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An Assessment of Radiotherapy and Surgery Utilisation and Health Outcomes, in Aboriginal and Non-Aboriginal People With Cancer in NSW, Australia, 2009–2018

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ABSTRACT

Introduction: Aboriginal patients face barriers to accessing cancer care. Few studies have evaluated the utilisation of radiotherapy or surgery in Aboriginal people. This study aims at assessing variation in types of cancer, degree of spread (DOS) at presentation, utilisation rates of cancer surgery and radiotherapy between Aboriginal and non-Aboriginal cancer patients.

Methods: Retrospective analysis of de-identified linked datasets. All patients with registered notifiable cancer in the NSW cancer registry 2009–2018 separated by Aboriginality status were included.

Results: Totally 389,992 people were diagnosed in NSW during study period; 8970 people (2.3%) identified as Aboriginal. In univariate analysis, Aboriginal people presented at diagnosis with statistically significant younger age, greater comorbidity, advanced (DOS) and greater proportions living in most disadvantaged areas than non-Aboriginal people. Based on univariate analysis, Aboriginal patients received radiotherapy more frequently than non-Aboriginal patients (30.3% versus 26.0%, $p < 0.01$). Non-Aboriginal patients underwent cancer surgery more frequently than Aboriginal patients (57.0% versus 51.2%, $p < 0.01$). When stratified by tumour type and adjustment for patient and clinical factors, radiotherapy and surgery utilisation varied by type of cancer.

Conclusions: The degree of cancer spread, and the presence of comorbidities remains a greater issue for Aboriginal people. Access to radiotherapy increased significantly for Aboriginal patients during the past 10 years. However, differences in surgical and radiotherapy utilisation exist. These differences can be partially explained by the greater DOS and presence of comorbidity in Aboriginal patients leading to less surgical intervention and greater requirement for radiotherapy.

1 | Introduction

Aboriginal and Torres Strait Islander cancer patients (respectively called here Aboriginal) face barriers to accessing cancer care, including historical trauma [1], lack of cultural understanding or respect shown by health care providers, lack of timely access to culturally safe services, remoteness to specialist health services and differing cultural beliefs about cancer [2, 3]. These factors may influence the timeliness and extent to which Aboriginal people present for diagnosis and treatment, contributing to poorer outcomes and higher mortality [4, 5]. In addition, Aboriginal people in rural/regional/remote areas face difficulties leaving their home, family and community to access city-based cancer services [1, 6–8]. Social and family obligations are competing priorities with cancer treatments, causing treatment interruptions or early cessation. Studies have identified that Aboriginal cancer patients often have more comorbidities at diagnosis than non-Aboriginal cancer patients [9] further complicating care. Similar poor outcomes have been identified in other indigenous populations including Inuit and Māori peoples [10, 11].

Previous studies in various Australian jurisdictions have identified that Aboriginal people had more advanced cancers at presentation [12] and were less likely than non-Aboriginal people to undergo surgery for lung [13–15], head and neck [16], breast [17], prostate [13] and cervical cancers [18]. However, most of these studies are of patients treated more than 15 years ago. Few studies have evaluated the utilisation of radiotherapy or surgery in Aboriginal and non-Aboriginal people [19, 20].

The aims of this study were to assess and compare the following between Aboriginal and non-Aboriginal cancer patients:

1. Types of cancer and degree of spread at presentation.
2. Use of cancer surgery overall and by cancer type
3. Use of radiotherapy overall and by cancer type

2 | Materials and Methods

This was a retrospective analysis of a de-identified linked dataset. We have reported using similar methodology when examining the radiotherapy utilisation of all NSW cancer patients [21].

The study protocol was developed with multiple indigenous co-authors (KG, SA, DS) and was supported by the Tharawal Aboriginal Corporation and approved by the NSW Population and Health Services Research Ethics Committee (NSW Ethics 2019/ETH01657). The study protocol and the paper were approved by the Aboriginal Health and Medical Research Ethics Committee (NSW AH&MRC 1770/21). This study brought together researchers from health services, epidemiological and data linkage fields, along with Aboriginal health professionals and researchers to conduct one of the largest and most comprehensive population-based studies on surgery and radiotherapy utilisation of Australian Aboriginal cancer patients given that a third of the national Aboriginal population live in NSW [22].

Data were obtained on patients diagnosed with a notifiable cancer (includes all age groups, all invasive cancers except non-melanoma skin cancer) from NSW Cancer Registry for the period 2009–2018. These data were linked to Admitted Patient Data Collection (APDC), and the Outpatient Radiation Oncology Dataset (OROD). Staging data were based on Degree of Spread as this is the staging system used by the NSW Cancer Registry. This system describes the stage in 5 categories—local, regional to adjacent organs, regional to lymph nodes, metastatic and unknown. Chemotherapy data were unavailable and therefore not examined. All data were probabilistically linked by the NSW Centre for Health Record Linkage, providing a de-identified database. With respect to identifying those with Aboriginal status, the Enhanced Reporting of Aboriginality (ERA) was used [23]. ERA is a method that improves reporting on the health of Aboriginal people from administrative data collections using record linkage. Enhanced reporting relies on having linked records from the same person collected from independent sources, such as hospital admissions, emergency department presentations, births and deaths. Each record in the chain of linked records contributes to the weight of evidence as to whether a person is truly Aboriginal but may have been recorded as being non-Aboriginal or 'unknown' on some records. It is important to mention that this method doesn't simply recover 'missing' Aboriginality values, but it often uncovers Aboriginal people coded as non-Aboriginal in the reference dataset. To apply the ERA method, the Aboriginal status data for every individual patient in the NSW Cancer Registry dataset were linked to APDC, Emergency Department Data Collection, Cause of Death Unit Record File, Registry of Births, Deaths and Marriages records and OROD. It was decided to exclude patients who declined to report their Aboriginal status ($n = 32$) and patients missing Aboriginal status ($n = 2974$).

Socio-economic status was classified into five quintiles (Quintile-1 most disadvantaged to Quintile-5 least disadvantaged) using the Index of Relative Socioeconomic Disadvantage (IRSD) [24]. Road distance from patient residence to nearest facility (including interstate facilities) was calculated using buffered geocodes of patient residence [25] and Geographic Information System Software (ArcGIS Desktop: Release-10. Redlands, CA: Environmental Systems Research Institute). Non-cancer-related comorbidity index scores, based on the Quan-modification of the Charlson comorbidity index calculation (CCI), [26] were calculated using the ICD-10 diagnosis codes from the APDC dataset, basing index calculations on the prior 2 years of admissions for each patient. Cells with less than 5 counts in them are suppressed to protect privacy.

Oncologic surgery episode was arbitrarily defined as any record of an oncological operation occurring within one year of a cancer diagnosis. The rate of radiotherapy was defined as any record of receiving external beam radiotherapy within one year of diagnosis. NSW patients who lived nearer to the border with other states may have received treatment in other states (cross borders) without being recorded in the NSW dataset. In our previous study [25] we found that 10,008/108,064 (9.3%) of patients accessed treatment across a state border. Therefore, patients whose closest treatment facility was across the border (cross borders) were excluded from the surgical and radiotherapy analysis. In addition, for the surgical

and radiotherapy utilisation analyses, we also excluded patients who had more than one cancer diagnosis during the study period as the surgery and radiotherapy code could not be attributed to one specific cancer. For the surgical utilisation calculations, we also removed patients who had cancers where surgery is predominantly in outpatient clinics where the APDC does not capture these surgeries (melanoma) and also cancers where surgery does not play a predominant role (haematological malignancy).

3 | Statistical Analysis

Chi-square tests were used to analyse the univariate relationship between radiotherapy and surgery utilisation with factors Aboriginality status, age group, degree of spread, area of remoteness, IRSD, year of diagnosis, Quan comorbidity index, distance from radiotherapy treatment centre and sex. Analysis was performed separately for each tumour site. A multivariable logistic regression was then used to analyse these factors with radiotherapy and surgery utilisation. As effect modification was expected, the following interactions were considered as part of the multivariable model; ARIA by degree of spread; Aboriginal status by ARIA; Aboriginal status by comorbidity; Aboriginal status by degree of spread; Aboriginal status by IRSD; and Aboriginal status by year group of diagnosis. Interactions amongst ARIA, IRSD, degree of spread, comorbidity and sex were also examined. Interactions that were significant remained in the final multivariable model. Hosmer–Lemeshow goodness-of-fit test [27] was used to check model fit. Probit models were considered for models with poor model fit. The statistical analysis was conducted in SAS Enterprise Guide version 8.2 and SPSS version 27. Within Aboriginal and non-Aboriginal patients, univariate comparisons were made between patients diagnosed by year groups (2009–2011, 2012–2015, 2016–2018) for differences in degree of spread, radiotherapy and surgical utilisation rates.

4 | Results

For the 10-year study period, 389,992 people were diagnosed with 414,980 cancers in NSW (Table 1). Of these cancer patients, 8970 (2.3%) identified as Aboriginal. For the radiotherapy utilisation rate calculations, there were 53,410 (13.7%) patients excluded from this part of the analysis as they either lived closer to an interstate cancer facility (26,712, 6.8%) or had more than one cancer diagnosis during the study period (21,809, 5.6%) or diagnosed with death certificate only (4889, 1.3%), leaving 336,582 (86.3%) patients being analysed for radiotherapy utilisation. In addition, for surgery utilisation, patients who were diagnosed with melanoma, haematopoietic cancers, unknown and other cancers (80,895, 20.7%) and patients who had no record in the Admitted Patient dataset (11,608, 3.0%) were excluded, leaving 244,079 (62.6%) patients being analysed for surgery utilisation.

4.1 | Age at Diagnosis

The mean age at diagnosis for Aboriginal patients was 59 years compared to 66 years for non-Aboriginal patients. 45.3% of Aboriginal patients diagnosed with cancer were less than 60 years old compared to 29.6% for non-Aboriginal patients, $p < 0.01$ (Table 1).

4.2 | Sociodemographic Status

31.7% of Aboriginal cancer patients live in the most disadvantaged areas and 7.4% live in the least disadvantaged areas compared to 19.7% and 20.1%, respectively for non-Aboriginal patients, $p < 0.01$. 65.2% of Aboriginal patients live in Major cities or Inner regional areas and 34.6% live in Outer regional and Remote or very remote areas compared to 83% and 17%, respectively for non-Aboriginal patients, $p < 0.01$ (Table 1). 62.5% of Aboriginal patients live within 50 km from the nearest radiotherapy facility compared to 80.5% for non-Aboriginal patients, $p < 0.01$ (Table 1).

4.3 | Quan Modification of the Charlson Comorbidity Index

75.2% of Aboriginal patients had no recorded comorbidity during the two-year pre-cancer diagnosis compared to 83.5% for non-Aboriginal patients, $p < 0.01$ (Table 1).

4.4 | Cancer Types

Compared to non-Aboriginal patients, Aboriginal patients had a greater proportion of head and neck, oesophagus, liver, lung, cervix, testis and kidney cancers; and lower proportions of colorectal cancer, melanoma, prostate, lymphoma and multiple myeloma (Table 1).

4.5 | Degree of Spread

Aboriginal patients at diagnosis presented with statistically significant greater proportion of regional spread to lymph nodes and/or distant metastasis for overall combined tumour sites (Table 1) ($p < 0.01$), and of specific tumour sites including head and neck, breast, melanoma and brain cancers (Table 2). Degree of spread improved, with a reduction in advanced disease and an increase in localised disease, between the years 2009–2011 and 2016–2018 cohorts for both Aboriginal and non-Aboriginal groups (Table 3).

4.6 | Surgical and Radiotherapy Utilisation Rates

Radiotherapy utilisation marginally increased in both patient groups during the study period ($p < 0.001$) (Table 3). Surgical utilisation did not significantly change in Aboriginal patients ($p = 0.177$) and increased for non-Aboriginal patients ($p < 0.001$) throughout the study period (Table 3). The proportion of cancer patients who underwent radiotherapy at least once within 1 year of diagnosis was 26.1%, with a greater proportion of Aboriginal patients undergoing radiotherapy than non-Aboriginal patients (30.3% versus 26.1%, $p < 0.01$), (Table 4). Despite a higher proportion of Aboriginal patients living 200 km or more from the nearest treatment facility

TABLE 1 | Sociodemographic and cancer characteristics by Aboriginality, NSW 2009–2018.

	Aboriginal *n* (%)	Non-aboriginal *n* (%)	Total *n* (%)	*p*
Study cohort				
Patients with single diagnosis				
Patients	8446 (2.3%)	358,132 (97.7%)	366,578 (100%)	
Patients with multiple diagnoses				
Patients	520 (2.2%)	22,894 (97.8%)	23,414 (100%)	
Cancers	1072 (2.2%)	47,330 (97.8%)	48,402 (100%)	
Total				
Patients	8966 (2.3%)	381,026 (97.7%)	389,992 (100%)	
Cancers	9518 (2.3%)	405,462 (97.7%)	414,980 (100%)	
Periods of diagnosis				
2009–2011	2389 (26.6%)	111,320 (29.2%)	113,709 (29.2%)	< 0.001
2012–2015	3564 (39.8%)	152,735 (40.1%)	156,299 (40.1%)	
2016–2018	3013 (33.6%)	116,971 (30.7%)	119,984 (30.8%)	
Age in years: Median [Interquartile] (range)	61[51,61,70] (0–100)	67[57,67,77] (0–107)	67[57,67,76] (0–107)	
Age groups (years)				
< 60	4064 (45.3%)	112,832 (29.6%)	116,896 (30.0%)	< 0.001
60–69	2522 (28.1%)	103,047 (27.0%)	105,569 (27.1%)	
70–79	1679 (18.7%)	95,049 (24.9%)	96,728 (24.8%)	
≥ 80	701 (7.8%)	70,098 (18.4%)	70,799 (18.2%)	
Sex				
Female	4192 (46.8%)	171,613 (45.0%)	175,805 (45.1%)	0.001
Male	4774 (53.2%)	209,413 (55.0%)	214,187 (54.9%)	
Country of birth				
Australian born	7818 (87.2%)	226,526 (59.5%)	234,344 (60.1%)	< 0.001
Overseas born	460 (5.1%)	109,028 (28.6%)	109,488 (28.1%)	
Missing	688 (7.7%)	45,472 (11.9%)	46,160 (11.8%)	
Degree of spread at diagnosis				
Localised to tissue of origin	3641 (41.7%)	167,494 (45.9%)	171,135 (45.8%)	< 0.001
Regional spread, adjacent organs	815 (9.3%)	37,223 (10.2%)	38,038 (10.2%)	
Regional spread, regional lymph nodes	1322 (15.2%)	48,352 (13.3%)	49,674 (13.3%)	
Distant metastases	1648 (18.9%)	59,212 (16.2%)	60,860 (16.3%)	
Unknown	1296 (14.9%)	52,262 (14.3%)	53,558 (143%)	
Index of relative socioeconomic disadvantage				
Most disadvantaged	2840 (31.7%)	75,185 (19.7%)	78,025 (20.0%)	< 0.001
Quintile-2	2266 (25.3%)	74,636 (19.6%)	76,902 (19.7%)	
Quintile-3	1820 (20.3%)	73,277 (19.2%)	75,097 (19.3%)	
Quintile-4	1357 (15.1%)	80,984 (21.3%)	82,341 (21.1%)	
Least disadvantaged	666 (7.4%)	76,686 (20.1%)	77,352 (19.8%)	

(Continues)

TABLE 1 | (Continued)

	Aboriginal *n* (%)	Non-aboriginal *n* (%)	Total *n* (%)	*p*
Missing	17 (0.2%)	258 (0.1%)	275 (0.1%)	
Accessibility/Remoteness Index of Australia				
Major cities	3398 (37.9%)	221,417 (58.1%)	224,845 (57.7%)	< 0.001
Inner regional	2452 (27.3%)	94,766 (24.9%)	97,218 (24.9%)	
Outer regional	2693 (30.0%)	61,981 (16.3%)	64,674 (16.6%)	
Remote/very remote	423 (4.6%)	2832 (0.7%)	3255 (0.8%)	
Cross borders				
Cross borders	650 (7.2%)	26,062 (6.8%)	26,712 (6.8%)	0.132
Non-cross borders	8316 (92.8%)	354,964 (93.2%)	369,280 (93.2%)	
Distance to nearest facility				
< 50 km	5599 (62.5%)	306,509 (80.5%)	312,108 (80.0%)	< 0.01
50–99 km	1056 (11.8%)	31,168 (8.2%)	32,224 (8.3%)	
100–149 km	734 (8.2%)	18,747 (4.9%)	19,481 (5.0%)	
150–199 km	383 (4.3%)	8702 (2.3%)	9085 (2.3%)	
200+ km	1191 (13.3%)	15,809 (4.2%)	17,000 (4.4%)	
Quan updated Charlson Comorbidity Index				
No comorbidity	6739 (75.2%)	318,234 (83.5%)	324,973 (83.3%)	< 0.001
Comorbidity = 1	948 (10.6%)	26,352 (6.9%)	27,300 (7.0%)	
Comorbidity ≥ 2	1279 (14.3%)	36,440 (9.6%)	37,719 (9.7%)	
Cancer site				
Prostate	1187 (13.2%)	63,939 (16.8%)	65,126 (16.7%)	< 0.001
Breast	1157 (12.9%)	50,326 (13.2%)	51,483 (13.2%)	
Colorectal	892 (9.9%)	45,368 (11.9%)	46,260 (11.9%)	
Melanoma	591 (6.6%)	39,345 (10.3%)	39,936 (10.2%)	
Lung	1153 (12.9%)	33,875 (8.9%)	35,028 (9.0%)	
Lymphoma	313 (3.5%)	16,872 (4.4%)	17,185 (4.4%)	
Head & neck	508 (5.7%)	13,286 (3.5%)	13,794 (3.5%)	
Other cancers	343 (3.8%)	11,947 (3.1%)	12,290 (3.2%)	
Kidney and renal pelvis	298 (3.3%)	10,895 (2.9%)	11,193 (2.9%)	
Leukaemia	237 (2.6%)	10,661 (2.8%)	10,898 (2.8%)	
Pancreas	227 (2.5%)	9722 (2.6%)	9949 (2.6%)	
Thyroid	228 (2.5%)	9664 (2.5%)	9892 (2.5%)	
Unknown	229 (2.6%)	9215 (2.4%)	9444 (2.4%)	
Uterus	199 (2.2%)	7605 (2.0%)	7804 (2.0%)	
Bladder	167 (1.9%)	7689 (2.0%)	7856 (2.0%)	
Stomach	168 (1.9%)	6673 (1.8%)	6841 (1.8%)	
Liver	263 (2.9%)	6261 (1.6%)	6524 (1.7%)	
Multiple Myeloma	102 (1.1%)	5340 (1.4%)	5442 (1.4%)	

(Continues)

TABLE 1 | (Continued)

	Aboriginal *n* (%)	Non-aboriginal *n* (%)	Total *n* (%)	*p*
Brain	107 (1.2%)	4968 (1.3%)	5075 (1.3%)	
Ovary	102 (1.1%)	4603 (1.2%)	4705 (1.2%)	
Oesophagus	128 (1.4%)	4123 (1.1%)	4251 (1.1%)	
Gall Bladder	76 (0.8%)	2648 (0.7%)	2724 (0.7%)	
Cervix	141 (1.6%)	2420 (0.6%)	2561 (0.7%)	
Testis	101 (1.1%)	2361 (0.6%)	2462 (0.6%)	
Vulva	42 (0.5%)	1000 (0.3%)	1042 (0.3%)	
Vagina	7 (0.1%)	220 (0.1%)	227 (0.1%)	
Total	8966 (100%)	381,026 (100%)	389,992 (100%)	

(12.2% vs. 3.0%) radiotherapy utilisation rates were significantly higher for Aboriginal compared to non-Aboriginal patients (24.6% vs. 18.9%, $p < 0.01$) (Table 5). The proportion of Aboriginal patients who underwent cancer surgery was significantly lower than for non-Aboriginal patients (51.2% versus 57.0%, $p < 0.01$). The difference was statistically significant for head and neck, stomach, liver, lung, breast and prostate cancers (Table 6). A higher proportion of Aboriginal patients had bladder surgery than non-Aboriginal (24.6% versus 17.2%, $p = 0.04$).

Adjusted odds ratios (AOR) (using multivariable logistic regression) for radiotherapy utilisation and surgery utilisation between Aboriginal and non-Aboriginal patients by tumour site are available in Table 7.

When compared to non-Aboriginal patients, increases in the odds of radiotherapy utilisation were observed in Aboriginal patients in rectum cancer with no comorbidities (OR 2 (1.3, 3.09)), lung cancer (OR 1.21 (1.06, 1.38)) and prostate cancer (OR 1.36 (1.17, 1.57)) and reduced odds in Oesophageal cancer with 1 comorbidity (OR 0.3 (0.12, 0.74)). Hosmer and Lemeshow goodness-of-fit tests were significant in the models for prostate, lung and cervix tumour sites indicating poor model fit. The use of probit models did not improve model fit.

Aboriginal patients had reduced odds in surgery for patients in stomach cancer (OR 0.44 (0.28, 0.68)), liver cancer (OR 0.58 (0.37–0.90)), head and neck cancer and with at least 2 comorbidities (OR 0.54 (0.38, 0.77)), lung cancer (OR 0.6 (0.48, 0.74)), breast cancer for patients in outer regional areas (OR 0.65 (0.46, 0.90)) and prostate cancer for patients diagnosed in 2016–2018 (OR 0.56 (0.42, 0.76)). Hosmer–Lemeshow goodness-of-fit tests were significant for the models in prostate, breast, colon and rectosigmoid, pancreas and thyroid tumour sites indicating poor model fit. Probit models did not improve model fits in these sites.

5 | Discussion

The univariate analysis in this study has identified that cancer in Aboriginal patients occurred at a younger age and were more advanced at presentation. Aboriginal patients were also likely to have significantly more comorbidities and live a greater distance from a cancer treatment centre. Over the duration of this study, the proportions of patients with localised spread have increased, and the proportions of distant metastasis has decreased for both Aboriginal and non-Aboriginal patients, with some tumours showing a halving of the more advanced stages of disease. The change in degree of cancer spread was more pronounced for the Aboriginal population. This suggests efforts to eliminate disadvantage and improve access to screening and other medical services are proving effective. This also supports other recent findings of a significant improvement in life expectancy amongst Aboriginal people in the Northern Territory [28]. However, these strategies have not closed the gap completely and so further efforts at improving screening rates and patient education remain important in further closing the gap. Further investigation into any modifiable causes for earlier onset of cancer in the Aboriginal population is warranted.

Based on crude percentages, Aboriginal patients had higher radiotherapy utilisation rates than non-Aboriginal patients. The reason for the higher radiotherapy utilisation rates may be partly related to the fact that they have a higher proportion of some cancers where radiotherapy plays a more significant role such as lung (12.9% vs. 8.9%), cervix (1.6% v 0.6%) and head and neck (5.7% vs. 3.5%). In addition, patients with more advanced disease at presentation are also more likely to be recommended for postoperative radiotherapy due to higher risk of locoregional recurrence or more likely to be recommended for curative radiotherapy as the extent of disease may preclude surgery, as has been shown when modelling radiotherapy needs in low- and low- to middle-income countries where advanced cancers prevail [29]. Patients with metastatic disease will also more likely receive palliative radiotherapy rather than surgery.

Our data show that Aboriginal and non-Aboriginal patients had higher radiotherapy and surgery utilisation when compared with other published series. Gibberd et al. [14] reported that 30.8% of Aboriginal people and 39.5% of non-Aboriginal in NSW (2001–2007) received surgery for nonmetastatic non–small-cell lung cancer (NSCLC), compared with 36.8% and 46.5%, respectively in this study. Hall et al. [13] found that 9.5% of all Aboriginal and 12.9% for non-Aboriginal lung cancer patients in Western Australia (1982–2001) had surgery compared

TABLE 2 | Tumour site[a] by aboriginal status and degree of cancer spread, NSW 2009–2018.

Degree of spread for different tumour Sites	Aboriginal *n* (%)	Non-aboriginal *n* (%)	Total *n* (%)	*p*
Head & neck				
Localised to tissue of origin	182 (33.5%)	5202 (36.6%)	5384 (36.5%)	0.008
Regional spread, adjacent organs	70 (12.9%)	1748 (12.3%)	1818 (12.3%)	
Regional spread, regional lymph nodes	173 (31.8%)	3738 (26.3%)	3911 (26.5%)	
Distant metastases	41 (7.5%)	888 (6.2%)	929 (6.3%)	
Unknown	78 (14.3%)	2634 (18.5%)	2712 (18.4%)	
Oesophagus				
Localised to tissue of origin	43 (30.7%)	1508 (34%)	1551 (33.9%)	0.152
Regional spread, adjacent organs	10 (7.1%)	268 (6%)	278 (6.1%)	
Regional spread, regional lymph nodes	16 (11.4%)	659 (14.9%)	675 (14.8%)	
Distant metastases	53 (37.9%)	1274 (28.7%)	1327 (29%)	
Unknown	18 (12.9%)	726 (16.4%)	744 (16.3%)	
Stomach				
Localised to tissue of origin	52 (29.2%)	2039 (28.6%)	2091 (28.7%)	0.180
Regional spread, adjacent organs	11 (6.2%)	507 (7.1%)	518 (7.1%)	
Regional spread, regional lymph nodes	38 (21.3%)	1149 (16.1%)	1187 (16.3%)	
Distant metastases	57 (32%)	2235 (31.4%)	2292 (31.4%)	
Unknown	20 (11.2%)	1188 (16.7%)	1208 (16.6%)	
Pancreas				
Localised to tissue of origin	36 (15.5%)	1772 (17.6%)	1808 (17.6%)	0.591
Regional spread, adjacent organs	17 (7.3%)	971 (9.7%)	988 (9.6%)	
Regional spread, regional lymph nodes	24 (10.3%)	1080 (10.8%)	1104 (10.7%)	
Distant metastases	119 (51.3%)	4807 (47.9%)	4926 (47.9%)	
Unknown	36 (15.5%)	1413 (14.1%)	1449 (14.1%)	
Colon and rectosigmoid				
Localised to tissue of origin	190 (27.2%)	10,979 (30.6%)	11,169 (30.5%)	0.102
Regional spread, adjacent organs	141 (20.2%)	7264 (20.3%)	7405 (20.3%)	
Regional spread, regional lymph nodes	184 (26.4%)	8042 (22.4%)	8226 (22.5%)	
Distant metastases	140 (20.1%)	7135 (19.9%)	7275 (19.9%)	
Unknown	43 (6.2%)	2442 (6.8%)	2485 (6.8%)	
Rectum				
Localised to tissue of origin	78 (30.8%)	4453 (36.2%)	4531 (36.1%)	0.190
Regional spread, adjacent organs	43 (17%)	1626 (13.2%)	1669 (13.3%)	
Regional spread, regional lymph nodes	56 (22.1%)	2836 (23.1%)	2892 (23.1%)	
Distant metastases	44 (17.4%)	1789 (14.6%)	1833 (14.6%)	
Unknown	32 (12.6%)	1589 (12.9%)	1621 (12.9%)	
Liver				
Localised to tissue of origin	125 (47.5%)	3069 (47.9%)	3194 (47.9%)	0.176
Regional spread, adjacent organs	11 (4.2%)	501 (7.8%)	512 (7.7%)	
Regional spread, regional lymph nodes	6 (2.3%)	182 (2.8%)	188 (2.8%)	
Distant metastases	52 (19.8%)	1221 (19%)	1273 (19.1%)	
Unknown	69 (26.2%)	1437 (22.4%)	1506 (22.6%)	

(Continues)

TABLE 2 | (Continued)

Degree of spread for different tumour Sites	Aboriginal *n* (%)	Non-aboriginal *n* (%)	Total *n* (%)	*p*
Gall Bladder				
Localised to tissue of origin	17 (22.1%)	584 (20.9%)	601 (20.9%)	0.687
Regional spread, adjacent organs	7 (9.1%)	427 (15.3%)	434 (15.1%)	
Regional spread, regional lymph nodes	14 (18.2%)	492 (17.6%)	506 (17.6%)	
Distant metastases	29 (37.7%)	961 (34.3%)	990 (34.4%)	
Unknown	10 (13%)	334 (11.9%)	344 (12%)	
Lung				
Localised to tissue of origin	244 (19.8%)	7084 (19.8%)	7328 (19.8%)	0.727
Regional spread, adjacent organs	69 (5.6%)	2086 (5.8%)	2155 (5.8%)	
Regional spread, regional lymph nodes	178 (14.4%)	5300 (14.8%)	5478 (14.8%)	
Distant metastases	539 (43.8%)	15,965 (44.6%)	16,504 (44.6%)	
Unknown	202 (16.4%)	5354 (15%)	5556 (15%)	
Melanoma				
Localised to tissue of origin	507 (79.8%)	34,499 (82.6%)	35,006 (82.6%)	0.001
Regional spread, adjacent organs	26 (4.1%)	1830 (4.4%)	1856 (4.4%)	
Regional spread, regional lymph nodes	41 (6.5%)	1709 (4.1%)	1750 (4.1%)	
Distant metastases	41 (6.5%)	1815 (4.3%)	1856 (4.4%)	
Unknown	20 (3.1%)	1904 (4.6%)	1924 (4.5%)	
Breast				
Localised to tissue of origin	583 (49%)	26,824 (52.1%)	27,407 (52%)	0.038
Regional spread, adjacent organs	33 (2.8%)	1714 (3.3%)	1747 (3.3%)	
Regional spread, regional lymph nodes	428 (35.9%)	16,743 (32.5%)	17,171 (32.6%)	
Distant metastases	82 (6.9%)	3050 (5.9%)	3132 (5.9%)	
Unknown	65 (5.5%)	3152 (6.1%)	3217 (6.1%)	
Vulva				
Localised to tissue of origin	27 (62.8%)	530 (50.2%)	557 (50.7%)	0.274
Regional spread, adjacent organs	[b]	[b]	[b]	
Regional spread, regional lymph nodes	8 (18.6%)	181 (17.1%)	189 (17.2%)	
Distant metastases	[b]	[b]	[b]	
Unknown	[b]	[b]	[b]	
Vagina				
Localised to tissue of origin	[b]	[b]	[b]	0.772
Regional spread, adjacent organs	[b]	[b]	[b]	
Regional spread, regional lymph nodes	[b]	[b]	[b]	
Distant metastases	[b]	[b]	[b]	
Unknown	[b]	[b]	[b]	
Cervix				
Localised to tissue of origin	57 (39.9%)	1095 (44.4%)	1152 (44.1%)	0.742
Regional spread, adjacent organs	28 (19.6%)	399 (16.2%)	427 (16.4%)	
Regional spread, regional lymph nodes	15 (10.5%)	264 (10.7%)	279 (10.7%)	
Distant metastases	21 (14.7%)	317 (12.8%)	338 (13%)	
Unknown	22 (15.4%)	392 (15.9%)	414 (15.9%)	

(Continues)

TABLE 2 | (Continued)

Degree of spread for different tumour Sites	Aboriginal *n* (%)	Non-aboriginal *n* (%)	Total *n* (%)	*p*
Uterus				
Localised to tissue of origin	129 (61.7%)	4774 (60.3%)	4903 (60.3%)	0.776
Regional spread, adjacent organs	39 (18.7%)	1359 (17.2%)	1398 (17.2%)	
Regional spread, regional lymph nodes	12 (5.7%)	425 (5.4%)	437 (5.4%)	
Distant metastases	20 (9.6%)	896 (11.3%)	916 (11.3%)	
Unknown	9 (4.3%)	464 (5.9%)	473 (5.8%)	
Ovary				
Localised to tissue of origin	19 (17.8%)	940 (19.6%)	959 (19.6%)	0.287
Regional spread, adjacent organs	17 (15.9%)	456 (9.5%)	473 (9.6%)	
Regional spread, regional lymph nodes	[b]	[b]	[b]	
Distant metastases	61 (57%)	2940 (61.3%)	3001 (61.2%)	
Unknown	7 (6.5%)	341 (7.1%)	348 (7.1%)	
Prostate				
Localised to tissue of origin	648 (52.9%)	34,478 (51.8%)	35,126 (51.9%)	< 0.001
Regional spread, adjacent organs	118 (9.6%)	9292 (14%)	9410 (13.9%)	
Regional spread, regional lymph nodes	16 (1.3%)	1032 (1.6%)	1048 (1.5%)	
Distant metastases	57 (4.7%)	2933 (4.4%)	2990 (4.4%)	
Unknown	385 (31.5%)	18,781 (28.2%)	19,166 (28.3%)	
Testis				
Localised to tissue of origin	73 (71.6%)	1711 (72%)	1784 (71.9%)	0.550
Regional spread, adjacent organs	8 (7.8%)	183 (7.7%)	191 (7.7%)	
Regional spread, regional lymph nodes	8 (7.8%)	157 (6.6%)	165 (6.7%)	
Distant metastases	12 (11.8%)	230 (9.7%)	242 (9.8%)	
Unknown	[b]	[b]	[b]	
Kidney and renal pelvis				
Localised to tissue of origin	193 (60.5%)	6783 (57.5%)	6976 (57.6%)	0.763
Regional spread, adjacent organs	53 (16.6%)	1961 (16.6%)	2014 (16.6%)	
Regional spread, regional lymph nodes	8 (2.5%)	283 (2.4%)	291 (2.4%)	
Distant metastases	40 (12.5%)	1654 (14%)	1694 (14%)	
Unknown	25 (7.8%)	1115 (9.5%)	1140 (9.4%)	
Bladder				
Localised to tissue of origin	74 (40.7%)	4032 (48.2%)	4106 (48%)	0.328
Regional spread, adjacent organs	40 (22%)	1596 (19.1%)	1636 (19.1%)	
Regional spread, regional lymph nodes	10 (5.5%)	424 (5.1%)	434 (5.1%)	
Distant metastases	22 (12.1%)	779 (9.3%)	801 (9.4%)	
Unknown	36 (19.8%)	1533 (18.3%)	1569 (18.4%)	
Brain				
Localised to tissue of origin	79 (71.8%)	3763 (72.8%)	3842 (72.8%)	0.041
Regional spread, adjacent organs	11 (10%)	374 (7.2%)	385 (7.3%)	
Distant metastases	7 (6.4%)	125 (2.4%)	132 (2.5%)	
Unknown	13 (11.8%)	898 (17.4%)	911 (17.3%)	

(Continues)

TABLE 2 | (Continued)

Degree of spread for different tumour Sites	Aboriginal *n* (%)	Non-aboriginal *n* (%)	Total *n* (%)	*p*
Thyroid				
Localised to tissue of origin	154 (62.3%)	6292 (61%)	6446 (61.1%)	0.747
Regional spread, adjacent organs	15 (6.1%)	843 (8.2%)	858 (8.1%)	
Regional spread, regional lymph nodes	50 (20.2%)	2099 (20.4%)	2149 (20.4%)	
Distant metastases	8 (3.2%)	363 (3.5%)	371 (3.5%)	
Unknown	20 (8.1%)	711 (6.9%)	731 (6.9%)	
Unknown cancers				
Localised to tissue of origin	13 (5.8%)	355 (4.2%)	368 (4.2%)	0.625
Regional spread, adjacent organs	8 (3.6%)	236 (2.8%)	244 (2.8%)	
Regional spread, regional lymph nodes	10 (4.5%)	468 (5.5%)	478 (5.5%)	
Distant metastases	149 (66.8%)	5898 (69.1%)	6047 (69.1%)	
Unknown	43 (19.3%)	1577 (18.5%)	1620 (18.5%)	
Other cancers				
Localised to tissue of origin	116 (32%)	4619 (36.1%)	4735 (36%)	0.100
Regional spread, adjacent organs	35 (9.7%)	1433 (11.2%)	1468 (11.2%)	
Regional spread, regional lymph nodes	23 (6.4%)	945 (7.4%)	968 (7.4%)	
Distant metastases	52 (14.4%)	1839 (14.4%)	1891 (14.4%)	
Unknown	136 (37.6%)	3962 (31%)	4098 (31.1%)	

Note: p value shows the difference between Aboriginal and non-Aboriginal patients.
[a]Excluding Lympho-haematopoietic cancers and cases notified by death or autopsy only.
[b]Cell counts were suppressed to address privacy issues around the reporting of small numbers.

TABLE 3 | Comparison of degree of spread, radiotherapy and surgery utilisation rates by Aboriginal status for years 2009–2011, 2012–2015 and 2016–2018.

Aboriginal status	Aboriginal *n* (%)				Non-aboriginal *n* (%)			
Years of diagnosis	2009–2011	2012–2015	2016–2018	*p*	2009–2011	2012–2015	2016–2018	*p*
Localised to tissue of origin	886 (39.2%)	1419 (41.2%)	1336 (44.2%)	0.001	46,342 (45%)	66,563 (45.6%)	54,589 (47.3%)	< 0.001
Regional spread, adjacent organs	235 (10.4%)	326 (9.5%)	254 (8.4%)		10,348 (10%)	15,194 (10.4%)	11,681 (10.1%)	
Regional spread, regional LN	367 (16.3%)	536 (15.6%)	419 (13.9%)		14,115 (13.7%)	19,789 (13.5%)	14,448 (12.5%)	
Distant metastases	456 (20.2%)	651 (18.9%)	541 (17.9%)		18,142 (17.6%)	23,534 (16.1%)	17,536 (15.2%)	
Unknown	314 (13.9%)	511 (14.8%)	471 (15.6%)		14,026 (13.6%)	21,018 (14.4%)	17,218 (14.9%)	
Radiotherapy utilisation	602 (30.0%)	870 (28.6%)	881 (32.6%)	< 0.005	23,035 (24.9%)	33,713 (25.7%)	28,861 (27.5%)	< 0.001
Surgical utilisation	782 (51.4%)	1230 (52.4%)	1031 (49.6%)	0.177[a]	37,512 (55.5%)	54,371 (57.4%)	43,745 (57.7%)	< 0.001

[a]Difference among the 3 periods is not statistically significant.

to 14% and 18.8%, respectively in this study. Moore et al. [16] reported that 43% of Aboriginal people and 50% of non-Aboriginal patients diagnosed with head and neck cancer in Queensland (1998–2004) received radiotherapy compared to 57% and 51%, respectively in this study. Valery et al. [19] in a matched cohort in Queensland (1997–2002), found that Aboriginal patients were less likely to undergo surgery than non-Aboriginal (48% versus 58%) and were less likely to receive radiotherapy. This

TABLE 4 | Actual 1-year radiotherapy utilisation rate by tumour site and Aboriginal status NSW 2009–2018.

Tumour site	Aboriginal given radiotherapy/Total (%)	Non-aboriginal given radiotherapy/Total (%)	Total given radiotherapy/Total (%)	*p*
Head and Neck	242/427 (56.7%)	5649/11108 (51.1%)	5891/11535 (51.1%)	0.02
Oesophagus	55/111 (49.5%)	1863/3532 (52.6%)	1918/3643 (52.6%)	0.563
Stomach	26/151 (17.2%)	1269/5849 (21.6%)	1295/6000 (21.6%)	0.229
Pancreas	17/188 (9%)	827/8544 (9.7%)	844/8732 (9.7%)	0.901
Colorectal	119/758 (15.7%)	4416/38615 (11.5%)	4535/39373 (11.5%)	<0.001
Colon-rectosigmoid	20/550 (3.6%)	754/28849 (2.6%)	774/29399 (2.6%)	0.138
Rectum	99/208 (47.6%)	3662/9766 (37.7%)	3761/9974 (37.7%)	0.004
Liver	11/231 (4.8%)	315/5585 (5.6%)	326/5816 (5.6%)	0.663
Gall Bladder	[a]	[a]	[a]	0.122
Lung	498/1019 (48.9%)	12,683/29472 (43.2%)	13,181/30491 (43.2%)	<0.001
Melanoma	30/522 (5.7%)	1077/33749 (3.2%)	1107/34271 (3.2%)	0.001
Breast	630/1021 (61.7%)	27,724/45004 (61.6%)	28,354/46025 (61.6%)	0.973
Vulva	10/35 (28.6%)	230/847 (27.2%)	240/882 (27.2%)	0.847
Vagina	[a]	[a]	[a]	1.000
Cervix	64/126 (50.8%)	1015/2152 (47.4%)	1079/2278 (47.4%)	0.463
Uterus	43/167 (25.7%)	1671/6600 (25.3%)	1714/6767 (25.3%)	0.928
Ovary	[a]	[a]	[a]	1.000
Prostate	271/995 (27.2%)	12,826/54621 (23.5%)	13,097/55616 (23.5%)	0.006
Testis	6/91 (6.6%)	109/2203 (5%)	115/2294 (5%)	0.458
Kidney—renal pelvis	22/254 (8.7%)	773/9063 (8.5%)	795/9317 (8.5%)	0.909
Bladder	29/134 (21.6%)	1230/5885 (20.9%)	1259/6019 (20.9%)	0.830
Brain	64/102 (62.7%)	2794/4548 (61.5%)	2858/4650 (61.5%)	0.837
Thyroid	[a]	[a]	[a]	1.000
Lymphoma	44/265 (16.6%)	2941/14641 (20%)	2985/14906 (20%)	0.190
Multiple Myeloma	25/88 (28.4%)	986/4581 (21.7%)	1011/4669 (21.7%)	0.149
Leukaemia	10/204 (4.9%)	302/9038 (3.4%)	312/9242 (3.4%)	0.234
Unknown	42/189 (22.2%)	1400/7094 (19.8%)	1442/7283 (19.8%)	0.405
Other Cancers	81/304 (26.6%)	2851/10520 (27.1%)	2932/10824 (27.1%)	0.892
Total	2351/7754 (30.3%)	85,598/328828 (26.1%)	87,949/336582 (26.1%)	<0.001

Note: p value shows the difference between aboriginal and non-Aboriginal patients.
[a]Cell counts were suppressed to address privacy issues around the reporting of small numbers.

study shows that 51% of Aboriginal patients underwent surgery compared to 57% for non-Aboriginal patients and 30% of Aboriginal patients received radiotherapy compared to 26% for non-Aboriginal patients. A West Australian matched study [20] showed that Aboriginal people were less likely to receive radiotherapy (OR 0.70, 95% CI 0.56–0.89, $p = 0.41$) or surgery (OR 0.57, 95% CI 0.45–0.73, $p = 0.53$), than non-Aboriginal people, which is opposite to what we have found.

Even though remoteness from treatment facilities is a more frequent problem proportionally for Aboriginal patients, the radiotherapy utilisation for Aboriginal patients is higher than that of non-Aboriginal patients, suggesting that many remote patients can access radiotherapy. Receipt of radiotherapy may also be influenced by socioeconomic factors and the out-of-pocket cost and side effects of other treatment such as surgery [30].

After stratifying by tumour type, and accounting for patient factors, significant increases in the odds of radiotherapy for Aboriginal people compared with non-Aboriginal people were observed in prostate, lung and rectum (with no comorbidities) cancer, whilst decreased odds were observed in oesophageal

TABLE 5 | Actual one-year radiotherapy utilisation rate by road distance to the nearest radiotherapy facility and Aboriginal status NSW 2009–2018.

Distance group	Aboriginal given radiotherapy/Total (%)	Non-aboriginal given radiotherapy/Total (%)	Total given radiotherapy/ Total (%)	*p*
< 50 km	1582/4961 (31.9%)	72,758/273554 (26.6%)	74,340/278515 (26.7%)	< 0.001
50–99 km	274/940 (29.1%)	6505/26030 (25%)	6779/26970 (25.1%)	0.002
100–149 km	179/607 (29.5%)	3200/13429 (23.8%)	3379/14036 (24.1%)	< 0.001
150–199 km	83/294 (28.2%)	1259/5873 (21.4%)	1342/6167 (21.8%)	0.004
200+ km	233/949 (24.6%)	1864/9863 (18.9%)	2097/10812 (19.4%)	< 0.001
Total	2351/7751 (30.3%)	85,586/328749 (26%)	87,937/336500 (26.1%)	< 0.001

Note: p value shows the difference between aboriginal patients and non-Aboriginal patients.

TABLE 6 | Actual one-year surgical utilisation[a] rate by tumour site and Aboriginal status, NSW 2009–2018.

Tumour site	Aboriginal had surgery/Total (%)	Non-aboriginal had surgery/Total (%)	Total Had surgery/ Total (%)	*p*[c]
Head and neck	213/396 (53.8%)	6388/10122 (63.1%)	6601/10518 (62.8%)	< 0.001
Oesophagus	[b]	[b]	[b]	0.324
Stomach	31/148 (20.9%)	1862/5761 (32.3%)	1893/5909 (32%)	0.003
Pancreas	33/185 (17.8%)	1614/8341 (19.4%)	1647/8526 (19.3%)	0.706
Colorectal	589/749 (78.6%)	29,741/38057 (78.1%)	30,330/38806 (78.2%)	0.786
Liver	26/224 (11.6%)	1059/5433 (19.5%)	1085/5657 (19.2%)	0.002
Gall Bladder	15/67 (22.4%)	724/2325 (31.1%)	739/2392 (30.9%)	0.141
Lung & Bronchus	137/978 (14%)	5230/27855 (18.8%)	5367/28833 (18.6%)	< 0.001
Non–small-cell lung cancer	120/326 (36.8%)	4692/10092 (46.5%)	4812/10418 (46.2%)	< 0.001
Breast	874/993 (88%)	38,986/43119 (90.4%)	39,860/44112 (90.4%)	0.013
Vulva	25/34 (73.5%)	575/826 (69.6%)	600/860 (69.8%)	0.706
Vagina	[b]	[b]	[b]	0.152
Cervix	59/124 (47.6%)	1102/2082 (52.9%)	1161/2206 (52.6%)	0.644
Uterus	143/165 (86.7%)	5656/6493 (87.1%)	5799/6658 (87.1%)	0.815
Ovary	61/88 (69.3%)	2748/3983 (69%)	2809/4071 (69%)	1.000
Prostate	322/898 (35.9%)	20,581/50075 (41.1%)	20,903/50973 (41%)	0.002
Testis	86/91 (94.5%)	1915/2138 (89.6%)	2001/2229 (89.8%)	0.157
Kidney & renal pelvis	128/251 (51%)	4918/8827 (55.7%)	5046/9078 (55.6%)	0.139
Bladder	33/134 (24.6%)	1004/5825 (17.2%)	1037/5959 (17.4%)	0.037
Brain	90/102 (88.2%)	3779/4457 (84.8%)	3869/4559 (84.9%)	0.402
Thyroid	174/206 (84.5%)	7582/8767 (86.5%)	7756/8973 (86.4%)	0.410
Total	3043/5948 (51.2%)	135,628/238131 (57%)	138,671/244079 (56.8%)	< 0.001

[a]Surgery utilisation: excluding melanoma, haematopoietic, unknown and other cancers, and cases notified by death or autopsy only.
[b]Cell counts were suppressed to address privacy issues around the reporting of small numbers.
[c]*p* value shows the difference between Aboriginal patients and non-Aboriginal patients.

(with 1 comorbidity) cancer. When analysing surgery utilisation, there were decreases in the odds of surgery for Aboriginal people in prostate (for patients diagnosed from 2016 to 2018), breast (in outer regional areas), lung, head and neck (in patients with 2 or more comorbidities), stomach and liver cancers. These associations are highly complex. We have not performed multiple

TABLE 7 | Odds ratios of radiotherapy and surgery utilisation for Aboriginal patients compared with non-Aboriginal patients, in separate multivariable logistic regression models for each tumour type.

	Radiotherapy utilisation	Surgery
Tumour site	Aboriginal versus. non-Aboriginal OR (95% CI)	Aboriginal versus. non-Aboriginal OR (95% CI)
Head and neck	1.24 (0.99, 1.56)	No comorbidities: 0.99 (0.74, 1.32) 1 comorbidity: 0.66 (0.4, 1.1) 2+ comorbidities: 0.54 (0.38, 0.77)
Oesophagus	No comorbidities: 1.49 (0.81, 2.75) 1 comorbidity: 0.3 (0.12, 0.74) 2+ comorbidities: 0.84 (0.42, 1.68)	0.29 (0.07, 1.22)
Stomach	0.67 (0.43, 1.04)	0.44 (0.28, 0.68)
Pancreas	0.78 (0.47, 1.32)	0.72[a] (0.44, 1.15)
Colon-rectosigmoid	1.36 (0.85, 2.16)	1.03[a] (0.81, 1.31)
Rectum	No comorbidities: 2 (1.3, 3.09) 1 comorbidity: 1.09 (0.57, 2.06) 2+ comorbidities: 0.86 (0.53, 1.41)	1 (0.71, 1.41)
Liver	0.85 (0.45, 1.62)	0.58 (0.37, 0.9)
Gall Bladder (GB)	0.29 (0.07, 1.22)	0.68 (0.36, 1.26)
Lung	1.21[a] (1.06, 1.38)	0.6 (0.48, 0.74)
Melanoma	1.5 (0.97, 2.31)	—
Breast	0.97 (0.85, 1.11)	Major City: 1.08[a] (0.77, 1.51) Inner regional: 1.13 (0.72, 1.78) Outer regional: 0.65 (0.46, 0.9) Remote/Very remote: 2.39 (0.74, 7.68)
Vulva	2.03 (0.81, 5.1)	1.22 (0.54, 2.76)
Vagina	0.79 (0.08, 8.36)	—
Cervix	0.97[a] (0.63, 1.49)	1.02 (0.68, 1.55)
Uterus	1.01 (0.68, 1.49)	1.02 (0.64, 1.64)
Ovary	0.76 (0.18, 3.21)	0.83 (0.5, 1.37)
Prostate	1.36[a] (1.17, 1.57)	2009–2011: 0.81[a] (0.6, 1.08) 2012–2015: 0.91 (0.72, 1.16) 2016–2018: 0.56 (0.42, 0.76)
Testis	1.2 (0.48, 3.03)	1.93 (0.76, 4.9)
Kidney—renal pelvis	1.1 (0.67, 1.81)	0.77 (0.58, 1.02)
Bladder	1.09 (0.7, 1.67)	1.2 (0.76, 1.88)
Brain	1.07 (0.7, 1.64)	1.81 (0.92, 3.55)
Thyroid	0.99 (0.35, 2.82)	0.83[a] (0.53, 1.29)
Lymphoma	0.75 (0.54, 1.05)	—
Multiple Myeloma	1.35 (0.84, 2.19)	
Leukaemia	1.1 (0.57, 2.14)	—
Unknown	1.13 (0.78, 1.64)	—
Other cancers	0.98 (0.75, 1.28)	—

Note: This table presents adjusted odds ratios of radiotherapy and surgery utilisation for Aboriginal patients compared with non-Aboriginal patients, in separate multivariable logistic regression models for each tumour type. Each model was adjusted for age group, year of diagnosis, degree of spread at diagnosis, Index of relative socioeconomic disadvantage, Area of remoteness, Quan Charlson comorbidity and distance from nearest radiotherapy treatment centre. Interactions were also considered in each model and vary by tumour types. Blank boxes relate to small numbers. Full details of each multivariable logistic model for radiotherapy utilisation and surgery for each tumour type are available upon request from the authors.

Abbreviation: CI, confidence interval.

[a]Indicates poor model fit based on Hosmer–Lemeshow goodness-of-fit test.

comparisons as this study is exploratory and will require further examination to confirm any observed associations. This would be of particular interest in the findings specific to examples such as Aboriginal patients being more likely to receive radiotherapy as an alternative to surgery for oesophageal cancer when comorbidities exist and Aboriginal head and neck cancer patients being less likely to receive surgery as comorbidities rise. However, other observations did not appear to have any valid reason for the association (e.g., lesser chance of Aboriginal patients having surgery in outer regional centres but not in very remote centres). The fact that the goodness of fit was poor for a number of tumours suggest that other variables not within the current dataset may be partly responsible for variations in treatment utilisation.

This study has strengths and limitations. The strengths include the size of the NSW dataset and access to linked surgery and radiotherapy data. One possible limitation is that patients closer to the borders may have missing treatment data as they cross the border for treatment. We have managed this by excluding those patients from the specific analyses related to surgical and radiotherapy utilisation. Another limitation is that it is likely that identification of Aboriginal status remains incompletely captured in administrative databases, in addition to problems associated with incompleteness of data such as Degree of Spread and the lack of availability of systemic therapy data to complete the picture. Interestingly, in the NSW dataset used by Supramaniam et al. [17], only 1% of breast cancer patients identified as being Aboriginal compared with 2.3% in our study, suggesting better capture of Aboriginal status in recent administrative datasets. The difference may also be partly attributed to using ERA method to enhance the reporting of cancer outcomes of Aboriginal people in NSW [23]. It is possible that some of these data deficiencies create some bias as it would be more likely that stage and Aboriginal status are more accurately captured for those undergoing treatment compared to those diagnosed in the community and not referred. Another limitation includes that this study did not analyse overall or cancer-specific survival against whether surgery, radiotherapy or both were administered as this would need to be done separately for each tumour site and degree of spread and is therefore beyond the scope of this paper. Future studies on individual cancer types could address these issues. The recording of comorbidity status relies on data from the Admitted Patient Data Collection, therefore relying on inpatient episodes of care; this will underreport the comorbidity status of all patient groups as comorbidity presence will not be scored for patients who have not had an inpatient episode during that time (although those having inpatient surgery for their cancer will have comorbidity recorded).

6 | Conclusion

This study provides a comprehensive assessment of Aboriginal tumour type and degree of spread, surgical and radiotherapy treatment utilisation in NSW and provides a baseline for further improvements in cancer care. Cancer degree of spread and the presence of comorbidities remains a greater issue for Aboriginal people along with earlier onset of cancer but is improving. Encouragingly, the degree of spread improved significantly throughout the study period suggesting strategies to improve screening, and earlier presentation has been of benefit. Access to radiotherapy improved significantly for Aboriginal patients in NSW during the past 10 years. However, differences in surgical and radiotherapy utilisation exist, partially explained by the greater degree of spread and presence of comorbidity in Aboriginal patients. Future work will assess survival in this cohort of patients.

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Ethics Statement

The study protocol was approved by the NSW Population and Health Services Research Ethics Committee (NSW Ethics 2019/ETH01657) and the Aboriginal Health and Medical Research Ethics Committee (NSW AH&MRC 1770/21). The Aboriginal Health and Medical Research Ethics Committee also approved the final version of this paper prior to journal submission. There were no live participants in this study and therefore informed consent was not required.

Conflicts of Interest

The authors certify that they have no conflicts of interest with this manuscript. Professor Shalini Vinod is on the Editorial Board of JMIRO.

Data Availability Statement

The data that support the findings of this study are available from The Centre for Record Health Linkage and Data custodians. Restrictions apply to the availability of these data, which were used under license for this study. Data are available from the author(s) with the permission of The Centre for Record Health Linkage and Data custodians.

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