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# BMJ Open

## Factors driving computed tomography utilisation in tertiary hospitals: A decomposition analysis using linked administrative data in Western Australia

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3 1 **Factors driving computed tomography utilisation in tertiary hospitals: A decomposition**  
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6 2 **analysis using linked administrative data in Western Australia**  
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3 34 **Abstract**  
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6 35 **Objectives:** This study aimed to examine the contribution of demographic and clinical  
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8 36 characteristics to the changing use of CT among people admitted to tertiary hospitals in Western  
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10 37 Australia (WA).

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13 38 **Design:** An observational cross-sectional study from 2003 to 2015

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16 39 **Setting:** Linked administrative health service data at individual level from WA

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18  
19 40 **Participants:** A total of 2,375,787 tertiary hospital admissions of people aged 18 years or older

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22 41 **Main outcome measure:** Number of CT's performed during tertiary hospital admission.

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25 42 **Methods:** A multivariable decomposition for nonlinear response model was used to decompose the  
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27 43 increasing use of CT into variation of (i) the distribution and (ii) the effect of the observed  
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29 44 characteristics.

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31  
32 45 **Results:** The rate of CT scanning increased by 112 CT scans per 1000 tertiary admissions between the  
33  
34 46 two periods. The variation in distribution of the observed demographic and clinical factors explained  
35  
36 47 nearly two thirds (62.7%) of the growth of CT use in which unplanned admissions accounted for the  
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38 48 largest proportion (50%). However, when the analysis is restricted to unplanned admissions, the  
39  
40 49 variation in distribution of the observed factors only explained 17% of the growth of CT use and the  
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42 50 rest was explained by change in the likelihood of having CT scan. Interestingly, compared with the  
43  
44 51 past period, the likelihood of having CT scan in population such as young adults (-2.8%), people living  
45  
46 52 in the rural/remote areas (-0.8%) and people transferred from secondary hospitals (-0.8%) were  
47  
48 53 significant lower in the recent period.

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51 54 **Conclusions:** Our study highlights a potential improvement in practice towards reducing medical  
52  
53 55 radiation exposure in certain high risk population. Given change in the likelihood of having CT scan  
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55 56 explained for a major component of the growth in CT use, this warrants more in-depth investigations  
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3 57 in clinical practices to better inform health policies promoting appropriate use of diagnostic imaging  
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5 58 tests.  
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8 **59 Strengths and limitations of this study**  
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- 10 ➤ 60 This study utilised a large linked administrative data over the period of 13 years that allowed  
11  
12 to measure the contribution of changes in demographic and clinical characteristics to the  
13 61  
14 changing use of CT.  
15 62  
16 ➤ 63 With a rich source of individual level data, this study identified a wide range of demographic  
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18 and clinical factors driving the use of CT scan in tertiary hospitals.  
19 64  
20 ➤ 65 Since the decomposition analysis methods only quantified the contribution of observed  
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22 factors, contribution of any unobserved factors to the change of CT use was summed in the  
23 66  
24 constant coefficient.  
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26 ➤ 68 Our data did not fully capture the use of CT in all secondary hospitals, hence, this study was  
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28 limited to assess the factors driving the use of CT scan in tertiary hospitals.  
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## 71 **Introduction**

72 Computed tomography (CT) is one of the most important technical developments in medicine and is  
73 now an essential part of clinical practice (1, 2). In Australia, CT accounted for 13% of diagnostic  
74 imaging tests with an average of 134 scans per 1000 people in 2017/18 (3, 4). It is estimated that  
75 diagnostic imaging tests increased the annual effective ionising radiation dose on the Australian  
76 population by 50% (5). In acknowledgement of the relatively high radiation burden of diagnostic  
77 imaging, Australia introduced Diagnostic reference levels (DRL) in 2011 providing a benchmark to  
78 facilitate monitoring and comparison of radiation dose between facilities (6).

79 Despite the advanced technology leading to significant contribution in healthcare, its increasing use  
80 has raised a concern about inappropriate use. Approximately one third of diagnostic imaging tests  
81 are estimated to be unnecessary or inappropriate, with the potential to do more harm than good  
82 and represent a waste of health care resources (7, 8). In the case of CT the potential harm includes  
83 exposure to ionising radiation and the associated risk of cancer to population. A previous study  
84 found a high rate of inappropriate CT among older patients and those with multi-morbidity (9).

85 In response to concerns of inappropriate utilisation of the advanced diagnostic technique, since  
86 early 2000, the Royal Australian and New Zealand College of Radiologists (RANZCR) have provided  
87 the standards of practice for clinical radiology (10). In Western Australia (WA), Diagnostic Imaging  
88 Pathways has been deployed to promote appropriate use of imaging (11, 12). Most recently, in 2015  
89 NPS MedicineWise launched the Australian "Choosing Wisely" campaigns promoting discussion on  
90 reducing low value care (13), changing health care provider behaviour and increasing patient  
91 knowledge. The overall intention is to improve patient safety and efficiency in health service  
92 utilisation (13).

93 While substantial effort is under way to promote appropriate use of imaging tests, current data  
94 reporting variation in potentially avoidable diagnostic imaging tests, particularly for CT over the last  
95 decade are limited (9, 14, 15). Recent studies mainly focus on examining the prevalence of low value

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3 96 care (16), the early trend of procedure uptake in hospital settings (17) and selected spinal imaging  
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5 97 (18) following Choosing Wisely campaigns. Therefore, better understanding of changes in the use of  
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7 98 CT scanning over the past decade and demographic and clinical factors driving the change in the use  
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9 99 of CT are necessary to support monitoring the use of CT scanning and to guide future research and  
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11 100 public health interventions. The aim of this study is to use decomposition analysis to examine factors  
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13 101 driving changes in CT use between two periods of time in tertiary hospitals in WA: recent (2013 to  
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15 102 2015) and past (2003 to 2005).

### 103 **Methods**

104 We conducted a retrospective observational cohort study of CT use in WA between 2003 and 2015  
105 using linked administrative health data at the individual patient level. Reporting follows the  
106 Reporting of studies Conducted using Observational Routinely-collected health Data (RECORD)  
107 guidelines (19).

### 108 **Data sources**

109 The data sources included three datasets:

- 110 (i) WA Hospital Morbidity Data system (January 2003- May 2016) providing information on  
111 diagnosis, date of admission and discharge from all hospitals in WA, and basic socio-  
112 demographic and clinical characteristics.
- 113 (ii) WA Emergency Department (ED) presentation data (January 2003- December 2016) providing  
114 details of presentation time and date, presentation type, triage code, major diagnostic group  
115 and basic socio-demographic characteristics.
- 116 (iii) WA Picture archiving and communication system (PACS) data (January 2003 to May 2016)  
117 providing documentation on all computed tomography (CT) scans conducted in tertiary  
118 including date of the scan, and the CT protocols used. All the datasets were linked using  
119 probabilistic matching algorithms with a level of data accuracy up to 99.9% (20, 21).



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3 120 Details of data linkage process is presented in the website of Western Australia Data Linkage  
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5 121 (<https://www.datalinkage-wa.org.au/dlb-services/linkage/>).

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8 122 **Study population**

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10 123 The study population consisted of all hospital admissions in the three tertiary hospitals in WA  
11  
12 124 between 2003 and 2015 inclusive, for people aged 18 years and older. The study population was  
13  
14 125 then constructed into two study periods; past period (2003-2005) and recent period (2013-2015). To  
15  
16 126 avoid over-counting hospital admissions, for example where a patient was transferred between  
17  
18 127 hospitals, consecutive tertiary hospital admission records for an individual were aggregated into a  
19  
20 128 single hospital admission where admission or discharge dates were nested or overlapping, or where  
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22 129 an admission date was within one day of the discharge date. A tertiary hospital admission was  
23  
24 130 counted from the first date of admission in a tertiary hospital—or where applicable—the date of a  
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26 131 prior associated tertiary ED presentation so long as it resulted in an admission, to the last discharge  
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28 132 date in tertiary hospitals.

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33 133 **Outcome measures**

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35 134 The outcome measure of this study was the number of CT scans performed within a tertiary hospital  
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37 135 admission. The number of CT scans was counted from the first day admitted to a tertiary  
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39 136 hospital/presentation to a tertiary ED until the last date of discharge for that admission. To avoid  
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41 137 over-counting the use of CT, multiple CT records with the same day and same anatomic areas were  
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43 138 collapsed into one CT event (22).

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47 139 **Independent measures**

48  
49 140 This study measured basic demographic and socioeconomic characteristics including age (18-44, 45-  
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51 141 64, 65-74, and 75+ years), sex, indigenous status, residential remoteness classified according to  
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53 142 Accessibility Remoteness of Australia index (ARIA) (23) (major cities, inner regional areas, outer  
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55 143 regional areas, remote and very remote), and quintiles of the Census-specific Socio-economic  
56  
57 144 Indexes for Areas (SEIFA) index of relative socioeconomic disadvantage (24) (least disadvantage, less  
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59 145 disadvantage, moderate disadvantage, high disadvantage, and highest disadvantage).

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3 146 Clinical characteristics included major clinical diagnostic groups and the number of morbidities.  
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5 147 Major clinical diagnostic groups included mental and behavioural disorders, circulatory system,  
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7 148 digestive system, endocrine, nutritional and metabolic diseases, musculoskeletal system, respiratory  
8  
9 149 system, injuries, and neoplasms. The conditions were identified in the principal diagnostic field of  
10  
11 150 the hospital morbidity data record using ICD-AM-10 (the International Statistical Classification of  
12  
13 151 Diseases and Related Health Problems, 10<sup>th</sup> Revision, Australian Modification). Multimorbidity was  
14  
15 152 ascertained using the Multipurpose Australian Comorbidity Scoring system (25) using ICD-AM-10  
16  
17 153 across all diagnostic fields and was classified into 0-1, 2-5 and 6+ comorbidities. In addition, an  
18  
19 154 admission was classified as having had a surgical procedure where the principal procedure field  
20  
21 155 included one of the 20 most common surgical procedure as per ACHI codes (the Australian  
22  
23 156 classification of health intervention) (26). Other independent measures included funding source  
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25 157 (public or private), admission type (elective or unplanned admission) and admission with/without a  
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27 158 transfer from secondary hospitals.  
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### 33 **Statistical analysis**

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36 160 Descriptive analysis was conducted to examine the distribution of socio-demographic and clinical  
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38 161 characteristics of the study population over two study periods; past period (2003-2005) and recent  
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40 162 period (2013-2015) as well as the whole study population (2003-2015). Multivariable decomposition  
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42 163 for nonlinear response models, an extension of Oaxaca-Blinder decomposition analysis (27), was  
43  
44 164 conducted to decompose the differential rate of CT use between the two study periods into  
45  
46 165 subcomponents attributable to observed factors. Using this method, the differences in the number  
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48 166 of CT scans per admission between the two study periods were broken down or “decomposed” into  
49  
50 167 two components; endowment and effect:  
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54 168 (1) The Endowment component depicts how much of the difference in the rate of CT use  
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56 169 (between the past and recent period) can be attributed to change in the distribution of all  
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58 170 observed factors such as socio-demographic and clinical characteristic in total and at the  
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3 171 individual factor level; the coefficient with 95% confidence interval in each factor quantifies the  
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5 172 contribution of the specific factor and is expressed in percentage of its contribution.  
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8 173 (2) The Effect component describes how much of the difference in the rate of CT use (between  
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10 174 the past and recent period) can be attributed to a change in the likelihood of having CT in total  
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12 175 and for each of the observed characteristics. The coefficient with 95% confidence interval in each  
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14 176 factor indicates the contribution of the specific factor.  
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18 177 The advantage of the multivariable decomposition approach is that it can account for variation due  
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20 178 to a change in the order of variables entering the model and provide standard errors to indicate a  
21  
22 179 significant contribution of the observed characteristics (28). We conducted decomposition analyses  
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24 180 for all tertiary admissions and for unplanned tertiary admissions separately using STATA SE 14 (27).  
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## 28 181 **Results**

### 29 182 **Characteristics of tertiary admissions with CT scan by study periods**

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32 183 Of a total of 2,375,787 tertiary hospital admissions over the 12 year period (2003-2015), 303,439  
33  
34 184 admissions (12.8%) had at least one CT scan. The proportion of admissions incorporating CT  
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36 185 increased from 8.9% in the past period (2003-2005) to 16.6% in the recent period (2013-2015) (Table  
37  
38 186 1). Overall, there was a small change in the distribution of both demographic and clinical  
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40 187 characteristics among admissions that included CT between the two study periods. For example, the  
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42 188 proportion of the patients who had a CT scan and were in the older age group (75+ years) increased  
43  
44 189 from 30.3% to 32.7% and people living in major cities with CT increased from 82.5% to 88.3%  
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46 190 between the past and recent period. Similarly within clinical characteristics, multi-morbidity (6+  
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48 191 morbidities) accounted for 27.8% of admissions with CT in the past period compared to 28.8% in the  
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50 192 recent period. Among major diagnostic groups in the past period, injuries, circulatory system, cancer  
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52 193 and digestive system accounted for 15.5%, 15.2%, 11.7% and 10.9% of admissions with CT,  
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54 194 compared to 18.8%, 13.1%, 7.9% and 11.2% in recent period. For other characteristics, admission  
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3 195 with CT in the recent period had a higher proportion of unplanned admission (90.1% vs. 86.8%) and  
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5 196 private funding sources (21.0% vs. 7.7%) compared with the past period.  
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### 8 197 **Decomposition results for the use of CT over the two periods**

9  
10 198 The results of the decomposition analysis of the difference in average number of CT scans between  
11  
12 199 the two periods for all tertiary admissions and unplanned at the aggregated level are presented in  
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14 200 Figure 1 (detail in Appendix- Table 1A-B). The difference in number of CT scans between two periods  
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16 201 was 112 scans per 1000 admissions for all tertiary admission and 117 scans per 1000 admissions for  
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18 202 unplanned tertiary admissions. While the change in the number of CT scans per admission across the  
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20 203 two analyses were not substantially different, a marked difference in the results of the  
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22 204 decomposition analysis was observed. Figure 1 shows that 62.7% of the difference in CT use for all  
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24 205 tertiary admission was explained by variation in the distribution of all observed characteristics of  
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26 206 which unplanned admissions were accounting for 50%. The rest of the difference in CT usage was  
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28 207 attributable to variation in the likelihood of having CT in each observed characteristics and  
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30 208 unobserved factors (constant coefficient).  
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35 209 In contrast, when the analysis was restricted to unplanned admissions, the variation in the  
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37 210 distribution of the observed characteristics explained only 17% of the difference in CT use between  
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39 211 two periods while 82.7% was due to variation in the likelihood of having CT according to observed  
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41 212 and unobserved factors included in the model.  
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### 45 213 ***Details of decomposition analysis for all tertiary admissions***

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48 214 Figure 2 presents decomposition analysis in details of all observed demographic and clinical  
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50 215 characteristics. Overall, changes in the distribution of the demographic characteristics including sex,  
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52 216 indigenous status, age, SEIFA and ARIA explained only -0.8% of the change in CT use. Change in the  
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54 217 distribution of the clinical characteristics including major principal diagnoses and groups of  
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56 218 morbidities accounted for 12.4% of the change in CT use. Half of this change (6.1%) was attributable  
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58 219 to multi-morbidity (6 or more morbidities) and 4.7% was due to injuries.  
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3 220 The effect components of the observed demographic characteristics summed to 6.8% while the  
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5 221 observed clinical characteristics was -2.6%. Interestingly, the negative coefficient in the young age  
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7 222 group suggests that in the most recent time period, the likelihood of having a CT scan for those with  
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9 223 young age was significantly lower than in the past period contributing -2.8% to the difference in the  
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11 224 number of CT scan per admission between the two periods. In addition, the likelihood of having CT  
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13 225 was higher for those identified as living in major cities in the recent period compared to the past  
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15 226 period, and lower for people from remote/very remote areas in the recent period compared to the  
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17 227 past period. The contribution of each component to the difference in the number of CT's per  
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19 228 admission between the two periods was 5.5% (p-value=0.02) and -0.8% (p-values<0.001),  
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21 229 respectively.

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26 230 For clinical characteristics, the results indicated a lower likelihood of having CT scanning during a  
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28 231 tertiary admission in the recent period than in the past period for all the diagnostic groups, with the  
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30 232 exception of those admitted for injuries and endocrine disorders. The increase in patients with  
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32 233 multi-morbidities (2-5 comorbidities) contributed 3.2% to the difference between the two periods.  
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36 234 For other factors, the likelihood of having a CT scan following transfer from a secondary hospital in  
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38 235 the recent period was significantly lower than in the past period, contributing -0.8% to the  
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40 236 difference between the two periods. A lower likelihood of having a CT scan in the recent period  
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42 237 compared with the past period for unplanned admission contributed -4.9% to the difference in CT  
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44 238 use between the two periods. Unobserved factors captured in the constant coefficient contributed  
45  
46 239 to 41.8% of the difference in CT usage between the two periods.

#### 240 ***Details of decomposition analysis for unplanned tertiary admissions***

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52 241 Figure 3 presents the results of decomposition analysis for unplanned admissions. Similar to the  
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54 242 results in all tertiary admissions, the results for unplanned admission indicate that a substantial  
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56 243 proportion of variation in CT use between the two study periods (10.0%) was attributable to the  
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58 244 observed clinical characteristics including multimorbidity and major diagnostic groups. However,  
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3 245 variation in the distribution of the observed demographic characteristics such as age, sex and  
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5 246 accessibility between two periods only explained a total of -0.5% the difference in CT use.  
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8 247 For the specific effect component, a similar finding to all tertiary admission was observed in  
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10 248 unplanned admissions. Specifically, a negative coefficient was also observed in young age groups  
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12 249 (18-44 years) that suggests a lower likelihood of having CT scan in this age group in the recent period  
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14 250 compared with the past. Likewise, a lower likelihood of having CT scan in the recent period  
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16 251 compared with the past period was observed among admissions with condition such as circulatory,  
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18 252 cancer, and respiratory; this accounted for -3.8%, -3.7%, and -2.7% of the difference between CT  
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20 253 use. The likelihood of having a CT scan after transfer from a secondary hospital in the recent period  
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22 254 was lower than in the past, contributing -7.5% to the difference in the number of CT scans between  
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24 255 the two periods.  
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## 29 256 **Discussion**

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32 257 This is the first study to examine the contribution of demographic and clinical characteristics to  
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34 258 changes in the rate of CT scanning in tertiary hospitals using multivariable decomposition analysis of  
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36 259 linked health administrative data over an extended period of time. We found that nearly two thirds  
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38 260 of the increase in the use of CT was attributable to changes in the distribution of observed  
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40 261 characteristics, with changes in proportion of unplanned admissions accounting for the largest  
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42 262 component. However when the analysis was restricted to unplanned admissions, changes in  
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44 263 distribution of the observed characteristics only explained about a fifth of the difference in CT usage  
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46 264 and the rest was explained by the effect component. In both decomposition analyses, clinical  
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48 265 characteristics (12.4% in all admissions and 10% in unplanned admissions) including major diagnostic  
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50 266 groups and comorbidities rather than demographic characteristics contributed substantially to  
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52 267 explain the variation in CT use between the two periods. Interestingly, our study observed a lower  
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54 268 likelihood of having a CT scan in the recent period (2013-2015) compared with the past period  
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56 269 (2003-2005) in two subgroups: young adults, which may reflect a movement towards minimising  
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3 270 medical radiation exposure in the high risk population, and admissions transferred from secondary  
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5 271 hospitals, reflecting either a reduction in inappropriate repeat imaging tests or greater access to CT  
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8 272 in non-tertiary hospitals.  
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10 273 A recent study examined factors driving the increasing use of CT scan in Australia with a focus on the  
11  
12 274 use of CT outside of public hospital settings (29). Although the study also used the decomposition  
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15 275 analysis approach, the only endowment component captured in this study was changes in the  
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17 276 population age structure; the rest of the difference in CT use was captured in the number of CT  
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19 277 scans per capita. The study found that a change in the number of CT scans per capita, interpreted as  
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21 278 a “scope shift”, rather than changes in the population age structure accounted for a major  
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23  
24 279 component in the change of CT use outside hospital settings over the period 1993 to 2013(29). The  
25  
26 280 previous study used changes in age structure as a marker of changes in need (eg an ageing  
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28 281 population), which had been postulated as the reason for increasing CT scanning rates. The finding  
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30 282 that changes in the age structure was responsible for only a small proportion of the rate of CT use  
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33 283 suggested that “scope shift” (i.e. changes in the practice of CT) was driving the rate of use. However,  
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35 284 the previous study was unable to determine what form these practice changes took. By using  
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37 285 multivariable decomposition analysis, our study provides a more comprehensive picture of the  
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39 286 contribution of demographic, clinical and other observed factors driving the change in CT use in the  
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42 287 hospital setting. This is because our analysis was able to differentiate the influence of changes in the  
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44 288 distribution (endowment component) from changes in the likelihood of CT (effect component)  
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46 289 across a large range of observed factors. While the setting was different, in line with the previous  
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48 290 study, we found a minimal contribution of changes in demographic characteristics on the variation in  
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51 291 the use of CT in tertiary hospitals.  
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53 292 Our study found that while many observed factors drive the increase of CT use, the change in the  
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56 293 likelihood of having CT scan in the young age group and in those with admissions transferred from  
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58 294 secondary hospitals (once the variation in the distribution of these factors was accounted for)  
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3 295 reduced the use of CT in the recent period compared with the past period. These finding are  
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5 296 encouraging as they confirm a reduction in two groups where there has been concern regarding  
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7 297 inappropriate imaging. The results coincide with the goals of education campaigns to raise provider  
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9 298 awareness of the risk of ionising radiation, especially among children and young adults (30-32). Since  
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11 299 children and young adults are more sensitive and have more years to develop radiation-induced  
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13 300 cancer (30, 31), radiologists have become more cautious and may have taken care to minimise  
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15 301 unnecessary CT scanning.  
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18  
19 302 Despite challenges due to the vast geographical spread of Australia, over the last 15 years diagnostic  
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21 303 imaging services have become more accessible to patients in both major cities and rural areas within  
22  
23 304 a timely and a reasonable distance from their home (31). A report in 2012 shows that more than  
24  
25 305 90% of Australians can get access to a comprehensive diagnostic imaging facility within a distance of  
26  
27 306 100km from their residential areas (31) and up to 80% of patients have access to a CT machine  
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29 307 within 10 km (31). Between 2003 and 2018, Australia increased the rate of CT equipment per head  
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31 308 of population from 40.6 to 67 per million (33, 34). The government also provided a diagnostic  
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33 309 imaging bulk billing incentive from November 2009 that increased the accessibility to the service  
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35 310 through improving patient affordability. In addition, the government endorsed the diagnostic  
36  
37 311 imaging review reform package in 2011 and implemented it between 2011 and 2016, funded  
38  
39 312 through the Medicare Benefits Schedule. One of the package objectives was to ensure accessibility  
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41 313 to quality diagnostic imaging services for people in rural and remote areas. In addition, the package  
42  
43 314 also aimed to promote for effective communication between practitioners and imaging service to  
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45 315 ensure appropriate imaging (31). The increasing availability and accessibility of diagnostic imaging, in  
46  
47 316 particular to CT scanners, raised concerns of potential overuse of CT scans increasing radiation  
48  
49 317 exposure to patients and contributing additional costs to the health care system (15). However, we  
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51 318 found that the likelihood of having CT scan in tertiary hospitals for people living in remote and very  
52  
53 319 remote areas in the recent period was less than in the past period. Although the magnitude of the  
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55 320 variation was small, it accounts for significantly lower use of CT scan in tertiary hospitals. Likewise,  
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3 321 the rate of CT scan among admissions transferred from the secondary hospital in the recent period  
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5 322 was also less than in the past period. This would be consistent with government efforts to ensure  
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7 323 accessibility of diagnostic imaging service in rural and remote areas as well as improved information  
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9 324 transfer between hospitals. Previous studies have highlighted the important role of image sharing  
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11 325 technology in improving provider access and avoiding duplication of investigations (35-37). However,  
12  
13 326 a recent study found that repeat CT scanning is relatively common for patients already imaged prior  
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15 327 to transfer to a tertiary hospital, although there was a valid clinical reason for repeat scanning in the  
16  
17 328 majority of cases (15). Despite signs of improvement in our study, further detailed exploration is  
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19 329 required to establish the proportion of avoidable repeat scans and therefore the potential benefit in  
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21 330 terms of reduced radiation exposure and costs.

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25  
26 331 This study has a number of limitations, largely due to the nature of linked administrative data. This  
27  
28 332 study only decomposed the difference in CT use between the two study periods based on the  
29  
30 333 available observed characteristics available in the administrative data. Thus, the contribution of  
31  
32 334 unobserved factors was not addressed in this study, although they are captured in the constant  
33  
34 335 value. This study only captured the use of CT in tertiary hospitals because we did not have  
35  
36 336 comprehensive data on CT use in non-tertiary settings, limiting our ability to determine whether the  
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38 337 lower likelihood of having CT in the recent period in some subgroups was due to changes in practice  
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40 338 or increasing accessibility of CT in other health care settings. While the linked administrative data  
41  
42 339 can comprehensively capture use of health services over time without loss to follow up, information  
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44 340 about clinical information is limited to relatively high-level diagnostic codes recorded in the HMDS.  
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46 341 Therefore, our study cannot provide information about the proportion of scans that were justified.

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50  
51 342 In conclusion, the use of CT in tertiary hospitals increased between the two study periods and this is  
52  
53 343 in keeping with international trends. The majority of the difference was explained by variation in the  
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55 344 distribution of the observed characteristics, particularly unplanned admissions and the clinical  
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57 345 characteristics of presenting patients. When the data were restricted to unplanned admissions,  
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3 346 changes in the likelihood of scanning were the major drivers of CT use, with the largest component  
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5 347 of this relating to unobserved factors. In both results, clinical characteristics appear to be substantial  
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7 348 component driving the growth of CT usage in tertiary hospital settings while the role of demographic  
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9 349 characteristics was minimal. Our study also highlights a potential improvement in practice towards  
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11 350 reducing medial radiation exposure through a decrease CTs in subpopulations such as young adults  
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13 351 and in those admitted via transfer admission from other hospitals. While the finding is limited to  
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15 352 tertiary settings, the method used in our study can be applied in a broader context to characterise  
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17 353 major factors driving the use of CT scanning as well as the use of diagnostic imaging tests. Our study  
18  
19 354 may assist to identify areas worthy of more in-depth investigations to better inform health policy  
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21 355 makers and interventions promoting appropriate use of diagnostic imaging tests.  
22  
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34  
35

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37  
38  
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42  
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44  
45 364 interpreting the data, writing and publishing the report.  
46  
47  
48

#### 49 365 **Authors' contributions**

50  
51  
52 366 RM, MB, JD, DM, PO, JSI, SM, NTH conceived the idea and study design for the manuscript. NTH, RM,  
53  
54 367 SM conducted data analyses and drafted the manuscript. RM, SM, NTH, MB contributed to  
55  
56 368 statistical expertise. RM, MB, JD, DM, PO, JSI, SM, NTH contributed in analysis, interpreting the  
57  
58 369 results, drafting and revising critically for important intellectual content of the manuscript. RM, MB,  
59  
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2  
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4  
5 371 manuscript for publication. The corresponding author attests that all listed authors meet authorship  
6  
7 372 criteria and that no others meeting the criteria have been omitted.  
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9

### 10 373 **Ethics approval and consent to participate**

11  
12  
13 374 Human research ethics approval was obtained from Curtin University Human Research Ethics  
14  
15 375 Committee (SMEC-80-10) and the WA Department of Health Human Research Ethics Committee  
16  
17 376 (2011/97) which exempted the study from requiring individual consent.  
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20

### 21 377 **Patient and public involvement**

22  
23  
24 378 A consumer representative was involved in the design of the grant used to fund this research.  
25  
26

### 27 379 **Patient consent**

28  
29  
30 380 Not applicable  
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### 33 381 **Data sharing statement**

34  
35 382 Data access is limited to only authors who require it for data analysis - the remaining authors do not  
36  
37 383 have access to the data but did have full access to the results of the data analysis. The data that  
38  
39 384 support the findings of this study are available from the relevant data custodians of the study  
40  
41 385 datasets. Restrictions by the data custodians mean that the data are not publicly available or able to  
42  
43 386 be provided by the authors. Researchers wishing to access the datasets used in this study should  
44  
45 387 refer to the WA data linkage application process ([https://www.datalinkage-wa.org.au/access-and-](https://www.datalinkage-wa.org.au/access-and-application)  
46  
47 388 application).  
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## 395 References

- 396 1. Korley FK, Pham JC, Kirsch TD. Use of Advanced Radiology During Visits to US Emergency  
397 Departments for Injury-Related Conditions, 1998-2007. *Jama*. 2010;304(13):1465-71.
- 398 2. Pelc NJ. Recent and future directions in CT imaging. *Ann Biomed Eng*. 2014;42(2):260-8.
- 399 3. The Royal Australian and New Zealand College of Radiologist. Radiology at a Glance Australia  
400 Sydney: The Royal Australian and New Zealand College of Radiologist; 2018 [Available from:  
401 <https://www.ranzcr.com/college/document-library/radiology-at-a-glance-australia>.
- 402 4. OECD Data. Computed tomography (CT) exams: OECD Data; 2018 [Available from:  
403 <https://data.oecd.org/healthcare/computed-tomography-ct-exams.htm>.
- 404 5. Australian Radiation Protection and Nuclear Safety Agency. Ionising Radiation and Health:  
405 Australian Government; 2015 [Available from:  
406 [https://www.arpansa.gov.au/sites/default/files/legacy/pubs/factsheets/IonisingRadiationandHealth](https://www.arpansa.gov.au/sites/default/files/legacy/pubs/factsheets/IonisingRadiationandHealth.pdf)  
407 [.pdf](https://www.arpansa.gov.au/sites/default/files/legacy/pubs/factsheets/IonisingRadiationandHealth.pdf).
- 408 6. Australian Radiation Protection and Nuclear Safety Agency. Current Australian national  
409 diagnostic reference levels for multi detector computed tomography: Australian Radiation  
410 Protection and Nuclear Safety Agency; 2018 [Available from: [https://www.arpansa.gov.au/research-](https://www.arpansa.gov.au/research-and-expertise/surveys/national-diagnostic-reference-level-service/current-australian-drls-update/mdct)  
411 [and-expertise/surveys/national-diagnostic-reference-level-service/current-australian-drls-](https://www.arpansa.gov.au/research-and-expertise/surveys/national-diagnostic-reference-level-service/current-australian-drls-update/mdct)  
412 [update/mdct](https://www.arpansa.gov.au/research-and-expertise/surveys/national-diagnostic-reference-level-service/current-australian-drls-update/mdct).
- 413 7. Picano E. Sustainability of medical imaging. *BMJ (Clinical research ed)*. 2004;328(7439):578-  
414 80.
- 415 8. Martins R, Raimundo P, Alves P, Monteiro R, Silva LD, Gomes A, et al. Appropriateness of  
416 Radiology Test Requests by an Emergency Department: A Retrospective Study. *Acta medica*  
417 *portuguesa*. 2020;33(1):7-14.
- 418 9. Tung M, Sharma R, Hinson JS, Nothelle S, Pannikottu J, Segal JB. Factors associated with  
419 imaging overuse in the emergency department: A systematic review. *The American journal of*  
420 *emergency medicine*. 2018;36(2):301-9.
- 421 10. The Royal Australian and New Zealand College of Radiologists. Quality and Standards  
422 Sydney: The Royal Australian and New Zealand College of Radiologists; 2019 [Available from:  
423 <https://www.ranzcr.com/our-work/quality-standards>.
- 424 11. Pathways. DI. Diagnostic Imaging Pathways.: Government of Western Australia; 2020 [
- 425 12. Bairstow PJ, Mendelson R, Dhillon R, Valton F. Diagnostic imaging pathways: development,  
426 dissemination, implementation, and evaluation. *International journal for quality in health care* :  
427 *journal of the International Society for Quality in Health Care*. 2006;18(1):51-7.
- 428 13. Bhatia RS, Levinson W, Shortt S, Pendrith C, Fric-Shamji E, Kallewaard M, et al. Measuring  
429 the effect of Choosing Wisely: an integrated framework to assess campaign impact on low-value  
430 care. *BMJ Quality & Safety*. 2015;24(8):523.
- 431 14. Ip IK, Morteale KJ, Prevedello LM, Khorasani R. Repeat abdominal imaging examinations in a  
432 tertiary care hospital. *Am J Med*. 2012;125(2):155-61.
- 433 15. Blazak P, Hacking C, Presneill J, Reade M. Early repeat computed tomographic imaging in  
434 transferred trauma and neurosurgical patients: Incidence, indications and impact. *Journal of medical*  
435 *imaging and radiation oncology*. 2018.
- 436 16. Colla CH, Morden NE, Sequist TD, Schpero WL, Rosenthal MB. Choosing wisely: prevalence  
437 and correlates of low-value health care services in the United States. *Journal of general internal*  
438 *medicine*. 2015;30(2):221-8.

- 1  
2  
3 439 17. Badgery-Parker T, Pearson S-A, Chalmers K, Brett J, Scott IA, Dunn S, et al. Low-value care in  
4 440 Australian public hospitals: prevalence and trends over time. *BMJ Quality & Safety*.  
5 441 2019;28(3):205.  
6 442 18. Hong AS, Ross-Degnan D, Zhang F, Wharam JF. Small Decline In Low-Value Back Imaging  
7 443 Associated With The 'Choosing Wisely' Campaign, 2012-14. *Health Aff (Millwood)*. 2017;36(4):671-9.  
8 444 19. Benchimol EI, Smeeth L, Guttman A, Harron K, Moher D, Petersen I, et al. The REporting of  
9 445 studies Conducted using Observational Routinely-collected health Data (RECORD) Statement. *PLoS*  
10 446 *medicine*. 2015;12(10):e1001885.  
11 447 20. Holman CD, Bass AJ, Rosman DL, Smith MB, Semmens JB, Glasson EJ, et al. A decade of data  
12 448 linkage in Western Australia: strategic design, applications and benefits of the WA data linkage  
13 449 system. *Australian health review : a publication of the Australian Hospital Association*.  
14 450 2008;32(4):766-77.  
15 451 21. Holman CD, Bass AJ, Rouse IL, Hobbs MS. Population-based linkage of health records in  
16 452 Western Australia: development of a health services research linked database. *Australian and New*  
17 453 *Zealand journal of public health*. 1999;23(5):453-9.  
18 454 22. Smith-Bindman R, Miglioretti DL, Larson EB. Rising use of diagnostic medical imaging in a  
19 455 large integrated health system. *Health Aff (Millwood)*. 2008;27(6):1491-502.  
20 456 23. AIHW. Rural, regional and remote health: a guide to remoteness classifications: AIHW; 2004  
21 457 [Available from: [https://www.aihw.gov.au/reports/rural-remote-australians/guide-to-remoteness-](https://www.aihw.gov.au/reports/rural-remote-australians/guide-to-remoteness-classifications/formats)  
22 458 [classifications/formats](https://www.aihw.gov.au/reports/rural-remote-australians/guide-to-remoteness-classifications/formats).  
23 459 24. Australian Bureau of Statistics. Census of Population and Housing: Socio-Economic Indexes  
24 460 for Areas Canberra: Australian Bureau of Statistics; 2011.  
25 461 25. Holman CD, Preen DB, Baynham NJ, Finn JC, Semmens JB. A multipurpose comorbidity  
26 462 scoring system performed better than the Charlson index. *Journal of clinical epidemiology*.  
27 463 2005;58(10):1006-14.  
28 464 26. Australian Institute of Health and Welfare. Admitted patient care 2014–15: Australian  
29 465 hospital statistics. Canberra: AIHW; 2016. Contract No.: Cat. no. HSE 172.  
30 466 27. Powers DA, Yoshioka H, Yun MS. mvdcmp: Multivariate decomposition for nonlinear  
31 467 response models. *Stata Journal*. 2011;11(4):556-76.  
32 468 28. Yun M-S. Decomposing differences in the first moment. *Economics Letters*. 2004;82(2):275-  
33 469 80.  
34 470 29. Wright CM, Bulsara MK, Norman R, Moorin RE. Increase in computed tomography in  
35 471 Australia driven mainly by practice change: A decomposition analysis. *Health Policy*.  
36 472 2017;121(7):823-9.  
37 473 30. Mendelson RM, Bairstow PJ. Inappropriate imaging: Why it matters, why it happens, what  
38 474 can be done. *Journal of medical imaging and radiation oncology*. 2010;54(3):173-7.  
39 475 31. Medical Benefits Reviews Task Group, Diagnostic Imaging Review Team. Review of funding  
40 476 for diagnostic imaging services: final report Department of Health; 2012.  
41 477 32. Mendelson R. Diagnostic Imaging Pathways Perth: Health Department of West Australia;  
42 478 2010 [Available from: [https://www.cancerwa.asn.au/resources/2015-08-19-Richard-Mendelson-](https://www.cancerwa.asn.au/resources/2015-08-19-Richard-Mendelson-presentation.pdf)  
43 479 [presentation.pdf](https://www.cancerwa.asn.au/resources/2015-08-19-Richard-Mendelson-presentation.pdf).  
44 480 33. Commonwealth of Australia. Availability and accessibility of diagnostic imaging equipment  
45 481 around Australia. Canberra ACT 2600: Parliament House; 2018. Contract No.: ISBN 978-1-76010-  
46 482 715-4.  
47 483 34. OECD Data. Computed tomography (CT) scanners: OECD Data; 2018 [Available from:  
48 484 <https://data.oecd.org/healthct/computed-tomography-ct-scanners.htm>.  
49 485 35. van de Wetering R, Batenburg R, Versendaal J, Lederman R, Firth L. A balanced evaluation  
50 486 perspective: picture archiving and communication system impacts on hospital workflow. *J Digit*  
51 487 *Imaging*. 2006;19 Suppl 1(Suppl 1):10-7.  
52 488 36. Chakera T, Nagree Y, Song S, Jones P. Bridging the communication gap between public and  
53 489 private radiology services. *Medical Journal of Australia*. 2009;191(10):558-60.  
60

1  
2  
3 490 37. Vest JR, Jung H-Y, Ostrovsky A, Das LT, McGinty GB. Image Sharing Technologies and  
4 491 Reduction of Imaging Utilization: A Systematic Review and Meta-analysis. J Am Coll Radiol.  
5 492 2015;12(12 Pt B):1371-9.e3.  
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7 493

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16 498 periods

17  
18 499 A. All tertiary admissions

19 500 B. Unplanned tertiary admissions  
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21 501 Figure 2. Details of decomposition analysis of the difference in average number of CT scans between  
22 502 the two periods for all tertiary admissions

23  
24 503 Figure 3. Details of decomposition analysis of the difference in average number of CT scans between  
25 504 the two periods for unplanned tertiary admissions

26  
27 505 **Appendix.** Results of decomposition analysis for all tertiary admissions and unplanned tertiary  
28 506 admissions  
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Table 2. Characteristics of the study population by study period and CT scan status

	Study period								All years 2003-2015 (2,375,787)			
	The past period (2003-2005) (N=519,286)				The recent period (2013-2015) (N=572,642)				Without CT scan		With CT scan	
	Without CT scan		With CT scan		Without CT scan		With CT scan		Without CT scan		With CT scan	
	N	%	N	%	N	%	N	%	N	%	N	%
<b>N</b>	473,120	91.1	46,166	8.9	477,462	83.4	95,180	16.6	2,072,348	87.2	303,439	12.8
<b>Female</b>	237,021	50.1	21,232	46.0	248,412	52.0	43,865	46.1	1,057,280	51.0	137,988	45.5
<b>Age groups</b>												
18-44years	134,467	28.4	10,954	23.7	145,181	30.4	20,075	21.1	621,452	30.0	67,456	22.2
45-64 years	144,820	30.6	12,797	27.7	150,139	31.4	27,225	28.6	651,941	31.5	87,319	28.8
65-74 years	91,075	19.2	8,447	18.3	83,797	17.6	16,798	17.6	368,070	17.8	53,332	17.6
75+ years	102,758	21.7	13,968	30.3	98,345	20.6	31,082	32.7	430,885	20.8	95,332	31.4
<b>Indigenous status</b>	31,708	6.7	2,111	4.6	32,061	6.7	4,540	4.8	137,806	6.6	14,156	4.7
<b>SEIFA</b>												
Least disadvantage	129,988	27.5	12,522	27.1	130,427	27.3	27,885	29.3	595,921	28.8	90,660	29.9
Less disadvantage	89,310	18.9	8,495	18.4	87,703	18.4	17,850	18.8	364,787	17.6	53,241	17.5
Moderate disadvantage	91,594	19.4	9,112	19.7	99,533	20.8	19,549	20.5	449,532	21.7	65,203	21.5
High disadvantage	89,421	18.9	8,923	19.3	95,607	20.0	18,104	19.0	388,311	18.7	57,090	18.8
Highest disadvantage	70,595	14.9	6,900	14.9	61,291	12.8	11,344	11.9	262,172	12.7	35,691	11.8
unknown	2,212	0.5	214	0.5	2,901	0.6	448	0.5	11,625	0.6	1,554	0.5
<b>ARIA</b>												
Major cities	411,062	86.9	38,086	82.5	416,708	87.3	84,046	88.3	1,807,380	87.2	261,292	86.1
Inner regional areas	29,622	6.3	3,663	7.9	19,675	4.1	3,508	3.7	108,562	5.2	15,908	5.2
Outer regional areas	16,251	3.4	2,155	4.7	19,417	4.1	3,814	4.0	75,935	3.7	13,210	4.4
Remote	8,968	1.9	1,283	2.8	10,654	2.2	1,901	2.0	44,727	2.2	7,336	2.4
Very Remote	6,205	1.3	894	1.9	8,167	1.7	1,458	1.5	28,389	1.4	4,731	1.6
Unknown	1,012	0.2	85	0.2	2,841	0.6	453	0.5	7,355	0.4	962	0.3
<b>Number of morbidity (MACSS)</b> (Median – IQR)	2	2-3	4	2-6	2	2-3	4	2-6	2	2-3	3	2-6
<b>Major clinical conditions</b>												



	Study period								All years			
	The past period (2003-2005) (N=519,286)				The recent period (2013-2015) (N=572,642)				2003-2015 (2,375,787)			
	Without CT scan		With CT scan		Without CT scan		With CT scan		Without CT scan		With CT scan	
	N	%	N	%	N	%	N	%	N	%	N	%
Mental and behaviour disorders	11,065	2.3	2,015	4.4	15,514	3.2	3,296	3.5	61,756	3.0	11,109	3.7
Circulatory system	35,636	7.5	7,038	15.2	38,534	8.1	12,434	13.1	162,138	7.8	41,737	13.8
Digestive system	31,437	6.6	5,026	10.9	38,055	8.0	10,678	11.2	150,492	7.3	32,897	10.8
Endocrine	9,160	1.9	823	1.8	11,074	2.3	1,381	1.5	46,268	2.2	5,165	1.7
Musculoskeletal system	21,153	4.5	1,532	3.3	21,477	4.5	2,819	3.0	93,520	4.5	9,231	3.0
Respiratory system	15,013	3.2	2,918	6.3	17,001	3.6	5,241	5.5	68,859	3.3	17,149	5.7
Injury	23,483	5.0	7,165	15.5	31,608	6.6	17,913	18.8	126,703	6.1	53,420	17.6
Cancer	21,608	4.6	5,389	11.7	22,465	4.7	7,520	7.9	96,232	4.6	28,783	9.5
<b>Funding sources</b>												
Public	447,927	94.7	42,612	92.3	416,248	87.2	75,202	79.0	1,894,581	91.4	258,126	85.1
Private	25,193	5.3	3,554	7.7	61,214	12.8	19,978	21.0	177,767	8.6	45,313	14.9
<b>Unplanned admissions</b>												
No	316,762	67.0	6,089	13.2	259,764	54.4	9,387	9.9	1,245,273	60.1	34,058	11.2
Yes	156,358	33.0	40,077	86.8	217,698	45.6	85,793	90.1	827,075	39.9	269,381	88.8
<b>Transferred from secondary hospitals</b>												
No	459,539	97.1	41,742	90.4	455,496	95.4	88,480	93.0	1,990,570	96.1	277,994	91.6
Yes	13,581	2.9	4,424	9.6	21,966	4.6	6,700	7.0	81,778	3.9	25,445	8.4
<b>Surgical procedure</b>												
No	457,900	96.8	42,803	92.7	449,708	94.2	87,721	92.2	1,975,259	95.3	280,008	92.3
Yes	15,220	3.2	3,363	7.3	27,754	5.8	7,459	7.8	97,089	4.7	23,431	7.7
<b>Morbidity group</b>												
0-1	103,369	21.85	6,165	13.35	116,826	24.47	13,361	14.04	514,216	24.81	46,686	15.4
2-5	349,557	73.88	27,175	58.86	329,844	69.08	54,377	57.13	1,452,109	70.07	175,377	57.8
6+	20,194	4.27	12,826	27.78	30,792	6.45	27,442	28.83	106,023	5.12	81,376	26.82



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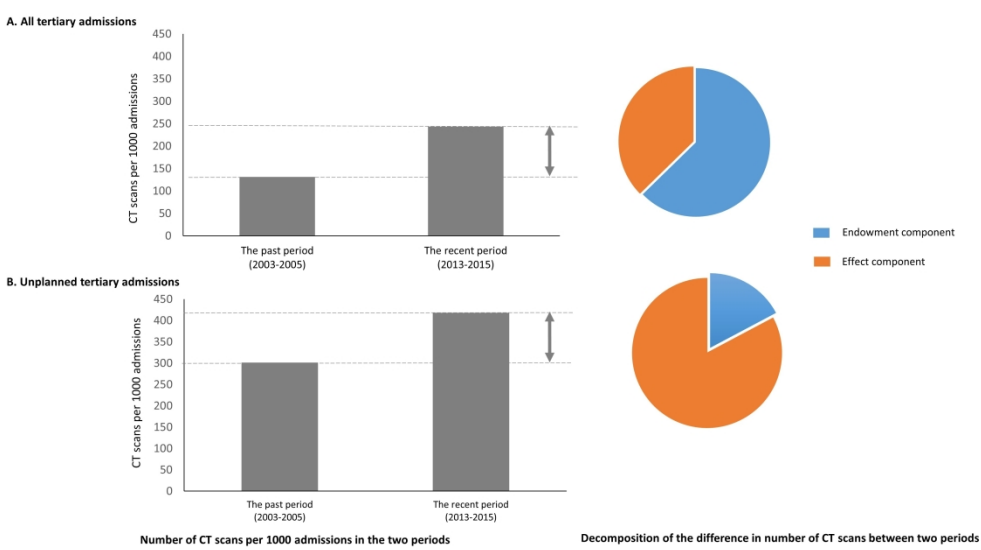


Figure 1

338x190mm (300 x 300 DPI)

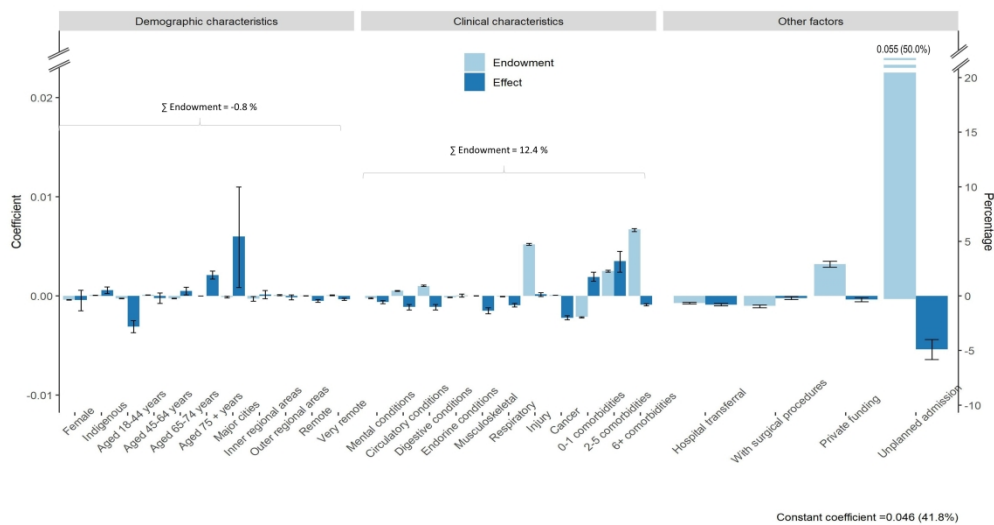


Figure 2

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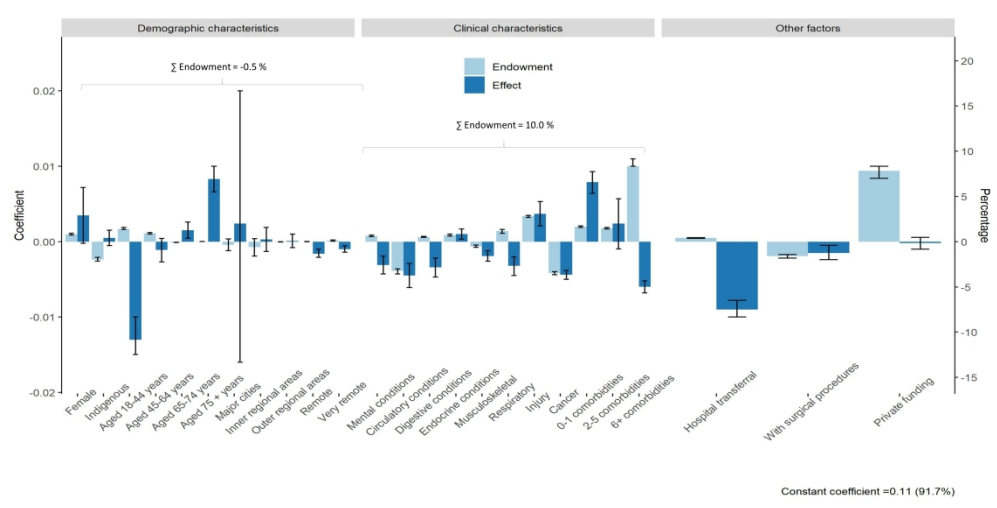


Figure 3

338x190mm (300 x 300 DPI)

Table 1A. Decomposition of the difference in the use of CT of all tertiary admissions between two periods

	Number of CT per admission	95% CI	
<b>The use of CT</b>			
The past period	0.131	0.129; 0.132	
The recent period	0.243	0.241; 0.245	
<b>Difference</b>	<b>0.112</b>	<b>0.110; 0.114</b>	
<b>Decomposition output</b>			
	Coefficient	95% CI	Percentage
Endowment component	0.069***	0.068; 0.070	62.7
Effect component	0.043***	0.041; 0.045	37.3
<b>1. Specific endowment component</b>			
Sex	-0.00039***	-0.00043; -0.00036	-0.4
Indigenous	0.000074***	0.000066; 0.000081	0.1
Age groups			
18-44 years	-0.00025***	-0.00027; -0.00023	-0.2
45-64 years	0.00010***	0.000089; 0.00011	0.1
65-74 years	-0.00025***	-0.00029; -0.00021	-0.2
75 + years	-0.0000039**	-0.0000066; -0.0000012	-0.004
SEIFA			
Least disadvantage	0.0000081	-0.0000085; 0.000025	0.01
Less disadvantage	-0.000020	-0.000053; 0.000013	-0.02
Moderate disadvantage	0.000056	-0.000060; 0.00017	0.1
High disadvantage	0.000061	-0.000015; 0.00014	0.1
Highest disadvantage	-0.00010	-0.00029; 0.000086	-0.1
Unknown	-0.000028	-0.000075; 0.000018	-0.2
ARIA			
Major cities	-0.00012**	-0.00020; -0.000034	-0.1
Inner regional areas	-0.00029*	-0.00052; -0.000055	-0.3
Outer regional areas	0.000076**	0.000027; 0.00013	0.1
Remote	0.000014	-0.0000095; 0.000037	0.01
Very Remote	0.000065**	0.000028; 0.00010	0.1
Unknown	-0.00015*	-0.00030; -0.0000086	-0.1
Major principal diagnoses			
Mental conditions	-0.00022***	-0.00028; -0.00017	-0.2
Circulatory conditions	0.00051***	0.00048; 0.00054	0.5
Digestive conditions	0.0010***	0.00096; 0.0011	0.9
Endocrine conditions	-0.00013***	-0.00016; -0.00011	-0.1
Musculoskeletal	0.0000029	-0.0000064; 0.000012	0.003
Respiratory	-0.000054***	-0.000080; -0.000028	-0.05
Injuries	0.0052***	0.0051; 0.0053	4.7
Cancer	0.000084***	0.000082; 0.000086	0.1
Number of morbidities			
0-1	-0.0021***	-0.0022; -0.0021	-1.9
2-5	0.0025***	0.0024; 0.0026	2.3
6 or more	0.0067***	0.0065; 0.0068	6.1
Private funding	0.0032***	0.0029; 0.0035	2.9

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3	Unplanned admission	0.055***	0.055; 0.056	50.0
4	Transferred from secondary hospitals	-0.00073***	-0.00081; -0.00065	-0.7
5	Had surgical procedures in hospital	-0.0010***	-0.0012; -0.00092	-0.9
6				
7	<b>2. Specific effect component</b>			
8	Sex	-0.00043	-0.0015; 0.00059	-0.4
9	Indigenous	0.00059***	0.00026; 0.00091	0.5
10	Age groups			
11	18-44 years	-0.0031***	-0.0037; -0.0025	-2.8
12	45-64 years	-0.00023	-0.00075; 0.00029	-0.2
13	65-74 years	0.00050*	0.00011; 0.00089	0.5
14	75 + years	0.0021***	0.0017; 0.0025	1.9
15	SEIFA			
16	Least disadvantage	0.00080	-0.00050; 0.0021	0.7
17	Less disadvantage	0.00054	-0.00037; 0.0014	0.5
18	Moderate disadvantage	0.00060	-0.00033; 0.0015	0.5
19	High disadvantage	0.00044	-0.00046; 0.0013	0.4
20	Highest disadvantage	0.00055	-0.00018; 0.0013	0.5
21	Unknown	-0.000070	-0.00017; 0.000031	-0.1
22	ARIA			
23	Major cities	0.0060*	0.00086; 0.011	5.5
24	Inner regional areas	0.00014	-0.00029; 0.00056	0.1
25	Outer regional areas	-0.00013	-0.00038; 0.00011	-0.1
26	Remote	-0.00050***	-0.00065; -0.00035	-0.5
27	Very Remote	-0.00032***	-0.00044; -0.00021	-0.3
28	Unknown	0.000092**	0.000037; 0.00015	0.1
29	Major principal diagnoses			
30	Mental conditions	-0.00062***	-0.00077; -0.00048	-0.6
31	Circulatory conditions	-0.0011***	-0.0014; -0.00087	-1.0
32	Digestive conditions	-0.0011***	-0.0014; -0.00087	-1.0
33	Endocrine conditions	0.000037	-0.00012; 0.00019	-0.1
34	Musculoskeletal	-0.0015***	-0.0018; -0.0012	-1.4
35	Respiratory	-0.00093***	-0.0011; -0.00076	-0.8
36	Injuries	0.00015	-0.000048; 0.00034	0.1
37	Cancer	-0.0022***	-0.0024; -0.0020	-2.0
38	Number of morbidities			
39	0-1	0.0019***	0.0015; 0.0024	1.7
40	2-5	0.0035***	0.0024; 0.0045	3.2
41	6 or more	-0.00089***	-0.0010; -0.00078	-0.8
42	Private funding	-0.00037***	-0.00057; -0.00017	-0.3
43	Unplanned admission	-0.0054***	-0.0064; -0.0044	-4.9
44	Transferred from secondary hospitals	-0.00089***	-0.0010; -0.00075	-0.8
45	Had surgical procedures in hospital	-0.00021**	-0.00035; -0.000062	-0.2
46	Constant	0.046***	0.041; 0.051	41.8

Note: \*\*\* if  $p$ -value<0.001; \*\* if  $p$ -value<0.01; \* if  $p$ -value<0.05

Table 1B. Decomposition of the difference in the use of CT for unplanned admissions between two periods

	Number of CT per admission	95% CI	
<b>The use of CT</b>			
The past period	0.301	0.298; 0.304	
The recent period	0.418	0.414; 0.420	
<b>Difference</b>	<b>0.117</b>	<b>0.112; 0.120</b>	
<b>Decomposition of the difference</b>			
	Coefficient	95% CI	Percentage
Endowment component	0.020***	0.019; 0.021	17.1
Effect component	0.096***	0.092; 0.10	82.1
<b>Specific endowment</b>			
Sex	0.00096***	(0.00087; 0.0011)	0.8
Indigenous	-0.0024***	(-0.0026; -0.0021)	-2.0
Age groups			
18-44 years	0.0017***	(0.0016; 0.0019)	1.4
45-64 years	0.0011***	(0.00099; 0.0012)	0.9
65-74 years	-0.00011***	(-0.00012; -0.000092)	-0.1
75 + years	0.0000087***	(0.0000039; 0.000013)	0.01
SEIFA			
Least disadvantage	0.00023	(-0.000026; 0.00048)	0.2
Less disadvantage	0.000092	(-0.0000057; 0.00019)	0.1
Moderate disadvantage	0.00018	(-0.00021; 0.00057)	0.2
High disadvantage	-0.000023	(-0.000097; 0.000050)	-0.02
Highest disadvantage	-0.00036	(-0.0011; 0.00040)	-0.3
Unknown	-0.00021	(-0.00053; 0.00011)	-0.2
ARIA			
Major cities	-0.00043	(-0.0012; 0.00037)	-0.4
Inner regional areas	-0.00073	(-0.0019; 0.00040)	-0.6
Outer regional areas	-0.000031**	(-0.000053; -0.0000085)	-0.03
Remote	0.00000088	(-0.0000017; 0.0000035)	0.001
Very Remote	0.00014***	(0.000071; 0.00021)	0.1
Unknown	-0.00068	(-0.0013; -0.000048)	-0.6
Major principal diagnoses			
Mental conditions	0.00076***	(0.00065; 0.00087)	0.6
Circulatory conditions	-0.0039***	(-0.0043; -0.0036)	-3.3
Digestive conditions	0.00063***	(0.00058; 0.00069)	0.5
Endocrine conditions	0.00088***	(0.00073; 0.0010)	0.7
Musculoskeletal	-0.00062***	(-0.00077; -0.00047)	-0.5
Respiratory	0.0014***	(0.0011; 0.0016)	1.2
Injuries	0.0034***	(0.0032; 0.0035)	2.8
Cancer	-0.0042***	(-0.0044; -0.0040)	-3.5
Number of morbidities			
0-1	0.0020***	(0.0019; 0.0021)	1.7
2-5	0.0018***	(0.0017; 0.0019)	1.5

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3	6 or more	0.010***	(0.010; 0.011)	8.3
4	Private funding	0.0094***	(0.0084; 0.010)	7.8
5	Transferred from secondary hospitals	0.00049***	(0.00044; 0.00054)	0.4
6	Admission with surgical procedures	-0.0019***	(-0.0022; -0.0017)	-1.6
7				
8	<b>Specific effect component</b>			
9				
10	Sex	0.0035	(-0.00021; 0.0072)	2.9
11	Indigenous	0.00050	(-0.00051; 0.0015)	0.4
12	Age groups			
13	18-44 years	-0.013***	(-0.015; -0.010)	-10.8
14	45-64 years	-0.0011	(-0.0027; 0.00042)	-0.9
15	65-74 years	0.0015**	(0.00046; 0.0026)	1.3
16	75 + years	0.0083***	(0.0066; 0.0100)	6.9
17				
18	SEIFA			
19	Least disadvantage	0.0024	(-0.0023; 0.0071)	2
20	Less disadvantage	0.0023	(-0.00092; 0.0055)	1.9
21	Moderate disadvantage	0.0018	(-0.0015; 0.0051)	1.5
22	High disadvantage	0.0015	(-0.0017; 0.0047)	1.3
23	Highest disadvantage	0.0020	(-0.00063; 0.0046)	1.7
24	Unknown	-0.00034	(-0.00086; 0.00017)	-0.3
25				
26	ARIA			
27				
28	Major cities	0.0024	(-0.016; 0.020)	2
29	Inner regional areas	0.00030	(-0.0013; 0.0019)	0.3
30	Outer regional areas	0.000092	(-0.00081; 0.00100)	0.1
31	Remote	-0.0016***	(-0.0021; -0.0010)	-1.3
32	Very Remote	-0.00099***	(-0.0014; -0.00056)	-0.8
33	Unknown	0.00058**	(0.00019; 0.00097)	0.5
34				
35	Major principal diagnoses			
36				
37	Mental conditions	-0.0031***	(-0.0043; -0.0019)	-2.6
38	Circulatory conditions	-0.0045***	(-0.0061; -0.0029)	-3.8
39	Digestive conditions	-0.0034***	(-0.0047; -0.0022)	-2.8
40	Endocrine conditions	0.0010***	(0.00033; 0.0017)	0.8
41	Musculoskeletal	-0.0019***	(-0.0026; -0.0012)	-1.6
42	Respiratory	-0.0032***	(-0.0045; -0.0020)	-2.7
43	Injuries	0.0037***	(0.0021; 0.0053)	3.1
44	Cancer	-0.0044***	(-0.0050; -0.0038)	-3.7
45				
46	Number of morbidities			
47				
48	0-1	0.0079***	(0.0064; 0.0093)	6.6
49	2-5	0.0024	(-0.00097; 0.0057)	2
50	6 or more	-0.0060***	(-0.0068; -0.0052)	-5
51	Private funding sources	-0.00020	(-0.00099; 0.00058)	-0.2
52	Transferred from secondary hospitals	-0.0090	(-0.010; -0.0078)	-7.5
53	Admission with surgical procedures	-0.0015**	(-0.0024; -0.00050)	-1.3
54	Constant	0.11***	(0.091; 0.12)	91.7
55				

Note: \*\*\* if p-value<0.001; \*\* if p-value<0.01; \* if p-value<0.05

**The RECORD statement – checklist of items, extended from the STROBE statement, that should be reported in observational studies using routinely collected health data.**

	Item No.	STROBE items	Location in manuscript where items are reported	RECORD items	Location in manuscript where items are reported
<b>Title and abstract</b>					
	1	(a) Indicate the study's design with a commonly used term in the title or the abstract (b) Provide in the abstract an informative and balanced summary of what was done and what was found		RECORD 1.1: The type of data used should be specified in the title or abstract. When possible, the name of the databases used should be included.  RECORD 1.2: If applicable, the geographic region and timeframe within which the study took place should be reported in the title or abstract.  RECORD 1.3: If linkage between databases was conducted for the study, this should be clearly stated in the title or abstract.	1.1 Abstract, data sources.  1.2 Abstract, data sources  1.3 Abstract, data sources.
<b>Introduction</b>					
Background rationale	2	Explain the scientific background and rationale for the investigation being reported			Introduction, lines 30-65
Objectives	3	State specific objectives, including any prespecified hypotheses			Introduction, lines 68-70
<b>Methods</b>					
Study Design	4	Present key elements of study design early in the paper			Methods- line 72-73 and Study population (line 85-93)
Setting	5	Describe the setting, locations, and relevant dates, including			Methods, data sources and study population



		<p>periods of recruitment, exposure, follow-up, and data collection</p>			
<p>Participants</p>	<p>6</p>	<p><i>(a) Cohort study</i> - Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up  <i>Case-control study</i> - Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls  <i>Cross-sectional study</i> - Give the eligibility criteria, and the sources and methods of selection of participants   <i>(b) Cohort study</i> - For matched studies, give matching criteria and number of exposed and unexposed  <i>Case-control study</i> - For matched studies, give matching criteria and the number of controls per case</p>		<p>RECORD 6.1: The methods of study population selection (such as codes or algorithms used to identify subjects) should be listed in detail. If this is not possible, an explanation should be provided.</p> <p>RECORD 6.2: Any validation studies of the codes or algorithms used to select the population should be referenced. If validation was conducted for this study and not published elsewhere, detailed methods and results should be provided.</p> <p>RECORD 6.3: If the study involved linkage of databases, consider use of a flow diagram or other graphical display to demonstrate the data linkage process, including the number of individuals with linked data at each stage.</p>	<p>6.1 Methods, study population and design.</p> <p>6.2 Methods, data sources.</p> <p>6.3 Methods, data source, reference 28 and 29</p>
<p>Variables</p>	<p>7</p>	<p>Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable.</p>		<p>RECORD 7.1: A complete list of codes and algorithms used to classify exposures, outcomes, confounders, and effect modifiers should be provided. If these cannot be reported, an explanation should be provided.</p>	<p>Methods, outcome measures, independent measures</p>
<p>Data sources/ measurement</p>	<p>8</p>	<p>For each variable of interest, give sources of data and details of methods of assessment (measurement).</p>			<p>Methods, data sources, outcome measures, and independent measures</p>

		Describe comparability of assessment methods if there is more than one group			
Bias	9	Describe any efforts to address potential sources of bias			Methods, statistical methods line 128-146
Study size	10	Explain how the study size was arrived at			Methods and Results (149-152)
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why			Methods, outcome measure, and independent measures
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) <i>Cohort study</i> - If applicable, explain how loss to follow-up was addressed <i>Case-control study</i> - If applicable, explain how matching of cases and controls was addressed <i>Cross-sectional study</i> - If applicable, describe analytical methods taking account of sampling strategy (e) Describe any sensitivity analyses			Methods, statistical methods
Data access and cleaning methods		..		RECORD 12.1: Authors should describe the extent to which the investigators had access to the	12.1 Methods  12.2 Methods, data sources

				database population used to create the study population.  RECORD 12.2: Authors should provide information on the data cleaning methods used in the study.	
Linkage		..		RECORD 12.3: State whether the study included person-level, institutional-level, or other data linkage across two or more databases. The methods of linkage and methods of linkage quality evaluation should be provided.	12.3 Methods, data sources (76-87)
<b>Results</b>					
Participants	13	(a) Report the numbers of individuals at each stage of the study ( <i>e.g.</i> , numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed) (b) Give reasons for non-participation at each stage. (c) Consider use of a flow diagram		RECORD 13.1: Describe in detail the selection of the persons included in the study ( <i>i.e.</i> , study population selection) including filtering based on data quality, data availability and linkage. The selection of included persons can be described in the text and/or by means of the study flow diagram.	13.1 Method, study population and Results (lines 149-152)
Descriptive data	14	(a) Give characteristics of study participants ( <i>e.g.</i> , demographic, clinical, social) and information on exposures and potential confounders (b) Indicate the number of participants with missing data for each variable of interest (c) <i>Cohort study</i> - summarise follow-up time ( <i>e.g.</i> , average and total amount)			Results, lines 153-163 and Table 1

1 2 3 4 5 6 7 8 9 10 11	Outcome data	15	<p><i>Cohort study</i> - Report numbers of outcome events or summary measures over time</p> <p><i>Case-control study</i> - Report numbers in each exposure category, or summary measures of exposure</p> <p><i>Cross-sectional study</i> - Report numbers of outcome events or summary measures</p>			Results, Table 1
12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27	Main results	16	<p>(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval). Make clear which confounders were adjusted for and why they were included</p> <p>(b) Report category boundaries when continuous variables were categorized</p> <p>(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period</p>			<p>Results,</p> <p>(a) Figure 1, 2, and 3 and Appendix, lines 165-234</p> <p>b) Categorisation provide in the methods (line 105-124)</p> <p>c) NA</p>
28 29 30 31 32	Other analyses	17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses			Methods lines 128-146
33	<b>Discussion</b>					
34 35	Key results	18	Summarise key results with reference to study objectives			Discussion, lines 236-251
36 37 38 39 40 41 42 43 44	Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias		RECORD 19.1: Discuss the implications of using data that were not created or collected to answer the specific research question(s). Include discussion of misclassification bias, unmeasured confounding, missing data, and changing eligibility over	Discussion, lines 310-320

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				time, as they pertain to the study being reported.	
1 2 3 4 5 6 7 8 9	Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence		Discussion and Conclusion section (lines 310-334).
10 11 12 13 14	Generalisability	21	Discuss the generalisability (external validity) of the study results		Australian context clear in manuscript with discussion of relevant literature
15	<b>Other Information</b>				
16 17 18 19 20 21	Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based		Role of the funding source, lines 341-344
22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44	Accessibility of protocol, raw data, and programming code		..	RECORD 22.1: Authors should provide information on how to access any supplemental information such as the study protocol, raw data, or programming code.	22.1 Supplementary data provided to justify results and interpretation. Line 345-350: The data that support the findings of this study are available from the relevant data custodians of the study datasets. Restrictions by the data custodians mean that the data are not publicly available or able to be provided by the authors. Researchers

					<p>wishing to access the datasets used in this study should refer to the WA data linkage application process (<a href="https://www.data-linkage-wa.org.au/access-and-application">https://www.data-linkage-wa.org.au/access-and-application</a>).</p>
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\*Reference: Benchimol EI, Smeeth L, Guttman A, Harron K, Moher D, Petersen I, Sørensen HT, von Elm E, Langan SM, the RECORD Working Committee. The REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) Statement. *PLoS Medicine* 2015; in press.

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# BMJ Open

## Factors driving computed tomography utilisation in tertiary hospitals: a decomposition analysis using linked administrative data in Western Australia

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3 1 **Factors driving computed tomography utilisation in tertiary hospitals: a decomposition**  
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6 2 **analysis using linked administrative data in Western Australia**  
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3 34 **Abstract**  
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6 35 **Objectives:** While computed tomography (CT) scanning plays a significant role in health care, its  
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8 36 increasing use has raised concerns about inappropriate use. This study investigated factors driving  
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10 37 the changing use of CT among people admitted to tertiary hospitals in Western Australia (WA).  
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13 38 **Design and setting:** A repeated cross-sectional study of CT use in WA in 2003-2005 and 2013-2015  
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15 39 using linked administrative health data at the individual patient level.  
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18 40 **Participants:** A total of 2,375,787 tertiary hospital admissions of people aged 18 years or older.  
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21 41 **Main outcome measure:** Rate of CT scanning per 1000 hospital admissions.  
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24 42 **Methods:** A multivariable decomposition model was used to quantify the contribution of changes in  
25  
26 43 patient characteristics and changes in the probability of having a CT over the study period.  
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29 44 **Results:** The rate of CT scanning increased by 112 CT scans per 1000 admissions over the study  
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31 45 period. Changes in the distribution of the observed patient characteristics were accounted for 62.7%  
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33 46 of the growth in CT use. However, among unplanned admissions, changes in the distribution of  
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35 47 patient characteristics only explained 17% of the growth in CT use, the remainder being explained by  
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37 48 changes in the probability of having a CT scan. Whilst the relative probability of having a CT scan  
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39 49 generally increased over time across most observed characteristics, it reduced in young adults (-  
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41 50 2.8%), people living in the rural/remote areas (-0.8%) and people transferred from secondary  
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43 51 hospitals (-0.8%).  
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48 52 **Conclusions:** Our study highlights potential improvements in practice towards reducing medical  
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50 53 radiation exposure in certain high risk population. Since changes in the relative probability of having  
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52 54 a CT scan (representing changes in scope) rather than changes in the distribution of the patient  
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54 55 characteristics (representing changes in need) explained a major proportion of the growth in CT use,  
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56 56 this warrants more in-depth investigations in clinical practices to better inform health policies  
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58 57 promoting appropriate use of diagnostic imaging tests.  
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3 58 **Strengths and limitations of this study**  
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- 5 59 ➤ This study utilised a large linked administrative dataset over a period of 13 years, allowing  
6  
7 the measurement of the contributions of changes in demographic and clinical characteristics  
8 60  
9 to the changing use of CT.  
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12 62 ➤ With a rich source of individual level data, this study identified a wide range of demographic  
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14 and clinical factors driving the use of CT in tertiary hospitals.  
15 63  
16 64 ➤ Since the decomposition analysis methods only quantified the contribution of observed  
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18 factors, contribution of any unobserved factors to the change of CT use was summed in the  
19 65  
20 constant coefficient.  
21 66  
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23 67 ➤ Our study was limited to assessing the factors driving the use of CT scanning in tertiary  
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25 (teaching) hospitals, therefore, caution is needed when generalising the results to other  
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27 settings.  
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## 71 Introduction

72 Computed tomography (CT) is one of the most important technical developments in medicine and is  
73 now an essential part of clinical practice (1, 2). In Australia, CT accounted for 13% of diagnostic  
74 imaging tests with an average of 134 scans per 1000 people in 2017/18 (3, 4). It is estimated that  
75 diagnostic imaging tests increased the annual effective ionising radiation dose on the Australian  
76 population by 50% (5). In acknowledgement of the relatively high radiation burden of diagnostic  
77 imaging, Australia introduced Diagnostic reference levels (DRL) in 2011 providing a benchmark to  
78 facilitate monitoring and comparison of radiation dose between facilities (6).

79 Despite the advanced technology leading to significant contribution in healthcare, its increasing use  
80 has raised a concern about inappropriate use. Approximately one third of diagnostic imaging tests  
81 are estimated to be unnecessary or inappropriate, with the potential to do more harm than good  
82 and represent a waste of health care resources (7, 8). In the case of CT the potential harm includes  
83 exposure to ionising radiation and the associated risk of cancer to population. A previous study  
84 found a high rate of inappropriate CT among older patients and those with multi-morbidity (9).

85 In response to concerns of inappropriate utilisation of the advanced diagnostic technique, since  
86 early 2000, the Royal Australian and New Zealand College of Radiologists (RANZCR) have provided  
87 the standards of practice for clinical radiology (10). In Western Australia (WA), Diagnostic Imaging  
88 Pathways has been deployed to promote appropriate use of imaging (11, 12). Most recently, in 2015  
89 NPS MedicineWise launched the Australian “Choosing Wisely” campaigns promoting discussion on  
90 reducing low value care (13), changing health care provider behaviour and increasing patient  
91 knowledge. The overall intention is to improve patient safety and efficiency in health service  
92 utilisation (13).

93 While substantial effort is under way to promote appropriate use of imaging tests, current data  
94 reporting variation in potentially avoidable diagnostic imaging tests, particularly for CT over the last  
95 decade are limited (9, 14, 15). Recent studies mainly focus on examining the prevalence of low value

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3 96 care (16), the early trend of procedure uptake in hospital settings (17) and selected spinal imaging  
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5 97 (18) following Choosing Wisely campaigns. Therefore, better understanding of changes in the use of  
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7 98 CT scanning over the past decade and demographic and clinical factors driving the change in the use  
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9 99 of CT are necessary to support monitoring the use of CT scanning and to guide future research and  
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11 100 public health interventions. The aim of this study is to use decomposition analysis to examine factors  
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13 101 driving changes in CT use between two periods of time in tertiary hospitals in WA: recent (2013 to  
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15 102 2015) and past (2003 to 2005).

### 103 **Methods**

104 We conducted an observational repeated cross-sectional study of CT use in WA in 2003-2005 and  
105 2013-2015 using linked administrative health data at the individual patient level. Reporting follows  
106 the Reporting of studies Conducted using Observational Routinely-collected health Data (RECORD)  
107 guidelines (19).

### 108 **Data sources**

109 The data sources included three datasets:

- 110 (i) WA Hospital Morbidity Data system (January 2003- May 2016) providing information on  
111 diagnosis, date of admission and discharge from all hospitals in WA, and basic socio-  
112 demographic and clinical characteristics.
- 113 (ii) WA Emergency Department (ED) presentation data (January 2003- December 2016) providing  
114 details of presentation time and date, presentation type, triage code, major diagnostic group  
115 and basic socio-demographic characteristics.
- 116 (iii) WA Picture archiving and communication system (PACS) data (January 2003 to May 2016)  
117 providing documentation on all computed tomography (CT) scans conducted in tertiary  
118 including date of the scan, and the CT protocols used. All the datasets were linked using  
119 probabilistic matching algorithms with a level of data accuracy up to 99.9% (20, 21).

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3 120 Details of data linkage process is presented in the website of Western Australia Data Linkage  
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5 121 (<https://www.datalinkage-wa.org.au/dlb-services/linkage/>).  
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## 8 122 **Study population**

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10 123 The study population consisted of all hospital admissions in all four tertiary (teaching) hospitals  
11  
12 124 located centrally in Perth, which accounted for nearly 50% of admissions in public hospitals, in WA  
13  
14 125 between 2003 and 2015 inclusive, for people aged 18 years and older. Non-tertiary admissions (i.e.  
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16 126 admission from secondary (district general) hospitals) were excluded as CT scans performed in the  
17  
18 127 hospitals are not consistently included in the PACS dataset. The study population was then  
19  
20 128 constructed into two study periods; past period (2003-2005) and recent period (2013-2015). To  
21  
22 129 avoid over-counting hospital admissions, for example where a patient was transferred between  
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24 130 hospitals, consecutive tertiary hospital admission records for an individual were aggregated into a  
25  
26 131 single hospital admission where admission or discharge dates were nested or overlapping, or where  
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28 132 an admission date was within one day of the discharge date. A tertiary hospital admission was  
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30 133 counted from the first date of admission in a tertiary hospital—or where applicable—the date of a  
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32 134 prior associated tertiary ED presentation so long as it resulted in an admission, to the last discharge  
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34 135 date in tertiary hospitals.  
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## 40 136 **Patient and Public Involvement**

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43 137 This study used linked administrative health data of all tertiary hospital admissions of people aged  
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45 138 18 years or older. The patients were not directly involved in the design or conduct of this study. Our  
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47 139 consumer representative (Mr John Stubbs) was involved in the design of the grant application used  
48  
49 140 to fund this research and is a member of the research team providing ongoing input to analysis of  
50  
51 141 the data, interpretation of the results and development of publications. The Western Australian Data  
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53 142 Linkage Branch and the data custodians of the WA Emergency Department Data Collection and the  
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55 143 Picture Archiving Communications System data provided data for this project.  
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3 145 **Outcome measures**  
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5 146 The outcome measure of this study was the number of CT scans performed within a tertiary hospital  
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7 147 admission. The number of CT scans was counted from the first day admitted to a tertiary  
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9 148 hospital/presentation to a tertiary ED until the last date of discharge for that admission. To avoid  
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11 149 over-counting the use of CT, multiple CT records with the same day and same anatomic areas were  
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14 150 collapsed into one CT event (22).  
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17 151 **Independent measures**  
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19 152 This study measured basic demographic and socioeconomic characteristics including age (18-44, 45-  
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21 153 64, 65-74, and 75+ years), sex, indigenous status, residential remoteness classified according to  
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23 154 Accessibility Remoteness of Australia index (ARIA) (23) (major cities, inner regional areas, outer  
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25 155 regional areas, remote and very remote), and quintiles of the Census-specific Socio-economic  
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27 156 Indexes for Areas (SEIFA) index of relative socioeconomic disadvantage (24) (least disadvantage, less  
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29 157 disadvantage, moderate disadvantage, high disadvantage, and highest disadvantage).  
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32  
33 158 Clinical characteristics included major clinical diagnostic groups and the number of morbidities.  
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35 159 Major clinical diagnostic groups included mental and behavioural disorders, circulatory system,  
36  
37 160 digestive system, endocrine, nutritional and metabolic diseases, musculoskeletal system, respiratory  
38  
39 161 system, injuries, and neoplasms. The conditions were identified in the principal diagnostic field of  
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41 162 the hospital morbidity data record using ICD-AM-10 (the International Statistical Classification of  
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43 163 Diseases and Related Health Problems, 10<sup>th</sup> Revision, Australian Modification). Multimorbidity was  
44  
45 164 ascertained using the Multipurpose Australian Comorbidity Scoring system (25) using ICD-AM-10  
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47 165 across all diagnostic fields and was classified into 0-1, 2-5 and 6+ comorbidities. In addition, an  
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49 166 admission was classified as having had a surgical procedure where the principal procedure field  
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51 167 included one of the 20 most common surgical procedure as per ACHI codes (the Australian  
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53 168 classification of health intervention) (26). Other independent measures included funding source  
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55 169 (public or private), admission type (elective or unplanned admission) and admission with/without a  
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59 170 transfer from secondary hospitals.  
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## 171 **Statistical analysis**

172 Descriptive analysis was conducted to examine the distribution of socio-demographic and clinical  
173 characteristics of the study population over two study periods; past period (2003-2005) and recent  
174 period (2013-2015) as well as the whole study population (2003-2015). Multivariable decomposition  
175 for nonlinear response models, an extension of Oaxaca-Blinder decomposition analysis (27), was  
176 conducted to decompose the differential rate of CT use between the two study periods into the  
177 endowment (distribution of observed patient characteristics) and effect (relative probability of  
178 having CT scan) components:

179 (1) The Endowment component quantifies the amount of the difference in the rate of CT use is  
180 explained by the changes in the distribution of observed socio-demographic and clinical  
181 characteristics between the two study periods.

182 (2) The Effect component describes how much of the difference in the rate of CT scanning is  
183 explained by a change in the relative probability of having CT across observed characteristics.

184 We conducted decomposition analyses for all tertiary admissions and for unplanned tertiary  
185 admissions separately using STATA SE 14 (27).

## 186 **Results**

### 187 **Characteristics of tertiary admissions with CT scan by study periods**

188 Of a total of 2,375,787 tertiary hospital admissions over the 12 year period (2003-2015), 303,439  
189 admissions (12.8%) had at least one CT scan. The proportion of admissions incorporating CT  
190 increased from 8.9% in the past period (2003-2005) to 16.6% in the recent period (2013-2015) (Table  
191 1). Overall, there was a small change in the distribution of both demographic and clinical  
192 characteristics among admissions that included CT between the two study periods. For example, the  
193 proportion of the patients who had a CT scan and were in the older age group (75+ years) increased  
194 from 30.3% to 32.7% and people living in major cities with CT increased from 82.5% to 88.3%

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3 195 between the past and recent period. Similarly within clinical characteristics, multi-morbidity (6+  
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5 196 morbidities) accounted for 27.8% of admissions with CT in the past period compared to 28.8% in the  
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7 197 recent period. Among major diagnostic groups in the past period, injuries, circulatory system, cancer  
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9 198 and digestive system accounted for 15.5%, 15.2%, 11.7% and 10.9% of admissions with CT,  
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11 199 compared to 18.8%, 13.1%, 7.9% and 11.2% in recent period. For other characteristics, admission  
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13 200 with CT in the recent period had a higher proportion of unplanned admission (90.1% vs. 86.8%) and  
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15 201 private funding sources (21.0% vs. 7.7%) compared with the past period.  
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### 19 202 **Decomposition results for the use of CT over the two periods**

20 203 The results of the decomposition analysis of the difference in average number of CT scans between  
21  
22 204 the two periods for all tertiary admissions and unplanned at the aggregated level are presented in  
23  
24 205 Figure 1 (detail in Appendix- Table 1A-B). The difference in the rate of CT scans between two periods  
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26 206 was 112 scans per 1000 admissions (95%CI, 110; 114 per 1000 admissions, p-value <0.001) for all  
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28 207 tertiary admission and 117 scans per 1000 admissions (95%CI, 112; 120 per 1000 admissions, p-value  
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30 208 <0.001) for unplanned tertiary admissions. While the change in the number of CT scans per  
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32 209 admission across the two analyses were not substantially different, a marked difference in the  
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34 210 results of the decomposition analysis was observed. Figure 1 shows that 62.7% of the difference in  
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36 211 CT use for all tertiary admission was explained by variation in the distribution of all observed  
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38 212 characteristics. The rest of the difference in CT usage was attributable to variation in the relative  
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40 213 probability of having CT in observed characteristics and unobserved factors (captured in constant  
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42 214 coefficient).  
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49 215 In contrast, when the analysis was restricted to unplanned admissions, the variation in the  
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51 216 distribution of the observed characteristics explained only 17% of the difference in CT use between  
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53 217 two periods while 82.7% was due to variation in the relative probability of having CT across observed  
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55 218 and unobserved factors.  
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### 58 219 **Details of decomposition analysis for all tertiary admissions**

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3 220 Figure 2 presents decomposition analysis in details of all observed demographic and clinical  
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5 221 characteristics. Overall, changes in the distribution of the demographic characteristics including sex,  
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7 222 indigenous status, age, SEIFA and ARIA explained only -0.8% of the change in CT use. Change in the  
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9 223 distribution of the clinical characteristics including major principal diagnoses and groups of  
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11 224 morbidities accounted for 12.4% of the change in CT use. Half of this change (6.1%) was attributable  
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13 225 to multi-morbidity (6 or more morbidities) and 4.7% was due to injuries.

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17 226 Over the study period changes in the relative probability of having a CT scan over the observed  
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19 227 patient characteristics resulted in a 6.8% increase in the rate of CT scanning, while changes in the  
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21 228 distribution of the characteristics of the observed patient characteristics reduced the rate of CT  
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23 229 scanning by 2.6%. Interestingly, the relative probability of having a CT scan for those with young age  
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25 230 was significantly lower than in the past period contributing 2.8% reduction in the number of CT scan  
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27 231 between the two periods. In addition, the relative probability of having CT was higher for those  
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29 232 identified as living in major cities in the recent period compared to the past period, and lower for  
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31 233 people from remote/very remote areas in the recent period compared to the past period. The  
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33 234 contribution of each component to the difference in the number of CT's per admission between the  
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35 235 two periods was 5.5% (p-value=0.02) and -0.8% (p-values<0.001), respectively.

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37 236 For clinical characteristics, the results indicated a lower relative probability of having a scan during a  
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39 237 tertiary admission in the recent period compared with the past period for all the diagnostic groups,  
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41 238 with the exception of those admitted for injuries and endocrine disorders. The increase in patients  
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43 239 with multi-morbidities (2-5 comorbidities) contributed 3.2% to the difference between the two  
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45 240 periods.

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47 241 For other factors, the relative probability of having a CT scan following transfer from a secondary  
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49 242 hospital in the recent period was significantly lower than in the past period, contributing 0.8%  
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51 243 reduction to the rate of CT scan between the two periods. A lower relative probability of having a CT  
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53 244 scan in the recent period compared with the past period for unplanned admission contributed -4.9%  
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3 245 to the difference in CT use between the two periods. Unobserved factors captured in the constant  
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5 246 coefficient contributed to 41.8% of the variation in CT usage between the two periods.  
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7

8 247 ***Details of decomposition analysis for unplanned tertiary admissions***  
9

10 248 Similar to all tertiary admissions, the results for unplanned admission (Figure 3) indicated that a  
11  
12 249 substantial proportion of variation in CT use between the two study periods (10.0%) was attributable  
13  
14  
15 250 to changes in the distribution of the observed clinical characteristics including multimorbidity and  
16  
17 251 major diagnostic groups. However, changes in the distribution of the observed demographic  
18  
19 252 characteristics such as age, sex and accessibility between two periods only explained a total of -0.5%  
20  
21 253 the change in CT use.  
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24 254 For the specific effect component, a similar finding was also observed in unplanned admissions.  
25  
26 255 Specifically, a lower relative probability of having a CT scan for those in the youngest age group (18-  
27  
28 256 44 years) was observed in the recent period compared with the past. Likewise, a lower relative  
29  
30 257 probability of having CT scan in the recent period versus the past period was observed among those  
31  
32 258 admitted for condition such as circulatory, cancer, and respiratory; this accounted for -3.8%, -3.7%,  
33  
34 259 and -2.7% of the difference in CT use. The relative probability of having a CT scan after transfer from  
35  
36 260 a secondary hospital in the recent period was lower than in the past, contributing -7.5% to the  
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38 261 change in the number of CT scans between the two periods.  
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43 262 **Discussion**  
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46 263 This is the first study to examine the contribution of demographic and clinical characteristics to  
47  
48 264 changes in the rate of CT scanning in tertiary hospitals using multivariable decomposition analysis of  
49  
50 265 linked health administrative data over an extended period of time. We found that nearly two thirds  
51  
52 266 of the increase in the use of CT was attributable to changes in the distribution of observed  
53  
54 267 characteristics, with changes in proportion of unplanned admissions accounting for the largest  
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56 268 component. However when the analysis was restricted to unplanned admissions, changes in  
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58 269 distribution of the observed characteristics only explained about a fifth of the difference in CT usage  
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3 270 and the rest was explained by the effect component. In both decomposition analyses, clinical  
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5 271 characteristics (12.4% in all admissions and 10% in unplanned admissions) including major diagnostic  
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7 272 groups and comorbidities rather than demographic characteristics contributed substantially to  
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10 273 explain the variation in CT use between the two periods. Interestingly, our study observed a lower  
11  
12 274 relative probability of having a CT scan in the recent period (2013-2015) compared with the past  
13  
14 275 period (2003-2005) in two subgroups: young adults, which may reflect a movement towards  
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16 276 minimising medical radiation exposure in the high risk population, and admissions transferred from  
17  
18 277 secondary hospitals, reflecting either a reduction in inappropriate repeat imaging tests or greater  
19  
20  
21 278 access to CT in non-tertiary hospitals.

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23  
24 279 A recent study examined factors driving the increasing use of CT scan in Australia with a focus on the  
25  
26 280 use of CT outside of the public hospital setting (28), which accounted for 73% of adult CT scans (29).  
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28 281 Although the study also used the decomposition analysis approach, the only endowment component  
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30 282 captured in this study was changes in the population age structure; the rest of the difference in CT  
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32 283 use was captured in the number of CT scans per capita. The study found that a change in the number  
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34 284 of CT scans per capita, interpreted as a “scope shift”, rather than changes in the population age  
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36 285 structure accounted for a major component in the change of CT use outside hospital settings over  
37  
38 286 the period 1993 to 2013 (28). The previous study used changes in age structure as a marker of  
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40 287 changes in need (e.g. an ageing population), which had been postulated as the reason for increasing  
41  
42 288 CT scanning rates. The finding that changes in the age structure was responsible for only a small  
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44 289 proportion of the rate of CT use suggested that “scope shift” (i.e. changes in the practice of CT) was  
45  
46 290 driving the rate of use. Our findings again confirmed that the impact of changing in age structure (i.e.  
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48 291 increasing proportion of older people) was not a major driver of the use of CT scanning. In addition,  
49  
50 292 by using multivariable decomposition analysis, our study provides a more comprehensive picture of  
51  
52 293 the contribution of various demographic, clinical and other observed factors driving the change in CT  
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54 294 use in the hospital setting. This is because our analysis was able to differentiate the influence of  
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56 295 changes in the distribution (endowment component) from changes in the relative probability of  
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3 296 having CT (effect component) across a large range of observed factors. Our study adds to the  
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5 297 literature by showing that it is the change in distribution of comorbidities and clinical conditions  
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7 298 which are often highly prevalent in the older population rather than the age of the population itself  
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9  
10 299 that contributed the largest component to the growth of CT use. This indicates the need of  
11  
12 300 strengthen public health interventions to promote healthy ageing to reduce the burden on health  
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14 301 care systems.

16  
17 302 Our study found that while many observed factors drive the increase of CT use, the change in the  
18  
19 303 relative probability of having CT scan in the young age group and in those with admissions  
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21 304 transferred from secondary hospitals (once the variation in the distribution of these factors was  
22  
23 305 accounted for) reduced the use of CT in the recent period compared with the past period. These  
24  
25 306 finding are encouraging as they confirm a reduction in two groups where there has been concern  
26  
27 307 regarding inappropriate imaging. The results coincide with the goals of education campaigns to raise  
28  
29 308 provider awareness of the risk of ionising radiation, especially among children and young adults (30-  
30  
31 309 32). Since children and young adults are more sensitive and have more years to develop radiation-  
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33 310 induced cancer (30, 31), radiologists have become more cautious and may have taken care to  
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35 311 minimise unnecessary CT scanning.

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40 312 Despite challenges due to the vast geographical spread of Australia, over the last 15 years diagnostic  
41  
42 313 imaging services have become more accessible to patients in both major cities and rural areas within  
43  
44 314 a timely and a reasonable distance from their home (31). A report in 2012 shows that more than  
45  
46 315 90% of Australians can get access to a comprehensive diagnostic imaging facility within a distance of  
47  
48 316 100km from their residential areas (31) and up to 80% of patients have access to a CT machine  
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50 317 within 10 km (31). Between 2003 and 2018, Australia increased the rate of CT equipment per head  
51  
52 318 of population from 40.6 to 67 per million (33, 34). The government also provided a diagnostic  
53  
54 319 imaging bulk billing incentive from November 2009 that increased the accessibility to the service  
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56 320 through improving patient affordability. In addition, the government endorsed the diagnostic  
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3 321 imaging review reform package in 2011 and implemented it between 2011 and 2016, funded  
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5 322 through the Medicare Benefits Schedule. One of the package objectives was to ensure accessibility  
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7 323 to quality diagnostic imaging services for people in rural and remote areas. In addition, the package  
8  
9 324 also aimed to promote for effective communication between practitioners and imaging service to  
10  
11 325 ensure appropriate imaging (31). The increasing availability and accessibility of diagnostic imaging, in  
12  
13 326 particular to CT scanners, raised concerns of potential overuse of CT scans increasing radiation  
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15 327 exposure to patients and contributing additional costs to the health care system (15). However, we  
16  
17 328 found that the relative probability of having CT scan in tertiary hospitals for people living in remote  
18  
19 329 and very remote areas in the recent period was less than in the past period. Although the magnitude  
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21 330 of the variation was small, it accounts for significantly lower use of CT scan in tertiary hospitals.  
22  
23 331 Likewise, the rate of CT scan among admissions transferred from the secondary hospital in the  
24  
25 332 recent period was also less than in the past period. This would be consistent with government  
26  
27 333 efforts to ensure accessibility of diagnostic imaging service in rural and remote areas as well as  
28  
29 334 improved information transfer between hospitals. Previous studies have highlighted the important  
30  
31 335 role of image sharing technology in improving provider access and avoiding duplication of  
32  
33 336 investigations (35-37). However, a recent study found that repeat CT scanning is relatively common  
34  
35 337 for patients already imaged prior to transfer to a tertiary hospital, although there was a valid clinical  
36  
37 338 reason for repeat scanning in the majority of cases (15). Despite signs of improvement in our study,  
38  
39 339 further detailed exploration is required to establish the proportion of avoidable repeat scans and  
40  
41 340 therefore the potential benefit in terms of reduced radiation exposure and costs.  
42  
43 341 This study has a number of limitations, largely due to the nature of linked administrative data. This  
44  
45 342 study only decomposed the difference in CT use between the two study periods based on the  
46  
47 343 available observed characteristics available in the administrative data. Thus, the contribution of  
48  
49 344 unobserved factors was not addressed in this study, although they are captured in the constant  
50  
51 345 value. This study only captured the use of CT in tertiary hospitals because we did not have  
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53 346 comprehensive data on CT use in non-tertiary settings, limiting our ability to determine whether the  
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3 347 lower relative probability of having CT in the recent period in some subgroups was due to changes in  
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5 348 practice or increasing accessibility of CT in other health care settings. While the linked administrative  
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7 349 data can comprehensively capture use of health services over time without loss to follow up,  
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9  
10 350 information about clinical information is limited to relatively high-level diagnostic codes recorded in  
11  
12 351 the HMDS. Therefore, our study cannot provide information about the proportion of scans that were  
13  
14 352 justified.

15  
16  
17 353 In conclusion, the use of CT in tertiary hospitals increased between the two study periods in keeping  
18  
19 354 with international trends. This is primarily due to changes in the distribution of unplanned  
20  
21 355 admissions and the clinical characteristics of presenting patients rather than changing demographic  
22  
23 356 characteristics. Among unplanned admissions only, changes in the relative probability of scanning  
24  
25 357 were the major drivers of CT use, with the largest component of this relating to unobserved factors.  
26  
27 358 In both results, clinical characteristics appear to be substantial component driving the growth of CT  
28  
29 359 usage in the tertiary hospital setting while the role of demographic characteristics was minimal. Our  
30  
31 360 study also highlights a potential improvement in practice towards reducing medial radiation  
32  
33 361 exposure through a decrease CTs in subpopulations such as young adults and in those admitted via  
34  
35 362 transfer admission from other hospitals. While the finding is limited to tertiary settings, the method  
36  
37 363 used in our study can be applied in a broader context to characterise major factors driving the use of  
38  
39 364 CT scanning as well as the use of diagnostic imaging tests. Our study may assist to identify areas  
40  
41 365 worthy of more in-depth investigations to better inform health policy makers and interventions  
42  
43 366 promoting appropriate use of diagnostic imaging tests.

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#### 57 58 59 371 **Competing interests**



1  
2  
3 372 The authors have no competing interest to declare. The institutions of RM, NH, DY, MB and DM  
4  
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6  
7 374 initiated research. The funding agreement ensured author independence in designing the study,  
8  
9 375 interpreting the data, writing and publishing the report.  
10  
11  
12

### 13 376 **Authors' contributions**

14  
15 377 RM, MB, JD, DM, PO, JSI, SM, NTH conceived the idea and study design for the manuscript. NTH, RM,  
16  
17 378 SM conducted data analyses and drafted the manuscript. RM, SM, NTH, MB contributed to statistical  
18  
19 379 expertise. RM, MB, JD, DM, PO, JSI, SM, NTH contributed in analysis, interpreting the results, drafting  
20  
21 380 and revising critically for important intellectual content of the manuscript. RM, MB, JD, DM, PO, JSI  
22  
23 381 secured funding for the study. All authors read and approved the final version of the manuscript for  
24  
25 382 publication. The corresponding author attests that all listed authors meet authorship criteria and  
26  
27 383 that no others meeting the criteria have been omitted.  
28  
29  
30

### 31 384 **Ethics approval and consent to participate**

32  
33 385 Human research ethics approval was obtained from Curtin University Human Research Ethics  
34  
35 386 Committee (SMEC-80-10) and the WA Department of Health Human Research Ethics Committee  
36  
37 387 (2011/97) which exempted the study from requiring individual consent.  
38  
39  
40

### 41 388 **Patient consent**

42  
43 389 Not applicable  
44  
45  
46  
47

### 48 390 **Data sharing statement**

49  
50  
51 391 Data access is limited to only authors who require it for data analysis - the remaining authors do not  
52  
53 392 have access to the data but did have full access to the results of the data analysis. The data that  
54  
55 393 support the findings of this study are available from the relevant data custodians of the study  
56  
57 394 datasets. Restrictions by the data custodians mean that the data are not publicly available or able to  
58  
59 395 be provided by the authors. Researchers wishing to access the datasets used in this study should  
60

396 refer to the WA data linkage application process (<https://www.datalinkage-wa.org.au/access-and->  
397 application).

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## 404 References

- 405 1. Korley FK, Pham JC, Kirsch TD. Use of Advanced Radiology During Visits to US Emergency  
406 Departments for Injury-Related Conditions, 1998-2007. *Jama*. 2010;304(13):1465-71.
- 407 2. Pelc NJ. Recent and future directions in CT imaging. *Ann Biomed Eng*. 2014;42(2):260-8.
- 408 3. The Royal Australian and New Zealand College of Radiologist. *Radiology at a Glance Australia*  
409 Sydney: The Royal Australian and New Zealand College of Radiologist; 2018 [Available from:  
410 <https://www.ranzcr.com/college/document-library/radiology-at-a-glance-australia>.
- 411 4. OECD Data. Computed tomography (CT) exams: OECD Data; 2018 [Available from:  
412 <https://data.oecd.org/healthcare/computed-tomography-ct-exams.htm>.
- 413 5. Australian Radiation Protection and Nuclear Safety Agency. *Ionising Radiation and Health:*  
414 Australian Government; 2015 [Available from:  
415 [https://www.arpsa.gov.au/sites/default/files/legacy/pubs/factsheets/IonisingRadiationandHealth](https://www.arpsa.gov.au/sites/default/files/legacy/pubs/factsheets/IonisingRadiationandHealth.pdf)  
416 [.pdf](https://www.arpsa.gov.au/sites/default/files/legacy/pubs/factsheets/IonisingRadiationandHealth.pdf).
- 417 6. Australian Radiation Protection and Nuclear Safety Agency. *Current Australian national*  
418 *diagnostic reference levels for multi detector computed tomography:* Australian Radiation  
419 Protection and Nuclear Safety Agency; 2018 [Available from: [https://www.arpsa.gov.au/research-](https://www.arpsa.gov.au/research-and-expertise/surveys/national-diagnostic-reference-level-service/current-australian-drls-update/mdct)  
420 [and-expertise/surveys/national-diagnostic-reference-level-service/current-australian-drls-](https://www.arpsa.gov.au/research-and-expertise/surveys/national-diagnostic-reference-level-service/current-australian-drls-update/mdct)  
421 [update/mdct](https://www.arpsa.gov.au/research-and-expertise/surveys/national-diagnostic-reference-level-service/current-australian-drls-update/mdct).
- 422 7. Picano E. Sustainability of medical imaging. *BMJ (Clinical research ed)*. 2004;328(7439):578-  
423 80.
- 424 8. Martins R, Raimundo P, Alves P, Monteiro R, Silva LD, Gomes A, et al. Appropriateness of  
425 Radiology Test Requests by an Emergency Department: A Retrospective Study. *Acta medica*  
426 *portuguesa*. 2020;33(1):7-14.
- 427 9. Tung M, Sharma R, Hinson JS, Nothelle S, Pannikottu J, Segal JB. Factors associated with  
428 imaging overuse in the emergency department: A systematic review. *The American journal of*  
429 *emergency medicine*. 2018;36(2):301-9.
- 430 10. The Royal Australian and New Zealand College of Radiologists. *Quality and Standards*  
431 Sydney: The Royal Australian and New Zealand College of Radiologists; 2019 [Available from:  
432 <https://www.ranzcr.com/our-work/quality-standards>.
- 433 11. Pathways. DI. *Diagnostic Imaging Pathways.:* Government of Western Australia; 2020 [  
434 12. Bairstow PJ, Mendelson R, Dhillon R, Valton F. Diagnostic imaging pathways: development,  
435 dissemination, implementation, and evaluation. *International journal for quality in health care* :  
436 *journal of the International Society for Quality in Health Care*. 2006;18(1):51-7.

13. Bhatia RS, Levinson W, Shortt S, Pendrith C, Fric-Shamji E, Kallewaard M, et al. Measuring the effect of Choosing Wisely: an integrated framework to assess campaign impact on low-value care. *BMJ Quality & Safety*. 2015;24(8):523.
14. Ip IK, Morteale KJ, Prevedello LM, Khorasani R. Repeat abdominal imaging examinations in a tertiary care hospital. *Am J Med*. 2012;125(2):155-61.
15. Blazak P, Hacking C, Presneill J, Reade M. Early repeat computed tomographic imaging in transferred trauma and neurosurgical patients: Incidence, indications and impact. *Journal of medical imaging and radiation oncology*. 2018.
16. Colla CH, Morden NE, Sequist TD, Schpero WL, Rosenthal MB. Choosing wisely: prevalence and correlates of low-value health care services in the United States. *Journal of general internal medicine*. 2015;30(2):221-8.
17. Badgery-Parker T, Pearson S-A, Chalmers K, Brett J, Scott IA, Dunn S, et al. Low-value care in Australian public hospitals: prevalence and trends over time. *BMJ Quality & Safety*. 2019;28(3):205.
18. Hong AS, Ross-Degnan D, Zhang F, Wharam JF. Small Decline In Low-Value Back Imaging Associated With The 'Choosing Wisely' Campaign, 2012-14. *Health Aff (Millwood)*. 2017;36(4):671-9.
19. Benchimol EI, Smeeth L, Guttman A, Harron K, Moher D, Petersen I, et al. The REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) Statement. *PLoS medicine*. 2015;12(10):e1001885.
20. Holman CD, Bass AJ, Rosman DL, Smith MB, Semmens JB, Glasson EJ, et al. A decade of data linkage in Western Australia: strategic design, applications and benefits of the WA data linkage system. *Australian health review : a publication of the Australian Hospital Association*. 2008;32(4):766-77.
21. Holman CD, Bass AJ, Rouse IL, Hobbs MS. Population-based linkage of health records in Western Australia: development of a health services research linked database. *Australian and New Zealand journal of public health*. 1999;23(5):453-9.
22. Smith-Bindman R, Miglioretti DL, Larson EB. Rising use of diagnostic medical imaging in a large integrated health system. *Health Aff (Millwood)*. 2008;27(6):1491-502.
23. AIHW. Rural, regional and remote health: a guide to remoteness classifications: AIHW; 2004 [Available from: <https://www.aihw.gov.au/reports/rural-remote-australians/guide-to-remoteness-classifications/formats>].
24. Australian Bureau of Statistics. Census of Population and Housing: Socio-Economic Indexes for Areas Canberra: Australian Bureau of Statistics; 2011.
25. Holman CD, Preen DB, Baynham NJ, Finn JC, Semmens JB. A multipurpose comorbidity scoring system performed better than the Charlson index. *Journal of clinical epidemiology*. 2005;58(10):1006-14.
26. Australian Institute of Health and Welfare. Admitted patient care 2014–15: Australian hospital statistics. Canberra: AIHW; 2016. Contract No.: Cat. no. HSE 172.
27. Powers DA, Yoshioka H, Yun MS. mvdcmp: Multivariate decomposition for nonlinear response models. *Stata Journal*. 2011;11(4):556-76.
28. Wright CM, Bulsara MK, Norman R, Moorin RE. Increase in computed tomography in Australia driven mainly by practice change: A decomposition analysis. *Health Policy*. 2017;121(7):823-9.
29. Gibson DAJ, Moorin RE, Holman CDAJ. Cohort study of Western Australia computed tomography utilisation patterns and their policy implications. *BMC health services research*. 2014;14:526-.
30. Mendelson RM, Bairstow PJ. Inappropriate imaging: Why it matters, why it happens, what can be done. *Journal of medical imaging and radiation oncology*. 2010;54(3):173-7.
31. Medical Benefits Reviews Task Group, Diagnostic Imaging Review Team. Review of funding for diagnostic imaging services: final report Department of Health; 2012.

- 1  
2  
3 487 32. Mendelson R. Diagnostic Imaging Pathways Perth: Health Department of West Australia;  
4 488 2010 [Available from: [https://www.cancerwa.asn.au/resources/2015-08-19-Richard-Mendelson-](https://www.cancerwa.asn.au/resources/2015-08-19-Richard-Mendelson-presentation.pdf)  
5 489 [presentation.pdf](https://www.cancerwa.asn.au/resources/2015-08-19-Richard-Mendelson-presentation.pdf).  
6 490  
7 491 33. Commonwealth of Australia. Availability and accessibility of diagnostic imaging equipment  
8 492 around Australia. Canberra ACT 2600: Parliament House; 2018. Contract No.: ISBN 978-1-76010-715-  
9 493 4.  
10 494 34. OECD Data. Computed tomography (CT) scanners: OECD Data; 2018 [Available from:  
11 495 <https://data.oecd.org/healthqt/computed-tomography-ct-scanners.htm>.  
12 496  
13 497 35. van de Wetering R, Batenburg R, Versendaal J, Lederman R, Firth L. A balanced evaluation  
14 498 perspective: picture archiving and communication system impacts on hospital workflow. J Digit  
15 499 Imaging. 2006;19 Suppl 1(Suppl 1):10-7.  
16 500 36. Chakera T, Nagree Y, Song S, Jones P. Bridging the communication gap between public and  
17 501 private radiology services. Medical Journal of Australia. 2009;191(10):558-60.  
18 502 37. Vest JR, Jung H-Y, Ostrovsky A, Das LT, McGinty GB. Image Sharing Technologies and  
19 503 Reduction of Imaging Utilization: A Systematic Review and Meta-analysis. J Am Coll Radiol.  
20 504 2015;12(12 Pt B):1371-9.e3.  
21  
22 505

## 504 List of tables

505 Table 1. Characteristics of the study population by study period and CT scan status

## 506 Figures

507 Figure 1. Decomposition analysis of the difference in average number of CT scans between the two  
508 periods

- 509 A. All tertiary admissions
- 510 B. Unplanned tertiary admissions

511 Figure 2. Details of decomposition analysis of the difference in average number of CT scans between  
512 the two periods for all tertiary admissions

513 Figure 3. Details of decomposition analysis of the difference in average number of CT scans between  
514 the two periods for unplanned tertiary admissions

515 **Appendix.** Results of decomposition analysis for all tertiary admissions and unplanned tertiary  
516 admissions

**Table 1. Characteristics of the study population by study period and CT scan status**

	Study period								All years 2003-2015 (2,375,787)			
	The past period (2003-2005) (N=519,286)				The recent period (2013-2015) (N=572,642)				Without CT scan (N= 2,072,348)		With CT scan (N= 303,439)	
	Without CT scan (N= 473,120)		With CT scan (N= 46,166)		Without CT scan (N= 477,462)		With CT scan (N= 95,180)		N	%	N	%
	N	%	N	%	N	%	N	%	N	%	N	%
<b>Female</b>	237,021	50.1	21,232	46.0	248,412	52.0	43,865	46.1	1,057,280	51.0	137,988	45.5
<b>Age groups</b>												
18-44years	134,467	28.4	10,954	23.7	145,181	30.4	20,075	21.1	621,452	30.0	67,456	22.2
45-64 years	144,820	30.6	12,797	27.7	150,139	31.4	27,225	28.6	651,941	31.5	87,319	28.8
65-74 years	91,075	19.2	8,447	18.3	83,797	17.6	16,798	17.6	368,070	17.8	53,332	17.6
75+ years	102,758	21.7	13,968	30.3	98,345	20.6	31,082	32.7	430,885	20.8	95,332	31.4
<b>Indigenous status</b>	31,708	6.7	2,111	4.6	32,061	6.7	4,540	4.8	137,806	6.6	14,156	4.7
<b>SEIFA</b>												
Least disadvantage	129,988	27.5	12,522	27.1	130,427	27.3	27,885	29.3	595,921	28.8	90,660	29.9
Less disadvantage	89,310	18.9	8,495	18.4	87,703	18.4	17,850	18.8	364,787	17.6	53,241	17.5
Moderate disadvantage	91,594	19.4	9,112	19.7	99,533	20.8	19,549	20.5	449,532	21.7	65,203	21.5
High disadvantage	89,421	18.9	8,923	19.3	95,607	20.0	18,104	19.0	388,311	18.7	57,090	18.8
Highest disadvantage	70,595	14.9	6,900	14.9	61,291	12.8	11,344	11.9	262,172	12.7	35,691	11.8
unknown	2,212	0.5	214	0.5	2,901	0.6	448	0.5	11,625	0.6	1,554	0.5
<b>ARIA</b>												
Major cities	411,062	86.9	38,086	82.5	416,708	87.3	84,046	88.3	1,807,380	87.2	261,292	86.1
Inner regional areas	29,622	6.3	3,663	7.9	19,675	4.1	3,508	3.7	108,562	5.2	15,908	5.2
Outer regional areas	16,251	3.4	2,155	4.7	19,417	4.1	3,814	4.0	75,935	3.7	13,210	4.4
Remote	8,968	1.9	1,283	2.8	10,654	2.2	1,901	2.0	44,727	2.2	7,336	2.4
Very Remote	6,205	1.3	894	1.9	8,167	1.7	1,458	1.5	28,389	1.4	4,731	1.6
Unknown	1,012	0.2	85	0.2	2,841	0.6	453	0.5	7,355	0.4	962	0.3
<b>Number of morbidity (MACSS)</b> (Median – IQR)	2	2-3	4	2-6	2	2-3	4	2-6	2	2-3	3	2-6
<b>Major clinical conditions</b>												

	Study period								All years			
	The past period (2003-2005)				The recent period (2013-2015)				2003-2015			
	(N=519,286)				(N=572,642)				(2,375,787)			
	Without CT scan		With CT scan		Without CT scan		With CT scan		Without CT scan		With CT scan	
(N= 473,120)		(N= 46,166)		(N= 477,462)		(N= 95,180)		(N= 2,072,348)		(N= 303,439)		
	N	%	N	%	N	%	N	%	N	%	N	%
Mental and behaviour disorders	11,065	2.3	2,015	4.4	15,514	3.2	3,296	3.5	61,756	3.0	11,109	3.7
Circulatory system	35,636	7.5	7,038	15.2	38,534	8.1	12,434	13.1	162,138	7.8	41,737	13.8
Digestive system	31,437	6.6	5,026	10.9	38,055	8.0	10,678	11.2	150,492	7.3	32,897	10.8
Endocrine	9,160	1.9	823	1.8	11,074	2.3	1,381	1.5	46,268	2.2	5,165	1.7
Musculoskeletal system	21,153	4.5	1,532	3.3	21,477	4.5	2,819	3.0	93,520	4.5	9,231	3.0
Respiratory system	15,013	3.2	2,918	6.3	17,001	3.6	5,241	5.5	68,859	3.3	17,149	5.7
Injury	23,483	5.0	7,165	15.5	31,608	6.6	17,913	18.8	126,703	6.1	53,420	17.6
Cancer	21,608	4.6	5,389	11.7	22,465	4.7	7,520	7.9	96,232	4.6	28,783	9.5
<b>Funding sources</b>												
Public	447,927	94.7	42,612	92.3	416,248	87.2	75,202	79.0	1,894,581	91.4	258,126	85.1
Private	25,193	5.3	3,554	7.7	61,214	12.8	19,978	21.0	177,767	8.6	45,313	14.9
<b>Unplanned admissions</b>												
No	316,762	67.0	6,089	13.2	259,764	54.4	9,387	9.9	1,245,273	60.1	34,058	11.2
Yes	156,358	33.0	40,077	86.8	217,698	45.6	85,793	90.1	827,075	39.9	269,381	88.8
<b>Transferred from secondary hospitals</b>												
No	459,539	97.1	41,742	90.4	455,496	95.4	88,480	93.0	1,990,570	96.1	277,994	91.6
Yes	13,581	2.9	4,424	9.6	21,966	4.6	6,700	7.0	81,778	3.9	25,445	8.4
<b>Surgical procedure</b>												
No	457,900	96.8	42,803	92.7	449,708	94.2	87,721	92.2	1,975,259	95.3	280,008	92.3
Yes	15,220	3.2	3,363	7.3	27,754	5.8	7,459	7.8	97,089	4.7	23,431	7.7
<b>Morbidity group</b>												
0-1	103,369	21.85	6,165	13.35	116,826	24.47	13,361	14.04	514,216	24.81	46,686	15.4
2-5	349,557	73.88	27,175	58.86	329,844	69.08	54,377	57.13	1,452,109	70.07	175,377	57.8
6+	20,194	4.27	12,826	27.78	30,792	6.45	27,442	28.83	106,023	5.12	81,376	26.82

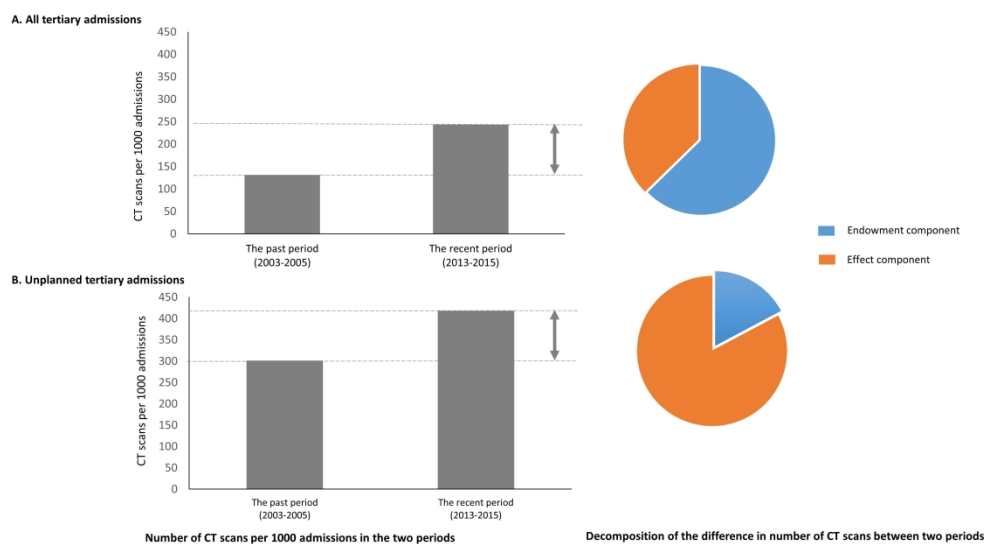


Figure 1. Decomposition analysis of the difference in average number of CT scans between the two periods

338x190mm (300 x 300 DPI)

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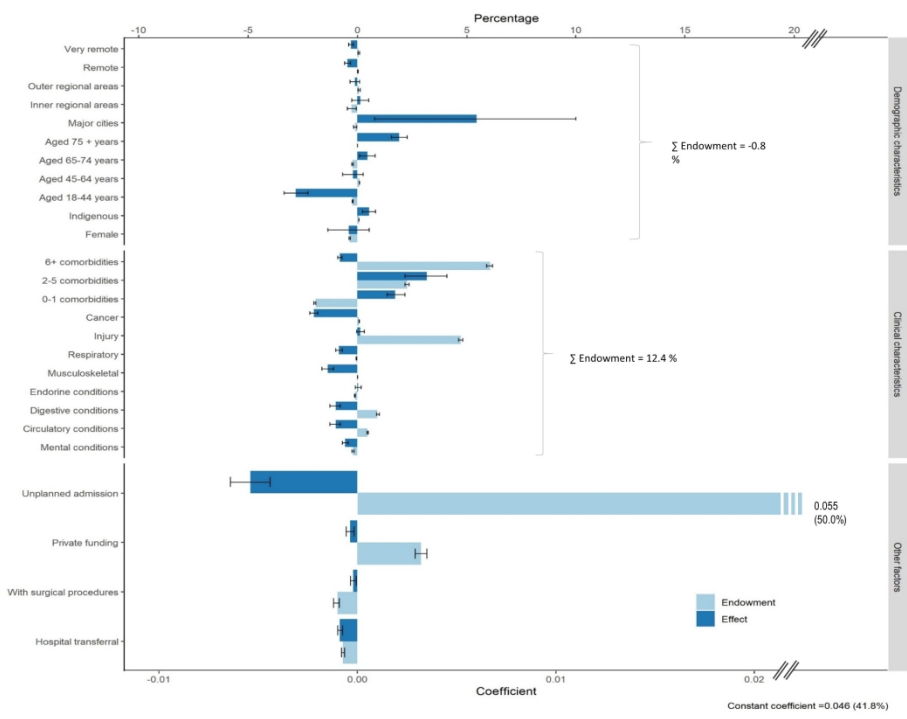


Figure 2. Details of decomposition analysis of the difference in average number of CT scans between the two periods for all tertiary admissions

254x190mm (300 x 300 DPI)



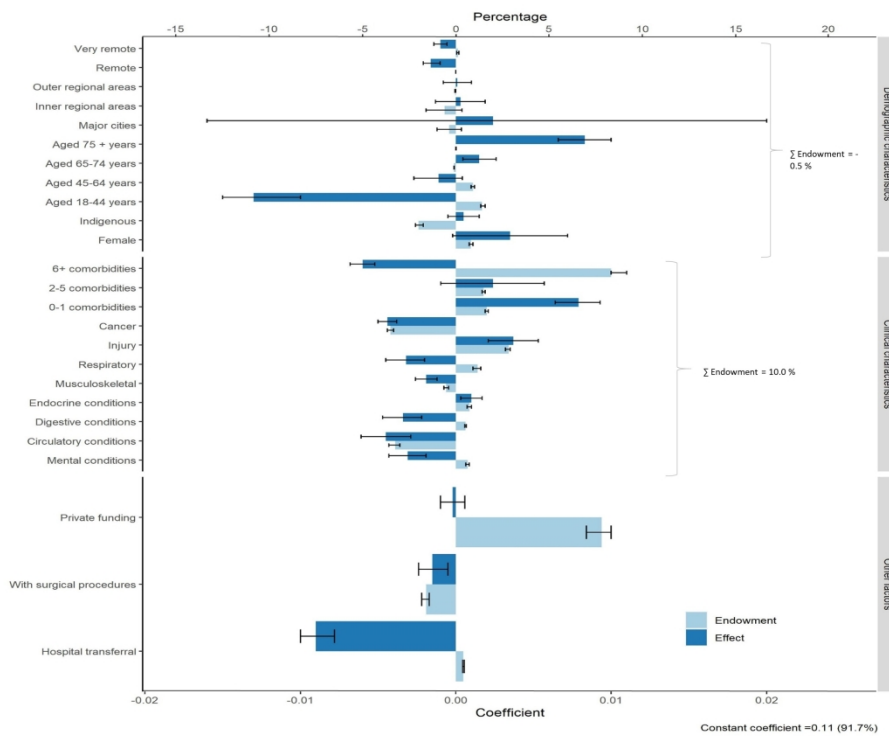


Figure 3. Details of decomposition analysis of the difference in average number of CT scans between the two periods for unplanned tertiary admissions

254x190mm (300 x 300 DPI)

Table 1A. Decomposition of the difference in the use of CT of all tertiary admissions between two periods

	Number of CT per admission	95% CI	
<b>The use of CT</b>			
The past period	0.131	0.129; 0.132	
The recent period	0.243	0.241; 0.245	
<b>Difference</b>	<b>0.112</b>	<b>0.110; 0.114</b>	
<b>Decomposition output</b>			
	Coefficient	95% CI	Percentage
Endowment component	0.069***	0.068; 0.070	62.7
Effect component	0.043***	0.041; 0.045	37.3
<b>1. Specific endowment component</b>			
Sex	-0.00039***	-0.00043; -0.00036	-0.4
Indigenous	0.000074***	0.000066; 0.000081	0.1
Age groups			
18-44 years	-0.00025***	-0.00027; -0.00023	-0.2
45-64 years	0.00010***	0.000089; 0.00011	0.1
65-74 years	-0.00025***	-0.00029; -0.00021	-0.2
75 + years	-0.0000039**	-0.0000066; -0.0000012	-0.004
SEIFA			
Least disadvantage	0.0000081	-0.0000085; 0.000025	0.01
Less disadvantage	-0.000020	-0.000053; 0.000013	-0.02
Moderate disadvantage	0.000056	-0.000060; 0.00017	0.1
High disadvantage	0.000061	-0.000015; 0.00014	0.1
Highest disadvantage	-0.00010	-0.00029; 0.000086	-0.1
Unknown	-0.000028	-0.000075; 0.000018	-0.2
ARIA			
Major cities	-0.00012**	-0.00020; -0.000034	-0.1
Inner regional areas	-0.00029*	-0.00052; -0.000055	-0.3
Outer regional areas	0.000076**	0.000027; 0.00013	0.1
Remote	0.000014	-0.0000095; 0.000037	0.01
Very Remote	0.000065**	0.000028; 0.00010	0.1
Unknown	-0.00015*	-0.00030; -0.0000086	-0.1
Major principal diagnoses			
Mental conditions	-0.00022***	-0.00028; -0.00017	-0.2
Circulatory conditions	0.00051***	0.00048; 0.00054	0.5
Digestive conditions	0.0010***	0.00096; 0.0011	0.9
Endocrine conditions	-0.00013***	-0.00016; -0.00011	-0.1
Musculoskeletal	0.0000029	-0.0000064; 0.000012	0.003
Respiratory	-0.000054***	-0.000080; -0.000028	-0.05
Injuries	0.0052***	0.0051; 0.0053	4.7
Cancer	0.000084***	0.000082; 0.000086	0.1
Number of morbidities			
0-1	-0.0021***	-0.0022; -0.0021	-1.9
2-5	0.0025***	0.0024; 0.0026	2.3
6 or more	0.0067***	0.0065; 0.0068	6.1
Private funding	0.0032***	0.0029; 0.0035	2.9

Unplanned admission	0.055***	0.055; 0.056	50.0
Transferred from secondary hospitals	-0.00073***	-0.00081; -0.00065	-0.7
Had surgical procedures in hospital	-0.0010***	-0.0012; -0.00092	-0.9
<b>2. Specific effect component</b>			
Sex	-0.00043	-0.0015; 0.00059	-0.4
Indigenous	0.00059***	0.00026; 0.00091	0.5
Age groups			
18-44 years	-0.0031***	-0.0037; -0.0025	-2.8
45-64 years	-0.00023	-0.00075; 0.00029	-0.2
65-74 years	0.00050*	0.00011; 0.00089	0.5
75 + years	0.0021***	0.0017; 0.0025	1.9
SEIFA			
Least disadvantage	0.00080	-0.00050; 0.0021	0.7
Less disadvantage	0.00054	-0.00037; 0.0014	0.5
Moderate disadvantage	0.00060	-0.00033; 0.0015	0.5
High disadvantage	0.00044	-0.00046; 0.0013	0.4
Highest disadvantage	0.00055	-0.00018; 0.0013	0.5
Unknown	-0.000070	-0.00017; 0.000031	-0.1
ARIA			
Major cities	0.0060*	0.00086; 0.011	5.5
Inner regional areas	0.00014	-0.00029; 0.00056	0.1
Outer regional areas	-0.00013	-0.00038; 0.00011	-0.1
Remote	-0.00050***	-0.00065; -0.00035	-0.5
Very Remote	-0.00032***	-0.00044; -0.00021	-0.3
Unknown	0.000092**	0.000037; 0.00015	0.1
Major principal diagnoses			
Mental conditions	-0.00062***	-0.00077; -0.00048	-0.6
Circulatory conditions	-0.0011***	-0.0014; -0.00087	-1.0
Digestive conditions	-0.0011***	-0.0014; -0.00087	-1.0
Endocrine conditions	0.000037	-0.00012; 0.00019	-0.1
Musculoskeletal	-0.0015***	-0.0018; -0.0012	-1.4
Respiratory	-0.00093***	-0.0011; -0.00076	-0.8
Injuries	0.00015	-0.000048; 0.00034	0.1
Cancer	-0.0022***	-0.0024; -0.0020	-2.0
Number of morbidities			
0-1	0.0019***	0.0015; 0.0024	1.7
2-5	0.0035***	0.0024; 0.0045	3.2
6 or more	-0.00089***	-0.0010; -0.00078	-0.8
Private funding	-0.00037***	-0.00057; -0.00017	-0.3
Unplanned admission	-0.0054***	-0.0064; -0.0044	-4.9
Transferred from secondary hospitals	-0.00089***	-0.0010; -0.00075	-0.8
Had surgical procedures in hospital	-0.00021**	-0.00035; -0.000062	-0.2
Constant	0.046***	0.041; 0.051	41.8

Note: \*\*\* if  $p$ -value < 0.001; \*\* if  $p$ -value < 0.01; \* if  $p$ -value < 0.05

Table 1B. Decomposition of the difference in the use of CT for unplanned admissions between two periods

	Number of CT per admission	95% CI	
<b>The use of CT</b>			
The past period	0.301	0.298; 0.304	
The recent period	0.418	0.414; 0.420	
<b>Difference</b>	<b>0.117</b>	<b>0.112; 0.120</b>	
<b>Decomposition of the difference</b>			
	Coefficient	95% CI	Percentage
Endowment component	0.020***	0.019; 0.021	17.1
Effect component	0.096***	0.092; 0.10	82.1
<b>Specific endowment</b>			
Sex	0.00096***	(0.00087; 0.0011)	0.8
Indigenous	-0.0024***	(-0.0026; -0.0021)	-2.0
Age groups			
18-44 years	0.0017***	(0.0016; 0.0019)	1.4
45-64 years	0.0011***	(0.00099; 0.0012)	0.9
65-74 years	-0.00011***	(-0.00012; -0.000092)	-0.1
75 + years	0.0000087***	(0.0000039; 0.000013)	0.01
SEIFA			
Least disadvantage	0.00023	(-0.000026; 0.00048)	0.2
Less disadvantage	0.000092	(-0.0000057; 0.00019)	0.1
Moderate disadvantage	0.00018	(-0.00021; 0.00057)	0.2
High disadvantage	-0.000023	(-0.000097; 0.000050)	-0.02
Highest disadvantage	-0.00036	(-0.0011; 0.00040)	-0.3
Unknown	-0.00021	(-0.00053; 0.00011)	-0.2
ARIA			
Major cities	-0.00043	(-0.0012; 0.00037)	-0.4
Inner regional areas	-0.00073	(-0.0019; 0.00040)	-0.6
Outer regional areas	-0.000031**	(-0.000053; -0.0000085)	-0.03
Remote	0.00000088	(-0.0000017; 0.0000035)	0.001
Very Remote	0.00014***	(0.000071; 0.00021)	0.1
Unknown	-0.00068	(-0.0013; -0.000048)	-0.6
Major principal diagnoses			
Mental conditions	0.00076***	(0.00065; 0.00087)	0.6
Circulatory conditions	-0.0039***	(-0.0043; -0.0036)	-3.3
Digestive conditions	0.00063***	(0.00058; 0.00069)	0.5
Endocrine conditions	0.00088***	(0.00073; 0.0010)	0.7
Musculoskeletal	-0.00062***	(-0.00077; -0.00047)	-0.5
Respiratory	0.0014***	(0.0011; 0.0016)	1.2
Injuries	0.0034***	(0.0032; 0.0035)	2.8
Cancer	-0.0042***	(-0.0044; -0.0040)	-3.5
Number of morbidities			
0-1	0.0020***	(0.0019; 0.0021)	1.7
2-5	0.0018***	(0.0017; 0.0019)	1.5

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3	6 or more	0.010***	(0.010; 0.011)	8.3
4	Private funding	0.0094***	(0.0084; 0.010)	7.8
5	Transferred from secondary hospitals	0.00049***	(0.00044; 0.00054)	0.4
6	Admission with surgical procedures	-0.0019***	(-0.0022; -0.0017)	-1.6
7				
8	<b>Specific effect component</b>			
9				
10	Sex	0.0035	(-0.00021; 0.0072)	2.9
11	Indigenous	0.00050	(-0.00051; 0.0015)	0.4
12	Age groups			
13	18-44 years	-0.013***	(-0.015; -0.010)	-10.8
14	45-64 years	-0.0011	(-0.0027; 0.00042)	-0.9
15	65-74 years	0.0015**	(0.00046; 0.0026)	1.3
16	75 + years	0.0083***	(0.0066; 0.0100)	6.9
17				
18	SEIFA			
19	Least disadvantage	0.0024	(-0.0023; 0.0071)	2
20	Less disadvantage	0.0023	(-0.00092; 0.0055)	1.9
21	Moderate disadvantage	0.0018	(-0.0015; 0.0051)	1.5
22	High disadvantage	0.0015	(-0.0017; 0.0047)	1.3
23	Highest disadvantage	0.0020	(-0.00063; 0.0046)	1.7
24	Unknown	-0.00034	(-0.00086; 0.00017)	-0.3
25				
26	ARIA			
27	Major cities	0.0024	(-0.016; 0.020)	2
28	Inner regional areas	0.00030	(-0.0013; 0.0019)	0.3
29	Outer regional areas	0.000092	(-0.00081; 0.00100)	0.1
30	Remote	-0.0016***	(-0.0021; -0.0010)	-1.3
31	Very Remote	-0.00099***	(-0.0014; -0.00056)	-0.8
32	Unknown	0.00058**	(0.00019; 0.00097)	0.5
33				
34	Major principal diagnoses			
35	Mental conditions	-0.0031***	(-0.0043; -0.0019)	-2.6
36	Circulatory conditions	-0.0045***	(-0.0061; -0.0029)	-3.8
37	Digestive conditions	-0.0034***	(-0.0047; -0.0022)	-2.8
38	Endocrine conditions	0.0010***	(0.00033; 0.0017)	0.8
39	Musculoskeletal	-0.0019***	(-0.0026; -0.0012)	-1.6
40	Respiratory	-0.0032***	(-0.0045; -0.0020)	-2.7
41	Injuries	0.0037***	(0.0021; 0.0053)	3.1
42	Cancer	-0.0044***	(-0.0050; -0.0038)	-3.7
43				
44	Number of morbidities			
45	0-1	0.0079***	(0.0064; 0.0093)	6.6
46	2-5	0.0024	(-0.00097; 0.0057)	2
47	6 or more	-0.0060***	(-0.0068; -0.0052)	-5
48	Private funding sources	-0.00020	(-0.00099; 0.00058)	-0.2
49	Transferred from secondary hospitals	-0.0090	(-0.010; -0.0078)	-7.5
50	Admission with surgical procedures	-0.0015**	(-0.0024; -0.00050)	-1.3
51	Constant	0.11***	(0.091; 0.12)	91.7

Note: \*\*\* if  $p$ -value < 0.001; \*\* if  $p$ -value < 0.01; \* if  $p$ -value < 0.05

**The RECORD statement – checklist of items, extended from the STROBE statement, that should be reported in observational studies using routinely collected health data.**

	Item No.	STROBE items	Location in manuscript where items are reported	RECORD items	Location in manuscript where items are reported
<b>Title and abstract</b>					
	1	(a) Indicate the study's design with a commonly used term in the title or the abstract (b) Provide in the abstract an informative and balanced summary of what was done and what was found		RECORD 1.1: The type of data used should be specified in the title or abstract. When possible, the name of the databases used should be included.  RECORD 1.2: If applicable, the geographic region and timeframe within which the study took place should be reported in the title or abstract.  RECORD 1.3: If linkage between databases was conducted for the study, this should be clearly stated in the title or abstract.	1.1 Abstract, data sources.  1.2 Abstract, data sources  1.3 Abstract, data sources.
<b>Introduction</b>					
Background rationale	2	Explain the scientific background and rationale for the investigation being reported			Introduction, lines 71-91
Objectives	3	State specific objectives, including any prespecified hypotheses			Introduction, lines 92-101
<b>Methods</b>					
Study Design	4	Present key elements of study design early in the paper			Methods- line 102-106 and Study population (line 121-134)
Setting	5	Describe the setting, locations, and relevant dates, including			Methods, data sources and study population

		periods of recruitment, exposure, follow-up, and data collection			
Participants	6	<p><i>(a) Cohort study</i> - Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up</p> <p><i>Case-control study</i> - Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls</p> <p><i>Cross-sectional study</i> - Give the eligibility criteria, and the sources and methods of selection of participants</p> <p><i>(b) Cohort study</i> - For matched studies, give matching criteria and number of exposed and unexposed</p> <p><i>Case-control study</i> - For matched studies, give matching criteria and the number of controls per case</p>		<p>RECORD 6.1: The methods of study population selection (such as codes or algorithms used to identify subjects) should be listed in detail. If this is not possible, an explanation should be provided.</p> <p>RECORD 6.2: Any validation studies of the codes or algorithms used to select the population should be referenced. If validation was conducted for this study and not published elsewhere, detailed methods and results should be provided.</p> <p>RECORD 6.3: If the study involved linkage of databases, consider use of a flow diagram or other graphical display to demonstrate the data linkage process, including the number of individuals with linked data at each stage.</p>	<p>6.1 Methods, study population and design.</p> <p>6.2 Methods, data sources.</p> <p>6.3 Methods, data source, reference 20 and 21</p>
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable.		RECORD 7.1: A complete list of codes and algorithms used to classify exposures, outcomes, confounders, and effect modifiers should be provided. If these cannot be reported, an explanation should be provided.	Methods, outcome measures, independent measures
Data sources/ measurement	8	For each variable of interest, give sources of data and details of methods of assessment (measurement).			Methods, data sources, outcome measures, and independent measures

		Describe comparability of assessment methods if there is more than one group			
Bias	9	Describe any efforts to address potential sources of bias			Methods, statistical methods line 171-184
Study size	10	Explain how the study size was arrived at			Methods and Results (187-190)
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why			Methods, outcome measure, and independent measures
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding (b) Describe any methods used to examine subgroups and interactions (c) Explain how missing data were addressed (d) <i>Cohort study</i> - If applicable, explain how loss to follow-up was addressed <i>Case-control study</i> - If applicable, explain how matching of cases and controls was addressed <i>Cross-sectional study</i> - If applicable, describe analytical methods taking account of sampling strategy (e) Describe any sensitivity analyses			Methods, statistical methods
Data access and cleaning methods		..		RECORD 12.1: Authors should describe the extent to which the investigators had access to the	12.1 Methods  12.2 Methods, data sources



				database population used to create the study population.  RECORD 12.2: Authors should provide information on the data cleaning methods used in the study.	
Linkage		..		RECORD 12.3: State whether the study included person-level, institutional-level, or other data linkage across two or more databases. The methods of linkage and methods of linkage quality evaluation should be provided.	12.3 Methods, data sources
<b>Results</b>					
Participants	13	(a) Report the numbers of individuals at each stage of the study ( <i>e.g.</i> , numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed) (b) Give reasons for non-participation at each stage. (c) Consider use of a flow diagram		RECORD 13.1: Describe in detail the selection of the persons included in the study ( <i>i.e.</i> , study population selection) including filtering based on data quality, data availability and linkage. The selection of included persons can be described in the text and/or by means of the study flow diagram.	13.1 Method, study population and Results (190-200)
Descriptive data	14	(a) Give characteristics of study participants ( <i>e.g.</i> , demographic, clinical, social) and information on exposures and potential confounders (b) Indicate the number of participants with missing data for each variable of interest (c) <i>Cohort study</i> - summarise follow-up time ( <i>e.g.</i> , average and total amount)			Results, lines 190-200 and Table 1

1 2 3 4 5 6 7 8 9 10 11	Outcome data	15	<p><i>Cohort study</i> - Report numbers of outcome events or summary measures over time</p> <p><i>Case-control study</i> - Report numbers in each exposure category, or summary measures of exposure</p> <p><i>Cross-sectional study</i> - Report numbers of outcome events or summary measures</p>			Results, Table 1
12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27	Main results	16	<p>(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval). Make clear which confounders were adjusted for and why they were included</p> <p>(b) Report category boundaries when continuous variables were categorized</p> <p>(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period</p>			<p>Results,</p> <p>(a) Figure 1, 2, and 3 and Appendix</p> <p>b) Categorisation provide in the methods</p> <p>c) NA</p>
28 29 30 31 32	Other analyses	17	Report other analyses done— e.g., analyses of subgroups and interactions, and sensitivity analyses			Methods lines 183-184
33	<b>Discussion</b>					
34 35	Key results	18	Summarise key results with reference to study objectives			Discussion, lines 262-277
36 37 38 39 40 41 42 43 44	Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias		RECORD 19.1: Discuss the implications of using data that were not created or collected to answer the specific research question(s). Include discussion of misclassification bias, unmeasured confounding, missing data, and changing eligibility over	Discussion, lines 340-351

				time, as they pertain to the study being reported.	
1 2 3 4 5 6 7 8 9	Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence		Discussion and Conclusion section (lines 352-365).
10 11 12 13 14	Generalisability	21	Discuss the generalisability (external validity) of the study results		Australian context clear in manuscript with discussion of relevant literature
15	<b>Other Information</b>				
16 17 18 19 20 21	Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based		Role of the funding source, lines 367-369
22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44	Accessibility of protocol, raw data, and programming code		..	RECORD 22.1: Authors should provide information on how to access any supplemental information such as the study protocol, raw data, or programming code.	22.1 Supplementary data provided to justify results and interpretation. Line 389-396: The data that support the findings of this study are available from the relevant data custodians of the study datasets. Restrictions by the data custodians mean that the data are not publicly available or able to be provided by the authors. Researchers

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					wishing to access the datasets used in this study should refer to the WA data linkage application process ( <a href="https://www.data-linkage-wa.org.au/access-and-application">https://www.data-linkage-wa.org.au/access-and-application</a> ).
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\*Reference: Benchimol EI, Smeeth L, Guttman A, Harron K, Moher D, Petersen I, Sørensen HT, von Elm E, Langan SM, the RECORD Working Committee. The REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) Statement. *PLoS Medicine* 2015; in press.

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