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Original Research Article

Benefit of linking hospital resource information and patient-level stroke registry data

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Abstract

Variation in the delivery of evidence-based care affects outcomes for patients with stroke. A range of hospital (organizational), patient, and clinical factors can affect care delivery. Clinical registries are widely used to monitor stroke care and guide quality improvement efforts within hospitals. However, hospital features are rarely collected. We aimed to explore the influence of hospital resources for stroke, in metropolitan and regional/rural hospitals, on the provision of evidence-based patient care and outcomes. The 2017 National Audit organizational survey (Australia) was linked to patient-level data from the Australian Stroke Clinical Registry (2016–2017 admissions). Regression models were used to assess the associations between hospital resources (based on the 2015 Australian National Acute Stroke Services Framework) and patient care (reflective of national guideline recommendations), as well as 90–180-day readmissions and health-related quality of life. Models were adjusted for patient factors, including the severity of stroke. Fifty-two out of 127 hospitals with organizational survey data were merged with 22 832 Australian Stroke Clinical Registry patients with an admission for a first-ever stroke or transient ischaemic attack (median age 75 years, 55% male, and 66% ischaemic). In metropolitan hospitals ($n = 42$, 20 977 patients, 1701 thrombolyzed, and 2395 readmitted between 90 and 180 days post stroke), a faster median door-to-needle time for thrombolysis was associated with ≥500 annual stroke admissions [−15.9 minutes, 95% confidence interval (CI) −27.2, −4.7], annual thrombolysis >20 patients (−20.2 minutes, 95% CI −32.0, −8.3), and having specialist stroke staff (dedicated medical lead and stroke coordinator; −12.7 minutes, 95% CI −25.0, −0.4). A reduced likelihood of all-cause readmissions between 90 and 180 days was evident in metropolitan hospitals using care pathways for stroke management (odds ratio 0.82, 95% CI 0.67–0.99). In regional/rural hospitals ($n = 10$, 1855 patients), being discharged with a care plan was also associated with the use of stroke clinical pathways (odds ratio 3.58, 95% CI 1.45–8.82). No specific hospital resources influenced 90–180-day health-related quality of life. Relevant to all international registries, integrating information about hospital resources with clinical registry data provides greater insights into factors that influence evidence-based care.

Keywords: registry, organizational, linked, stroke, quality of care, outcomes

Introduction

Stroke care is complex, and variation in hospital delivery of evidence-based treatments affects the quality of care and outcomes for patients [1, 2]. A range of hospital (organizational), patient, and clinical factors can affect the receipt of evidence-based care [3]. Registries are widely used to monitor stroke care and guide quality improvement efforts within hospitals to ultimately improve the care provided to patients with stroke [4–7]. A systematic review identified >28 national stroke registries internationally [8]. Generally, evidence-based clinical performance data from patients with stroke and transient ischaemic attack (TIA) are collected from the acute admission, often with linkage to administrative claims databases for details on death and rehospitalizations [5, 9]. Many stroke registries also collect various patient outcomes at differing time periods post stroke [8]. Although national and international recommendations related to systems of care and resources for stroke exist [10, 11], these organizational data are rarely collected routinely in registries.

In Australia, the quality of care and outcomes for patients with acute stroke are monitored via the National Audit of Acute Services (herein referred to as the Audit) and the Australian Stroke Clinical Registry (AuSCR). Since 2007, acute hospital services are assessed for their performance against national clinical guidelines in a subset of 40 cases using retrospective methods in the Audit [12]. At the same time, the hospital staff are requested to complete an organizational survey to describe the resources and infrastructure for stroke in their hospital [12]. Participation in the Audit is voluntary and offered to all hospitals treating patients with stroke. In

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the AuSCR, hospitals voluntarily collect a minimum national standard dataset on all patients admitted with stroke or TIA [4]. Participating hospitals use an opt out or waiver of consent process, with outcome data from survivors of stroke obtained once between 90 and 180 days after admission via a survey distributed by the AuSCR office.

The primary purpose of the AuSCR is to facilitate quality improvement efforts within hospitals by providing standardized local data benchmarked to peer, state, and national performance. In order to maximize the information that can be derived from the AuSCR, it is important to understand the resources for stroke that are available in the participating hospitals and how these resources may influence stroke care or patient outcomes. The aim of this study was to explore the influence of hospital resources for stroke in metropolitan and regional/rural hospitals on the provision of evidence-based patient care and outcomes.

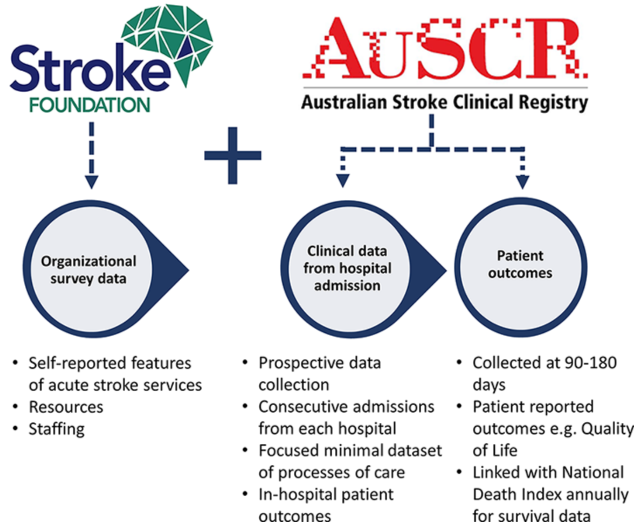

Figure 1 Data sources involved in linkage.

Methods

Data sources

The Australian Stroke Data Tool (https://australianstrokecoalition.org.au/projects/ausdat/) is the online data collection system used for the Audit and the AuSCR. These data are collected independently by different data custodians but in the same tool. Within the system, the same hospital identifier is available. Until now, the data from the organizational survey from the Audit have not been integrated with the data from the AuSCR. The datasets are outlined as follows:

(i) 'National Audit organizational survey' (data custodian Stroke Foundation): The 2017 organizational survey dataset was used from the Audit (with corresponding patient-level clinical data being obtained from the previous year). The organizational survey includes 104 questions covering service access, workforce availability, team coordination and assessment, and ongoing education opportunities (Online Supplement Table S1) [12].

(ii) 'Australian Stroke Clinical Registry' (data custodian Florey Institute): Patient-level data from the AuSCR for admissions from 2016 to 2017 were selected as these corresponded to the period for the Audit. Patient demographics, a minimum core dataset of care processes, and in-hospital outcomes are collected (Online Supplement Table S1) [4]. Patient outcomes collected at 90–180 days include health-related quality of life (HRQoL) (European Quality of Life 5 dimension 3 Level Version and European Quality of Life - Visual Analogue Scale) [13], readmissions, disability (modified Rankin Scale) [14], and mortality by annual linkage to the National Death Index.

Data linkage and variables used in the analyses

The datasets were linked by a common hospital identifier (Fig. 1). Hospital-level linkage was undertaken by T.P. and M.F.K. Hospitals with <30 cases in the AuSCR for the 2016–2017 period were excluded. The variables used in the analyses from the survey included hospital resources such as the presence of a dedicated medical lead, stroke coordinator position, use of telemedicine, and care pathways for management. These were based on recommendations in the 2015 National Acute Stroke Services Framework for Australia [11]. Additionally, the hospital features including annual stroke admissions and thrombolysis volume (based on being above or below the overall median number) were considered. Hospital resources varied based on locality; therefore, the analyses were stratified by location, considering geographical remoteness and town size [15]: 'metropolitan' (metropolitan area or area within 20 km of a town with >50 000 residents) and 'regional/rural' (more remote areas not considered 'metropolitan'). From the AuSCR dataset, adherence to a core dataset of prioritized care processes [16] was explored including the provision of intravenous thrombolysis, door-to-needle (DTN) times (time from arrival at the hospital to thrombolysis), and being discharged on antihypertensive medications or with a discharge care plan that the patient and family were involved in developing. Access to stroke unit care was also considered, referring to organized care provided within a specific ward in a hospital, by a multidisciplinary team who specializes in stroke management [17]. In addition, self-reported all-cause hospital readmissions and the EQ-VAS, as a global measure of HRQoL, were included as patient outcomes in these analyses.

Statistical analysis

Descriptive statistics were used to describe the AuSCR–Audit-linked cohort including hospital resources. Multivariable, multi-level regression models were used to determine the association between hospital resources and (i) adherence to care processes and (ii) patient outcomes including readmissions and EQ-VAS. Logistic regression was undertaken for adherence to care processes and quantile regression for DTN and HRQoL. Models were adjusted for patient factors including age, sex, socioeconomic position (Index of Relative Socio-Economic Advantage and Disadvantage) [18], prior stroke, in-hospital stroke, stroke type, and ability to walk on admission (a surrogate for stroke severity) [19], in addition to access to stroke unit care and clustering by hospital. A sensitivity analysis was undertaken whereby we excluded the variable 'access to stroke unit care' in the relevant models to reflect wider models of stroke care in some countries. Standard techniques to check for collinearity and model fit were implemented to determine variables included in the final models.

Results

Of the 127 hospitals that completed the Audit survey (2017), 53 participated in the AuSCR in 2016–2017 (one hospital was removed from the analysis as only 17 cases were provided). The final merged dataset from the 52 matched hospitals included 22 832 adults with first-ever stroke/TIA event recorded in the AuSCR (median age 75 years, 55% male, and 66% ischaemic stroke), including 20 977 cases from 42 metropolitan hospitals (10 252 follow-ups), and 1855 cases from 10 regional hospitals (931 follow-ups). From the survey, almost all were public hospitals (metropolitan 95% and regional 100%), had a stroke unit (metropolitan 100% and regional 80%), and delivered intravenous thrombolysis (metropolitan 98% and regional 80%). Specialist stroke resources were common, with 83% metropolitan hospitals and 50% regional hospitals reporting a dedicated stroke medical lead and coordinator role (stroke coordinator or clinical nurse consultant) (Table 1).

In univariable analyses, we found that a variety of hospital resources and features were associated with greater adherence to care processes (Online Supplement Table S2). In metropolitan hospitals, 1701 patients with ischaemic stroke received intravenous thrombolysis, with a median DTN time of 72 minutes. Results of multivariable modelling demonstrated that in metropolitan areas, median DTN times were 16 minutes faster at larger hospitals (≥500 annual stroke admissions) compared to smaller hospitals, 20 minutes faster at hospitals delivering thrombolysis to >20 patients/annually compared to those with a smaller thrombolysis volume, and almost 13 minutes faster at hospitals with a dedicated medical lead for stroke and stroke coordinator (Table 2). All regional/rural hospitals in the AuSCR had access to onsite telehealth for clinical decision-making. At regional/rural hospitals that used clinical care pathways for managing stroke, patients were over three times more likely to be discharged with care plans [odds ratio 3.58, 95% confidence interval (CI) 1.45–8.82] (Table 3). No variation to the main results was found when excluding stroke unit access from the relevant statistical models.

Overall, 2395 patients (22%) reported being readmitted to the hospital (all cause) between 90 and 180 days following admission for stroke (2195 metropolitan and 200 regional). An 18% reduction in readmissions was noted for patients treated at metropolitan hospitals using clinical care pathways during the acute admission (odds ratio 0.82, 95% CI 0.67–0.99) (Fig. 2). Overall, 48% of patients reported problems with mobility, 30% with self-care, and 56% with completion of usual activities, 48% had pain/discomfort, and 46% had anxiety or depression. The median VAS for the cohort was 73 (Q1: 50, Q3:85). The greatest determinants of lower HRQoL for patients treated in metropolitan hospitals included having had a prior stroke or a stoke while in hospital for another condition, as well as the inability to walk on admission (Online Supplement Figure S1). While we found that patients treated at hospitals with protocols for reviewing patients on discharge reported lower HRQoL (–1.7, 95% CI –3.2, –0.3), this was not a clinically meaningful difference and warrants further investigation.

Discussion

Statement of principal findings

In this study, we have exemplified the benefits of supplementing registry data with information about hospital resources, using data from Australia, to provide greater insights into the factors that influence evidence-based care in the hospital and 90–180-day patient outcomes. In metropolitan areas, we found that DTN times were ∼13 minutes faster in hospitals employing specialist stroke staff (dedicated medical lead and coordinator role), even after adjusting for patient factors. Experience in delivering thrombolysis (e.g. higher number of patients thrombolyzed annually) was also associated with improved DTN times. In addition, the benefit was seen in the provision of discharge care plans (regional/rural hospitals) and reduction in readmissions between 90 and 180 days (metropolitan hospitals) with the use of care pathways for managing stroke during the admission.

Interpretation within the context of the wider literature

Similar to the AuSCR, internationally there are few national stroke registries that routinely currently collect information on hospital features, which may further explain variations in care. As part of the Paul Coverdell National Acute Stroke Program in the USA, organizational data, such as the presence of a designated stroke team, use of care pathways/protocols, telehealth capabilities, and participation in quality improvement initiatives, are collected in an annual survey in addition to the patient-level data [20]. Similarly, the Sentinel Stroke National Audit Programme (SSNAP, https://www.strokeaudit.org/About-SSNAP.aspx), undertaken in the UK, also includes a biennial organizational survey.

The potential benefit of incorporating both clinical and hospital details to identify factors to improve evidence-based care has been reported. Clinical data from the USA Get With The Guidelines-Stroke registry have been combined with hospital-level characteristics from the American Hospital Association (e.g. academic or non-academic status, stroke volume, and geographical region) to assess the influence on specific thrombolysis metrics [21, 22]. While these studies included a more limited range of hospital features than that considered in our study, hospitals with greater annual volumes of thrombolyzed patients, shorter DTN [21], and onset to thrombolysis times were also reported [22]. In the UK, the Stroke Improvement National Audit Programme focused primarily on care provided within the first 72 hours post stroke and preceded the SSNAP. Published studies have also reported on the influence of hospital organizational features (from the Sentinel Audit) on the quality of stroke care provided (measured using clinical data from the Stroke Improvement National Audit Programme) [23, 24]. Similarly, these results demonstrated that hospitals delivering a higher volume of thrombolysis (>50 annually) achieved reduced DTN times [24]. Although the volumes reported were larger than in our study, the benefit of more experience is evident. Furthermore, consideration to the wider influence of organizational features was reported in the study by Bray et al. in 2013 using these UK data [23]. Rather than considering the hospital features individually as in our study, an overall composite organizational score was developed. A higher organization score, which considered staffing (numbers, type, and training level), facilities (e.g. provision of continuous physiological monitoring), and

Table 1. Hospital resources by location.

Hospital resources[a]	All		Metropolitan		Regional/rural	
	Hospital, N= 52, *n* (%)	Cases, *N* = 22 832, *n* (%)	Hospital, *N* = 42, *n* (%)	Cases, *N* = 20 977, *n* (%)	Hospital, *N* = 10, *n* (%)	Cases, *N* = 1855, *n* (%)
Public hospital	50 (96)	22 218 (97)	40 (95)	20 363 (97)	10 (100)	1855 (100)
Annual stroke admissions						
<75	5 (9)	676 (3)	2 (5)	440 (2)	3 (30)	236 (13)
75–199	17 (33)	5084 (22)	10 (24)	3465 (17)	7 (70)	1619 (87)
200–349	13 (25)	5126 (23)	13 (31)	5126 (24)	0 (0)	0 (0)
350–499	4 (8)	1904 (8)	4 (9)	1904 (9)	0 (0)	0 (0)
≥500	13 (25)	10 042 (44)	13 (31)	10 042 (48)	0 (0)	0 (0)
Service access/resources						
Stroke unit	50 (96)	22 832 (99)	42 (100)	20 977 (100)	8 (80)	1581 (85)
1–4 stroke unit beds	22 (44)	5997 (27)	14 (33)	4416 (21)	8 (100)	1581 (100)
5–9 stroke unit beds	13 (26)	7748 (35)	13 (31)	7748 (37)	0 (0)	0 (0)
≥10 stroke unit beds	15 (30)	8813 (39)	15 (36)	8813 (42)	0 (0)	0 (0)
Provides intravenous thrombolysis	49 (94)	22 270 (98)	41 (98)	20 605 (98)	8 (80)	1665 (90)
Thrombolysis offered 24 hours, 7 days	44 (90)	20 515 (92)	36 (88)	18 850 (91)	8 (100)	1665 (100)
Thrombolyzed ≥20 patients annually[c]	23 (47)	14 091 (63)	22 (54)	13 682 (66)	4 (50)[d]	1063 (64)
Emergency department protocols for rapid triage of patients presenting with acute stroke	49 (94)	22 295 (98)	40 (95)	20 518 (98)	9 (90)	1777 (96)
Defined and documented processes, policy, or clinical pathway for assessing patients with suspected TIA	46 (89)	21 375 (94)	38 (90)	19 937 (95)	8 (80)	1438 (78)
Endovascular stroke therapy 24 hours, 7 days	10 (19)	7768 (34)	10 (24)	7768 (37)	0 (0)	0 (0)
Onsite neurosurgery	16 (31)	9673 (42)	16 (38)	9673 (46)	0 (0)	0 (0)
Access to high dependency/intensive care unit	51 (98)	22 720 (99)	42 (100)	20 977 (100)	9 (90)	1743 (94)
Telemetry available for at least 72 hours	51 (98)	22 115 (97)	41 (98)	20 260 (97)	10 (100)	1855 (100)
Admit all patients with TIA or have access to TIA clinic within 48 hours	14 (27)	6295 (28)	12 (29)	6015 (29)	2 (20)	280 (15)
Onsite telehealth for clinical decision-making (used in last 6 months)	31 (60)	14 898 (65)	21 (50)	13 043 (62)	10 (100)	1855 (100)
Access to specialist services, e.g. palliative care, cardiology, and vascular surgery	38 (73)	19 305 (85)	34 (81)	18 540 (88)	4 (40)	765 (41)
Organization of workforce/staffing						
Dedicated stroke medical lead	41 (79)	19 571 (86)	36 (86)	18 545 (88)	5 (50)	1026 (55)
Coordinator role[b]	47 (90)	21 480 (94)	39 (93)	19 762 (94)	8 (80)	1718 (93)
Dedicated stroke medical lead AND coordinator role[b]	40 (77)	19 234 (84)	35 (83)	18 208 (87)	5 (50)	1026 (55)
Dedicated multidisciplinary team for stroke	51 (98)	22 832 (99)	42 (100)	20 977 (100)	9 (90)	1659 (89)
Team coordination and assessment processes						
Care pathway for managing stroke	43 (83)	19 734 (86)	35 (83)	18 153 (87)	8 (80)	1581 (85)
Involved in quality improvement over the last 2 years	52 (100)	22 832 (100)	42 (100)	20 977 (100)	10 (100)	1855 (100)
Programme for continuing education of staff related to stroke management	46 (88)	21 136 (93)	39 (93)	19 614 (94)	7 (70)	1522 (82)
Assessment for rehabilitation and ongoing care						
Standardized processes for assessing the suitability for further rehabilitation	46 (88)	20 513 (90)	38 (90)	19 135 (91)	8 (80)	1378 (74)
Coordination with rehabilitation service providers	51 (98)	21 917 (96)	41 (98)	20 062 (96)	10 (100)	1855 (100)
Routine involvement of patients and carers in rehabilitation process	52 (100)	22 832 (100)	42 (100)	20 977 (100)	10 (100)	1855 (100)
Discharge care plan and management protocols for fever, glucose, and swallow dysfunction	30 (58)	13 857 (61)	23 (55)	12 388 (59)	7 (70)	1469 (79)
Discharge care plan routinely provided	32 (62)	14 815 (65)	25 (60)	13 346 (64)	7 (70)	1469 (79)
Local protocols for routinely reviewing stroke patients discharged from hospital	32 (62)	16 156 (71)	27 (64)	15 112 (72)	5 (50)	1044 (56)

[a]Based on recommendations in the 2015 National Acute Stroke Services Framework; [b]includes stroke coordinator or clinical nurse consultant; [c]based on the median thrombolysis number in metropolitan hospitals; [d]>10 (median) used for regional/rural hospitals. TIA: Transient Ischemic Attack

service level (e.g. access to 24/7 imaging and thrombolysis), was found to be associated with an improved general care quality [23].

Most data linkage studies focus on 'patient-to-patient' linkage, whereas in the current example, we are linking one set of hospital survey responses to data from many individual patients using a 'one-to-many' approach. Our analyses highlight the benefits of these data in unpacking the clinical journey. Shorter DTN times are an important metric as 1.9 million brain cells die every minute after stroke, and earlier restoration of blood flow with clot-busting medication improves patient outcomes [25]. It has been reported that each 15-minute decrease in treatment delay in providing intravenous thrombolysis provides, on average, 1 month

Table 2. Multivariable models of hospital and patient factors associated with various care processes in metropolitan hospitals[a].

	Received intravenous thrombolysis[b], OR (95% CI)	Median door-to-needle time (minutes), coefficient (95% CI)	Accessed stroke unit care, OR (95% CI)	Antihypertensive medication on discharge, OR (95% CI)	Discharge care plan[c], OR (95% CI)
Patient factors					
Male	1.06 (0.95, 1.19)	2.7 (–2.2, 7.6)	**1.18 (1.10, 1.27)**	**1.19 (1.11, 1.29)**	**1.13 (1.02, 1.25)**
Age	**0.99 (0.98, 0.99)**	0.03 (–0.14, 0.20)	1.00 (0.99, 1.01)	**1.03 (1.03, 1.04)**	**0.99 (0.98, 0.99)**
Prior stroke	**0.61 (0.52, 0.71)**	5.3 (–1.8, 12.5)	0.98 (0.89, 1.07)	1.08 (0.98, 1.19)	**0.87 (0.77, 0.99)**
Socioeconomic position[d]					
Most disadvantaged	[Reference]	[Reference]	[Reference]	[Reference]	[Reference]
Second most disadvantaged	**1.26 (1.03, 1.55)**	2.2 (–7.6, 12.0)	0.94 (0.82, 1.07)	0.87 (0.76, 1.00)	1.00 (0.84, 1.20)
Third most disadvantaged	**1.21 (1.00, 1.45)**	–1.1 (–12.0, 9.8)	0.98 (0.87, 1.11)	**0.85 (0.75, 0.96)**	1.03 (0.87, 1.22)
Fourth most disadvantaged	1.11 (0.92, 1.35)	–4.4 (–13.9, 5.0)	0.93 (0.82, 1.06)	**0.83 (0.73, 0.95)**	1.09 (0.91, 1.30)
Least disadvantaged	1.14 (0.93, 1.39)	–4.2 (–10.9, 2.6)	0.99 (0.85, 1.15)	**0.76 (0.66, 0.88)**	1.16 (0.95, 1.41)
Haemorrhagic stroke	–	–	**0.60 (0.54, 0.67)**	1.00 (0.88, 1.13)	0.90 (0.73, 1.10)
In-hospital stroke	0.83 (0.63, 1.10)	**24.8 (0.99, 48.7)**	**0.36 (0.30, 0.42)**	0.97 (0.80, 1.18)	0.88 (0.64, 1.22)
Unable to walk on admission	**2.48 (2.17, 2.82)**	**–7.8 (–14.2, –1.4)**	**1.37 (1.26 1.49)**	0.94 (0.86, 1.02)	1.09 (0.98, 1.21)
Process factors					
Access to stroke unit care	–	–	–	**1.85 (1.68, 2.03)**	**1.42 (1.25, 1.60)**
Discharge to usual residence	–	–	–	**1.16 (1.06, 1.26)**	**1.63 (1.28, 2.09)**
Hospital factors					
Presence of dedicated medical lead for stroke AND coordinator role[e]	1.45 (0.92, 2.29)	**–12.7 (–25.0, –0.4)**	1.70 (0.74, 3.92)	1.36 (0.87, 2.13)	1.97 (0.46, 8.46)
Emergency department protocols for rapid triage of patients with acute stroke	0.86 (0.39, 1.91)	–12.8 (–59.99, 34.5)	–	–	–
Access to telehealth, used for clinical decision-making in the last 6 months	1.30 (0.96, 1.75)	4.2 (–5.9, 14.42)	0.97 (0.52, 1.82)	0.90 (0.64, 1.28)	1.64 (0.53, 5.12)
Delivered intravenous thrombolysis to >20 patients/year[f]	**3.19 (2.25, 4.52)**	**–20.2 (–32.0, –8.3)**	–	–	–
Number of stroke unit beds					
1–4	–	–	[Reference]	–	–
5–9	–	–	0.95 (0.45, 2.03)	–	–
≥10	–	–	2.34 (0.97, 5.60)	–	–
Admit all patients with TIA or have access to TIA clinic in 48 hours	–	–	0.94 (0.45, 1.95)	1.18 (0.74, 1.79)	2.44 (0.64, 9.33)
Use of clinical care pathway for managing stroke	–	–	0.66 (0.30, 1.45)	0.70 (0.45, 1.09)	3.75 (0.91, 15.48)
≥500 annual stroke admissions	1.15 (0.81, 1.65)	**–15.9 (–27.2, –4.7)**	1.05 (0.48, 2.30)	0.79 (0.51, 1.21)	1.28 (0.33, 4.99)

OR: odds ratio; CI: confidence interval; TIA: transient ischemic attack; [a]adjusted for factors shown in each model, as well as clustering by hospital; [b]ischaemic stroke; [c]if discharged to the community, e.g. usual residence, or supported accommodation; [d]determined using Index of Relative Socioeconomic Advantage and Disadvantage; [e]coordinator role defined as stroke coordinator or clinical nurse consultant; [f]determined from median at metropolitan hospitals. Bold text: $P < .05$. Access to endovascular clot retrieval, onsite neurosurgery, specialist services, and admissions are collinear.

of additional disability-free life [26]. Therefore, the 13- and 20-minute reductions seen at hospitals with dedicated medical leads and coordinators and with higher thrombolysis volumes, respectively, are considered clinically important findings. The adoption of various strategies including rapid triage, imaging protocols, and early stroke team involvement has also been effective in reducing DTN times in acute stroke care [27, 28]. While more detailed information about the processes involved with delivering thrombolysis was not collected in this study, similar to prior research [27], we identified potential advantages in having specialist stroke staff on reducing DTN s times. The value of both a coordinator and dedicated medical lead highlights the potential importance of the collaboration in addressing large system changes. The use of care pathways, in particular within regional/rural hospitals, was associated with over a 3-fold increase in the likelihood of discharge care plans being provided, which has proven benefit on longer-term patient outcomes [29]. Considering that one of the greatest contributors to the significant cost of stroke is hospital readmissions [30], the 18% reduction in all-cause readmissions reported for patients treated at metropolitan hospitals using care plans is substantial in terms of freeing up hospital resources and reducing costs. Although the mechanism of this is unclear, care plans can assist in avoiding acts of omission for care provision and enhance teamwork and communication [31], with a flow on effects in reducing the cost of stroke [32].

Implications for policy, practice, and research

The merged dataset provides a more robust patient cohort than the Audit clinical cross-sectional data permits, particularly for aspects of care such as the provision of thrombolysis that is only applicable to a small number of patients. In addition to patient and clinical factors, hospital organizational features can affect the receipt of evidence-based care [33]. Therefore, having access to data that incorporate a diverse range of patient, clinical as well as organizational factors, will permit more granular investigations into why variation in evidence-based care provision exists. The inclusion of these

Table 3. Multivariable models of hospital and patient factors associated with various care processes in regional/rural hospitals[a].

	Received intravenous thrombolysis[b], OR (95% CI)	Median door-to-needle time (minutes), coefficient (95% CI)	Accessed stroke unit care, OR (95% CI)	Antihypertensive medication on discharge, OR (95% CI)	Discharge care plan[c], OR (95% CI)
Patient factors					
Male	1.12 (0.74, 1.70)	7.1 (–4.9, 19.0)	1.22 (0.94, 1.58)	0.94 (0.73, 1.20)	1.21 (0.89, 1.66)
Age	0.99 (0.97, 1.00)	0.2 (–0.14, 0.49)	**1.01 (1.00, 1.02)**	**1.04 (1.03, 1.05)**	**0.98 (0.97, 0.99)**
Prior stroke	**0.54 (0.30, 0.98)**	4.6 (–54.1, 63.2)	**1.43 (1.02, 2.01)**	**1.40 (1.03, 1.91)**	1.08 (0.74, 1.57)
Socioeconomic position[d]					
Most disadvantaged	[Reference]	[Reference]	[Reference]	[Reference]	[Reference]
Second most disadvantaged	1.24 (0.74, 2.07)	**–26.4 (–49.9, –2.9)**	1.07 (0.79, 1.45)	1.07 (0.80, 1.44)	0.78 (0.54, 1.14)
Third most disadvantaged	1.56 (0.78, 3.13)	**–29.8 (–57.6, –2.0)**	1.21 (0.72, 2.04)	1.24 (0.76, 2.04)	1.29 (0.65, 2.58)
Fourth most disadvantaged	0.97 (0.43, 2.20)	**–45.5 (–72.3, –18.7)**	**2.66 (1.35, 5.25)**	0.69 (0.44, 1.10)	0.81 (0.43, 1.54)
Least disadvantaged	–	–	0.76 (0.21, 2.77)	0.53 (0.16, 1.84)	0.89 (0.13, 6.00)
Haemorrhagic stroke	–	–	0.90 (0.58, 1.41)	0.69 (0.44, 1.08)	0.91 (0.22, 3.80)
In-hospital stroke	0.61 (0.14, 2.63)	–0.4 (–36.0, 35.2)	0.78 (0.37, 1.63)	**0.46 (0.23, 0.93)**	0.92 (0.22, 3.87)
Unable to walk on admission	**1.90 (1.21, 2.98)**	6.3 (–10.3, 23.0)	**1.50 (1.15 1.96)**	**0.69 (0.53, 0.90)**	1.20 (0.85, 1.69)
Process factors					
Access to stroke unit care	–	–	–	**1.96 (1.45, 2.65)**	**5.47 (3.76, 7.96)**
Discharge to usual residence	–	–	–	0.99 (0.76, 1.30)	0.99 (0.44, 2.28)
Hospital factors					
Presence of dedicated medical lead for stroke AND coordinator role[e]	0.88 (0.51, 1.49)	–20.2 (–44.7, 4.1)	1.10 (0.84, 1.45)	0.75 (0.39, 1.42)	1.42 (0.83, 2.42)
Delivered intravenous thrombolysis to >10 patients/year[f]	0.94 (0.43, 2.08)	–15.0 (–33.6, 3.6)	–	–	–
Number of stroke unit beds					
2	–	–	[Reference]	–	–
4	–	–	0.87 (0.65, 1.16)	–	–
Admit all patients with TIA or have access to TIA clinic in 48 hours	–	–	**6.99 (4.03, 12.15)**	1.93 (0.96, 3.90)	0.91 (0.47, 1.75)
Use of clinical care pathway for managing stroke	–	–	–	0.48 (0.21, 1.08)	**3.58 (1.45, 8.82)**
<100 annual stroke admissions	0.74 (0.31, 1.77)	9.2 (–21.6, 40.0)	**2.65 (1.84, 3.83)**	**1.98 (1.11, 3.53)**	1.65 (0.98, 2.78)

OR: odds ratio; CI: confidence interval; TIA: transient ischemic attack; [a]adjusted for factors shown in each model, as well as clustering by hospital; [b]ischaemic stroke; [c]if discharged to the community, e.g. usual residence, or supported accommodation; [d]determined using Index of Relative Socioeconomic Advantage and Disadvantage; [e]coordinator role defined as stroke coordinator or clinical nurse consultant; [f]determined from median at regional/rural hospitals. Bold text: $P < .05$. All regional/rural hospitals had access to telehealth and emergency department protocols for rapid triage.

additional details also permits the assessment of whether the hospital has adequate resources for managing stroke and will enable subsequent comparisons of the resources for stroke care and the outcomes of when these are modified or augmented. Identifying important hospital resources related to the quality of care and improved stroke outcomes may be useful for advocacy to inform policy, practice, and quality improvement recommendations.

Given the importance of timely treatment with thrombolysis, these findings may have implications for the configuration and certification of stroke services. Additional policy considerations include emergency medical services directing patients with suspected stroke to stroke-capable hospitals [34, 35] or wider centralization of stroke services to create smaller numbers of high-volume specialist services, as undertaken in the UK with hyperacute stroke units [36]. The practical implications of larger metropolitan hospitals, with greater annual stroke admissions having reduced DTN times, are interesting to consider. Even in metropolitan areas, admissions can be influenced by the population density in the catchment area and geography [24]. Other available stroke services within the hospital (e.g. endovascular clot retrieval services) can also impact pre-hospital bypass models and direct routing of patients to more specialized centres. Within the context of Australia and elsewhere, the number of hospitals with greater experience administering intravenous thrombolysis is likely to increase with the more widespread use of telemedicine options, particularly in regional locations [37, 38]. It is also important to consider the variation in DTN times that still exists and how these can be optimized for all patients, regardless of the time or day presenting to the hospital [39]. The investment in adequate specialist staffing, which can improve such processes, is also an important policy consideration within hospitals, whereby the offsets from fewer readmissions when coupled with care plans are relevant.

Recent context-specific organizational criteria required to deliver evidence-based care are outlined in the 2019 National Acute Services Framework for Australia [17]. This framework considers different criteria related to the therapeutic capability (e.g. access to endovascular clot retrieval services) and stroke volume (annual number of stroke admissions) in stroke-capable hospitals including Comprehensive and Primary Stroke Centres, as well as General Hospitals [17]. At the current time, a pilot programme is also being implemented by the Australian Stroke Coalition to develop a system for certifying stroke units in Australian hospitals (Stroke Unit Certification Program|Stroke Foundation—Australia). In the USA, Canada, and across Europe, stroke centre certification programmes have led to improved access to important organizational features that have enhanced stroke care services and patient outcomes [40, 41]. However, a benefit has also been seen in prior research with the adoption of successful

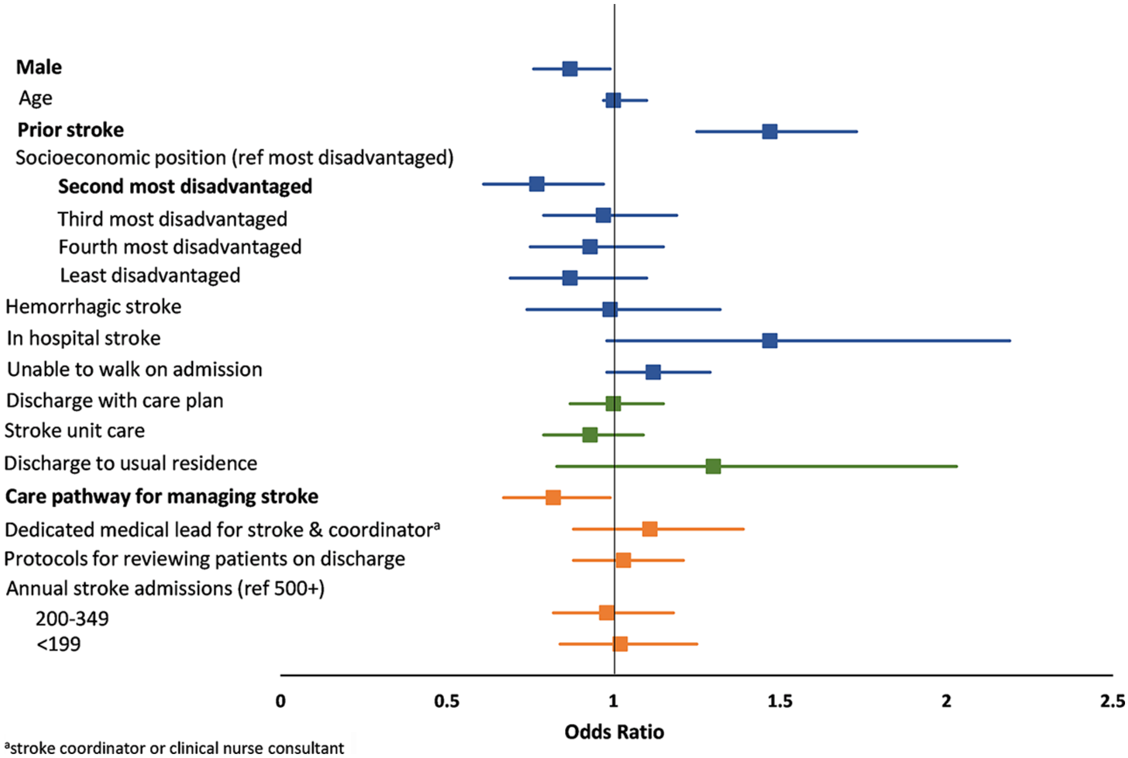

Figure 2 Hospital, patient, and process factors associated with all-cause readmissions at 90–180 days, at metropolitan hospitals.

experiences from high-performing or ‘exemplar’ hospitals to those with poorer performance [42].

Significant work has already been undertaken in Australia to link data from general practitioners, ambulance presentations, hospital administrative datasets, the AuSCR, inpatient rehabilitation admissions, and Medicare and medication dispensing claims data [43]. This linkage fills a gap in moving towards an integrated national data platform for stroke in Australia.

Strengths and limitations

However, we acknowledge that the organizational information collected in the survey is not validated but self-reported by experienced and knowledgeable staff, with multiple team members completing the survey together at times. Incongruous results based on prior audits are identified and clarified with hospital staff. Hospital readmissions were also self-reported and not validated with any hospital administrative data. It is also important to acknowledge that the organizational survey data collected may not be specific to each individual patient. For example, we do not know whether or not a patient was seen by the stroke coordinator during their stay; rather, the influence of such a position on care delivery is likely multifactorial, encouraging a more coordinated approach to care. While national clinical guidelines outline the range of evidence-based care recommendations, the focus of this study was on the core national care processes collected within the AuSCR for acute stroke. The labour-intensive nature of prospective, continuous data collection for the AuSCR can mean that hospitals with less resources for stroke or smaller numbers of admission tend not to participate, leading to a potential bias in participation. In particular, we found that the hospitals in this study that participated in the AuSCR had more resources for stroke care based on the organizational survey responses. For example, 96% of the AuSCR hospitals reported having a stroke unit, and 90% had a stroke coordinator role, compared with the hospitals participating in the Audit in 2017, where only 75% had a stroke unit and reported having a coordinator [44]. Even the regional/rural hospitals in AuSCR exhibited more organized stroke services, with all 10 having access to onsite telehealth compared to just >50% Australia wide [44].

Currently, the organizational survey is only completed every 2 years in Australia, which is similar to the SSNAP in the UK. Nevertheless, the notion of collecting hospital resource details annually, as is done with the Paul Coverdell National Acute Stroke Program, is important. This would provide increased information about variation in care and potentially patient outcomes in reporting of not only the AuSCR data but stroke registry data being collected around the world. Importantly, this has the potential to assist in directing targeted quality improvement activities.

Conclusion

Information on hospital resources to supplement patient-level data creates the possibility to explore a wider range of organizational factors that might explain the variation in the quality of stroke care and health outcomes. Increased access to selected processes of care appears to be influenced by the presence of dedicated medical leads/coordinators and thrombolysis volume in metropolitan hospitals and the use of clinical care pathways in regional/rural hospitals. These data provide important contextual information to plan quality improvement efforts with hospitals for stroke or TIA management.

Supplementary data

Supplementary data are available at *INTQHC* online.

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Data availability

Information on the approval processes involved to access data from this study is available from the corresponding author.

Author contributions

Tara Purvis (Data analysis, Drafting of the manuscript [lead]), Dominique A. Cadilhac (Study design, Interpretation of the data [equal]), Monique F. Kilkenny (Study design, Interpretation of the data [equal]), Dominique A. Cadilhac (Editing of the manuscript [supporting]), Kelvin Hill (Editing of the manuscript [supporting]), Adele K. Gibbs (Editing of the manuscript [supporting]), Jot Ghuliani (Editing of the manuscript [supporting]), Sandy Middleton (Editing of the manuscript [supporting]), and Monique F. Kilkenny (Editing of the manuscript [supporting]).

Ethics

Approval to conduct this study was obtained from Monash University Human Research Ethics Committee (Project ID 22903), the AuSCR Research Task Group and Management Committee (approved 11 May 2020), and the AuSDaT Coordinating Committee (28 September 2020).

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