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RESEARCH

# Interval Cancer Characteristics, Staging and Survival Among National Bowel Cancer Screening Program Participants, Western Australia, 2018: A Retrospective Observational Cohort Study

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## ABSTRACT

**Objective:** To examine the features of interval colorectal cancer (interval CRC) in Western Australia in the context of the National Bowel Cancer Screening Program (NBCSP), including incidence, characteristics and survival by NBCSP participant characteristics.

**Study Design:** Retrospective observational cohort study, analysis of linked National Cancer Screening Register and Western Australian Cancer Registry data.

**Participants, Setting:** Participants in the Western Australian NBCSP (50–74 years of age) with negative immunochemical faecal occult blood test (iFOBT) results during the 2018 screening round (1 January 2018–31 December 2018) were followed up for interval CRC diagnoses until 31 December 2020, and for death until 30 September 2022.

**Main Outcome Measures:** Crude and adjusted incidence rates of interval CRC were analysed overall and by sex, age group and residential socio-economic and remoteness categories. Survival outcomes for people with interval CRC were also assessed.

**Results:** Of 122,851 NBCSP participants with negative screening results in 2018, 51 people were diagnosed with interval CRC during follow-up (crude incidence rate, 21 per 100,000 person-years; 95% confidence interval [CI], 16–27). The adjusted incidence rate ratio of interval CRC was higher for men than women (adjusted incidence rate ratio [aIRR], 5; 95% CI, 3–11) and for people aged 70–74 years than for those aged 50–59 years (aIRR, 3; 95% CI, 1–6). Nineteen of 51 interval CRCs were diagnosed 19–24 months after negative iFOBT results, 25 were located on the right side of the colon and 34 were adenocarcinomas. Only 13 interval CRCs were stage I tumours at diagnosis. During follow-up (median, 33 months; interquartile range, 28–42 months), the all-cause mortality rate among the 51 people with interval CRC was 41 per 1000 person-years (95% CI, 18–92), and the colorectal cancer mortality rate was 35 per 1000 person-years (95% CI, 14–83).

**Conclusions:** We provide a comprehensive analysis of interval CRC staging and clinical characteristics in the context of the NBCSP in Western Australia, facilitating the definition of benchmarks for monitoring programme performance.

**Plain Language Summary**

**The known**: The National Bowel Cancer Screening Program has operated in Australia since 2006. National monitoring reports now include information about the number of interval cancers, but comprehensive staging and clinical information for Western Australia was unavailable.

**The new**: Among 122,851 people with negative screening tests in 2018, 51 were diagnosed with interval colorectal cancer within 2 years. Men and people aged 70–74 years had higher rates, with most cancers detected at stages II–III.

**The implications**: Our findings provide insights into the performance of National Bowel Cancer Screening Program in Western Australia. The interval cancer rate is an important quality measure for population-based screening programmes. Comprehensive reporting and performance benchmarking are important for improving the programme.

## 1 | Introduction

In Australia, colorectal cancer (bowel cancer) is the fourth most frequently diagnosed cancer and the second leading cause of death; 5-year survival from diagnosis for people aged 50–74 years is 75% [1, 2]. The colorectal cancer rate increases with age, from 6 per 1000 persons aged 0–49 to 26 per 1000 persons aged 50–74 years and 45 per 1000 persons aged 75 years or older [1, 3]. To reduce the prevalence of colorectal cancer, the Australian government introduced the National Bowel Cancer Screening Program (NBCSP) in 2006 [4]. The programme initially offered screening to people turning 55 and 65 and was progressively expanded to include additional age groups until biennial screening for all people aged 50–74 years was fully implemented by December 2019 [4, 5]. Since 2019, free immunochemical faecal occult blood tests (iFOBT or faecal immunochemical test) are mailed every 2 years to all people aged 50–74 years. Participants are asked to collect samples from two separate bowel motions; if the test result for either sample is positive (20 μg haemoglobin/g faeces or more), the person is referred for colonoscopy. Most overseas programmes, in contrast, use single faeces samples [6, 7]. In 2024, NBCSP eligibility was expanded to include people aged 45–49 years, but people in this age group must request the testing kit [6–8].

Interval colorectal cancers (interval CRCs) are colorectal cancers diagnosed after a negative screening test result and before the next scheduled screening episode [1, 8]. They may arise from lesions missed by screening or subsequently develop from undetected precancerous lesions or normal mucosa, but the pathway cannot be retrospectively determined from screening data. As the prognostic features of most interval cancers are poorer than for screen-detected cancers, including more advanced disease stage, the associated risk of death is higher [9]. Monitoring the interval cancer rate (the proportion of cancers that arise during the interval period) is therefore required to evaluate the effectiveness of screening programmes and improve programme quality; a lower interval cancer rate indicates better programme performance [10, 11]. Different interval CRC rates have been reported for European screening programmes. In the Netherlands (2006–2014), the rate was 23% for a cohort that underwent three rounds of biennial iFOBT screening [12]; in Slovenia (2011–2012), 14% of cancers were interval cancers (biennial iFOBT screening) [13]. The interval cancer proportion was larger in earlier programmes: 32%–46% of detected cancers over four rounds of biennial iFOBT screening in Spain (2000–2010) [14] and 31%–48% in Scotland with biennial guaiac-based FOBT screening (2000–2007) [15]. Established screening programmes routinely monitor interval CRC rates to optimise their screening protocols [16, 17].

During the early years of the NBCSP in piloted age groups (2006–2010), interval CRC was diagnosed within 2 years of negative iFOBT results in 646 of 15,454 programme participants diagnosed with colorectal cancer (4%) [18]. The 2025 NBCSP monitoring report, which included national interval cancer data for 2018, reported that there were six interval CRCs per 10,000 participants with negative or inconclusive screening test results [2]. However, detailed staging and clinical characteristics for interval CRCs are not included in national monitoring reports. The NBCSP has identified the interval CRC rate as a key programme performance indicator, but the characteristics of interval CRCs have not been comprehensively investigated in Australia since its pilot report. Information about interval CRC staging, morphology and survival is critical for refining screening protocols and comparing programme performance with national and overseas benchmarks.

We therefore assessed the distribution of interval CRC by the socio-demographic characteristics of NBCSP participants and cancer clinical characteristics, estimating crude and adjusted rates of interval CRC and survival with interval CRC, by analysing linked National Cancer Screening Register and Western Australian Cancer Registry data for residents of Western Australia who participated in the 2018 NBCSP screening round.

## 2 | Methods

We undertook a retrospective observational cohort study. We analysed data for NBCSP participants in Western Australia with negative iFOBT test results from 1 January 2018 to 31 December 2018, followed up for interval CRC diagnosis until 31 December 2020 and death until 30 September 2022. We report our study in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [19].

### 2.1 | Data Sources

We analysed de-identified data extracted from the National Cancer Screening Register (NCSR) and the Western Australian Cancer Registry (WACR). The NCSR is funded by the Australian government to support cervical and bowel cancer screening programmes. The Cancer Network WA extracted NCSR raw data for people in Western Australia aged 50–74 years screened during the 2018 screening round (1 January to 31 December 2018) for whom the NBCSP iFOBT result was negative. The dataset included information on the month and year of birth, sex, postcode and date of the negative iFOBT result.

The WACR extracted data for all colorectal cancer diagnoses in Western Australia from 1 January 2018 to 31 December 2020, and matched them with NBCSP participants with negative NBCSP iFOBT results from 1 January 2018 to 31 December 2018. The WACR used three matching methods: two probabilistic record linkage techniques based on Levenshtein and Jaro–Winkler distance and a fuzzy matching technique based on Levenshtein distance [20–22]. Records identified by the fuzzy matching method (which were also present in the other two methods) were automatically included; records unique to the probabilistic methods underwent manual review. For records with address or postcode mismatches, additional WACR datasets were consulted to confirm whether discrepancies were due to address changes. Information about colorectal cancer diagnosis date, tumour site, morphology, grade, cancer stage, death date and cause of death was extracted.

### 2.2 | Study Population

We analysed data for all NBCSP participants in Western Australia aged 50–74 years with negative iFOBT results during the 2018 screening round. Participants were followed up from the date of the negative iFOBT test result until 24 months after the test result or the date they were diagnosed with colorectal cancer, whichever was earliest, consistent with data availability and the Australian Institute of Health and Welfare (AIHW) definition of interval CRC [1]. As the date of the next screening episode was not available and the date of death was available only for people diagnosed with colorectal cancer, these criteria could not be incorporated into the definition of interval CRC follow-up.

### 2.3 | Identifying Interval Colorectal Cancers

Interval CRC was defined, in alignment with the AIHW performance indicator definition for the NBCSP [1], as a new colorectal cancer (International Statistical Classification of Diseases and Related Health Problems, tenth revision, Australian modification [ICD-10-AM] codes C18–C20) diagnosed during the 24 months following a negative iFOBT result. Appendiceal cancers (ICD-10-AM C18.1) have been excluded from definitions of interval CRC in some studies [23], but we included them to be consistent with the AIHW bowel cancer definition [5]. Our interval CRC definition differs from those of overseas studies that included people with both negative and inconclusive iFOBT results. Inconclusive results refer to participants with positive iFOBT results and negative subsequent colonoscopy assessments; as the NCSR does not have complete data on follow-up colonoscopy assessments (this would require linkage with hospital data, beyond the scope of our study), we could not extend our study population to include this group.

### 2.4 | Covariates

We extracted data on age, sex (biological sex recorded in the dataset; gender was not available), tumour stage at diagnosis, tumour location and tumour morphology. Socio-economic status of residential postcode was classified using the Index of Relative Socio-economic Disadvantage (IRSD) [24], geographic remoteness using the Accessibility/Remoteness Index of Australia (ARIA+) [25]. The population of Western Australia is highly urbanised; the Perth metropolitan area is the major hub and much of the population living outside the Perth area live in areas classified as remote or very remote. The IRSD is based on socio-economic conditions such as income and education; ARIA+ is based on access to services. Together, they provide measures of socio-economic and geographic disadvantage at the area level, based on residential postcode rather than individual circumstances.

### 2.5 | Statistical Analysis

Interval CRC incidence rates (per 100,000 person-years) were calculated by dividing the number of interval CRCs during the 24 months after negative iFOBT results by the total number of person-years for participants with negative test results during the 2018 screening round (number of participants with negative iFOBT results multiplied by the number of years of follow-up [i.e., 2 years] or the number of years until interval CRC was identified, whichever was earliest) [26]. Data for participants without interval CRC were censored at 24 months after negative iFOBT results, as death dates were not available for participants without cancer in the absence of linkage to the birth, death and marriage registry. Raw and adjusted incidence rates are reported overall and by covariate. Adjusted incidence rates (adjusted for age, sex, remoteness category and socio-economic disadvantage category) were calculated using Poisson regression. Adjusted incidence rate ratios (aIRRs; with 95% confidence intervals, CIs) were calculated using Cox proportional hazards regression adjusted for age, sex, remoteness category and socio-economic disadvantage category.

Mortality for participants with interval CRC (per 1000 person-years) was calculated using the number person-years from cancer diagnosis until death or end of follow-up (30 September 2022). Survival curves are depicted as Kaplan–Meier plots. All analyses were undertaken in Stata 18.

### 2.6 | Ethics Statement

The study was approved by the human research ethics committees of the Western Australian Department of Health (RGS0000006176) and Curtin University (HRE20230414).

## 3 | Results

Negative iFOBT results during the 2018 NBCSP screening round were recorded for 122,851 Western Australia residents; 65,082 were women (53.0%), 56,045 (45.6%) were aged 60–69 years, 85,746 (69.8%) lived in major cities and 35,795 (29.1%) lived in areas in the socio-economically least disadvantaged quintile (IRSD quintile 1) (Table 1).

A total of 90 individuals with negative NBCSP screening results during 2018 who were subsequently diagnosed with colorectal cancer in 2018–2020 were identified through WACR linkage. Eighty-nine records were found by all three matching methods and automatically included in the matched dataset; 82 records identified by one or two methods underwent manual review, with

**TABLE 1** | Characteristics of Western Australian participants with negative immunochemical faecal occult blood test results during the 2018 National Bowel Cancer Screening Program screening round.

| Characteristics | Number |
|---|---|
| Participants | 122,851 |
| Sex | |
| Female | 65,082 (53.0%) |
| Male | 57,769 (47.0%) |
| Age group (years) | |
| 50–59 | 39,890 (32.5%) |
| 60–69 | 56,045 (45.6%) |
| 70–74 | 26,916 (21.9%) |
| Remoteness (ARIA+ category) | |
| Major cities | 85,746 (69.8%) |
| Inner/outer regional | 25,778 (21.0%) |
| Remote/very remote | 4426 (3.6%) |
| Unknown | 6901 (5.6%) |
| Socio-economic disadvantage (IRSD quintile) | |
| 1 (least disadvantaged) | 35,795 (29.1%) |
| 2 | 20,037 (16.3%) |
| 3 | 20,597 (16.8%) |
| 4 | 26,713 (21.7%) |
| 5 (most disadvantaged) | 12,749 (10.4%) |
| Unknown | 6960 (5.8%) |

Abbreviations: ARIA+, Accessibility and Remoteness Index of Australia; IRSD, Index of Relative Socio-economic Disadvantage.

one additional record confirmed as a true match. The true positive rate was 89 of 90 for fuzzy matching, 90 of 102 for Levenshtein distance matching and 90 of 158 for Jaro–Winkler matching. After removing two duplicate records and one misclassified melanoma case, 87 interval CRC cases were identified. Of these, 51 met study inclusion criteria and were included in the analysis.

Fifty-one people with negative iFOBT results during the 2018 screening round were subsequently diagnosed with interval CRC; 42 were men, 21 were aged 60–69 years, 33 lived in major cities and 29 lived in areas included in IRSD quintiles 1–3. The incidence of interval CRC increased with time from negative screening result; the largest proportion of interval CRCs were diagnosed at 19–24 months (19 of 51). Twenty-five of 51 interval CRCs were located on the right side of the colon, and 34 were adenocarcinomas. Thirteen interval CRCs were diagnosed at Stage I (Table 2).

### 3.1 | Interval Colorectal Cancer Rates

The overall crude interval CRC incidence rate was 21 (95% CI, 16–27) per 100,000 person-years. The adjusted incidence rate was higher for men (40 [95% CI, 17–63] per 100,000 person-years) than women (9 [95% CI, 2–16] per 100,000 person-years; aIRR, 5; 95% CI, 3–11). By age group, the adjusted incidence rate was highest for people aged 70–74 years (39 [95% CI, 13–65] per 100,000 person-years; *v* 50–59 years: aIRR, 3; 95% CI, 1–6). Differences in adjusted incidence rates by socio-economic disadvantage and remoteness categories were not statistically significant (Table 3). Adjusted incidence rates were similar between inner and outer regional areas (19 [95% CI, 7–31] per 100,000 person-years) and major cities (20 [95% CI, 12–27] per 100,000 person-years), with an adjusted IRR of 1 (95% CI, 1–2). Remote and very remote areas could not be reported due to low cell counts.

### 3.2 | Survival With Interval Colorectal Cancer

The median duration from the diagnosis of interval CRC to either the end of follow-up (30 September 2022) or date of death was 33 months (interquartile range, 28–42 months; range, 4–53 months). Six people with interval CRC died during the follow-up period; all six deaths were cancer-related, either colorectal cancer or malignant melanoma of the skin (unspecified). The overall survival rate was 88%. The all-cause mortality rate was 41 (95% CI, 19–92) per 1000 person-years; the colorectal cancer-specific mortality rate was 35 (95% CI, 14–83) per 1000 person-years. Survival was poorer for women than men with interval CRC, and survival by age group was poorest for people aged 50–59 years (Figure 1).

## 4 | Discussion

We calculated incidence rates based on exposure time (number of person-years) to facilitate comparisons with overseas benchmarks [27]. We found that the crude interval CRC incidence rate among participants with negative bowel screening results during the 2018 NBCSP screening round was 21 cases per 100,000 person-years (95% CI, 16–27). After adjustment for demographic factors, sex and age remained significant predictors of interval CRC. The incidence rate was higher for men than for women, and for people aged 70–74 years than for those aged 50–59 years, consistent with patterns reported by the AIHW for Australia [2]. Of 51 cases of interval CRC, the tumour was located on the right side in 25 cases and had an adenocarcinoma morphology in 34 cases. Only 13 interval CRCs were diagnosed at stage I, a substantially smaller proportion than that of cancers detected by iFOBT screening during the pilot NBCSP phase (1098 of 2478, 44%) [18], illustrating that interval cancers are often detected at a later stage, which is associated with poorer survival. We found that the survival rate with interval CRC was lower for women than men and for people aged 50–59 years than for older people. Our findings provide insights into the epidemiology of interval CRC and the performance of the NBCSP in Western Australia.

Our findings regarding the characteristics of interval CRC were very similar to those reported for population-based screening programmes in Scotland [15, 27], the Netherlands [23, 28], Italy [29] and a recent meta-analysis of iFOBT-based screening programmes [26]. Several studies have also reported that interval CRC rates are higher for men and people aged 60 years or older [23, 26, 29]. The higher interval CRC incidence in men than

**TABLE 2** | Characteristics of Western Australian participants with negative immunochemical faecal occult blood test results during the 2018 National Bowel Cancer Screening Program screening round and subsequently diagnosed with interval colorectal cancer.

| Characteristics | Number |
|---|---|
| People with interval colorectal cancers | 51 |
| Time since negative immunochemical faecal occult blood test result to diagnosis (months) | |
| 0–6 | 7 |
| 7–12 | 10 |
| 13–18 | 15 |
| 19–24 | 19 |
| Sex | |
| Female | 9 |
| Male | 42 |
| Age group (years) | |
| 50–59 | 10 |
| 60–69 | 21 |
| 70–74 | 20 |
| Remoteness (ARIA+ category)[a] | |
| Major cities | 33 |
| Inner/outer regional | 10 |
| Remote/very remote | |
| Unknown | |
| Socio-economic disadvantage (IRSD quintile)[b] | |
| 1 (least disadvantaged) | 13 |
| 2 | 9 |
| 3 | 7 |
| 4 | 12 |
| 5 (most disadvantaged) | < 6 |
| Unknown | < 6 |
| Tumour grade | |
| Intermediate/moderately differentiated | 13 |
| Highly/poorly differentiated | 14 |
| Other | 24 |
| Tumour location | |
| Right side | 25 |
| Left side | 7 |
| Overlapping, appendix, rectum, rectum other parts | 19 |
| Tumour morphological type | |
| Adenocarcinoma | 34 |
| Other[c] | 17 |
| Tumour stage at diagnosis | |
| I | 13 |
| II | 9 |
| III | 15 |
| IV | 7 |
| Unstageable | 7 |

Abbreviations: ARIA+, Accessibility and Remoteness Index of Australia; IRSD, Index of Relative Socio-economic Disadvantage.
[a]Remoteness (ARIA+ category): Remote/very remote, and unknown is not reported due to low cell count.
[b]Socio-economic disadvantage (IRSD quintile): 5 (most disadvantaged), and unknown is not reported due to low cell count.
[c]Mucinous adenocarcinoma, neuroendocrine, signet ring cell carcinoma and other.

women reflects the higher prevalence of colorectal cancer risk factors, including smoking, alcohol consumption, sedentary lifestyle, poor diet and lower screening participation [30]. With respect to tumour characteristics, a systematic review reported that 22% of interval CRCs were detected at an early stage (Dukes A or TNM stage I) [26]. Some studies have found that interval CRCs are more frequently located in the right side or proximal colon than screen-detected cancers [15, 23, 28, 29], others have found no difference in location distribution [27]. It should be noted that the cited studies concerned programmes based on single faecal sample screening [31–33]. Despite the reported benefits of the dual sample approach used in Australia [34–36], the interval CRC rate we found for Western Australia is similar to that in countries with single-sample approaches. The long-term cost–benefit implications and impact on screening participation of a one-sample approach in Australia should be examined, particularly as the need to refrigerate stool samples is a recognised barrier to participation [6].

Interval CRC incidence rates differ between programmes because of differences in haemoglobin thresholds for defining positive iFOBT results, screening strategies (including sample collection protocols) and participation rates. The crude incidence rate we report is not significantly different from the pooled estimate in a recent meta-analysis of seven iFOBT-based screening programmes (15 per 100,000 person-years; 95% CI, 8–30 per 100,000 person-years) [26].

We found no significant variation in interval CRC incidence by remoteness or socio-economic disadvantage. Previous studies have reported that overall colorectal cancer incidence and positive screening test result rates are higher in non-metropolitan areas, possibly reflecting greater disease burden and less access to health care [2]. However, our ability to detect geographic variation was limited by small sample sizes, particularly in remote and very remote areas.

Colorectal cancer-specific mortality among people with interval CRC in our study (35 [95% CI, 14–83] deaths per 1000 person-years) may suggest poorer outcomes compared with the

**TABLE 3** | Incidence of interval colorectal cancer in Western Australian participants with negative immunochemical faecal occult blood test results during the 2018 National Bowel Cancer Screening Program screening round, by participant characteristics.

| Characteristics | Interval colorectal cancers | Person-years | Incidence rate, per 100,000 person-years (95% CI) | | Adjusted incidence rate ratio (95% CI) |
|---|---|---|---|---|---|
| | | | Crude | Adjusted[a] | |
| All people | 51 | 245,663.4 | 21 (16–27) | | |
| Sex | | | | | |
| Female | 9 | 130,157.6 | 7 (4–13) | 9 (2–16) | 1 |
| Male | 42 | 115,505.8 | 36 (27–49) | 40 (17–63) | 5 (3–11) |
| Age group (years) | | | | | |
| 50–59 | 10 | 79,772.2 | 13 (7–23) | 14 (3–25) | 1 |
| 60–69 | 21 | 112,073.4 | 19 (12–29) | 20 (7–34) | 2 (1–3) |
| 70–74 | 20 | 53,817.8 | 37 (24–58) | 39 (13–65) | 3 (1–6) |
| Remoteness (ARIA+ category)[b] | | | | | |
| Major cities | 33 | 171,466.2 | 19 (14–27) | 20 (12–27) | 1 |
| Inner/outer regional | 10 | 51,548.3 | 19 (10–36) | 19 (7–31) | 1 (1–2) |
| Remote/very remote | | | | | |
| Unknown | | | | | |
| Socio-economic disadvantage (IRSD quintile)[c] | | | | | |
| 1 (least disadvantaged) | 13 | 71,581.0 | 18 (11–31) | 26 (5–47) | 1 |
| 2 | 9 | 40,067.2 | 23 (12–43) | 32 (5–59) | 1 (1–3) |
| 3 | 7 | 41,185.4 | 17 (8–36) | 24 (2–45) | 1 (0–2) |
| 4 | 12 | 53,417.4 | 23 (13–40) | 31 (8–53) | 1 (1–3) |
| 5 (most disadvantaged) | < 6 | — | — | — | — |
| Unknown | < 6 | — | — | — | — |

Abbreviations: ARIA+, Accessibility and Remoteness Index of Australia; CI, confidence interval; IRSD, Index of Relative Socio-economic Disadvantage.
[a]Adjusted for age, sex, remoteness category and socio-economic disadvantage category (IRSD).
[b]Remoteness (ARIA+ category): Remote/very remote, and unknown is not reported due to low cell count. Unknown ARIA+ category was excluded from the adjusted model due to multicollinearity.
[c]Socio-economic disadvantage (IRSD quintile): 5 (most disadvantaged), and unknown is not reported due to low cell count.

overall 5-year relative survival of 74% for patients with CRC aged 50–74 years diagnosed in 2012–2016 [37], though the wide CI interval reflects the small number of deaths and limits definitive conclusions. We found that mortality was higher among women than men with interval CRC, but the number of deaths was small and follow-up relatively short. The sex difference in survival could reflect the interplay between screening participation and test performance characteristics. The colorectal cancer screening programme participation rate is higher for women than men both overseas [30] and in Australia (44% *v* 40% of invited persons) [2]. However, the sensitivity of iFOBT-based colorectal cancer screening is lower for female than male participants, leading to higher false-negative rates; specific strategies are needed to overcome this difference [38]. The combination of higher female participation but lower test sensitivity could lead to a higher incidence of more aggressive or difficult to detect interval cancers in female patients, possibly explaining the poorer survival we report.

### 4.1 | Limitations

Our preliminary evaluation of interval CRC in Western Australia should be interpreted cautiously. First, we analysed data only for people who participated in the 2018 NBCSP round, capturing a single year of the biennial screening cycle. As full programme implementation was completed in 2019, the 2018 dataset included 11 of the 13 biennial age groups (people aged 50, 54, 58, 60, 62, 64, 66, 68, 70, 72 or 74 years; ages 52 and 56 were added in 2019 [39]). Second, the date of the next screening round for people screened in 2018 was unknown and not

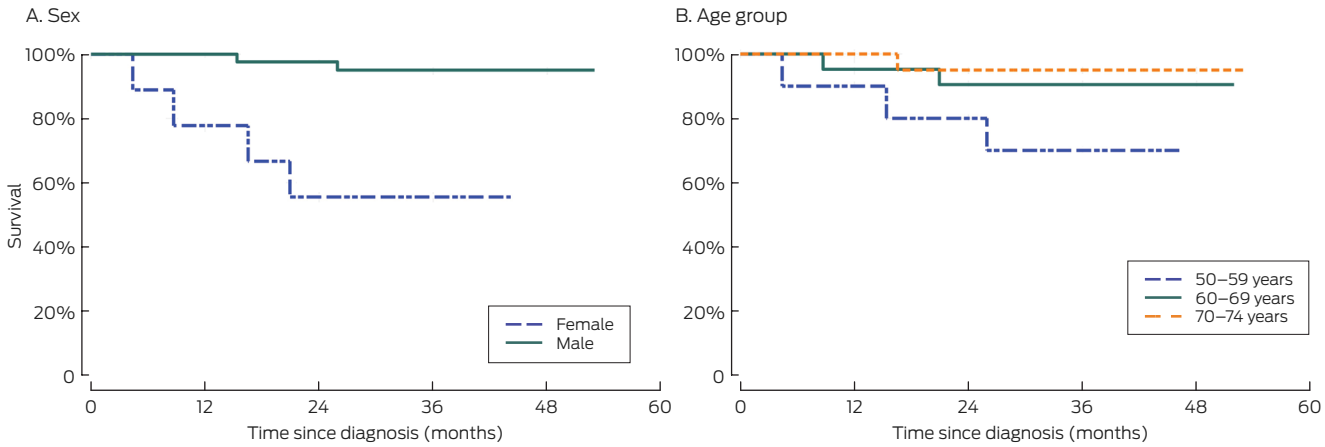


**FIGURE 1** | All-cause mortality among 51 Western Australian participants diagnosed with interval colorectal cancer after negative immunochemical faecal occult blood test results during the 2018 National Bowel Cancer Screening Program screening round, by sex and age group: Kaplan–Meier survival analysis.

considered when defining interval CRC, potentially leading to slightly overestimating its incidence. Some interval CRC could have been detected during subsequent screening rather than being genuine interval CRC; however, the absence of a rapid increase in cancer detection rates in the later time periods (7–12, 13–18, 19–24 months) suggests that subsequent screening rounds did not substantially contribute to case identification. Third, mortality data were available only for people with cancer diagnoses, possibly overestimating the time at risk for participants who died during follow-up and slightly depressing the estimated interval CRC incidence. However, given the 24-month follow-up period, this bias was probably minor. Furthermore, survival was assessed only for people with interval CRC, precluding comparisons with people with screen-detected colorectal cancer and reducing the ability to assess screening programme sensitivity. As the median time for mortality follow-up was only 33 months, our analysis may not have had sufficient statistical power to detect differences in survival by age group and sex.

## 4.2 | Conclusion

Our study provides the first comprehensive analysis of interval CRC clinical characteristics, staging and survival outcomes among Western Australia NBCSP participants, complementing recently published national surveillance data and establishing a foundation for future analyses and comparisons with overseas screening programmes. To further assess screening programme effectiveness, comprehensive data linkage is essential. Linking screening participant records with the WACR, hospital morbidity data and mortality data would enable accurate identification of screen-detected and other cancers, assessment of screening sensitivity, and evaluation of the broader impact of population-based screening programmes on health outcomes.

Our findings provide novel insights into the epidemiology and clinical characteristics of interval CRC in Western Australia, including detailed staging, morphology and survival information not available in national NBCSP monitoring reports. By establishing comprehensive clinical profiles of interval cancers through linkage of registry datasets, our approach facilitates comparisons with overseas benchmarks and provides a methodological framework for enhanced surveillance and comparative analyses of screening programmes. Our findings advance knowledge of interval cancer characteristics and outcomes, supporting evidence-based strategies for early detection and reducing the disease burden.

### Author Contributions

**Shantelle J. Smith:** conceptualisation, project administration, writing (original draft preparation), writing (review and editing); **Rachael Moorin:** conceptualisation, writing (review and editing); **Dagmawi Tadesse:** conceptualisation, data curation, writing (review and editing); **Kathleen O'Connor:** conceptualisation, funding acquisition, writing (review and editing); **Thi Ninh Ha:** conceptualisation, formal analysis, investigation, supervision, writing (review and editing).

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### Disclosure

Not commissioned; externally peer reviewed.

### Conflicts of Interest

The authors declare no conflicts of interest.

### Data Availability Statement

The de-identified data we analysed are not publicly available and cannot be shared as we do not have ethics approval to do so.

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