

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**

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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 by
32 2.5% (from 85.6% to 88.2%). For NSW residents who lived adjacent to a jurisdictional
33 border, hospitalisation counts increased by up to 210% and procedure rates by up to 70%.

34

35 **Conclusions**

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

40

41 **Abstract word count:** 250

42

43 **Keywords**

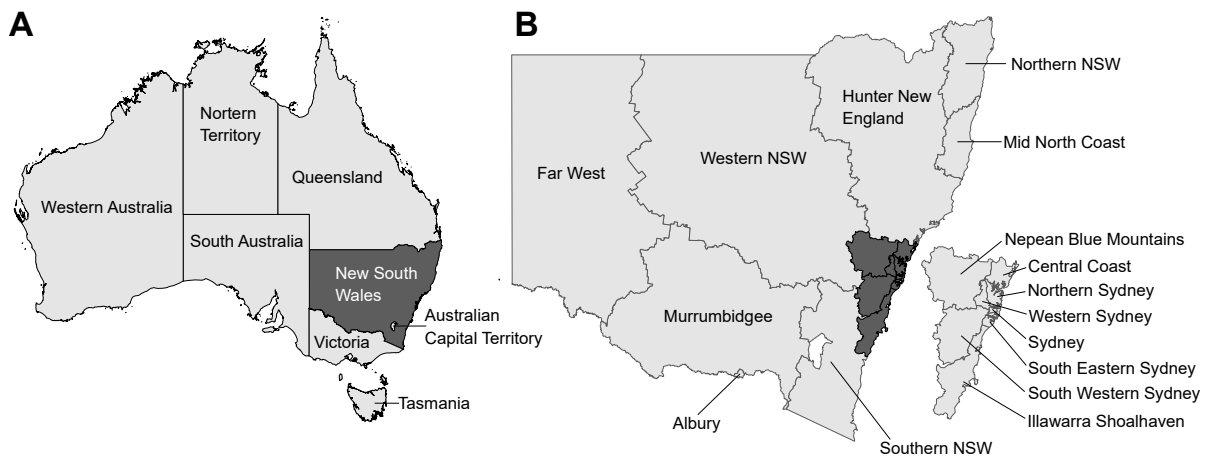
44 Linked data, linked records, health administrative data, hospitalisation, heart attack, STEMI,
45 angiography, percutaneous coronary intervention, coronary artery bypass graft.

46 **Introduction**

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

61
62 After a STEMI, patient outcomes are related to timely assessment and revascularisation. A
63 STEMI is a type of heart attack with occlusion of some of the coronary arteries that supply
64 oxygen-rich blood to the heart and requires treatment for restoration of the blood flow
65 (revascularisation). Angiography is a diagnostic procedure used to visualise blood vessels
66 and assess blockages, whereas Percutaneous Coronary Intervention (PCI) and Coronary
67 Artery Bypass Graft (CABG) are procedures for restoring blood flow. There are international
68 guidelines relating to timelines for the assessment and treatment of management of Acute
69 Coronary Syndrome (ACS), including STEMI [2-8]. In NSW, the State Cardiac Reperfusion
70 Strategy aims to streamline services to minimise the time to treatment for suspected ACS
71 [10]. The NSW State Cardiac Reperfusion Strategy includes: pre-hospital assessment for
72 primary angioplasty, such as PCI, whereby a patient with a confirmed STEMI is immediately
73 transported to a cardiac catheterisation laboratory, bypassing other hospitals; pre-hospital
74 thrombolysis administered by paramedics; and clinical support and nurse administered
75 thrombolysis for small hospitals [8].

76
77 There are many challenges in providing timely treatment for STEMI for residents of NSW,
78 including both geographical [9] and socioeconomic considerations [6, 10-12]. NSW is a large
79 state (covering 809,444 square kilometres) with a large and diverse population. In 2017, the
80 population in NSW was approximately 7.9 million, which included 5.9 million people (75%)
81 aged 20 years and over, 5.9 million (75%) who lived in a major city, 1.5 million (19%) in inner
82 regional areas, around 480,000 (6%) in outer regional and remote areas, and over 275,000
83 (3%) Aboriginal people [1, 13]. Geographic isolation means that treatment guidelines need
84 to consider unavoidable delays in the provision of treatment [9], whereas people in
85 historically disadvantaged groups (including Aboriginal people) are less likely to receive
86 treatment following cardiac events and have poorer outcomes [6, 10-12]. Furthermore, the
87 available resources for coronary care vary by hospital, and in remote areas of NSW, the
88 nearest facility with a cardiac catheterisation laboratory may be across a jurisdictional
89 border - in Queensland (QLD), Victoria (VIC), South Australia (SA), or the Australian Capital
90 Territory (ACT).



91
 92 **Figure 1. (A) States and territories of Australia (B) Local Health Districts in NSW, 2017.**
 93 **Inset shows detail of the Sydney metropolitan area.**

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

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

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

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

122 **Methods**

123 **Study design**

124 Observational cohort study using linked population health data.
 125

126 **Study population**

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

129

130 **Data sources**

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

138

139 **Data linkage**

140 Linkage was carried out by the Centre for Health Record Linkage for NSW and ACT data [19];
141 Centre for Victorian Data Linkage for VIC data [20]; Queensland Statistical Analysis and
142 Linkage Unit for QLD data [21]; SA NT DataLink for SA data [22]; the Australian Institute of
143 Health Welfare Data Linkage Unit for MBS and NDI records and cross-jurisdictional linkage
144 of hospital records [23].

145

146 **Definitions**

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

151

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

156

157 *Geographic Remoteness*: 2016 Accessibility and Remoteness Index of Australia (ARIA+)
158 classified based on the Statistical Local Area or Statistical Area of residence [13].

159

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

166

167 *Time to cardiac procedure*: the elapsed days between the date of initial STEMI
168 hospitalisation and the date of earliest angiography, PCI, or CABG procedure from linked
169 hospital or MBS records.

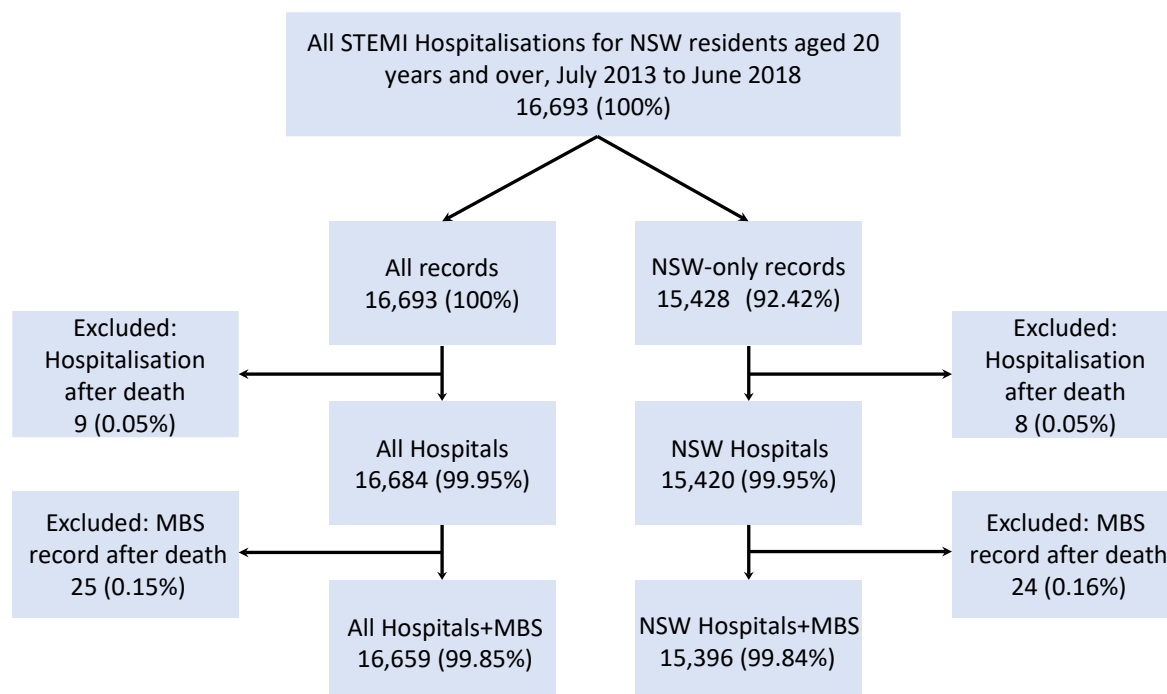
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Data preparation

Prior to analysis, we created four cohort datasets:

1. "NSW Hospitals" – NSW hospital records for NSW residents, linked to NDI death records with NSW as state of registration.
2. "NSW Hospitals+MBS" – NSW hospital records for NSW residents, linked to all NDI death records and MBS records.
3. "All Hospitals" – ACT, NSW, QLD, SA, VIC hospital records for NSW residents, linked to all NDI death records.
4. "All Hospitals+MBS" – ACT, NSW, QLD, SA, VIC hospital records for NSW residents, linked to all NDI death records and MBS records.

For each of the above cohort datasets, we created records of STEMI Hospitalisations by merging contiguous and overlapping hospital records to create a single record of continuous periods of hospital care accounting for transfers across facilities: 15,428 for the NSW Hospitals datasets and 16,693 for the All Hospitals datasets. We excluded linked records from each cohort where the hospital admission dates or MBS item service dates were after the date of death (0.1% to 0.2% of linked records) (Figure 2). There were 15,420 hospitalisations in the NSW Hospitals cohort, 15,396 hospitalisations in the NSW Hospitals+MBS cohort, 16,684 hospitalisations in the All Hospitals cohort, and 16,659 hospitalisations in the All Hospital+MBS cohort. For the All Hospitals datasets, we also categorised hospitalisations as being entirely within NSW, entirely outside NSW, or included a transfer across the NSW border.



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

197 We calculated the elapsed days between date of initial STEMI hospitalisation and dates of
198 earliest angiography, PCI, and CABG from hospital and MBS records. Approximately 9,425
199 hospital records (56.6%) were missing a date for a reported angiography, PCI, or CABG
200 procedure (4.0% of first reported procedures and 55.4% of additional procedures were
201 missing a date). In these cases, we applied the following logic: (a) where angiography and
202 PCI were reported on the same hospital record, and the date was reported for one
203 procedure, the date was used for both procedures; (b) where angiography and CABG were
204 reported together on the same hospital record, and the angiography date was missing, the
205 date of CABG was used; (c) where a procedure date was missing and the hospital stay was
206 24 hours or less, the procedure was assumed to have happened within a day of admission;
207 (d) where procedure date was missing on the hospital record and the procedure was
208 reported on the MBS with a service date within the hospital stay, the MBS date was used. In
209 the All Hospitals+MBS dataset, 1.2% of angiography dates, 1.0% of PCI dates, and 3.0% of
210 CABG dates were extracted from the MBS; (e) For the 868 (5.2%) remaining hospital
211 records, time to procedure was imputed using statistical models (see statistical analysis).

212

213 **Statistical analysis**

214 We calculated the proportion of STEMI Hospitalisations which were followed by an
215 angiography or a PCI (within 7 days of admission) or a CABG (within 28 days of admission)
216 using a survival analysis (Kaplan-Meier curve) with death before procedure treated as a
217 competing risk. For hospital records with missing procedure dates, we used negative
218 binomial general additive models to impute time to procedure. We created separate models
219 per procedure type using all hospital records with valid procedure dates. Each model had
220 time to procedure as the response (as elapsed days from admission), with age of patient,
221 geographic remoteness of residence, year of admission, hospital type (public or private),
222 and length of stay as predictors. Overall, time to procedure was imputed for 5.3% of
223 angiographies, 5.4% of PCIs, and 4.0% of CABGs for STEMI Hospitalisations in the All
224 Hospitals+MBS dataset. For STEMI Hospitalisations where angiography was carried out, the
225 percentage with angiography being undertaken within 7 days of admission was similar
226 between hospitalisations with valid dates (98%) and those with imputed dates (99%). The
227 same was true for PCIs undertaken within 7 days (96% vs. 98%) and CABGs carried out
228 within 28 days (72% vs. 70%). We carried out data preparation and imputation using SAS
229 Enterprise Guide 7.15 [25] and survival analysis using the survival package 3.1-8 in R (version
230 3.6.3) [26, 27].

231

232 **Results**

233 **STEMI hospitalisations**

234 In 2013-14 to 2017-18, for NSW residents aged 20 years and over, there were 15,420 STEMI
235 Hospitalisations in the NSW Hospitals dataset, 15,396 in the NSW Hospitals +MBS dataset,
236 16,684 All Hospitals dataset, and 16,659 in the All Hospitals+MBS dataset. Demographic
237 characteristics were similar between the datasets (Table 1): approximately 72% of
238 hospitalisations were for men, 4% were for Aboriginal people, 27% were for people aged
239 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					
<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 interstate border					
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					
Interstate border					
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)

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

244

245 The addition of non-NSW hospital and MBS records increased the enumeration of STEMI
 246 Hospitalisations for NSW residents by 8%, and this increase was greatest for Aboriginal
 247 people and residents of regional and border LHDs (Table 1). The number of hospitalisations
 248 for Aboriginal people increased by 19%, and for residents of inner regional and outer

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

253

254 Approximately 10% of all STEMI Hospitalisations across the study period included stays in
 255 non-NSW hospitals (Table 3). Of the 16,659 STEMI Hospitalisations in the All Hospitals+MBS
 256 dataset, 14,979 (89.9%) were entirely within NSW hospitals, 693 (4.2%) were entirely in
 257 non-NSW hospitals, and 987 (5.9%) included transfers between NSW and non-NSW
 258 hospitals (Table 3). Hospitalisations of border LHD residents were more likely to include
 259 stays in non-NSW hospitals (range: 1.3-84.3% of hospitalisations) than hospitalisations of
 260 non-border LHD residents (0.9-2.8% of hospitalisations) (Table 3).

261

262 **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 interstate border			
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)
Interstate border			
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)

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

264

265 STEMI procedure rates

266 Cross-jurisdictional and MBS data slightly increased angiography and PCI rates for all NSW,
 267 and the increases were greatest for residents of regional and remote areas (Table 4 & 5). For
 268 total NSW, the additional data increased the angiography rate by 2.5% (Table 4) and PCI rate
 269 from 2.3% for PCI (Table 5). The increases were similar among the various demographic
 270 groups, except for residents of regional and remote areas whose rates increase by 5.3-6.5%

271 (Table 4 & 5). By contrast, the additional data resulted in negligible increases in CABG rates
 272 for NSW and all demographic groups (Table 6).

273

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

Demographic group	NSW Hospitals (%)	NSW Hospitals+MBS (%)	All Hospitals (%)	All Hospitals+MBS (%)	NSW Hospitals vs. All Hospitals+MBS Difference (%)
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					
<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

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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 Difference (%)
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					
<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

278

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

Demographic Group	NSW Hospitals (%)	NSW Hospitals+MBS (%)	All Hospitals (%)	All Hospitals+MBS (%)	NSW Hospitals vs. All Hospitals+MBS Difference (%)
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					
<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

281
 282 Cross-jurisdictional and MBS dramatically increased angiography and PCI rates for border
 283 LHD residents. The magnitude of increase varied greatly across LHDs. For example, the
 284 reported percentage of hospitalisations where angiography was undertaken within 7 days
 285 increased by more than 70% for residents of Far West LHD, by 70% for Southern NSW LHD,
 286 by 64% for Albury Local Government Area (LGA), and by 25% for Northern NSW LHD (Table
 287 7). Similar patterns were seen for the percentage of hospitalisations where PCI was
 288 undertaken within 7 days (Table 8). The increase in percentage of patients from border LHDs
 289 that received angiography and PCI was mainly due to the inclusion of non-NSW hospital
 290 data, and to a lesser degree, the inclusion of MBS data (Tables 7 & 8). The marginal
 291 increases in angiography and PCI rates for non-border LHDs were mainly due to inclusion of
 292 MBS data (Tables 7 & 8).

293
 294 In contrast to angiography and PCI, the addition of cross-jurisdictional hospital and MBS
 295 data resulted in a small increase in CABG rates for all LHDs. The greatest increases were for
 296 Far west LHD (9%) and Albury LGA (9%) (Table 9). These modest increases were mainly due
 297 to addition of non-NSW hospital records and to a lesser degree, MBS records (Table 9). The
 298 additional data reduced CABG rates for several LHDs due to the addition of STEMI
 299 hospitalisations where CABG was not carried out (Table 9).

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

Local Health District	NSW Hospitals (%)	NSW Hospitals+MBS (%)	All Hospitals (%)	All Hospitals+MBS (%)	NSW Hospitals vs. All Hospitals+MBS Difference (%)
No interstate border					
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
Interstate border					
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

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

303 ² Percentage based on small counts suppressed

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

Local Health District	NSW Hospitals (%)	NSW Hospitals+MBS (%)	All Hospitals (%)	All Hospitals+MBS (%)	NSW Hospitals vs. All Hospitals+MBS Difference (%)
No interstate border					
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
Interstate border					
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

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

307 ²Percentage based on small counts suppressed

308
309

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 Difference (%)
No interstate border					
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
Interstate border					
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

310
311

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

²Percentage based on small counts suppressed

312 **Discussion**

313 We demonstrated the advantages of using a national linkage project for enumeration of
314 STEMI hospitalisations and associated rates of angiography, PCI, and CABG for NSW
315 residents. This study included over 156 million linked records from six Australian
316 jurisdictions (five States and territories and the Federal government) and adds to the
317 growing body of work showing substantial benefits of cross-jurisdictional linkage projects
318 [15, 28, 29].

319
320 STEMI requires urgent assessment and treatment, and in NSW, patients with STEMI are
321 transferred to the nearest hospital with a cardiac catheterisation service, which may be in
322 an adjacent jurisdiction. We found that 10% of STEMI Hospitalisations for NSW residents
323 included stays in non-NSW hospitals. Incorporating non-NSW hospital records and MBS data
324 increased enumeration of STEMI hospitalisations by 8% and the percentage of STEMI
325 hospitalisations where procedures were undertaken within 7 days of admission by 2.5%.
326 When considering border LHDs, the enumeration of STEMI hospitalisations increased by up
327 to 213% and the percentage of hospitalisations where patients received diagnostic or
328 revascularisation procedures by up to 70%. This was because up to 84% of STEMI
329 hospitalisations for a border LHDs residents may include stays in non-NSW hospitals. Our
330 results illustrate that rates of STEMI hospitalisation and revascularisation procedures for
331 NSW residents are under-estimated when using data only from NSW hospitals, and
332 particularly for communities close to the NSW border.

333
334 Although the addition of non-NSW hospital records increased enumeration of cardiac
335 procedures more so than the addition of MBS data, MBS data provided useful information
336 on dates of procedures. The main advantage of MBS data is that it includes information on
337 procedures carried for private patients or in outpatient clinics across Australia. This means
338 that even though our study may under-estimate the number of STEMI hospitalisations due
339 to missing private hospital data from ACT, SA, and VIC, we were able to reasonably measure
340 the overall rates of diagnostic and revascularisation procedures. Furthermore, MBS data
341 provided procedure date information for hospital records without a valid date: 1% for
342 angiography or PCI and 3% for CABG.

343
344 Our findings demonstrate that cross-jurisdictional linkage improves the reporting on
345 healthcare access for Aboriginal people in NSW. This is because a larger proportion of
346 Aboriginal people than non-Aboriginal people live in remote areas [1, 30]. The addition of
347 cross-jurisdictional data increased the enumeration of hospitalisations for Aboriginal people
348 more so than non-Aboriginal people. This greater relative increase for Aboriginal people was
349 due to both the inclusion of non-NSW hospitalisations and the additional sources of
350 evidence of Aboriginality provided by MBS data for the ERA algorithm [24]. Improved
351 reporting on healthcare access for Aboriginal people is particularly important given the
352 inequity of poorer healthcare outcomes for Aboriginal compared to non-Aboriginal people
353 [31, 32].

354
355 The strength of this study is that it is a large population-based study and reflects care
356 provided by the largest jurisdiction in Australia. However, the study is limited by the
357 absence of private hospital data from ACT, VIC, and SA, which may further improve the

358 enumeration of NSW residents admitted interstate and produce a better picture of cross-
359 border patient flows. The NSW State Reperfusion Strategy includes fibrinolysis either as pre-
360 hospital thrombolysis administered by paramedics or nurse administered thrombolysis for
361 small hospitals [8]. Information on fibrinolysis was not included in the current study and
362 inclusion of ambulance and emergency department data in future work would enable
363 assessment of pre-hospital access to thrombolysis, pre-hospital assessment for primary
364 angioplasty, and elapsed time to receiving angiography and PCI from first contact with the
365 health system following STEMI.

366

367 **Conclusion**

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

371

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382 NT DataLink, and Australian Institute of Health Welfare Data Linkage Unit carried out data
383 linkage for the project.

384

385 **Statement on conflicts of interest**

386 The authors declare that they have no competing interests.

387

388 **Ethics Statement**

389 Ethical approval for the Better Cardiac Care Collaborative Data Linkage Project was obtained
390 from the NSW Aboriginal Health and Medical Research Council Ethics Committee (1087/15),
391 NSW Population and Health Service Research Ethics Committee (2015/03/580), ACT Health
392 Human Research Ethics Committee (ETH.3.15.048), and Australian Institute of Health
393 Welfare Ethics Committee (EO2019-4-1106), SA Department of Health and Wellbeing
394 Human Research Ethics Committee (HREC/19/SAH/34), SA Aboriginal Health Research Ethics
395 Committee (04-19-834), and ACT Calvary Public Hospital Human Research Ethics Committee
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502

503 **Abbreviations**

- 504 ACT – Australian Capital Territory
505 ACS – Acute Coronary Syndrome
506 CABG – Coronary Artery Bypass Graft
507 ERA – Enhanced Reporting of Aboriginality
508 LGA – Local Government Area
509 LHD – Local Health District
510 MBS – Medicare Benefits Schedule
511 NDI – National Death Index
512 NSW – New South Wales
513 PCI – Percutaneous Coronary Intervention
514 QLD – Queensland
515 SA – South Australia
516 STEMI – ST-Elevation Myocardial Infarction
517 VIC – Victoria

1 **Supplementary materials for:**

2

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

6

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

8

9 **Appendix A:**

10 **Table S1. MBS items providing a source of evidence of Aboriginality for the ERA 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

11

12 **Table S2. Procedure codes**

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

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

13

14 **Table S3. Diagnosis codes (ICD10-AM)**

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