Cancer Epidemiology 80 (2022) 102243

Contents lists available at ScienceDirect

Cancer Epidemiology

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

# Colorectal cancer and country of birth in New South Wales, Australia: All-of-population data for prioritising health service delivery and research

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ARTICLE INFO

*Keywords:*
Colorectal cancer stage/treatment/survival
Birth country

ABSTRACT

*Introduction:* Cancer care and outcomes differ across cultural groups in Australia. Quantifying these differences facilitates prioritisation and targeting of services and research. All-of-population data are needed by health agencies to understand and fulfil their cancer-control responsibilities. Compiling these data can be challenging while maintaining privacy. We have used data linkage to gain population-wide colorectal cancer data on stage (degree of spread), treatment, and survival in New South Wales (NSW), Australia, by country of birth (COB), and consider service implications.

*Methods:* We studied colon and rectal cancers diagnosed in 2003–2016 and recorded on the NSW Cancer Registry (n = 41,575), plus linked hospital data and data from Australian Medical and Pharmaceutical Benefits payments, other treatment data and death records. Outcomes for 12 COB categories were analysed using multiple logistic and proportional hazards regression, with Australia as the reference category.

*Results:* Compared with Australian born, the adjusted odds ratio for distant spread of colon cancer was higher for people born in Lebanon and the United Kingdom. Treatment was less common for people born in China (surgery), Germany (systemic), Italy (surgery), New Zealand (any treatment) and Vietnam (all treatments), while treatment for rectal cancer was more common for people born in Italy (surgery), United Kingdom (radiotherapy, systemic therapy), and Vietnam (surgery), and less frequent for people born in China (radiotherapy). Adjusted 5-year survival was higher for people born in China, Italy, Vietnam, Greece (colon), Lebanon (colon) and other non-English speaking countries. More advanced stage was negatively related to having surgery and survival.

*Conclusions:* This study illustrates how linked data can enable comparisons of multiple outcomes for colorectal cancer by country of birth across an entire population. Results disclose "big picture" variations in population characteristics, stage, treatment and survival. This will enable better targeting and prioritisation of services and inform research priorities to address disparities.

## 1. Introduction

Colorectal cancer (CRC) is common in Australia and the second leading cause of cancer death after lung cancer [1]. The elevated incidence in Australia and other high-income countries has been attributed to physical inactivity and obesity, tobacco smoking, heavy alcohol consumption and poor diet. These and other risk factors are known to vary by country [1,2].

*Abbreviations:* COB, Country of birth; CRC, colorectal cancer; NSW, New South Wales; NSWCR, New South Wales Cancer Registry; AIHW, Australian Institute of Health and Welfare; APDC, NSW Admitted Patient Data Collection; MBS, Australian Medicare Benefits Schedule; PBS, Australian Pharmaceutical Benefits Scheme; NSW RBDM, the New South Wales Register of Births, Deaths and Marriages; NDI, National Death Index; CHeReL, the Centre for Health Record Linkage; SEIFA, Socio-Economic Indexes for Areas; SES, Socio-economic status; ACHI, Australian Classification of Health Interventions; OR, odds ratio; HR, hazards ratio.

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https://doi.org/10.1016/j.canep.2022.102243
Received 3 July 2022; Received in revised form 15 August 2022; Accepted 21 August 2022
Available online 27 August 2022

New South Wales (NSW), which is Australia's most populous state, has a diverse multicultural population. The percentage of NSW residents born outside of Australia approximates 28% [3], with about a quarter of the population mainly speaking a non-English language at home [3,4]. Previous Australia studies have shown differences in cancer incidence and mortality by broad regions of birth and languages spoken [5–8]. For colorectal cancer, incidence was highest in people born in Australia and those from other high income English-speaking countries [5]. NSW residents born in Australia and other English-speaking countries also had a higher risk of death from colorectal cancer than those born in non-English speaking countries [6]. Migrants were more often diagnosed with distant cancer than people born in Australia, although this varied by cancer type [6,7]. A report of a NSW study cohort indicated that bowel cancer screening was lower among migrants compared to the Australian-born [9], with potential effects on outcomes.

A study restricted to a NSW metropolitan administrative health district found region of birth was not associated with having treatment for colorectal adenocarcinoma [10]. In that cohort, people born in Asia and the Middle East were younger at diagnosis and had fewer metastatic cancers than Australian-born residents. It was not clear whether these local results applied to the NSW population overall.

To date, no state-wide study in Australia has examined colorectal cancer by individual countries of birth (COB). Previous studies generally grouped countries into broader regions of mainly English speaking or non-English speaking groups. This may have masked individual country differences. Investigating differences in cancer experience by specific COB, as in an earlier study of breast cancer [11], provides important data for health system planning and prioritisation of cancer services.

The aim of this study was to demonstrate the utility of data linkage for bringing population-wide data together for quantifying differences in CRC stage (degree of spread) at diagnosis, treatment, and 5-year survival in NSW by COB. We also use these data to investigate the influence of sociodemographic and clinical features at diagnosis on outcomes by COB (i.e., age, sex, socioeconomic status, and comorbidity). This was "Big Picture" research undertaken to set the scene for prioritising health service delivery and more detailed research.

## 2. Methods

### 2.1. Data, population and study design

A retrospective population cohort was investigated, using New South Wales Cancer Registry (NSWCR) data [12], linked with data from the NSW Admitted Patient Data Collection (APDC) [13], the Australian Medicare Benefits Schedule (MBS) [14], the Pharmaceutical Benefits Scheme (PBS) [15], the NSW Register of Births, Deaths and Marriages (RBDM), and National Death Index (NDI) [16]. Privacy-protecting protocols were used to produce de-identified data for analysis [17,18]. Linkage was performed by the Centre for Health Record Linkage (CHeReL) for NSW-based data and the Australian Institute of Health and Welfare (AIHW) for national data.

The study cohort comprised people aged 18+ years at diagnosis with invasive cancers of the colon (ICD C18) and rectum (ICD C19-C20) diagnosed in 2003–2016, excluding multiple primary cancers [19,20]. Because treatments by interstate hospitals were not recorded in NSW record systems, the data for residents from five administrative health districts adjacent to NSW borders (13.7% of the NSW population) were regarded as potentially incomplete and were excluded [21].

To define COB, the NSWCR uses the Standard Australian Classification of Countries issued by the Australian Bureau of Statistics [22]. Based on case numbers, participants were grouped into the following COB categories: Australia, New Zealand, the United Kingdom, China (excluding Hong Kong, Macau, and Taiwan), Germany, Greece, Italy, Lebanon, the Philippines, Vietnam, and for remaining participants, by "other English speaking" or "other non-English speaking" countries. People of unknown COB (5.4%) were excluded. In total, 41,575 people were included in the study, 27,524 with colon and 14,051 with rectal cancer.

The NSWCR, administered by Cancer Institute NSW, applies international cancer registry standards [12,23]. Degree of spread is categorised as local, regional, distant or unknown, as defined in international guidelines [24,25]. The Socio-Economic Index for Areas (SEIFA), which classifies residential areas by Index of Relative Socio-economic Disadvantage in quintiles [26], is coded at census collection district level.

Data on surgery, radiotherapy and systemic agents (chemotherapeutic, targeted and immunological) were obtained from linked NSW hospital data and Australian Medicare and Pharmaceutical Benefits claims for a follow-up period of 12 months from diagnosis. To derive Charlson Comorbidity Index scores [27], hospital inpatient diagnostic codes (ICD-10) were examined for the 12-month period leading to diagnosis. The National Death Index used in this study covered deaths of people who died in NSW or other Australian jurisdictions.

### 2.2. Statistical analyses

Cross-tabulations were used to describe cohort characteristics for COB categories by sex, age at diagnosis (classified as 18–59, 60–69, 70–79 and 80+ years), SEIFA quintile of residence (1−5), year of diagnosis (2003–04 to 2015–16 in two-year periods), stage (local, regional, distant, unknown), and Charlson comorbidity index score (0 or ≥1).

Multiple logistic regression was used to examine distant spread and any recorded treatment, curative surgery, radiotherapy or systemic therapy within 12 months from diagnosis by COB. Analyses were adjusted for age, sex, comorbidity, SEIFA residential quintile and diagnostic year. Analyses of treatment were also adjusted for stage at diagnosis. Unknown stage was excluded due to insufficient numbers.

Multiple proportional hazards regression was undertaken to investigate determinants of death (all-cause) up to five years from diagnosis, adjusting for the same covariates as in the logistic regression analyses, and in addition, treatment by surgery, radiotherapy and systemic therapy. Follow-up of survival was from diagnosis to death, five years, or April 30th, 2020, whichever came first. Those who had no record of death and no medical activity recorded on relevant datasets (NDI, PBS, MBS or APDC) for the last two years were considered lost to follow-up and were censored at the last recorded activity date. This was to account for the possibility of people travelling back to their birth country following CRC diagnosis, such that death status was not recorded in Australia.

Missing values for SEIFA were rare (0.37%) and were imputed as the mean value '3' to retain all records in analyses. No missing values were found for other variables after unknown COB and unknown stage were excluded.

Colon and rectal cancers were analysed separately due to differences in epidemiological characteristics and treatments. For colon cancer, radiotherapy was uncommon and not analysed separately.

SAS/STAT® Version 9.4 [28] was used for analyses.

## 3. Results

### 3.1. Descriptive characteristics at diagnosis, by COB

#### 3.1.1. Colon

People born in Australia were diagnosed at an average age of 70 years and had a slightly higher proportion of females (53.4%). The following differences were found when compared with people born in Australia (Table 1):

- Age at diagnosis – an older age distribution for people born in Greece, Italy and the United Kingdom; and a younger age for those born in Lebanon, New Zealand, the Philippines and Vietnam.

**Table 1**
Sociodemographic and colon cancer characteristics by country of birth in NSW (total number of people 27,524).

| Country of Birth | | Australia (N = 18,627) | New Zealand (N = 452) | United Kingdom (N = 1851) | Other English speaking (N = 386) | China (mainland) (N = 598) | Germany (N = 246) | Greece (N = 455) | Italy (N = 747) | Lebanon (N = 315) | Philippines (N = 164) | Vietnam (N = 248) | Other non-English speaking (N = 3435) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | % (n) | % (n) | % (n) | % (n) | % (n) | % (n) | % (n) | % (n) | % (n) | % (n) | % (n) | % (n) |
| Sex | M | 46.6 (8679) | 51.5 (233) | 52.4 (970) | 51.8 (200) | 50.2 (300) | 42.7 (105) | 58.5 (266) | 62.1 (464) | 53.3 (168) | 32.9 (54) | 53.2 (132) | 54.1 (1857) |
| | F | 53.4 (9948) | 48.5 (219) | 47.6 (881) | 48.2 (186) | 49.8 (298) | 57.3 (141) | 41.5 (189) | 37.9 (283) | 46.7 (147) | 67.1 (110) | 46.8 (116) | 45.9 (1578) |
| Age at diagnosis (years) | 18–59 | 20.3 (3779) | 34.7 (157) | 15.8 (293) | 29.3 (113) | 26.9 (161) | 11.4 (28) | 8.8 (40) | 9.0 (67) | 29.2 (92) | 48.2 (79) | 49.2 (122) | 22.9 (785) |
| | 60–69 | 23.8 (4424) | 25.2 (114) | 25.1 (464) | 24.1 (93) | 19.4 (116) | 30.1 (74) | 23.3 (106) | 20.9 (156) | 29.2 (92) | 21.3 (35) | 19.4 (48) | 26.7 (918) |
| | 70–79 | 29.5 (5495) | 22.8 (103) | 29.3 (543) | 25.6 (99) | 29.3 (175) | 30.1 (74) | 44.4 (202) | 39.4 (294) | 27.0 (85) | 20.1 (33) | 20.6 (51) | 29.2 (1002) |
| | 80 + | 26.5 (4929) | 17.3 (78) | 29.8 (551) | 21.0 (81) | 24.4 (146) | 28.5 (70) | 23.5 (107) | 30.8 (230) | 14.6 (46) | 10.4 (17) | 10.9 (27) | 21.3 (730) |
| Charlson Comorbidity | 0 | 83.4( 15,530) | 86.5 (391) | 83.3 (1541) | 84.7 (327) | 84.4 (505) | 84.1 (207) | 85.7 (390) | 78.4 (586) | 81.6 (257) | 88.4 (145) | 89.1 (221) | 83.2 (2858) |
| | > 0 | 16.6 (3097) | 13.5 (61) | 16.7 (310) | 15.3 (59) | 15.6 (93) | 15.9 (39) | 14.3 (65) | 21.6 (161) | 18.4 (58) | 11.6 (19) | 10.9 (27) | 16.8 (577) |
| SEIFA disadvantage | 1 (most) | 23.2 (4313) | 15.0 (68) | 20.1 (372) | 10.1 (39) | 22.2 (133) | 19.9 (49) | 14.3 (65) | 19.8 (148) | 32.7 (103) | 23.8 (39) | 61.3 (152) | 23.6 (810) |
| | 2 | 21.3 (3969) | 20.4 (92) | 20.3 (375) | 16.1 (62) | 22.6 (135) | 19.1 (47) | 25.3 (115) | 22.0 (164) | 30.2 (95) | 27.4 (45) | 23.0 (57) | 21.2 (729) |
| | 3 | 19.4 (3606) | 20.1 (91) | 19.6 (363) | 17.9 (69) | 20.9 (125) | 21.1 (52) | 29.2 (133) | 22.6 (169) | 18.4 (58) | 23.8 (39) | 8.9 (22) | 19.2 (661) |
| | 4 | 18.7 (3480) | 19.5 (88) | 19.2 (356) | 23.3 (90) | 17.9 (107) | 19.9 (49) | 18.9 (86) | 22.8 (170) | 8.3 (26) | 18.3 (30) | 3.2 (8) | 17.0 (583) |
| | 5 | 17.5 (3259) | 25.0 (113) | 20.8 (385) | 32.6 (126) | 16.4 (98) | 19.9 (49) | 12.3 (56) | 12.9 (96) | 10.5 (33) | 6.7 (11) | 3.6 (9) | 19.0 (652) |
| Stage (degree of spread) | Localised | 31.1 (5471) | 29.5 (129) | 30.2 (525) | 27.4 (101) | 24.8 (141) | 32.2 (74) | 25.7 (112) | 28.8 (204) | 24.7 8(75) | 23 (37)** | 23.9 (57) | 26.4 (865) |
| | Regional | 45.8 (8064) | 45.5 (199) | 43.2 (752) | 44.7 (165) | 52.3 (297) | 43.5 (100) | 49.7 (216) | 45.8 (324) | 46.1 (140) | 48.8 (80) | 51.3 (122) | 48.8 (1597) |
| | Distant | 23.2 (4084) | 24.9 (109) | 26.7 (463) | 27.9 (103) | 22.9 (130) | 24.3 (56) | 24.6 (107) | 25.4 (180) | 29.3 (89) | 26.8 (44) | 24.8 (59) | 24.8 (813) |
| | Unknown | 5.4 (1008) | 3.3 (15) | 6.0 (111) | 4.4 (17) | 5.0 (30) | 6.5 (16) | 4.4 (20) | 5.2 (39) | 3.5 (11) | (<5)* | 4.0 (10) | 4.7 (160) |
| Year of diagnosis | 2003–2004 | 13.2 (2457) | 11.3 (51) | 13.8 (255) | 11.1 (43) | 11.9 (71) | 9.8 (24) | 12.7 (58) | 12.2 (91) | 12.1 (38) | 6.1 (10) | 9.3 (23) | 11.4 (390) |
| | 2005–2006 | 13.5 (2513) | 13.1 (59) | 14.0 (260) | 15.3 (59) | 11.7 (70) | 16.7 (41) | 13.6 (62) | 14.6 (109) | 9.2 (29) | 16.5 (27) | 7.3 (18) | 12.1 (417) |
| | 2007–2008 | 14.2 (2650) | 14.8 (67) | 15.2 (282) | 13.0 (50) | 14.2 (85) | 12.6 (31) | 12.1 (55) | 14.7 (110) | 11.1 (35) | 14.0 (23) | 15.3 (38) | 13.7 (471) |
| | 2009–2010 | 14.1 (2627) | 16.4 (74) | 14.6 (270) | 13.0 (50) | 12.2 (73) | 13.0 (32) | 17.8 (81) | 13.5 (101) | 17.1 (54) | 11.0 (18) | 13.7 (34) | 13.9 (476) |
| | 2011–2012 | 14.5 (2701) | 11.7 (53) | 14.0 (259) | 15.8 (61) | 14.4 (86) | 18.7 (46) | 17.1 (78) | 17.3 (129) | 18.1 (57) | 18.3 (30) | 16.1 (40) | 15.6 (536) |
| | 2013–2014 | 14.1 (2632) | 15.7 (71) | 12.9 (238) | 13.7 (53) | 14.7 (88) | 13.0 (32) | 14.3 (65) | 15.0 (112) | 14.6 (46) | 17.7 (29) | 15.7 (39) | 15.3 (524) |
| | 2015–2016 | 16.4 (3047) | 17.0 (77) | 15.5 (287) | 18.1 (70) | 20.9 (125) | 16.3 (40) | 12.3 (56) | 12.7 (95) | 17.8 (56) | 16.5 (27) | 22.6 (56) | 18.1 (621) |

* Note: Suppression applied due to small number with unknown stage;
** this is not the exact number – due to cell suppression to prevent back calculation.

- Sex – a higher proportion of males among those born in Greece (59%) and Italy (62%); and a lower proportion of males in those born in the Philippines (33%).
- Socioeconomic disadvantage – more disadvantage among people born in Lebanon, the Philippines and Vietnam; and lesser disadvantage among those born in New Zealand, the United Kingdom and "other English-speaking" countries.
- Calendar years at diagnosis – recent diagnosis more common in those born in China, Lebanon and Vietnam.
- Comorbidity – less frequently recorded in people born in Vietnam and the Philippines, and more frequently in those born in Italy.
- Stage – higher proportion with distant spread recorded in people born in Lebanon, the Philippines, the United Kingdom and "other English-speaking countries".

#### 3.1.2. Rectum

People born in Australia were diagnosed at a mean age of 66 years with a higher proportion of males (59%). Compared with people born in Australia, the following differences applied (Table 2):

- Sex – a higher proportion of males in those born in Italy (69%), Lebanon (68%), the United Kingdom (65%) and Vietnam (65%).
- Age at diagnosis – an older age distribution for those born in Greece, Italy and the United Kingdom; and a younger age distribution for those born in Lebanon, New Zealand, the Philippines, Vietnam and "other English-speaking" countries.
- Socioeconomic disadvantage – greater disadvantage in those born in Lebanon and Vietnam, and less disadvantage in those born in New Zealand, Germany and "Other English-speaking" countries.
- Calendar years at diagnosis – more recent diagnostic periods for those born in China, Lebanon and New Zealand.
- Comorbidity – less frequently recorded for people born in "Other English-speaking" countries.
- Stage – higher proportion with regional spread at diagnosis. The proportion with distant spread ranged from 17% to 25%.

### 3.2. Stage at diagnosis

#### 3.2.1. Colon

The unadjusted percentage of people with distant disease at diagnosis ranged from 23% (Australia and China) to 29% (Lebanon) (Table 1). The adjusted results (Table 3) are shown as odds ratios (OR) and 95% confidence intervals (described as different to the reference category only when '1' was outside the interval). Results showed that those born in Lebanon, the United Kingdom, and "other English-speaking" countries had a higher risk of distant disease at diagnosis (OR 1.3, 1.2 and 1.3, respectively), compared with people born in Australia. An increased OR for distant disease also applied to males, living in more disadvantaged areas, ages $< 60$ years and having at least one comorbid condition recorded.

#### 3.2.2. Rectum

Unadjusted percentages of distant disease at diagnosis ranged from 17% (Vietnam) to 25% (Germany; see Table 2). Logistic regression results (Table 3) did not indicate clear differences in distant disease by COB partly because of the wider confidence intervals than for colon cancer. Males and those with recorded comorbidity had higher odds of distant disease. Those from the least disadvantaged areas had lower ORs for distant disease than those from more disadvantaged areas.

### 3.3. Treatment

#### 3.3.1. Colon

Unadjusted results indicated that 73% of people were recorded as having surgery, 38% as having systemic therapy, and 85% as having any treatment (surgery, radiotherapy, systemic therapy).

Compared to people born in Australia, the adjusted OR of having a treatment for colon cancer was lower (0.6–0.9, Table 4) for people born in China (surgery, any), Germany (systemic), Italy (surgery, any), New Zealand (any), Vietnam (surgery, systemic, any) and "other non-English speaking" countries (surgery, systemic, any). Degree of spread was strongly related to treatment reception for surgery (OR 0.1, distant vs local; 0.35, regional vs local) and systemic therapy (OR 27, distant vs local; and 14, regional vs local). Treatment was more common for those aged 60–79 years (OR 1.2–1.4 surgery) and those in less disadvantaged SEIFA residential areas (OR 1.1–1.4 surgery, systemic, any). A lower OR was shown for those recording comorbidity (0.6 surgery, 0.5 systemic therapy), males (0.9 surgery), older age (0.88 systemic therapy) and with a more recent diagnostic period (0.96 surgery, 0.97 any).

#### 3.3.2. Rectum

Unadjusted results indicated that most people (80%) had surgery, 31% had radiotherapy, 50% had systemic therapy, and 91% had any treatment (surgery, radiotherapy or systemic therapy).

Compared with people born in Australia, the adjusted OR of treatment was higher for people born in Italy (OR 2.2, surgery), United Kingdom (1.2 radiotherapy and 1.3 systemic therapy), and Vietnam (2.8 surgery), but lower for people born in China (0.7 radiotherapy) (Table 4). Degree of spread was strongly associated with treatment by surgery (OR 0.03, distant vs local; 0.42, regional vs local), systemic therapy (13.4, distant vs local; 8.6, regional vs local) and radiotherapy (1.8, distant vs local; 2.6, regional vs local). Higher treatment exposure was observed for those from less disadvantaged SEIFA residential areas (OR 1.2–1.7 surgery, systemic, any) and male sex (1.3 radiotherapy) whereas a lower OR was found for those with recorded comorbidity (0.8 surgery, 0.4 radiotherapy, 0.6 systemic therapy, 0.5 any), and older age (0.89–0.96, all therapies). Year of diagnosis was marginally associated with treatment.

### 3.4. 5-year survival

#### 3.4.1. Colon

Adjusted results, reported using Hazard Ratios (HR) and 95% confidence limits, indicated that the risk of death at 5 years from diagnosis was lower for people born in China, Greece, Italy, Lebanon, Vietnam, and "other non-English speaking" countries (HR 0.6–0.9) (Table 5), compared with the Australian born. Degree of spread was strongly related to survival (HR 9.3 distant vs local, 1.7 regional vs local). A higher risk of death was also associated with male sex (HR 1.1), recorded comorbidity (HR 1.6), and higher age in years (HR 1.05). By contrast, a lower HR was associated with living in less disadvantaged areas (0.8–0.9) and being diagnosed in more recent years (HR 0.96). A lower HR applied to people who had surgery and those having systemic therapy, whereas a higher HR to those having radiotherapy. Time-varying effects applied to systemic therapy and radiotherapy, with time-varying terms therefore included in regression models.

#### 3.4.2. Rectum

Compared with people born in Australia, the adjusted HR of death was lower for people born in China, Italy, Vietnam, and "Other non-English speaking" countries (0.6–0.9) (Table 5). Risks of death were higher for males (HR 1.2), recorded comorbidity (1.3), older age at diagnosis (1.05), and more advanced stage (6.6 distant vs local, 1.5 regional vs local). By comparison, a lower risk of death applied to less socially disadvantaged residential areas (HR 0.8–0.9) and more recent diagnostic years (0.96). People having surgery had a lower HR, as to a lesser degree did people having systemic therapy.

## 4. Discussion

The linked data demonstrated sociodemographic differences for people diagnosed with CRC that reflected the composition of the NSW

**Table 2**
Sociodemographic and rectal cancer characteristics by country of birth in NSW (total number of people 14,051).

| Country of Birth | | Australia (N = 8849) | New Zealand (N = 241) | United Kingdom (N = 1051) | Other English speaking (N = 177) | China (mainland) (N = 339) | Germany (N = 171) | Greece (N = 231) | Italy (N = 397) | Lebanon (N = 206) | Philippines (110) | Vietnam (N = 125) | Other non-English speaking (N = 2154) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | % (n) | % (n) | % (n) | % (n) | % (n) | % (n) | % (n) | % (n) | % (n) | % (n) | % (n) | % (n) |
| Sex | M | 59.3 (5245) | 63.5 (153) | 64.9 (682) | 58.8 (104) | 59.6 (202) | 62.0 (106) | 62.8 (145) | 68.8 (273) | 68.0 (140) | 57.3 (63) | 64.8 (81) | 62.1 (1337) |
| | F | 40.7 (3604) | 36.5 (88) | 35.1 (369) | 41.2 (73) | 40.4 (137) | 38.0 (65) | 37.2 (86) | 31.2 (124) | 32.0 (66) | 42.7 (47) | 35.2 (44) | 37.9 (817) |
| Age at diagnosis (years) | 18–59 | 31.5 (2787) | 41.9 (101) | 22.4 (235) | 42.4 (75) | 37.5 (127) | 21.6 (37) | 10.4 (24) | 12.3 (49) | 37.9 (78) | 51.8 (57) | 54.4 (68) | 33.1 (712) |
| | 60–69 | 27.7 (2453) | 28.2 (68) | 29.3 (308) | 29.4 (52) | 21.5 (73) | 33.3 (57) | 31.2 (72) | 22.9 (91) | 32.5 (67) | 28.2 (31) | 22.4 (28) | 29.6 (637) |
| | 70–79 | 23.8 (2103) | 21.6 (52) | 29.7 (312) | 18.1 (32) | 27.4 (93) | 31.0 (53) | 39.4 (91) | 42.1 (167) | 20.9 (43) | 11.8 (13) | 11.2 (14) | 23.4 (505) |
| | 80 + | 17.0 (1506) | 8.3 (20) | 18.6 (196) | 10.2 (18) | 13.6 (46) | 14.0 (24) | 19.0 (44) | 22.7 (90) | 8.7 (18) | 8.2 (9) | 12.0 (15) | 13.9 (300) |
| Charlson Comorbidity | 0 | 82.5 (7302) | 83.8 (202) | 81.8 (860) | 90.4 (160) | 85.3 (289) | 86.5 (148) | 81.8 (189) | 83.6 (332) | 85.0 (175) | 88.2 (97) | 82.4 (103) | 83.2 (1793) |
| | > 0 | 17.5 (1547) | 16.2 (39) | 18.2 (191) | 9.6 (17) | 14.7 (50) | 13.5 (23) | 18.2 (42) | 16.4 (65) | 15.0 (31) | 11.8 (13) | 17.6 (22) | 16.8 (361) |
| SEIFA disadvantage | 1 (most) | 22.5 (1987) | 17.4 (42) | 20.6 (216) | 7.9 (14) | 24.8 (84) | 17.5 (30) | 18.2 (42) | 22.2 (88) | 35.9 (74) | 22.7 (25) | 52.8 (66) | 24.2 (521) |
| | 2 | 21.6 (1912) | 19.9 (48) | 19.6 (206) | 18.1 (32) | 20.6 (70) | 21.1 (36) | 22.9 (53) | 20.4 (81) | 30.1 (62) | 16.4 (18) | 22.4 (28) | 21.4 (460) |
| | 3 | 19.9 (1761) | 18.7 (45) | 18.8 (198) | 16.4 (29) | 18.3 (62) | 17.0 (29) | 25.1 (58) | 19.4 (77) | 17.0 (35) | 24.5 (27) | 14.4 (18) | 20.5 (442) |
| | 4 | 18.8 (1665) | 22.4 (54) | 19.7 (207) | 28.2 (50) | 18.0 (61) | 22.2 (38) | 19.9 (46) | 23.2 (92) | 8.3 (17) | 28.2 (31) | 4.8 (6) | 15.6 (337) |
| | 5 | 17.2 (1524) | 21.6 (52) | 21.3 (224) | 29.4 (52) | 18.3 (62) | 22.2 (38) | 13.9 (32) | 14.9 (59) | 8.7 (18) | 8.2 (9) | 5.6 (7) | 18.3 (394) |
| Degree of spread | 1 Localised | 32.1 (2842) | 28.2 (68) | 31.8 (334) | 28.2 (50) | 30.4 (103) | 33.3 (57) | 29.4 (68) | 33.8 (134) | 26.7 (55) | 32.7 (36) | 20.0 (25) | 30.7 (661) |
| | 2 Regional | 40.2 (3553) | 43.2 (104) | 39.2 (412) | 36.7 (65) | 44.2 (150) | 35.7 (61) | 44.2 (102) | 39.5 (157) | 48.1 (99) | 41.8 (46) | 54.4 (68) | 42.1 (906) |
| | 3 Distant | 19.9 (1764) | 22.4 (54) | 21.2 (223) | 22.0 (39) | 17.4 (59) | 24.6 (42) | 17.7 (41) | 19.9 (79) | 20.4 (42) | 19.1 (21) | 16.8 (21) | 20.1 (433) |
| | Unknown | 7.8 (690) | 6.2 (15) | 7.8 (82) | 13.0 (23) | 8.0 (27) | 6.4 (11) | 8.7 (20) | 6.8 (27) | 4.9 (10) | 6.4 (7) | 8.8 (11) | 7.1 (154) |
| Year of diagnosis | 2003–2004 | 13.3 (1178) | 8.3 (20) | 12.5 (131) | 14.7 (26) | 7.4 (25) | 15.8 (27) | 16.9 (39) | 11.3 (45) | 10.7 (22) | 11.8 (13) | 7.2 (9) | 10.8 (232) |
| | 2005–2006 | 14.2 (1253) | 12.9 (31) | 15.1 (159) | 16.4 (29) | 13.3 (45) | 9.4 (16) | 14.3 (33) | 16.9 (67) | 6.3 (13) | 9.1 (10) | 8.0 (10) | 12.1 (261) |
| | 2007–2008 | 15.7 (1393) | 15.4 (37) | 14.9 (157) | 18.6 (33) | 14.7 (50) | 14.6 (25) | 13.0 (30) | 17.4 (69) | 13.1 (27) | 16.4 (18) | 8.0 (10) | 15.1 (326) |
| | 2009–2010 | 14.4 (1275) | 16.6 (40) | 16.3 (171) | 12.4 (22) | 13.6 (46) | 16.4 (28) | 10.4 (24) | 14.1 (56) | 15.5 (32) | 16.4 (18) | 16.0 (20) | 15.5 (334) |
| | 2011–2012 | 14.0 (1238) | 12.9 (31) | 15.3 (161) | 11.9 (21) | 13.6 (46) | 15.2 (26) | 16.0 (37) | 13.1 (52) | 18.0 (37) | 16.4 (18) | 26.4 (33) | 15.6 (335) |
| | 2013–2014 | 13.1 (1159) | 12.9 (31) | 11.9 (125) | 9.6 (17) | 14.7 (50) | 14.0 (24) | 13.4 (31) | 13.1 (52) | 18.4 (38) | 17.3 (19) | 18.4 (23) | 14.1 (303) |
| | 2015–2016 | 15.3 (1353) | 21.2 (51) | 14.0 (147) | 16.4 (29) | 22.7 (77) | 14.6 (25) | 16.0 (37) | 14.1 (56) | 18.0 (37) | 12.7 (14) | 16.0 (20) | 16.9 (363) |

**Table 3**
Adjusted odds ratios and 95% confidence interval (CI)* for distant spread at diagnosis for colon and rectal cancers; NSW 2003–2016.

| Predictor | | Colon OR (95% CI) (N = 26,084) | Rectum OR (95% CI) (N = 12,974) |
|---|---|---|---|
| Country of birth | Australia (ref.) | 1.00 | 1.00 |
| | New Zealand | 1.08 (0.87,1.35) | 1.16 (0.85,1.58) |
| | United Kingdom | **1.22 (1.09,1.36)** | 1.09 (0.93,1.28) |
| | Other English speaking | **1.30 (1.03,1.63)** | 1.33 (0.92,1.92) |
| | China (mainland) | 0.97 (0.79,1.18) | 0.84 (0.63,1.13) |
| | Germany | 1.11 (0.82,1.50) | 1.35 (0.94,1.93) |
| | Greece | 1.12 (0.90,1.40) | 0.88 (0.62,1.25) |
| | Italy | 1.14 (0.96,1.35) | 0.99 (0.77,1.28) |
| | Lebanon | **1.29 (1.00,1.66)** | 0.94 (0.66,1.33) |
| | Philippines | 1.18 (0.83,1.67) | 0.94 (0.58,1.52) |
| | Vietnam | 0.97 (0.72,1.30) | 0.74 (0.46,1.19) |
| | Other non-English speaking | 1.08 (0.99,1.18) | 1.00 (0.88,1.12) |
| Sex | Female (ref.) | 1.00 | 1.00 |
| | Male | **1.10 (1.04,1.16)** | **1.13 (1.04,1.24)** |
| Age at diagnosis (years) | 18–59 (ref.) | 1.00 | 1.00 |
| | 60–69 | **0.84 (0.77,0.91)** | 0.93 (0.84,1.04) |
| | 70–79 | **0.74 (0.68,0.81)** | 0.92 (0.82,1.03) |
| | 80 + | **0.76 (0.70,0.83)** | 1.01 (0.89,1.15) |
| SEIFA Disadvantage | 1 (most) (ref.) | 1.00 | 1.00 |
| | 2 | 0.95 (0.87,1.03) | 0.90 (0.80,1.02) |
| | 3 | **0.88 (0.81,0.97)** | 0.93 (0.82,1.05) |
| | 4 | **0.87 (0.79,0.95)** | **0.77 (0.67,0.87)** |
| | 5 (least) | **0.81 (0.74,0.88)** | **0.74 (0.65,0.85)** |
| Year of diagnosis | Continuous (2003–2016) | 0.99 (0.99,1.002) | 1.00 (0.99,1.01) |
| Charlson Comorbidity | 0 (ref.) | 1.00 | 1.00 |
| | > 0 | **1.36 (1.26,1.47)** | **1.28 (1.15,1.43)** |

OR – odds ratio; 95% CI – 95% confidence interval; SEIFA - Socio-Economic Indexes for Areas socio-economic status; ref. – reference
Unknown stage of spreading excluded in defining the outcome (distant versus localised and regional)
* Adjusted for sex, age at diagnosis, SEIFA, year of diagnosis, and comorbidity index;

population [3,4]. Those from the Philippines, Vietnam, Lebanon and New Zealand tended to be younger at diagnosis. Socioeconomic disadvantage appeared more pronounced in those born in Lebanon, the Philippines, and Vietnam compared with Australia. Lower socioeconomic status may have been associated with a lesser understanding of, and poorer access to, health services, as reported by World Health Organization in relation to health inequities in migrants in Europe [29].

The odds ratio for diagnosis with distant disease for colon cancer was higher in people born in Lebanon, the Philippines, United Kingdom and "other English-speaking" countries. Further investigation is needed to understand why migrants from the United Kingdom and "other English-speaking countries", for whom there would be few language barriers, had poorer outcomes. Greater promotion of participation in colorectal screening along with high-quality care may help to level outcomes for COB groups that are more likely to have advanced disease [9].

The linked data also revealed treatment variations by COB. Further investigation into cultural and other factors may indicate reasons and point to means of improving health service delivery. Treatment was negatively associated with poorer social economic status; the health system will need to address this inequity. Degree of spread was strongly associated with treatment selection, reflecting the influence placed in treatment guidelines on care by stage at diagnosis.

Higher survival (i.e., lower HR in Table 5) was indicated for people not born in Australia, with exception of colon cancer for patients born in New Zealand. Hypotheses for possible reasons include a "healthy migrant effect", preferences given to healthier people in migration programmes [30]; and the potential for death data to be missing because some migrants return to their birth countries when near death, resulting in lack of death recording in Australia [31,32]. Efforts were made in the study to adjust for people lost to follow-up, but this may have been only partially effective. A sensitivity analysis was conducted by assuming death for those with distant spread and censoring those with non-distant spread, but results remained largely unchanged and were considered confirmatory. Further study is needed to measure the impact of loss to follow-up.

### 4.1. Strengths and limitations

This study of multidimensional differences by stage, treatment and survival at the level of 12 COB categories groups was made possible by optimising power through inclusion of the NSW-wide population. Multiple data sources were linked and contributed to describing tumour characteristics, treatment profiles, and outcomes. These included the population-based cancer registry and linked hospital, health benefit, and population-wide death data. Study results indicated the profiles of residents having poorer outcomes where greater emphasis on education and promotion of screening and associated good-quality care may be needed. The study could be repeated periodically to evaluate effects of remedial measures at a population level and by COB. Study limitations should also be noted. COB was well recorded but information on spoken language, English proficiency and ethnic group was not available for analysis. It is also evident that COB would have varied in accuracy if used as an indicator of ethnicity or culture at an individual person level.

Another drawback was the possibility of incomplete treatment data. To counter this, we excluded data for13.7% of residents due to proximity to NSW borders, where increased opportunity for loss of data occurred due to cross-border treatment outside the scope of NSW data collection. However, the effect of this exclusion appears to have been small in statistical terms. For example, while retaining these residents would have reduced the proportion receiving surgical procedures among residents of these areas who were born in Australia, Germany, and Other English-speaking countries, the difference was only marginal (up to 3%).

Another study limitation was that residential area (metro/region) which could affect service access and outcomes was not included due to constraints of small case numbers in regional areas. Also, treatment by surgery, radiotherapy, and systemic therapy was only classified on a binary scale indicating the single fact of whether the specific therapy was received, without further detail (e.g., chemotherapy dose or duration). We were also unable track any treatment or death recorded outside of Australia.

## 5. Conclusions

1. These linked data revealed variations by COB in sociodemographic characteristics among patients with colorectal cancer; an example was more evidence of socioeconomic disadvantage among those born in Lebanon, the Philippines, and Vietnam than in Australia.
2. The data indicated differences in stage; examples were more advanced stages of colon cancers among those born in Lebanon and the United Kingdom compared with the Australian born. The data also showed treatment variations; examples included less evidence of treatment of colon cancer for people born in China, Germany, Italy, New Zealand, and Vietnam. Higher 5-year survival was indicated for people born in China, Italy, and Vietnam, which was contrary to assessed treatment exposure.
3. The population-wide scale of these linked data optimised power to measure multi-dimensional outcomes by COB. These data cover a broad range of items and reveal differences at a broad level that are candidates for prioritised service delivery and more in-depth health-service research.

## Funding

No external financial support was received for this research.

**Table 4**
Adjusted odds ratios and 95% confidence interval (CI)* for treatment (first 12 months from diagnosis), NSW 2003–2016.

| Predictor | | Colon (N = 26,084) | | | Rectal (N = 12,974) | | | |
|---|---|---|---|---|---|---|---|---|
| | | Any treatment OR (95% CI) | Surgery OR (95% CI) | Systemic OR (95% CI) | Any treatment OR (95% CI) | Surgery OR (95% CI) | Radiotherapy OR (95% CI) | Systemic OR (95% CI) |
| Country of birth | Australia (ref.) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| | New Zealand | **0.74 (0.55,1.00)** | 0.82 (0.65,1.04) | 0.91 (0.72,1.16) | 0.98 (0.52,1.83) | 1.11 (0.73,1.71) | 0.94 (0.70,1.26) | 1.07 (0.78,1.48) |
| | United Kingdom | 0.87 (0.75,1.004) | 0.91 (0.80,1.03) | 1.00 (0.88,1.14) | 0.95 (0.72,1.25) | 1.05 (0.85,1.30) | **1.19 (1.03,1.39)** | **1.27 (1.08,1.49)** |
| | Other English speaking | 0.83 (0.60,1.15) | 0.89 (0.69,1.14) | 0.85 (0.65,1.10) | 0.83 (0.40,1.71) | 0.69 (0.43,1.12) | 1.11 (0.78,1.58) | **1.70 (1.13,2.53)** |
| | China (mainland) | **0.68 (0.53,0.86)** | **0.73 (0.60,0.89)** | 0.87 (0.71,1.07) | 0.75 (0.47,1.20) | 0.99 (0.69,1.43) | **0.68 (0.52,0.89)** | 0.79 (0.60,1.04) |
| | Germany | 0.69 (0.48,1.01) | 0.97 (0.70,1.35) | **0.67 (0.48,0.94)** | 0.78 (0.42,1.45) | 0.80 (0.50,1.28) | 0.88 (0.61,1.26) | 0.85 (0.58,1.23) |
| | Greece | 0.77 (0.58,1.01) | 0.81 (0.64,1.02) | 0.89 (0.70,1.12) | 1.13 (0.61,2.08) | 1.43 (0.89,2.28) | 0.82 (0.59,1.13) | 0.86 (0.62,1.19) |
| | Italy | **0.79 (0.63,0.97)** | **0.80 (0.67,0.96)** | 0.89 (0.74,1.08) | **2.27 (1.30,3.97)** | **2.16 (1.47,3.16)** | 0.99 (0.78,1.26) | 1.04 (0.81,1.34) |
| | Lebanon | 1.12 (0.76,1.64) | 0.84 (0.64,1.10) | 0.97 (0.73,1.27) | 1.84 (0.82,4.17) | 1.35 (0.83,2.19) | 1.17 (0.86,1.58) | 0.76 (0.54,1.06) |
| | Philippines | 1.16 (0.66,2.05) | 0.84 (0.58,1.21) | 1.29 (0.88,1.90) | 0.94 (0.35,2.54) | 1.25 (0.63,2.50) | 0.95 (0.62,1.46) | 0.93 (0.58,1.48) |
| | Vietnam | **0.62 (0.43,0.91)** | **0.73 (0.54,0.99)** | **0.65 (0.48,0.89)** | 1.64 (0.57,4.72) | **2.80 (1.31,5.97)** | 0.89 (0.60,1.34) | 1.12 (0.71,1.75) |
| | Other non-English speaking | **0.73 (0.65,0.82)** | **0.74 (0.68,0.81)** | **0.88 (0.80,0.97)** | 0.91 (0.73,1.12) | 1.11 (0.95,1.30) | 0.98 (0.88,1.09) | 0.94 (0.84,1.06) |
| Sex | Female (ref.) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| | Male | 1.01 (0.94,1.09) | **0.92 (0.86,0.98)** | 1.00 (0.94,1.06) | 0.94 (0.81,1.10) | 1.00 (0.89,1.12) | **1.31 (1.21,1.42)** | 1.07 (0.98,1.16) |
| Age at diagnosis | Continuous | **0.94 (0.94,0.95)** | | **0.88 (0.88,0.89)** | **0.90 (0.89,0.91)** | **0.94 (0.94,0.95)** | **0.96 (0.95,0.96)** | **0.89 (0.88,0.89)** |
| Age at diagnosis (years)** | 18–59 (ref) | | 1.00 | | | | | |
| | 60–69 | | **1.23 (1.13,1.35)** | | | | | |
| | 70–79 | | **1.41 (1.29,1.54)** | | | | | |
| | 80 + | | 1.09 (0.99,1.19) | | | | | |
| SEIFA SES Disadvantage | 1 (most) (ref.) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| | 2 | **1.19 (1.06,1.33)** | **1.10 (1.01,1.21)** | **1.14 (1.04,1.25)** | **1.26 (1.02,1.55)** | **1.21 (1.03,1.42)** | 0.90 (0.80,1.01) | **1.21 (1.07,1.37)** |
| | 3 | **1.16 (1.04,1.30)** | **1.12 (1.02,1.22)** | **1.18 (1.07,1.30)** | **1.36 (1.09,1.69)** | **1.25 (1.06,1.48)** | **0.87 (0.78,0.99)** | **1.15 (1.01,1.30)** |
| | 4 | **1.27 (1.13,1.43)** | **1.16 (1.05,1.27)** | **1.31 (1.19,1.44)** | **1.51 (1.19,1.91)** | **1.35 (1.13,1.60)** | 0.90 (0.80,1.02) | **1.25 (1.10,1.42)** |
| | 5 (least) | **1.44 (1.27,1.63)** | 1.07 (0.97,1.18) | **1.42 (1.29,1.56)** | **1.70 (1.32,2.19)** | **1.42 (1.18,1.70)** | **0.74 (0.65,0.84)** | **1.19 (1.04,1.36)** |
| Year of diagnosis | Continuous (2003–2016) | **0.97 (0.96,0.98)** | **0.96 (0.95,0.97)** | 1.00 (0.99,1.01) | 0.99 (0.97,1.01) | **0.95 (0.93,0.96)** | **1.05 (1.04,1.06)** | **1.02 (1.01,1.03)** |
| Degree of spread | Local (ref.) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| | Regional | **0.77 (0.69,0.85)** | **0.35 (0.32,0.38)** | **14.2 (12.9,15.6)** | **0.79 (0.63,0.996)** | **0.42 (0.35,0.51)** | **2.61 (2.37,2.86)** | **8.63 (7.82,9.53)** |
| | Distant | **0.28 (0.26,0.31)** | **0.10 (0.09,0.11)** | **27.2 (24.5,30.2)** | **0.12 (0.10,0.15)** | **0.03 (0.03,0.04)** | **1.79 (1.60,2.00)** | **13.4 (11.9,15.2)** |
| Charlson Comorbidity | 0 (ref.) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| | > 0 | **0.51 (0.47,0.56)** | **0.58 (0.54,0.63)** | **0.51 (0.46,0.55)** | **0.53 (0.45,0.63)** | **0.77 (0.67,0.88)** | **0.40 (0.35,0.45)** | **0.64 (0.57,0.71)** |

* Adjusted for sex, age at diagnosis, SEIFA, year of diagnosis, stage comorbidity index and histology type; excluded people with unknown degree of spread due to low numbers. OR – adjusted odds ratio; 95% CI – 95% confidence interval; SEIFA - Socio-Economic Indexes for Areas socio-economic status; ref. – reference.

** Age did not show linear relationship with surgery and was therefore modelled separately using age group.

**Table 5**
Adjusted hazard ratios and 95% confidence intervals (CI)* for death following colon and rectal cancer diagnosis; NSW 2003–2016.

| Predictor | | Colon HR (95% CI) (N = 26,084) | Rectum HR (95% CI) (N = 12,974) |
|---|---|---|---|
| Country of birth | Australia (ref.) | 1.00 | 1.00 |
| | New Zealand | 1.04 (0.89,1.23) | 0.98 (0.79,1.21) |
| | United Kingdom | 0.93 (0.86,1.01) | 0.94 (0.84,1.06) |
| | Other English speaking | 0.95 (0.81,1.13) | 0.90 (0.68,1.18) |
| | China (mainland) | **0.68 (0.58,0.80)** | **0.77 (0.63,0.94)** |
| | Germany | 0.93 (0.75,1.16) | 0.83 (0.64,1.06) |
| | Greece | **0.73 (0.63,0.85)** | 0.88 (0.71,1.08) |
| | Italy | **0.88 (0.78,0.99)** | **0.80 (0.67,0.96)** |
| | Lebanon | **0.74 (0.60,0.90)** | 0.88 (0.68,1.15) |
| | Philippines | 0.81 (0.62,1.05) | 0.88 (0.62,1.23) |
| | Vietnam | **0.77 (0.61,0.99)** | **0.60 (0.38,0.93)** |
| | Other non-English speaking | **0.86 (0.80,0.91)** | **0.86 (0.79,0.94)** |
| Sex | Female (ref.) | 1.00 | 1.00 |
| | Male | **1.12 (1.08,1.17)** | **1.16 (1.09,1.23)** |
| Age at diagnosis | Continuous (transformed) | **1.05 (1.05,1.06)** | **1.05 (1.04,1.05)** |
| SEIFA Disadvantage | 1 (most) (ref.) | 1.00 | 1.00 |
| | 2 | **0.91 (0.85,0.96)** | 0.95 (0.87,1.04) |
| | 3 | **0.89 (0.84,0.95)** | 0.93 (0.85,1.02) |
| | 4 | **0.84 (0.79,0.90)** | **0.89 (0.82,0.98)** |
| | 5 (least) | **0.81 (0.76,0.86)** | **0.81 (0.74,0.90)** |
| Year of diagnosis (2003–2016) | Continuous (2013–2016) | **0.96 (0.96,0.97)** | **0.96 (0.95,0.97)** |
| Degree of spread | Local (ref.) | 1.00 | 1.00 |
| | Regional | **1.71 (1.61,1.82)** | **1.49 (1.37,1.62)** |
| | Distant | **9.31 (8.68,9.98)** | **6.57 (5.94,7.27)** |
| Charlson Comorbidity | 0 (ref.) | 1.00 | 1.00 |
| | > 0 | **1.58 (1.50,1.67)** | **1.28 (1.18,1.38)** |
| Treatment received (ref.: no surgery, no radiotherapy, no systemic therapy, respectively) | Surgery | **0.64 (0.61,0.67)** | **0.36 (0.33,0.39)** |
| | Radiotherapy | **1.50 (1.35,1.67)** | 1.02 (0.92,1.13) |
| | Systemic therapy | **0.63 (0.59,0.67)** | **0.46 (0.41,0.51)** |
| Time varying term | Time x chemotherapy | **1.001 (1.001,1.001)** | **1.001 (1.001,1.001)** |
| | Time x radiotherapy | **1.00 (1.000,1.001)** | **1.00 (1.000,1.000)** |

HR – adjusted hazards ratio; 95% CI – 95% confidence interval; SEIFA - Socio-Economic Indexes for Areas socio-economic status; ref – reference.

* Adjusted for sex, age at diagnosis, SEIFA, year of diagnosis, histology type, stage, comorbidity and treatment; excluded people with unknown degree of spread due to low numbers.

## CRediT authorship contribution statement

**George W. Zhao**: Conceptualization, Study design, Data analysis, Data acquisition, Interpretation of the data, Manuscript writing, Critical revisions. **David M. Roder**: Conceptualization, Study design, Interpretation of the data, Manuscript writing. **Sarah White**: Interpretation of the data, Manuscript writing, Critical revisions. **Enmoore Lin**: Conceptualization, Study design, Data acquisition, Interpretation of the data, Manuscript writing, Critical revisions. **Sheetal Challam**: Conceptualization, Interpretation of the data, Critical revisions. **Alana Little**: Interpretation of the data, Critical revisions. **Andre Renzaho**: Interpretation of the data, Critical revisions. **Leissa Pitts**: Interpretation of the data, Critical revisions. **Winston Liauw**: Interpretation of the data, Critical revisions. **David Currow**: Conceptualization, Study design, Data acquisition, Interpretation of the data, Critical revisions. All authors have read and approved the final version.

## Competing interests

The authors declare that they have no competing interests.

## Data availability

Data used in this study are available from the Cancer Institute NSW and Australian Institute of Health and Welfare, but restrictions may apply due to use of these data under license. Nonetheless data are available from the authors upon reasonable request and with permission of the Cancer Institute NSW and the Australian Institute of Health and Welfare.

## Acknowledgements

The authors are grateful to the NSW Ministry of Health for access to NSW data. We like to acknowledge AIHW and CHeReL for data linkage, Nicola Creighton and Richard Walton for their valuable inputs.

### *Ethics approval and consent to participate*

Approval was given for the study by the NSW Population and Health Services Research Ethics Committee (HREC/15/CIPHS/15). This followed a scientific review guided by the STROBE checklist for observational studies in epidemiology.

### *Consent for publication*

Not applicable.

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