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Interdisciplinary interactions, social systems and technical infrastructure required for successful implementation of mobile stroke units: A qualitative process evaluation

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Abstract

Rationale: Mobile stroke units (MSUs) are increasingly being implemented to provide acute stroke care in the prehospital environment, but a comprehensive implementation evaluation has not been undertaken.

Aim: To identify successes and challenges in the pre- and initial operations of the first Australian MSU service from an interdisciplinary perspective.

Methods: Process evaluation of the Melbourne MSU with a mixed-methods design. Purposive sampling targeted key stakeholder groups. Online surveys (administered June–September 2019) and semistructured interviews (October–November 2019) explored experiences. Directed content analysis (raters' agreement 85%) and thematic analysis results are presented using the Interactive Sociotechnical Analysis framework.

Results: Participants representing executive/program operations, MSU clinicians and hospital-based clinicians completed 135 surveys and 38 interviews. Results converged, with major themes addressing successes and challenges: stakeholders, vehicle, knowledge, training/education, communication, work processes and working relationships.

Conclusions: Successes and challenges of establishing a new MSU service extend beyond technical, to include operational and social aspects across prehospital and hospital environments.

KEYWORDS

ambulances, health services research, hospitals, implementation science, mixed methods research, mobile stroke unit, process evaluation, qualitative research, stroke

1 | INTRODUCTION

Globally, stroke is the second leading cause of death and is ranked third for adult disability.[1] Patients with suspected stroke require rapid assessment and diagnosis and expert healthcare to optimize options for treatment to reduce the risk of disability or death. The earlier delivery of time-sensitive interventions supports improved patient outcomes, whereby every minute saved can make a difference.[2,3] In recent years, medical advances have led to new treatment options such as endovascular clot retrieval[4] and wider time windows for treatment with the use of advanced imaging techniques (e.g., from 3 to 4.5 h to most recently, 9 h) for patients with ischaemic stroke.[5] However, treatment within 'the golden hour', the first 60 min from symptom onset, will provide the greatest improvements in patient outcomes.[6] Such rapid treatment delivery is difficult to achieve due to lack of public awareness, prehospital Emergency Medical Services (EMS) responses, and the dynamics within complex hospital settings.[7]

The latest innovation to fast-track diagnosis and treatment for stroke are through mobile stroke units (MSUs). MSUs are specialized ambulances that typically house the necessary diagnostic technology (e.g., computerized tomography [CT] scanner for brain scans, point-of-care testing) and have an interdisciplinary team of paramedics and hospital clinicians with expertise in stroke (e.g., neurologist, stroke nurse, radiographer).[8,9] This combination supports the assessment of patients with suspected stroke, accurate diagnosis and the commencement of treatment before transport to hospital for ongoing management.

These ambulance-based services offer a new model of care for many locations and are a disruption to the usual approach to providing prehospital and hospital-based emergency care for people with suspected stroke and require significant resourcing.[10,11] There is evidence that MSUs are associated with improved treatment timeframes,[12,13] treatment rates[14] and patient outcomes[15] and are potentially a cost-effective model of care for suspected stroke in densely populated regions.[6,16,17] However, to be successful, the MSU must be established seamlessly into the health system with feasible clinical protocols and organizational policies.[9,10] A call for research into how to best integrate MSUs into healthcare systems has been made.[18]

Very little has been reported from an implementation perspective on the establishment of MSU services. Further, to our knowledge, no systematic and comprehensive evaluation of the implementation of an MSU has been undertaken by a group external to those responsible for providing the service. The aims of this study were to identify factors important to the success (including what was done well) and the challenges (including areas for improvement) in the pre- and initial operations of implementing a new MSU service in Australia from an interdisciplinary perspective. Specifically, we sought to describe:

- the initiation and development phase of an MSU (i.e., preoperational)
- the first 24 months of MSU operations (i.e., operational), and
- important factors related to the various components of the operational protocol for this model of care (i.e., standby, dispatch, on-scene, transfer, stand down).

2 | METHODS

2.1 | Study design

We used a retrospective, mixed-methods design using a survey and interviews/focus groups with a range of stakeholders to enable a comprehensive process evaluation of the Melbourne MSU.[13] Our evaluation included two studies: preoperational and initial operational aspects (presented here) and the ongoing operations (presented elsewhere).[19] We used two qualitative research methods: written responses to two-open-ended survey questions and verbal responses via interviews and focus groups.[20] The qualitative approach supports a nuanced exploration of the experiences of stakeholders and provides insights into influential contextual and environmental factors.[21] We have used the consolidated criteria for reporting qualitative research (COREQ).[22] We undertook a constructivist approach which assigns individuals to construct their own meaning and knowledge of new experiences within their current knowledge and systems.[23] This approach has been recommended to

understand aspects such as attitudes, knowledge and behaviour to support healthcare interventions.[24]

2.2 | Setting and context

Operational details, initial clinical-effectiveness and cost-effectiveness outcomes of the Melbourne MSU have been recently published.[13,16] Briefly, the Melbourne MSU is the first MSU established in Australia as the result of a multiorganizational collaboration between the Royal Melbourne Hospital (RMH), Ambulance Victoria (AV), the University of Melbourne, the Florey Institute of Neuroscience and Mental Health, the Stroke Foundation and RMH Neuroscience Foundation.[13] The collaborators received initial funding in 2015–2016 and the model of care was launched in November 2017. Similar to MSUs established in other countries, the Melbourne MSU includes a CT scanner and a multidisciplinary clinical team: a CT radiographer and two paramedics (optimal combination is one advanced life support [ALS] and one mobile intensive care ambulance [MICA] paramedic, but sometimes two ALS paramedics), coupled with stroke-specific expertise provided by a neurologist/senior stroke fellow and a specialized stroke nurse.[25] During the study period, the MSU was operational Monday to Friday, 8 AM to 6 PM and within a 20 km radius of its location at RMH. Based on structured call-taking and problem identification by EMS call takers, the MSU is co-dispatched with a standard ambulance for suspected stroke cases within 6 h of symptom onset (now within 12 h), during operational hours. The MSU can respond directly to other ambulance crew requests and also can self-dispatch through scanning radio traffic for appropriate indicators. After a preliminary assessment by co-dispatched paramedics, patients are assessed, diagnosed and, where relevant, treated in the field by the MSU team. If the standard ambulance arrives before the MSU and paramedics determine that a suspected stroke is unlikely, then the MSU can be released so that it may attend other stroke cases as directed by dispatch. If a stroke diagnosis is confirmed, patients are managed by the MSU team and either transported to hospital in the MSU or handed back (in those not requiring thrombolysis or other MSU-specific intervention) to the original paramedics to transport to the nearest relevant hospital that can provide additional interventions (e.g., stroke unit care).

2.3 | Participants

Purposive sampling was used to identify potential participants best placed to provide details about the establishment and implementation of the Melbourne MSU within the first 24 months of operation. In the first instance, the MSU Project Manager and contacts at receiving hospital (i.e., insider assistants) identified individuals that the research team should approach. We sought data from clinical staff (e.g., paramedics and clinicians on the MSU, clinicians at receiving hospitals), operational (e.g., project leads) and project team (e.g., project management, executives, Steering Committee) members. In addition, all emergency call takers and dispatchers, and paramedics co-dispatched with the MSU were encouraged to participate. Therefore, representation from different disciplines and multiple organizations representing Emergency Services Telecommunications Authority (ESTA), AV, and hospitals—MSU clinician-provider hospital (RMH) and patient-receiving hospitals (eight metropolitan, thrombolysis capable hospitals)—was targeted.

2.4 | Survey design

The final survey was a maximum of 49 items, including 7 demographic and 12 open-text items (see Supporting Information: 1 for survey content). The number of items presented varied with participant's role to ensure relevance. For example, only clinicians and paramedics working on or with the MSU (i.e., not operational team members or organizational executives) were presented with items targeting the clinical experience of working within the MSU program.

Items targeted the preoperational stage (e.g., Were you involved in the decision making to implement the MSU program?) and operational stage (e.g., 'Describe three barriers to working with the MSU program in your role/team/organization', open-text response). Two open-ended questions specific to the establishment and implementation phase: *Describe three features that were helpful in the implementation of the MSU program* and *Describe three features to be improved about the implementation*. Participants were also asked if they would be willing to participate in interviews or focus groups to explore their MSU experience further. Survey items were reviewed by members of the MSU operational team to fine-tune wording and identify item relevance to potential participants.

2.5 | Interviews/focus groups schedule

The semistructured interview/focus group schedule included a series of open-ended questions (see Supporting Information: 2 for complete schedule) targeting the experience or opinions of participants, particularly related to the operational and organizational aspects of the MSU model. Interviews/focus groups commenced with *Can you describe your experience working with the MSU*, and were followed by questions to address the aims of the current study. Preliminary survey results, such as particular challenges, were also used to probe participant experiences. Prompts (e.g., *What do you mean by that?* or *Can you explain that further?*) were used to clarify and extend participant responses.

2.6 | Data collection

The online survey (using Qualtrics™, XM) was distributed using multiple strategies via email invitation (sent by authors D. E. and T. P.) to the project team, MSU clinicians and paramedics, and hospital-based clinicians, and was also circulated via internal websites (intranet, internal social network) for those within ESTA and AV. Surveys were administered between June and September 2019 with a reminder for

completion circulated after 2–3 weeks. Completion of surveys provided implied consent, and data were anonymous unless participants provided their contact details for being involved in a subsequent interview/focus group (data kept separate from responses).

A purposive sample of participants who expressed interest in also participating in the interviews/focus groups were emailed directly by author T. P. The author T. P. (experienced qualitative researcher with expertise in stroke research) conducted interviews face-to-face or via telephone, and all focus groups were conducted face-to-face during October and November 2019. To commence, participants were advised that their responses would be used to improve the implementation process of the current MSU and the development of any future service. With participants' consent, all interviews and focus groups were audio-recorded and transcribed verbatim. Participants had the option to review their transcript before analysis.

2.7 | Data analyses

Initially, an inductive approach (no a priori framework) was used for analysis of the open-ended survey responses and the in-depth interviews/focus group transcripts by authors K. L. B. (PhD, psychology) and S. H. (Hons, psychology). Preliminary analysis revealed categories depicting technical as well as social aspects of the MSU model. It was subsequently agreed that the Interactive Sociotechnical Analysis (ISTA)[26] framework was relevant to present the findings of this study (Figure 1). This framework supports examining the relationships and interactions between technical/physical (e.g., scanner in the MSU, communication tools, receiving hospitals) as well as social aspects (e.g., clinicians on the MSU, co-dispatched paramedics, clinicians at receiving hospitals and current healthcare and systems) of the current healthcare system and the MSU model. Thus, results are presented with ISTA components identified, using a deductive approach.

2.7.1 | Survey data analysis

Directed content analysis[27] was undertaken for the responses to the two open-ended questions. As part of the total evaluation and good practice,[28] dual coding was undertaken for 59% of open-text survey responses by authors K. L. B. and S. H., receiving 85% interrater agreement. For these specific responses, one author (S. H.) read all responses, allocated them to a subcategory, subsequently grouped them under broader categories. Initial results were reviewed by a second author (K. L. B.) who allocated these to themes within the ISTA framework and categorized into preoperational and operational categories, with allocation and refinements discussed and agreed by the independent research team members (K. L. B., S. H., T. P., D. A. C.).

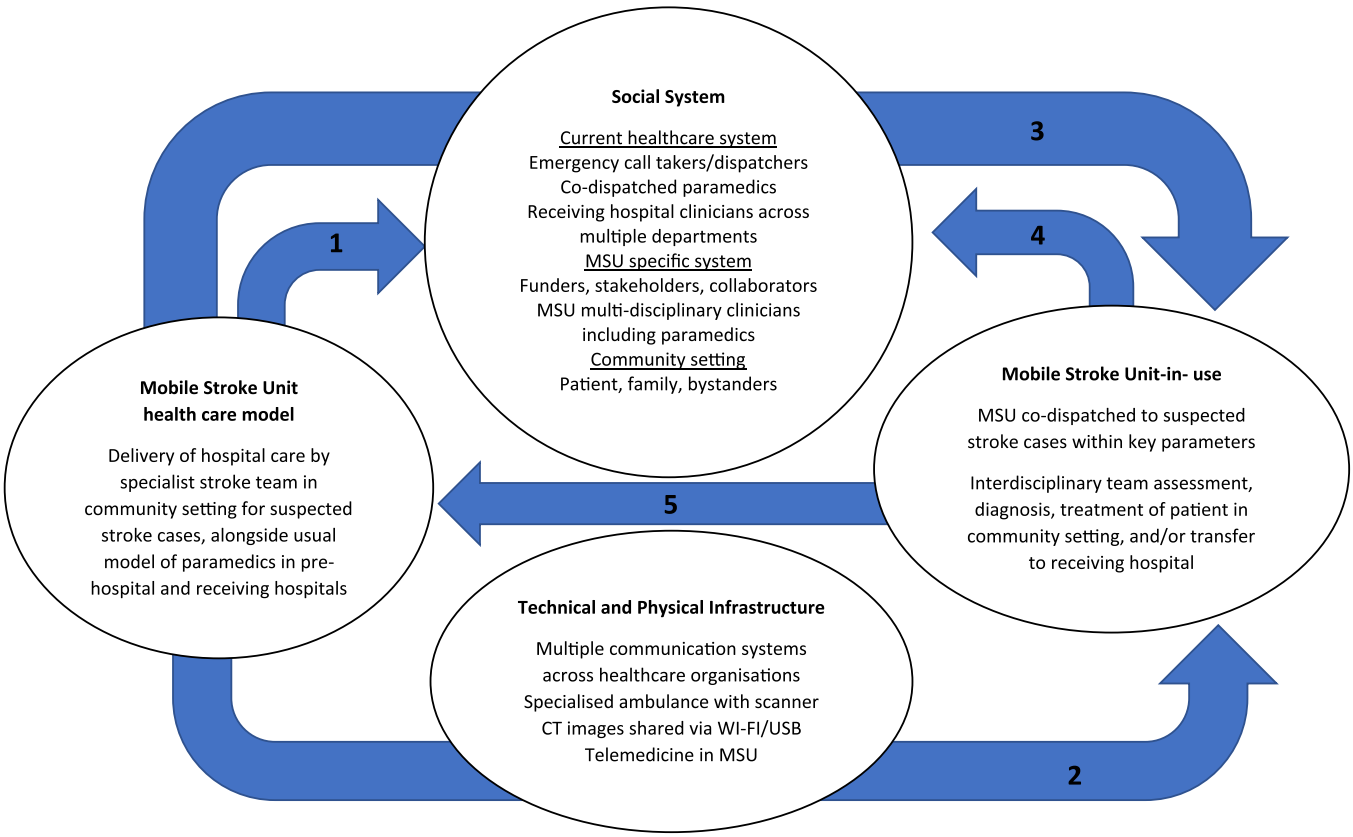

FIGURE 1 Interactive Sociotechnical Analysis model. Adapted from Harrison et al.[26] for mobile stroke units.

2.7.2 | Interviews/focus groups

For the interviews and focus groups, procedures for descriptive thematic analysis[29] were followed. In brief, all interview and focus group transcripts were repeatedly read by one author (K. L. B.) (Phase 1 familiarization with the data), followed by line-by-line analysis of text to identify initial categories relevant to the aims of this study (Phase 2 coding). These categories were subsequently grouped into themes (Phase 3 generating initial themes) and refined (Phase 4 reviewing themes). Analysis undertaken within NVivo (v12). Resultant themes were allocated to 'required for success' or 'challenge to overcome' during preoperational and operational phases. Each theme was reviewed by T. P. (interviewer, BPhysio Hons, MSc) and D. A. C. (research PI, PhD Public Health) during the final phases (Phase 5 defining and naming themes, Phase 6 writing up), with final presentation endorsed by all authors. Illustrative quotes are provided verbatim, with grammar corrected.

3 | RESULTS

In total, 135 participants completed the survey, of which 72 indicated that they were happy to participate in interviews or focus groups, with 38 participants involved in individual interviews ($n = 23$) or focus groups ($n = 15$ participants in total; $n = 5$ groups, ranging from two to four participants). Interested participants were selected to ensure a balance of stakeholder roles (Table 1), positive and negative feedback, and availability within timeframes. Three key project staff who had not completed the survey were directly approached by author T. P. to be interviewed; all three agreed to participate.

From the interviews/focus groups, a range of broad factors were identified as contributing to the success of the MSU implementation, in both preoperational ($n = 7$ themes) and first 24 months of operations ($n = 7$ themes) phases (Supporting Information: Table I). These were predominantly within the ISTA domains of a new model with current and new social systems. A number of challenges were identified that were overcome or had to be considered further during the preoperational ($n = 5$ themes) and when operating ($n = 9$ themes) (Supporting Information: Table II). From the survey, 98 participants indicated 207 items that were helpful and 101 participants provided 203 items that could be improved regarding the implementation of the MSU. Features considered to be helpful during implementation of the MSU (Supporting Information: Table III) were identified with similar frequency in the preoperational phase ($n = 8$ themes, $n = 31$ detailed subthemes) and the MSU was operational ($n = 9$ themes, $n = 23$ detailed subthemes), while more areas to be improved for implementation (Supporting Information: Table IV) were identified during the operational phase ($n = 9$ themes, 33 detailed subthemes) than in the preoperational phase ($n = 8$ themes, 17 detailed subthemes).

3.1 | Data triangulation

Themes and subthemes converged across both sources (i.e., interviews/focus groups and open-text survey responses) and also complemented each other (e.g., provided additional details). Therefore, results have been combined for presentation (triangulation): perceived factors for success (Table 2) and challenges (Table 3) to implementation for preoperational and operational phases are presented. Illustrative quotes are presented in-text.

3.2 | Overall

A common theme identified was the innovation of the MSU model of care and the multiple organizations and individuals involved to deliver the MSU, reflecting the interaction between the ISTA domains of a new model and social systems. The MSU was a new concept for stroke care, for prehospital care, and the Melbourne implementation was the first within Australia.

> Well, the reality was, we didn't know the people, we didn't know-- everything was new to us. The concept was new. We didn't know what we didn't know. All we had was, we had two senior neurologists that had exposure with mobile stroke units in other parts of the world. We had people, benefactors who were willing to provide money. But the reality was that it was a totally new concept and it was trying to get everybody together in a reasonably tight timeline to make it operational. (Participant 19, AV project team)

As such, the project received considerable attention and had a high profile within the stroke clinician community and more broadly, including media attention.

3.3 | Factors influencing preoperational phase

3.3.1 | Success factors for preoperational phase

Before the MSU being operational, important factors identified included the commitment of those collaborating to deliver the MSU, and the significant trust and goodwill between the organizations and individuals involved (ISTA domain, social systems). Also raised was the skill of the multidisciplinary project team members, many of whom were internationally known, well-respected senior personnel within participating organizations, with both clinical and operations management expertise.

> I think everyone understood their roles, and there were certainly some crossing over of roles and no one got precious about that. So I think they had good people from all specialties working there who were

TABLE 1 Participants completing surveys and interviews/focus groups, by organization and role

Categorization	Role	Survey N = 135	%	Interviews N = 38	%
Worked with MSU	ESTA dispatcher	11	8	3	8
	Ambulance Victoria paramedics	68	50	6	16
	ALS paramedic co-dispatched	49		4	
	MICA paramedic co-dispatched	18		1	
	MICA paramedic (communications support paramedic—worked with ESTA call takers/dispatchers)	1		1	
	Clinicians from receiving hospitals[a]	17	13	11	29
	Pharmacist	1		1	
	Stroke nurse	7		3	
	Radiographer			1	
	Neurologist/stroke fellow/neurointerventionalist	9		6	
Worked on MSU[b]	Ambulance Victoria paramedics	13	10	4	11
	ALS paramedic	7		1	
	MICA paramedic	6		3	
	Clinical staff	11[c]		3[d]	8
	Radiographer	4			
	Nurse	3		1	
	Neurologist/stroke fellow	4		2	
MSU Project Team member	Organization Executive or Manager only (Ambulance Victoria)	6	4	0	0
	Program operational team	9	7	11	29
	Melbourne health	0	0	1	3
	Ambulance Victoria	2		3	
	Also worked as paramedic on MSU	3		3	
	Also worked as clinical staff on MSU	4		4	

Note: May not add to 100% due to rounding.

Abbreviations: ALS, advanced life support; ESTA, Emergency System Telecommunications Authority; MICA, mobile intensive care ambulance; MSU, mobile stroke unit.

[a]Excluding clinical staff from Royal Melbourne Hospital also working on the MSU.

[b]Includes staff with no project team involvement.

[c]Including seven staff from Royal Melbourne Hospital who also referred to themselves as working for receiving hospitals.

[d]Including two staff from Royal Melbourne Hospital who also referred to themselves as working for receiving hospitals.

> able to work together really well. (Participant 13, Paramedic on MSU & project team member)

Recruiting MSU clinicians with not just clinical expertise, but with personalities that would work well together was raised. The hands-on, team-oriented training and education that was undertaken before going live was also identified as important to success.

> I think the way they trained us, the initial training that we had with AV, and the training we had with neurologists and nurses together, and the radiographers, you can see three different organisations, with everyone pushing for this thing to work. I mean, the importance of it, the training, the camaraderie, having a lot of the training together. Traditionally, we would be all trained separately and then come together. I noticed that. (Participant 10, Paramedic on the MSU)

3.3.2 | Challenges for the preoperational phase

Themes relating to the challenges of the preoperational phase were also predominantly from interactions between the new

TABLE 2 Perceived factors contributing to the success of the establishment (preoperational period) and implementation (operational period) of the Melbourne MSU

THEME (ISTA component/s)	Stage of implementation	
	Pre-MSU operational	Throughout first 24 months of operations
Overall/context (MSU model and social system)	New concept, project, team; high profile, received considerable attention; input/involvement from multiple organizations and disciplines required	
Stakeholder factors (MSU model, MSU-in-use, social system)	Drive, focus, desire, commitment—by key individuals from multiple organizations and multiple disciplines to make it happen	Acceptance from political/senior management across all participating organizations/disciplines[a]
	Trust and goodwill—between multiple organizations and representative individuals involved, all working toward same goal	Considerable effort and flexibility made by individuals, teams, organizations
Work processes (MSU model, MSU-in-use, social system)	Recruitment principles for MSU team members (e.g., clinical expertise required but also personality, able to work well in teams to be considered; self-nominated indicating strong motivation)	Staffing model works
	Formalized documentation including collaborative agreements between stakeholders, clinical protocols	Centralized management, having contact points for concerns, having a main contact at receiving hospital
	Pressures to meet timelines (external, funder/s, profile); 'go live' dates published pushed people to deliver on time	Flexibility in operations including in MSU protocol—changes were (able to be) undertaken in field, operational area (geographical)
Vehicle (technical and physical infrastructure)	–	Technical communication equipment/service works
		Technical support for CT available
Communication (MSU model-in-use and social system)	Information provided for launch and during launch—*no further details provided*	Information disseminated via multiple methods to various stakeholders on an ongoing basis, including bulletin updates and using stakeholder links
	Regular meetings with operational team, clinical team, and other stakeholders, as relevant; including specific meetings to discuss roles/responsibilities	Multiorganization and multidisciplinary meetings for sharing, refining and problem-solving; feedback loops/issues resolution processes within disciplines and across organizations
		Communication between MSU team members was clear during dispatch/at scene and from clinical team members (e.g., with nursing co-ordinator via email, meetings) including establishing a communication system across clinical stakeholders
Knowledge (MSU model-in-use and social system	Visiting established MSUs overseas	Having peers who have already been on the MSU
	Understanding potential patient benefits	Learning from the MSU staff on scene
	Knowledge about work role[a]	
Dispatch process (technical and physical infrastructure)	Implementing MSU into AV response grid	Auto-dispatch of MSU, was easy to dispatch
	Dispatch guidelines were clear and were known[a]	Easy to request MSU
Working relationships (MSU model, MSU model-in-use and social system)	Organization level—multiorganization and multidisciplinary team approach to development of MSU model Team level—Project Team—multidisciplinary, cross trained; self-selected; respected clinical expertise, experience & intellect; senior personnel; briefing/debriefing sessions with interdisciplinary team/experts[a] Individual level—AV staff helpful, positive[a]	Organization level—Good relationships with other stakeholders[a] Team level—MSU teamwork; MSU team members worked well together, group discussions within MSU crew about patient management plan; ongoing support from colleagues in hospital Individual level—Receptive hospital staff, working with a person with experience

(Continues)

TABLE 2 (Continued)

THEME (ISTA component/s)	Stage of implementation	
	Pre-MSU operational	Throughout first 24 months of operations
Resources (social system)	Funding was available, funding was received from multiple sources	–
Outcomes (interactions of MSU model, MSU-in-use, technical and physical infrastructure, social system)	–	Readily identified benefits—provision of patient/hospital/definitive care (main benefit); positive emotions experienced by team/s; two-way, interactive learning opportunities between clinicians and paramedics; collaborative, team spirit; receiving hospital benefits included patient arrived fully triaged, facilitated patient throughput in hospital
Training and education (MSU model, MSU-in-use and social system)	Considerable training provided including orientation/familiarization training, sufficient before the go-live date, including site visits by MSU and team to AV branches and receiving hospitals	Continuing training when MSU became operational, including training with the MSU crew and learning material provided in rooms designated for paramedics in hospitals
	Multiorganization/multidiscipline hands-on training including trial case sessions for MSU team, and specific training and information provided about IV and CT scanner	Profile of stroke raised/interest from & promoted by other hospitals
	Multimethod training including learning materials provided via video/intranet (including for ACT FAST), information provided during induction process and opportunity to shadow paramedics	–

Abbreviations: AV, Ambulance Victoria; CT, computerized tomography; ISTA, Interactive Sociotechnical Analysis framework; MSU, mobile stroke unit.
[a]Factor relevant for both preoperational and operational periods.

model and current and new social systems. Participants indicated that the initial protocol development could have been improved with input from all stakeholders earlier than what had occurred and that some of the practical issues could have been resolved earlier if these roles had been in place sooner. This involvement would include seeking input from receiving hospitals regarding their requirements and processes.

> … it took some time for us to then identify functional leads such as head of radiography,… the stroke nurse… and to appoint a neurology coordinator… (Participant 20, Project Team member)

> I think that if we had to do it again, I think it would be probably more sensible to get the key stakeholders all involved, try and work out how it'll work for each of the key stakeholders. (Focus Group, recording 18, Clinicians at receiving hospital)

Participants indicated that the selection of the vehicle was based on an ambulance body that was available in Australia with which AV were already familiar and could house the CT identified for use, rather than designed specifically for the MSU's purpose (interaction between ISTA domains of new model, technical and physical infrastructure, and social systems).

3.4 | Factors influencing operational phase

3.4.1 | Success factors for operational phase

Similar to the preoperational phase, important success features during the first 24 months of operation, came from interactions between the new model and current and new social systems. These features were the multiorganizational and multidisciplinary working relationships undertaken during operations, including the flexibility demonstrated, the feedback and meetings to discuss and solve issues that arose—either operationally or clinically.

> A strong collaboration, regular meetings, and once we got going, and once we became operational … an Issues, Decisions and Actions [IDA] Log. And so that's a method to be able to track any new issues that have come up. What are we doing about it? What's the time frame? And who's responsible? So that each fortnightly IDA meeting you would go through your register and work out where things are at. Establishing correct workflows, again, in collaboration. And practicing those workflows to make sure that they actually work and they do what you want it to do. (Participant 20, MBC Project team)

TABLE 3 Key challenges overcome/factors for consideration that hindered the establishment (preoperational period) and implementation (operational period) of the Melbourne MSU

THEME (ISTA component/s)	Stage of implementation	
	Pre-MSU operational	Throughout first 24 months of operations
Overall/context (MSU model and social system)	New concept, project, team; high profile, received considerable attention; input/involvement from multiple organizations and disciplines required	
Resources (social system, technical and physical infrastructure)	Questioned if establishing and operating an MSU is the best use of limited resources—MSU expensive (other uses of funds possible), the MSU is a finite resource—availability and accessibility limited	Staffing—fewer staff on MSU crew, more staff required
	Appropriate facilities for MSU paramedics when on standby required	Change the current location of the MSU base; secure dry storage of MSU required
Knowledge (MSU model and MSU-in-use, social systems)	Challenging project, little known re MSUs internationally and locally	Changes to practice take time and experience, changes include to clinical practice, working relationships and environments
	Increased awareness of purpose and potential benefits of the MSU required	More information required, including dissemination of numbers treated and outcomes, interim results to all stakeholders
		Clarity re MSU role lacking—for paramedics in field (e.g., delays waiting for MSU warranted?) and receiving hospital
Work processes (MSU model, MSU-in-use, social system)	MSU protocol development: to include early input from all stakeholders, including all members of the interdisciplinary team and the receiving hospitals	Clarification of protocols for paramedics as to when and how to request MSU, while waiting for MSU truck and when to clear; MSU not in AV stroke KPI (e.g., time on scene extended)
	Clearer dispatcher protocol, including improvements required for specificity of patient parameters	Improved protocol for determining MSU availability and location required
		Rostering—complex, variation across organizations (half day to 2-month rotations), deskilling concerns as stroke-specific cohort (paramedics, radiographers)
		Other—including designated meet points for MSU to Ambulance transfer patient, interagency review of cases, staff welfare during the process, streamlining care at receiving hospital, scans available for receiving hospital before MSU arrival
Training/education (MSU model, MSU-in-use, social system)	More training required; AV operations training for MSU hospital clinicians, more stroke clinical training/education for paramedics (both MSU-based and co-dispatched, rural AV paramedics)	Increase in learning own/other's roles required; detailed on-boarding for new team members required, including opportunity to shadow MSU role and role/discipline-specific in situ support
	Awareness of MSU required by all paramedics, including those to be co-dispatched; relevant specifics missing in early disseminations	Learning on the job had to be undertaken
	More training to familiarize with specific aspects of MSU model: MSU crew with the MSU vehicle, including mock up unit available and familiarization of receiving hospitals for paramedics	Refresher training/education particularly for paramedics due to infrequent exposure
	Improve education about the need for a MSU truck and improve training/education around dispatch and ACT FAST	
Communication (MSU model-in-use and social system)	–	Communication challenges (mode, timing)—between ESTA/AV and MSU; and between MSU and receiving hospital

(Continues)

TABLE 3 (Continued)

THEME (ISTA component/s)	Stage of implementation	
	Pre-MSU operational	**Throughout first 24 months of operations**
		Require specific communication systems including an alternative radio system for the MSU and AV, and an approved communication system across all stakeholders including written documentation at receiving hospital and transferring of scans
		Sharing of information between MSU and receiving hospital often dependent upon pre-established personal relationships; clear, consistent notification required including early notification for complex cases
Vehicle (technical and physical infrastructure)	Vehicle build had to comply with local, Australian regulations rather than international (where previous MSUs established)	MSU vehicle—issues as the vehicle was unique; multiple repairs required, requires a local engineer
	Selection of vehicle body was in line with available and familiar vehicle body, focused on within current AV fleet	Improve vehicle design—leveling of vehicle for scanning, stretcher loading and unloading process, thermoregulation, suspension, location of jacks, windows in cabin, arrangement of seating (team members affected in back)
		Improve vehicle functions—communication between front and back of vehicle, CT capability, acute care facilities
Working relationships (MSU model, MSU model-in-use and social system)	Organizational level—All key stakeholders should be involved early in implementation Team level—*not detailed* Individual level—Interpersonal frustrations experienced with expanding timelines for launch of MSU	Organizational level—MSU project was perceived as particularly RMH-centred (MSU base and majority of MSU clinicians' home hospital), leading to feelings of exclusion by other participating clinicians and receiving hospitals; greater transparency about patient destination required Team level—Working with MSU team—ownership of prehospital space versus stroke case expertise; additional clarity required between MSU crew and co-dispatched ambulance crew roles given variation in patient processes (e.g., MSU does or does not scan, does or does not transport), clearer protocols required for paramedics how to work with MSU crew on scene; MSU clinicians to provide appropriate nonstroke care; Increased utilization of the paramedic role Individual level—Better interpersonal relations between crew required

Note: Factor relevant for both preoperational and operational periods.

Abbreviations: AV, Ambulance Victoria; CT, computerized tomography; ESTA, Emergency System Telecommunications Authority; ISTA, Interactive Sociotechnical Analysis framework; KPI, Key Performance Indicator; MSU, mobile stroke unit; RMH, Royal Melbourne Hospital.

> And that's one thing that's been really admirable that Royal Melbourne do exceptionally well. They do it every couple of weeks, all of their staff go, and we're certainly invited to it. And they bring up all the patients that they've scanned and haven't scanned on the MSU. And whoever the treating doctor was, they present the case. They talk about what they did, why they did it, and their rationale. And I certainly have spoken up in a couple of those, and it's just been learning, because as much as we're learning, they're learning as well. Even between the five of us, post job we'll all generally have a good talk about what we did and why we did it and stuff. Yeah, that actually has been a really good thing. (Participant 06, Paramedic on MSU)

Important factors for success included the range of benefits that were identified: the delivery of optimal care in a prehospital setting, the shared learning amongst MSU stroke experts and paramedicine experts, and having patients transferred to receiving hospitals expertly triaged facilitating throughput for some patients/hospitals. It was often noted that protocol changes needed to be incorporated while in the field to ensure smooth operations and that the MSU team generally worked well together, with a strong team spirit.

> I think that's fantastic - that we're able to accelerate the speed at which we're able to deliver interventions to patients. And working in the actual team environment with a group that are all obviously very dedicated; the nurses, the radiographers, and the paramedics are all fantastic to work with, and function, in my experience generally, extremely well as a team. So those aspects have been particularly positive and better than I had expected. (Participant 27, Clinician on the MSU)

3.4.2 | Challenges for the operational phase

Once operational, some of the main challenges were due to the vehicle, its layout and features.

> It's hard to communicate with the radio because there's a wall between us, nowhere to mix up drugs, not that that's a big issue, but there's just lots of little things. The heat in the back of the truck, we are having trouble at times with the air conditioning. The heat can be phenomenal in the back of the truck because you've got a CT scanner that's emitting heat all the time. (Participant 16, Clinician on MSU)

Design impacted on communication challenges between MSU team members within the ambulance (i.e., having to repeat information from the cab to the rear) and team members experiencing motion sickness in the back of the vehicle (no windows) (interactions between ISTA domains of MSU-in-use and technical and physical infrastructure). Changes for clinicians on the MSU included variations to usual practice, as well as the environment in which clinicians usually based at hospitals had to provide care.

> Well, so in terms of clinical decision-making, the main way it changes how I would manage patients is the fact that we don't have a CT perfusion on the ambulance. (Participant 27, Clinician on MSU)

> (Note: CT perfusion is an additional brain image performed routinely in emergency departments that improves diagnostic certainty and permits thrombolysis in selected patients >4.5 h after stroke onset)

> I've been frequently to housing commission houses (public housing) [and] the clean injecting room in [Melbourne suburb name] and other sorts of areas like that. So you don't always feel completely comfortable in that environment …the paramedics are particularly helpful at ensuring that we operate in a safe manner. Those things I obviously would never, generally, have to deal with being on the ward. (Participant 27, Clinician on MSU)

The other two main themes frequently mentioned were challenges surrounding communication, and specifically from those who had to work with the MSU team. Communication difficulties were reported between all involved personnel, including between ESTA/AV and the MSU team, and between the MSU and those within the receiving hospital (interaction between MSU-in-use, technical and physical infrastructure and social systems). There was no single communication system that was accepted across all stakeholders involved in patient care.

> It's sort of on a case-by-case basis if I think they need a verbal handover, and it also depends on whether or not we've been called to another job because trying to call someone, especially if you're stuck on hold to switchboard, when you're driving at 130Ks an hour with the sirens on, isn't always practical, especially if you get carsick. (Participant 27, clinician on MSU)

The sharing of patient clinical information between the MSU team and receiving hospitals was often dependent upon pre-established personal relationships.

> There is a clinical data sheet that's filled on the MSU which carries a lot of the clinical data but there are no good mechanisms for reliable transfer of that clinical information. How do I get access to that information in a timely fashion? … (Focus Group, recording 18, clinician at receiving hospital)

For those working with the MSU team, in particular the co-dispatched paramedics, there was often uncertainty in the early period as to the role of the MSU and how to integrate the prehospital care with stroke-specific care (interaction between MSU-in-use with new and current social systems).

> We're going to head towards the hospital. If you can meet us along the way and you make it to us, we'll stop, but we're not going to sit here on scene with a patient who's having a stroke waiting for the stroke truck. (Participant 14, co-dispatched paramedic)

> … it's more about maybe educating the actual staff on the truck. Like maybe the non-paramedic staff a bit more about how to work with crews on scene or how to-- because obviously it's not just about the brain… (Participant 12, co-dispatched paramedic)

It was often acknowledged that changes to practice takes time and examples in clinical care and clinical practice were described. For example, in interviews/focus groups, experienced clinicians referred

to the introduction of cardiac care provided in field, as an example of a change that took some time, but was now established practice, and dispatchers noticed over time changes in the areas and range to which the MSU would respond.

> And just getting those distances. I think they didn't understand how far and how quickly you can travel across Melbourne in an ambulance [with] lights and sirens when they first started. (Participant 07, ESTA dispatcher)

Some of these were associated with other changes, such as hospital clinicians working outside of the hospital setting as well as working with paramedics.

3.4.3 | Important factors within the distinct stages of operating with this new model of care (i.e., standby, dispatch, on-scene, transfer, stand down)

In addition to overall important pre- and operational factors, some important factors to consider for implementing an MSU model are specific to the (often-repeated) daily operational stages of the MSU and team (Table 4): the MSU vehicle and team on standby (i.e., waiting for a patient case callout), MSU dispatched to patient, MSU on-scene with co-dispatched paramedics, MSU transporting to receiving hospital, and/or MSU stand-down (no longer required)/clear (able to leave hospital). Important factors were identified specific to one or more of these stages. Operating an MSU meant bringing together multiple workplace cultures which impacts beyond sharing clinical care of a patient. For example, while on standby, the MSU vehicle and team is usually located at a central hospital, similar to other MSUs.[11] This model means that paramedics were based at a hospital without the facilities usually available to them at their typical AV branches (e.g., only a few other paramedics on site, comfortable seating, nonshared kitchen facilities) between cases throughout their shift. For hospital clinicians working on the MSU ambulance, this meant working with paramedic colleagues who, when working on usual ambulances, do not have to return to a hospital-based office between patient cases. Another workforce consideration is that AV paramedics typically have a number of time-based performance indicators that were applied to the MSU but these were novel to hospital clinicians' practices. For example, factors related to indicators included difficulties meeting AV departure time metrics after receiving dispatch call (i.e., time from call to rolling to be within 90 s) due to the dispersion of MSU team member locations within the base hospital. Alternatively, hospital clinicians on the MSU staying with the patient at the receiving hospital impacting on required AV clear times from hospitals after patient transferred.

The importance of being flexible was often demonstrated. For example, there was variation for the MSU dispatch protocol (e.g., MSU dispatched outside 20 km radius, MSU team members identifying relevant cases to attend from the radio) and variation in how patient details were communicated to receiving hospitals (e.g., via usual AV methods, via phone call or electronic messaging to a hospital colleague). Communication difficulties are mentioned in dispatch (e.g., difficulties communicating between MSU team members due to vehicle design, the takeover of the dispatch radio line when paramedic crews on scene and MSU team members communicating precludes dispatcher using radio line for other cases) and transport/receiving (e.g., variation in communication mode, no single system used by all clinicians involved with MSU and the MSU patients). The accuracy of the dispatch protocol with frequent call-outs to nonstroke cases was experienced as frustrating by some MSU personnel but reported as expected by others. Receiving hospitals were mostly continuing to scan patients upon arrival were required: due to not having or using the MSU scan, requiring a different type of scan or assessing if the stroke was evolving.

4 | DISCUSSION

Optimal stroke care requires multidisciplinary teams from various organizations to undertake clinical processes rapidly in an emergency context. This multicomponent process increases the complexity of integrating MSU models of care within usual care systems. To date, most studies of MSUs have had a focus on clinical outcomes, with detailed evidence on how MSUs have been implemented lacking. In a review of the MSU literature (search dates between 1990 and 2017, 38 papers identified)[9] the authors of only four papers reported implementation factors.[10,11,30,31]

Addressing this gap, we found that important factors differed from the preoperational phase to the operational stages in terms of the success and challenges, and experiences differed based on the stakeholder group. The importance of the multiple organizations, the multidisciplinary personnel involved, communication between those working on and those working with the MSU team, and the teamwork required were identified, in addition to factors specific to the MSU vehicle.

In our study, we found that during the initial stages of developing the MSU model, the majority of influential factors were associated with individuals and organizational approaches. Personnel were drawn from multiple disciplines, various organizations involved and the flexibility, trust and goodwill between them was an important contributor to delivering the MSU model. Our results are consistent with those that have been described in establishing the Houston MSU,[11] including the importance of project leadership, stakeholder collaboration,[10] staffing,[9] and excellent stakeholder cooperation.[11] This alignment of results illustrates the relevance across contexts similar to Australia and the United States of America. Our results provide important details regarding these stages. Consistently reported was the positive attitudes and determination of personnel within the current healthcare system to deliver the MSU. Consideration of the MSU team members' working environment (new, small, multidisciplinary) led to clinical expertise not being the only consideration for recruitment. Personality factors, such as calm,

TABLE 4 Key areas of discussion presented across MSU/patient journey pathway

On standby *(MSU team not engaged with patient case, waiting for contact/for dispatch)*	Dispatch *(MSU called to patient scene)*	At scene *(MSU at patient scene)*	Transport/receiving *(MSU transporting patient to/engaging with receiving hospital)*	Stand down/clear *(MSU no longer required/MSU cleared from hospital)*
Workplace culture changes—AV team members had nowhere to relax (unlike at usual AV branches), feeling judged and not belonging at the hospital base for the MSU; hospital clinicians wanting to return into hospital at end of case (other work to do), not in community/coffee shop with pager (as AV paramedics can do between patient callouts)	**Multiple dispatch pathways**—ESTA matrix = formal protocol, AV Clinician over rules matrix as more details come in, paramedic on-scene request to dispatcher, MSU job selection from job details heard over radio	**Patient assessment**—having to learn to work together at scene: co-dispatched paramedic team to commence assessment; MSU team having to juggle providing professional space to on-scene paramedics but time critical to assess and treat stroke; MSU team expertise available to assess patient, but the patient is 'not just the brain'; stroke case not always scanned; variation in neurologists deciding to scan or not	**Communication between MSU and hospital pre-arrival**—variation across mode (text, call, radio), content of details (thrombolysed or not, bolus amount or not) and who provided details; variation of contact if assessed as stroke/ECR case (to stroke team and/or ED and/or stroke consultant) or not (to ED only); if MSU stood down or not; documentation sometimes incomplete/inconsistently provided; personal working relationships (e.g., between MSU team member and receiving hospital staff member) can influence handover pathways; need one-to-many communication system	**Stand down**— various methods including by MSU team (MSU neurologist) can cancel based on call-taker details, or paramedic on-scene can cancel via SitRep details If paramedics on scene indicate MSU not needed, MSU sometimes still attended (e.g., if close by, if MSU team determined required) If cancelled, MSU still attending—sometimes well received, paramedics on-scene sometimes surprised, concerned or confused if stand down/cancel protocol not followed
Communication— three modes typically used (phone, pager, radio)—not all work in all places within hospital (e.g., no mobile coverage); MSU team member/s can be without direct communication depending upon where they are within hospital	Dispatched **outside protocol**—sometimes dispatched beyond 20 km radius of RMH (e.g., MSU already in location for another callout), MSU jumps jobs as heard preferred case (more relevant symptoms, younger patient) over radio	**Decision to treat**—made by neurologist/doctor; stroke nurse assists decision	**Receiving hospital processes**—MSU assessment and transport yields little change to usual internal processes for some hospitals versus facilitates patient care pathway (if stroke or not) for ED, MSU assessment influences diagnosis process as expert stroke triage conducted; experienced colleagues on MSU, many known to receiving hospital stroke team; image transfer between MSU and receiving hospital mostly smooth now, but not initially; not all hospitals use USB (DICOM & remote) provided images; imaging repeated usually (various reasons: image quality, CTP required, trial eligibility criterion); who conducts MSU handover to receiving hospital staff varies; MSU drug delivery (i.e., bolus) has flow-on issue including balance of amount/reimbursement expense/hospital charting; low numbers brought in by MSU, low numbers thrombolysed	**Clear**— time that paramedics are clear after transporting patient to receiving hospital; clear times with MSU sometimes quicker than ALS, sometimes not; AV team members of MSU (paramedics) ready to clear hospital, but MSU clinicians staying with patient at receiving hospital; AV have clear KPI metrics to achieve, so sometimes problematic

(Continues)

TABLE 4 (Continued)

On standby *(MSU team not engaged with patient case, waiting for contact/for dispatch)*	Dispatch *(MSU called to patient scene)*	At scene *(MSU at patient scene)*	Transport/receiving *(MSU transporting patient to/engaging with receiving hospital)*	Stand down/clear *(MSU no longer required/MSU cleared from hospital)*
Medication stocking **outside protocol**—storeroom does not receive radio/pager contact so if both paramedics there, can miss call, but should have two paramedics doing medications	Dispatch **protocol accuracy**—high nonstroke callouts, expected by some, MSU team frustrated at stroke rate initially, if multiple cases, who to get resource first?	**Decision to transport**—Pre-MSU arrival, if co-dispatch on scene, and MSU further than hospital, then discussion if ALS to transport; If MSU/RMH medications provided, then MSU; ALS truck can be faster than MSU (size); to which hospital depends on location but if ECR or trial eligibility;	**Benefits identified for multiple groups** including Patients (early scans, mobilizing teams faster, treatment delivered earlier); Clinicians (particularly stroke team as patient expertly assessed/diagnosed already, same language in handover between MSU team and hospital staff; NIHSS completed, treatment commenced); improved working relationships for clinicians across disciplines, across hospitals; MSU team provide staff/support to receiving hospital when transporting patient	**Documentation** seems to be duplicated on MSU—nurse notes, AV notes into AV patient record system (VACIS) No formal field in VACIS that MSU attended; able to be included in ad hoc notes
Meeting AV KPI metric difficulties—an AV time metric is time-to-rolling (90 s)—but need all MSU personnel on truck, not just paramedics, before MSU rolling; some delays experienced as team members dispersed across different parts of hospital	**MSU variation over time** in identifying cases—MSU team changing when will go—would have gone for a facial droop nursing home in early days but not now	**Delays on scene**—concerns mostly early on from paramedics; on scene, waiting for MSU, waiting for MSU to scan; AV metric, time is brain; close to hospital	**Critiques** included perceptions that MSU facilitates patient numbers for RMH; feedback on MSU patients and numbers required by receiving hospital; concerns re deskilling stroke assessment practices of those in peripheral hospitals if MSU transports patients elsewhere; USB hardware issue; availability of drug used on MSU not at receiving hospital; stroke care variation across receiving hospitals	**End of day**—paramedics shut down MSU at base hospital.
	Communication mode limitations for dispatcher with other trucks/cases as only a single channel (when on radio to MSU, other calls are blocked); within MSU team between front and back of truck (having to repeat information); between paramedics on scene and MSU truck (MSU requirements, SitRep changes)	**Roles** sometimes clear, sometimes not (paramedics and MSU clinicians); mostly changed, sometimes not; MSU being operational role changes AV usual role (assessment, diagnosis, treatment, transport); regular ambulance sometimes transports patient with stroke, needs to stay on scene and provide care if patient unwell	**MSU perspectives** include variation in hospitals' response to MSU; paramedic providing care in line with hospital requirements; personal 'special' working relationships influence handover pathways (e.g., MSU team members contacts known colleague at receiving hospital); stroke care variation in receiving hospitals	

TABLE 4 (Continued)

On standby *(MSU team not engaged with patient case, waiting for contact/for dispatch)*	Dispatch *(MSU called to patient scene)*	At scene *(MSU at patient scene)*	Transport/receiving *(MSU transporting patient to/engaging with receiving hospital)*	Stand down/clear *(MSU no longer required/MSU cleared from hospital)*
	MSU unable to be dispatched—on another job, out of hours, out of range, out of service	**Interactions between ALS and MSU** respectful, collegiate, collaborative, but some learning curves and frustrations; MSU paramedic (MICA) have run interference/liaison (e.g., explaining paramedics may be on scene but still need to get to patient, take history, assessment, before SitRep available)		
	Dispatchers/paramedics adapting to MSU requirements, availability, awareness of MSU changed over time and able to consider if MSU relevant for case	**MSU hardware** scanner—not able to scan all patients, nor scan in all conditions Scan quality reduced and not CTP available impacting clinical dx making Scan transfers—can delay diagnosis by a few minutes (getting reviewed by other clinician), required for transfers (USB or wireless) Stretcher—needs troubleshooting		
	Do not get **patient feedback** (call taker, dispatcher) yet still believe MSU has value, patient benefits	**Variation by staff member**—assessment, diagnosis, transfer differently; experience (in discipline, working with paramedics), confidence (in discipline, in role), home hospital (to follow-up patient, for trial)		
		Environment influences—extrication smooth/needs work; environmental safety concerns new for hospital clinicians		

Abbreviations: ALS, advanced life support; AV, Ambulance Victoria; DICOM, Digital Imaging and Communications in Medicine; ECR, endovascular clot retrieval; ESTA, Emergency System Telecommunications Authority; KPI, Key Performance Indicator; MSU, mobile stroke unit; RMH, Royal Melbourne Hospital; SitRep, situation report; VACIS, Victorian Ambulance Clinical Information System.

engaging and inclusive were incorporated to maximize team cohesion and performance.

Key challenges that had to be overcome during the MSU development required simultaneous undertakings for project planning and design of the vehicle. In particular, this included the selection and operations of the CT scanner and patient stretcher,[11] in addition to the clinical care of patients. Although MSU team member roles were identified early, not all team members were involved from the beginning when planning of the service commenced, nor were receiving hospitals engaged early. For example, having a stroke nurse involved in the discussion about the layout of the vehicle interior might have been helpful in achieving a more efficient on-board workflow. While the MSU model was in focus for the immediate MSU team, this was not so for all receiving hospitals. As such, a number of perceived concerns were subsequently identified, that could likely have been addressed before going live, either through protocol changes or stronger communication with stakeholders.

Most challenges were identified when the MSU was in use and interacting with the established healthcare context. For example, although team-based training had been undertaken, as reported elsewhere,[9,11] and was positively received, in-field experience heightened awareness of the importance of integrating the various roles involved. Attending cases included the involvement of the MSU clinicians, the MSU paramedics and the co-dispatched paramedics, all of whom were on scene, as well as those at the receiving hospital. The integration of these roles at a single patient scene required individuals to learn together; not only learn their role but to learn the roles of others and how they interacted. In particular, co-dispatched paramedics expressed initial concern about having to wait on scene for the MSU, counter-intuitive to their 'load and go' approach for rapid stroke care. Often for the first time, hospital clinicians learnt about the community-based workspace of paramedics while paramedics learnt about stroke care undertaken by stroke experts usually within hospital settings. This shared learning and education was highlighted as a main benefit of working with the MSU. For example, with the MSU-in-use, interactions not usually experienced by hospital personnel were noted (e.g., paramedics having to extract a patient from their house compared with the patient usually delivered to emergency department with preliminary history provided) and paramedics having to ensure MSU clinicians' safety. Conversely, co-dispatched paramedics could see expert stroke assessment, diagnosis and treatment occur. This dynamic provided positive learning experiences, upskilling opportunities and mutual respect for all involved.

A number of limitations were noted with the MSU vehicle design which impacted the team when travelling to/from a patient, assessing and treating patients.[17] Similar to previous MSUs,[11] the vehicle selected was not one designed specifically for the MSU team and patients. While a resourceful, cost-effective approach,[32] vehicle base and specific use should be carefully considered for the safety and comfort of clinicians and patients in future MSU developments.

Important factors extended beyond the MSU vehicle and MSU clinical team. Integration of two workforces and work cultures, albeit with a common goal, requires careful consideration. Further, interactions between these multidisciplinary team members are undertaken in environments new to hospital clinicians (e.g., prehospital, community, patient homes) and with new colleagues for paramedics, requiring significant new patterns of work and working relationships. Receiving hospital clinicians and processes are also impacted; aspects of assessment, diagnosis and treatment have occurred prehospital, including stroke expert triage and the commencement of thrombolysis treatment. In addition, the technological aspects of the MSU model extend beyond the MSU vehicle itself, including communication systems between co-dispatched paramedics and MSU team, the MSU team and receiving hospitals, such as sharing of patient details or the sharing of CT scan images via Wi-Fi or USB. The EMS communication system has been identified as an obstacle requiring ongoing attention in other MSUs.[11] Our work suggests a single communication system across EMS, MSU and receiving hospitals is warranted to address difficulties with current systems and associated workarounds.

4.1 | Strengths, limitations and future research

Strengths of the research include the two distinct timeframes (preoperational and operational), the inclusion of participants from various roles and organizations involved in and impacted by the MSU, and an independent research group. While previous work has considered aspects important in implementation of their MSUs,[10,11,30,31] they have been limited by their descriptive approach, and typically undertaken by those involved in developing and operating the MSU. The use of in-depth interviews/focus groups and open-ended survey questions across a range of stakeholders, as well as considering the results within an established framework incorporating both social and technical aspects of healthcare were strengths of our systematic approach. In turn, our results provide a depth of information absent in prior studies of establishing MSU services. Positioning results within the ISTA framework shows that interactions between key factors, including considering integration of new and current social systems, are fundamental to the success of the MSU model. Despite these strengths, the results need to be considered with a number of limitations in mind. First, participants were self-nominating, as such selection bias should be considered. In addition, these results are based on participant subjective reports, and perceptions and experiences may vary between individuals within the same situation. The anonymous survey responses from a broader group typically aligned with interview results. Possible social desirability bias was addressed with an experienced interviewer and stroke researcher who was not previously involved in any aspect of the MSU development, operational or evaluation. Second, our single-point data collection after almost 24 months of operations required a reliance on retrospective recollection of participants. Pressures for the MSU to become operational and resource availability did not support a pre- and postmeasures design. Completing the contractual paperwork across multiple organizations (e.g., healthcare providers, academic institutions) and achieving multisite ethics approval was a

complicated and lengthy process, which precluded preoperational data collection. Important factors before the initial commencement of MSU development may have been neglected. For example, while securing funding from multiple sources was noted, as with other MSUs,[11] the factors that contributed to securing the funding were not outlined by our participants.

5 | CONCLUSION

Despite considerable attention being focused on the technical aspects of the MSU, particularly locating a CT scanner in an ambulance, the established systems in which the MSU vehicle is embedded were particularly important. Factors to leverage for MSU pre- and initial operations include involving all those whose work practices change with the MSU model (including all multidisciplinary MSU team members, co-dispatched paramedics and clinicians from receiving hospitals), highlighting the benefits for patients and clinicians, and ensuring systems are tailored to support and incorporate the MSU model functions. These functions include organizational communication platforms, incorporation of pre-hospital care details to hospital records, and changes to monitoring systems for on-scene metrics. Future research is required to consider if changes will be required across the longer term and how these identified factors may vary as the MSU fleet is extended; that is, how best to support the sustainability and maximize the benefits of the emerging MSU model.

AUTHOR CONTRIBUTIONS

Dominique A. Cadilhac conceived and supervised all aspects of the research; Dominique A. Cadilhac and Kathleen L. Bagot designed the evaluation and wrote the protocol; Damien Easton facilitated access to participants; Tara Purvis and Shaun Hancock collected the data; Kathleen L. Bagot and Shaun Hancock conducted analyses; Kathleen L. Bagot prepared the initial manuscript; Dominique A. Cadilhac, Tara Purvis, Henry Zhao, Skye Coote, Damien Easton, Bruce C. V. Campbell, Steve M. Davis, Geoff A. Donnan, Shane Foster, Francesca Langenberg, Karen Smith, Michael Stephenson, Stephen Bernard, Sharon McGowan, Bernard Yan, Peter Mitchell, Sandy Middleton reviewed results, provided input and approved the final version of the manuscript.

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CONFLICTS OF INTEREST

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

ETHICS STATEMENT

Approval for this research was obtained from Melbourne Health Human Research Ethics Committee (HREC/17/MH/375), Ambulance Victoria Research Governance (R18-038) and Monash University Human Research Ethics Committee (20158).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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