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

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Abstract

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

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

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

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

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

Keywords
linked data; linked records; health administrative data; hospitalisation; heart attack; STEMI; angiography; percutaneous coronary intervention; coronary artery bypass graft

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Introduction

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

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

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

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

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

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

Methods

Study design

Observational cohort study using linked population health data.

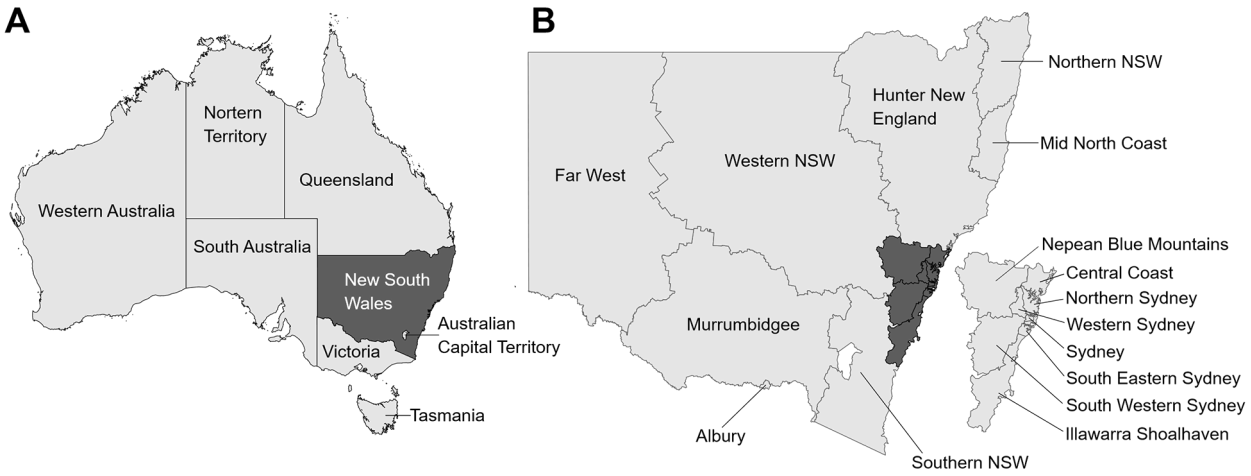
Study population

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

Data sources

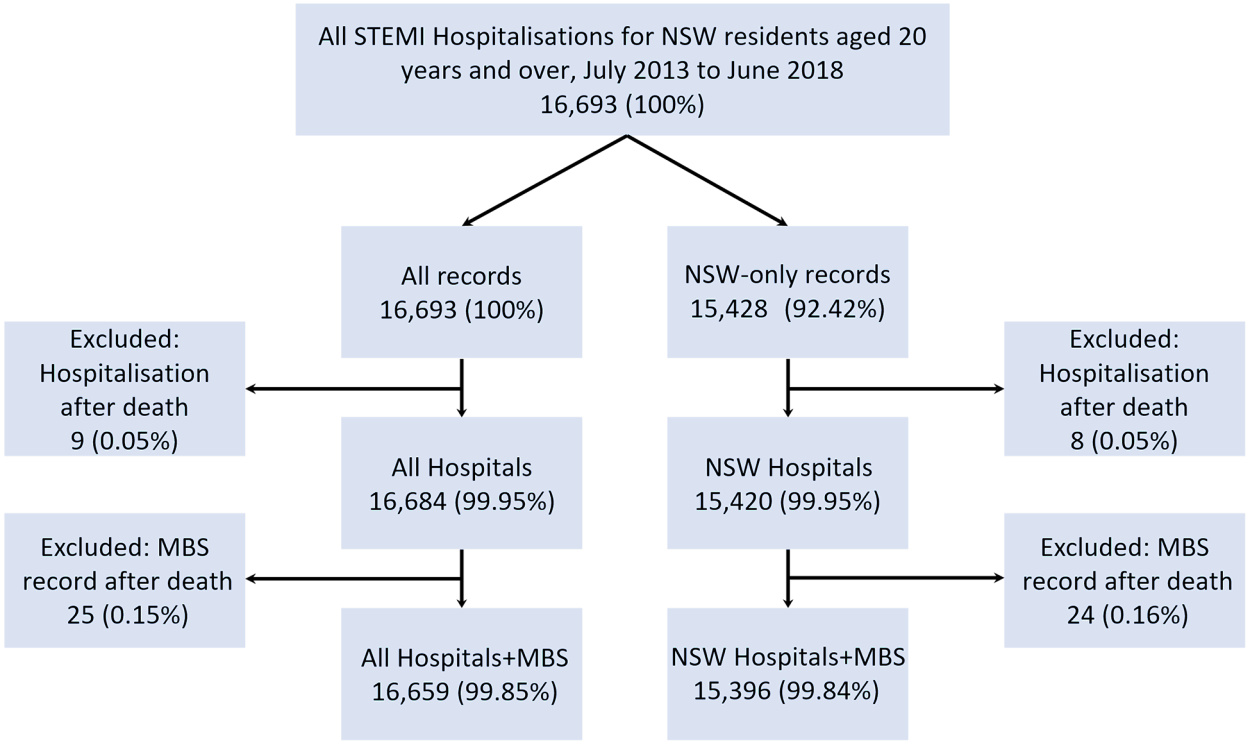
De-identified linked records of the following data collections: NSW Admitted Patient Data Collection, ACT Admitted Patient Collection, QLD Hospital Admitted Patient Data Collection, VIC Admitted Episodes Dataset, SA Inpatient Hospital Separations, MBS, and National Death Index (NDI) data. For NSW and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

Figure 1: (A) States and territories of Australia (B) local health districts in NSW. Inset shows detail of the Sydney metropolitan area



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

Figure 2: Flow diagram with study inclusion and exclusion criteria



Data linkage

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

Definitions

Aboriginal: Includes both Aboriginal and Torres Strait Islander people. An Enhanced Reporting of Aboriginality (ERA) variable was created using a weight of evidence from linked records for each person to correct for the under-reporting of Aboriginal people on administrative health data (Supplementary Table 1) [24].

Cardiac procedure: Angiography, PCI and CABG reported on hospital or MBS records using codes shown in Supplementary Table 2. Where a PCI was reported, angiography was also considered to have been carried out. Recording date of the procedure is mandatory for the first reported procedure on admitted patient records and may also be reported for other procedures.

Geographic remoteness: 2016 Accessibility and Remoteness Index of Australia (ARIA+) classified based on the Statistical Local Area or Statistical Area of residence [13]. ARIA+ is a continuous score based on the road distance to service towns of different sizes. We categorised geographic remoteness into three categories of accessibility: Major Cities defined as areas with relatively unrestricted accessibility (score less than or equal to 0.20); Inner Regional areas defined as those with some restrictions to accessibility (score 0.20 to 2.40); and Outer Regional and Remote areas defined as those with significantly restricted accessibility (score greater than 2.40).

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

STEMI hospitalisation: A continuous period of hospital care represented by linked contiguous hospital records that start with an acute care record and urgency of admission of 'emergency' and has either a principal diagnosis of STEMI on the initial record or a cardiac principal diagnosis (Supplementary Table 3) on the initial record with a subsequent record with a principal diagnosis of STEMI within 24 hours of initial admission (i.e., a record following transfer to another facility).

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

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 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. The NSW Hospitals and All Hospitals + MBS cohorts provide a comparison of single jurisdiction and cross-jurisdiction linkage projects to enumerate STEMI and STEMI treatments for NSW residents.

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

Statistical analysis

We calculated the proportion of STEMI Hospitalisations which were followed by an angiography or a PCI (within 7 days of admission) or a CABG (within 28 days of admission) using a survival analysis (Kaplan-Meier curve) with death before procedure treated as a competing risk. For hospital records with missing procedure dates, we used negative binomial general additive models to impute time to procedure. We created separate models per procedure type using all hospital records with valid procedure dates. Each model had time to procedure as the response (as elapsed days from admission), with age of patient, geographic remoteness of residence, year of admission, hospital type (public or private), and length of stay as predictors. Overall, time to procedure was imputed for

Table 1: Characteristics of STEMI hospitalisations by cohort dataset

Demographic group	NSW Hospitals	NSW Hospitals+MBS	All Hospitals	All Hospitals+MBS	NSW Hospitals vs. All Hospitals+MBS
	No. (%)	No. (%)	No. (%)	No. (%)	Difference (%)
Sex					
Males	10,993 (71.3)	10,979 (71.3)	11,980 (71.8)	11,965 (71.8)	972 (8.8)
Females	4,426 (28.7)	4,416 (28.7)	4,703 (28.2)	4,693 (28.2)	267 (6.0)
Aboriginality					
Aboriginal	618 (4.0)	668 (4.3)	680 (4.1)	735 (4.4)	117 (18.9)
Non-Aboriginal	14,789 (95.9)	14,716 (95.6)	15,979 (95.8)	15,900 (95.4)	1,111 (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	2,625 (17.0)	2,621 (17.0)	2,852 (17.1)	2,848 (17.1)	223 (8.5)
55–64	3,874 (25.1)	3,870 (25.1)	4,201 (25.2)	4,196 (25.2)	322 (8.3)
65–74	3,570 (23.2)	3,568 (23.2)	3,941 (23.6)	3,939 (23.6)	369 (10.3)
75–84	2,633 (17.1)	2,630 (17.1)	2,828 (17.0)	2,825 (17.0)	192 (7.3)
85+	1,725 (11.2)	1,714 (11.1)	1,782 (10.7)	1,771 (10.6)	46 (2.7)
Remoteness					
Major cities	10,774 (69.9)	10,756 (69.9)	11,128 (66.7)	11,110 (66.7)	336 (3.1)
Inner regional	3,280 (21.3)	3,277 (21.3)	3,993 (23.9)	3,990 (24)	710 (21.6)
Outer regional and remote	1,326 (8.6)	1,323 (8.6)	1,524 (9.1)	1,520 (9.1)	194 (14.6)
Total[1]	15,420 (100)	15,396 (100)	16,684 (100)	16,659 (100)	1,239 (8.0)

[1]Total includes NSW residents whose demographic information was unknown.

5.3% of angiographies, 5.4% of PCIs, and 4.0% of CABGs for STEMI Hospitalisations in the All Hospitals+MBS dataset. For STEMI Hospitalisations where angiography was carried out, the percentage with angiography being undertaken within 7 days of admission was similar between hospitalisations with valid dates (98%) and those with imputed dates (99%). The same was true for PCIs undertaken within 7 days (96% vs. 98%) and CABGs carried out within 28 days (72% vs. 70%). We carried out data preparation and imputation using SAS Enterprise Guide 7.15 [26] and survival analysis using the survival package 3.1-8 in R (version 3.6.3) [27, 28].

Results

STEMI hospitalisations

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

The addition of cross-jurisdictional data increased the enumeration of STEMI Hospitalisations for NSW residents by 8%, and this increase was greatest for Aboriginal people and residents of regional areas and border LHDs (Tables 1 and 2). The number of hospitalisations for Aboriginal people increased by 19%, and for residents of inner regional and outer regional and remote areas by 22% and 15%, respectively. Across LHDs, the increase in enumeration was greatest for residents of Southern NSW LHD (213%), Albury Local Government Area (131%), Far West LHD (131%), and Northern NSW HD (67%), all of which share borders with other jurisdictions (Table 2).

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

STEMI procedure rates

Cross-jurisdictional data slightly increased angiography and PCI rates for all NSW, and the increases were greatest for residents of regional and remote areas (Tables 4, 5). For total NSW, the additional data increased the angiography rate by 2.5 percentage points (Table 4) and PCI rate by 2.3 percentage points (Table 5). The increases were similar among the various demographic groups, except for residents of regional and remote areas whose rates increased by 5.3-6.5 percentage points (Tables 4, 5). By contrast, the additional

Table 2: STEMI hospitalisations by local health district of residence and cohort dataset

Local health district	NSW Hospitals	NSW Hospitals+MBS	All Hospitals	All Hospitals+MBS	NSW Hospitals vs. All Hospitals+MBS
	No. (%)	No. (%)	No. (%)	No. (%)	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	1,653 (10.7)	1,652 (10.7)	1,679 (10.1)	1,678 (10.1)	25 (1.5)
South Eastern Sydney	1,514 (9.8)	1,512 (9.8)	1,535 (9.2)	1,533 (9.2)	19 (1.3)
Illawarra Shoalhaven	1,018 (6.6)	1,015 (6.6)	1,034 (6.2)	1,031 (6.2)	13 (1.3)
Western Sydney	1,817 (11.8)	1,813 (11.8)	1,833 (11.0)	1,829 (11.0)	12 (0.7)
Nepean Blue Mountains	821 (5.3)	819 (5.3)	833 (5)	831 (5.0)	10 (1.2)
Northern Sydney	1,454 (9.4)	1,452 (9.4)	1,473 (8.8)	1,471 (8.8)	17 (1.2)
Central Coast	833 (5.4)	832 (5.4)	856 (5.1)	855 (5.1)	22 (2.6)
Mid North Coast	608 (3.9)	608 (3.9)	623 (3.7)	623 (3.7)	15 (2.5)
Border with another Australian jurisdiction					
Hunter New England	2,575 (16.7)	2,571 (16.7)	2,638 (15.8)	2,633 (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)
Total[1]	15,420 (100)	15,396 (100)	16,684 (100)	16,659 (100)	1,239 (8.0)

[1]Total includes NSW residents whose local health district of residence was unknown.

Table 3: STEMI hospitalisations by source of record and local health district of residence

Local health district	Entirely within NSW hospitals	Includes stay in non-NSW hospital	All hospitalisations
	No. (%)	No. (%)	No. (%)
No border with another Australian jurisdiction			
Sydney	923 (98.9)	10 (1.1)	933 (100)
South Western Sydney	1,651 (98.4)	27 (1.6)	1,678 (100)
South Eastern Sydney	1,512 (98.6)	21 (1.4)	1,533 (100)
Illawarra Shoalhaven	1,015 (98.4)	16 (1.6)	1,031 (100)
Western Sydney	1,813 (99.1)	16 (0.9)	1,829 (100)
Nepean Blue Mountains	819 (98.6)	12 (1.4)	831 (100)
Northern Sydney	1,451 (98.6)	20 (1.4)	1,471 (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	2,567 (97.5)	66 (2.5)	2,633 (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)
Total[1]	14,979 (89.9)	1,680 (10.1)	16,659 (100)

[1]Total includes NSW residents whose local health district of residence was unknown.

data resulted in negligible increases in CABG rates for total NSW and all demographic groups (Table 6).

Cross-jurisdictional data dramatically increased angiography and PCI rates for border LHD residents. The magnitude of increase varied greatly across LHDs. For example, the reported percentage of hospitalisations where angiography was undertaken within 7 days increased by more than 70 percentage points for Far West LHD residents, by 70

Table 4: Angiography 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	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 and remote	77.3	78.0	83.2	83.4	6.1
Total	85.7	86.4	87.8	88.2	2.5

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 and remote	51.4	52.2	56.2	56.7	5.3
Total	68.9	69.7	70.6	71.2	2.3

percentage points for Southern NSW LHD residents, by 64 percentage points for Albury Local Government Area (LGA) residents, and by 25 percentage points for Northern NSW LHD residents (Table 7). Similar patterns were seen for the percentage of hospitalisations where PCI was undertaken within 7 days (Table 8). The increase in angiography and PCI

Table 6: CABG within 28 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	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 and remote	11.2	11.4	11.2	11.4	0.2
Total	6.7	6.7	6.7	6.8	0.1

Table 7: Angiography within 7 days of STEMI admission by local health district of residence 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
Total[1]	85.7	86.4	87.8	88.2	2.5

[1]Total includes NSW residents whose local health district of residence was unknown.
[2] Percentage based on small counts supressed.

rates for patients from LHDs bordering another Australian jurisdiction was mainly due to the inclusion of non-NSW hospital data, and to a lesser degree, the inclusion of MBS data (Tables 7, 8). The marginal increases in angiography and PCI rates for LHDs without borders to another Australian

Table 8: PCI within 7 days of STEMI admission by local health district of residence 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	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
Total[1]	68.9	69.7	70.6	71.2	2.3

[1]Total includes NSW residents whose local health district of residence was unknown.
[2]Percentage based on small counts supressed.

jurisdiction were mainly due to inclusion of MBS data (Tables 7, 8).

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

Discussion

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

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

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

Our findings demonstrate that cross-jurisdictional linkage improves the reporting on healthcare access for Aboriginal people in NSW. This is because a larger proportion of Aboriginal people than non-Aboriginal people live in remote

Table 9: CABG within 28 days of STEMI admission by local health district 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
Total[1]	6.7	6.7	6.7	6.8	0.1

[1]Total includes NSW residents whose local health district of residence was unknown.
[2]Percentage based on small counts supressed.

areas [1, 31]. The addition of cross-jurisdictional data increased the enumeration of hospitalisations for Aboriginal people more so than non-Aboriginal people. This greater relative increase for Aboriginal people was due to both the inclusion of non-NSW hospitalisations and the additional sources of evidence of Aboriginality provided by MBS data for the ERA algorithm [24]. Improved reporting on healthcare access for Aboriginal people is particularly important given the inequity of poorer healthcare outcomes for Aboriginal compared to non-Aboriginal people [32, 33].

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

Conclusion

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

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Statement on conflicts of interest

The authors declare that they have no competing interests.

Ethics statement

Ethical approval for the Better Cardiac Care Collaborative Data Linkage Project was obtained from the NSW Aboriginal Health and Medical Research Council Ethics Committee (1087/15), NSW Population and Health Service Research Ethics Committee (2015/03/580), ACT Health Human Research Ethics Committee (ETH.3.15.048), and Australian Institute of Health Welfare Ethics Committee (EO2019-4-1106), SA Department of Health and Wellbeing Human Research Ethics Committee (HREC/19/SAH/34), SA Aboriginal Health Research Ethics Committee (04-19-834), and ACT Calvary Public Hospital Human Research Ethics Committee (15-2019).

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Abbreviations

ACT: Australian Capital Territory
ACS: Acute Coronary Syndrome
CABG: Coronary Artery Bypass Graft
ERA: Enhanced Reporting of Aboriginality
LGA: Local Government Area
LHD: Local Health District
MBS: Medicare Benefits Schedule
NDI: National Death Index
NSW: New South Wales
PCI: Percutaneous Coronary Intervention
QLD: Queensland
SA: South Australia
STEMI: ST-Elevation Myocardial Infarction
VIC: Victoria

Appendix A

Supplementary Table 1: Medicare benefit schemeitems providing a source of evidence of aboriginality for the enhanced reporting of aboriginalityalgorithm

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

Supplementary Table 2: 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							
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

[1]International Statistical Classification of Diseases and Related Health Problems, Australian Modification.
[2]Australian Classification of Health Interventions.

Supplementary Table 3: 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

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

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