

1 **Title**

2 The impact of cross-jurisdictional patient flows on ascertainment of hospitalisations and
3 cardiac procedures for ST-segment-elevation myocardial infarction in an Australian
4 population.

5

6 **Authors**

7 Igic B, Farber R, Alfaro-Ramirez M, Nelson M, Taylor L K.

8

9 **Abstract**

10 **Introduction**

11 The patient journey for residents of New South Wales (NSW) Australia with ST-elevation
12 myocardial infarction (STEMI) often involves transfer between hospitals and these can
13 include stays in hospitals in other jurisdictions.

14

15 **Objective**

16 To estimate the change in enumeration of STEMI hospitalisations and time to subsequent
17 cardiac procedures for NSW residents using cross-jurisdictional linkage of administrative
18 health data.

19

20 **Methods**

21 Records for NSW residents aged 20 years and over admitted to hospitals in NSW and four
22 adjacent jurisdictions (Australian Capital Territory, Queensland, South Australia, and
23 Victoria) between 1 July 2013 and 30 June 2018 with a principal diagnosis of STEMI were
24 linked with records of the Australian Government Medicare Benefits Schedule (MBS). The
25 number of STEMI hospitalisations, and rates of angiography, percutaneous coronary
26 intervention and coronary artery bypass graft were compared for residents of different local
27 health districts within NSW with and without inclusion of cross-jurisdictional data.

28

29 **Results**

30 Inclusion of cross-jurisdictional hospital and MBS data increased the enumeration of STEMI
31 hospitalisations for NSW residents by 8% (from 15,420 to 16,659) and procedure rates from
32 85.6% to 88.2%. For NSW residents who lived adjacent to a jurisdictional border,
33 hospitalisation counts increased by up to 210% and procedure rates by up to 70 percentage
34 points.

35

36 **Conclusions**

37 Cross-jurisdictional linked hospital data is essential to understand patient journeys of NSW
38 residents who live in border areas and to evaluate adherence to treatment guidelines for
39 STEMI. MBS data are useful where hospital data are not available and for procedures that
40 may be conducted in out-patient settings.

41

42 **Abstract word count:** 250

43

44 **Keywords**

45 Linked data, linked records, health administrative data, hospitalisation, heart attack, STEMI,
46 angiography, percutaneous coronary intervention, coronary artery bypass graft.

47

48 **Introduction**

49 Ischaemic heart disease is a major cause of death and hospitalisation in New South Wales
50 (NSW) [1]. New South Wales (NSW) is the most populous jurisdiction in Australia and is
51 home to one third of the Australian population (Figure 1). In Australia, healthcare is
52 provided by both state-based and federally funded services. In NSW, the state-based health
53 care services are provided by 15 Local Health Districts (LHDs), each responsible for providing
54 public hospital and ambulatory health services for their respective residents (Figure 2).
55 There is also a large private sector including private hospitals and private care within the
56 public hospitals. The cost of private and outpatient healthcare is subsidised by a federal
57 fund universal public health insurance system. Between July 2017 and June 2018, there
58 were almost 3 million inpatient episodes of care (records) for residents of NSW (34,621
59 records per 100,000 population), of which approximately 158,000 (5.3%) were for
60 circulatory diseases (1,660 records per 100,000 population) [1]. In 2018, approximately
61 14,600 NSW residents died from circulatory diseases, and 40% of these deaths were due to
62 ischemic heart disease, which includes ST-elevation myocardial infarction (STEMI) [1].

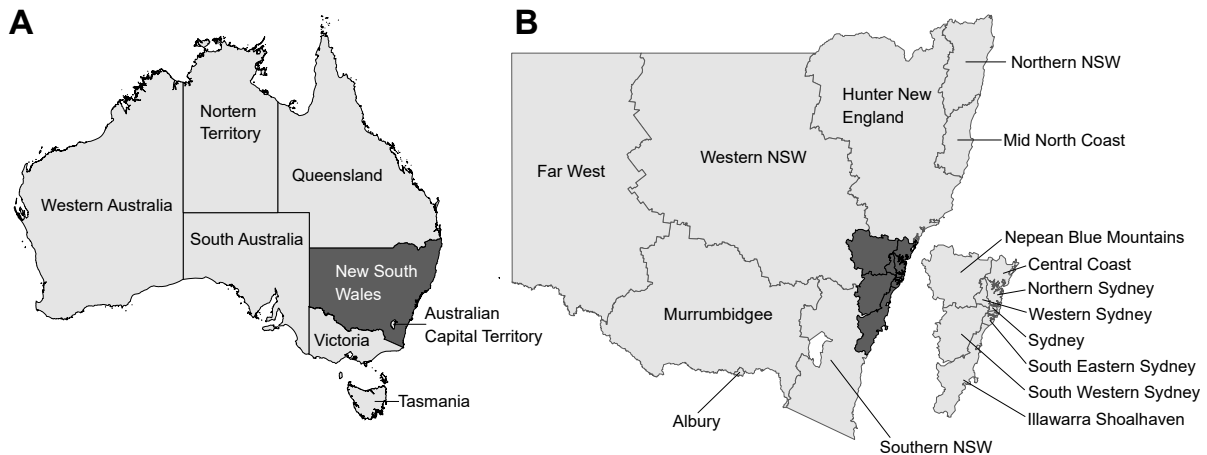
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64 After a STEMI, patient outcomes are related to timely assessment and revascularisation. A
65 STEMI is a type of heart attack caused by occlusion of some of the coronary arteries that
66 supply oxygen-rich blood to the heart and requires treatment for restoration of the blood
67 flow (revascularisation). Angiography is a diagnostic procedure used to visualise blood
68 vessels and assess blockages, whereas Percutaneous Coronary Intervention (PCI) and
69 Coronary Artery Bypass Graft (CABG) are procedures for restoring blood flow. There are
70 international guidelines relating to timelines for the assessment and treatment of Acute
71 Coronary Syndrome (ACS), including STEMI [2-8]. In NSW, the State Cardiac Reperfusion
72 Strategy aims to streamline services to minimise the time to treatment for suspected ACS
73 [10]. The NSW State Cardiac Reperfusion Strategy includes: pre-hospital assessment for
74 primary angioplasty, such as PCI, whereby a patient with a confirmed STEMI is immediately
75 transported to a cardiac catheterisation laboratory, bypassing other hospitals; pre-hospital
76 thrombolysis administered by paramedics; and clinical support and nurse administered
77 thrombolysis for small hospitals [8].

78

79 There are many challenges in providing timely treatment for STEMI in NSW, including both
80 geographical [9] and socioeconomic considerations [6, 10-12]. NSW is a large state (covering
81 809,444 square kilometres) with a large and diverse population. In 2017, the population in
82 NSW was approximately 7.9 million, which included 5.9 million people (75%) aged 20 years
83 and over, 5.9 million (75%) who lived in a major city, 1.5 million (19%) in inner regional
84 areas, around 480,000 (6%) in outer regional and remote areas, and over 275,000 (3%)
85 Aboriginal people [1, 13]. Geographic isolation means that treatment guidelines need to
86 consider unavoidable delays in the provision of treatment [9], whereas people in historically
87 disadvantaged groups (including Aboriginal people) are less likely to receive treatment
88 following cardiac events and have poorer outcomes [6, 10-12]. Furthermore, the available
89 resources for coronary care vary by hospital, and in remote areas of NSW, the nearest

90 facility with a cardiac catheterisation laboratory may be across a jurisdictional border - in
91 Queensland (QLD), Victoria (VIC), South Australia (SA), or the Australian Capital Territory
92 (ACT).



93
94 **Figure 1. (A) States and territories of Australia (B) Local Health Districts in NSW, 2017.**
95 **Inset shows detail of the Sydney metropolitan area.**

96 §Albury Local Government Area is reported separately as Albury hospital is managed under
97 contract by Albury Wodonga Health who provide services to Northern VIC and Southern
98 NSW.

99

100 The patient journey of NSW residents with a STEMI often involves transfers between
101 hospitals, and these can include stays in hospitals outside NSW. Failing to account for cross-
102 jurisdictional transfers may underestimate both hospitalisation and provision of treatment
103 [14, 15]. The care and treatment of a person following a STEMI event may be reported in
104 more than one record within unlinked administrative data. Using linked data permits a
105 better understanding of the patient journey by accounting for transfers between hospitals
106 and procedures performed in subsequent admissions or in a non-admitted patient settings
107 [10-12]. Where parts of the patient journey are outside of NSW, incorporating linked
108 hospital data from other jurisdictions may create a more complete picture of the patient
109 journey and improve the enumeration of STEMI events and cardiac procedures compared
110 with using NSW hospital data alone.

111

112 The Medicare Benefit Schedule (MBS) is an additional important source of information for
113 capturing the provision of treatment and dates of procedures [16-18]. The MBS is Australia's
114 universal public health insurance system that administers claims-based payment or co-
115 payment for health services other than those in public hospitals and community health
116 centres. It contains information on dates of procedures carried out in private hospitals and
117 outpatient clinics across Australia; however, it does not contain information on diseases,
118 conditions, or location of treatment [16-18].

119

120 The objective of this study was to estimate the change in enumeration of STEMI
121 hospitalisations and time to subsequent angiography, PCI, and CABG procedures for NSW
122 residents using cross-jurisdictional linkage of hospital and MBS data.

123

124 **Methods**

125 **Study design**

126 Observational cohort study using linked population health data.

127

128 **Study population**

129 NSW residents aged 20 years and over admitted to hospital for STEMI between 1 July 2013
130 to 30 June 2018 in NSW and adjacent jurisdictions (ACT, QLD, SA, and VIC).

131

132 **Data sources**

133 De-identified linked records of the following data collections: NSW Admitted Patient Data
134 Collection, ACT Admitted Patient Collection, QLD Hospital Admitted Patient Data Collection,
135 VIC Admitted Episodes Dataset, SA Inpatient Hospital Separations, MBS, and National Death
136 Index (NDI) data. For NSW and QLD, records for all public and private hospitals were
137 included; for ACT, SA, and VIC, records for public hospitals were included. MBS data are only
138 available for cardiac procedures of private patients treated in public or private hospitals and
139 patients treated in outpatient clinics.

140

141 **Data linkage**

142 Linkage was carried out by the Centre for Health Record Linkage for NSW and ACT data [19];
143 Centre for Victorian Data Linkage for VIC data [20]; Queensland Statistical Analysis and
144 Linkage Unit for QLD data [21]; SA NT DataLink for SA data [22]; the Australian Institute of
145 Health and Welfare Data Linkage Unit (AIHWDLU) for MBS and NDI records and cross-
146 jurisdictional linkage of hospital records [23]. In summary, jurisdictional data linkage units
147 carried out linkage of their respective datasets and assigned a jurisdictional Project Person
148 Number (PPN) to groups of records for the same person in the Study Population within the
149 jurisdiction. Jurisdictions provided jurisdictional PPNs and personal identifiers to the
150 AIHWDLU, which linked the jurisdictional datasets, MBS and NDI records and assigned a
151 national PPN. The AIHWDLU supplied the national PPNs to the respective jurisdictions,
152 which supplied the jurisdictional content data with national PPNs to the investigators.
153 AIHWDLU supplied MBS and NDI data with national PPNs directly to the investigators. The
154 investigators compiled the contributed datasets into a single dataset for analysis.

155

156 **Definitions**

157 *Aboriginal*: Includes both Aboriginal and Torres Strait Islander people. An Enhanced
158 Reporting of Aboriginality (ERA) variable was created using a weight of evidence from linked
159 records for each person to correct for the under-reporting of Aboriginal people on
160 administrative health data (Table S1) [24].

161

162 *Cardiac procedure*: Angiography, PCI and CABG reported on hospital or MBS records using
163 codes shown in Table S2. Where a PCI was reported, angiography was also considered to
164 have been carried out. Recording date of the procedure is mandatory for the first reported
165 procedure on admitted patient records and may also be reported for other procedures.

166

167 *Geographic Remoteness*: 2016 Accessibility and Remoteness Index of Australia (ARIA+)
168 classified based on the Statistical Local Area or Statistical Area of residence [13]. ARIA+ is a
169 continuous score based on the road distance to service towns of different sizes. We

170 categorised geographic remoteness into three categories of accessibility: Major Cities
171 defined as areas with relatively unrestricted accessibility (score less than or equal to 0.20);
172 Inner Regional areas defined as those with some restrictions to accessibility (score 0.20 to
173 2.40); and Outer Regional & Remote areas defined as those with significantly restricted
174 accessibility to goods (score greater than 2.40).

175

176 *NSW resident*: Person with a Statistical Local Area or Statistical Area of residence in NSW as
177 defined by the Australian Bureau of Statistics [25], derived from residential address
178 information on the first hospital record for a STEMI Hospitalisation.

179

180 *STEMI Hospitalisation*: A continuous period of hospital care represented by linked
181 contiguous hospital records that start with an acute care record and urgency of admission of
182 'emergency' and has either a principal diagnosis of STEMI on the initial record or a cardiac
183 principal diagnosis (Table S3) on the initial record with a subsequent record with a principal
184 diagnosis of STEMI within 24 hours of initial admission (i.e., a record following transfer to
185 another facility).

186

187 *Time to cardiac procedure*: Elapsed days between the date of initial STEMI hospitalisation
188 and the date of earliest angiography, PCI, or CABG procedure from linked hospital or MBS
189 records.

190

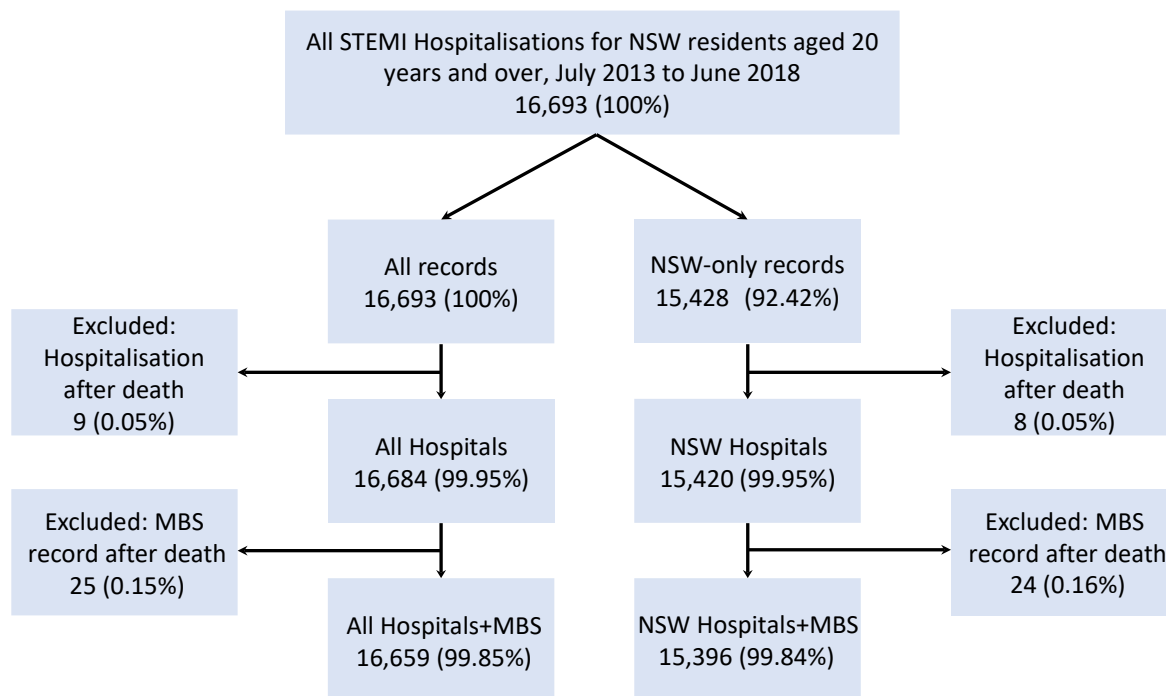
191 **Data preparation**

192 Prior to analysis, we created four cohort datasets:

- 193 1. "NSW Hospitals" – NSW hospital records for NSW residents, linked to NDI death records
194 with NSW as state of registration.
- 195 2. "NSW Hospitals+MBS" – NSW hospital records for NSW residents, linked to all NDI
196 death records and MBS records.
- 197 3. "All Hospitals" – ACT, NSW, QLD, SA, VIC hospital records for NSW residents, linked to
198 all NDI death records.
- 199 4. "All Hospitals+MBS" – ACT, NSW, QLD, SA, VIC hospital records for NSW residents,
200 linked to all NDI death records and MBS records.

201

202 For each of the above cohort datasets, we created records of STEMI Hospitalisations by
203 merging contiguous and overlapping hospital records to create continuous periods of
204 hospital care accounting for transfers across facilities: 15,428 for the NSW Hospitals
205 datasets and 16,693 for the All Hospitals datasets. We excluded linked records from each
206 cohort where the hospital admission dates or MBS item service dates were after the date of
207 death (0.1% to 0.2% of linked records) (Figure 2). There were 15,420 hospitalisations in the
208 NSW Hospitals cohort, 15,396 hospitalisations in the NSW Hospitals+MBS cohort, 16,684
209 hospitalisations in the All Hospitals cohort, and 16,659 hospitalisations in the All
210 Hospital+MBS cohort. For the All Hospitals datasets, we also categorised hospitalisations as
211 being entirely within NSW, entirely outside NSW, or included a transfer across the NSW
212 border. The NSW Hospitals and All Hospitals + MBS cohorts provide a comparison of single
213 jurisdiction and cross-jurisdiction linkage projects to enumerate STEMI and STEMI
214 treatments for NSW residents.



216

217

Figure 2. Flow diagram with study inclusion and exclusion criteria.

218

219 We calculated the elapsed days between date of initial STEMI hospitalisation and dates of
 220 earliest angiography, PCI, and CABG from hospital and MBS records. Approximately 9,425
 221 hospital records (56.6%) were missing a date for a reported angiography, PCI, or CABG
 222 procedure (4.0% of first reported procedures and 55.4% of additional procedures were
 223 missing a date). In these cases, we applied the following logic: (a) where angiography and
 224 PCI were reported on the same hospital record, and the date was reported for one
 225 procedure, the date was used for both procedures; (b) where angiography and CABG were
 226 reported together on the same hospital record, and the angiography date was missing, the
 227 date of CABG was used; (c) where a procedure date was missing and the hospital stay was
 228 24 hours or less, the procedure was assumed to have happened within a day of admission;
 229 (d) where procedure date was missing on the hospital record and the procedure was
 230 reported on the MBS with a service date within the hospital stay, the MBS date was used. In
 231 the All Hospitals+MBS dataset, 1.2% of angiography dates, 1.0% of PCI dates, and 3.0% of
 232 CABG dates were extracted from the MBS; (e) For the 868 (5.2%) remaining hospital
 233 records, time to procedure was imputed using statistical models (see statistical analysis).

234

235 **Statistical analysis**

236 We calculated the proportion of STEMI Hospitalisations which were followed by an
 237 angiography or a PCI (within 7 days of admission) or a CABG (within 28 days of admission)
 238 using a survival analysis (Kaplan-Meier curve) with death before procedure treated as a
 239 competing risk. For hospital records with missing procedure dates, we used negative
 240 binomial general additive models to impute time to procedure. We created separate models
 241 per procedure type using all hospital records with valid procedure dates. Each model had
 242 time to procedure as the response (as elapsed days from admission), with age of patient,

243 geographic remoteness of residence, year of admission, hospital type (public or private),
244 and length of stay as predictors. Overall, time to procedure was imputed for 5.3% of
245 angiographies, 5.4% of PCIs, and 4.0% of CABGs for STEMI Hospitalisations in the All
246 Hospitals+MBS dataset. For STEMI Hospitalisations where angiography was carried out, the
247 percentage with angiography being undertaken within 7 days of admission was similar
248 between hospitalisations with valid dates (98%) and those with imputed dates (99%). The
249 same was true for PCIs undertaken within 7 days (96% vs. 98%) and CABGs carried out
250 within 28 days (72% vs. 70%). We carried out data preparation and imputation using SAS
251 Enterprise Guide 7.15 [26] and survival analysis using the survival package 3.1-8 in R (version
252 3.6.3) [27, 28].
253

254 **Results**

255 **STEMI hospitalisations**

256 In 2013-14 to 2017-18, for NSW residents aged 20 years and over, there were 15,420 STEMI
257 Hospitalisations in the NSW Hospitals dataset, 15,396 in the NSW Hospitals +MBS dataset,
258 16,684 All Hospitals dataset, and 16,659 in the All Hospitals+MBS dataset. Demographic
259 characteristics were similar between the datasets (Table 1): approximately 72% of
260 hospitalisations were for men, 4% were for Aboriginal people, 27% were for people aged
261 over 75 years, and 67% were for people living in a major city (Table 1).

Table 1. Characteristics of STEMI hospitalisations by cohort dataset

Demographic group	NSW Hospitals No. (%)	NSW Hospitals+MBS No. (%)	All Hospitals No. (%)	All Hospitals+MBS No. (%)	NSW Hospitals vs. All Hospitals+MBS Difference (%)
Sex					
Males	10993 (71.3)	10979 (71.3)	11980 (71.8)	11965 (71.8)	972 (8.8)
Females	4426 (28.7)	4416 (28.7)	4703 (28.2)	4693 (28.2)	267 (6.0)
Aboriginality					
Aboriginal	618 (4.0)	668 (4.3)	680 (4.1)	735 (4.4)	117 (18.9)
Non-Aboriginal	14789 (95.9)	14716 (95.6)	15979 (95.8)	15900 (95.4)	1111 (7.5)
Age (years)					
<35	137 (0.9)	137 (0.9)	145 (0.9)	145 (0.9)	8 (5.8)
35-44	856 (5.6)	856 (5.6)	935 (5.6)	935 (5.6)	79 (9.2)
45-54	2625 (17.0)	2621 (17.0)	2852 (17.1)	2848 (17.1)	223 (8.5)
55-64	3874 (25.1)	3870 (25.1)	4201 (25.2)	4196 (25.2)	322 (8.3)
65-74	3570 (23.2)	3568 (23.2)	3941 (23.6)	3939 (23.6)	369 (10.3)
75-84	2633 (17.1)	2630 (17.1)	2828 (17.0)	2825 (17.0)	192 (7.3)
85+	1725 (11.2)	1714 (11.1)	1782 (10.7)	1771 (10.6)	46 (2.7)
Remoteness					
Major cities	10774 (69.9)	10756 (69.9)	11128 (66.7)	11110 (66.7)	336 (3.1)
Inner regional	3280 (21.3)	3277 (21.3)	3993 (23.9)	3990 (24)	710 (21.6)
Outer regional & remote	1326 (8.6)	1323 (8.6)	1524 (9.1)	1520 (9.1)	194 (14.6)
Total¹	15420 (100)	15396 (100)	16684 (100)	16659 (100)	1239 (8.0)

¹Total includes NSW residents whose demographic information was unknown.

Table 2. STEMI hospitalisations by Local Health District of residence and cohort dataset

Local Health District	NSW Hospitals No. (%)	NSW Hospitals+MBS No. (%)	All Hospitals No. (%)	All Hospitals+MBS No. (%)	NSW Hospitals vs. All Hospitals+MBS Difference (%)
No border with another Australian jurisdiction					
Sydney	927 (6.0)	926 (6.0)	934 (5.6)	933 (5.6)	6 (0.6)
South Western Sydney	1653 (10.7)	1652 (10.7)	1679 (10.1)	1678 (10.1)	25 (1.5)
South Eastern Sydney	1514 (9.8)	1512 (9.8)	1535 (9.2)	1533 (9.2)	19 (1.3)
Illawarra	1018 (6.6)	1015 (6.6)	1034 (6.2)	1031 (6.2)	13 (1.3)
Shoalhaven	1817 (11.8)	1813 (11.8)	1833 (11.0)	1829 (11.0)	12 (0.7)
Western Sydney	821 (5.3)	819 (5.3)	833 (5)	831 (5.0)	10 (1.2)
Nepean Blue Mountains	1454 (9.4)	1452 (9.4)	1473 (8.8)	1471 (8.8)	17 (1.2)
Northern Sydney	833 (5.4)	832 (5.4)	856 (5.1)	855 (5.1)	22 (2.6)
Central Coast	608 (3.9)	608 (3.9)	623 (3.7)	623 (3.7)	15 (2.5)
Coast	Border with another Australian jurisdiction				
Hunter New England	2575 (16.7)	2571 (16.7)	2638 (15.8)	2633 (15.8)	58 (2.3)
Northern NSW	492 (3.2)	491 (3.2)	821 (4.9)	820 (4.9)	328 (66.7)
Southern NSW	206 (1.3)	206 (1.3)	645 (3.9)	645 (3.9)	439 (213.1)
Murrumbidgee	507 (3.3)	507 (3.3)	650 (3.9)	650 (3.9)	143 (28.2)
Western NSW	858 (5.6)	855 (5.6)	867 (5.2)	864 (5.2)	6 (0.7)
Far West	49 (0.3)	49 (0.3)	113 (0.7)	113 (0.7)	64 (130.6)
Albury	48 (0.3)	48 (0.3)	111 (0.7)	111 (0.7)	63 (131.3)
Total¹	15420 (100)	15396 (100)	16684 (100)	16659 (100)	1239 (8.0)

265 ¹ Total includes NSW residents whose Local Health District of residence was unknown.

266

267 The addition of cross-jurisdictional data increased the enumeration of STEMI
 268 Hospitalisations for NSW residents by 8%, and this increase was greatest for Aboriginal
 269 people and residents of regional and border LHDs (Table 1). The number of hospitalisations
 270 for Aboriginal people increased by 19%, and for residents of inner regional and outer

271 regional and remote areas by 22% and 15%, respectively. Across LHDs, the increase in
 272 enumeration was greatest for residents of Southern NSW LHD (213%), Albury Local
 273 Government Area (131%), Far West LHD (131%), and Northern NSW HD (67%), all of which
 274 share borders with other jurisdictions (Table 2).

275

276 Approximately 10% of all STEMI Hospitalisations across the study period included stays in
 277 non-NSW hospitals (Table 3). Of the 16,659 STEMI Hospitalisations in the All Hospitals+MBS
 278 dataset, 14,979 (89.9%) were entirely within NSW hospitals, 693 (4.2%) were entirely in
 279 non-NSW hospitals, and 987 (5.9%) included transfers between NSW and non-NSW
 280 hospitals (Table 3). Hospitalisations of residents in LHDs bordering another Australian
 281 jurisdiction were more likely to include stays in non-NSW hospitals (range: 1.3-84.3% of
 282 hospitalisations) than hospitalisations of residents in LHDs without borders to another
 283 Australian jurisdiction (0.9-2.8% of hospitalisations) (Table 3).

284

285 **Table 3. STEMI hospitalisations by source of record and Local Health District of residence**

Local Health District	Entirely within NSW Hospitals No. (%)	Includes stay in non-NSW Hospital No. (%)	All Hospitalisations No. (%)
No border with another Australian jurisdiction			
Sydney	923 (98.9)	10 (1.1)	933 (100)
South Western Sydney	1651 (98.4)	27 (1.6)	1678 (100)
South Eastern Sydney	1512 (98.6)	21 (1.4)	1533 (100)
Illawarra Shoalhaven	1015 (98.4)	16 (1.6)	1031 (100)
Western Sydney	1813 (99.1)	16 (0.9)	1829 (100)
Nepean Blue Mountains	819 (98.6)	12 (1.4)	831 (100)
Northern Sydney	1451 (98.6)	20 (1.4)	1471 (100)
Central Coast	831 (97.2)	24 (2.8)	855 (100)
Mid North Coast	608 (97.6)	15 (2.4)	623 (100)
Border with another Australian jurisdiction			
Hunter New England	2567 (97.5)	66 (2.5)	2633 (100)
Northern NSW	258 (31.5)	562 (68.5)	820 (100)
Southern NSW	101 (15.7)	544 (84.3)	645 (100)
Murrumbidgee	495 (76.2)	155 (23.8)	650 (100)
Western NSW	853 (98.7)	11 (1.3)	864 (100)
Far West	22 (19.5)	91 (80.5)	113 (100)
Albury	23 (20.7)	88 (79.3)	111 (100)
Total¹	14979 (89.9)	1680 (10.1)	16659 (100)

286 ¹Total includes NSW residents whose Local Health District of residence was unknown.

287

288 **STEMI procedure rates**

289 Cross-jurisdictional data slightly increased angiography and PCI rates for all NSW, and the
 290 increases were greatest for residents of regional and remote areas (Table 4 & 5). For total
 291 NSW, the additional data increased the angiography rate by 2.5 percentage points (Table 4)
 292 and PCI rate by 2.3 percentage points (Table 5). The increases were similar among the

293 various demographic groups, except for residents of regional and remote areas whose rates
 294 increased by 5.3-6.5 percentage points (Table 4 & 5). By contrast, the additional data
 295 resulted in negligible increases in CABG rates for total NSW and all demographic groups
 296 (Table 6).

297

298 **Table 4. Angiography within 7 days of STEMI admission by demographic group and cohort**
 299 **dataset**

Demographic group	NSW Hospitals (%)	NSW Hospitals+MBS (%)	All Hospitals (%)	All Hospitals+MBS (%)	NSW Hospitals vs. All Hospitals+MBS Percentage point change
Sex					
Males	89.8	90.6	91.5	92.1	2.3
Females	75.6	76.2	78.3	78.5	2.9
Aboriginality					
Aboriginal	88.5	88.6	90.7	90.7	2.2
Non-Aboriginal	85.6	86.3	87.7	88.1	2.5
Age (years)					
<35	94.9	94.9	93.8	93.8	-1.1
35-44	94.9	95.6	96.3	96.7	1.8
45-54	95.0	95.5	96.2	96.5	1.5
55-64	94.0	94.7	95.9	96.3	2.3
65-74	90.3	91.2	92.3	93.0	2.7
75-84	80.5	81.1	82.8	83.2	2.7
85+	46.2	47.0	48.2	48.7	2.5
Remoteness					
Major cities	88.4	89.0	89.0	89.4	1.0
Inner regional	80.3	81.6	86.1	86.8	6.5
Outer regional & remote	77.3	78.0	83.2	83.4	6.1
Total	85.7	86.4	87.8	88.2	2.5

300

301

Table 5. PCI within 7 days of STEMI admission by demographic group and cohort dataset

Demographic group	NSW Hospitals (%)	NSW Hospitals+MBS (%)	All Hospitals (%)	All Hospitals+MBS (%)	NSW Hospitals vs. All Hospitals+MBS Percentage point change
Sex					
Males	73.5	74.4	75.0	75.6	2.1
Females	57.4	58.0	59.4	59.7	2.3
Aboriginality					
Aboriginal	63.8	63.9	64.7	64.5	0.7
Non-Aboriginal	69.1	69.9	70.9	71.5	2.0
Age (years)					
<35	67.9	67.9	66.9	66.9	-1.0
35-44	77.6	78.3	78.8	79.3	1.7
45-54	79.6	80.3	80.1	80.7	1.1
55-64	78.2	79.0	79.7	80.2	2.0
65-74	72.2	73.0	73.9	74.5	2.3
75-84	59.8	60.5	61.8	62.2	2.4
85+	34.8	35.6	36.7	37.3	2.5
Remoteness					
Major cities	74.1	74.8	74.7	75.2	1.1
Inner regional	58.8	59.8	64.6	65.2	6.4
Outer regional & remote	51.4	52.2	56.2	56.7	5.3
Total	68.9	69.7	70.6	71.2	2.3

302

303 **Table 6. CABG within 28 days of STEMI admission by demographic group and cohort**
 304 **dataset**

Demographic Group	NSW Hospitals (%)	NSW Hospitals+MBS (%)	All Hospitals (%)	All Hospitals+MBS (%)	NSW Hospitals vs. All Hospitals+MBS Percentage point change
Sex					
Males	7.9	8.0	8.0	8.0	0.1
Females	3.6	3.6	3.7	3.7	0.1
Aboriginality					
Aboriginal	8.9	9.3	8.7	9.0	0.1
Non-Aboriginal	6.6	6.6	6.7	6.7	0.1
Age (years)					
<35	5.1	5.1	5.5	5.5	0.4
35-44	3.9	3.9	3.7	3.7	-0.2
45-54	6.2	6.3	6.3	6.4	0.2
55-64	8.1	8.2	8.2	8.3	0.2
65-74	9.5	9.6	9.3	9.4	-0.1
75-84	5.9	6.0	6.2	6.3	0.4
85+	0.8	0.8	0.8	0.8	0
Remoteness					
Major cities	5.9	5.9	5.9	5.9	0
Inner regional	7.3	7.5	7.6	7.7	0.4
Outer regional & remote	11.2	11.4	11.2	11.4	0.2
Total	6.7	6.7	6.7	6.8	0.1

305
 306 Cross-jurisdictional data dramatically increased angiography and PCI rates for border LHD
 307 residents. The magnitude of increase varied greatly across LHDs. For example, the reported
 308 percentage of hospitalisations where angiography was undertaken within 7 days increased
 309 by more than 70 percentage points for Far West LHD residents, by 70 percentage points for
 310 Southern NSW LHD residents, by 64 percentage points for Albury Local Government Area
 311 (LGA) residents, and by 25 percentage points for Northern NSW LHD residents (Table 7).
 312 Similar patterns were seen for the percentage of hospitalisations where PCI was undertaken
 313 within 7 days (Table 8). The increase in angiography and PCI rates for patients from LHDs
 314 bordering another Australian jurisdiction was mainly due to the inclusion of non-NSW
 315 hospital data, and to a lesser degree, the inclusion of MBS data (Tables 7 & 8). The marginal
 316 increases in angiography and PCI rates for LHDs without borders to another Australian
 317 jurisdiction were mainly due to inclusion of MBS data (Tables 7 & 8).

318
 319 In contrast to angiography and PCI, the addition of cross-jurisdictional data resulted in a
 320 small increase in CABG rates for all LHDs. The greatest increases were for Far west LHD (9
 321 percentage points) and Albury LGA (9 percentage points) (Table 9). These modest increases
 322 were mainly due to addition of non-NSW hospital records and to a lesser degree, MBS

323 records (Table 9). The additional data reduced CABG rates for several LHDs due to the
 324 addition of STEMI hospitalisations where CABG was not carried out (Table 9).

325

326 **Table 7. Angiography within 7 days of STEMI admission by Local Health District of residence**
 327 **and cohort dataset**

Local Health District	NSW Hospitals (%)	NSW Hospitals+MBS (%)	All Hospitals (%)	All Hospitals+MBS (%)	NSW Hospitals vs. All Hospitals+MBS Percentage point change
No border with another Australian jurisdiction					
Sydney	85.5	86.1	85.8	86.2	0.7
South Western Sydney	88.4	89.0	88.5	89.1	0.7
South Eastern Sydney	90.6	90.8	90.6	90.8	0.2
Illawarra Shoalhaven	86.1	86.3	86.2	86.4	0.3
Western Sydney	91.6	91.8	91.7	91.9	0.3
Nepean Blue Mountains	90.4	90.7	90.5	90.9	0.5
Northern Sydney	89.4	89.9	89.5	90.1	0.7
Central Coast	85.1	85.5	85.4	85.6	0.5
Mid North Coast	86.2	86.5	86.2	86.5	0.3
Border with another Australian jurisdiction					
Hunter New England	85.9	86.2	86.1	86.3	0.4
Northern NSW	61.2	68.2	85.6	86.2	25.0
Southern NSW	17.5	24.8	85.1	87.4	69.9
Murrumbidgee	80.5	81.1	84.3	84.6	4.1
Western NSW	90.2	90.4	90.4	90.6	0.4
Far West	<15	<15	70.8	72.6	np ²
Albury	20.8	37.5	81.1	84.7	63.9
Total¹	85.7	86.4	87.8	88.2	2.5

328 ¹ Total includes NSW residents whose Local Health District of residence was unknown.

329 ² Percentage based on small counts suppressed

330 **Table 8. PCI within 7 days of STEMI admission by Local Health District of residence and**
 331 **cohort dataset**

Local Health District	NSW Hospitals (%)	NSW Hospitals+MBS (%)	All Hospitals (%)	All Hospitals+MBS (%)	NSW Hospitals vs. All Hospitals+MBS Percentage point change
No border with another Australian jurisdiction					
Sydney	70.2	71.1	70.1	70.8	0.6
South Western Sydney	74.2	74.2	74.3	74.3	0.1
South Eastern Sydney	76.2	76.7	76.3	76.8	0.6
Illawarra Shoalhaven	65.9	66.1	66.0	66.2	0.3
Western Sydney	77.8	78.0	77.8	78.1	0.3
Nepean Blue Mountains	76.1	76.4	76.5	76.8	0.7
Northern Sydney	76.8	78.2	76.9	78.4	1.6
Central Coast	65.8	65.9	66.0	66.0	0.2
Mid North Coast	59.2	60.2	59.6	60.5	1.3
Border with another Australian jurisdiction					
Hunter New England	67.1	67.4	67.1	67.5	0.4
Northern NSW	48.2	55.0	69.1	70.0	21.8
Southern NSW	13.6	19.9	72.4	74.4	60.8
Murrumbidgee	54.2	54.6	57.4	57.5	3.3
Western NSW	65.3	65.5	65.6	65.9	0.6
Far West	<15	<15	38.9	38.9	np ²
Albury	12.5	22.9	66.7	69.4	56.9
Total¹	68.9	69.7	70.6	71.2	2.3

332 ¹ Total includes NSW residents whose Local Health District of residence was unknown.

333 ² Percentage based on small counts suppressed

334
335

Table 9. CABG within 28 days of STEMI admission by demographic group and cohort dataset

Local Health District	NSW Hospitals (%)	NSW Hospitals+MBS (%)	All Hospitals (%)	All Hospitals+MBS (%)	NSW Hospitals vs. All Hospitals+MBS Percentage point change
No border with another Australian jurisdiction					
Sydney	5.6	5.6	5.9	5.9	0.3
South Western Sydney	6.4	6.4	6.3	6.3	-0.1
South Eastern Sydney	7.3	7.3	7.2	7.2	-0.1
Illawarra Shoalhaven	11.6	11.6	11.7	11.7	0.1
Western Sydney	6.1	6.1	6.1	6.1	0
Nepean Blue Mountains	4.4	4.4	4.3	4.3	-0.1
Northern Sydney	4.9	4.9	4.9	4.9	0
Central Coast	6.8	6.9	7.0	7.0	0.2
Border with another Australian jurisdiction					
Hunter New England	5.0	5.1	5.2	5.2	0.2
Northern NSW	1.2	1.8	3.7	3.7	2.5
Mid North Coast	11.0	11.2	11.4	11.4	0.4
Southern NSW	<3	<3	4.5	5.3	np ²
Murrumbidgee	9.9	9.9	9.2	9.4	-0.5
Western NSW	12.6	12.6	12.6	12.6	0
Far West	0	<15	8.0	8.8	8.8
Albury	0	<12	9.0	9.0	9
Total¹	6.7	6.7	6.7	6.8	0.1

336
337

¹ Total includes NSW residents whose Local Health District of residence was unknown.

² Percentage based on small counts suppressed

338 **Discussion**

339 We demonstrated the advantages of using a national linkage project for enumeration of
340 STEMI hospitalisations and associated rates of angiography, PCI, and CABG for NSW
341 residents. This study included over 156 million linked records from six Australian
342 jurisdictions (five States and territories and the Federal government) and adds to the
343 growing body of work showing substantial benefits of cross-jurisdictional linkage projects
344 [15, 29, 30].

345
346 STEMI requires urgent assessment and treatment, and in NSW, patients with STEMI are
347 transferred to the nearest hospital with a cardiac catheterisation service, which may be in
348 an adjacent jurisdiction. We found that 10% of STEMI Hospitalisations for NSW residents
349 included stays in non-NSW hospitals. Incorporating non-NSW hospital records increased
350 enumeration of STEMI hospitalisations by 8%, and together with MBS data, the percentage
351 of STEMI hospitalisations where procedures were undertaken within 7 days of admission by
352 2.5 percentage points. When considering residents of LHDs with borders to another
353 Australian jurisdiction that has an inpatient medical facility, the enumeration of STEMI
354 hospitalisations increased by up to 213% and procedures rates increased by up to 70
355 percentage points. This was because up to 84% of STEMI hospitalisations for residents of
356 these LHDs may include stays in non-NSW hospitals. Our results illustrate that rates of
357 STEMI hospitalisation and revascularisation procedures for NSW residents are under-
358 estimated when using data only from NSW hospitals, and particularly for communities close
359 to the NSW border.

360
361 Although the addition of non-NSW hospital records increased enumeration of cardiac
362 procedures more so than the addition of MBS data, MBS data provided useful information
363 on the dates of procedures. The main advantage of MBS data is that it includes information
364 on procedures carried out for private patients or in outpatient clinics across Australia. This
365 means that even though our study may under-estimate the number of STEMI
366 hospitalisations due to missing private hospital data from ACT, SA, and VIC, we were able to
367 reasonably measure the overall rates of diagnostic and revascularisation procedures for
368 NSW residents. Furthermore, MBS data provided procedure date information for hospital
369 records without a valid date: 1% for angiography or PCI and 3% for CABG.

370
371 Our findings demonstrate that cross-jurisdictional linkage improves the reporting on
372 healthcare access for Aboriginal people in NSW. This is because a larger proportion of
373 Aboriginal people than non-Aboriginal people live in remote areas [1, 31]. The addition of
374 cross-jurisdictional data increased the enumeration of hospitalisations for Aboriginal people
375 more so than non-Aboriginal people. This greater relative increase for Aboriginal people was
376 due to both the inclusion of non-NSW hospitalisations and the additional sources of
377 evidence of Aboriginality provided by MBS data for the ERA algorithm [24]. Improved
378 reporting on healthcare access for Aboriginal people is particularly important given the
379 inequity of poorer healthcare outcomes for Aboriginal compared to non-Aboriginal people
380 [32, 33].

381
382 The strength of this study is that it is a large population-based study. However, the study is
383 limited by the absence of private hospital data from ACT, VIC, and SA, which may further

384 improve the enumeration of NSW residents admitted interstate and produce a better
385 picture of cross-border patient flows. The NSW State Reperfusion Strategy includes
386 fibrinolysis either as pre-hospital thrombolysis administered by paramedics or nurse
387 administered thrombolysis for small hospitals [8]. Information on fibrinolysis was not
388 included in the current study. Inclusion of ambulance and emergency department data in
389 future work would enable assessment of pre-hospital access to thrombolysis, pre-hospital
390 assessment for primary angioplasty, and elapsed time to receiving angiography and PCI from
391 first contact with the health system following STEMI. Our study focussed on STEMI because
392 of the clear clinical pathway directed by the NSW state reperfusion strategy. Since STEMI is
393 the most severe type of ACS, and recommendations include urgent assessment and
394 treatment at a cardiac catheterisation laboratory, which may require transport across a
395 jurisdictional border [8]. Future work should examine cross-border flows and treatment
396 pathways for other types of ACS, such as non-ST-elevation myocardial infarction and
397 unstable angina.

398

399 **Conclusion**

400 Cross-jurisdictional data are essential for examining the patient journeys of NSW residents
401 who live in border areas and to evaluate adherence to guidelines for treatment of STEMI.
402 MBS data improves capture of cardiac procedure activity for private patients.

403

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414 NT DataLink, and Australian Institute of Health Welfare Data Linkage Unit carried out data
415 linkage for the project. We thank an anonymous reviewer and Dr. Merran Smith for their
416 comments on earlier version of the manuscript.

417

418 **Statement on conflicts of interest**

419 The authors declare that they have no competing interests.

420

421 **Ethics Statement**

422 Ethical approval for the Better Cardiac Care Collaborative Data Linkage Project was obtained
423 from the NSW Aboriginal Health and Medical Research Council Ethics Committee (1087/15),
424 NSW Population and Health Service Research Ethics Committee (2015/03/580), ACT Health
425 Human Research Ethics Committee (ETH.3.15.048), and Australian Institute of Health
426 Welfare Ethics Committee (EO2019-4-1106), SA Department of Health and Wellbeing
427 Human Research Ethics Committee (HREC/19/SAH/34), SA Aboriginal Health Research Ethics

428 Committee (04-19-834), and ACT Calvary Public Hospital Human Research Ethics Committee
429 (15-2019).

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538

539	Abbreviations
540	ACT – Australian Capital Territory
541	ACS – Acute Coronary Syndrome
542	CABG – Coronary Artery Bypass Graft
543	ERA – Enhanced Reporting of Aboriginality
544	LGA – Local Government Area
545	LHD – Local Health District
546	MBS – Medicare Benefits Schedule
547	NDI – National Death Index
548	NSW – New South Wales
549	PCI – Percutaneous Coronary Intervention
550	QLD – Queensland
551	SA – South Australia
552	STEMI – ST-Elevation Myocardial Infarction
553	VIC – Victoria

1 **Supplementary materials for:**

2

3 Imputing time to cardiac procedures following acute myocardial infarction hospitalisation using Australian administrative health data

4

5 Iqic B, Farber R, Alfaro-Ramirez M, Nelson M, Taylor L K.

6

7 **Appendix A:**

8 **Table S1. Medicare Benefit Scheme items providing a source of evidence of Aboriginality for the Enhanced Reporting of Aboriginality**

9 **algorithm**

Category 1 Professional Attendances	Group A14 Health Assessments	Subgroup 2 Aboriginal And Torres Strait Islander Peoples Health Assessment	715
Category 8 Miscellaneous Services	Group M11 Allied Health Services For Indigenous Australians Who Have Had A Health Check	NA	81300-81360
	Group M12 Services Provided By A Practice Nurse Or Aboriginal And Torres Strait Islander Health Practitioner On Behalf OF A Medical Practitioner	Subgroup 3 Services Provided By A Practice Nurse Or Aboriginal And Torres Strait Islander Health Practitioner On Behalf OF A Medical Practitioner	10987

10

11 **Table S2. ICD-10-AM¹ ACHI² procedure codes [1]**

Hospital data

Angiography

38215-00 38218-00 38218-01 38218-02

PCI

38300-00 38303-00 38306-00 38306-01 38306-02 38309-00 38312-00 38312-01

38315-00 38318-00 38318-01 90218-00 90218-01 90218-02 90218-03 90218-01

CABG

38300-01 38303-01 38306-03 38306-04 38306-05 38497-00 38497-01 38497-02

38497-03 38497-04 38497-05 38497-06 38497-07 38500-00 38500-01 38500-02

38500-03 38500-04 38500-05 38503-00 38503-01 38503-02 38503-03 38503-04

38503-05 38505-00 90201-00 90201-01 90201-02 90201-03

Medicare Benefits Schedule items

Angiography

Category 3 Therapeutic Procedures Group T8 Surgical Operations Subgroup 6 Cardio-thoracic Subheading 1 Cardiology procedures 38215-38246

PCI

Category 3 Therapeutic Procedures Group T8 Surgical Operations Subgroup 6 Cardio-thoracic Subheading 8 Surgery for ischaemic heart disease 38300-38318

CABG

Category 3 Therapeutic Procedures Group T8 Surgical Operations Subgroup 6 Cardio-thoracic Subheading 3 Endovascular interventional procedures 38497-38504

12 ¹ International Statistical Classification of Diseases and Related Health Problems, Australian Modification

13 ² Australian Classification of Health Interventions

14 **Table S3. Diagnosis codes (ICD-10-AM [1])**

ST-elevation myocardial infarction (STEMI) principal diagnosis:

I21.0 - I21.3, I22.0, I22.1, I22.8

Cardiac principal diagnosis:

I00-I02, I05-I09, I10 – I15, I20 – I25, I30-I52, I70 – I72, I74, I77.0, R00, R01, R03, R07

15 ¹International Statistical Classification of Diseases and Related Health Problems, Australian Modification

16

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