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ORIGINAL ARTICLE

Impact of the first wave of COVID-19 on stroke admissions across three tertiary hospitals in Brisbane

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Key words
COVID-19, coronavirus, SARS-CoV-2, pandemic, stroke, hospital presentations.

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Abstract

Background: COVID-19 has caused a global shift in healthcare-seeking behaviour; however, presentation rates with serious conditions, such as stroke in low COVID-19-prevalence cities, has received less attention.
Aims: To determine if there was a significant reduction in stroke admissions, delivery of acute reperfusion therapies, or increased delays to presentation during the first wave of the COVID-19 pandemic.
Methods: A multicentre, retrospective, observational cohort study was performed across three tertiary hospitals in Brisbane, Australia. Cases were identified using ICD-10 codes and then individually reviewed for eligibility using prespecified inclusion and exclusion criteria. All metrics were compared over 3 months from 1 March to 31 May 2020 with two corresponding 3-month periods in 2018 and 2019.
Results: There was a mean of 2.15 (95% CI 1.87–2.48) stroke admissions per day in the examined pandemic months compared with 2.13 (95% CI 1.85–2.45) and 2.26 (95% CI 1.97–2.59) in March to May 2018 and 2019 respectively, with no significant difference found ($P = 0.81$). There was also no difference in rates of intravenous thrombolysis ($P = 0.82$), endovascular thrombectomy ($P = 0.93$) and time from last known well to presentation ($P = 0.54$). Conversely, daily emergency department presentations (including non-stroke presentations) significantly reduced ($P < 0.0001$).
Conclusions: During the early months of the COVID-19 pandemic there was no significant reduction in stroke presentations, use of acute reperfusion therapies or delays to presentation, despite a reduction in ED presentations for any cause. Our results differ from the global experience, with possible explanations, including differences in public health messaging and healthcare infrastructure.

Introduction

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is a highly transmissible novel coronavirus first detected in December 2019, which causes an infectious disease called coronavirus disease 2019 (COVID-19). In early 2020, COVID-19 spread precipitously around the world, resulting in devastating impacts, including death,[1] economic collapse[2] and social isolation.[3] From a neurological perspective, COVID-19 is known to increase the risk of stroke (ischaemic more than haemorrhagic), while also being associated with Guillain-Barre syndrome, encephalitis and a range of neurological symptoms.[4] In a large retrospective study of COVID-19 patients, 1.6% suffered an ischaemic or haemorrhage stroke.[5] Cryptogenic strokes with large vessel occlusion have also been reported in young COVID-19 patients.[6] A variety of atypical mechanisms have been reported, including a hypercoagulable state, disseminated intravascular coagulation, necrotising encephalopathy, vasculitis and cardiomyopathy.[7] In

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addition to the risk of stroke, worldwide there have been reports of reduced hospital presentations during COVID-19 outbreaks, including those for serious and life-threatening conditions, including stroke and myocardial infarction.[8–11] In areas with a high COVID-19 prevalence, patients may have been deterred from presenting to hospital due to fears of exposure to infection and perceived or real limitations of hospital resources.

Despite the spread of COVID-19 globally, Australia, including Queensland, has maintained a relatively low incidence of COVID-19 with low case numbers during the first wave.[12] The first confirmed Queensland case was on 28 January 2020, with Queensland declaring COVID-19 a public health emergency on 29 January. Subsequently, during this early phase, there was widespread media coverage and frequent public health announcements relating to COVID-19 that had early flow-on effects for social behaviour, including hoarding of groceries and toilet paper.[13] However, by 1 March 2020 there had only been nine cases in Queensland and by 31 May there were 1058 cumulative cases. During this 3-month period there was a peak of 78 cases in a single day and only 25 cases reported in all of May 2020.[12] The cumulative incidence in Queensland from March to May was 0.02%,[14] compared with high-incidence cities, such as New York City, where an estimated cumulative incidence of 22.7% through 29 March 2020 was reported.[15] During this time, public health measures were enacted, including international border closure on 19 March, non-essential services suspension on 23 March and interstate borders closure on 25 March.[16]

There were concerns among some Australian medical practitioners that during this time period there was a reduction in healthcare-seeking behaviour, including for serious conditions,[17,18] mirroring large shifts that have been observed overseas.[19] Healthcare avoidance and delayed presentation for serious but treatable conditions, such as stroke, have obvious and potentially irreversible consequences for patient outcomes. Public health communication must be balanced between delivering the required message, while not creating undue fear that might directly affect health outcomes from other conditions. This is particularly pertinent in a setting where there is a low incidence of the condition in question, in this case COVID-19.

Aims

The present study aimed to examine whether the COVID-19 pandemic in Brisbane affected: (i) the number of stroke admissions; (ii) the time from last known well (LKW) to stroke presentation; (iii) the number of patients receiving thrombolysis (IVT) and endovascular thrombectomy (EVT); and (iv) total hospital presentations. Our hypotheses were that there would be a reduction in admissions to hospital with stroke, fewer patients presenting overall, delays to presentation with stroke and fewer patients receiving reperfusion therapies.

Methods

Study design and setting

A multicentre, retrospective observational cohort study design was used across three major stroke centres in Brisbane: Princess Alexandra Hospital (PAH),[20] an EVT centre serving a population of approximately 1 200 000; Royal Brisbane and Women's Hospital (RBWH),[20] an EVT centre serving a population of 1 million; and Mater Hospital. Ethics approval was granted by the Mater Misericordiae Ltd. Human Research Ethics Committee (HREC/MML/66638 (V2)).

Patients

Presentations and admissions at each hospital were reviewed from 2018 to 2020. The primary analysis considered three time periods to minimise seasonal effects on the results, including the COVID-19 period (1 March to 31 May 2020) and historical control periods (1 March to 31 May in 2018 and 2019). Subsequent secondary analyses were conducted on the entire 27-month period, the results of which are included in the Supporting Information S1. All patients' electronic medical records were individually reviewed for eligibility that was limited to patients diagnosed with either an ischaemic stroke or intracerebral haemorrhage (ICH). Exclusions were inpatient stroke when admitted for another reason, patients transferred from another hospital, traumatic ICH, other types of intracranial haemorrhage and a lack of neuroimaging to exclude stroke mimics and/or confirm the diagnosis.

Data collection

Data for hospital presentations and admissions were extracted from the hospital information systems at each institute. A list of encounters was generated using a range of ICD-10 codes (I-61, I-63, I-64, I-69, G-45, G-46) and filtered by admissions between 1 March 2018 and 31 May 2020. Each encounter was individually reviewed using the medical chart contained within the electronic medical records to determine eligibility according to the prespecified inclusion and exclusion criteria. Baseline demographic information, including age and sex were also collected. Other data collected

included date and time of presentation, LKW time, use of IVT and EVT, results of neuroimaging studies and discharge diagnosis.

Statistical analysis

Admission counts per day and IVT/EVT cases per day were modelled using generalised linear models with Poisson distribution and presented as estimated daily rates with 95% confidence intervals (CI) along with *P*-values for comparisons between groups. The primary analyses compared equivalent periods of March through May for 2018 and 2019 representing the pre-COVID-19 periods and 2020 representing the COVID-19 period. A secondary analysis was conducted incorporating all data, using season as a covariate. LKW to presentation time (WTP) was analysed based on a log-normal distribution, with results presented as geometric means with corresponding 95% CI and *P*-values. Waiting times can be modelled using negative binomial or log-normal distributions,[21] but the log-normal distribution had a better fit to the data based on PP plots (percentile-percentile plot). All analyses were performed in JMP Pro (ver. 16.1; SAS Institute, Cary, NC, USA).

Results

In total, 10 067 encounters were reviewed and 2065 were eligible. The mean patient age was 68.0 years during the COVID-19 period, similar to 2018 (67.8 years) and 2019 (69.5 years). Fifty-four percent of cases admitted in 2020 were male compared with 62% in 2018 and 54% in 2019. The proportion of patients with ischaemic stroke was also comparable at 80.8% versus 82.7% and 76% respectively.

Primary outcome

The mean number of stroke admissions per day was 2.15 (95% CI 1.87–2.48) during the COVID-19 period compared to 2.13 (95% CI 1.85–2.45) and 2.26 (95% CI 1.97–2.59) during the 2018 and 2019 historical control periods respectively, with no significant difference found ($P = 0.81$) using a Poisson maximum likelihood generalised regression model (Table 1, Fig. 1). There were no significant differences in rates of admission between periods for either ischaemic stroke ($P = 0.97$) or ICH ($P = 0.18$). A post-hoc analysis (Supporting Information S1) comparing the COVID-19 time period to the preceding 24-month period, found a significant reduction in daily stroke admissions ($P = 0.022$). However, when adjusted for seasonal effects the difference was not significant ($P = 0.81$), with a consistent decrease in stroke admissions seen annually each Autumn, coinciding with the study period.

Secondary outcomes

The mean number of IVT cases per day was 0.32 (95% CI 0.22–0.45) during the COVID-19 period with no significant difference seen ($P = 0.82$) compared with 2018 (0.27; 95% CI 0.18–0.40) and 2019 (0.27; 95% CI 0.18–0.40). The mean number of EVT cases per day also did not differ ($P = 0.93$) with 0.22 (95% CI 0.14–0.34) in 2020 compared to 0.20 (95% CI 0.12–0.31) in 2018 and 0.22 (95% CI 0.14–0.34) in 2019.

Furthermore, using a linear model on a log-transformed LKW to presentation time, WTP time in minutes was also not significantly different ($P = 0.54$) during the COVID-19 period (383.9; 95% CI 300.2–490.8) compared with the comparable periods in 2018 (455.6; 95% CI 355.5–583.8) and 2019 (384.3; 95% CI 302.8–487.8; Fig. 2).

Despite no difference in stroke-related measures, the overall number of emergency department presentations per day during the COVID-19 period was significantly lower ($P < 0.0001$) during the relevant 3-month period in 2020 (542; 95% CI 537–546) compared with 2018 (570; 95% CI 565–575) and 2019 (587; 95% CI 583–592) (Figs 3,4).

Discussion

In this retrospective, observational study, the presentation time, rates of admissions and treatments for stroke were reviewed during the onset of the COVID-19 pandemic and compared with historical control periods. This was performed following reports of reduced hospital presentations for serious conditions in the early phases of the pandemic, which presents an obvious risk to patient outcomes. However, despite these reports, the results of this study demonstrated no difference in hospital presentations with stroke. These results included admissions with ischaemic stroke and ICH, in three major stroke centres in Brisbane, a city with a low incidence of COVID-19 at the time. Additionally, there was no difference in time to presentation and rates of reperfusion therapies, despite a significant reduction in overall emergency department presentations.

Across the three hospitals included in the study there were numerical differences during the COVID-19 period, which did not reach statistical signifcance, including an apparent increase in stroke admissions, IVT and EVT at PAH, and either no change or a numerical decrease in these measures at RBWH and Mater (Supporting Information S1). Likewise, there was a statistically

Table 1 Primary and secondary outcomes

	Pre COVID-19 (2018)†	Pre COVID-19 (2019)‡	COVID-19 (2020)§	Total	*P*-value
Primary outcome					
Diagnosis					
Intracerebral haemorrhage, *n* (%)	34 (17.3)	50 (24.0)	38 (19.2)	122 (20.3)	
Ischaemic stroke, *n* (%)	162 (82.7)	158 (76.0)	160 (80.8)	480 (79.7)	
All strokes, *N*	196	208	198	602	
Mean stroke admissions/day (95% CI)	2.13 (1.85–2.45)	2.26 (1.97–2.59)	2.15 (1.87–2.48)		0.81
Secondary outcome					
Thrombolysis, (%)¶	25 (15.4)	25 (15.8)	29 (18.1)	79	
Mean thrombolysis cases/day (95% CI)	0.272 (0.183–0.403)	0.272 (0.183–0.403)	0.315 (0.219–0.454)		0.82
Endovascular thrombectomy, *n* (%)¶	18 (11.1)	20 (12.7)	20 (12.5)	58	
Mean endovascular thrombectomy cases/day (95% CI)	0.196 (0.12–0.31)	0.22 (0.14–0.34)	0.22 (0.14–0.34)		0.93
Geometric means of last known well to presentation time (95% CI) (min)	455.6 (355.5–583.8)	384.3 (302.8–487.8)	383.9 (300.2–490.8)		0.54
Mean total emergency department presentations/day (95% CI)	570 (565–575)	587 (583–592)	542 (537–546)		<0.0001

†1 March to 31 May 2018.
‡1 March to 31 May 2019.
§1 March to 31 May 2020.
¶Number as a percentage of admissions with ischaemic stroke. CI, confidence interval.

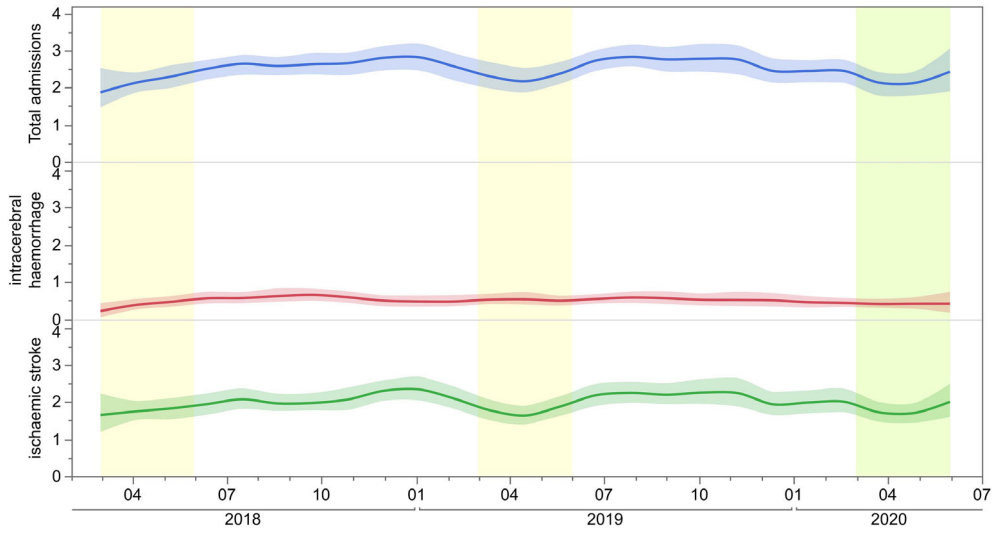

Figure 1 Stroke admissions per day‡ from 1 March 2018 to 31 May 2020 divided into ischaemic stroke, intracerebral haemorrhage and all stroke admissions. The relevant COVID-19 time period (1 March to 31 May 2020) is highlighted green, while the historical control periods (1 March to 31 May 2019 and 1 March to 31 May 2018) are highlighted yellow. Daily admissions plotted using a generalised linear regression model with Poisson distribution including 95% confidence interval.

significant decrease in LKW to presentation time at PAH with a numerical increase at the other sites not reaching statistical significance. There were no official changes to hospital or pre-hospital procedures or policies during this time, which might account for the apparent difference. However, PAH was the largest stroke centre in this study, so it remains possible that unofficial changes in procedure for this site may have affected the results.

In contrast to our findings, two major global studies which used the SVIN COVID-19 Global Stroke Registry to examine the global impact of COVID-19 on stroke metrics have found detrimental effects.[10,11] One study,

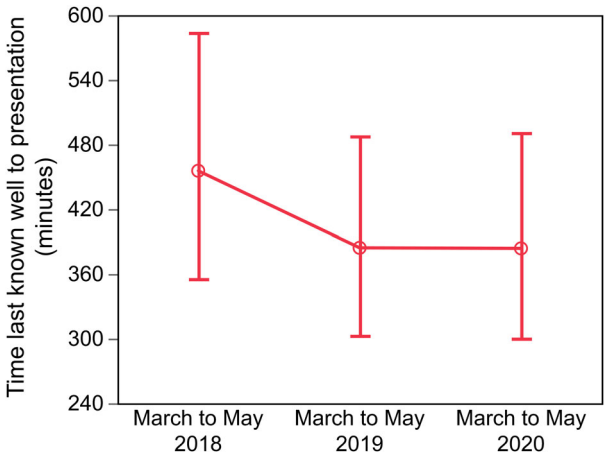

Figure 2 Least squares mean plot of last known well to presentation time in minutes during the COVID-19 period compared to the relevant historical control periods.

measuring the rates of IVT, IVT transfers and hospitalisations across 70 countries over 4 months from March to June 2020 found an 11.5% reduction in stroke admissions, a 13.2% reduction in IVT and 11.9% reduction in interfacility IVT transfers.[11] Likewise, another study included 40 countries over a 3-month period from March to May 2020 and found a decline in ischaemic stroke, ICH and EVT rates, which did not vary according to the COVID-19 hospitalisation burden.[10] World Stroke Organisation (WSO) surveys in multiple countries, including Chile, Columbia, Iran, Greece, the United Kingdom and Italy, also found a sharp reduction in stroke presentations related to COVID-19, up to 80% in some countries.[22] There are several possible explanations for this phenomenon, including hospital healthcare resource limitations, overcrowded emergency departments, overburdened ambulance services and hospital avoidance due to fear of contagion.

In contrast to the regions evaluated in the above studies, Australia had a much lower incidence of COVID-19 during the first wave of the pandemic, presenting a unique situation where public health messaging was likely similar to what occurred in these other regions, but the resource burdens and risks of infection were lower. Despite this, Australian studies examining the effects of COVID-19 on stroke presentations have been few. The largest study evaluated data obtained from the Australian Stroke Clinical Registry (AuSCR),[23] which includes 61 public hospitals across Australia. Similar to the present study, the authors evaluated comparable time frames and found no difference in stroke presentations or onset to arrival time. Importantly, the present study differs in several ways, which may serve to strengthen the real-world applicability of the results. First, it is limited to one city with a centralised healthcare system with a relatively equal distribution of healthcare resources and healthcare accessibility. Furthermore, this study captures the health seeking behaviour across a homogenous setting of public health measures and population behaviour, which might vary across the different cities that are captured in registry data. These variations could depend on many confounding factors, including diverse demographics, varying prevalence of COVID-19 and different public health messaging. There have been a few other small Australian studies that have produced varied results, including reporting a reduction in

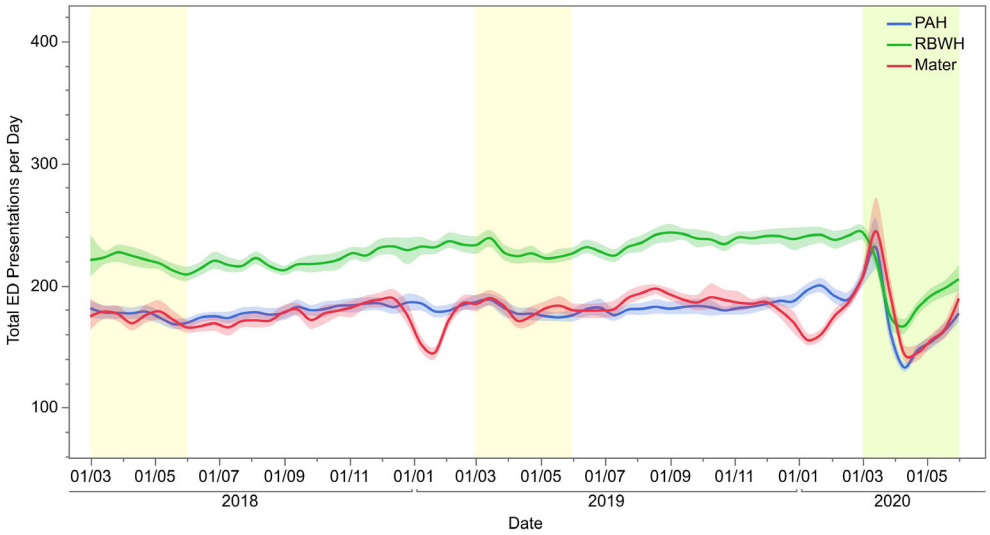

Figure 3 Total emergency department presentations per day from 1 March 2018 to 31 May 2020. The relevant COVID-19 time period (1 March to 31 May 2020) is highlighted green, while the historical control periods (1 March to 31 May 2019 and 1 March to 31 May 2018) are highlighted yellow.

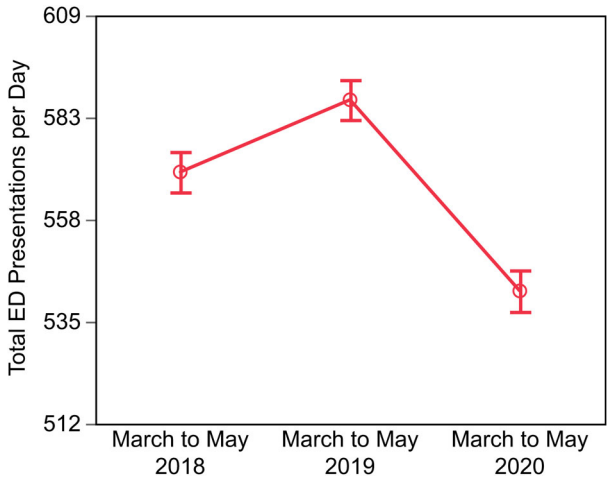

Figure 4 Least squares mean plot of total emergency department presentations per day during the COVID-19 period compared with the relevant historical control periods.

the volume of code stroke activations in Victoria;[24] no reduction in category 1 ED presentations with stroke and myocardial infarction in Melbourne;[25] and a reduction in ED presentations in Sydney.[26]

Emergency department presentations

Although the overall reduction in emergency department presentations in the present study was less than 10%, the degree of reduction in 2020 is likely partly offset by patients presenting with respiratory and/or mental health symptoms related to the COVID-19 pandemic who might not have presented in previous years. Notably, there was an initial increase (Fig. 3) in emergency department presentations at two of the three studied hospitals, the cause of which is uncertain but may relate to presentations for COVID-19 testing prior to the establishment of dedicated fever clinics. A definitive conclusion about this could not be determined without analysing the cause of all ED presentations and/or final diagnosis, which was beyond the scope of this study. Despite this, the individual and collective health impacts of reduced ED presentations should not be underestimated. Nationally, a marked early decrease in ED presentations was seen, decreasing by 38% from the week starting 9 March to the week starting 30 March 2020,[27] slowly increasing subsequently but still being 8.4% lower on 22 June 2020 compared with the same time period in 2019.[27]

Public messaging considerations

Australia has been successful to date in limiting spread and mortality rates from COVID-19.[28] There are many potential factors contributing to this success, including geographic isolation and wealth, with early decisive Government responses at all levels and public health messaging also likely important factors.[29] To prepare its response to the pandemic, in April 2020, the Australian Government commissioned a report from a task force comprising the country's leading universities entitled *COVID-19 Roadmap to Recovery: A Report for the Nation*.[30] The report contained analysis and recommendations from leading epidemiologists, scientists, infectious diseases experts and First Nations scholars, highlighting communication, a two-way process involving policymakers and communities, as being central to managing the pandemic.

It is important for public health messaging during pandemics to be clear, credible, empathetic and open. It should also be proactive in addressing misinformation, neither exaggerating or minimising associated risks.[29] The lack of change to stroke admissions in Brisbane during the early phase of the pandemic demonstrated in the present study may in part be due to effective communication by the public health authorities and these results provide reassurance that while internationally there were significant impacts to the timing and quality of stroke care, the same has not been seen in Brisbane.

Limitations

The present study featured the two largest hospitals in Brisbane but did not include all hospitals, so it is difficult to draw definitive conclusions about the lack of effect from COVID-19 on overall stroke presentations. Furthermore, both PAH and RBWH are part of broader Hospital and Health Service (HHS) networks that deliver healthcare to a large proportion of the population of South-East Queensland, with a possibility of varied presentation patterns to different hospitals confounding the results.

Due to the observational nature of this study, there is potential for other confounders, such as changes in stroke incidence over time, changes in quality of stroke care over time and population growth influencing the outcome. This was reduced by maintaining consistent methodology for patient selection across all hospitals, excluding inter-hospital transfers, which might introduce bias towards presentation severity, and annual comparison of the same 3-month period to minimise seasonal effects.

The effect of COVID-19 on minor stroke admissions was not specifically examined because National Institutes of Health Stroke Scale (NIHSS) data was inconsistently available in the case records. It was felt likely that the inconsistency of NIHSS reporting could be confounded by factors, including stroke severity and delay to presentation and introduce bias. Therefore, this study did not

address whether there was a reduction in presentations with non-disabling stroke.

This study focussed on the effects of COVID-19 on patient presentation behaviour and therefore did not examine the effects of COVID-19 on patient care or outcomes due to changes in processes. Despite this, the similar numbers of cases receiving acute stroke interventions provides some evidence to suggest that service delivery was not adversely affected. More concerningly, AuSCR data showed a reduction in the utilisation of acute stroke units during the first few months of COVID-19 compared with historical controls, as well as finding longer door-to-needle times during the peak pandemic period.[23] Therefore, it is essential for hospitals to audit the consequences of COVID-19 and update policies related to pandemic or disaster management. This will ensure the treatment quality of unrelated emergencies, such as stroke and myocardial infarction are not adversely affected.

Conclusions

This study demonstrated no significant changes to stroke presentations at three major stroke centres during the early phase of the COVID-19 pandemic across Brisbane, a city with a low incidence of infections. Despite a decrease in overall ED presentations, there was no difference in stroke admissions, rates of reperfusion therapies and no delays to presentation over the 3 months evaluated. This study provides insight into healthcare seeking patterns in a unique pandemic context and contrasts findings from international registries, which have demonstrated pandemic related deteriorations in stroke presentations and stroke care. Therefore, efforts should be made to identify factors contributing to the difference across cities and ensure continuity and consistency of stroke care delivery if future case surges occur. Further studies examining hospital process times during COVID-19 would also be useful to understand whether hospital-specific protocols might lead to undesired effects on the provision of stroke care.

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Supporting Information

Additional supporting information may be found in the online version of this article at the publisher's web-site:

Table S1 Comparison of the COVID-19 period compared to 24 months prior.
Table S2. Comparison of outcomes divided by hospital.
Figure S1 Stroke admissions per day from 1 March 2018 to 31 May 2020 divided into ischaemic stroke and intracerebral haemorrhage and divided by hospital. †The relevant COVID-19 time period (1 March to 31 May 2020) is highlighted green, while the historical control periods (1 March to 31 May 2019 and 1 March to 31 May 2018) are highlighted yellow.
Figure S2 Mean lysis rates per day divided by hospital (Mater excluded due to very low lysis numbers) during the COVID-19 period to the relevant historical control periods.
Figure S3 Mean mechanical thrombectomy per day divided by hospital during the COVID-19 period to the relevant historical control periods.
Figure S4 Last known well to presentation time divided by hospital during the COVID-19 period to the relevant historical control periods.

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