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# Effects of clinical and socioeconomic factors on Medicare and patient costs for colorectal cancer in Australia: a retrospective multivariate regression analysis

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## ABSTRACT

**Objective** We study how clinical and socioeconomic factors influence colorectal cancer (CRC) costs for patients and Medicare in Australia. The study seeks to extend the limited Australian literature on CRC costs by analysing comprehensive patient-level medical services and pharmaceutical cost data.

**Design, setting and participants** Using the Victorian Cancer Registry, we identified all patients in Victoria who were diagnosed with CRC from 2010 to 2019 and extracted their linked 2010–2021 Medicare data. This data includes expenses from the Pharmaceutical Benefits Scheme and Medicare Benefits Schedule services. We examined variables such as disease stage, CRC type, molecular profile, metastasis status and demographics (eg, age, birth country, socioeconomic level via the SEIFA index, and native language). We applied descriptive and log-linear multivariate regression analyses to explore patient and Medicare costs related to CRC treatment.

**Results** Costs significantly rise with advanced cancer stages, especially on medication costs. Patients' average out-of-pocket (OOP) expenses are roughly $A441 per year. Key cost influencers are gender, age and socioeconomic status. On average, males incur 13.5% higher annual costs, a significantly larger OOP expense, than females. Compared with patients aged 50 or below, there is a 7.1% cost increase for individuals aged 50–70 and an 8.8% decrease post-70, likely reflecting less intensive treatment for the elderly. Socioeconomic factors show a clear gradient. Wealthier areas experience higher costs, especially among native English speakers. Costs also vary based on cancer's anatomical location and specific genetic mutations.

**Conclusion** The research highlights that CRC treatment expenses for patients and Medicare differ considerably due to factors such as diagnostic stage, demographics, anatomical location of the tumour and mutations. These cost variations lead to concerns about healthcare equality and decision-making autonomy. Policymakers may need to focus on early detection, increased support for advanced-stage patients, gender-sensitive healthcare, and equitable access to treatment across different socioeconomic groups.

## STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ The study's inclusive approach analyses a broad demographic and multiple factors, enhancing the understanding of colorectal cancer (CRC) costs in Victoria, Australia.
⇒ Examining diverse variables, the research offers detailed insights into healthcare costs related to CRC.
⇒ Using 2010–2021 Medicare data provides a realistic view of CRC treatment costs, aiding policy relevance.
⇒ Limitations include omitting non-Medicare expenses, such as inpatient hospital costs or fees from private providers, leading to potential underestimation of CRC's financial impact.
⇒ The study's reliance on administrative data excludes essential lifestyle factors (smoking, diet, exercise), impacting its overall applicability.

## INTRODUCTION

Cancer, a major global health challenge, accounts for nearly 10 million deaths annually worldwide.[1 2] Worldwide, colorectal cancer (CRC) is the third most frequently diagnosed cancer and the second leading cause of cancer-related deaths in 2020.[3]

In Australia, CRC is the second most common cause of cancer death, contributing to 18% of the country's health burden with over 15 000 new cases diagnosed each year.[4] CRC surpassed other cancers as the most costly cancer in Australia, with healthcare expenditures exceeding $A1 billion in 2013.[5]

Australia has a universal health insurance coverage, Medicare, which provides subsidised medical and hospital services through the Medicare Benefits Schedule (MBS) and subsidises prescription drugs through the Pharmaceutical Benefits Scheme (PBS). It was introduced in 1984 to ensure that

all Australians have access to free or low-cost essential healthcare.[6]

Under Medicare, the Australian government subsidises the cost of many medical services, including visits to doctors and specialists, tests and examinations, and some surgical and therapeutic procedures. The amount of subsidy, known as the Medicare benefit, is set for each service listed in the MBS. The Medicare benefit is a fixed amount for each service, regardless of the actual fee charged by the medical practitioner. If the practitioner charges more than the Medicare benefit, the patient pays the difference as an out-of-pocket cost. Therefore, out-of-pocket costs can vary depending on the practitioner's fee and the patient's financial circumstances despite the Medicare benefit being the same for all eligible beneficiaries. There are annual safety net thresholds for out-of-pocket costs, after which the Medicare benefit increases to provide further financial assistance.[6]

As the other important part of Medicare, the PBS subsidises the cost of selected prescription medicines, reducing out-of-pocket costs for Australian citizens. There are over 5200 brand name, generic, biologic and biosimilar medicine reimbursed by the PBS. Only safe and effective products are considered for reimbursement with an independent medical advisory committee providing recommendations on what should be listed on the PBS. There are also annual PBS safety net thresholds for out-of-pocket costs.[7]

As prevalence of CRC and the cost to treat CRC increases over time, it is important to understand their implications on Medicare spending and patient payment. Consequently, a comprehensive understanding of CRC treatment costs and the underlying population risk factors is critical for budgeting Medicare, prioritising preventive measures and conducting economic evaluations for CRC prevention and control programmes.

Our study aims to provide evidence on the impact of clinical and socioeconomic factors on CRC treatment costs using Medicare data for all patients in Victoria who were diagnosed for CRC between 2010 and 2019. Victoria is the second most populous state in Australia with about 7 million residents. While extensive research has been conducted in Europe and the USA[8–12], to the best of our knowledge, the existing Australian literature on this topic remains limited, with notable exceptions being the studies by Goldsbury *et al*[13] and Lal *et al*.[14]

Goldsbury *et al*[13] conducted a comprehensive analysis by linking administrative health records with self-reported data from a large cohort of residents in New South Wales in Australia. Their study focused on 1200 colon and 546 rectal cancer cases diagnosed between 2006 and 2013, revealing that resource utilisation increased with disease severity, the presence of comorbidities, and younger patient age. However, their investigation was restricted to patients aged 45 and above. In contrast, our study encompasses a broader demographic, including all age groups, and focuses on patients in Victoria diagnosed with CRC from 2010 to 2019.

Lal *et al*[14] explored variations in healthcare spending for CRC patients in South Australia, considering factors such as socioeconomic status (SES) and geographic remoteness. They found that both use of medical services and pharmaceutical expenditures were fairly equitable across patient populations. Yet, their research was specifically tailored to expenditures in privately funded hospital visits and medical services from private providers. Our study incorporates data for both public and private hospital patients and examines direct CRC-related medical services and pharmaceutical costs. Additionally, we delve deeper into the analysis of direct healthcare system costs associated with various crucial clinical factors such as disease stage, molecular profile and metastasis status, as well as key socioeconomic factors related to healthcare use, including age, gender and SES.

Our comprehensive analysis of clinical and socioeconomic factors affecting CRC treatment costs offers valuable insights for guiding the development of effective healthcare strategies and informing policy decisions.

## METHODS

### Data collection and patient inclusion

We used a retrospective, population-based dataset of adults 18 years and older diagnosed with CRC in Victoria, Australia, from 2010 to 2019. We first identified all patients in Victoria who were diagnosed with CRC from 2010 to 2019 using the Victorian Cancer Registry data. We then extracted all Medicare data and National Death Index between 2010 and 2021 for these patients, including prescription medicines covered in the PBS and doctor visits and procedures covered in the MBS. This linkage was carried out by the Centre for Victorian Data Linkage and the Australian Institute of Health and Welfare Data Linkage Unit. A total of 29 892 individuals were included in the analysis.

Through the established linked dataset, several demographic and clinical covariates were available, including demographic variables such as gender, age at diagnosis, birth country, socioeconomic status (SEIFA index), native language, as well as clinical factors like type of CRC, year of diagnosis and stage at diagnosis. Molecular profile (RAS mutation status) and metastasis status were inferred. The former was determined through PBS records of medications used in RAS wild-type disease such as cetuximab, and the latter was deduced from hospital episodes indicating secondary metastasis.

Our focus was on items directly related to CRC cancer treatment reimbursed by Medicare, which were included in two data files: PBS and MBS. For each patient, we extracted PBS data from the diagnosis date to 31 December 2021, keeping all records in the 'antineoplastic agents' Body System category, which are used to treat cancer. From the MBS, we included all items related to surgery and radiotherapy used to treat CRC. Notably, the provision of palliative care services was not considered in our study. In Australia, palliative care is delivered

by a spectrum of government agencies, private and not-for-profit bodies in a range of settings including specialistic inpatient wards, community-based services, public and private hospitals, general practices, and community aged care services. A major challenge continues to be the identification of palliative care, including end-of-life care, within Australian existing data collections and health settings, especially in community, primary care and residential aged care settings.[15] Given these limitations, palliative care could not be consistently costed from our dataset.

### Cost measures and covariates

For each patient per year, separately for MBS and PBS, we calculated Medicare reimbursement costs, patient out-of-pocket costs (or copayments), and the sum of the two which were gross charges by service providers. We calculated the sum of MBS and PBS costs, also breaking down by patient payments and Medicare reimbursement costs. As mentioned above, we only included MBS and PBS items related to CRC treatment, not other non-CRC treatment occurred for CRC patients. This is an important difference because CRC patients often have other comorbidities. We adjusted all monetary values spanning from 2010 to 2021 to reflect the 2021 Australian dollar value, using the Australian Consumer Price Index.[16]

In our regression analysis, we controlled for the following covariates: (i) clinical factors, including type of CRC (rectal or colon), disease stage at the time of diagnosis, RAS mutation status and metastasis status indicating the cancer has spread, and (ii) patients' demographics, including age, birth country, socioeconomic status (Socio-Economic Indexes for Areas) and English as first language. Socio-Economic Indexes for Areas (SEIFA) is a measure created by the Australian Bureau of Statistics that assesses the socioeconomic conditions of different geographical areas. SEIFA uses a wide range of data, including income, educational attainment, employment and more to create an index value for different regions.[17] SEIFA comprises four different indices, the specific index used here is the Index of Relative Socio-Economic Disadvantage. Based on this index, areas are categorised into quintiles and used in the analysis. In general, SEIFA scores are lower in remote and regional areas compared with metropolitan areas.

A full list of the clinical factors and patient demographics in our analysis, their definitions and corresponding summary statistics, can be found in online supplemental appendix table A1.

### Statistical analyses

We used a log-linear regression model to analyse the effects of patient clinical and demographic factors on total costs ($C_{it}$) charged by service providers from the MBS and PBS databases, the corresponding Medicare reimbursement costs ($B_{it}$), and patient out-of-pocket (OOP) costs ($O_{it}$) of patient $i$ in the $t$th year from diagnosis ($t \geq 0$). The model can be expressed as follows:

$$\begin{aligned} logC_{it} &= X_{it}'\alpha_c + d_t'\beta_c + d_r'\delta_c + \varepsilon_{it} \\ logB_{it} &= X_{it}'\alpha_b + d_t'\beta_b + d_r'\delta_b + \omega_{it} \\ logO_{it} &= X_{it}'\alpha_o + d_t'\beta_o + d_r'\delta_o + \xi_{it} \end{aligned} \quad (1)$$

where $X_{it}$ denotes the vector of clinical and demographic factors, $d_t$ and $d_r$ denote indicator variables that respectively indicate year after diagnosis and diagnosis year fixed effects, with $\varepsilon_{it}$, $\omega_{it}$, $\xi_{it}$ denoting error terms. We estimated three equations in (1) separately by ordinary least squares and clustered the standard errors by patient. In addition, we conducted subsample analyses by estimating (1) respectively for medical services listed in MBS and medicines listed in PBS.

### Patient and public involvement

Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

## RESULTS

### Descriptive analysis

We analysed 29 892 patients diagnosed with CRC at various stages between 2010 and 2019 and found that the costs associated with their treatment vary significantly by stage and over time. Stage I patients constitute 26.43% of the sample, stage II 27.52%, stage III 26.80% and stage IV 19.25%. Summary statistics from 149 817 annual claim records in table 1 show that the mean annual cost per patient for medical services (MBS) is $A1409, and for pharmaceutical services (PBS) is $A2451. Patients' OOP expenses averaged $A441 annually. The total mean direct cost for CRC treatment was $A3860 per annum, with Medicare reimbursement costs averaging at $A3420.

Table 2 provides a detailed breakdown of the mean total costs, which is a sum of MBS and PBS costs, and the two components of total costs associated with CRC treatment (OOP expenses and Medicare costs), by disease stage and year from diagnosis for the first 5 years post-diagnosis. The year immediately following a stage IV diagnosis has an average direct total cost of $A19 562, mainly driven by PBS claims, while stage I patients incur a more moderate total cost of $A4631. Costs generally decline for all stages from the first to the fifth year post-diagnosis, but the disparity in costs between the stages persists, with stage IV patients consistently incurring the highest expenses. The data also highlights that while OOP expenses are a smaller fraction of the total costs, they still pose a significant financial burden on patients, emphasising the need for a nuanced understanding of CRC treatment costs across different stages and over time.

### Factors affecting CRC costs

Table 3 presents key factors that significantly affect the average annual CRC total direct costs, OOP costs and Medicare costs, covering CRC-related MBS and PBS items. All results are after controlling for other covariates. Gender plays a crucial role, with male patients incurring

Table 1 Descriptive statistics of annual costs, out-of-pocket expenses and Medicare costs per patient in CRC treatment

| | | Min | Q1 | Median | Mean | Q3 | Max | SD |
|---|---|---|---|---|---|---|---|---|
| Annual cost | MBS | 0 | 46 | 333 | 1409 | 1037 | 62316 | 3092 |
| | PBS | 0 | 0 | 0 | 2451 | 0 | 237000 | 9830 |
| | Total | 0 | 50 | 465 | 3860 | 1771 | 243178 | 10629 |
| Annual OOP | MBS | 0 | 0 | 0 | 405 | 240 | 18627 | 1039 |
| | PBS | 0 | 0 | 0 | 36 | 0 | 4326 | 155 |
| | Total | 0 | 0 | 0 | 441 | 298 | 18793 | 1081 |
| Annual Medicare | MBS | 0 | 46 | 284 | 1004 | 800 | 46924 | 2282 |
| | PBS | 0 | 0 | 0 | 2416 | 0 | 236993 | 9760 |
| | Total | 0 | 49 | 346 | 3420 | 1305 | 242696 | 10270 |

Sample size is 149 817, which is total number of annual claim records from 2010 to 2021 for 29892 patients diagnosed with CRC in 2010–2019 in our dataset.
CRC, colorectal cancer; MBS, Medicare Benefits Schedule; OOP, out-of-pocket; PBS, Pharmaceutical Benefits Scheme.

13.5% higher direct costs, 66% higher OOP expenses and 13.6% more Medicare rebates compared with females. Age is another factor; costs increase by about 7.1% for patients aged 50–70 and decrease by 8.8% for those over 70. Socioeconomic status also affects costs: patients from higher SEIFA quintiles have significantly greater OOP and Medicare costs. Patients for whom English is a primary language see a 27.1% rise in total costs and a substantial 397.7% increase in OOP expenses. Stage IV diagnosis correlates with a 55.4% increase in total costs and a 70.1% increase in rebates; whereas, stages II and III see reduced costs and rebates.

The anatomical location of the tumour and the presence of specific mutations also impact costs. Rectal cancer patients experience about 13.7% higher costs, 72.3% higher OOP expenses and 14.1% more in rebates compared with colon cancer patients. Presenting with a tumour that does not harbour a RAS mutation (RAS wild-type) is associated with a significant cost increase—up to 794.9% in total costs, 807.8% in OOP and 858.8% in Medicare costs, which might be due to the use of epidermal growth factor receptor monoclonal antibodies (cetuximab, panitumumab). Metastasis leads to a 99.5% jump in total costs, a 301.7% increase in OOP and a 106.0% rise in rebates. These figures underline the complexity and variability in CRC treatment costs, suggesting the need for gender-specific healthcare strategies, early interventions, and consideration of various demographic and clinical factors.

Online supplemental appendix table A2 focuses on the average annual cost, OOP expenses and Medicare rebates concerning only medical services listed in MBS. Male patients and those with rectal tumours tend to have higher costs across all categories. As for age factors, people aged between 50 and 70 see a slight cost increase, and those over 70 experience a significant reduction, particularly in OOP expenses. Socioeconomic factors and language proficiency in English also contribute to elevated costs. Patients diagnosed at advanced CRC stages (III and IV) register lower medical service costs, possibly due to fewer aggressive treatments. RAS wild-type markers and metastasis significantly escalate costs. Table A2 also includes costs related to medicine in the PBS and shows similar trends regarding gender and age, but it indicates that rectal cancer patients have lower annual medicine costs. There is also a statistically significant decline in PBS costs, OOP expenses and Medicare rebates for those over 70.

When comparing online supplemental appendix table A2 to table 3, which combines both MBS and PBS data, several differences become evident. The influence of tumour location and age varies depending on whether medical or pharmaceutical services are considered. Socioeconomic factors like SEIFA quintile influence costs across all tables but are magnified in table 3, particularly for OOP expenses. The trends for CRC stage at diagnosis differ notably between the tables, especially for stage IV, suggesting that medicine costs impose a more considerable financial burden for later-stage treatments than medical services. Overall, the data suggests complex interplay between various demographic and clinical factors that influence the financial burden of CRC treatment.

To shed light on whether it is types of services or overall utilisation that drives the cost disparities across demographic subgroups, we undertook two additional analyses. First, we regressed the annual total number of different types of medical services and the total number of medical services received by patients against the same set of clinical and demographic factors and indicator variables as in the regressions in (1). Second, we performed similar regressions for the annual total number of different types of medications and the total number of medications.

Results in online supplemental appendix table A3 indicate that male patients use 1.5% more medical services than female patients; however, the diversity of services received by male and female patients is not statistically different. Male patients received 8.6% more medications, which were 1.6% more diverse than those received by female patients. Rectal cancer patients received 21.5%

**Table 2** Average total direct cost (in $A) and component MBS and PBS, out-of-pocket expenses and rebate by CRC stage at diagnosis and year post-diagnosis in the first 5 years post-diagnosis

| Year / stage | | I | II | III | IV |
|---|---|---|---|---|---|
| First year | Total cost | 4631 | 4950 | 9358 | 19562 |
| | MBS | 4107 | 4055 | 4525 | 3653 |
| | PBS | 525 | 895 | 4834 | 15909 |
| | OOP | 1432 | 1396 | 1581 | 1263 |
| | Cost to Medicare (rebate) | 3200 | 3554 | 7777 | 18299 |
| Second year | Total cost | 1390 | 1869 | 3683 | 15159 |
| | MBS | 828 | 836 | 999 | 1262 |
| | PBS | 561 | 1034 | 2684 | 13897 |
| | OOP | 243 | 235 | 296 | 421 |
| | Cost to Medicare (rebate) | 1147 | 1635 | 3386 | 14738 |
| Third year | Total cost | 1158 | 1714 | 3689 | 12766 |
| | MBS | 635 | 647 | 849 | 1349 |
| | PBS | 524 | 1067 | 2839 | 11416 |
| | OOP | 163 | 163 | 218 | 364 |
| | Cost to Medicare (rebate) | 995 | 1551 | 3470 | 12402 |
| Fourth year | Total cost | 1301 | 1638 | 3098 | 10065 |
| | MBS | 654 | 609 | 729 | 1121 |
| | PBS | 647 | 1029 | 2369 | 8944 |
| | OOP | 172 | 154 | 190 | 307 |
| | Cost to Medicare (rebate) | 1129 | 1484 | 2908 | 9758 |
| Fifth year | Total cost | 1151 | 1709 | 2566 | 8122 |
| | MBS | 634 | 625 | 696 | 1106 |
| | PBS | 517 | 1083 | 1870 | 7016 |
| | OOP | 164 | 158 | 175 | 271 |
| | Cost to Medicare (rebate) | 987 | 1551 | 2391 | 7851 |

CRC, colorectal cancer; MBS, Medicare Benefits Schedule; OOP, out-of-pocket; PBS, Pharmaceutical Benefits Scheme.

more medical services than colon cancer patients, with these services being 7.1% more diverse. Hence, the higher medical service and medication costs for male patients, and the higher medical service costs for rectal cancer patients, are driven by higher overall utilisation. Compared with colon cancer patients, the higher costs associated with rectal cancer patients may also be due to the routine use of multimodality neoadjuvant and adjuvant therapies.

Individuals aged between 51 and 70 experienced a 6.0% increase in the number of different types of medical services and a 7.1% increase in overall utilisation, while the diversity of medications decreased by 5.5% and the total number of medications decreased by 9.9%. For those older than 70, there was an 11.0% increase in the number of different types of medical services and a 10.2% increase in overall utilisation, with a 27.4% decrease in the diversity of medications and a 45.2% decrease in the total number of medications. These cost differences in medical services and medications between age groups therefore seem to be influenced by both the diversity of services and overall utilisation. Similarly, estimates in Table A3 suggest that elevated medical service costs related to socioeconomic factors and English proficiency are driven by both the variety of services and overall utilisation.

Patients with stage II colorectal cancer experienced a 3.5% decrease in the diversity of medical services but a 4.6% increase in overall utilisation, with a 22.2% increase in the total number of medications. Those with stage III cancer saw an 11.2% decrease in the diversity of medical services and a 5.3% decrease in overall utilisation but a 10.8% increase in the diversity of medications and a 29.7% increase in the total number of medications. Patients with stage IV cancer had a 15.5% decrease in the diversity of medical services with no significant effect on overall utilisation, while the diversity of medications increased by 32.1% and the total number of medications increased by 49.2%. Lower medical service costs for patients with advanced CRC stages seem to be due to fewer types of services, while higher medication costs are driven by increased overall utilisation.

Individuals with RAS wild-type markers had a 19.6% increase in the diversity of medical services, a 70.3% increase in overall utilisation, a 37.0% increase in the diversity of medications and a 77.4% increase in the total number of medications. Patients with metastasis experienced a 16.0% increase in the diversity of medical services, a 35.7% increase in overall utilisation, a 44.3% increase in the diversity of medications and an 82.4% increase in the total number of medications. Elevated medical service and medication costs associated with RAS wild-type markers and metastasis are significantly influenced by both the diversity of services received and overall utilisation, with overall utilisation playing a notably larger role.

It is important to highlight that although our additional analyses focus on the diversity of services and their overall usage, cost disparities may also be significantly influenced by variations in the intensity of usage for each individual service type. This highlights the need for future research to further disentangle the underlying factors contributing to increased costs for certain subgroups.

## DISCUSSION

### The context of existing studies

Understanding the economic implications of CRC treatment is crucial for healthcare policymakers, practitioners and researchers to understand the financial burden on the healthcare system and to optimise resource allocation for efficient care delivery.

Table 3 Estimated marginal effects on average annual total direct cost, OOP and rebate per patient

| | Total cost | | | OOP | | | Rebate | | |
|---|---|---|---|---|---|---|---|---|---|
| | M.E. | | P value | M.E. | | P value | M.E. | | P value |
| Male | 13.5% | § | 0.000 | 66.0% | § | 0.000 | 13.6% | § | 0.000 |
| (SE) | (0.014) | | | (0.075) | | | (0.013) | | |
| Rectal (vs colon) | 13.7% | § | 0.000 | 72.3% | § | 0.000 | 14.1% | § | 0.000 |
| (SE) | (0.016) | | | (0.084) | | | (0.015) | | |
| Age (vs age ≤50) | | | | | | | | | |
| Age ≤70 and age >50 | 7.1% | ‡ | 0.006 | −38.9% | § | 0.000 | 8.9% | § | 0.000 |
| (SE) | (0.025) | | | (0.112) | | | (0.024) | | |
| Age >70 | −8.8% | § | 0.000 | −79.8% | § | 0.000 | −6.0% | ‡ | 0.009 |
| (SE) | (0.025) | | | (0.116) | | | (0.024) | | |
| Born in Australia | 9.4% | § | 0.001 | 134.8% | § | 0.000 | 8.2% | ‡ | 0.005 |
| (SE) | (0.026) | | | (0.131) | | | (0.025) | | |
| SEIFA quintile (vs first) | | | | | | | | | |
| Second | 14.4% | § | 0.000 | 230.1% | § | 0.000 | 10.8% | § | 0.000 |
| (SE) | (0.022) | | | (0.130) | | | (0.021) | | |
| Third | 28.2% | § | 0.000 | 907.1% | § | 0.000 | 19.2% | § | 0.000 |
| (SE) | (0.022) | | | (0.126) | | | (0.021) | | |
| Fourth | 41.2% | § | 0.000 | 1931.3% | § | 0.000 | 27.3% | § | 0.000 |
| (SE) | (0.022) | | | (0.123) | | | (0.021) | | |
| Fifth | 72.8% | § | 0.000 | 6927.8% | § | 0.000 | 47.1% | § | 0.000 |
| (SE) | (0.022) | | | (0.119) | | | (0.021) | | |
| English first language | 27.1% | § | 0.000 | 397.7% | § | 0.000 | 22.3% | § | 0.000 |
| (SE) | (0.028) | | | (0.149) | | | (0.026) | | |
| CRC stage (vs I) | | | | | | | | | |
| II | −5.9% | § | 0.001 | −3.1% | | 0.771 | −3.2% | * | 0.041 |
| (SE) | (0.018) | | | (0.109) | | | (0.016) | | |
| III | −25.1% | § | 0.000 | 5.5% | | 0.683 | −22.7% | § | 0.000 |
| (SE) | (0.027) | | | (0.131) | | | (0.026) | | |
| IV | 55.4% | § | 0.000 | 30.3% | † | 0.060 | 70.1% | § | 0.000 |
| (SE) | (0.036) | | | (0.141) | | | (0.036) | | |
| RAS wild-type | 794.9% | § | 0.000 | 807.8% | § | 0.000 | 858.8% | § | 0.000 |
| (SE) | (0.033) | | | (0.092) | | | (0.033) | | |
| Metastasis | 99.5% | § | 0.000 | 301.7% | § | 0.000 | 106.0% | § | 0.000 |
| (SE) | (0.024) | | | (0.114) | | | (0.023) | | |

Robust standard errors shown in parentheses are obtained via clustering by patient. Also included in all regression are 9 diagnosis year indicators and 11 year-post-diagnosis indicators.
*5%.
†10%.
‡1%.
§0.1%.
CRC, colorectal cancer; OOP, out-of-pocket; SEIFA, Socio-Economic Indexes for Areas.

In the USA, studies like those by Karaca-Mandic *et al*[18] and Chastek *et al*[8] have investigated these financial implications, identifying increased costs following the introduction of new treatment regimens and considerable differences in healthcare costs based on the stage of CRC at diagnosis (The expenditures defined in Karaca-Mandic *et al*[13] reflect total annual payments made by each enrollee (copayments, deductibles, excluded expenses) and by all third-party payers (primary and secondary coverage, net of negotiated discounts). The expenditures in Chastek *et al*[8] were healthcare costs identified from claim records from a large US health insurance database affiliated with

Optum, which included total, medical, drug therapy, chemotherapy and biologic therapy costs.). Meanwhile, Lakdawalla *et al*[19] proposed a nuanced concept of the 'quality-adjusted cost of care,' which offsets the rise in drug costs by considering improvements in health. They posited that patients undergoing first-line (rather than second or third) treatment could potentially have derived greater benefit had they been able to access innovative therapies sooner (referring to lengthy approval time). Paramore *et al*[20] highlighted the additional financial burden associated with metastatic colorectal cancer (mCRC), illustrating the cost implications of advanced disease stages.

European studies, like those by Henderson *et al*[21] and Corral *et al*,[9] have emphasised the variability in costs between countries and across disease stages, attributing a significant proportion of the total economic cost to non-healthcare costs such as loss of productivity. Furthermore, Tilson *et al*[22] focused on estimating the lifetime cost of CRC treatment in Ireland, underscoring the necessity for cost-effective management and treatment strategies.

Although there is limited literature on the costs of CRC in Australia, studies by Goldsbury *et al*,[5 13] Carter *et al*[23] and Thompson *et al*[24] have offered insights on a range of factors that influence treatment costs, including the site and stage of cancer, the type of treatment modality, and patient demographics. These studies highlight the role of systemic therapies and surgical interventions in escalating costs associated with CRC. Additionally, research by Lal *et al*,[14] Beckmann *et al*[25] and Yu *et al*[26] has shown that socioeconomic determinants significantly impact healthcare expenditure for CRC, with more advantaged groups having higher utilisation of palliative healthcare services.

Reviews such as those by Yabroff, Borowski, and Lipscomb[12] and Degeling *et al*[27] have critically assessed existing literature and models, revealing considerable heterogeneity in cost estimation methodologies and structural uncertainty in model-based cost-effectiveness analyses. These findings underscore the need for standardised methodologies in future research.

In summary, while CRC has a significant economic impact with various influencing factors, gaps remain in the literature concerning a comprehensive examination of how both clinical and socioeconomic factors affect CRC treatment costs in specific regions and countries. These gaps, along with the noted variability in methodologies, highlight the need for further research and standardisation in cost estimation approaches. It is also important to consider the quality of care and socioeconomic disparities in healthcare expenditure and access.

### Implications of our findings

Our results indicate that CRC treatment costs vary significantly depending on the stage of diagnosis, patient demographics, and other factors such as anatomical location of the tumour and presence or absence of specific mutations. In the immediate year following diagnosis, costs notably escalate with advancing cancer stage. Male patients incur higher costs compared with females, and older patients (50–70) have increased costs compared with younger and very elderly patients (>70).

The study reveals a wide disparity in OOP expenses and Medicare reimbursement among different groups, drawing attention to issues surrounding healthcare equality. For example, patients from higher socioeconomic backgrounds and those speaking English as a primary language tend to have higher treatment costs and OOP expenses, potentially highlighting healthcare inequalities. Several possible reasons could account for these observations. Higher-income individuals may opt for private healthcare services, which are often more costly. They may also be more proactive about seeking care and might undergo more intensive diagnostic testing and follow-up care or pursue more lines of therapy, leading to higher costs. Higher costs associated with English as a primary language, as opposed to non-native speakers, might hint at potential language barriers leading to non-native speakers and immigrants using healthcare services less frequently due to language barriers, lack of familiarity with the healthcare system, or fear of discrimination. It could also be that patients who speak English as a primary language may be more proactive about seeking a variety of treatments or second opinions, which can result in higher costs. These call for a reflection on if wealth dictates the equality of care, and whether healthcare equality is truly being achieved in a culturally diverse society such as Australia.[28]

The cost implications tied with metastasis and diagnosis at higher stages suggest a pressing need for policies that prioritise early detection and intervention. Programmes that increase awareness, improve access to screening, and facilitate early diagnosis can help prevent disease stage progression, for example, metastasis, which can be both life-saving and cost-reducing in the long term. The study also highlights the need for targeted care for rectal cancer patients, who experience higher costs compared with those with colon conditions.

This study has several limitations that should be acknowledged. First, the scope of our research focuses primarily on evaluating the influence of various clinical and socioeconomic factors on Medicare and patient costs related to services covered by Medicare. It does not include costs for services not covered by Medicare. As such, while the findings are valuable for informing public policy, they may not be fully applicable to the complete landscape of CRC treatment costs. Specifically, our data does not encompass inpatient hospital costs (eg, accommodation, surgical charges not included in our set of MBS items) or additional fees charged by private providers above Medicare schedule fees. Additionally, our study relies on administrative data that lacks information on key lifestyle factors like smoking, exercise and dietary habits. These factors are not only pertinent to CRC risk but can also significantly impact treatment outcomes. Therefore, the absence of these variables could affect the comprehensiveness and generalisability of our results.

Our findings underscore the need for policies aimed at reducing these disparities, such as offering increased financial support or subsidised care for those in lower socioeconomic brackets.[29 30] Enhanced support structures are needed for CRC patients diagnosed of stage IV, given their unique cost and reimbursement dynamics. These could include a greater focus on palliative care, access to experimental treatments[31] or other specialised programmes. Gender-sensitive approaches in healthcare delivery and financial support mechanisms could also be beneficial, as the results indicate that male patients generally incur higher costs. Lastly, this study highlights potential language and cultural barriers faced by non-native English speakers and immigrants, who tend to have lower costs and rebate. As such, implementing strategies to enhance healthcare access and outcomes for these populations, such as translation services and culturally sensitive care, could be effective.[29]

In sum, our findings imply that a targeted strategy for CRC management should encompass timely detection, enhanced support for late-stage patients, and the assurance of socioeconomic parity in treatment access and options. Additionally, this study sheds light on the potential advantage of adopting gender-responsive healthcare practices and formulating tactics to bridge linguistic and cultural divides. Future research can build on these findings to further dissect the economic aspects of CRC treatment and explore potential strategies for cost optimisation and enhanced patient support.

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