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Inter-hospital transfers and door-to-balloon times for STEMI: a single centre cohort study

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Abstract

Background Key performance indices such as door-to-balloon times have long been recognized as quality metrics in reducing time to care for patients with acute coronary syndromes (ACS). In the situation where patients do not present to a facility capable of 24/7 percutaneous coronary interventions (PCI) delays in time to therapy can exceed the recommendation of 90 min or less. This study aimed to evaluate the impact of transfers on performance indices for patients diagnosed with ST-segment elevation myocardial infarction (STEMI). **Methods** Over a seven month collection period, all patients presenting with symptoms suggestive of ACS and admitted for PCI were studied. Patients were divided into dichotomous groups of direct presentations or transfers from a secondary non-PCI capable hospital with key times recorded, including symptom-onset, first hospital and PCI-capable hospital arrival and balloon inflation times to evaluate time of treatment for STEMI patients. **Results** Of the 87 patients diagnosed with STEMI, transferred patients experienced statistically significant delays in symptom-onset to the PCI-capable hospital (PCI-H) arrival (215 *vs.* 95 min, $P < 0.001$), symptom-onset to balloon inflation (225 *vs.* 160 min, $P = 0.009$) and first hospital arrival to balloon inflation times (106 *vs.* 56 min, $P < 0.001$). Only 28% ($n = 9$) of transferred patients underwent balloon inflation within 90 min from first hospital arrival, while 60% ($n = 19$) did within 120 min, although all received balloon inflation within 90 min from arrival at the PCI-H. After controlling for confounding factors of socio-economic status, presentation date/ time and diagnostic category, transferred patients experienced an average 162% longer delays from symptom-onset to PCI-H door arrival, and 98% longer delays in symptom-onset to balloon inflation; compared to patients who present directly to the PCI-H. No statistically significant differences were noted between transferred and direct patients when measured from PCI-H door-to-balloon times. **Conclusions** This study shows that transferred patients experience a greater overall system delay, compared to patients who present directly for PCI, significantly increasing their time to treatment and therefore infarct times. Despite the majority of transfers experiencing pre-hospital activation, their treatment hospital arrival to balloon times are no less than direct presenters after controlling for confounding factors, further compounding the overall delay to therapy.

1   Introduction

Cardiovascular disease is recognised as a leading cause of death and disability across the globe with troubling disparities noted between metropolitan and rural communities.[1–3] Australia has identified this as an area of priority under the National Health Priority Area initiative.[4] Specifically, acute coronary syndrome (ACS) which collectively spans presentations of acute myocardial infarction, including ST-segment elevation myocardial infarction (STEMI), Insert (NSTEMI) and unstable angina[5,6], was the cause of death for 6.1% Western Australians in 2015.[7] Presentations of STEMI are considered medical emergencies and positive outcomes including lower mortality rates are highly correlated with timely reperfusion of the culprit vessel.[8–11] Given this time crucial nature, there has been considerable focus surrounding the reduction of measurable performance indices for time to therapy, namely door-to-electrocardiogram

(DTE), door-to-needle (DTN) and door- to-balloon (DTB) times for ACS patients; and more recently time from first medical contact to balloon times (FMC-B). Reduction in time to therapy is associated with improved outcomes and as such several international professional organisations have reached a consensus, calling for DTE times within 10 min for all presentations and DTB times of 90 min or less for patients who present direct to a hospital equipped with a cardiac catheterisation laboratory (CCL) for percutaneous coronary interventions (PCI).[8,9,12,13] Those patients who require transfers for PCI should have early activation of the CCL to reduce avoidable delays.[13] The 2016 Australian Clinical Guidelines for the Management of Acute Coronary Syndromes recommends primary PCI as the preferred reperfusion strategy for those patients diagnosed with STEMI, if it can be performed within 90 min of first medical contact (FMC); otherwise proceed to thrombolysis in the absence of contraindications.[14] Prior to the 2016 update, DTB times within 90 min were the key performance objective in Australia.[13]

Timely transfer to PCI capable hospitals has been shown to reduce rates of death, re-infarction and stroke compared to on-site fibrinolysis[14,15] and strategies have been introduced to reduce avoidable delays namely emergency department activation;[16,17] pre-hospital activation;[17] 30 min mobilisation of on call staff;[16,17] and ambulance based electrocardiogram (ECG) results transmission.[18,19]

The aim of this study was to analyse the impact of inter-hospital transfers within the Perth Metropolitan region on overall time-to-treatment when a patient needs to be transferred from a non-PCI capable metropolitan hospital to a facility that can offer round-the-clock PCI.

2   Methods

2.1   Study population

Data of all Western Australians resident patients aged 18 years or older who presented to a single Perth metropolitan teaching hospital, PCI-capable hospital (PCI-H), with round-the-clock CCL facilities with a diagnosis of STEMI between June 2013 and December 2013 were de-identified for analysis. Data for every admission to the PCI-H Cardiovascular Medicine Department are routinely collected as part of the department's standard clinical management program, as a single-centre cardiac registry. Human Research Ethical approval was obtained prior to data collection from the Human Research Ethics Committees of the Western Australian Department of Health, Curtin University, and the PCI-H.

2.2   Characteristics of participants

Socio-demographic data included a unique de-identified patient number, birth year, sex and postcode of residence; in addition to the clinical variables of admission date, discharge date, time of symptom-onset, PCI-H arrival time, time of ECG, time of CCL activation, procedure start time, time of first balloon inflation, procedure end time, principal diagnosis, principal procedure (PCI, stent insertions, coronary artery bypass graft), mode of arrival, length of stay in hospital and mode of discharge from the PCI-H. Additionally for those patients who were transferred from another hospital, first hospital arrival time and first hospital departure time were also available. Time-to-event variables were calculated from the difference in the time recorded between the two key events of interest and span symptom-onset to first hospital arrival [STD (First)], symptom-onset to PCI-H arrival [STD (PCI-H)], symptom-onset to first balloon inflation (STB), first hospital arrival to first balloon inflation [DTB (First)], PCI-H arrival-to-first balloon inflation [DTB (PCI-H)], first hospital length of stay (referral LOS) and inter-hospital transfers (IHTs), all measured in min. Pharmacological treatments are not coded in the data and as such DTN times could not be assessed, and it is unknown if transferred patients received thrombolytic therapy prior to transfer. Times of ambulance arrival were not recorded within the dataset and as such FMC to balloon times could not be evaluated.

2.3   Statistical analysis

All analyses were performed using SPSS Statistics Version 22 (IBM Corporation, Armonk, NY, USA). Statistical significance was assigned at the level of $P < 0.05$. Categorical data were reported as frequencies and percentages, while continuous variables were reported as mean or medians, with standard deviations and range. 'Between-group' analyses were completed using Mann-Whitney *U* Test and the Pearson Chi Squared test, respectively. Multivariable generalised linear modelling applying a Gamma distribution with a log link function were performed to evaluate key times and identify predictors impacting length of stay for STEMI patients: candidate variables were chosen as those likely to contribute to confounding given the observational nature of the study (sex, age, socio-economic status, method of arrival to the PCI-H, presentation date/time, pre-hospital ECG, pre-hospital activation and transfer status) and were included in final models after backwards stepwise selection using $P > 0.05$ as the level of significance for variable inclusion.

3   Results

Table 1 presents 107 subjects who met inclusion criteria

Table 1. Socio-demographic, clinical characteristics and outcomes for all patient diagnosed with STEMI by transfer status.

	All (*n* = 107)		Direct (*n* = 66)		Transfers (*n* = 41)	
	n[*]	%[**]	*n*[*]	%[**]	*n*[*]	%[**]
Age, yrs	60 ± 11.7		60 ± 11.3		59 ± 12.3	
Sex						
Male	87	81.3	56	84.8	31	75.6
Female	20	18.7	10	15.2	10	24.4
SEIFA						
Highest disadvantage	7	6.6	5	7.6	2	5.0
High disadvantage	8	7.5	3	4.5	5	12.5
Moderate disadvantage	15	14.2	11	16.7	4	10.0
Less disadvantage	16	15.1	11	16.7	5	12.5
Least disadvantage	60	56.6	36	54.5	24	60.0
Health service area						
North metropolitan	95	89.6	57	86.4	38	95.0
South metropolitan	8	7.5	6	9.1	2	5.0
Western Australia country	3	2.8	3	4.5	0	0.0
Arrival mode						
Medical transport	90	86.5	52	78.8	38	100.0
Private transport	14	13.5	14	21.2	-	-
Presentation date/time[^]						
Weekday, 8 am–5 pm	40	40.0	26	44.1	14	34.1
Weekday, after hours	33	33.0	19	32.2	14	34.1
Weekend, 8 am–5 pm	16	16.0	8	13.6	8	19.5
Weekend, after hours	11	11.0	6	10.2	5	12.2
Pre-hospital activation						
Yes	27	42.9	15	30.0	12	92.3
No	36	57.1	35	70.0	1	7.7
Pre-hospital ECG (without electronic transmission)						
Yes	27	30.0	23	42.6	4	11.1
No	63	70.0	31	57.4	32	88.9
Primary diagnosis						
STEMI	87	81.3	51	77.3	36	87.8
NSTEMI	6	5.6	5	7.6	1	2.4
Unstable angina	1	0.9	0	0.0	1	2.4
Subsequent AMI[+]	10	9.3	8	12.1	2	4.9
Other	3	2.8	2	3.0	1	2.4
Principal procedure						
PCI	24	22.4	16	24.2	8	19.5
PCI + Stent insertion	80	74.8	49	74.2	31	75.6
Coronary artery bypass graft	1	0.9	0	0.0	1	2.4
Other intervention, non-coronary	2	1.9	1	1.5	1	2.4
Length of stay, days	3 (0–32)		3 (0–16)		3 (1–32)	
In-hospital mortality						
Discharged	101	94.4	62	93.9	39	95.1
Deceased	6	5.6	4	6.1	2	4.9

Data are presented as means ± SD or median (interquartile range). [*]Refer to due to missing data, 'n' may not sum to the total sample size of 107. [**]Refer to percentage of total reported cases for each characteristic within each group. [^]Refer to first hospital of presentation. [+]Refer to within 28 days of original AMI. AMI: acute myocardial infarction; ECG: electrocardiogram; NSTEMI: non-ST-segment elevation myocardial infarction; PCI: percutaneous coronary interventions; SEIFA: socio-economic indexes for areas; STEMI: ST-segment elevation myocardial infarction.

with a mean age of 60 years, of which 85% were males predominantly from the North Metropolitan Health Service catchment area (90%). Medical transport was attributed to 86% of those who presented directly to the PCI-H, while it is unknown how patients presented to the first non-PCI-H. All transfers were via ambulance. Pre-hospital activation occurred in 30% of direct presentations and 92% of transfers, conversely pre-hospital ECGs were obtained in 43% of direct presentations but only in 11% of transfers prior to arriving at the first non-PCI capable hospital. Primary PCI was attempted in 97% of patients, of which 75% went on to have at least one stent inserted in the target vessel. Median length of stay was three days with an in-hospital mortality rate of 6% ($n = 6$).

Analysis was limited to only those patients diagnosed as STEMI, as this categorises those in immediate need of PCI. As shown in Table 2, in the crude (unadjusted for potential confounders) analysis no statistically significant differences were noted in time between symptom-onset and first hospi-

tal arrival between direct and transfers. Transferred patients experienced statistically significant delays in STD (PCI-H) times (215 *vs.* 95 min, $P < 0.001$), STB times (224 *vs.* 160 min, $P = 0.009$) and DTB (First) times (106 *vs.* 58 min, $P < 0.001$). However, transferred patients DTB (PCI-H) times were statistically significantly shorter than direct presenters (34 *vs.* 58 min, $P = 0.012$). This trend continues in Table 3 with 28% of transfers having experienced balloon inflation within 90 min of first hospital arrival; and 59% within 120 min, and yet all transfers met target when measured from DTB (PCI-H) times.

Table 4 shows that after accounting for confounding by socio-economic status, presentation date/time, transfer status, pre-hospital activation, pre-hospital ECG, mode of transport to the PCI-H, age and sex, statistically significant differences were observed with transfers having on average 118% longer delays from symptom-onset to first hospital arrival. This difference was further exacerbated when comparisons were made between STD (PCI-H) times, with transferred

Table 2.   Crude key times to treatment for all patients diagnosed with STEMI by transfer status.

	All ($n = 51$)	Direct ($n = 42$)	Transfers ($n = 9$)	$P > Z^*$
[a]STD (First)	90 (56–165)	95 (59–148)	76 (41–277)	0.711
[b]STD (PCI-H)	110 (72–215)	95 (59–148)	215 (146–695)	< 0.001
[c]STB	181 (135–289)	160 (125–250)	224.5 (166–405)	0.009
[d]DTB (First)	80 (53–109)	57.5 (44–81)	106.5 (89–145)	< 0.001
[e]DTB (PCI-H)	54 (41–77)	57.5 (44–81)	34 (30–56)	0.012
[f]LOS (Referral hospital)	43 (36–72)	-	43 (36–72)	-
[g]IHT travel time	25 (17–35)	-	25 (17–35)	-

Data are presented as median (interquartile range). [a]Refer to symptom onset to first hospital door arrival. [b]Refer to symptom onset to PCI-H door arrival. [c]Refer to symptom onset to balloon inflation. [d]Refer to first hospital door arrival to balloon inflation. [e]Refer to PCI-H door arrival to balloon inflation. [f]Refer to referral hospital length of stay. [g]Refer to inter-hospital transfer travel time. [*]Refer to test between direct and inter-hospital transfer patients using Mann Whitney *U*. DTB: door-to-balloon; IHT: inter-hospital transfer; LOS: length of stay; PCI-H: percutaneous coronary interventions-capable hospital; STB: symptom onset to balloon inflation; STD: symptom onset to first hospital door arrival; STEMI: ST-segment elevation myocardial infarction.

Table 3.   Crude numbers and percentages of patient door-to-balloon times for all STEMI[*] patients by transfer status.

	All ($n = 87$)	Direct ($n = 51$)	Transfers ($n = 36$)	$P > Z^{**}$
[a]DTB (First)				
90 min or less	49 (62.8%)	40 (87.0%)	9 (28.1%)	< 0.001
Greater than 90 min	29 (37.2%)	6 (13.0%)	23 (71.9%)	
[b]DTB (First)				
120 min or less	61 (78.2%)	42 (91.3%)	19 (59.4%)	0.001
Greater than 120 min	17 (21.8%)	4 (8.7%)	13 (40.6%)	
[c]DTB (PCI-H)				
90 min or less	51 (89.5%)	40 (87.0%)	11 (100.0%)	0.205
Greater than 90 min	6 (10.5%)	6 (13.0%)	0	

[a]Refer to first hospital door arrival to balloon inflation (90 min or less). [b]Refer to first hospital door arrival to balloon inflation (120 min or less). [c]Refer to PCI-H door arrival to balloon inflation. [*]Refer to patients with confirmed ST-elevation myocardial infarction on electrocardiogram. [**]Refer to test between direct and inter-hospital transfer patients using Chi Squared. DTB: door-to-balloon; PCI-H: percutaneous coronary interventions-capable hospital; STEMI: ST-segment elevation myocardial infarction.

Table 4.   Adjusted mean times to treatment and length of stay by transfers, pre-hospital ECG activation.

	Generalised linear model[♦]				Estimated marginal means[***]					
	Coef[*]	**95% CI**		***P* > Z**[**]	**Mean**	**95% CI**		**Mean**	**95% CI**	
		Lower	**Upper**			**Lower**	**Upper**		**Lower**	**Upper**
Transfer status										
		Inter-hospital transfer is baseline				Direct presentation			Inter-hospital transfer	
[a]STD (First)	1.18	0.49	1.87	0.001	113	83	154	369	205	665
[b]STD (Tertiary)	1.62	1.05	2.19	< 0.001	110	85	143	555	340	906
[c]STB	0.98	0.58	1.39	< 0.001	167	141	198	447	307	652
[d]DTB (First)	1.26	0.91	1.61	< 0.001	55	48	64	195	143	267
[e]DTB (PCI-H)	0.19	−0.17	0.55	0.308	55	48	63	67	49	91
CCL activation										
		No activation is baseline				Pre-hospital activation			No pre-hospital activation	
[c]STB	0.34	0.01	0.68	0.045	230	184	289	324	239	441
[d]DTB (First)	0.81	0.52	1.10	< 0.001	69	58	83	156	120	202
[e]DTB (PCI-H)	0.74	0.49	1.00	< 0.001	39	32	46	81	69	95
ECG										
		No ECG is baseline				Pre-hospital ECG			No pre-hospital ECG	
[c]STB	−0.51	−0.85	−0.17	0.004	353	256	487	212	171	262
[d]DTB (First)	0.15	−0.13	0.42	0.286	97	75	125	112	95	133
[e]DTB (PCI-H)	0.27	0.02	0.52	0.033	49	41	59	64	55	75
Length of stay, days (For those with DTBs 90 min or less)										
		DTB > 90 min is baseline				DTB 90 min or less			DTB greater than 90 min	
[d]DTB (First)	0.510	0.204	0.816	0.001	4	3	5	7	5	9
[e]DTB (PCI-H)	0.593	0.137	1.048	0.011	4	4	5	8	5	13

[a]Refer to symptom onset to first hospital door arrival. [b]Refer to symptom onset to PCI-H door arrival. [c]Refer to symptom onset to balloon inflation. [d]Refer to first hospital door arrival to balloon inflation. [e]Refer to PCI-H door arrival to balloon inflation. [♦]Refer to models were adjusted for sex, age, socio-economic status, method of arrival to PCI-H, presentation date/time, pre-hospital ECG, pre-hospital activation and transfer status. [*]Refer to coefficient B (relative proportional change in the mean value of the outcome variable in those transferred compared with the mean value in the baseline group). [**]Refer to test between groups within transfer status, cardiac catheterisation laboratory activation and pre-hospital ECG; using Wald Chi Square. [***]Refer to estimated marginal means adjust for the covariate by reporting the means of year for each level of the factor at the mean value of the covariate. DTB: door-to-balloon; ECG: electrocardiogram; PCI-H: percutaneous coronary interventions-capable hospital; STB: symptom onset to balloon inflation; STD: symptom onset to first hospital door arrival.

patients facing delays on average 162% greater than their direct counterparts, with model predicted average delays of 555 min (340–906 min) compared to 110 min (85–143 min) respectively. Transferred patients also experienced statistically significantly longer delays in STB times of 98% with model based predicted delays for direct patients at 167 min (141–198 min) rising to 447 min (307–652 min) for transfers. First hospital DTB times are 1.26 times longer for transferred patients, with the model predicting average times of 195 min (143–267 min) compared to just 55 min (48–64 min) for direct presentations. However, when measured from PCI-H arrival, no significant differences were observed.

Failure to have a pre-hospital activation notably increased DTB (First) by 81% and DTB (PCI-H) by 74%, increasing the overall time to treatment burden with pre-

dicted average first hospital DTB times of 69 min for those with pre-hospital activation jumping to 156 min for those without. Pre-hospital ECG statistically significantly reduced DTB (PCI-H) by 27% with an estimated marginal means of 49 min (41–59 min); increasing to 64 min (55–75 min) for those who did not have a pre-hospital ECG. Experiencing DTB times of 90 min or less measured from both the first hospital and the PCI-H were found to significantly reduce the estimated mean length of stay by 51% and 59%, from four days to seven days (5–9 days) and eight days (5–13 days), respectively.

4   Discussion

Despite DTB times from first hospital of presentation resulting in significantly longer delays to treatment for

transferred patients, the majority of these patients experience pre-hospital activation and therefore fortunately have similar, if not improved, DTB (PCI-H) times compared to direct presentations. However, the inherent delay associated with initial presentation to a secondary hospital without CCL capabilities, requiring triage and diagnosis prior to transfer by road to a CCL hospital has important implications in the Western Australians setting with travel notably hindering time to treatment.[20] An Italian study[21] showed similar results with the overall time to treatment metric longer for inter hospital transfers; but those same patients showed a significantly shorter door to balloon delay when measured from the single centre, due to early mobilisation of the CLL team. Rezaee, *et al*.[18] broke down the different components of delay after emergency medical services arrival and after accounting for 15 min as the median time-on-scene, a further 29–32 min for in-hospital assessment and transfer from the ED to the CCL and consequent balloon inflation, found the maximum allowable transport time was 43–46 min. In the Greater Perth region, this figure may be challenging to achieve for outer metro patients, let alone their rural and remote counterparts due to the distances involved. Average travel times by road, from the most northern, southern and eastern tips of the Greater Perth region (Greater Capital City Statistical Areas) to Perth City central are 75 min.[22] Inter hospital transfers are a topic of debate worldwide with numerus initiatives addressing the need to reduce transfer related delays in the primary treatment of ACS.[23] A 2012 study from Brazil, *et al*.[24] showed direct presentations were associated with decreased total ischemia time, improve myocardial reperfusion markers and a non-significant decrease in hospital mortality; despite an integrated system which allows for a 60 minute-time interval for inter-hospital transfer.

Pre-hospital ECGs have previously shown to reduce DTB times,[25] although this was not the case in our study when measured from first hospital DTB times, after controlling for the effects of transfers status and pre-hospital activation. However, PCI-H DTB times were impacted with 27% shorter DTB times for patients who had a pre-hospital ECG (49 *vs*. 64 min, $P = 0.033$). Similarly to this study, it has previously been shown any in-hospital time saving benefits from the acquisition of pre-hospital ECGs were only fully realised with the addition of pre-hospital CCL activation.[18]

No statistically significant differences were noted in sociodemographic factors between direct and transfers for patient diagnosed as STEMI as per the International Classification of Disease.[26] Further, there were no statistically significant differences in the type of interventions per-

formed. In lieu of more detailed data on severity of disease, these figures indicate transferred patients were no more or less critical than direct presentations. Taking into consideration the overall longer delay to PCI therapy due to triage at the first hospital and time to transfer, in conjunction with pre-hospital activation, it would be reasonable to expect rapid DTB times once arriving at PCI-H to reduce overall delay burden. Unfortunately, this was not the case. Although the transfers occurred within recommended guidelines for a single hospital, the overall system delay needs to be taken into consideration.

The data does not include information on how patients arrived at secondary hospitals. Ambulance ECG was introduced to Western Australia in during 2012/2013.[27] Assuming all patients with ECG changes consistent with STEMI were taken directly to an available CCL, the patients who required transfer from a secondary hospital would have either self-presented to their nearest emergency department or were current inpatients. Given the transfer cohort would have known diagnoses of STEMI at the time of transfer, with 78% having pre PCI-H CCL activation, it would be reasonable to expect rapid PCI-H DTB times. Although within the guidelines for a single-centre, overall the burden of delay for these patients is well outside recommendations.

The single most effective measure to reduce the time burden from first medical contact to definitive treatment has been shown to utilise ambulance-initiated ECG. Early identification of STEMI changes en route means patients can be rerouted directly to a PCI-equipped hospital, avoiding transfers after ED triage.[5,11,28,29] A secondary option is the development of a coordinated system to record the time of ED arrival or ambulance retrieval, which can then be accessed at the final receiving hospital to contribute to the time metrics analysis. Data including ECG changes, biomarkers and any initial treatments are recorded. There is compelling evidence Cardiac Registries across the world drive continuous improvements in patient care and inform a medical centres ability to adhere to guideline recommendations. Such registries can be utilised in conjunction with linked administrative health data, to complete the long term picture of the burden of ACS and the short- and long-term outcomes.[28,30–32]

If primary PCI cannot be performed within 90 min of first medical contact, thrombolysis should be considered as a primary reperfusion method. Every patient in this study was transferred for primary PCI as part of the inclusion criteria. However, as this is a single centre study, treatments and therapies initiated at the first hospital of treatment were not coded within the data to identify those patients being transferred for rescue PCI.

It is beyond the scope of this study to analyze patient outcomes post-therapy. Clinical recommendations have been established for the known improvements in outcomes with reduced time to therapy and as such the focus of the paper is on the impact of transfers on time to therapy, rather than short- and long-term outcomes. However, it has previously been shown that for every 30-minute delay in PCI, there is a 1% increase in absolute risk of dying in hospital;[16,33] while another study showed an increase of 7.5% in risk of one-year mortality for every 30 min delay to treatment.[34] In accordance with these findings, the median referral hospital length of stay of 52 min and mean transfer time of 25 min infers the addition of over an hour to the overall patient journey, ultimately increasing the absolute risk of in-hospital mortality by 2.0% with the one-year mortality risk at least 15% greater for transferred patients.

4.1 Limitations

Some limitations in our study should be acknowledged. Despite this study focusing on a single centre in the Perth Metropolitan area, all presentations of STEMI within the study time period were included, avoiding selection bias. Although the single centre nature may limit generalisability, reputable peer-reviewed publications[35,36] and leading epidemiological theorists[37] acknowledge cohort studies rely on validity or international comparisons to avoid systematic error. As such, they do not need to be random sample of a large population to provide generalisable knowledge. Internationally renowned cohort studies, such as the British Doctors Study and US Nurses' Health Study are regarded as generalizable knowledge despite their highly selected study samples, as external validity of generalisation depends on considerations regarding effect modification rather than bias/confounding. The study sample included individuals from all five tiers of socio-economic status from north metropolitan, south metropolitan and Western Australians country health catchment areas. The strength of this study is the routine and systematic nature of the collection of data on all patents presenting to the centre which reduced both selection and recall bias and the comprehensive inclusion of both clinical and administrative data points, allowing for the analysis of time to therapy, not typically possible with administrative datasets. This study was limited by the lack of available data pertaining to why patients presented to a secondary hospital in the first instance and as such determinants of why patients did not present directly to the PCI-H are unknown.

Further times of ambulance arrival are not recorded within the data; and as such FMC-B cannot be measured. However, some patients would have self-presented to the first non-PCI hospital via private transport. In these instances, the secondary hospital arrival time would in fact be their FMC. A brief analysis of linked administrative health data using Emergency Department records in Western Australia shows 58% of ACS patients arriving at secondary hospitals were via private transport. Although this data is derived from a different source, it is from the same pool of ACS patients in Western Australia and therefore these percentages are likely to be generalisable to our sample. Thus, if the secondary hospital arrival time is used as proxy for FMC, this would be the actual FMC for approximately 58% of our patients. The remaining 42% would therefore have time-to-treatments that are an under-estimation of the true burden of delay. In addition, there are no variables within the dataset that outline if the hospital received an ambulance ECG transmission; or if the PCI-H was notified of the incoming transfer. In lieu of this information, time of ECG, CCL activation and PCI-H arrival times were used to calculate pre-hospital ECGs for all patients; and pre-PCI-H activation of the CCL for transfers. Further limitations included the small number of cases in the dataset and some incomplete/empty data variables, particularly in time variables. The study was unable to follow patients after discharge and therefore unable to further assess 30-day and one-year mortality. However, these outcomes were beyond the scope of this study, which was concerned with determining the magnitude of delay associated with transfer from hospital type rather than its impact on patient outcomes.

4.2 Conclusions

Transferred patients' overall delay times from symptom-onset to balloon inflation is 98% longer than that of direct presentations, resulting in significantly longer infarct times and potentially poorer outcomes in the long term. This study highlights the extent to which the transfer process adds to the time to treatment burden and system delay. Despite pre-CCL capable hospital activation, PCI-H DTB times are not statistically significantly shorter than their direct cohort counterparts, representing a missed opportunity in the system to reduce the time delay burden for patients who required transfer for PCI. Inter-hospital transfers will remain an ongoing and unavoidable reality in Western Australia's emergent treatment of ACS due to geographic and service provision challenges. The need for efficient triage to streamline transfer processes, avoidance of any unnecessary transfers by presenting directly to CCL facilities where possible, continuing education for the general public about using ambulance services and continued performance of pre-hospital activations are crucial to reduce system delay in the treatment of ACS.

Acknowledgments

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