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Real-world, feasibility study to investigate the use of a multidisciplinary app (Pulsara) to improve prehospital communication and timelines for acute stroke/STEMI care

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ABSTRACT

Objectives To determine if a digital communication app improves care timelines for patients with suspected acute stroke/ST-elevation myocardial infarction (STEMI).

Design Real-world feasibility study, quasi-experimental design.

Setting Prehospital (25 Ambulance Victoria branches) and within-hospital (2 hospitals) in regional Victoria, Australia.

Participants Paramedics or emergency department (ED) clinicians identified patients with suspected acute stroke (onset <4.5 hours; n=604) or STEMI (n=247).

Intervention The Pulsara communication app provides secure, two-way, real-time communication. Assessment and treatment times were recorded for 12 months (May 2017–April 2018), with timelines compared between 'Pulsara initiated' (Pulsara) and 'not initiated' (no Pulsara).

Primary outcome measure Door-to-treatment (needle for stroke, balloon for STEMI) Secondary outcome measures: ambulance and hospital processes.

Results Stroke (no Pulsara n=215, Pulsara n=389) and STEMI (no Pulsara n=76, Pulsara n=171) groups were of similar age and sex (stroke: 76 vs 75 years; both groups 50% male; STEMI: 66 vs 63 years; 68% and 72% male). When Pulsara was used, patients were off ambulance stretcher faster for stroke (11(7, 17) vs 19(11, 29); p=0.0001) and STEMI (14(7, 23) vs 19(10, 32); p=0.0014). ED door-to-first medical review was faster (6(2, 14) vs 23(8, 67); p=0.0001) for stroke but only by 1 min for STEMI (3 (0, 7) vs 4 (0, 14); p=0.25). Door-to-CT times were 44 min faster (27(18, 44) vs 71(43, 147); p=0.0001) for stroke, and percutaneous intervention door-to-balloon times improved by 17 min, but non-significant (56 (34, 88) vs 73 (49, 110); p=0.41) for STEMI. There were improvements in the proportions of patients treated within 60 min for stroke (12%–26%, p=0.15) and 90 min for STEMI (50%–78%, p=0.20).

Conclusions In this Australian-first study, uptake of the digital communication app was strong, patient-centred care timelines improved, although door-to-treatment times remained similar.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ In this Australian-first study, a single digital communication smartphone/tablet app was implemented in the prehospital and within-hospital setting.
⇒ Multiple health services (25 ambulance branches, 2 hospitals) and different clinician groups (paramedics; emergency, stroke/neurology, cath lab clinicians, radiologists) were involved.
⇒ Participants were patients with suspected stroke (<4.5 hours) or suspected ST-elevation myocardial infarction identified by paramedics or emergency clinicians.
⇒ As a pragmatic feasibility study, limitations include the non-randomised controlled design and a relatively small sample size, not powered for long-term clinical outcomes.

INTRODUCTION

Cardiovascular disease is the leading cause of death and disability in Australia, with over 75 000 patients experiencing a stroke or STEMI (ST-elevation myocardial infarction) cardiac eventeach year.[1] A key element to achieving better outcomes is rapid patient assessment and treatment.[2 3] International guidelines detail evidence-based emergency treatment for both stroke and STEMI, including medications (ie, aspirin and thrombolysis) and interventional procedures (eg, revascularisation) to reopen blocked blood vessels in the brain and heart (collectively referred to as 'reperfusion therapies'). For STEMI, the benefits of reperfusion therapy are maximised when administered within the first 90 min following symptom onset, including less myocardial damage, fewer complications, and better short-term and

long-term outcomes.[4–7] Similarly, for stroke 'time is brain': every minute saved in delivering thrombolysis (<4.5 hours) equates to an extra day of disability free survival,[8] every 20 min saved in delivering endovascular thrombectomy (EVT) equates to an extra 3 months of disability-free survival.[9]

Timely treatment delivery for acute ischaemic stroke and STEMI requires a co-ordinated, interdisciplinary approach across multiple settings. In addition, advances in time-critical reperfusion therapies have brought the need for better integration of prehospital and intrahospital systems of care into sharp focus. Preliminary assessment, diagnosis and sometimes treatment is undertaken by paramedics in the community (prehospital) setting, and subsequently by clinicians in the emergency department (ED), as well as either hospital stroke (neurology and radiology) or cardiology clinicians (catheterisation laboratory (cath lab)). Prehospital notification of incoming patient details by paramedics provides advance notice and time for these multiple, interdisciplinary hospital teams to mobilise, prepare, and prioritise patient cases leading to faster onset-to-treatment times.[10] For example, Australian registry data shows a 50% increase in the proportion of patients receiving primary percutaneous intervention (PCI) within guideline time frames when prehospital notification is undertaken (within 90 min: 61.3% without prehospital notification vs 89.3% with prehospital notification).[11]

Prehospital notification to the hospital team about an incoming patient is a key time saving procedure for improving patient treatment times.[12] Interdisciplinary prehospital communication is however often fragmented with clinicians dispersed geographically, across health services and reliant on multiple separate communication systems, such as radio, phone and paging systems, for the one patient. This disjointed system leads to repetition of documenting clinical details, transmission of incorrect or out of date clinical information and subsequent treatment delays. New digital applications allow end-to-end communication so that patients' clinical details such as symptoms, assessments, treatment or contraindications, and subsequent time metrics are transparent to all clinicians involved, from within the community and into the hospital setting. These types of end-to-end communication tools have not been trialled within the Australian context for prehospital and hospital emergency care management for acute cardiovascular and cerebrovascular conditions. To date, very few reports from other countries of HIPAA (Health Insurance Portability and Accountability Act) compliant options have been published[13–15] with no single system being used from first responders to hospital treatment.

Our aim was to undertake a real-world, pilot feasibility study and determine if a secure, digital communication app (Pulsara), operating both between and within health services, could improve the timelines for the different stages involved in the interdisciplinary processes of care for patients with suspected acute stroke or STEMI.

METHODS

Design

A quasi-experimental, pragmatic design was used with the control group defined as those patients not receiving the intervention within the study period, compared with those who did. Differences between the two hospitals precluded a pre–post design; specifically, the cardiac PCI lab at one site only commenced soon after the intervention began. Following a 6-month feasibility pilot at hospital 1 (August 2016 to February 2017), a 12-month evaluation was conducted in hospitals 1 and 2 (May 2017 to April 2018) simultaneously.

Setting

This real-world pilot feasibility study for application within the Australian context was undertaken within two large regional hospitals in Victoria, Australia, (hospital 1=534 beds, hospital 2=361 beds) and 25 Ambulance Victoria (AV) branches (emergency medical service; EMS). A single EMS agency (AV) covers the state of Victoria.[16] In 2017–2018, the two hospital EDs received 111 322 ED presentations per annum, 58 048 (52%) triaged as category 1–3 (ie, requiring attention within 30 min).[17] Both hospitals treat patients with acute ischaemic stroke or STEMI, including access to cardiac PCI and support from the Victorian Stroke Telemedicine service.[18] Patients requiring EVT for cerebral large vessel occlusion are urgently transferred to hospitals in metropolitan Melbourne.

Digital health technology

The Pulsara smartphone/tablet app (Pulsara; www.pulsara.com) is designed for secure (HIPAA compliant) sharing of patient details, symptoms, arrival time, plus tracking of treatment time metrics (eg, arrival at ED, CT brain imaging, PCI cath lab, stroke/STEMI reperfusion times) and possible contraindications for treatment (figure 1). Images are securely sent to expedite hospital triage/patient identification (eg, patient's driver's licence, utility accounts) or facilitate patient care (eg, medication lists, ambulance vitals or ECG results). Patient details and team member status (eg, which clinicians have acknowledged the incoming case) are available to case-relevant users. Pulsara has condition-specific modules (ie, stroke, STEMI, trauma, sepsis, mental health) with disease-specific data fields (eg, last known well time for stroke). Minimum data fields allow rapid input and sharing, with clinical updates pushed simultaneously to all users on a case. On conclusion, a case summary is provided to all those involved, and data extractions (eg, for monitoring and feedback) can be made immediately or cumulatively.

Pulsara can be activated by ambulance paramedics to prenotify patient's arrival to the hospital ED, or the hospital can initiate a case for 'walk-ins' or hospital inpatients, as relevant. The ED can then simultaneously alert and synchronise care across multiple hospital departments as relevant (eg, Cath Lab, Radiology, Cardiac team, Stroke team), prior to the ambulance arriving at the ED

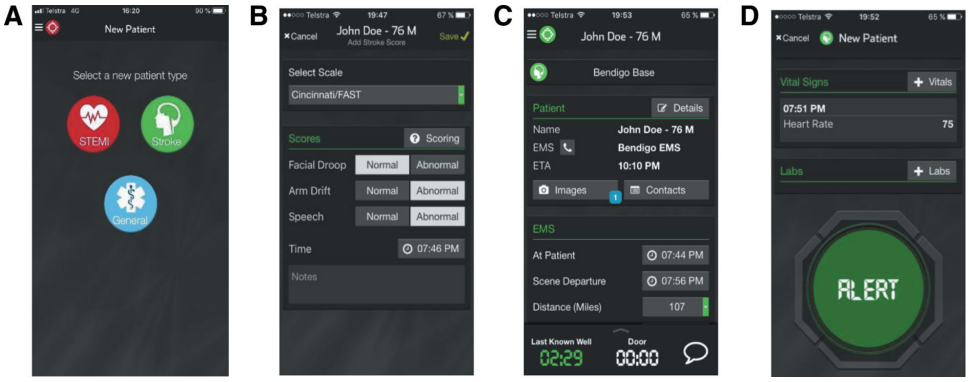

Figure 1 Screen shots Pulsara stop stroke/STEMI (V.4.6 originally implemented June 2016, V.11 in use November 2020): (A) select patient condition, (B) enter patient symptoms, (C) adding images (eg, driver's licence) or messages, (D) alert emergency department. see www.Pulsara.com for video. STEMI, ST-elevation myocardial infarction.

with a patient. The Pulsara app was downloaded onto paramedics' and clinicians' personal and/or dedicated work smartphones with dedicated iPads situated in ED, Cardiology and Radiology. At the time of implementation in 2016, only the stroke and STEMI modules were available (Pulsara V.4.6).

Procedure

Eligible patients were those with suspected acute stroke (with symptom onset <4.5 hours or unknown onset) or STEMI, as identified by AV or hospital personnel. For AV paramedics, if cases required prenotification, then Pulsara was to be activated. As this was a research study, usual paramedic communication systems were a medicolegal requirement throughout the evaluation period; that is, activating Pulsara was an additional procedure required of paramedics and hospital personnel. At the time of the trial, usual prenotification communication systems involved patient information exchanged via multiple systems, with some variations across different hospitals. Communication flow generally involved paramedics radioing to an AV Clinician who forwarded information via phone to the ED. Where relevant, the ED then activated a 'stroke alert' or 'cardiac alert' by notifying switchboard where pager messages were activated to those on the team. Fax was used between AV and the ED to share ECG results and between ED and Radiology to indicate CT required.

Prehospital and hospital assessment and treatment times were recorded, patient at triage, patient off AV stretcher, ambulance hospital departure time, with hospital times of patient arrival in ED (door time) and first medical review. For patients with suspected stroke, CT time available and thrombolysis time (where relevant), and for patient with suspected STEMI undergoing primary PCI, procedure start time and balloon time were collected systematically (case report forms) from sources independent from the project; that is, from AV and hospital data systems.

Patient and public involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

Statistical analyses

To examine group differences between when Pulsara was or was not used, χ^2 tests for categorical, and Kruskal-Wallis tests for continuous variables, were conducted within STATA (V.16). The primary outcome was door-to-treatment (needle for stroke and balloon for STEMI, with secondary outcomes for ambulance metrics as arrival at hospital to triage, arrival at hospital to off-stretcher and arrival at hospital to hospital departure times with hospital metrics as door-to-first medical review, door-t0-CT (stroke only), door-to-procedure (STEMI only). KB had full access to all the data in the study and takes responsibility for its integrity and the data analysis. Data quality checks were undertaken.

RESULTS

There were 604 patients with suspected acute stroke and 247 with suspected STEMI identified by paramedics and hospital personnel (table 1). Pulsara was activated for 64% of stroke cases and 69% of STEMI cases. When Pulsara was activated, the majority (57%) of stroke cases were initiated by paramedics. Hospital ED staff activated a Pulsara case on behalf of the paramedics in 16% of

Table 1 Activation of Pulsara

Activation status and location	Stroke N=604	STEMI N=247
Not activated	215 (36%)	76 (31%)
Activated cases	389 (64%)	171 (69%)
Ambulance victoria (AV)	223 (57%)	71 (42%)
Emergency department on behalf of AV	41 (11%)	28 (16%)
Emergency department (walk-in, inpatient)	125 (32%)	72 (42%)

Table 2 Demographics of participants for stroke and STEMI

Demographic	Stroke N=604			STEMI N=247		
	Without Pulsara N=215	With Pulsara N=389	P value	Without Pulsara N=76	With Pulsara N=171	P value
Sex, male n (%)	107 (50)	195 (50)	0.69	52 (68)	123 (72)	0.51
Age, years median (IQR)	76 (63–84)	75 (62–82)	0.25	66 (57–79)	63 (55–74)	0.35

STEMI, ST-elevation myocardial infarction.

cases for STEMI, while 42% of cases were self-presenting. Patients were similar in age and gender for stroke and STEMI cohorts regardless of whether Pulsara was, or was not, activated (table 2).

Stroke

For suspected stroke cases, the median times (IQRs) for paramedic metrics with (n=206) and without (n=272) Pulsara are reported in table 3. Compared with cases where Pulsara was not initiated, use of Pulsara by paramedics resulted in triage 4 min faster (p=0.0001), off stretcher 8 min faster (p=0.0001), and paramedics departed hospital 5 min faster (p=0.0001). Overall, the time between patient ambulance loaded and hospital arrival for stroke was 5 min faster if Pulsara was used (18 min vs 13 min p<0.0009). On arrival at hospital, 92% of strokes with Pulsara were triaged as emergency (categories 1 and 2), compared with 47% without Pulsara (p=0.000).

Hospital-based time metrics for patients with suspected stroke are reported in table 4. Compared with cases where Pulsara was not used, patient first medical review was 17 min faster (p=0.0001), and CT scan undertaken 44 min faster (p=0.0001) when Pulsara was used. As Pulsara was used in 96% (52/54) of patients receiving thrombolysis, door to needle times (DTNT) were compared with the equivalent pre-Pulsara period (same time period, 12 months earlier). DTNT improved by 6 min (p=0.36) with a higher but non-significant proportion receiving treatment within 60 min (12% pre-Pulsara vs 25% Pulsara; p=0.15).

ST-elevation myocardial infarction

For STEMI cases, median time (IQRs) for paramedic metrics with (n=73) and without (n=84) Pulsara are reported in table 5. Compared with cases where Pulsara was not initiated, use of Pulsara resulted in triage 3 min faster (p=0.004), and off stretcher 5 min faster (p=0.014). Paramedics departed the hospital 14 min slower (p=0.031). Overall, the time between patient ambulance loaded and hospital arrival for STEMI was 23 min faster if Pulsara was used (45 min vs 22 min p<0.006). On arrival at hospital, 100% of STEMI patients with Pulsara were triaged as emergency (categories 1 and 2), compared with 86% without Pulsara (p=0.19).

Hospital-based metrics for STEMI cases are reported in table 6. Time from patient arriving in ED and first medical review was similar (1 min faster, p=0.25), PCI procedure start time improved by 6 min (p=0.42), and door-to-balloon by 17 min although not significant (p=0.41). With Pulsara, there was increased proportion of PCI procedures (door-to-balloon time, DTBT) started within 90 min (50% no Pulsara to 78% Pulsara, p=0.20).

DISCUSSION

Our prospective, real-world feasibility study is the first to systematically examine the use of Pulsara for the treatment of stroke and STEMI across the entire patient care journey; that is, from patient assessment in the community to patient treatment in hospital. Health services' agreement and subsequent participation in the trial indicates the feasibility of implementing a single communication system across multiple health services (ie, AV and two regional hospitals). This agreement extended across clinicians within multiple disciplines (eg, ED, Radiology, Neurology, Cardiology). There was excellent uptake in the use of Pulsara by clinicians with over 90% use in stroke cases receiving thrombolysis, and STEMI cases undergoing PCI. For all eligible cases however, Pulsara was not activated for approximately one-third of both stroke and STEMI cases. During this research study, clinicians had to use usual communication systems and Pulsara was an additional step, that was not undertaken in 100% of eligible cases. Our process evaluation data[19] suggest that

Table 3 Ambulance metrics for suspected stroke

AV metric median minutes (IQR)	Without Pulsara N=206	With Pulsara N=272	Time difference (p value)
Arrive hospital and triage time	N=2047 (3–11)	N=2723 (2–7)	–4 min, 0.0001
Arrive hospital and off-stretcher time	N=20 319 (11–29)	N=27 211 (7–17)	–8 min, * 0.0001
Arrive hospital and depart hospital time	N=20 650 (36–58)	N=27 245 (35–57)	–5 min,* 0.14

*These results are if Pulsara was initiated by AV or hospital. N varies due to missing data.
AV, ambulance victoria.

Table 4 Hospital metrics for suspected stroke

Hospital metric median minutes (IQR)	Without Pulsara	With Pulsara	Difference (p value)
Door-to-first medical review	N=155 23 (8–67)	N=319 6 (2–14)	−17 min, 0.0001
Door-to-CT completed	N=130 71 (43–147)	N=300 27 (18–44)	−44 min, 0.0001
	Pre-Pulsara*	**With Pulsara**	
Door-to-needle*	N=2684 (74–106)	N=5178 (58–101)	−6 min, 0.36
Door-to-needle* <60 min n, %	3/2612	13/51 25	0.15

*Pulsara used on 96% (52/54) tPA cases, so with and without Pulsara comparisons cannot be made. Comparisons made between with and pre-Pulsara period (equivalent months in prior year). N varies between first medical review and CT as not all cases received a CT scan.

paramedics report that cases where Pulsara was not used were largely due to issues of technology (eg, forgot password/PIN), time constraints (eg, added time) or human error (eg, remembering to use the app) reasons. Implementation of the Pulsara digital communication application resulted in faster metrics of the patient arriving at hospital and being at triage when Pulsara was used, as well as patient off ambulance stretcher times for both stroke and STEMI cases. Hospital metrics for stroke cases also improved significantly with door-to-first medical review and door-to-CT completed more rapidly. Improvements in door-to-treatment times for suspected stroke (door-to-needle) and STEMI (door-to-procedure/balloon) did not reach significance, possibly due to small sample sizes, however, they were in the expected direction.

Previous studies evaluating the use of Pulsara have not compared metrics across both prehospital and within hospital for treatment of stroke and STEMI. A single hospital comparison of tPA stroke cases (n=34 preuse/n=34 postuse of Pulsara) demonstrated a 28% significant improvement (77 to 56 min, p=0.001) in DTNT, as well as greater proportion of cases achieving DTNT <60 min (32%–82%, p=0.001) after Pulsara implementation.[20] In a larger retrospective cohort study of stroke codes at 12 medical centres (n=2589) using Pulsara, those cases activated by EMS were more likely to receive tPA than those with ED activation (20% vs 12%, p<0.0001).[21] Cases with EMS activation had shorter door to CT (6 min, 95% CI (−10.3,−2)) and shorter DTNT (12.8 min, 95% CI (−21 to −4.6)).[21] For treatment of STEMI, a pre (4 months)/post (6 months) retrospective hospital study that implemented Pulsara reported reduced DTBT by 22% (91 min to 71 min, p=0.05), and greater numbers of DTBT cases <60 min (56%–80%).[13]

The importance of time to treatment is well established. The mantra for urgency in the treatment of STEMI and stroke has been that 'time is muscle' and 'time is brain' respectively, with a focus on reperfusion achieved within 60 min (stroke), 30 min (for STEMI thrombolysis) and 90 min (for STEMI-PCI). Treatment, however, can be inconsistent. One in three STEMI patients in Australia did not receive any form of reperfusion and of those who did, only one in three received it in an optimal time frame.[22] Comparing STEMI populations from regional (predominantly receiving thrombolysis) and metro hospitals (predominantly receiving PCI) indicated no difference in reperfusion rates, and no difference in long-term outcomes. This emphasises that time to reperfusion is more important than modality of reperfusion.[22] It is clear that reducing total system delay (from first medical contact to reperfusion therapy) is more strongly associated with mortality than patient delay in seeking care.[23] In recent 2018 data from an Australian registry (Victorian Cardiac Outcomes Registry), it was found that 81% of PCI cases are treated within 90 min (median time to PCI 58 min (IQR: 39–83)). This increased to 89% with

Table 5 Ambulance metrics for suspected STEMI

AV metric median minutes (IQR)	Without Pulsara N=73	With Pulsara* N=84	Time difference (p value)
Arrive hospital and triage time	6 (3–10)	3 (2–6)	−3 min, 0.004
Arrive hospital and off-stretcher time	19 (10–32)	14 (7–23)	−5 min, 0.014
Arrive hospital and depart hospital time for all suspected STEMI cases	56 (40–84)	70 (50–90)	+14 min, † 0.031
Arrive hospital and depart hospital time for primary PCI cases only	N=8 50 (33–67)	N=31 76 (58–97)	+16 min, † 0.008
Arrive Hospital and depart hospital time for non-primary PCI cases only	N=39 64 (47–84)	N=29 66 (48–86)	+2 min, † 0.59

*Includes if AV or ED activate App.
†Extended time with patients being transferred on ambulance stretchers to Cath Lab and paramedics staying to watch PCI procedure (new Cath Lab). N varies due to missing data.
AV, ambulance victoria; ED, emergency department; PCI, percutaneous intervention; STEMI, ST-elevation myocardial infarction.

Table 6 Hospital metrics for suspected STEMI

Hospital metric median minutes (IQR)	Without Pulsara	With Pulsara	T Difference (p value)
Door to first medical review	N=524 (0–14)	N=1423 (0–7)	−1 min 0.25
Door to procedure start time for primary PCI*	N=641 (27–87)	N=6135 (19–59)	−6 min, 0.42
Door to procedure start time† for primary PCI <90 min	5/6 83%	55/6190%	0.60
Door to balloon time	N=473 (49–110)	N=4656 (34–88)	−17 min, 0.41
Door to balloon <90 min	2/4 50%	36/46 78%	0.20

*Includes if AV or ED activate App.
†Procedure time reported as balloon time may have delays within operation - balloon time not captured for all cases. Direct admits precluded door times for 8 patients. N varies as not all cases had a procedure/balloon and there were missing data for some balloon times.
AV, ambulance victoria; ED, emergency department; PCI, percutaneous intervention; STEMI, ST-elevation myocardial infarction.

prehospital notification. However, in the one-third of cases where there was no prehospital notification, only 61% were treated with PCI <90 min (median time to PCI 80 min; IQR: 56–112).[11]

Improvements in one aspect of healthcare may have implications in another areas. For example, with the use of Pulsara for STEMI cases (with prehospital notification, sharing ECGs, etc), the entire cardiac team was often fully mobilised before the patient arrived in the ED triage area. Patients were transferred directly from triage to the cath lab on the ambulance stretcher, rather than moving the patient to an ED stretcher. This streamlined care was reflected in a longer time for paramedics to depart hospital (by 14 min; p=0.031). Recent advances in stroke care now support the prehospital delivery of thrombolysis via the Mobile Stroke Unit (ie, a specialised ambulance with a CT scanner and stroke team).[24] Immediate and accurate sharing of patient clinical and treatment information with the receiving hospital is essential. A single communication system such as Pulsara that covers both the prehospital and within-hospital settings further supports the integration of treatment advances that span both community and medical settings.

Our study has a number of strengths, including evaluation with two acute medical conditions involving different clinician groups, across multiple health services. A number of limitations, however, need to be considered when reviewing results. First, the design of this feasibility study was pragmatic with a non-randomised controlled design that was not powered for clinical effectiveness or patient outcomes (eg, morbidity/mortality). This limitation includes no control for casemix. As Pulsara was an additional communication system, it was up to individual paramedic and hospital clinicians to decide to activate the app for eligible cases, which did not consistently occur. It is possible that, in some cases, paramedics may have not activated Pulsara if it was felt that the patient symptoms were perhaps too mild. For example, 92% of stroke cases with Pulsara vs 47% (p<0.000) without Pulsara were categorised as Emergency care (ED triage categories 1 and 2). This difference was less evident for STEMI cases. However, this reflects practice in the real world where paramedic clinical judgement is focused on the optimal rapid treatment of patients, particularly if they feel the symptoms are severe. Another consideration is that for STEMI PCI cases, the sites were not equivalent prior to the Pulsara implementation period (ie, no cath lab at one site during the pre-Pulsara period but opened the same week that the Pulsara intervention period commenced); comparisons were therefore between cases that used and did not use Pulsara. This approach accounted for changes across time, such as other improvements within the hospital/s. Pulsara was also used in a very high proportion of cases receiving stroke thrombolysis (96%), illustrating clinicians' willingness to use Pulsara for their acute cases. However, this uptake necessitated a pre–post comparison for DTNT times (comparison times were sourced from the same period in the previous year at each hospital). Second, although the overall small number of tPA/PCI cases in these regional hospitals were low and precluded achieving statistical significance, the consistent clinically significant time improvements suggest improved patient outcomes are likely. Our inclusion of both ambulance and walk-in (no time for medical team to mobilise prior to patient arrival) cases suggests our reported time saving are conservative. Finally, it is also important to note that for medicolegal surety, the usual communication systems were retained throughout the study period; that is, the use of Pulsara was in addition to usual communications. We would, therefore, anticipate even faster timelines when Pulsara is not an additional step, but the only communication system utilised. Despite this, the ease of use and benefits of time saved for paramedics and ED clinicians in removal of repetition of information was readily apparent with clinicians electing to use Pulsara in addition to usual systems.

In conclusion, the use of Pulsara led to shorter timelines in the care of patients with suspected stroke and STEMI. While stroke thrombolysis/PCI numbers were perhaps small, the gains were similarly apparent, with increased numbers within defined treatment time windows (<60/<90 min). Strong uptake suggests the clinical utility of such a communication system. Patient-centred care needs a patient-centred communication system incorporating patients identified in the community by first responders, then assessed and treated by multiple

clinicians within the community and hospital setting. Our research provides evidence that Pulsara can be used as a single digital communication system to enhance the emergency management of patients across multiple conditions. Identifying significant improvements in the time lines for other acute conditions such as trauma, sepsis and mental health warrants further research.

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Contributors CB conceived and supervised all aspects of the research and is responsible for the overall content as the guarantor; KB designed the evaluation and wrote the protocol; TC and DP collected the data; KB and JK completed analyses; CB and KB prepared the initial manuscript; DAC contributed to the study design, supervision and provided critical revision of the manuscript; MV, JK, SB, KS, GH, TC, DP, DB, MB, VN, WP, HH, BK, AS, PC, EO, RS, TK, CH and DS reviewed results, provided input and all authors approved the final version of the manuscript.

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Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval Approval for this research was obtained from Human Research Ethics Committees from participating hospitals (Bendigo Health HREC approval: LRN/16/BHCG/5, 22 March 2016; Ballarat Health Services HREC approval LRN/17/BHSSJOG/13, 28 April 2017) and the Ambulance Victoria Research and Governance Committee (R16-005, 3 May 2016). HRECs waived the requirement for informed consent from patients.

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Data availability statement Data may be obtained from a third party and are not publicly available. All data relevant to the study are included in the article or uploaded as online supplemental information. The authors confirm that the data supporting the findings of this study are available within the article (and/or) its online supplemental materials. Patient-level raw data are subject to third party restrictions and are not publicly available due to the possibility that the privacy of research participants could be compromised.

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