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ORIGINAL ARTICLE

Centralised Management System and Hot Transfer for ST-Elevation Myocardial Infarction in Western NSW: Closing the Gap in Current Models of Rural ST-Elevation Myocardial Infarction Care

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Background Rural vs metropolitan ST-elevation myocardial infarction (STEMI) patients experience delayed access to percutaneous coronary intervention (PCI). Existing New South Wales (NSW) Statewide Cardiac Reperfusion Strategy protocols provide thrombolysis and ambulance diversion for patients within 90 minutes of a PCI centre in regional and rural NSW. Rural patients presenting to non-PCI hospitals and those more than 90 minutes from PCI are not routinely, urgently, diverted under existing protocols.

Method Western NSW Local Health District, covering 250,000 km^2 and a population of 278,759, implemented a centralised management system (CMS) in 2019, in partnership with NSW Ambulance, utilising existing STEMI thrombolysis protocols and extending "drip and ship" protocols for "hot transfer" of all patients to the 24/7 PCI centre, by direct ambulance diversion up to 120 minutes by road, or via multi-stage transfer by road or air, or via interhospital transfer. Data for 2 years post-CMS was compared to historical controls. Time from first clinical contact (FCC) to reperfusion, FCC to PCI centre, major adverse clinical events and percentage of patients undergoing angiography within 24 hours were compared in "medium" (90–120 minutes) and "long" (>120 minutes) transfer zones, not covered by existing protocols.

Results Outcomes were recorded for 274 patients before and 348 after CMS implementation (17% medium and 31% long transfer zones). Medium and long transfer zones had greater proportions of smokers and Indigenous patients than short transfer zones. There was significantly lower ambulance utilisation in the long (38%) compared with the short transfer zone (55%, $p<0.001$). In the long transfer zone, there were significant improvements in FCC to reperfusion (40 vs 48 minutes, $p<0.05$), FCC to PCI centre (296 vs 344 minutes, $p<0.01$), and angiography in 24 hours (77% vs 58%, $p<0.01$), with no significant differences in major adverse clinical events.

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Conclusions A rural STEMI CMS, with "hot transfer", can deliver patients from a vast geographical area directly to a rural PCI centre. Patients furthest away, with the greatest risk profile, benefit the most. Extension of this program and development of 24/7 PCI in NSW rural cardiac hubs stands to improve timely, definitive treatment, including access to angiography within 24 hours.

Keywords ST-elevation myocardial infarction • Clinical outcomes • Rural

Introduction

Australians living outside major cities experience higher rates of hospitalisation for cardiovascular disease [1]. Mortality in remote and very remote areas is 1.4 times higher than in major cities [1]. Indigenous Australians have a two-fold higher aged-standardised cardiac mortality, and a greater proportion live outside major cities [1]. In short, the further a person lives from a metropolitan centre, the greater their risk of hospitalisation and death from ST-elevation myocardial infarction (STEMI) [2].

Inroads have been made to reduce these disparities with telehealth, pre-hospital thrombolysis programs and the establishment of rural cardiac catheter labs in New South Wales (NSW) [3,4]. Patients with acute coronary syndrome (ACS) presenting to non-percutaneous coronary intervention (PCI) capable hospitals have been reported to have lower rates of angiography (70% vs 81%) [5]. Although inpatient and 30-day mortality rates may not show large differences compared with patients presenting to PCI-capable sites, risk-adjusted mortality at 18 months has been reported to be 21% higher [6,7]. This is not surprising, as late or no STEMI reperfusion can lead to more extensive infarction and a greater risk of complications. Bureau of Health Information (BHI) data for 30-day acute myocardial infarction (AMI) mortality in NSW show that mortality for rural patients presenting to rural cardiac centres decreased from 2009 onwards (Supplementary Table 1) [8,9]. Although this improvement is multifactorial, the establishment of NSW rural catheter labs at the rural cardiac centres corresponds to this timeframe. Mortality in patients with AMI presenting directly to PCI-capable rural cardiac centres is below the state average (see Supplementary Table 1), even though not all of these sites have 24/7 PCI service capability. However, mortality in rural areas overall remains higher than metropolitan, suggesting the remaining excess AMI mortality is contributed by patients presenting to non–PCI-capable sites. Rural STEMI patients experience delayed access to PCI compared with metropolitan patients [6]. Improving direct access for rural and remote STEMI patients (i.e., living outside of major cities, hereafter referred to as rural) to PCI centres could be expected to further reduce excess morbidity and mortality towards metropolitan outcomes.

The NSW statewide cardiac reperfusion strategy (SCRS) was implemented in the Western NSW Local Health District (WNSWLHD) in March 2014. The SCRS established electrocardiogram (ECG) reading services in each local health district (LHD) to support NSW Ambulance (NSWA) in the provision of either Pre-Hospital Assessment for Primary Angioplasty (PAPA) or Pre-hospital Thrombolysis (PHT) for STEMI. In areas outside major cities, the SCRS involves ambulance diversion, within 90 minutes by road, to deliver more patients directly to PCI centres, but has no routine system in place to deliver STEMI patients >90 minutes or those self-presenting to non-PCI hospitals directly to a cardiac centre. Access to rural primary PCI (PPCI) is very limited, and thrombolysis remains the main reperfusion treatment. PPCI is only offered where transfer times and cardiac catheter lab activation within 90 minutes can be confidently achieved within available resources and is at the discretion of the ECG reading services within each rural LHD. Rural patients are less likely to call an ambulance; hence, the full benefit of SCRS ambulance diversion has not been realised [10]. The use of ECG reading services has significantly improved rural STEMI detection and provision of immediate management by a cardiologist, providing a platform for further improvements to models of care [11,12].

In response to the remaining gap in the existing rural STEMI protocols for patients >90 minutes from a PCI centre and those presenting to non-PCI hospitals, the current study aimed to evaluate an innovative model of care that included NSWA's implementation of routine, protocol-driven, immediate transfer of all STEMI patients from across the 250,000 km^2 WNSWLHD to the single PCI-capable rural cardiac centre in Orange, without waiting to assess reperfusion. We hypothesised that the centralised management system (CMS) would improve times from first clinical contact (FCC) to reperfusion, FCC to the PCI centre, major adverse clinical events (MACEs) and the proportion of patients receiving angiography within 24 hours for patients presenting >90 minutes from the PCI centre.

Methods

Setting

The WNSWLHD is a rural health district covering 250,000 km^2, or just under one-third of NSW, roughly equivalent to the area of the United Kingdom, albeit with a substantially smaller population (278,759 compared with 67 million in the United Kingdom), 13% of whom identify as Aboriginal Australians [13]. There are 38 inpatient facilities located up to 563 kilometres from the single cardiac catheter lab in Orange (Figure 1 [14]).

Study Design

A quasi-experimental design explored the impact of the LHD-wide STEMI CMS, which combined existing thrombolysis protocols with routine "hot transfer" to the PCI centre and was implemented by NSWA and all hospitals within the WNSWLHD. Patients were considered eligible for inclusion if they met STEMI criteria adapted from the Australian Clinical Guidelines (i.e., chest discomfort or pain of >20 minutes and an ECG with ST-segment elevation in two or more contiguous leads), had left main or STEMI equivalent ECG with ongoing ischaemic symptoms, and were for active treatment [15]. Patients were excluded from analysis if they had been transferred from another LHD for treatment within the WNSWLH or if they were deemed palliative or not for active treatment.

Key aspects of the CMS intervention include mandated transmission of all STEMI ECGs to the WNSWLHD ECG reading service at first contact (as per the SCRS), immediate cardiologist contact to analyse the ECG, confirm the diagnosis, and immediate "hot transfer" of all STEMI patients to the PCI-capable hospital (Figure 2). The immediate "hot transfer" was facilitated by the implementation of a new protocol by NSWA that expedited the direct transfer of patients to the PCI-capable hospital within a 120-minute transport time by road or by contact with the Aeromedical Control Centre to request transfer/retrieval (via road, helicopter, or fixed-wing aircraft) for patients >120 minutes from the PCI centre. Patients received pre-hospital or in-hospital thrombolysis in accordance with NSWA and NSW Health STEMI management protocols.

PPCI was only available to patients presenting to the PPCI centre, or calling an ambulance within the diversion zone, and able to be reliably delivered to the PCI centre within 60 minutes, at the direction of the cardiologist. There was no routine PPCI component of this protocol due to limited resourcing and known rural transfer delays, particularly for patients self-presenting to non-PCI hospitals. Thrombolysis remained the main reperfusion method. Patients were assessed on arrival at the PCI centre and were taken directly to the lab if there was ongoing chest pain or persistent ST-elevation on ECG. Patients who had clinically reperfused were taken to the lab within 24 hours. It was a flaw in the protocol that reperfusion was assessed based on the 60-minute ECG, in line with usual post-lysis assessment; however, many long transfer zone patients were still in transit at 60 minutes, so the arrival ECG and clinical assessment, rather than the 60-minute ECG was used in determining urgent lab activation. The arrival ECG was not always coded in the results, leaving some inaccuracy in the coding of "rescue PCI" vs PCI within 24 hours. This model of care aligns with current NSW Health and Cardiac Society of Australia and New Zealand (CSANZ) guidelines recommending early or immediate transfer to a PCI-capable hospital for angiography within 24 hours following thrombolysis [15,16].

Patients calling an ambulance were transferred directly to the PCI centre, even if they were >90 minutes away. Patients self-presenting or delivered to non-PCI hospitals were urgently transferred between hospitals to the PCI centre. This intervention was aimed at improved outcomes for patients presenting to non-PCI hospitals, particularly those furthest away, with little anticipated impact on patients calling an ambulance within 90 minutes who were already diverted, either for PPCI or post-thrombolysis, under existing protocols. Analysis was, therefore, in "short" (<90 minutes), "medium" (90–120 minutes), and "long" (>120 minutes) distance ambulance transfer regions. All STEMI patients treated in the WNSWLHD for 2 years post-CMS implementation (1 May 2019–30 April 2021) were included in the analysis, with an opt-out consent, and were compared to historical controls over a 2-year period pre-implementation (1 January 2014–31 December 2015). This time period was selected as electronic records were available, and it pre-dated a partial adoption of extended ambulance transfers in some areas of the WNSWLHD that were outside of standard NSWA protocols.

Outcome Measures

Primary outcome measures were times from FCC when an ECG was first diagnostic of STEMI, to reperfusion treatment, and from FCC to PCI centre arrival, in-hospital MACE (defined as major bleeding, re-infarction or stroke), and proportion having angiography within 24 hours. Outcomes were compared pre- and post-CMS implementation in three transfer zones.

Data Analysis

Demographic clinical characteristics, time from FCC to reperfusion treatment, and FCC to PCI centre and proportion having angiography in 24 hours were compared for pre- (2014–2015) and post-CMS implementation (2019–2021). Analyses were stratified by three road transfer time regions: short (<90 minutes by road to the PCI centre), medium (90–120 minutes), or long (>120 minutes). The short transfer zone reflects the existing SCRS protocol diversion of patients within 90 minutes to the PCI-capable hospital. The new protocol included road ambulance diversion of patients 90–120 minutes. The delineation of a long transfer region is because patient transfer for this region is typically by air (fixed wing or helicopter), resulting in greater delays due to limited aircraft assets across NSW; however, the new NSWA protocol included a process of expediated requests to the Aeromedical Control Centre to request transfer/retrieval for patients greater than 120 minutes from the PCI centre.

For the primary outcomes of FCC to reperfusion treatment and FCC to PCI centre arrival, median times (with interquartile range [IQR]) were compared pre- and post-implementation using non-parametric statistics. The distribution of continuous data was explored using the Kolmogorov–Smirnov test. Categorical data are presented as numbers and proportions. Chi-square analyses were conducted to compare pre- and post-implementation groups on categorical data and linear by linear associations across transfer time regions (short, medium, long). All analyses were performed in IBM SPSS v25, and p-values <0.05 deemed indicative of statistical significance.

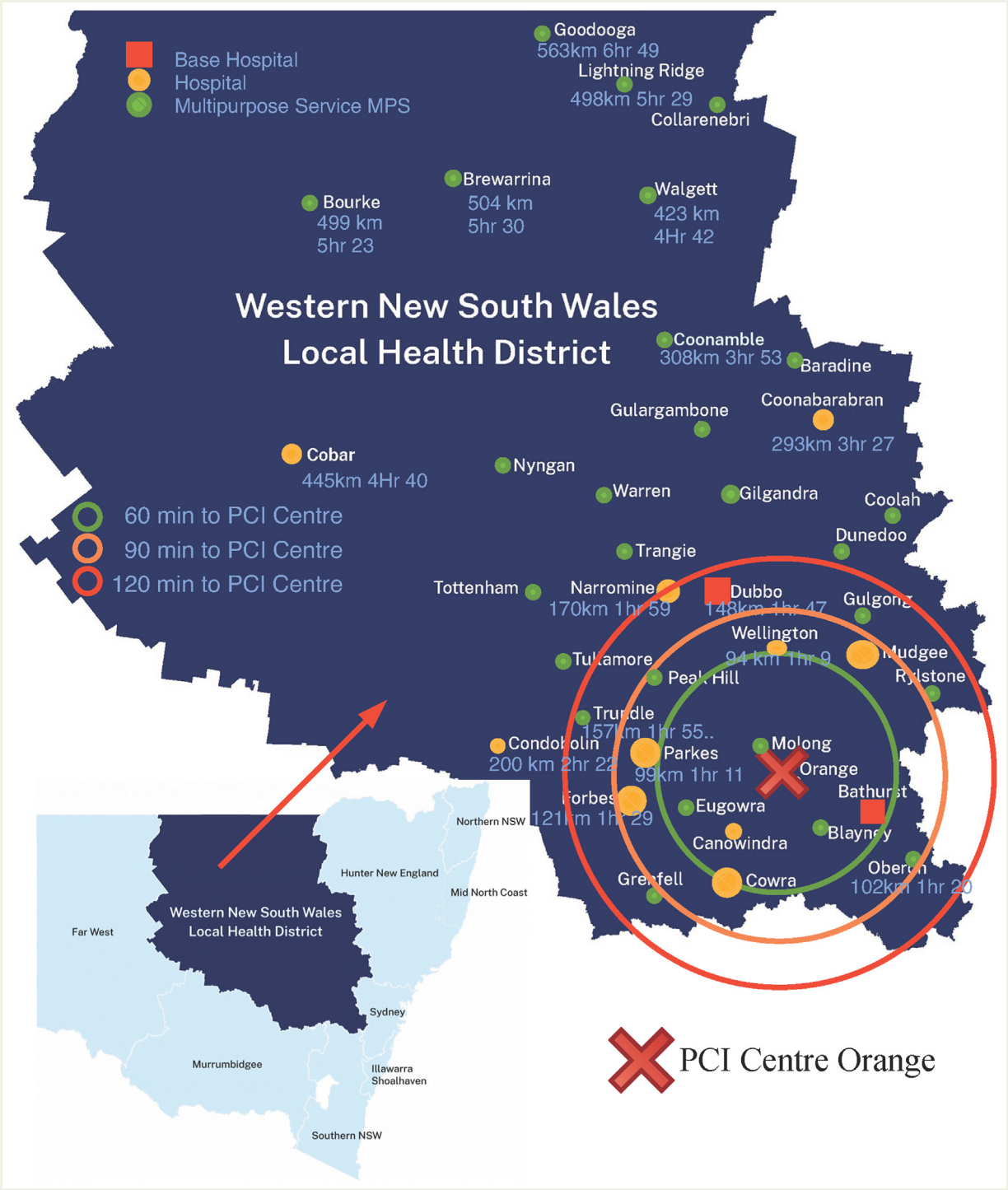

Figure 1 Map of Western NSW Local Health District and facilities Adapted with permission from NSW Health [14]. Abbreviations: MPS, multipurpose service; PCI, percutaneous coronary intervention

Ethics Approval

This project received ethics approval from the Greater Western Human Research Ethics Committee (#2019/ETH09496) and the Aboriginal Health and Medical Research Council (AH&MRC) Ethics Committee (1483/19), with an opt-out consent.

Results

Data were obtained for 622 WNSWLHD STEMI patients; 274 pre- and 348 post-CMS implementation. Approximately half of all patients presented within the short transfer zone (53% pre- and 51% post-CMS), approximately one-fifth in the

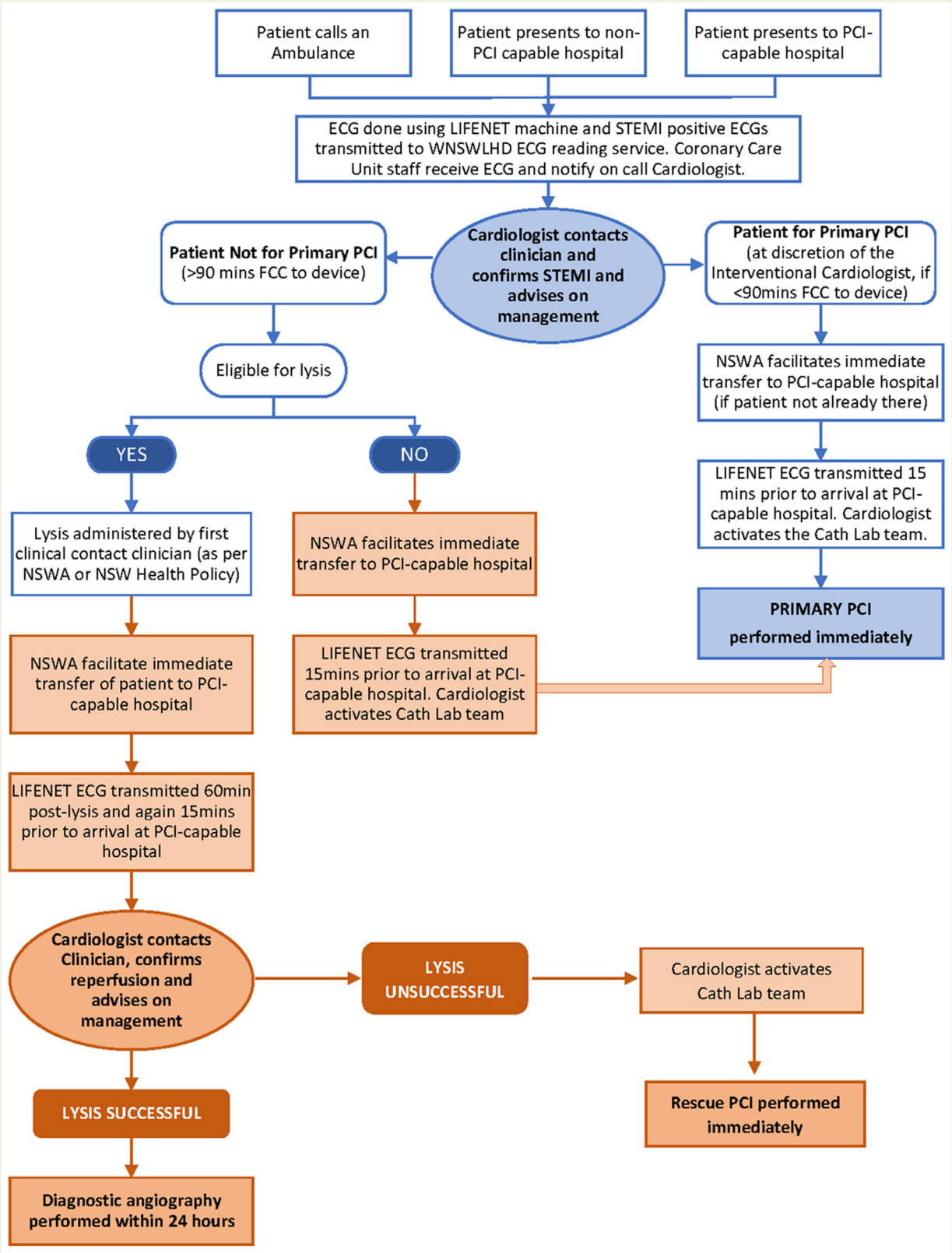

Figure 2 Centralised STEMI management system with NSW Ambulance 'Hot' transfer protocol. Blue colour coding indicates part of existing Statewide Cardiac Reperfusion Strategy, orange colour coding indicates extension to current study protocol. Abbreviations: ECG, electrocardiogram; FCC, first clinical contact; NSW, New South Wales; NSWA, NSW Ambulance; PCI, percutaneous coronary intervention; STEMI, ST-Elevation Myocardial Infarction; WNSWLHD, Western NSW Local Health District.

medium zone (18% and 17%, respectively) and 31% in the long zone (29% and 32% respectively; not significant).

Demographic characteristics and risk factors were comparable between the pre- and post-CMS groups (Table 1), except for a significant increase in the proportion of patients with prior myocardial infarction in the post-CMS group ($p<0.01$). In comparing patient characteristics within the transfer zones, there were clear trends by distance from the PCI centre, reflecting known health inequities with increasing remoteness. Patients in the long transfer zone were younger, more likely to identify as Indigenous and had higher rates of current smoking. They were also less likely to call an ambulance (38% long vs 55% short zone, $p<0.001$) (Table 2). Indigenous patients were overrepresented in the overall STEMI cohort, compared to the 13% of Indigenous patients residing in the WNSWLHD. This was most marked in the long transfer zone (26% Indigenous vs 8% short zone, $p<0.001$; Table 2). Of all eligible patients, 96% of the post-CMS cohort were successfully transported by NSWA directly to the PCI centre.

In the long transfer zone, median FCC to reperfusion treatment time (40 minutes [IQR 30–61] post-CMS vs 48 minutes [32–76] pre-CMS, $p<0.05$) (Figure 3), and FCC to PCI centre time (296 minutes [246-367] post vs 344 minutes [249–527] pre, $p< 0.01$) (Figure 4) improved significantly, with no significant differences in MACE (<5% vs 8%, $p=0.24$; Table 3). This significant improvement in transfer time from FCC to PCI-capable hospital for patients in the long transfer zone was apparent for those who called an ambulance and for those who self-presented to a non-PCI hospital (Table 3). The medium zone FCC to PCI centre time also decreased from 288 (IQR 212–424) to 243 (186–336) minutes ($p=0.03$) (Figure 3), but this improvement was only significant for those calling an ambulance (Table 3). There was no significant change for the short transfer region. Of note, transfer times within the short transfer zone during the post-CMS period were significantly better for patients calling an ambulance (median 95 minutes) compared with those self-presenting to a non-PCI site (167 minutes, $p<0.001$).

PPCI was only able to be provided to 68 patients (11%), all except one transferred from within the short transfer zone. Thrombolysis, rather than PPCI, was the most common reperfusion therapy for patients (short: 57% vs medium: 81% vs long: 80%,; Table 3). The proportion receiving an angiogram within 24 hours increased significantly from pre- to post-CMS for those in the medium (77% to 91%, $p<0.05$) and long transfer regions (58% to 77%, $p<0.01$), with no significant change for those in the short transfer region (Figure 5).

Length of stay (LOS) did not significantly decline post-CMS, in fact for those fully managed within Western NSW, median LOS increased slightly (from 3.2 to 3.7 days; Table 3). A total of 131 patients required onward transfer to a metropolitan centre, with the rate increasing pre-CMS (18%, n=48) to post-CMS (25%, n=83, $p<0.05$). During the post-CMS period, the most common reason for transfer was coronary artery bypass graft (n=42), followed by high-risk PCI (n=25). Total patient journey LOS in all facilities was 13.3 days pre- and 12.3 days post-CMS (not significant) for those requiring metropolitan transfer.

In-hospital MACE occurred in 9.6% of patients (9.9% pre-implementation vs 9.5% post-CMS, not significant), with no significant differences within transfer zones from pre- and post-CMS (Table 3). In-hospital mortality occurred in 31 patients, 4% pre-implementation

Table 1 Characteristics of pre- and post-CMS cohorts, stratified by transfer zone.[a]

Characteristic	Pre-CMS	Post-CMS	p-value
Number of patients	274	348	
Age (yrs), median (IQR)			
Short transfer	65 (53–75)	64 (55–73)	0.80
Medium transfer	57 (52–67)	60 (52–70)	0.44
Long transfer	59 (51–71)	62 (52–72)	0.44
Sex (male)			
Short transfer	106 (73)	134 (75)	0.58
Medium transfer	39 (80)	43 (74)	0.51
Long transfer	60 (76)	93 (83)	0.23
Indigenous			
Short transfer	7 (5)	20 (11)	0.037
Medium transfer	8 (16)	14 (24)	0.32
Long transfer	22 (28)	28 (25)	0.66
Current smoker			
Short transfer	58 (40)	67 (38)	0.88
Medium transfer	29 (62)	30 (52)	0.42
Long transfer	36 (46)	56 (51)	0.71
Comorbid conditions[b]			
Hypertension	143 (52)	207 (60)	0.07
Hyperlipidaemia	118 (43)	159 (46)	0.51
Obesity	93 (34)	121 (35)	0.78
Diabetes mellitus	52 (19)	69 (20)	0.78
Atrial fibrillation	19 (7)	31 (9)	0.37
Prior myocardial infarction	40 (15)	81 (23)	0.007
Prior stroke/transient ischaemic attack	13 (5)	26 (8)	0.16
Prior stent	32 (12)	58 (17)	0.08
Prior CABG	13 (5)	11 (3)	0.31
Family history ischaemic heart disease	149 (55)	191 (58)	0.56

All values are n (%) unless otherwise specified.

[a]Short transfer region: STEMI occurred ≤90 minutes from PCI-capable hospital; medium transfer region: STEMI occurred between >90 and 120 minutes from PCI-capable hospital; long transfer region: STEMI occurred >120 minutes from PCI-capable hospital. Co-morbidities and family history were not stratified due to small numbers.

[b]Note, it was possible for patients to have had multiple co-morbid conditions.

Abbreviations: CMS, Centralised Management System; IQR, interquartile range; CABG, coronary artery bypass graft surgery; PCI, percutaneous coronary intervention; STEMI, ST-elevation myocardial infarction.

Table 2 Comparison of patient characteristics across transfer zones (pre- and post-CMS combined).[a]

Characteristic	Short transfer	Medium transfer	Long transfer	p-value
Number	324	107	191	
Age (yrs), median (IQR)	64 (55–74)	59 (52–67)	61 (52–71)	0.004
Indigenous	27 (8)	22 (21)	50 (26)	<0.001
Smoking status				0.019
Current	125 (39)	59 (56)	92 (49)	
Past	96 (30)	22 (21)	45 (24)	
Never	102 (32)	24 (23)	52 (28)	
Prior myocardial infarction	53 (16)	23 (22)	45 (24)	0.04
Called ambulance	179 (55)	52 (49)	73 (38)	<0.001
Road distance travelled, median (IQR)	55 (36–104)	153 (153–157)	202 (196–228)	

All values are n (%) unless otherwise specified.

[a]Short transfer region: STEMI occurred ≤ 90 minutes from PCI-capable hospital; medium transfer region: STEMI occurred between >90 and 120 minutes from PCI-capable hospital; long transfer region: STEMI occurred >120 minutes from PCI-capable hospital.

Abbreviations: CMS, centralised management system; IQR, interquartile range; PCI, percutaneous coronary intervention; STEMI, ST-elevation myocardial infarction.

and 6% post-implementation (p=0.32). In both the pre-CMS cohort and the post-CMS cohorts, 3% of patients presented with an out-of-hospital cardiac arrest (pre-CMS n=8/274 vs post-CMS n=11/348; p=0.86).

Discussion

There are poorer outcomes in regional and rural Australia for cardiovascular disease with excess mortality, particularly for STEMI, which requires urgent, time-sensitive treatment [1,2]. This disproportionally affects Indigenous communities due to a greater proportion of the Indigenous population living in rural and remote areas [1,17]. The reasons for poorer outcomes are multifactorial and are exacerbated by distance and limited healthcare resources. When patients can directly access rural cardiac centres, their mortality is below the state average and more in line with metropolitan results (Supplementary Table 1) [8,9]. Improving equity of timely access to a PCI centre remains key to closing the remaining gap [18]. Although the establishment of rural cardiac catheter laboratories in NSW has made a difference in patient mortality for myocardial infarction, not all rural NSW cardiac catheter labs provide 24/7 PCI and direct transfer of STEMI patients to PCI centres, post-lysis, has been limited to

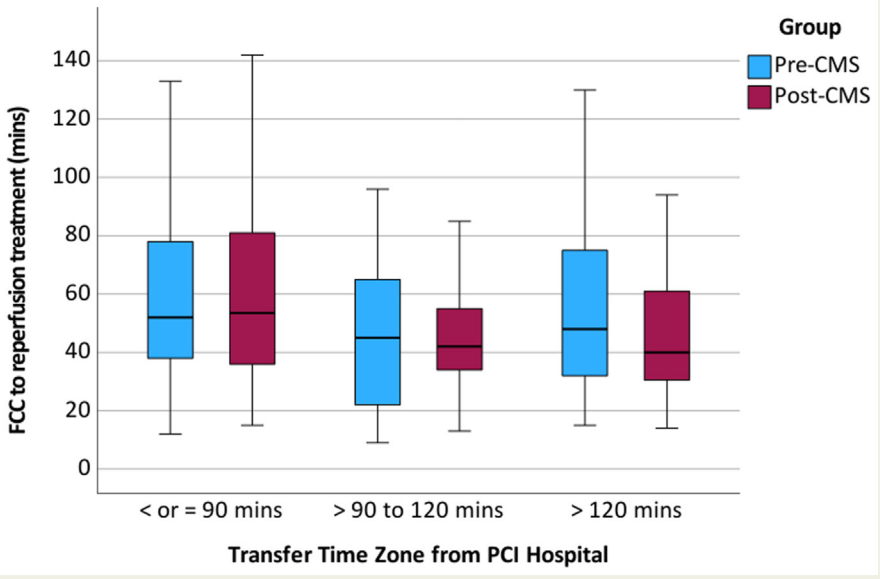

Figure 3 Time (minutes) from first clinical contact to reperfusion treatment from pre- to post-CMS implementation, by transfer zone.

Abbreviations: CMS, centralised management system; FCC, first clinical contact; PCI, percutaneous coronary intervention

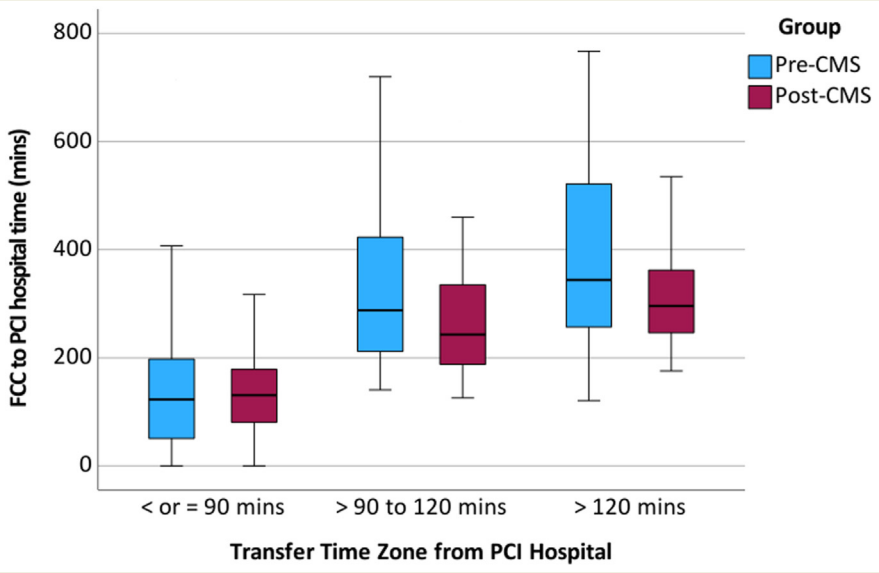

Figure 4 Time (minutes) from first clinical contact to PCI centre from pre- to post-CMS, by transfer zone.
Abbreviations: CMS, centralised management system; FCC, first clinical contact; PCI, percutaneous coronary intervention

patients who call an ambulance and are within 90 minutes [19]. Patients furthest away, without direct access to a PCI centre, have no routine, immediate post-thrombolysis transfer system under the current SCRS protocol and this group has the poorest outcomes.

The current study has contributed to closing the gap between rural and metropolitan cardiovascular outcomes by demonstrating that 96% of eligible rural STEMI patients can be consistently delivered directly to a 24/7 PCI-capable rural centre over a 2-year period, within existing resources. The major change of routine diversion of STEMI patients in this study benefited those patients who were >90 minutes distance from the PCI centre, who were not covered under existing STEMI transfer protocols. The significant demographic differences between patients within 90 minutes of the PCI centre vs those in the long transfer zone underlines the major challenges in achieving further reductions in excess rural cardiac mortality, as those further away have higher rates of smoking, Indigenous heritage, prior infarction and are less likely to call an ambulance, compounding treatment delays. It is this group, that benefited most from this centralised STEMI management and transport system. In this group a reduction in FCC to reperfusion treatment and FCC to PCI centre times was achieved, with a significant improvement in the proportion of patients receiving angiography within 24 hours [12].

However, there is room for further improvement in models of care, with transfer times achieved in this study remaining too long to make routine PPCI a viable service delivery option in a rural setting, except perhaps for patients within the short transfer zone who called an ambulance (median 95 minutes post-CMS implementation). Even post-CMS and with urgent interhospital transfer protocol implementation, patients in the short transfer zone who self-presented to a non–PCI-capable hospital had a median FCC to PCI hospital time of 167 minutes, well outside the 90–120-minute timeframe required for PPCI. Although transfer times improved in the medium zone (243 minutes) and the long zone (296 minutes), they remain prolonged, illustrating the ongoing challenges posed by distance and by limited ambulance resources and aircraft assets in rural NSW.

LOS did not show a decline post-CMS implementation. This may have been due to a number of factors, including the major impacts of COVID-19 on hospital bed utilisation and patient transfers between facilities in 2020 and 2021, the publication of the COMPLETE (Complete versus Culprit-Only Revascularization Strategies to Treat Multivessel Disease after Early PCI for STEMI) trial in 2019, which supported a strategy of staged PCI of non-culprit lesions on the index admission [20], leading to increased LOS for patients requiring staged procedures, and to the prolonged total LOS experienced by patients requiring onward transfer to a metropolitan site, particularly those waiting in the rural centre for a cardiac pacing device. A greater proportion of patients in the post-CMS group had prior myocardial infarction, indicating an increased complexity in this cohort, which may have impacted LOS. We also observed an increased rate of onward transfer to a metropolitan centre post-CMS, typically for coronary artery bypass graft or high-risk PCI, consistent with the post-CMS cohort having greater complexity and co-morbidities, including a higher proportion with prior myocardial infarction.

Although the CMS had some positive impacts on patients in the long transfer zone, there was an apparent overall lack of clinical benefit. This can be attributed to several factors. First, due to population distribution, patients in the short

Table 3 Clinical characteristics, transfer details and outcomes for patients presenting with STEMI within Western NSW LHD from pre- to post-CMS implementation.

Variable	Pre-CMS n=274	Post-CMS n=348	p-value
PPCI, n (%)	28 (10)	40 (11)	0.61
Thrombolysed, n (%)	193 (70)	233 (67)	
Short transfer[a]	90 (62)	96 (54)	0.16
Medium transfer	42 (86)	45 (78)	0.28
Long transfer	61 (77)	92 (82)	0.40
Rescue PCI, n (%)	70/193 (36)	90/233 (39)	0.62
Coronary angiography received	267 (97)	337 (97)	0.65
FCC to Angiogram within 24 hours, n (%)			
Short transfer	112 (79)	147 (86)	0.13
Medium transfer	36 (77)	50 (91)	0.048
Long transfer	46 (58)	81 (77)	0.006
Final revascularisation, n (%)			
Total receiving PCI[b]	211 (77)	272 (78)	0.73
Second staged PCI	27 (10)	36 (10)	0.84
CABG	46 (17)	42 (12)	0.09
Alternate diagnosis[c]	12 (4)	31 (9)	0.027
Medical	33 (12)	50 (14)	0.40
Distance (km) from FCC to PCI-hospital, median (IQR)			
Short transfer	n=129	n=154	
Paramedic	55 (97)	55 (81)	0.70
Non-PCI hospital	101 (66)	83 (49)	0.25
Medium transfer	n=49	n=58	
Paramedic	156 (12)	155 (8)	0.59
Non-PCI hospital	153 (17)	153 (0)	0.99
Long transfer	n=79	n=113	
Paramedic	226 (98)	257 (115)	0.34
Non-PCI hospital	271 (186)	242 (250)	0.41
Time (mins) from FCC to PCI hospital, median (IQR)			
Short transfer	n=129	n=153	
Paramedic	85 (110)	95 (103)	0.19
Non-PCI hospital	183 (117)	167 (98)	0.17
Medium transfer	n=49	n=56	
Paramedic	304 (432)	201 (196)	0.015
Non-PCI hospital	268 (124)	256 (113)	0.87
Long transfer	n=79	n=107	
Paramedic	355 (312)	294 (129)	0.048
Non-PCI hospital	344 (268)	301 (104)	0.043
If rescue PCI, time (mins) from lysis to PCI hospital, median (IQR)			
	140 (144)	124 (120)	0.66
Short transfer	80 (112)	86 (51)	0.34
Medium transfer	199 (78)	203 (104)	0.69
Long transfer	258 (135)	201 (109)	0.39
LOS[d] (days) if fully managed in WNSWLHD, median (IQR)			
	3.2 (2.8)	3.7 (2.1)	0.014
LOS[d] (days) if managed outside WNSWLHD, median (IQR)			
	13.3 (11.2)	12.3 (10.9)	0.76
MACE, n (%)			
Short transfer	16 (11)	19 (11)	0.94
Medium transfer	8 (16)	5 (9)	0.22
Long transfer	<5[e]	9 (8)	0.24
Major bleeding	12 (4)	10 (3)	0.31
Re-infarct	8 (3)	<5[e]	0.11
Stroke	<5[e]	8 (2)	0.45
In-hospital death	11 (4)	20 (6)	0.32

[a]Short transfer region: STEMI occurred ≤90 minutes from PCI capable hospital; medium transfer region: STEMI occurred between >90 and 120 minutes from PCI capable hospital; long transfer region: STEMI occurred >120 minutes from PCI capable hospital.

[b]Total receiving PCI includes primary PCI, rescue PCI, and stent post successful lysis.

[c]Alternative diagnoses included Takotsubo, SCAD, peri/myocarditis, cardiomyopathy and other.

[d]LOS, length of stay includes total time in-hospital for patients admitted to more than one facility.

[e]Actual numbers supressed due to low counts, as per NSW Health recommendations regarding privacy and reporting of small numbers, i.e., minimum value of five individuals within a table cell.

Abbreviations: STEMI, ST-Elevation Myocardial Infarction; CMS, centralised management system; PPCI, primary percutaneous coronary intervention; PCI, percutaneous coronary intervention; FCC, first clinical contact; CABG, coronary artery bypass graft surgery; IQR, interquartile range; LOS, length of stay; WNSWLHD, Western NSW Local Health District; MACE, major adverse clinical event; SCAD, spontaneous coronary artery dissection.

transfer zone were the largest group, and they were already being diverted to the PCI centre. Second, patients in the medium and long transfer zones were more likely to benefit from the protocol but made up a smaller proportion. Although some benefits were achieved, such as a greater percentage receiving angiography within 24 hours, these groups also had higher rates of co-morbidities which may have contributed to the lack of immediate effect on mortality and MACE. The total numbers in the long transfer zone were insufficient to reach significant power to detect a difference. In addition, whilst a reduction in transfer time was achieved, due to limited resources, there was still a median of over 4 hours (296 min) in the long transfer zone to the PCI centre. Achieving better reductions in the transfer times would be needed to make a greater impact on outcomes. Third, the data collected may not reflect the impact of clinical benefits of reduced transfer times and an increased proportion of

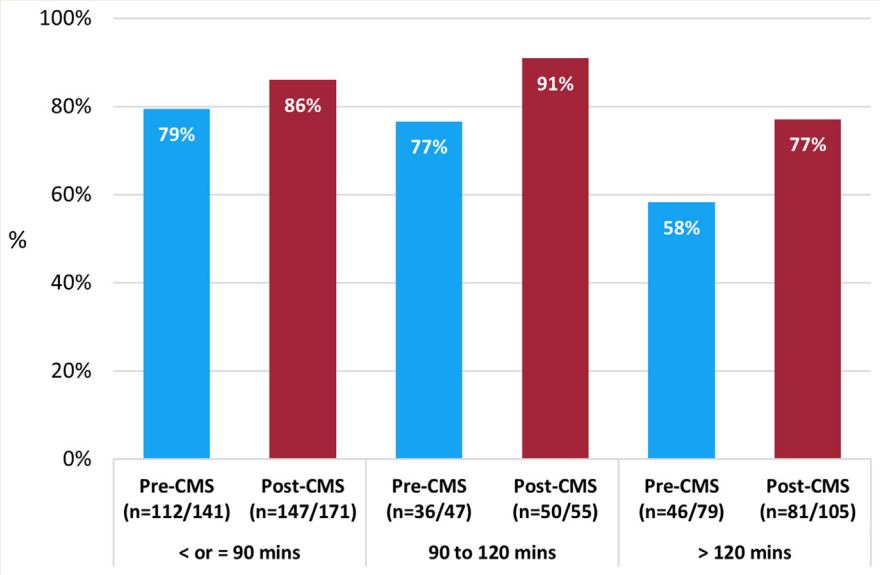

Figure 5 Proportion of patients with first clinical contact to angiography within 24 hours, pre- and post-CMS implementation, presented by transfer zone.
Abbreviations: CMS, centralised management system; PCI, percutaneous coronary intervention

long transfer patients achieving angiography within 24 hours. These outcomes are more likely to be apparent during patient follow-up, such as reduction of subsequent heart failure or improved left ventricular function on follow-up echocardiography. The study did not collect this medium- and longer-term follow-up data. Finally, the main clinical impact of the CMS is for patients requiring rescue PCI, and they were only a small proportion of the cohort.

The demand for cardiac services in rural areas is likely to increase disproportionately to metropolitan areas due to existing health inequalities, combined with greater migration of older retirees to regional settings, which has proceeded with greater momentum following the COVID-19 pandemic [21]. Orange is the only rural NSW public hospital cardiac centre currently offering routine 24/7 STEMI transfer and PCI. Other centres, such as Wagga Wagga, have an established public-private model of acute infarct PCI service, and some centres offer infarct PCI within lab operating hours. Enhancement of all existing rural NSW cardiac centres to develop and fund 24/7 PCI services would be essential before this protocol could be translated to other rural LHDs in NSW. Additional cardiac catheter lab staffing and ambulance resources are needed before PPCI could safely become a greater component of rural STEMI management.

Strengths and Limitations

Our study was a cohort study comparing a historical (pre-CMS) to a contemporary (post-CMS) group. We acknowledge the inherent methodological weakness of pre-/post-implementation studies. In this instance, factors that may have changed over time and influenced observed outcomes include changes in cardiac catheter lab availability, staffing levels, staff experience and the impact of COVID-19 on health service access, including transfers. Ideally, the historical data would have been taken from the timeframe immediately prior to the addition of the CMS to the existing SCRS, but due to ad hoc, but not routine, ambulance diversion in WNSWLHD out to the greater 90–120-minute radius in the 18 months prior to the formal, protocol-driven transfer study commencement, historical controls were taken from an earlier time period. The historical 2 years selected was at the commencement of the SCRS in WNSWLHD when electronic medical and catheter lab records were available. The prospective study period was impacted by the COVID pandemic from 2020 to 2021, which sometimes caused transport delays, particularly for patients requiring metropolitan transfer, emphasising the need for locally based rural services to be as self-sufficient as possible. The study was not powered to detect differences in mortality, and the study site already had lower than expected mortality (i.e., risk standard mortality ratio <1) during the pre-CMS implementation period (Supplementary Table 1). A patient risk score was not routinely calculated for pre- and post-cohorts, an angiography syntax score was not recorded, and markers of infarct size were not compared, limiting the ability to adjust for patient and coronary anatomy complexity in comparing clinical outcomes.

Conclusion

A rural STEMI CMS, with immediate hot transfer, can deliver most STEMI patients from a vast geographical area directly to a rural PCI centre. Patients furthest away, with the greatest risk profile, benefit the most. Rates of receipt of

coronary angiography within 24 hours increased significantly in these patients. Extension of the model to other rural LHDs, with increased cardiac catheter lab and NSWA resources, has the potential to reduce inequities in rural vs metropolitan STEMI outcomes. Such an expansion would facilitate data collection on larger rural cohorts, allowing comprehensive analysis of clinical impacts.

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Declaration of Competing Interests

There are no conflicts of interest to disclose.

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Appendices

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.hlc.2024.11.029

References

[1] Australian Institute of Health and Welfare. Heart, stroke and vascular disease: Australian facts. Available at: https://www.aihw.gov.au/reports/heart-stroke-vascular-diseases/hsvd-facts/contents/disease-types#deaths. [accessed 15.3.24].
[2] Kotwal S, Ranasinghe I, Brieger D, Clayton P, Cass A, Gallagher M. Long-term outcomes of patients with acute myocardial infarction presenting to regional and remote hospitals. Heart Lung Circ. 2016;25:124–31.
[3] Tideman PA, Tirimacco R, Senior DP, Setchell JJ, Huynh LT, Tavella R, et al. Impact of a regionalised clinical cardiac support network on mortality among rural patients with myocardial infarction. Med J Aust. 2014;200:157–60.
[4] Elder A, Dunkerton S, Arnold R, French A, Amos D, Ryan E, et al. Early cardiologist input via LIFENET ECG transmission and pre-hospital thrombolysis achieves improved lysis times for STEMI in a rural setting. Heart Lung Circ. 2016;25:S269.
[5] Ayad M, Hyun K, D'Souza M, Redfern J, Gullick J, Ryan M, et al. Factors that influence whether patients with acute coronary syndromes undergo cardiac catheterisation. Med J Aust. 2021;214:310–7.
[6] Chew DP, French J, Briffa TG, Hammett CJ, Ellis CJ, Ranasinghe I, et al. Acute coronary syndrome care across Australia and New Zealand: The SNAPSHOT ACS study. Med J Aust. 2013;199:185–91.
[7] Brieger DB, Chew DP, Redfern J, Ellis C, Briffa TG, Howell TE, et al. Survival after an acute coronary syndrome: 18-month outcomes from the Australian and New Zealand SNAPSHOT ACS Study. Med J Aust. 2015;203:368. D.
[8] Bureau of Health Information. Exploring clinical variation in mortality. Mortality following hospitalisation, seven clinical conditions, NSW The Insight Series. 2023. Available at: www.bhi.nsw.gov.au/__data/assets/pdf_file/0003/356529/report-insights_exploring-clinical-variation-in-mortality-2017.pdf. July 2012–June 2015. [accessed 13.11.23].
[9] Bureau of Health Information. Mortality following hospitalisation for seven clinical conditions, July 2015–June 2018. Available at: www.bhi.nsw.gov.au/__data/assets/pdf_file/0007/557827/BHI_Mortality_2015-2018_REPORT.pdf. [accessed 13.11.23].
[10] Reed B, Bendall JC. Rurality as a factor in ambulance use in health emergencies. Aust J Paramedicine. 2015;12:1–6.
[11] Dee F, Savage L, Leitch JW, Collins N, Loten C, Fletcher P, et al. Management of acute coronary syndromes in patients in rural Australia: the MORACS randomized clinical trial. JAMA Cardiol. 2022;7:690–8.
[12] Elder A, Dunkerton S, Arnold R, French A, Amos D, Ryan E. Providing primary and rescue PCI in a rural base hospital: a review of the first 24/7 service in NSW. Heart Lung Circ. 2016;25:S190.
[13] Western NSW Local Health District. Western NSW LHD strategic plan 2020–2025. Healthier rural people, thriving communities. Available at: https://wnswlhd.health.nsw.gov.au/wp-content/uploads/2021/08/WNSWLHD-Strategic-Plan.pdf. [accessed 13.11.23].
[14] NSW Government. Local health districts and specialty networks. Available at: https://www.health.nsw.gov.au/lhd/Pages/default.aspx. [accessed 25.8.24].
[15] Chew DP, Scott IA, Cullen L, French JK, Briffa TG, Tideman PA, et al. National Heart Foundation of Australia and Cardiac Society of Australia and New Zealand: Australian clinical guidelines for the management of acute coronary syndromes 2016. Heart Lung Circ. 2016;25:895–951.
[16] NSW Health Agency for Clinical Innovation. Pathway for acute coronary syndrome (PACSA). Available at: https://aci.health.nsw.gov.au/networks/eci/clinical/clinical-tools/cardiology/pathway-for-acute-coronary-syndrome. [accessed 15.3.24].
[17] Taylor LK, Nelson MA, Gale M, Trevena J, Brieger DB, Winch S, et al. Cardiac procedures in ST-segment-elevation myocardial infarction - the influence of age, geography and Aboriginality. BMC Cardiovasc Disord. 2020;20:224.
[18] Australian Institute of Health and Welfare. Indigenous health and well-being. Available at: https://www.aihw.gov.au/reports/australias-health/indigenous-health-and-wellbeing. [accessed 13.11.23].
[19] Farshid A, Brieger D, Hyun K, Hammett C, Ellis C, Rankin J, et al. Characteristics and clinical course of STEMI patients who received no reperfusion in the Australia and New Zealand SNAPSHOT ACS Registry. Heart Lung Circ. 2016;25:132–9.
[20] Mehta SR, Wood DA, Storey RF, Mehran R, Bainey KR, Nguyen H, et al. Complete revascularization with multivessel PCI for myocardial infarction. N Engl J Med. 2019;381:1411–21.
[21] Australian Bureau of Statistics. More growth in the regions during the pandemic. Available at: https://www.abs.gov.au/media-centre/media-releases/more-growth-regions-during-pandemic. [accessed 13.11.23].