grade		
Well differentiated	Ref	–
Moderately differentiated	0.78 (0.57, 1.06)	0.1054
Poorly differentiated	0.73 (0.54, 1.00)	0.0474*
Undifferentiated/anaplastic	0.47 (0.29, 0.75)	0.0017*

Abbreviations: OR = odds ratio, CI = confidence interval, Ref = reference group.

⁺ Adjusted for radiation boost, age at diagnosis, race/ethnicity, socioeconomic status, stage at diagnosis, histology, and tumor grade.

* Indicates statistical significance at 0.05 level.

cervical cancer (HR = 1.16, 95% CI 1.01–1.34, $p = 0.0330$) and death from all causes (HR = 1.14, 95% CI 1.01–1.28, $p = 0.0333$). There was no significant survival advantage of BT compared to other EBRT boost for cancer-specific or all-cause mortality. Older age was significantly associated with increased mortality from all-causes, but not with death from cervical cancer. Compared to non-Hispanic whites, black patients had significantly worse survival from both cervical cancer (HR = 1.57, 95% CI 1.24–2.00, $p = 0.00002$) and all causes (HR = 1.47, 95% CI 1.19, 1.81, $p = 0.0003$), while Hispanic and Asian/Pacific Islander patients had better survival than white patients. Those in the lowest SES group had significantly worse survival than higher SES patients in both survival models, while patients in the middle SES groups had significantly disparate survival with respect to all-causes only. Patients diagnosed with later stages were less likely to survive, with stage III patients nearly twice more likely to die than patients with stage IB2 disease from both cervical cancer and all causes. Patients with stage IV disease had more than quadruple the risk of death from cervical cancer (HR = 4.67, 95% CI 3.31–6.60, $p < 0.0001$) and a similar risk of death from all causes (HR = 3.91, 95% CI 2.89, 5.30, $p < 0.0001$) compared to patients diagnosed early.

4. Discussion

Patterns of care studies established the essential role of BT in the management of cervical cancer, and linked its use to improvements in pelvic control and disease free survival [1,11,12]. Consistent with other reports in the literature, our study shows a poor utilization rate. Only 45% of eligible patients are treated with BT in California, with 37% of patients not receiving a boost. Furthermore, we found a corresponding detriment in CSS and OS for patients not receiving BT. Specific populations tended to have a poorer overall survival despite the use of

Table 3
Results of Cox regression for cervical cancer-specific and all-cause mortality of women who initially received radiation for the treatment of cervical cancer in California, 2004–2014.

Variable	Cervical cancer mortality		All-cause mortality	
	HR ⁺ (95% CI)	p-Value	HR ⁺ (95% CI)	p-Value
Radiation boost				
Brachytherapy	Ref	–	Ref	–
Other EBRT	1.07 (0.90, 1.28)	0.4470	1.05 (0.91, 1.22)	0.4945
None	1.16 (1.01, 1.34)	0.0330*	1.14 (1.01, 1.28)	0.0333*
Age at diagnosis				
<50 years	Ref	–	Ref	–
50–59 years	1.03 (0.88, 1.21)	0.6996	1.21 (1.06, 1.39)	0.0065*
60–69 years	1.10 (0.92, 1.33)	0.3040	1.33 (1.14, 1.56)	0.0004*
70–79 years	1.16 (0.92, 1.47)	0.2139	1.84 (1.54, 2.21)	<0.0001*
80+ years	1.38 (0.94, 2.03)	0.1025	3.52 (2.77, 4.46)	<0.0001*
Race/ethnicity				
Non-Hispanic White	Ref	–	Ref	–
Non-Hispanic Black	1.57 (1.24, 2.00)	0.0002*	1.47 (1.19, 1.81)	0.0003*
Hispanic	0.89 (0.76, 1.03)	0.1180	0.80 (0.70, 0.91)	0.0006*
Asian/Pacific islander	0.86 (0.70, 1.05)	0.1336	0.81 (0.68, 0.96)	0.0124*
Socioeconomic status				
Lowest	1.30 (1.03, 1.64)	0.0263*	1.49 (1.21, 1.82)	0.0001*
Lower-middle	1.20 (0.95, 1.52)	0.1238	1.40 (1.14, 1.71)	0.0013*
Middle	1.19 (0.94, 1.51)	0.1453	1.31 (1.06, 1.60)	0.0109*
Upper-middle	1.12 (0.88, 1.44)	0.3551	1.19 (0.96, 1.47)	0.1192
Highest	Ref	–	Ref	–
Stage at diagnosis				
IB2	Ref	–	Ref	–
II	1.22 (0.94, 1.58)	0.1413	1.25 (1.00, 1.56)	0.0516
III	1.92 (1.51, 2.44)	<0.0001*	1.83 (1.49, 2.25)	<0.0001*
IVA	4.67 (3.31, 6.60)	<0.0001*	3.91 (2.89, 5.30)	<0.0001*
Histology				
Squamous cell carcinoma	Ref	–	Ref	–
Adenocarcinoma	1.17 (0.98, 1.38)	0.0769	1.21 (1.05, 1.40)	0.0091*
Other	1.09 (0.86, 1.38)	0.4719	1.23 (1.01, 1.49)	0.0397*
Tumor grade				
Well differentiated	Ref	–	Ref	–
Moderately differentiated	1.42 (1.05, 1.90)	0.0214*	1.33 (1.04, 1.69)	0.0218*
Poorly differentiated	1.76 (1.31, 2.36)	0.0002*	1.65 (1.30, 2.10)	<0.0001*
Undifferentiated/anaplastic	1.31 (0.85, 2.01)	0.2205	1.19 (0.84, 1.71)	0.3304

Abbreviations: HR = hazard ratio, CI = confidence interval, Ref = reference group.

⁺ Adjusted for radiation boost, age at diagnosis, race/ethnicity, socioeconomic status, stage at diagnosis, histology, and tumor grade.

* Indicates statistical significance at 0.05 level.

BT, such as those in low SES and black patients. Elderly patients >80 years old were less likely to be treated with BT. Therefore, our study highlights the potential areas for radiation healthcare delivery improvement and disparities of care in California.

Numerous data in the literature are consistent with our findings of a low utilization of BT, with impact on CSS and OS. Han et al. used the SEER database to examine trends in BT utilization. The study found that the rate of BT utilization rate decreased from 83% in 1988 to 58% in 2009 ($p < 0.001$), with a sharp decline in 2003 to 43% [5]. Furthermore, they found that BT was associated with higher 4-year cause-specific survival (CSS; 64.3% vs 51.5%, $p < 0.001$) and overall survival (OS; 58.2% vs 46.2%, $p < 0.001$) [5]. There may have been differences seen based on Medicare coding, but regardless, their data showed a downward trend in BT [13]. A recent study showed only 44% of patients receive standard CRT and BT, with a subsequent OS advantage versus patients not treated within standard guidelines [7]. Interestingly, in this study an EBRT boost conferred a higher survival advantage over no boost, but not over those who received BT (HR 0.554, $p < 0.001$) [7]. Gill et al. also used the National Cancer Database to review the trends of BT and emerging radiation techniques for locally advanced cervical cancer [4]. Advanced radiation treatment modalities like intensity modulated radiation therapy (IMRT) and stereotactic body radiation therapy (SBRT) use increased from 3.3% to 13.9% in the same period ($p < 0.01$), but they found a survival advantage to patients treated with BT versus these techniques [4]. Unfortunately, most of the data exploring boost modalities has a component of selection bias, with the patients being offered BT potentially more medically fit. Our analysis showed improved CSS and OS with the use of BT, like the

aforementioned investigations. The distinction of this study from the literature examining the utilization trends of brachytherapy as it uses the CCR, where all patients in California with a cancer diagnosis are mandated by law to be reported to the registry, allowing for a robust and diverse population. Also, it allows for analysis of the state's standard of care trends for cervical cancer, to help with resource allocation and potential funding strategies in the future.

Cancer therapy in the elderly is an evolving field with great relevance given that it is estimated that by 2030, people aged >65 years old will represent about 20% of the American population [14]. In our investigation, the population less likely to be treated with BT are the elderly >80 years old. Moore et al. recently performed an ancillary data review of the cooperative oncology group studies of GOG protocols 113, 120, 165 and 219 that examined chemoradiation and BT with data stratified by decade of age with a goal of evaluating patients ≥65 [15]. They found that BT was not completed in 35% of patients ≥70 as compared to 13% of pts <40 on these clinical trials, where patients are often treated in large academic centers with radiation specific brachytherapy and gynecologic programs [15]. The possible reasons for a decline in the use of brachytherapy in the elderly could be reflective of patient comorbidity, anatomical changes due to age such as vaginal stenosis, or the comfort level of the brachytherapist for sedation or procedural complications in a patient with advanced age.

FIGO Stage IVA patients have historically done poorly with standard therapy, with a 5 year OS of 16%, presumably poor due to locally aggressive disease with high risk for distant failure [16]. Based on recent image guided brachytherapy reports, the prognosis of stage IVA patients have increased dramatically to an actuarial 5 year CSS and OS of 32% and 40%,

suggesting the impact of local therapy on survival [17]. Our study reports one of the largest stage IVA patient populations in the literature with 165 patients, and only 31% of these patients received BT, and 41% received no boost at all. These patients had >4.5-fold risk of dying of cervical cancer versus those with stage 1B2. Our data highlights a stage of patients where efforts could be targeted for BT offerings.

Given our study using the CCR, and multiple studies in the literature showing a decline in the use of BT, it prompts the question: who is not being offered BT and why? The National Cancer Institute has incorporated into its cancer therapy goals the further elucidation of health care disparities. Our study shows that patients in the lowest SES have worse CCS and OS compared with patients in higher SES strata. Complex and interrelated factors contribute to the observed disparities in cancer death among racial, ethnic, and underserved groups. The most obvious factors are associated with a lack of health care coverage and low SES. In California, our study showed a decrease in cervical cancer outcomes for black patients and those from low SES neighborhoods. Cervical cancer treatment, in general, is often plagued by confounders of being in a low SES, such health related challenges like tobacco and substance abuse, poor nutrition, poor social support and access, which adversely affects long term outcomes [18,19]. Furthermore, patients with a poor SES often lack medical coverage, have barriers and unequal access to improvements in cancer treatment that may contribute to observed differences in survival. Among cervical cancer studies, there continues to be poor accrual among minority and low income females, highlighting the disparities of cancer care and innovation in this population [20,21].

The underutilization of BT is likely multifactorial. Our study identifies underserved populations for potential delivery targets. However, the use of BT and its ability to serve patients is dependent on availability of both adequate equipment and trained operators. In a study examining BT utilization rate, patients were served in areas where BT equipment was available [22]. Further, the rise in radiation technologic advances such as an increase in IMRT and SBRT for cervical cancer could be replacing BT [4]. The data in the literature on SBRT for definitive cervical cancer consists of small observational series of patients reported [23,24]. Our data did not show a difference in CSS or OS between BT or an EBRT boost. Perhaps there are subsets of patients that have a high risk of systemic failure, for example those with lymph node burden, where local control with BT would not be as impactful to the overall prognosis or quality of life. At this time, given the available literature, BT remains the standard treatment for all locally advanced cervical cancer patients [2]. In addition, our data was unable to detail specific institutional brachytherapy case load which can influence both quality and practice patterns of brachytherapy [25]. Gynecologic brachytherapy requires a coordinated and skilled team, which may limit the number of cancer treatment centers that could offer the care required for brachytherapy services [26]. In fact, lower utilization of BT is seen in lower patient volume treatment centers, suggesting a lack of programmatic development for these specialized procedures [4]. The workflow and labor intensity of BT, including the time that the implant, treatment planning and physics delivery consumes could also be a limiting step in the era of efficiency demands of healthcare delivery [26].

Yet another option to target disparities among SES, the elderly, and black patients in California would be to establish centers of excellence for gynecological brachytherapy to further support streamlined and efficient care. For example, a high volume center would be a referral basin for surrounding counties for optimal patient management. Also, emerging technology in the form of electronic telemedicine consultation, specialized physician-to-physician communication, online tools, and targeted education programs for physicians and mid-level providers may increase awareness. In addition, brachytherapy utilization awareness can increase with targeted recruitment to cervical cancer clinical trials. For example, when patients enroll on NRG oncology cooperative group clinical trials, the brachytherapy selection and quality is specifically reviewed by a team of radiation oncologists and radiation physics

with expertise in image guided brachytherapy to ensure proper applicator placement, prescription guidance, and dose distributions.

5. Limitations

A potential limitation of our study is the reported treatment variability in cancer registries [27–29]. CCR data for Los Angeles was examined for patients with breast cancer and found that data were accurate for hospital-based settings, and that the receipt of radiation therapy was 72% as verified by the medical record [28]. In a study using the SEER database, 41.6% of breast cancer patients received RT according to registry coding versus 49% per Medicare claims, $p < 0.001$ [27]. The variation in radiation reporting was dependent on the timeframe of the SEER registry, rural setting, or if the radiation was delayed [27]. Our database itself could have selection bias or confounding due CCR reporting within geographical regions of California. Despite the caveats with registry data, a valid strength of this study is its large population base, which in this study allows us to investigate 4387 cervical cancer patients from California. All patients in this study received radiation therapy as first course of treatment thus underreporting of boost radiation among this cohort is unlikely. Unfortunately, the CCR does not prospectively collect data on loco-regional failure which would be helpful to determine patterns of failure, or target quality assurance in BT.

6. Conclusions

The overall utilization in California for a BT in locally advanced cervical cancer was low at 45% during this period, with a subsequent decrease in survival outcomes compared to no boost. BT use was lower in patients >80 and stage IVA patients. Black patients and those in low SES had worse CSS. Identification of specific target populations and outcomes will help resource allocation and strategies in the optimal treatment of locally advanced cervical cancer, and the appropriate use of gynecologic brachytherapy.

Author contributions

JM-conceptualization, data curation, formal analysis, investigation, methodology, project administration, resources, supervision, validation, visualization, writing - original draft, and writing - review and editing; AK-conceptualization, data curation, formal analysis, investigation, methodology, project administration, validation, writing - original draft, and writing - review and editing; CY-conceptualization, writing - review and editing; IH-conceptualization, writing - review and editing; MK-conceptualization, writing - review and editing; AM: conceptualization, writing - review and editing; LM-conceptualization, writing - review and editing; JE-conceptualization, writing - review and editing; SB-conceptualization, writing - original draft, and writing - review and editing; RV-conceptualization, funding acquisition, investigation, writing - review and editing; RC-conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, resources, software, supervision, validation, visualization, writing - original draft, and writing - review and editing.

Conflict of interest statement

The authors declare that there are no conflicts of interest.

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