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Implementation of a provincial acute stroke pathway and its impact on access to advanced stroke care in Saskatchewan

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ABSTRACT

Background For ischaemic stroke, outcome severity is heavily time dependent. Systems of care need to be in place to ensure that patients with stroke are treated quickly and appropriately across entire health regions. Prior to this study, the province of Saskatchewan, Canada did not have a provincial stroke strategy in place.

Methods A quality improvement project was undertaken to create and evaluate a provincial stroke strategy. The Saskatchewan Acute Stroke Pathway was created using a multidisciplinary team of experts, piloted at five stroke centres and then implemented provincially. The number of stroke alerts, door-to-imaging, door-to-needle, door-to-groin puncture times and treatment rates were collected at all centres. Improvements over time were analysed using run charts and individuals control charts.

Results The number of stroke alerts province-wide trended upwards in the last 6 months of the study. There were no clear trends or shifts in the proportion of stroke alerts treated with alteplase or endovascular therapy. Across the province, the weighted mean door-to-imaging time decreased from 21 to 15 min, the weighted mean door-to-needle time decreased from 62 to 47 min and the mean door-to-groin puncture time decreased from 83 to 70 min. There was high variability in the degree of improvement from centre to centre.

Conclusions The implementation of a province wide acute stroke pathway has led to improvement in stroke care on a provincial basis. Further work addressing intercentre variability is ongoing.

INTRODUCTION

Problem description

Stroke is a leading cause of disability in Canada and worldwide. For ischaemic stroke specifically, outcome severity is heavily dependent on the timeliness of treatment. Early, fast and appropriate treatment is essential in order to ensure the best outcomes for patients.[1] This means that systems of care need to be in place to ensure patients with stroke are treated quickly and appropriately across entire health regions. In 2014, the province of Saskatchewan, Canada (population: 1.2 million) was one of only three Canadian provinces which did not have a provincial stroke strategy. Following, we will explain the development and implementation of the Saskatchewan Acute Stroke Pathway (ASP) and its impact on the acute treatment of stroke across the province.

Available knowledge

Suspected patients with stroke require urgent attention, evaluation and treatment from the prehospital environment through to acute in hospital treatment. Canadian Stroke Best Practice Guidelines state that the goal of emergency medical services (EMS) on scene of a suspected patient with stroke is to 'recognise and mobilise'. Patients should be screened for signs of stroke using the Face, Arm, Speech and Time (FAST) assessment and patients exhibiting any FAST symptoms should undergo further screening for stroke severity to assess if the patient could be a candidate for endovascular therapy (EVT).[2] Following this transport protocols must be in place to facilitate the transfer of suspected patients with acute stroke who are potentially eligible for alteplase and/or EVT.

Once the patient arrives in the emergency department (ED), they require immediate evaluation. A coordinated response is needed across different healthcare teams to ensure quick access to imaging, vital sign monitoring, neurological exams and lab work so treatment is not delayed. Reducing any delays in patient with stroke treatment is essential as for patients with ischaemic stroke both alteplase and EVT are highly time sensitive. For patients with large vessel occlusions (LVO), every 15 min delay in alteplase treatment results in 8 fewer among 1000 patients achieving an excellent outcome (modified Rankin Scale (mRS) score 0–1 at 90 days).[3] The same time delay for EVT results in 25 fewer among 1000 achieving an independent outcome (mRS 0–2 at 90 days).[4]

Implementing protocols based on best practice guidelines can encourage the

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prioritisation of the patient with hyperacute stroke in the local ED, leading to decreased treatment times and ultimately resulting in better outcomes for stroke survivors. There have been at least a dozen single-centre quality improvement initiatives in recent years aimed at streamlining and standardising stroke care have been undertaken worldwide.[5] This includes the seminal study in Helsinki, Finland where over the course of several years, 12 measures were introduced to reduce door-to-needle (DTN) time in patients with stroke. The initiatives were: education of EMS, hospital prenotification of incoming patient with stroke, preordering lab tests and diagnostic imaging, immediate reading of the CT scan by stroke physician, premixing alteplase, delivering alteplase on CT table, relocation of the CT scanner to the ED, transferring the patient from the EMS stretcher to the CT scanner, patient swarmed on arrival in the CT room, acquisition of patient medical record/history before arrival, performing point-of-care INR testing on the CT table and reserving advanced imaging for unclear cases. The implementation of this protocol reduced median DTN time from 105 to 20 min.[6] This model was repeated in Melbourne, Australia where DTN times were reduced from a median of 43–25 min in-hours (off-hours times remained unchanged).[7]

In Calgary, Canada, the Hurry Acute Stroke Treatment and Evaluation (HASTE) programme implemented similar changes to acute stroke workflow including prenotification from EMS of an incoming stroke alert, sending out a STAT stroke page to all members of the stroke care team, registering the patient as unknown (following processes used in trauma admissions), standardised provincial order sets for patients with stroke, moving the patient directly from the EMS stretcher to the CT, and administering alteplase in the CT/imaging area. This resulted in a reduction of median DTN time from 53 to 35 min.[8]

Multicentre stroke improvement efforts have been fewer with the majority of published results showing substantially less improvement in DTN than single-centre efforts.[9–13] A recent example of a multicentre quality improvement effort which successfully reduced median DTN from 68 to 36 min across 17 hospitals is the Quality Improvement and Clinical Research Programme in Alberta, Canada.[14–16]

Rationale and specific aims

Given the abundance of evidence for faster stroke treatment and the state of substandard performance in Saskatchewan, we set out to improve stroke treatment across the entire province via the Saskatchewan ASP. The ASP set out to improve stroke care, including consistency in care, for all patients with stroke regardless of geographic location. Specifically, the ASP aimed to: (1) increase the proportion of patients with stroke treated with alteplase and/or EVT and (2) provide these treatments to patients faster through decreasing door-to-imaging times, DTN times and door-to-groin puncture times (DTGT). Canadian Stroke Best Practice Recommendations were used as province wide targets: door-to-imaging time of 15 min, DTN times of 30 min (urban centres) and 60 min (rural centres) and DTGT of 60 min.

METHODS

This paper is written according to the SQUIRE V.2.0 guidelines for reporting quality improvement studies.[17]

Context

The province of Saskatchewan, Canada (area: 651 900 km^2; population: 1.2 million) has nine hospitals which treat patients with acute stroke, one of which has offered EVT since 2008. Approximately 2000 Saskatchewan residents per year are hospitalised due to stroke. Prior to this quality improvement initiative, Saskatchewan did not have a strategy to deliver acute stroke care. Care was fragmented, did not follow best practice guidelines and no process measurement was in place.

Interventions

Implementation

Throughout 2014, a multidisciplinary team of experts was assembled to create the Saskatchewan ASP. This team spanned the Ministry of Health, the Saskatchewan Health Quality Council, the individual Saskatchewan Health Regions, EMS, and patient representatives. Over 2 years, the patient and provider processes in treating stroke were process mapped such that key areas of improvement aligned with current Canadian Stroke Best Practice Guidelines. The team identified priorities for system improvement, identified resourcing gaps, supported the implementation of the ASP, monitored progress towards ASP goals and communicated performance metrics with stakeholders. Part of this communication involved travelling to each stroke centre to learn the individual challenges each centre was facing in the treatment of patients with stroke and provide education on the implementation of the ASP protocols.

Stroke centre designation

First, the ASP involved designating hospitals for stroke treatment. Nine hospitals which treat patients with acute stroke were identified. One provides access to EVT at all hours of the day, 365 days a year and was designated as a Comprehensive Stroke Centre (CSC). Eight others provide 24/7 access to advanced neuroimaging and administration of thrombolysis and were designated as Primary Stroke Centres (PSC). The designation followed the recommendations of the Canadian Stroke Best Practice Guidelines. Hospital locations are shown in online supplemental figure I.

Prior state of stroke care

Prior to the ASP, patients with suspected stroke within 3.5 hours from onset were termed a ‘stroke alert’ by EMS. There was no identified plan to bypass stroke alert patients to centres capable of treating patients with stroke.

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This was especially problematic given the significant rural geography of the province. Air support units (at the time only fixed wing air ambulance) were only engaged when patients were being transported from the far northern areas of the province. There was no established referral programme for patients to access neurology services. There was not a plan in place to identify and transfer patients with LVO. Finally, there was significant variation in care with no standardised work, order sets, data collection, bypass protocols and outcome measurements.

Asp implementation

The ASP made changes to (1) EMS bypass and transport protocols, (2) The Stroke Alert Window, (3) ED processes and (4) data collection.

The ASP made several changes to EMS protocols: (1) the Face Arm Speech Time (FAST) stroke screen was adopted provincially for EMS to identifying stroke alerts. This was further expanded to include a field screen for LVO (FAST-Vision, Aphasia Neglect (VAN); (2) the stroke alert window was increased to 12 hours from last seen normal and (3) stroke alerts bypassed preferentially routed to the predefined and designated stroke centres.

Within the ED several best practices for acute stroke treatment were implemented to decrease door-to-imaging and door-to-treatment times. The goal was to meet Canadian Best Practice Guidelines with 90% of tPA eligible patients receiving tPA within 60 min of arrival. These processes closely reflected that of the HASTE programme under taken by the Calgary Stroke Programme.[8] ED protocols were implemented to improve DTN times. This included standard order sets, on-site training, establishing a thrombolysis kit, improved communication with neurology and expedited interpretation and reporting of the CT imaging. The ASP team also worked very closely with radiology departments at stroke centres across the province on reading neurovascular imaging, assessing and reporting LVO in radiology reports, and creating a plan for 24-hour access to CT/CT angiography (CTA) for stroke alerts. A provincial standard of a plain head CT and CTA of the carotid arteries and Circle of Willis was instituted. This also included changes in workflow such that CT and CTA would be performed sequentially without returning to the ED in between scans. Subsequently, multiphase CTA protocols were implemented to allow for identification of collaterals in LVO patients.[18]

For patients with LVO, who may be eligible for EVT, a protocol for communication with the CSC needed to be established. Standard work was implemented through the various transfer centres to allow for improved transport processes. The processes allowed for transport of all patients from the other eight acute stroke centres to the CSC for consideration of EVT for LVO. The selection of these patients followed that of the Endovascular Treatment for Small Core and Anterior Circulation Proximal Occlusion with Emphasis on Minimising CT to Recanalisation Times (ESCAPE) trial.[19] The ESCAPE protocol for handling of LVO patient formed the basis of the protocols implemented at the CSC. Additionally, the ASP aimed for increased telehealth and remote consultation to improve patient care.

ASP implementation pilot phase

Between June 2015 and December 2016, five different centres (the CSC and PSC B–E) trialled the proposed changes through a series of Plan-Do-Study-Act (PDSA) cycles at different times. PDSA cycles were used as many of the centres had limited stroke care expertise. One example of a PDSA cycle is the implementation of emergency room stroke teams. In local and provincial planning sessions the makeup and role of the stroke team was decided on, these teams were then implemented in the pilot centres, and DTN times studied. The results of these PDSA trials were reviewed by the ASP committee and successful interventions were incorporated into the final stroke pathway which was deployed province wide in January 2017 with all sites reporting data metrics by August 2017. The data group reviewed the metrics on a monthly basis. The Chair of the Committee provided immediate feedback to the stroke centres on the individual performance and how they compared with provincial metrics.

Study of the interventions

To measure the impact of the quality improvement initiative process metrics were collected during the stroke pathway's deployment. The process metrics reported were the number of stroke alerts (FAST + presenting within 12 hours of last seen well), door-to-imaging time, DTN time and the number of stroke alerts who received alteplase. At the CSC DTGT and the number of stroke alerts who received EVT were also collected. A provincial data sharing agreement allowed the data to be collected monthly in aggregate by the Saskatchewan Health Quality Council.

Measures and analyses

All nine centres were engaged in the provincial pathway and reporting data for 2 years from August 2017 to July 2019. Where available, pilot data (June 2015–December 2016) and the beginning of the provincial launch (January 2017–July 2017) are also reported. Data were visualised on a monthly aggregate level for each hospital. Province-wide average treatment times were calculated weighted by the number of monthly stroke alerts reported at each hospital. Data were visualised using both run charts and control charts which are commonly used graphics in quality improvement initiatives which allow one to discern if a process change has resulted in sustained improvement.[20]

Patient involvement

A data sharing agreement was created between each health region and the Saskatchewan Health Quality Council for the reporting of de-identified data for this project. Patient partners were consulted in the creation of

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the ASP and were also given the opportunity to critically review this manuscript.

RESULTS

Data collection

Data collection procedures changed midway through the study in two of the stroke centres (H & I). As such patients with acute stroke who would not be classified as 'stroke alerts' per this study's definition were included in the quality improvement data collection. Since the change the centres are working towards improving their data capture. For this reason, results from these two centres have not been included in this manuscript.

Stroke alerts and treatment rates

Province wide the number of stroke alerts per month varied between 79 and 148 across the study period. A run chart displaying the month over month variation in number of stroke alerts is presented in online supplemental figure II. No clear shifts (defined as six consecutive points above or below the median) in the number of stroke alerts occurred during the study period. While the number of alerts begins to increase near the end of the study no clear upward trends (five or more consecutive data points all moving in the same direction) are seen. The majority of stroke alerts presented to the CSC. Consistent with the province wide data there was no clear shift in the number of stroke alerts presenting to the CSC over the study period however a trend of increasing number of stroke alerts emerged between February 2019 and June 2019 (online supplemental figure III). Run charts for the number of stroke alerts per month for the eight PSC are also given in online supplemental figures III–IV. PSC D saw a sustained shift above the initial median of 6 stroke alerts per month to a new median of 14 stroke alerts per month after March 2018. PSC G experienced a downward trend in the number of stroke alerts per month from April to September 2018. The other PSC exhibited no clear trends or shifts in the number of stroke alerts per month.

Across the 2-year period, 9.01% of stroke alerts were treated with alteplase. This fluctuated over the study period between 2.04% and 13.74% of stroke alerts treated with alteplase each month. However, there were no sustained trends or shifts in the number of patients treated with alteplase (online supplemental figure V). As many of the stroke centres experienced low stroke alert volume on a monthly basis results were not stratified by stroke centre.

Across the 2-year period 4.78% of stroke alerts received EVT. This fluctuated over the study period between 1.79% and 10.71% of stroke alerts receiving EVT each month. This translates to a median of 6 stroke alerts receiving EVT per month. There were no clear shifts or trends in the number of stroke alerts receiving EVT per month over the study period (online supplemental figure V).

Treatment time metrics

During the pilot phase, the weighted average door-to-imaging time was 21 min (mean of monthly averages weighted based on number of stroke alerts/month/centre). Over the course of the ASP, the weighted average time dropped to 15 min with very little variability month over month. Figure 1 displays a control chart with the weighted average door-to-imaging time across the ASP. As displayed, during the pilot phase wide variability in door-to-imaging time was seen; however, after the launch of the ASP door-to-imaging time quickly stabilised. All sites experienced an improvement in door-to-imaging time over the course of the study (online supplemental figures VI, VII).

During the pilot phase, the weighted average DTN time was 62 min (mean of monthly averages weighted based on number of stroke alerts receiving alteplase/month/centre). After the launch of the ASP the weighted average DTN time across the province decreased to 47 min and a reduction in variability was observed (figure 2). This decrease was partially driven by marked improvement at the CSC which experienced a reduction in DTN time from 48 to 32 min (online supplemental figure VIII).

The performance of the PSC was variable. Three of the PSC (centres B, C and E) saw improvements in DTN time over the course of the study (online supplemental figures VIII–IX). The largest improvement was seen at PSC C, which saw its average DTN time reduced by 31 min. One PSC (centre D), saw an increase in DTN time from 66 to 78 min (online supplemental figure VIII) and two PSC (centres F and G) saw no change in their average DTN time over the course of the study (online supplemental figures IX).

At the launch of the ASP the average DTGT for patients receiving EVT was 83 min (mean of monthly averages). Over time, this average dropped to 70 min (figure 3). The month over month variability in DTGT was high throughout the study period; however, some improvement in variability was seen.

DISCUSSION

We report the results of a province wide stroke system improvement initiative. Over the course of the study we observed an increase in the number of acute stroke alerts, especially in the final 6 months. We also have reported a very high rate of thrombolysis use among stroke alerts compared with other Canadian studies.[21 22] The rate of thrombolysis use province wide across the study period was 9.01% (with month over month fluctuation to as high as 13.74%) which is comparable to recent work in the Netherlands.[23 24] Although it should be noted that the populations among these studies differ, here the denominator used is stroke alerts (determined in the field) whereas other study rates came from chart review of diagnosed ischaemic strokes.

A priori a target of 15 min province wide was set for average door-to-imaging time. After the implementation

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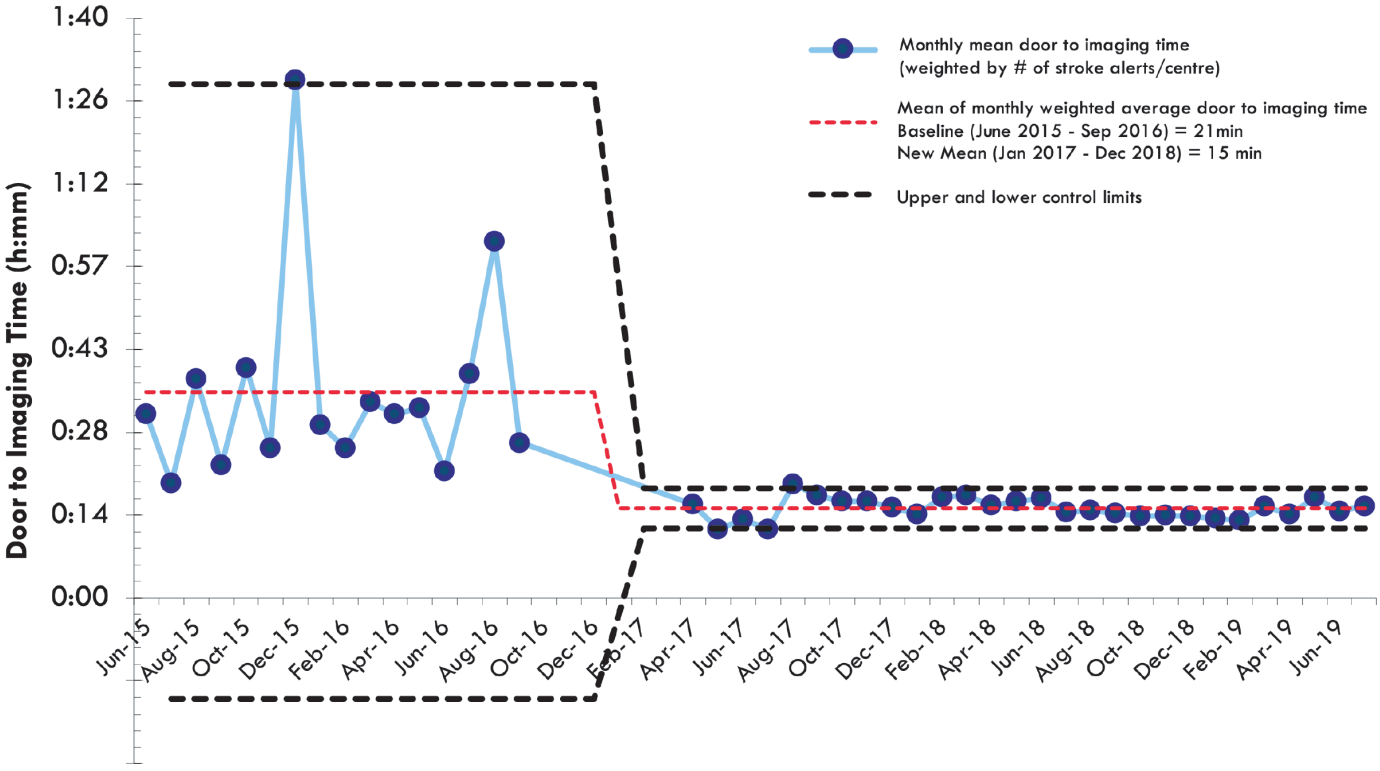

Figure 1 Individuals control chart displaying door-to-imaging time for all centres in Saskatchewan. The monthly average door-to-imaging time (weighted by number of stroke alerts/month/centre) is displayed using the blue dots. The mean of monthly weighted averages is displayed using the red dashed line. The upper and lower control limits are displayed using the black dashed lines. The baseline mean was 21 min, the new mean was 15 min province wide. Provincially, during the pilot period, the system experienced instability with wide control limits. After the Launch, the system gradually became stable with narrow control limits.

of the ASP this target was met. Overall, the province reached an average DTN time of 47 min a reduction of 15 min from baseline. While outcomes data was not collected in this study, prior work has shown that a province wide reduction in DTN time of 31 min (median) lead to an increased percentage of patients discharged home from acute care, a reduction in in-hospital mortality, and a 10-day increase in 90-day hometime (the number of days a patient spends at home in the first 90 after stroke).[25]

Individual DTN targets were different for rural and urban centres. The target for urban centres was 30 min based on the target median from the Canadian Best Practice Guidelines and the target for rural centres was 60 min (based on the 90th percentile target from the Canadian Best Practice Guidelines).[2] The CSC and PSC E are both located in urban areas; the CSC came close to the 30 min target having an average DTN time of 32 min. While PSC E exhibited a 15 min reduction in average DTN time it did not meet the 30 min target. Among the rural centres, PSC F met the 60 min target, although this centre had an average DTN time of 59 min at the start of the study and experienced no change during the study. PSC C nearly met this target ending the study with an average DTN time of 61 min, a 31 min reduction from study start. Although PSC B did not meet the 60 min target it did see an improvement in DTN time of >30 min. Centre D saw an increase in DTN time over the course of the study and centres F and G had no change in DTN time. It was identified that low case volumes and staff familiarity with stroke protocols likely contributed to the lack of improvement seen at these centres.

Although a 13 min improvement in DTGT was seen over the course of the study, there is still work to be done to achieve the goal of 60 min. There was much variability in DTGT month over month with some months achieving an average of 44 min so with continued quality improvement efforts this goal is within reach. A continuous feedback cycle is required to ensure continued centre compliance and engagement with the protocols over the longer term. There was determined to be significant variation between endovascular operators. Additional work was undertaken to reduce this variation and included additional training and implementing fellowship training requirements for performing endovascular stroke therapy

Successes

The Saskatchewan ASP represents a province wide systematic improvement to hyperacute stroke care. The key success in the process has been engagement of stroke caregivers at multiple sites and the establishment of stroke champions. Facility-based stroke leadership teams played a key role in knowledge translation, local education of EMS partners and implementation of new protocols, engagement of local medical and health system

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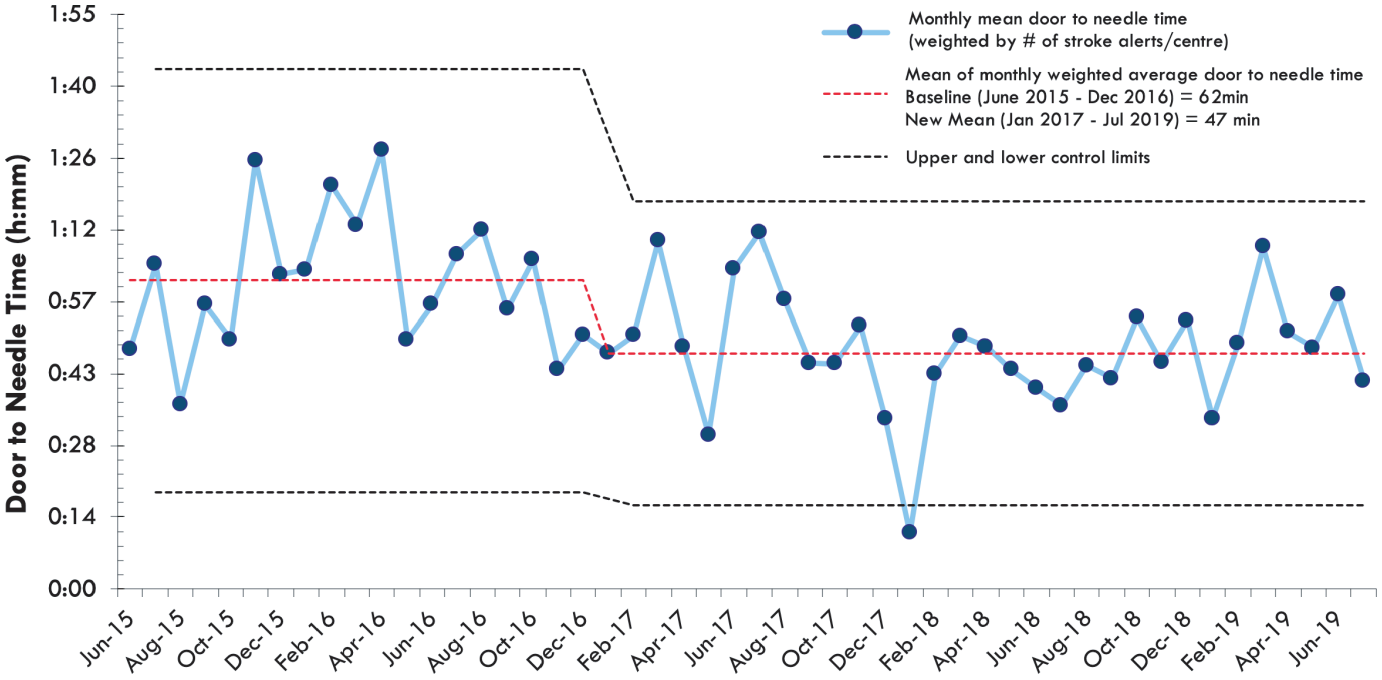

Figure 2 Individuals control chart displaying door-to-needle time for all centres in Saskatchewan. The monthly average door-to-needle time (weighted by number of stroke alerts/month/centre) is displayed using the blue dots. The mean of monthly weighted averages is displayed using the red dashed line. The upper and lower control limits are displayed using the black dashed lines. The baseline mean was 62 min, the new mean was 47 min. Provincially, during the pilot period, the system experienced instability with wide control limits. After the Launch, the system gradually became stable with narrow control limits.

leadership, development of local data collection processes and continuous improvement in all of the above. The provincial ASP committee provided not only medical leadership but practical support and feedback to facility-based stroke teams that helped maintain their commitment to change. Another success was the collaborative nature of the programme. Process improvements were discussed regularly with multidisciplinary teams across several centres allowing the centres to learn from one another. This was key to the success of the programme. In public healthcare systems, there represents competing interests for both funding and time. We have found that engagement by passionate champions of stroke care is the key success.

The use of process mapping represented a significant step to define the entire hyperacute stroke process. The continued studying and refinement of the acute stroke process has led to a culture of continuous improvement in Saskatchewan. The process improvement followed the stroke patient journey in the hyperacute setting. This included improvements with EMS notification and protocols, transport destination improvements and ER and imaging protocols. Centres were very receptive to the majority of the proposed improvement changes because of a perception of inferior stroke care being offered in their community and the province as a whole.

The data collection strategy that was developed allowed for very timely feedback as to centre performance and benchmarking to provincial and national standards. The ASP implementation team provided multiple onsite visits to all of the stroke centres. This was a fundamental component to the success of the implementation and maintenance of the pathway.

Challenges

System wide change management is not without challenges. Physician engagement was likely the most significant barrier that had to be overcome. This was addressed by involving physician experts across the province to lead the work. This included neurology and neurosurgery but also emergency medicine and family practice. Significant variation in performance metrics was seen between the centres. Factors likely affecting this was overall centre engagement and interest, case volumes and experience and regular participation in monthly performance review meetings. Unfortunately, the likely top reason for variation was degree of interest in improving stroke care at the individual centres. Centres with better teamwork between nursing and physician leaders and staff seemed to anecdotally correlate with better performance metrics. The ASP implementation team travelled to the PSCs to provide education sessions; this allowed the team to better understand the barriers and issue at the local level and address them with both local and provincial health leaders.

There was a significant shortage of stroke experts particularly in the field of neurology. This resulted in a state of overwork for the existing call physicians. This was mitigated by using internal medicine and emergency medicine physicians as stroke experts and eventual hiring of dedicated stroke neurologists to support the team. The funding issues and need for additional resources to improve provincial stroke care occurred because the

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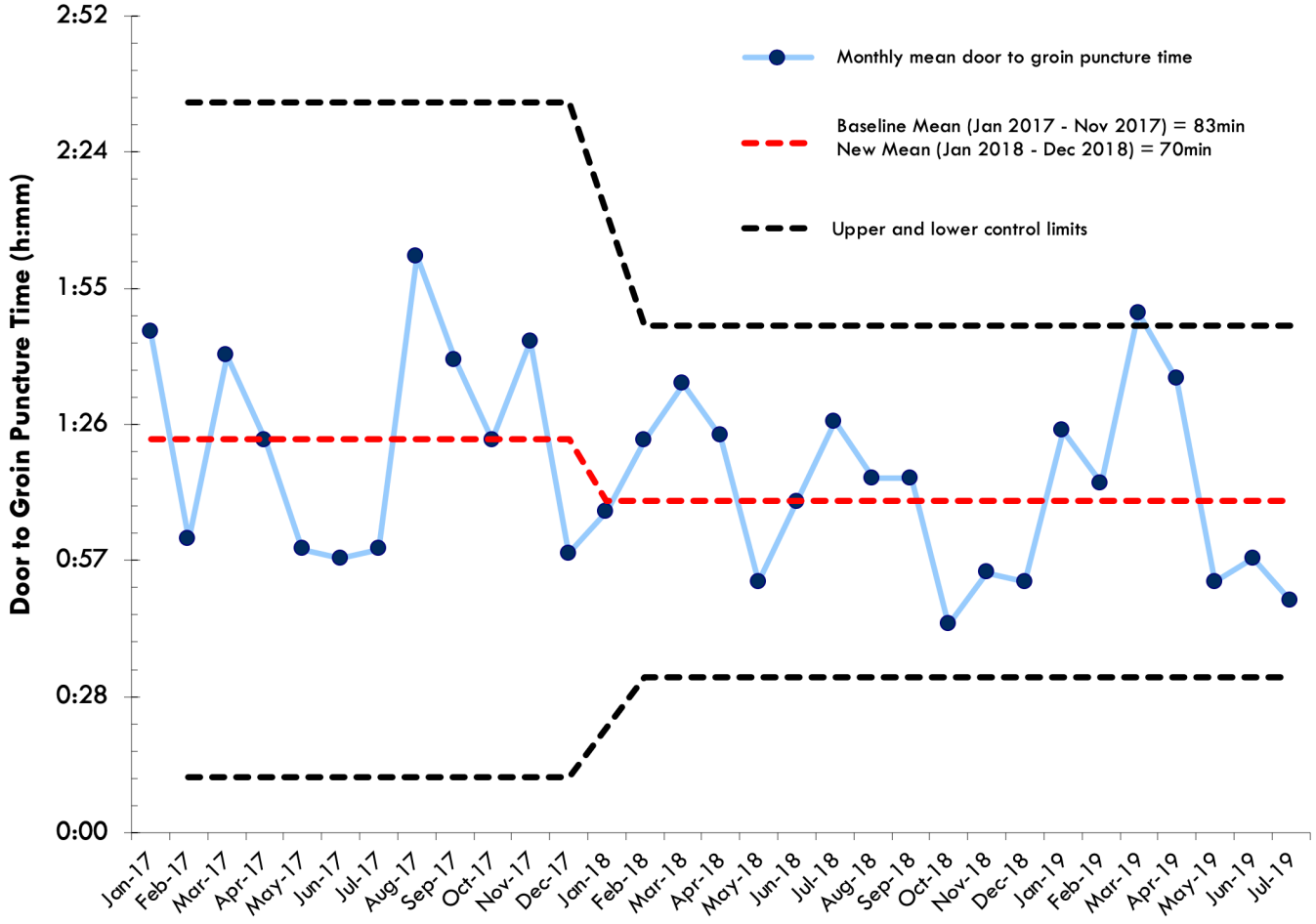

Figure 3 Individuals control chart displaying the monthly average door-to-groin puncture time at the comprehensive stroke centre. The monthly average door-to-groin puncture time is displayed using the blue dots. The mean of monthly averages is displayed using the red dashed line. The upper and lower control limits are displayed using the black dashed lines. The baseline mean was 83 min which was reduced to 70 min after the launch of the acute stroke pathway. At the start of the programme high variability and wide control limits were seen; however, over the course of the study variability decreased.

work followed Canadian Best Practice Guidelines and were data driven. Policy and decision-makers were able to prioritise the work because of the evidence supporting its overall benefit on a provincial scale.

Data collection and analysis represented a significant and ongoing challenge. The data is collected by the local stroke champions and due to the nature of the data sharing agreements are sent in aggregate to the Saskatchewan Health Quality Council. The availability of data in aggregate only has limited the analyses which could be performed in this study and future work with more granular data may provide better insight into the patient level nuances of system change. The local collection generally occurs 'off the side of one's desk' and dedicated data collection personnel have not been provided or funded.

Limitations

This work represents an initial effort to improve hyperacute stroke care in an entire province. It did not directly address stroke prevention, haemorrhagic stroke, in-patient acute care or rehabilitation services. It only represents improvements in a small component of the spectrum of stroke care.

As the data sharing agreement in place prohibited the reporting of individual patient data the data reporting for this study did not occur on the individual patient level. Province wide average treatment times needed to be weighted by number of stroke alerts/month at each centre. As such this is not the most accurate representation of treatment times across the province and any comparisons with national benchmarks difficult as they typically (1) medians or other percentiles and (2) meant for implementation and interpretation using individual patient data.

The rates of thrombolysis and EVT utilisation were calculated from the total number of stroke alerts. A more accurate representation of these utilisation rates would require the number of confirmed patients with stroke as the denominator (as in the Canadian Best Practice measurement guideline).[2] This requires confirmation by a stroke expert and a more sophisticated data collection

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strategy. The initial data metrics elected to not include transfer times from PSC to CSC. This information would have been useful as later case reviews identified door-in-door-out and transfer times to be issues in multiple centres. Significant data collection issues were also noted within centres H and I which require ongoing work to resolve and precluded the data from these centres being included in this analysis. However, these centres did participate in the ASP and are likely to have seen some benefit from it.

Future work

Subsequent to this, we have been developing a centralised dashboard for stroke treatment data across the province. This would allow stroke teams to assess their performance in real time and allow for more granular data collection. The province of Saskatchewan and the Saskatchewan Health Authority have embarked on a comprehensive stroke strategy. This will include all aspects of stroke care including prevention, haemorrhagic stroke pathway, acute care, rehabilitation, community care and palliative care. This comprehensive strategy has also involved the recruitment of additional stroke neurologists assigned to centres which struggled to improve during this time frame. Future work will also include the collection of patient outcomes such that future progress can also be evaluated from this lens. This will hopefully lead to improvements in the other equally important components of stroke care.

Conclusions

We present the planning and implementation of a province wide ASP. The work has led to improvement in stroke care on a provincial basis and most importantly has allowed all patients access to stroke mitigating therapies regardless of where they live in the province.

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Contributors JKH wrote the manuscript. VNO analysed all data and produced figures. VNO, GH, BRG, JH, LS, LL, LP and MK were involved in study design and data collection. MK oversaw the study. All authors provided critical review of the manuscript.

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Competing interests None declared.

Patient consent for publication Not required.

Ethics approval As this was a quality improvement initiative, ethical approval was waived by the University of Saskatchewan Research Ethics Board.

Provenance and peer review Not commissioned; externally peer reviewed.

All data relevant to the study are included in the article.

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Supplemental Materials: The Implementation of a Provincial Acute Stroke Pathway and Its impact on Access to Advanced Stroke Care in Saskatchewan

Jessalyn K. Holodinsky PhD, Vivian N. Onaemo MBBS MPH PhD, Ruth Whelan RN MN, Gary Hunter, MD, Brett R. Graham, MD, Jessica Hamilton MSc, Laura Schwartz MSc, Lori Latta, BA, Lissa Peeling, MD, Michael E. Kelly MD PhD

Table of Contents

Supplemental Figures

Figure I. Map of Saskatchewan displaying the location of all stroke centres.
Figure II. Run chart displaying the number of stroke alerts province wide.
Figure III. Run chart displaying the number of stroke alerts presenting to the Comprehensive Stroke Centre and Primary Stroke Centres B – D across the study period
Figure IV. Run chart displaying the number of stroke alerts presenting to the Primary Stroke Centres E – G across the study period
Figure V. Run chart displaying the number and percent of stroke alerts receiving alteplase (top) and endovascular therapy (bottom) per month in Saskatchewan.
Figure VI. Individuals control chart displaying the mean door to imaging time at the Comprehensive Stroke Centre and Primary Stroke Centres B – D across the study period
Figure VII. Individuals control chart displaying the mean door to imaging time at the Primary Stroke Centres E – G across the study period
Figure VIII. Individuals control chart displaying the mean door to needle time at the Comprehensive Stroke Centre and Primary Stroke Centres B – D across the study period
Figure IX. Individuals control chart displaying the mean door to needle time at the Primary Stroke Centres E – G across the study period

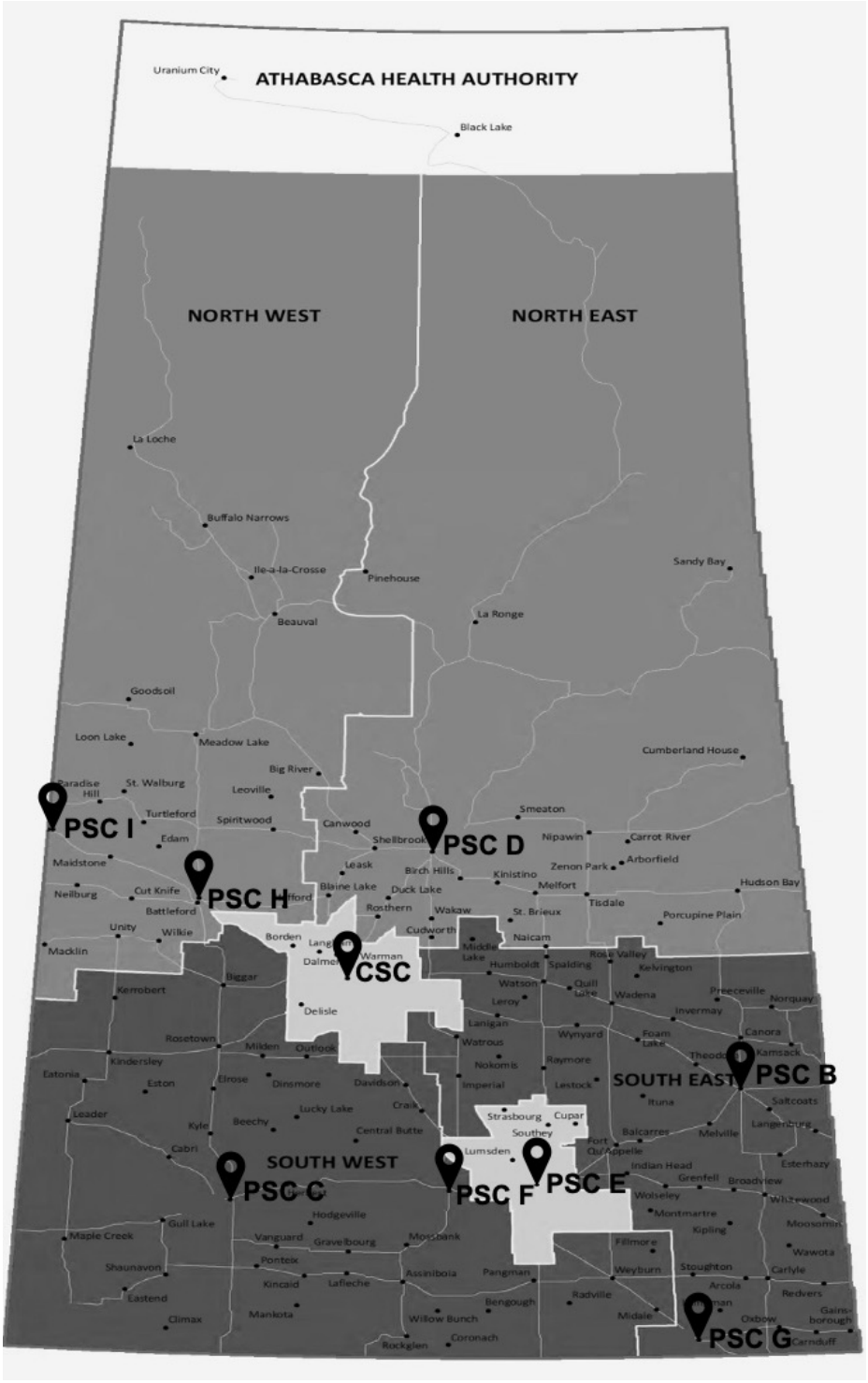

Figure I. Map of Saskatchewan displaying the location of all stroke centres.

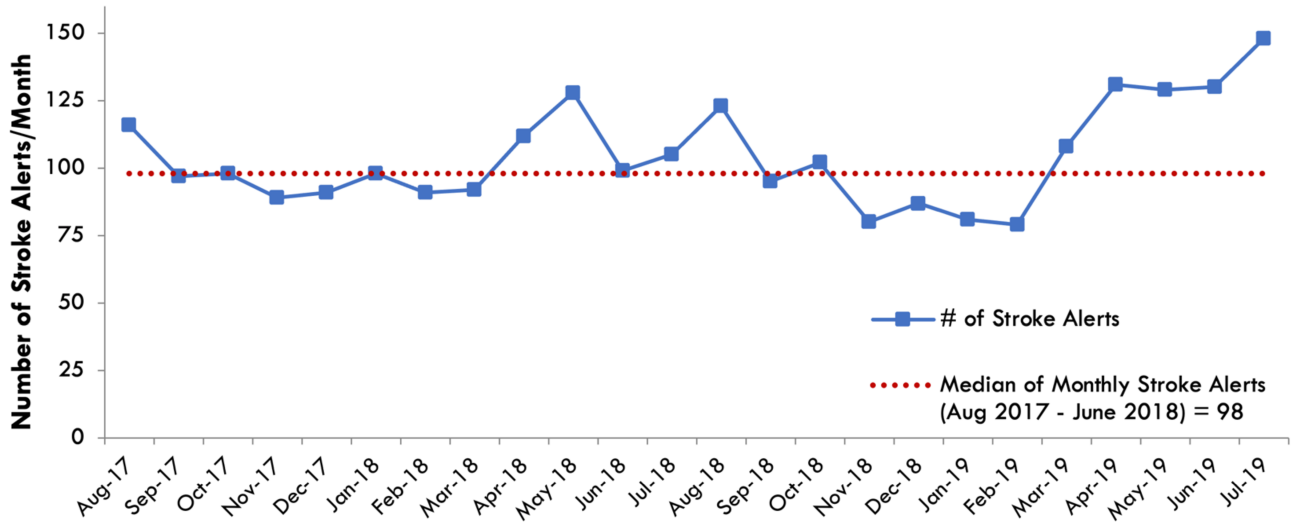

Figure II. Run chart displaying the number of stroke alerts per month in Saskatchewan between August 2017 and July 2019. The red line on the graph indicates the median number of stroke alerts per month in the first year of the initiative (August 2017 to June 2018) which was 98. While the number of alerts begins to increase near the end of the study no clear upward trends (5 or more consecutive data points all moving in the same direction) are seen

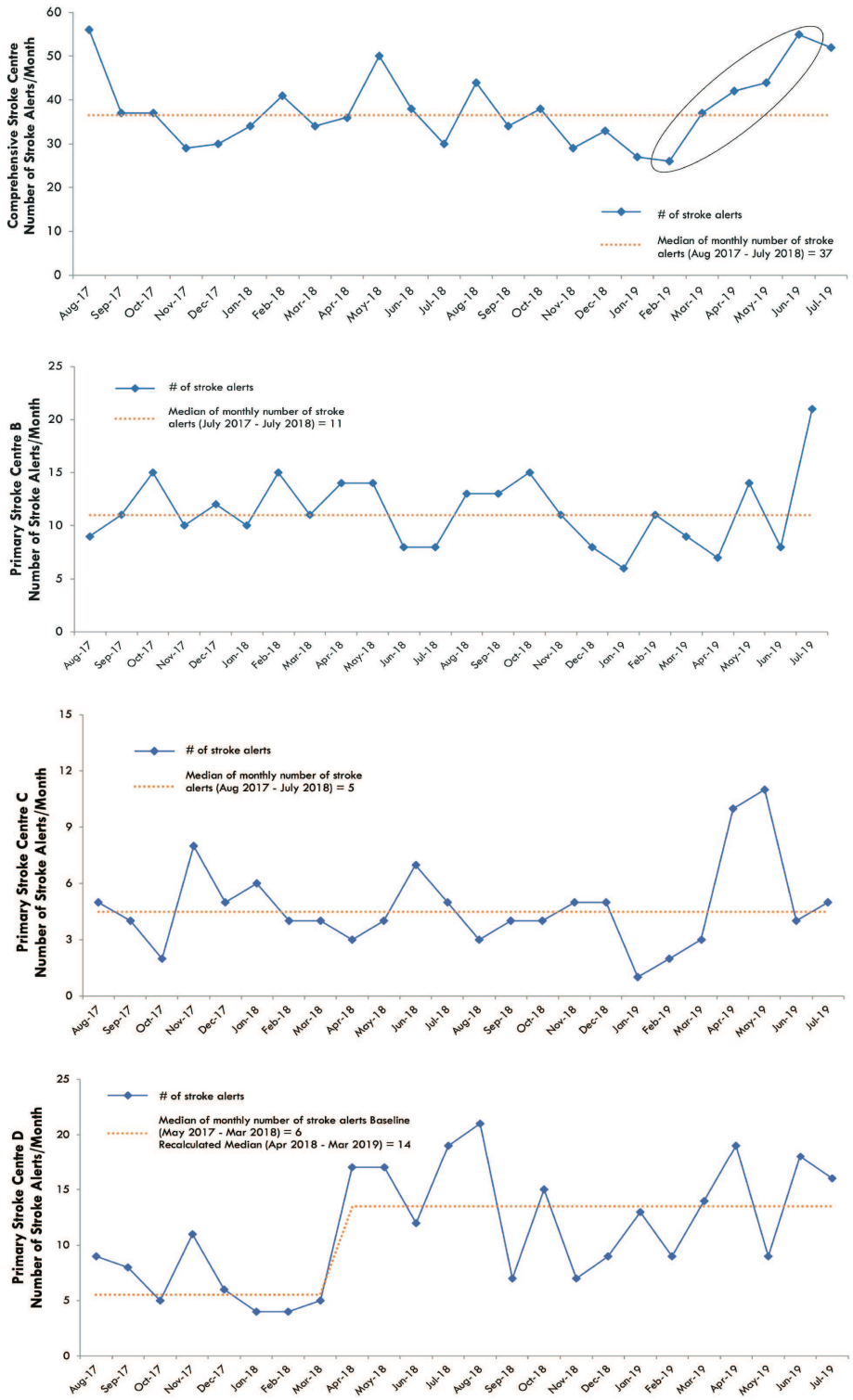

Figure III. Run charts displaying the number of stroke alerts presenting to the Comprehensive Stroke Centre and Primary Stroke Centres B – D between August 2017 and July 2019. The blue markers indicate the number of stroke alerts presenting to each centre per month. The red line on the graph indicates the median number of stroke alerts per month at each centre calculated during the first year of the study. A clear trend is seen at the Comprehensive Stroke Centre between February 2019 and June 2019 (circled). A trend is defined as 5 or more consecutive data points all moving in the same direction. No clear trends or shifts are seen at Primary Stroke Centres B or C. After a sustained shift above the median the median for Primary Stroke Centre D was recalculated.

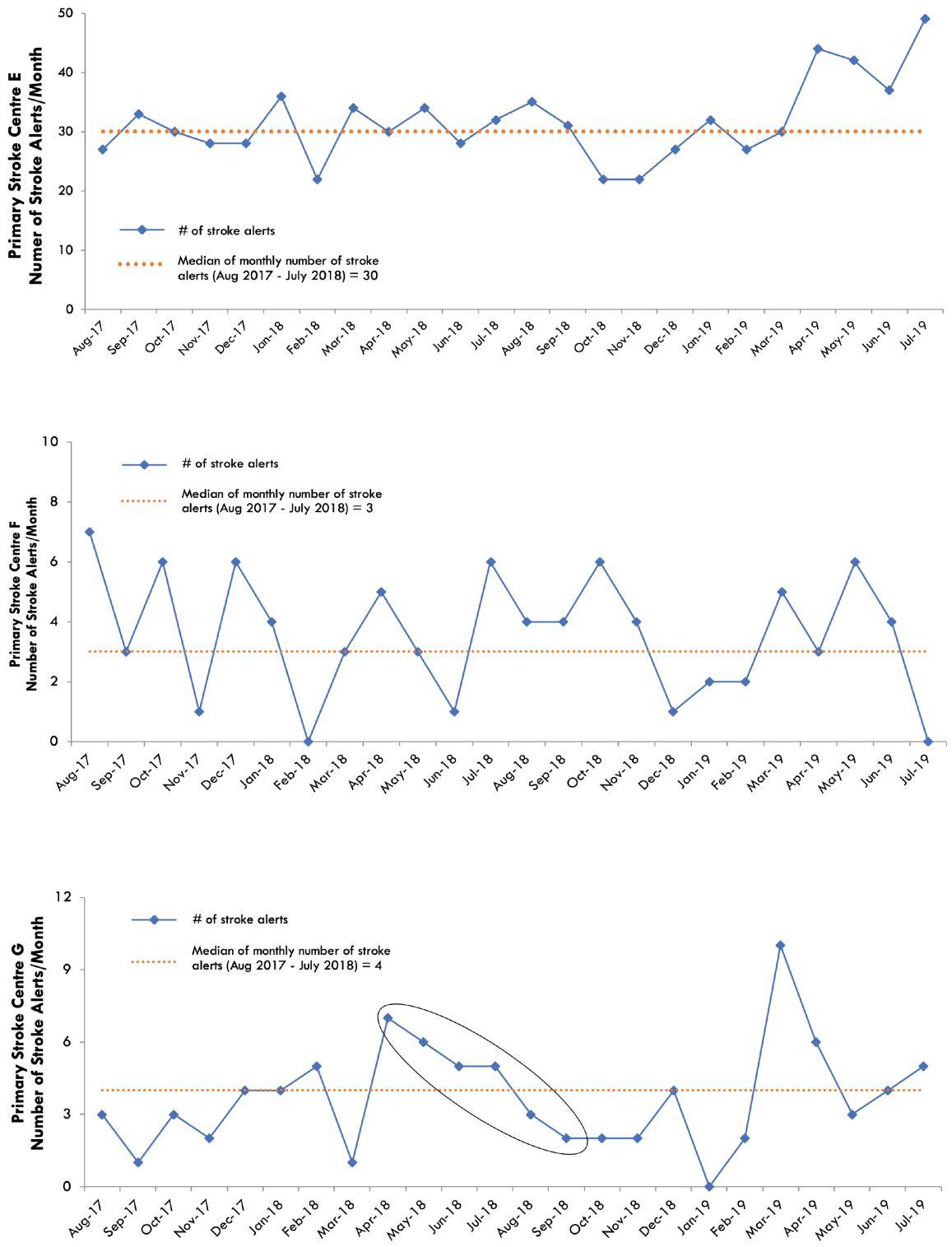

Figure IV. Run charts displaying the number of stroke alerts presenting to Primary Stroke Centres E – G between August 2017 and July 2019. The blue markers indicate the number of stroke alerts presenting to each centre per month. The red line on the graph indicates the median number of stroke alerts per month at each centre calculated during the first year of the study. A downward trend is seen between April 2018 and September 2018 at Centre G (circled), no other trends or shifts are seen at these centres.

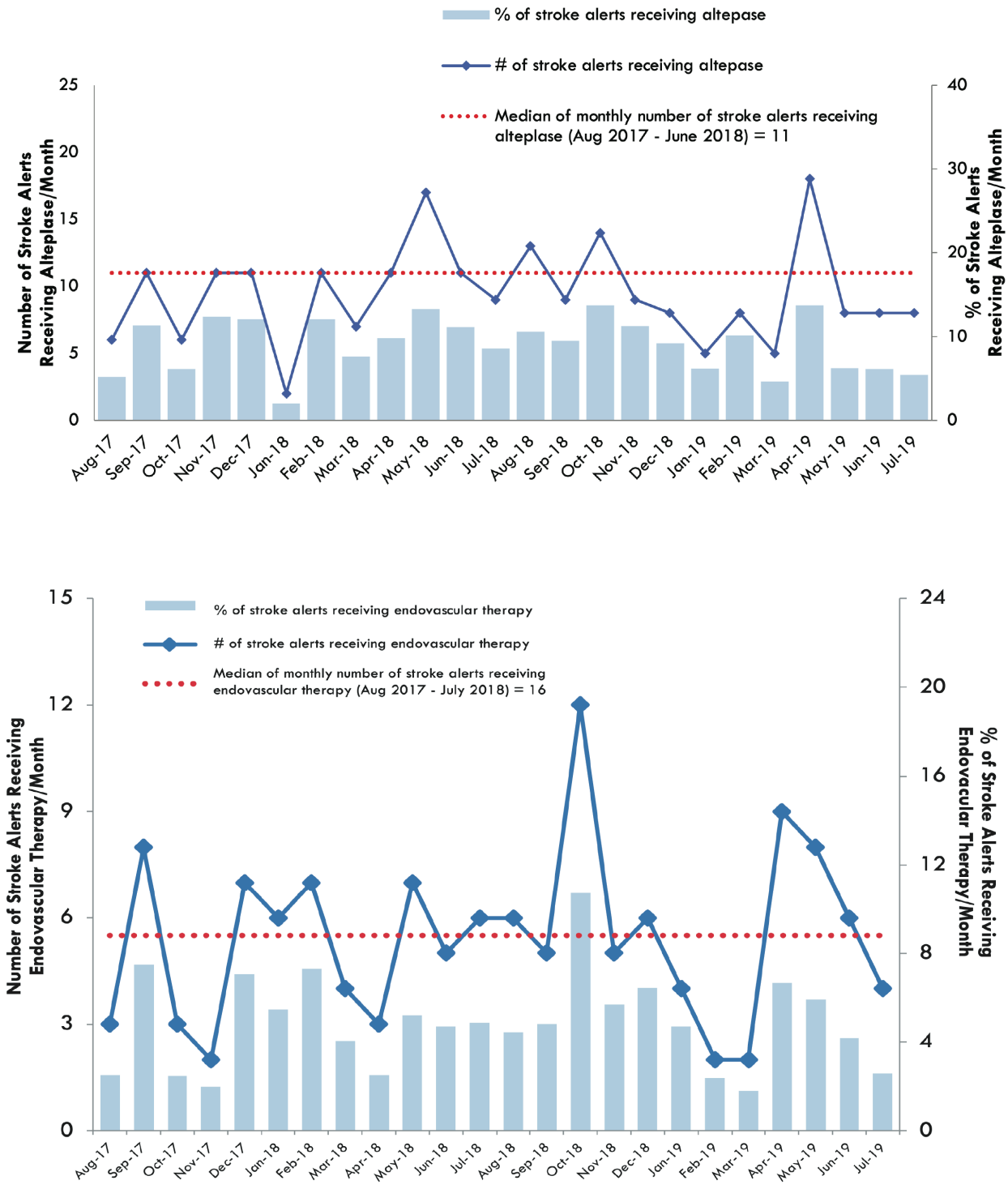

Figure V. Run chart displaying the number and percent of stroke alerts receiving alteplase (top) and endovascular therapy (bottom) per month in Saskatchewan. The number of stroke alerts treated is displayed using the dark blue line and the percentage of total stroke alerts treated is displayed using the light blue bars. The red line indicates the median of the monthly number of treated patients in the first year of the initiative.

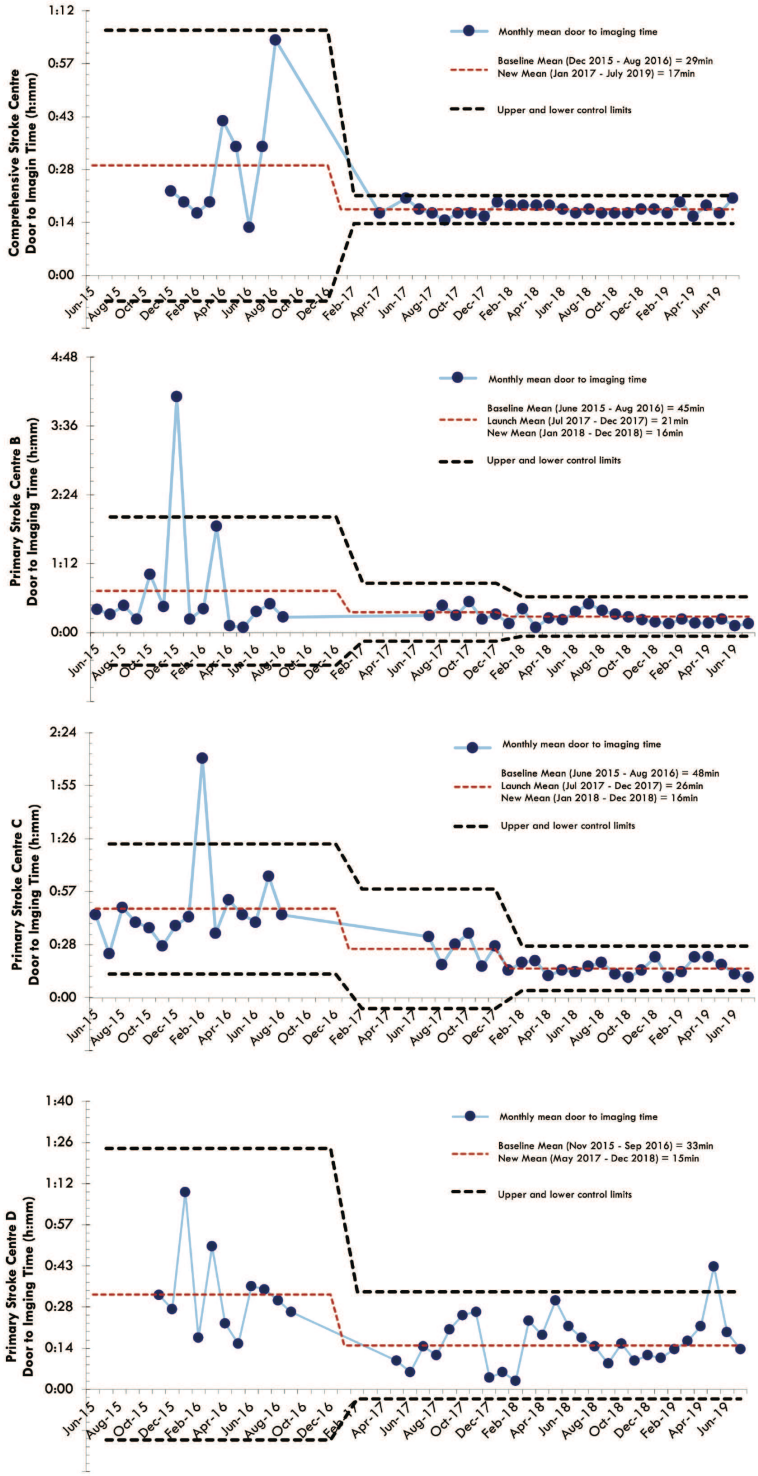

Figure VI. Individuals control chart displaying the monthly mean door to imaging time at the Comprehensive Stroke Centre and Primary Stroke Centres B – D. The monthly mean door to imaging time is displayed using the blue dots. The longer-term mean at baseline, launch, and after launch is displayed using the red dashed line. The upper and lower control limits are displayed using the black dashed lines. All four centres displayed wide control limits at the start of the acute stroke pathway and experienced a decrease in door to imaging time and narrower controls limits over the course of the study.

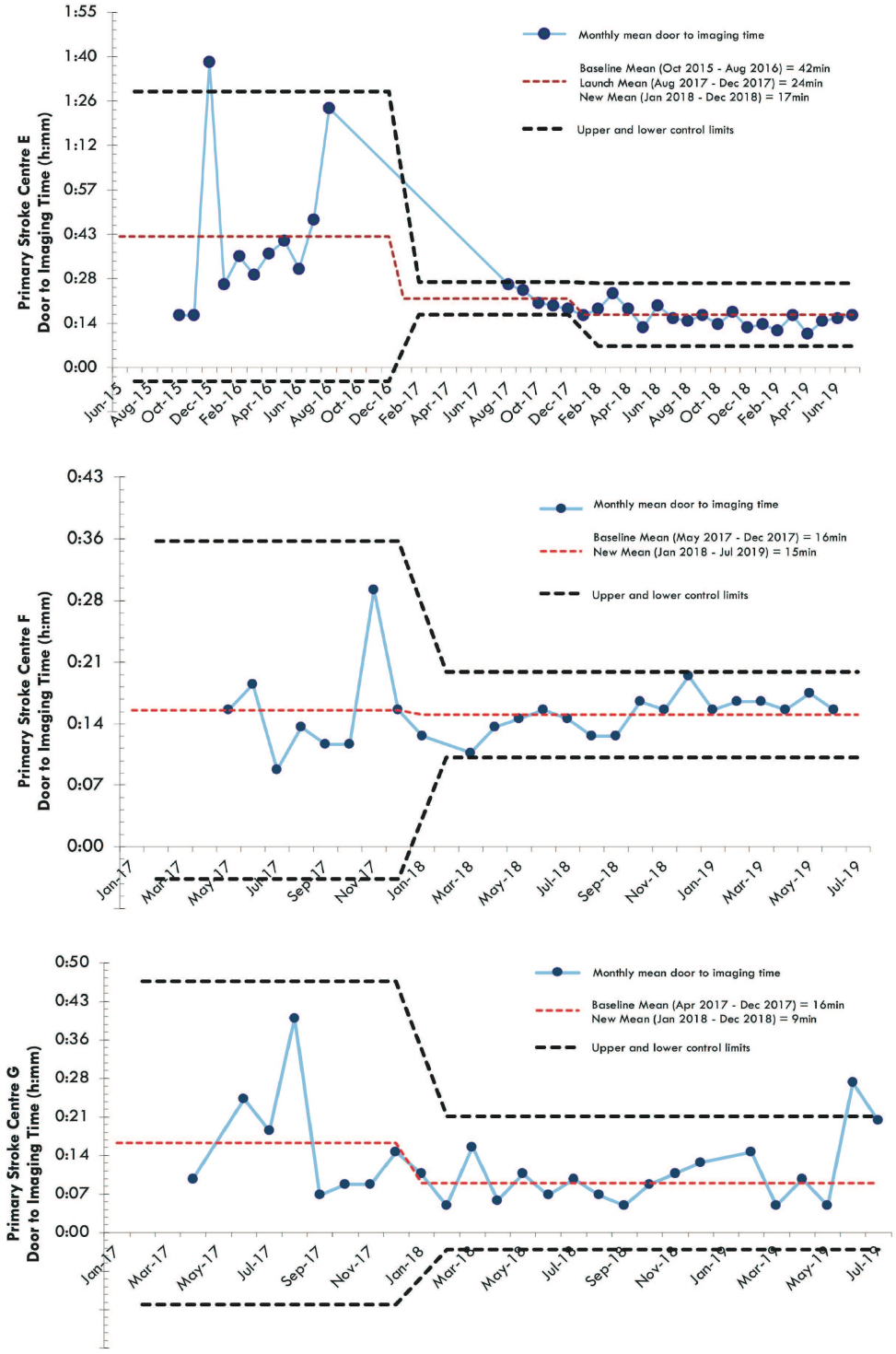

Figure VII. Individuals control chart displaying the monthly mean door to imaging time at Primary Stroke Centres E – G. The monthly mean door to imaging time is displayed using the blue dots. The longer-term mean at baseline, launch, and after launch is displayed using the red dashed line. The upper and lower control limits are displayed using the black dashed lines. Centre E and G displayed wide control limits at the start of the acute stroke pathway and experienced a decrease in door to imaging time and narrower controls limits over the course of the study. Centre F only experienced a 1-minute improvement in door to imaging time but did see more stability in door to imaging time and a decrease in control limits over the course of the study.

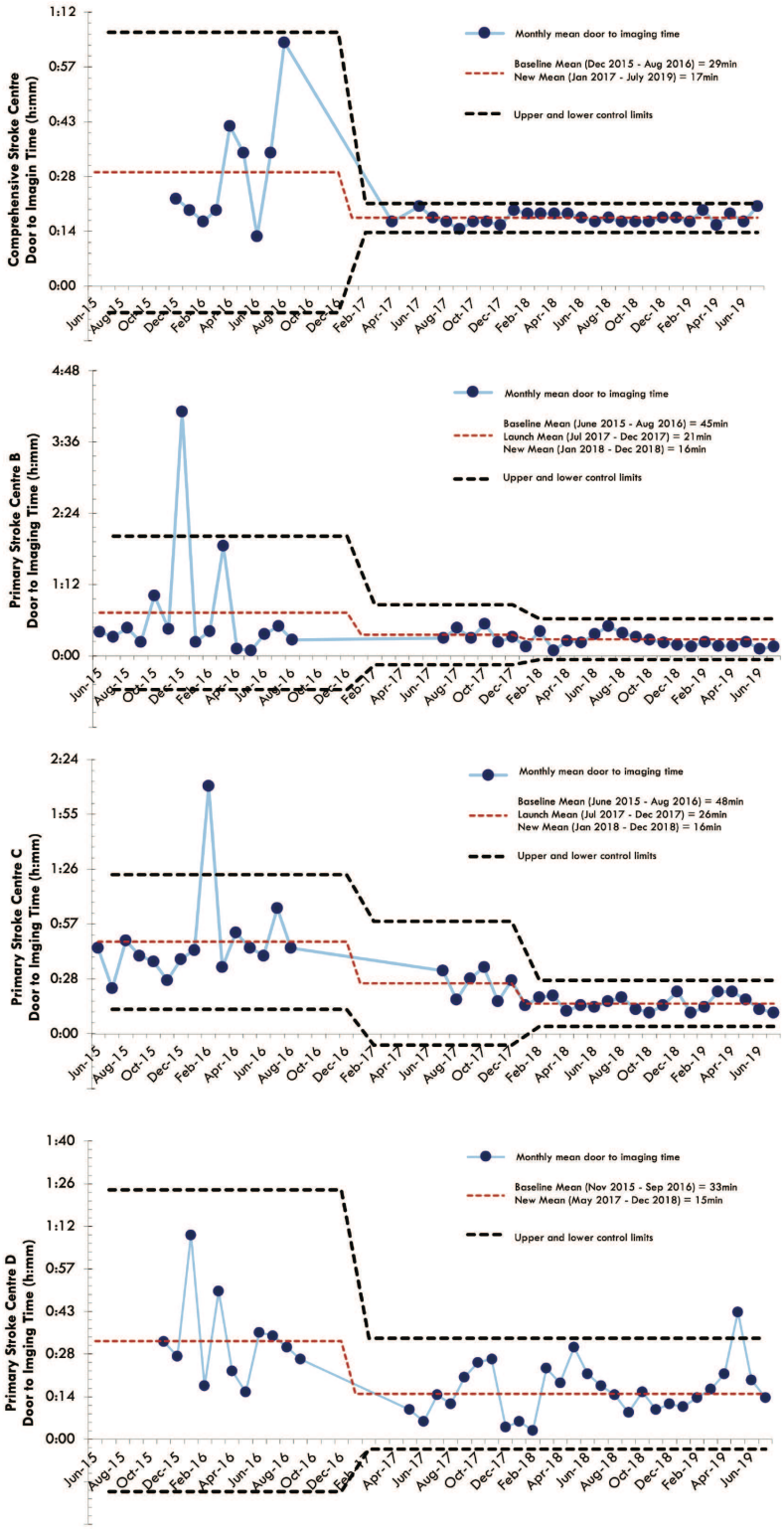

Figure VIII. Individuals control chart displaying the monthly mean door to needle time at the Comprehensive Stroke Centre and Primary Stroke Centres B – D. The monthly mean door to needle time is displayed using the blue dots. The longer-term mean at baseline, launch, and after launch is displayed using the red dashed line. The upper and lower control limits are displayed using the black dashed lines. Three of the centres displayed wide control limits at the start of the acute stroke pathway and experienced a decrease in door to needle time and narrower controls limits over the course of the study. While Centre D saw an increase in door to needle time.

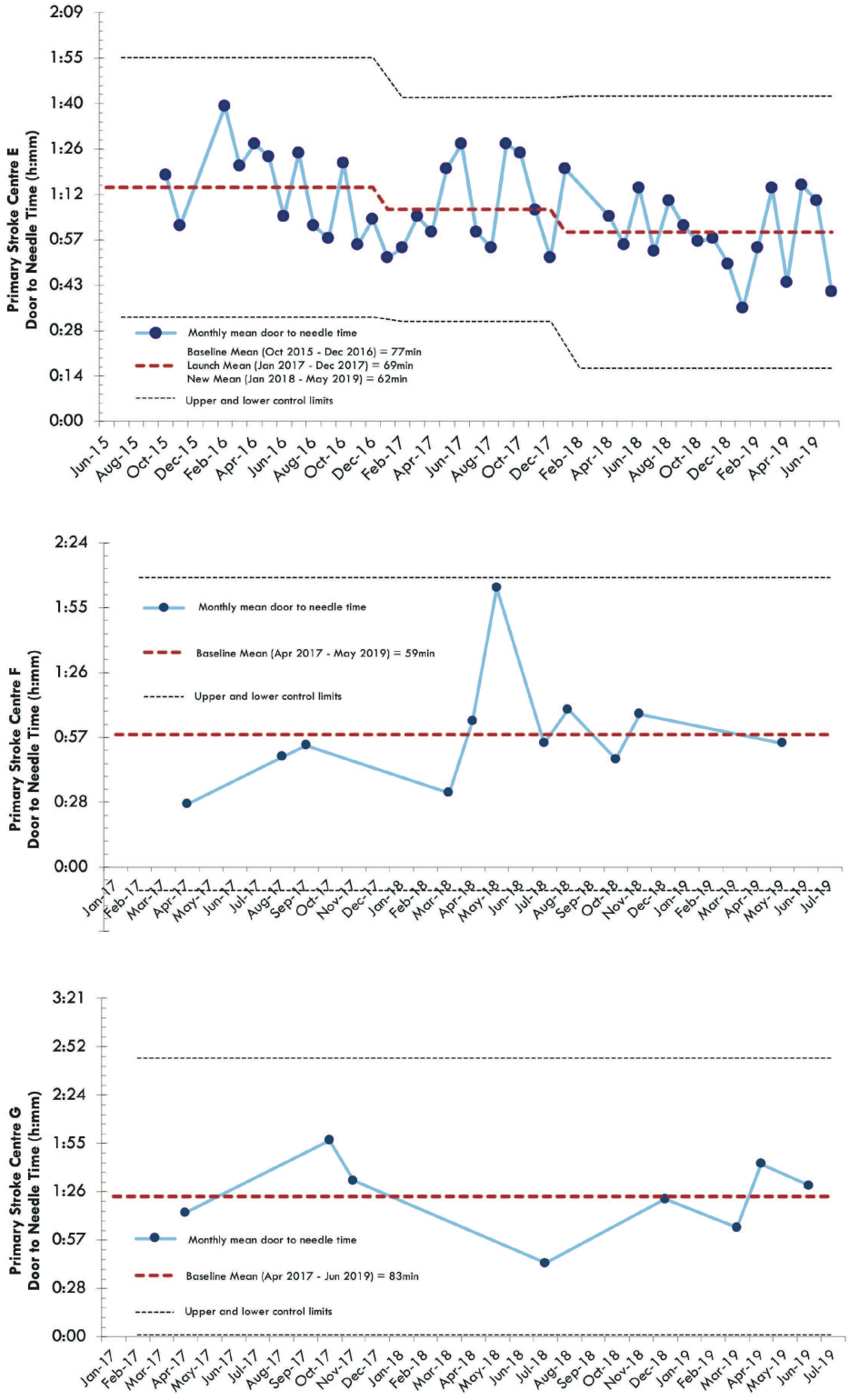

Figure IX. Individuals control chart displaying the monthly mean door to needle time at Primary Stroke Centres E – G. The monthly mean door to needle time is displayed using the blue dots. The longer-term mean at baseline, launch, and after launch is displayed using the red dashed line. The upper and lower control limits are displayed using the black dashed lines. While Centre E experienced improvement over the course of the study Centres F and G saw no improvement.