Initiative to Improve Door to Needle Times in Acute Ischemic Stroke Treatment

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Abstract

Acute ischemic stroke affects 696,000 people annually and is a leading cause of disability in the United States (Benjamin et al., 2017; CDC, 2012). Tissue plasminogen activator (tPA) is the mainstay of treatment with earlier administration associated with improved benefits (Hacke et al., 2004; Lees et al., 2010). Despite this, less than one third of patients in the United States are treated with tPA in less than 60 minutes from presentation (Fonarow et al., 2011). With significant improvements in multiple stroke outcomes appreciated with each 15-minute improvement in door to needle (DTN) time, reduction of DTN is essential to improve outcomes and reduce disability (Saver et al., 2013). Stroke related disability imposes a significant economic burden, further supporting the need to decrease treatment times and improve stroke outcomes (Sreedharan et al., 2013). Telestroke technology was placed within the Computed Tomography (CT) imaging suites at two institutions to improve DTN times when a stroke neurologist is not on-site. A retrospective review of the Providence Stroke Registry was conducted to determine median DTN time for patients treated with tPA in the emergency department. The intention to treat analysis showed there was no difference in the median DTN time prior to CT telestroke installation (44.0 minutes) and after CT telestroke installation (44.0 minutes, p=0.909). In the post-intervention period, CT telestroke was utilized in 38.8% of patients, traditional telestroke in 44.8%, and the remaining 16.4% were evaluated at bedside. Within the post-intervention period, the median DTN time was shown to significantly improve by 9.5 minutes when using CT telestroke as compared to using traditional telestroke (38.5 minutes versus 48.0 minutes, p=0.011). The use of CT telestroke in the treatment of acute ischemic stroke patients decreased DTN time when the stroke neurologist is not on-site.

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Introduction

Acute stroke affects 795,000 people annually in the United States, of which 87% are ischemic strokes (Benjamin et al., 2017). Intravenous thrombolysis with tissue plasminogen activator (tPA) remains the foundation of acute ischemic stroke treatment and has been demonstrated to improve stroke outcomes. The American Heart Association/ American Stroke Association (AHA/ASA) guidelines for the early management of acute ischemic stroke endorse the use of tPA for patients with ischemic stroke presenting within 4.5 hours of stroke symptom onset or last known to be well (Powers et al., 2019). Several randomized controlled trials have investigated the benefits and risks of tPA in the treatment of acute ischemic stroke (See Appendix A for pivotal tPA in ischemic stroke trials). The use of intravenous tPA in patients within 3 hours of stroke onset has been demonstrated to significantly improve functional outcomes at 3 months despite an increased risk of symptomatic intracranial hemorrhage with administration (The National Institute of Neurological Disorders and Stroke rt-PA Stroke Study Group, 1995). Additionally, a significant functional benefit of treatment between 3 and 4.5 hours has been appreciated (Hacke et al., 2004; Hacke et al., 2008). Although the absolute benefit was somewhat reduced compared to treatment within the earlier time window, treatment is associated with significantly improved functional outcomes and the occurrence of large parenchymal hemorrhage did not appear to increase with increasing time to treatment with tPA (Lees et al., 2010). There is no significant difference in symptomatic intracranial hemorrhage, mortality at 3 months or independence at 3 months between those patients treated 0-3 hours from onset and those treated 3-4.5 hours from ischemic stroke onset (Wahlgren et al., 2008). As a result of this evidence, intravenous tPA administration is recommended by the AHA/ASA in select acute ischemic stroke patients who can be treated within 3 to 4.5 hours of stroke symptom onset or last known normal (Powers et al., 2019). Despite this recommendation, the Food and Drug Administration has not approved the extended time window on the labeling of Alteplase in the United States (Food and Drug Administration, 2015).

Although evidence supports the use of tPA in extended time windows, greater benefit is appreciated with earlier treatment. Data suggests the earlier a patient can be treated with tPA the higher the probability of achieving favorable outcomes (Lees et al., 2010). A meta-analysis of six of the major randomized tPA trials demonstrated significantly improved outcomes at 3 months with decreased times to treatment (Hacke et al., 2004). Extension of these findings and inclusion of additional studies and patients similarly demonstrated an increased functional benefit and decreased mortality as the time to treatment decreased (Lees et al., 2010). Interventions to improve treatment times, or door-to-needle (DTN) times, are of the highest priority to reduce the individual and community burdens of stroke.

Problem Description

Acute ischemic stroke is a leading cause of long-term disability in the United States (CDC, 2012). Currently, there is estimated to be between 5.4 and 6.6 million stroke survivors in the United States, with approximately 60% of those survivors left with moderate to severely impaired functional status (Skolarus, Freedman, Feng, Wing, & Burke, 2016; Sreedharan, Unnikrishnan, Amal, Sarma, & Sylaja, 2013). Disability contributes to a large economic burden through increased care needs and loss of employment status (Sreedharan et al., 2013). The annual cost for stroke specific caregiving for an elderly stroke survivor is approximately $18.2 billion (Skolarus et al., 2016). In 2008, an additional $15.5 million was attributed to lost productivity and premature mortality costs (CDC, 2012). Despite significantly improved stroke outcomes with the use of tPA overall use of tPA in eligible patients remains low in the United States (Fang, Cutler, & Rosen, 2010). Improving functional benefits and reducing disability is dependent not only on the use of tPA but also on the expeditious treatment with tPA (Lees et al., 2010). However, less than one third of acute ischemic stroke patients in the United States treated with tPA have DTN times ≤60 minutes (Fonarow et al., 2011). As acute ischemic stroke imposes a significant economic burden, improving functional outcomes through efforts to reduce DTN times has an impact on the larger health care system.

Available Knowledge

The Get with the Guidelines-Stroke (GWTG) program was implemented in 2003 as a national registry for scientific advancement and to improve quality of care and stroke outcomes (Fonarow et al., 2010; Ormseth, Sheth, Saver, Fonarow, Schwamm, 2017). The program has demonstrated a statistically significant increase in adherence to identified performance measures increasing overall compliance with clinical guidelines (Howard et al., 2018). With increasing adherence to GWTG measures, there were significant improvements in ischemic stroke outcomes including an increased proportion of patients discharged home, decreased length of stay, decline in in-hospital mortality, decrease in death 30-days from admission and a decline in 1-year mortality (Fonarow et al., 2010; Song et al., 2016). In addition, those patients receiving intravenous tPA within 60 minutes of arrival were more likely to be discharged home and less likely to have a symptomatic intracranial hemorrhage within 36 hours of treatment (Tong et al., 2018). For every 15-minute improvement in the treatment time, significant improvements in multiple stroke outcomes were demonstrated (Saver et al., 2013).

To further improve these DTN times Target Stroke was developed as a nationwide quality improvement initiative (American Heart Association, 2018). The primary goal of Target Stroke is a DTN time of ≤60 minutes in ≥85% of acute ischemic stroke patients, with secondary goals of DTN times of ≤45 minutes in ≥75% of patients and DTN ≤30 minutes in ≥50% of patients (American Heart Association, 2018). Improvements in DTN times for tPA administration is significantly associated with improved in-hospital mortality, decreased symptomatic intracranial hemorrhage and increased proportion of patients discharged home (Fonarow et al., 2014). Decreasing DTN times is well demonstrated to decrease disability and improve stroke outcomes.

Several factors have been shown to have an on impact DTN times. Patient characteristics associated with DTN times less than 60 minutes include male gender, white race, and a medical history without previous stroke (Fonarow et al., 2011; Kamal, Sheng et al., 2017; Tong et al., 2018). Patients presenting with more severe strokes as indicated by a higher presenting National Institute of Health Stroke (NIHSS) score were more likely to have DTN times less than 60 and 45 minutes (Tong et al., 2018). Those patients presenting to the hospital institution by ambulance in contrast to private vehicle were associated with decreased DTN times (McVerry et al., 2019; Tong et al., 2018). While patient characteristics are not modifiable, there are system characteristics which also have an impact on DTN times and are more amenable to change and improvement. Among hospitals admitting more than 300 stroke patients annually, those with a stroke unit, teaching hospitals or those hospitals that were certified stroke centers, DTN times were significantly less than 60 minutes (Tong et al., 2018). The proportion of patients treated with tPA and DTN times less than 60 minutes, 45 minutes and 30 minutes were significantly greater in Comprehensive Stroke Centers compared to Primary Stroke Centers (Man et al., 2018). Arrival to the hospital by ambulance with pre-notification has been associated with decreases in DTN times as compared to arrival by ambulance without pre-hospital notification (McVerry et al., 2019). Implementation of a pre-notification system at a system level may improve DTN times for individual institutions. In addition, use of telestroke when a stroke neurologist is not on-site has been shown to be significantly associated with decreased DTN times (Sanders, Patel, Kiely, Gwynn, & Johnston, 2016). However, the most significant factor found to be independently associated with decreased DTN times was treatment occurring during normal working hours versus treatment outside of regular working hours to include nights and weekends (McVerry et al., 2019). Identification of system level factors impacting door to needle times is valuable in the evaluation of quality improvement initiatives to improve DTN times.

Rationale

The Model for Improvement framework and the Plan-Do-Study-Act (PDSA) cycle tool is used to inform the conduct of this quality improvement initiative (Langley et al., 2009). The Model for Improvement is composed of foundational concepts that drive the PDSA cycle including understanding the final goal of the change, understanding the impact of the change on the goal and exploring what changes will result in an improvement (Langley et al., 2009). The primary objective of this quality improvement initiative and PDSA cycle is to improve DTN times in acute ischemic stroke patients treated with tPA. Time of day and weekend hours have been described as an independent factor in determining DTN times, with thrombolysis occurring outside normal working hours associated with increased DTN times (McVerry et al., 2019). While the institution has maintained DTN times compliant with AHA/ASA guidelines and national goals, the DTN times have been inconsistent and greater after hours. This suggests opportunities for improvement, particularly outside of normal working hours when DTN times were as much as 20 minutes longer. Understanding areas in which the institution is excelling and areas requiring improvement is critical in planning (Bollegala et al., 2016). As the telestroke camera is utilized outside of normal working hours when the stroke neurologist is not on-site, telestroke was placed in the CT scanner to decrease the time from patient arrival to neurology consult, diagnosis, and ultimately DTN time, or treatment.

To understand the impact of the improvement initiative, the DTN times prior to and following the placement of the telestroke technology within the CT suite were collected and analyzed. The outcome measures have been informed by the AHA/ASA guidelines for the early management of acute ischemic stroke, GWTG outcome measures and the goals established by the Target Stroke initiative. While it is important to compare data to predictions and summarize findings, it is also critical to reflect on the data to reveal additional areas of focus to perpetuate improvement (Langley et al., 2009). Findings from this quality improvement initiative determine if telestroke technology located in the CT scanner has an impact on DTN times in addition to promoting the evaluation of other areas for improvement. The data obtained will inform the next iteration of the PDSA cycle to continue the cycle of improvement.

Specific Aims

A telestroke unit was placed within the CT suites on July 28, 2019 for use in the evaluation of acute ischemic stroke patients beginning July 29, 2019. The purpose of this quality improvement initiative was to evaluate the effectiveness of telestroke technology in the CT suite to decrease DTN times in acute ischemic stroke patients eligible for thrombolysis with tPA when a stroke neurologist is not on-site. DTN times were assessed at two community hospitals. Specifically, the following was evaluated:

- The DTN times prior to locating telestroke technology in the CT suite between January 1, 2019 and July 28, 2019.
- The DTN times after telestroke technology was installed in the CT suite between July 29, 2019 and February 29, 2020.

Methods

Context

This project took place within two community hospitals, Providence Portland Medical Center (PPMC) and Providence St. Vincent Medical Center (PSVMC) located in Portland, Oregon, which are part of Providence St. Joseph Health and Services network. Providence Portland Medical Center is a 483-bed hospital with an acute care neuro-telemetry unit. It is certified by the Joint Commission as a Thrombectomy Capable Stroke Center treating approximately 15.2% of the 488 acute ischemic stroke admissions with tPA between June 2018 and July 2019 (Providence Health and Services, 2019). Providence St. Vincent Medical Center is a 523-bed hospital with a dedicated 12 bed NeuroCritical Care unit (Providence Health and Services, 2020a). Providence St. Vincent Medical Center is certified by the Joint Commission as a Comprehensive Stroke Center with 550 ischemic stroke patients admitted and 12.4% of patients treated with tPA June 2018 through July 2019 (Providence Health and Services, 2020b). In 2018, PPMC and PSVMC treated 100% of stroke patients with intravenous tPA in less than 60 minutes, 73% within 45 minutes and 33% in less than 30 minutes from the time of presentation (Providence Health and Services, 2020b). However, DTN times were noted to be approximately 20 minutes longer during nights and on weekends.

The current stroke treatment model includes a shared stroke team, including vascular neurologists, neuroradiologists, neurosurgeons, and interventional neuroradiologists are available to evaluate and treat acute ischemic stroke patients 24 hours a day, 7 days a week on-site or through a telestroke network (Providence Health and Services, 2020b). While a stroke neurologist is present at each site Monday through Friday 0800 to 1600, an on-call stroke team covers both facilities after hours and on weekends. When the stroke neurologist cannot be physically present to evaluate a patient, most often outside of regular working hours, traditional telestroke is utilized to evaluate patients in the emergency department (ED). Acute stroke protocols also include pre-notification from emergency medical services (EMS) for patients with stroke symptoms, a direct route to CT and the administration of thrombolytics prior to labs being resulted if the patient is not on anticoagulants and the medical history is well known.

Intervention

Telestroke monitors were permanently placed in the CT suites located at PPMC and PSVMC on July 28, 2019, with anticipation of improving DTN times by allowing for evaluation by telestroke concurrently with imaging preparation. Stroke neurologists, ED nurse champions, and ED physician liaisons were informed of the new CT telestroke equipment and encouraged to use it and provide feedback to develop a standardized process.

Study of the Intervention

The focus of this project was to evaluate the impact of utilization of CT telestroke technology on DTN times in acute ischemic stroke patients treated with tPA when a stroke neurologist was not on site. Regular working hours are defined as Monday through Friday 0800 to 1600 and therefore, outside regular working hours, or off-hours, are defined as Monday through Thursday between 1600 and 0800 (weeknight) and Friday 1600 to Monday 0800 (weekend). Door to needle times were assessed prior to and following placement of the monitors to determine the impact of telestroke technology within the CT suite.

A retrospective review of the Providence Stroke Registry was conducted inclusive of all acute ischemic stroke patients presenting to PPMC and PSVMC emergency departments and treated with tPA between January 2019 and February 2020. The Providence Stroke Registry consists of the Get with the Guidelines and RealTime databases. All in-hospital acute ischemic strokes were excluded from data collection. Emergency department patients with fluctuating symptoms or developing symptoms while in the ED were considered to be inpatients at the time of tPA administration and were therefore excluded.

The proposed quality improvement initiative was determined by the Providence St. Joseph Institutional Review Board (IRB) and the Oregon Health and Sciences University IRB to not meet the conditions of human subject research and did not require IRB review. Privacy of patient information was maintained throughout the conduct of this project.

Measures

Demographic and baseline case characteristics were collected including age, gender, race, presenting NIHSS score, time of arrival in the emergency department, time of tPA bolus initiation, use of telestroke, telestroke camera used, documented reason for delay in thrombolysis and weeknight versus weekend treatment. DTN time is defined as the time of patient arrival in the ED to the time of tPA bolus initiation. The case was defined as having used CT telestroke technology if the CT telestroke camera was used at any point in the patient's evaluation, otherwise it was classified as a traditional telestroke case. If no camera was utilized, the patient was determined to have been assessed at bedside.

The following measures were evaluated for this project:

- The DTN times for acute ischemic stroke patients treated with tPA in the emergency department outside of normal working hours prior to installation of

CT telestroke technology between January 2019 and July 28, 2019. This is the pre-intervention time period.

- The DTN times for acute ischemic stroke patients treated with tPA in the emergency department outside of normal working hours after implementation of CT telestroke between July 29, 2019 and February 2020. This is the post-intervention time period.

Analysis

The baseline characteristics and demographics were expressed as direct counts and percentages. Baseline characteristics between the pre and post-intervention groups were compared using an independent t-test for continuous variables and Pearson's chi-square for categorical variables. Normality testing revealed the distribution of DTN times between groups did not follow a normal distribution. Therefore, nonparametric tests were used to determine the differences in distribution between the pre-intervention and post-intervention groups. Specifically, the Mann-Whitney U test was used to examine differences in DTN times between groups. Categorical outcome variables were depicted as direct counts and percentages. All analyses were performed using SPSS software (IBM version 26). A 2-tailed value of $P<0.05$ was considered statistically significant.

Ethical Considerations

As the conduct of this project did not involve the implementation of any interventions, the ethical considerations for this project included the maintenance of patient data privacy and insurance of the accuracy and completeness of collected data. Patient data was de-identified, and information was stored on a password encrypted computer maintained in a secure location at all times. Confidentiality was maintained in accordance with Providence St. Joseph Health.

Results

Details of patient abstraction and exclusion are detailed in Appendix B. A total of 111 patients were included in the final analysis with 44 patients included in the pre-intervention group and 67 included in the post-intervention group. Appendix C shows the patient demographics and baseline characteristics. The mean distribution of age, race, gender, mode of arrival, initial NIHSS score and weekend treatment versus weeknight were comparable between the groups. Due to the limited racial diversity of the sample, races other than white were grouped for analysis. Similarly, the demographics and case characteristics for the CT telestroke used versus traditional telestroke used in the post-intervention period were analyzed with no significant difference detected between the groups (See Appendix C for details of the demographics and case characteristics). Missing data was excluded from analysis of the related category. For instance, those patients with race undefined were excluded from the race analysis between the groups and patients missing mode of arrival information were excluded from the mode of arrival analysis.

The intention-to-treat analysis demonstrated the median DTN time in the post-intervention group was unchanged from the pre-intervention group (median 44 minutes; p=0.909) (See Appendix C). While not significant, there was improvement in the percentage of patients treated with tPA within 30 minutes from the pre-intervention period to the post intervention time period (15.9%, 23.9%, p=0.311). There was little change in the percentage of patients treated within 45 minutes and 60 minutes from the pre-intervention group to the post-intervention group (56.8% versus 56.7%, p=0.992; 77.3% versus 76.1%, p=0.888 respectively). Percentages of patients achieving Target Stroke treatment goals are detailed in Appendix C.

Considering each institution separately, the median DTN time at PPMC improved 8 minutes from the pre-intervention to the post-intervention time period, although this was not statistically significantly (median 49 minutes, 41 minutes respectively, p=0.158). There was improvement in treatment in less than 30 minutes from 15.8% in the pre-intervention to 28.1% of patients in the post-intervention period (p=0.315). There was significant improvement in those treated within 45 minutes from 36.8% in the pre-intervention group to 65.6% in the post intervention group (p=0.046). Conversely, the median DTN time at PSVMC increased 3 minutes from the pre-intervention to the post-intervention time period (median 43 minutes versus 46 minutes, p=0.233). Although there was no improvement appreciated in the overall median DTN times, there was improvement in the percentage of patients treated within 30 minutes of presentation from 16% in the pre-intervention time period to 20% in the post intervention time period (p=0.693). The percentage of patients treated within 45 and 60 minutes decreased from the pre-intervention period to the post-intervention period (72.0% versus 48.6%, p=0.070; 84.0% versus 68.6%, p=0.174 respectively).

Based on the original hypothesis, (the use of CT telestroke would improve DTN times when stroke neurologists were not on-site) DTN times when CT versus traditional telestroke was utilized was assessed. In the post-intervention group, evaluation was accomplished with CT telestroke in 38.8% (n=26), with traditional telestroke exclusively in 44.8% (n=30) and at the bedside in 16.4% (n=11). Additionally, traditional telestroke was used for evaluation in 97.7% of patients (n=43) in the pre-intervention group. Those patients evaluated by the stroke neurologist at the bedside during the off-hours time period were excluded. There was an improvement of 5.5 minutes in the median DTN time from the pre-intervention period to the post intervention period with the utilization of CT telestroke (median DTN 38.5 minutes, 44.0 minutes respectively, p=0.128). In the post intervention group, there was a significant improvement of 9.5 minutes in the median DTN time with the use of CT versus traditional telestroke (38.5 minutes versus 48.0 minutes, p=0.011). Improvement in DTN times with the use of CT telestroke versus traditional telestroke was maintained when analyzing each facility separately. Providence Portland Medical Center demonstrated a significant decrease in DTN times of 18.5 minutes when utilizing CT telestroke (p=0.014). Providence St. Vincent Medical Center showed a non-significant improvement of 4.5 minutes when using CT telestroke compared to traditional telestroke (p=0.308). Results and details of the analysis for CT telestroke versus traditional telestroke are detailed in Appendix C.

Discussion

Summary

The primary objective of this quality improvement initiative was to determine the impact of utilization of telestroke technology within the CT suite on the DTN times in the treatment of acute ischemic stroke patients when a stroke neurologist is not on-site. The DTN times in the post-intervention group did not improve from the DTN times in the pre-intervention group in the intention-to-treat analysis. Additional analysis demonstrated an improvement in median DTN time between the pre-intervention group using traditional telestroke and the post-intervention period using CT telestroke. Furthermore, there was a statistically significant improvement in DTN time with the use of the CT telestroke as compared to the use of traditional telestroke in the post-intervention period. In addition to improvements in median DTN times, there were also improvements in the percentage of patients treated within 30 minutes. Small reductions in median DTN times and improvements in the percentage of patients treated within 30 minutes contribute to improved clinical outcomes. As DTN times are decreased further it is challenging to elicit a significant change in DTN time. Small changes appreciated in DTN times with a single intervention contribute to larger clinical impacts over time. Those hospitals implementing a greater number of initiatives to decrease DTN times were more likely to have shorter DTN times (Xian et al., 2017). The reduction of DTN time by one-minute results in an average of 1.8 days of extra healthy life for each stroke patient treated with thrombolytics (Meretoja et al., 2014). Utilization of multiple interventions, each having a small impact on treatment times, may result in a significant decrease in DTN time and subsequent improvement in clinical outcomes.

Interpretation

Many initiatives have been implemented to decrease DTN times in an effort to improve stroke patient outcomes. Streamlining processes to decrease the time of arrival to key time points, such as door to imaging, in the evaluation and treatment of an acute stroke patient has been shown to decrease DTN times (Mong, Tiah, Wong & Tan, 2019). This current quality improvement project aimed to decrease the time from arrival to neurology consultation to decrease the time to treatment. Additional processes strongly associated with a reduction in DTN time includes direct transport to imaging, premixing of tPA and a visual display of time elapsed from arrival (Xian et al., 2017). A quality improvement effort inclusive of the administration of alteplase in the CT suite has been shown to significantly reduce DTN times (Kamal, Holodinsky et al., 2017; Xian et al., 2017). Many quality improvement initiatives include multiple interventions to decrease DTN time. Implementing multi-step protocols to include the administration of thrombolytics in the CT suite have been implicated in reducing DTN times (Ajmi et al., 2019; Tran et al., 2019). While tPA could feasibly be administered in the CT suite during periods when the stroke neurologist is not on-site using CT telestroke, the primary objective of this assessment was to evaluate the impact of CT telestroke on DTN time and the frequency of tPA administration in the CT suite was not assessed.

Analysis demonstrated no difference in median DTN times between the pre-intervention period and the post-intervention period. However, there was an improvement in the percentage of patients treated within 30 minutes of presentation. An increased percentage of patients treated within 30 minutes of presentation was observed within each facility when considered separately. Despite the lack of statistical significance, there is clinical significance for improving the percentage of patients treated within 30 minutes as this leads to an increased likelihood of improved functional outcomes in a higher percentage of patients. Although the percentages of patients treated within 45 minutes and 60 minutes remained approximately the same from pre-intervention to post-intervention, there was significant improvement in those treated within 45 minutes of presentation at PPMC. The difference in improvement trends between the facilities supports the presence of unexplained contextual features impacting DTN times. Concurrent quality initiatives to improve DTN times and stroke outcomes may have influenced differences in DTN times at each facility. To better understand these differences, further research would be required.

Inability to demonstrate a change in DTN time between the pre-intervention group and the post-intervention group may be related to a few key factors. A total of 17.1% of patients in the dataset had documented delays in thrombolysis related to eligibility or medical interventions. The most commonly documented delay in thrombolysis was related to patient eligibility and was reported in 65.5% of delays. Extended time to consent, primarily related to prolonged conversations with patients and families, was found to be the primary reason for delay. Extended consent conversations occurred more frequently in mild strokes with an NIHSS score of 7 or less. Determination of eligibility delays have been shown to be strongly associated with treatment times greater than 60 minutes (Kamal, Sheng et al., 2017). Medical delays occurred in 27.5% of documented delays and included interventions to treat hypertension and complications related to intravenous access. With delays more frequently documented in the post intervention group (22.4%) as compared to the pre-intervention group (9.1%), this could have influenced the significance of CT telestroke on DTN times. In the subset of patients, excluding those with documented eligibility or medical delays in thrombolysis, the median DTN improved from 43 minutes in the pre-intervention group to 41 minutes in the post-intervention ($p=0.568$). Although this is not significant from a statistical perspective, the clinical implications of reducing DTN times by 2 minutes are more significant.

While DTN times may have been influenced by delays, the most significant factor implicated in the unchanged DTN times from pre-intervention to post-intervention is the frequency of use of CT telestroke. In the post-intervention period CT telestroke was only utilized in 38.8% of cases, with equivalent usage between PPMC and PSVMC (40.6% versus 37.1%, $p=0.770$). Variable utilization may be related to lack of familiarity and standardization of the technology prior to assessment of its use in the post-intervention group. Designating a period of time to ensure new protocols are fully implemented has contributed to the accuracy of assessment of quality improvement initiatives to reduce DTN times (Tran et al., 2019). Simulation-based training to increase familiarity, improve efficiency of clinical implementation and increase adherence have also been implicated in the successful implementation of a quality improvement protocol (Ajmi et al., 2019). Although there were discussions to introduce and familiarize providers with the CT telestroke technology, utilization was not fully implemented or standardized. Allowing for a period of time to increase clinical familiarity and experience using CT telestroke may have improved usage, providing a more accurate assessment of the impact of CT telestroke in the post-intervention period.

Evaluation of changes in DTN times between the pre-intervention and post-intervention period does not fully represent the impact of CT telestroke. While telestroke is primarily used after hours and on weekends, CT telestroke was only used in 46.4% of cases treated with tPA while a stroke neurologist was not on-site. Similar to the pre-intervention time period, traditional telestroke was utilized for acute ischemic stroke evaluation when the stroke neurologist was not on-site. Although weekends were defined as outside of regular working hours, a stroke neurologist may be present rounding on inpatient stroke patients during the daytime hours on the weekends. This accounts for the bedside evaluations observed in both the pre-intervention and post-intervention periods. As the intent of this quality improvement initiative was to evaluate the impact of CT telestroke technology on DTN times when the stroke neurologist was not present on-site, those patients evaluated at the bedside were excluded. Using CT telestroke demonstrated a 5.5 minute reduction in median door to needle time from the pre-intervention period. While this was not a statistically significant reduction, it is clinically meaningful. To further isolate the impact of CT telestroke, DTN times with the use of CT telestroke versus traditional telestroke were assessed in the post-intervention period, reducing confounding features that may influence DTN times. A statistically and clinically significant reduction of 9.5 minutes was appreciated between the use of CT telestroke and traditional telestroke when the stroke neurologist was not on-site. The effect was preserved when considering each institution separately, although the number of cases are small and the effect was not statistically significant at PSVMC. Improvement in DTN times related to CT telestroke is appreciated. A positive effect on the reduction of DTN times through allocation of physical resources in the emergency department specifically to acute stroke care has been appreciated in other quality improvement initiatives (Shpak et al., 2019). Telestroke within the CT suite can be utilized to reduce DTN times in the treatment of acute ischemic stroke patients when the stroke neurologist is not present on-site. This, in conjunction with other methods to reduce DTN times, contributes to clinically relevant reductions in in-hospital mortality, reduction in symptomatic intracranial hemorrhage and increased discharge to home. Therefore, the clinically significant reduction of DTN times has impacts on improving stroke outcomes and reducing disability.

Limitations

This project has several limitations. The project was an observational study performed within a limited time period. The time period in which the data collection was conducted reduced the overall study population included, limiting the number of patients evaluated with CT telestroke in the post-intervention group. Other time constraints impacted the ability to standardize the quality improvement intervention to fully appreciate the effectiveness and assess sustainability. More extensive data collection periods would be required to establish the sustainability of the reduction in DTN times with the use of CT telestroke. It is likely there were unaccounted factors influencing DTN times during the study period as indicated by the difference in effects appreciated at each facility. In addition, factors related to using either camera were not addressed. For instance, the opportunity to use the telestroke camera in instances of a late code stroke activation may not have been feasible. Lastly, all data was abstracted for this project from a database which relies on the accuracy and completeness of the primary data abstraction process.

Conclusions

Installing telestroke within the CT scanner has been shown to be effective in significantly reducing DTN times during periods when a stroke neurologist is not present on-site. As a method to reduce DTN times, the use of telestroke within the CT suite may be implemented at other facilities without a stroke neurologist on-site. Standardization of CT telestroke may contribute to increased usage of CT telestroke and further reductions in DTN times and assessment of sustainability would require a longer evaluation period. Further study should include assessment of stroke outcomes such as sICH and 90-day mRS to ensure safety while decreasing DTN times.

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Appendix A

Summary of pivotal trials for tissue plasminogen activator treatment in acute ischemic stroke

Table 1A

Pivotal Tissue Plasminogen Activator Trials

Trial	tPA Dose	Time Window	Primary Endpoints	Findings	Comments
ECASS I (Hacke et al., 1995)	1.1 mg/kg (100 mg maximum)	≤6 hours	BI and mRS at 90-days	No significant difference in BI scores or mRS scores between those treated with placebo and those treated with tPA at 90± 14 days; Intention to treat analysis demonstrates significant increase in death from intracranial hemorrhage in tPA group; Intention to treat analysis 90-day mortality significantly greater in the tPA treated group	Excluded patients <18 and >80 years of age
tPA for Acute Ischemic Stroke (NINDS, 1995)	0.9 mg/kg (90 mg maximum)	≤ 3 hours (180 minutes)	Part 1: Improvement in score of ≥4 on the NIHSS within 24 hours of stroke onset Part 2: BI, mRS, GOS and NIHSS at 3 months	Part 1: No statistical difference between placebo and tPA group. Part 2: Significant improvement in BI, mRS, GOS and NIHSS at 3 months in the tPA group as compared to the placebo group; No significant difference at 90 days in mortality between the groups. Significantly increased number of patients with symptomatic intracranial hemorrhage in the tPA group within 36 hours of treatment (7.14% vs. 1.2 %)	
ECASS II (Hacke et al., 1998)	0.9 mg/kg (90 mg maximum)	≤6 hours	mRS score at 90-days dichotomized for favorable outcome (score 0-1) and unfavorable (score 2-6)	No significant difference in favorable outcome between the tPA group and the placebo group; No difference in mortality at 30 or 90 days between the treatment groups; Symptomatic intracranial hemorrhage occurred more frequently in tPA group (8.8% vs. 3.4%)	Excluded patients <18 and >80 years of age
ATLANTIS (Clark et al., 1999)	0.9 mg/kg (90 mg maximum)	3-5 hours	Excellent neurological recovery defined as NIHSS≤1 at 90 days	No difference appreciated between the tPA and placebo group	Excluded patients <18 and >80 years of age; Trial stopped prematurely based on the interim analysis indicating "treatment was unlikely to prove beneficial"
ECASS III (Hacke et al., 2008)	0.9 mg/kg (90 mg maximum)	3-4.5 hours	Disability at 90 days dichotomized as a favorable outcome defined as a mRS score of 0 or 1 or an unfavorable outcome defined as a mRS score of 2-6	A favorable outcome was significantly more associated with the tPA group than the placebo group (52.4% vs. 45.2%, odds ratio 1.34, 95% confidence interval 1.02-1.76, P= 0.04); Symptomatic intracranial hemorrhage occurred more frequently in the tPA group (2.4% vs. 0.2%; P=0.008); Mortality did not differ between the groups	Excluded patients <18 and >80 years of age
IST-3 (Sandercock et al., 2012)	0.9 mg/kg (90 mg maximum)	≤6 hours	Proportion of patients alive and independent defined by an OHS 0-2 at 6 months	No difference in proportion of patients alive and independent between the groups at 6 months; Symptomatic intracranial hemorrhage occurred in 7% of patients in the tPA group within 7 days vs 1% in the	53% (1617) of total enrollment were older than 80 years of age

control group; Similar mortality at 6 months in both groups

Note. Adapted from "Intravenous thrombolysis for acute ischemic stroke within 3 hours versus between 3 and 4.5 hours of symptom onset," by N.T. Cheng and A.S. Kim, 2015, *The Neurohospitalist, 5*(3) p.103. Copyright 2015 by The Authors. tPA= tissue plasminogen activator; BI= Barthel Index; mRS= modified Rankin Scale; NIHSS= National Institute of Health Stroke Scale; GOS= Glasgow Outcome Scale; OHS= Oxford Handicap Score; DWI= Diffusion weighted imaging; FLAIR=Fluid attenuated inversion recovery; MRI= Magnetic resonance imaging; NINDS= National Institute of Neurological Disorders and Stroke; ECASS= European Cooperative Acute Stroke Study; ATLANTIS= Alteplase ThromobLysis for Acute Noninterventional Therapy in Ischemic Stroke; IST-3= Third International Stroke Trial; WAKE-UP= MRI-Guided Thrombolysis for Stroke with Unknown Time of Onset.

Appendix B

Patient Inclusion Algorithm

Patients were abstracted from the Providence Stroke Registry inclusive of the Get with the Guidelines database (GWTG) and the Real Time database. The registry is inclusive of all stroke and transient ischemic attack (TIA) patients admitted to Providence Portland Medical Center (PPMC) and Providence St. Vincent Medical Center (PSVMC). Patients receiving tissue plasminogen activator (tPA) were filtered and included in the final analysis as depicted in Figure 1B.

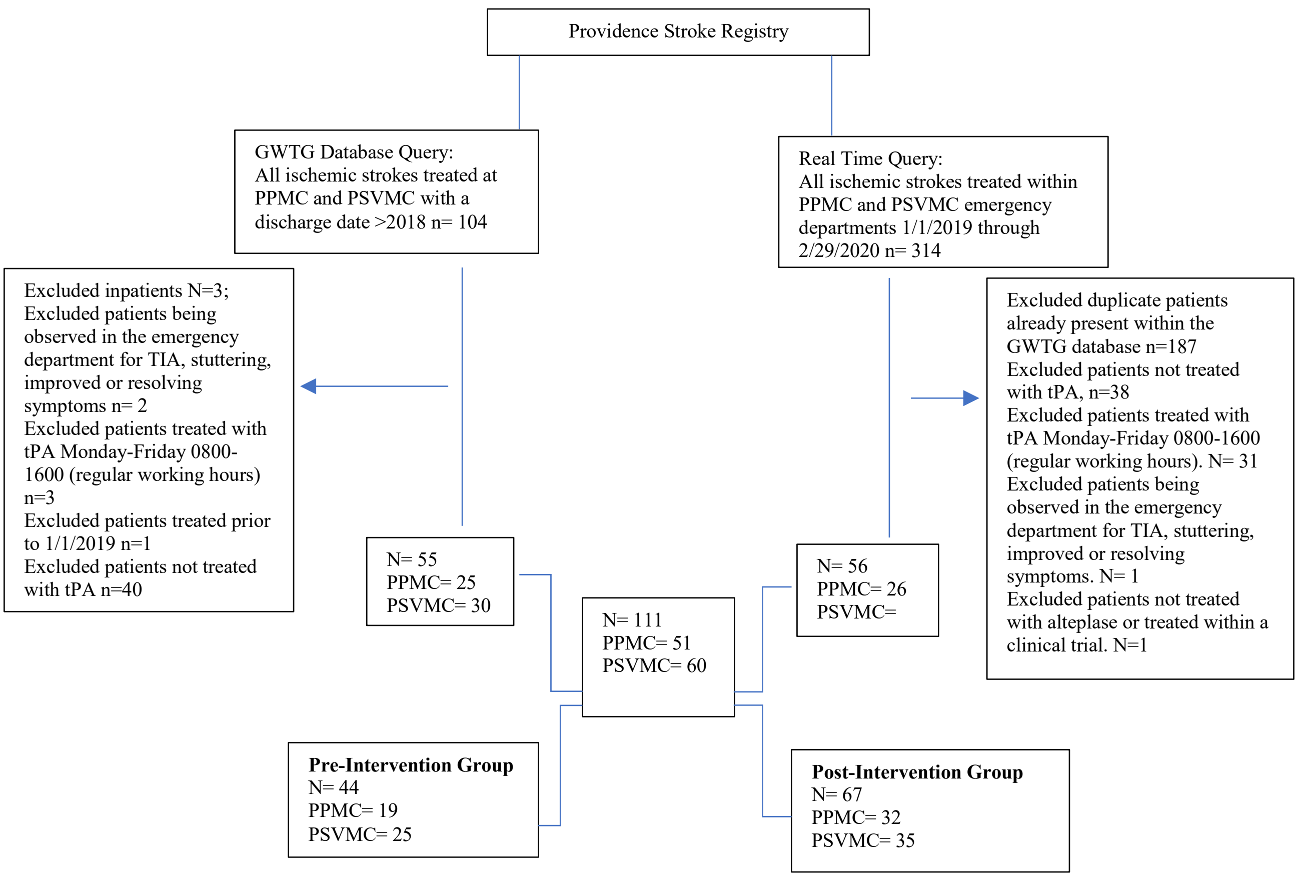

Figure 1B. Algorithm with exclusion criteria and included numbers for patient selection and inclusion in the assessment of the quality improvement initiative.

Appendix C

Results of the Initiative to Improve Door to Needle Times

The results of the statistical analyses performed as per the analysis plan in the conduct of this quality improvement initiative are presented.

Table 1C

Demographics and characteristics of patients receiving thrombolytics pre and post quality improvement initiative

Parameter	Pre-Intervention (n=44)	Post-Intervention (n=67)	P-Value
Mean Age in years (n=111)	68.16 ± 14.85	69.43 ± 16.19	0.676
Gender (n=111)			
Male	54.5% (n=24)	47.8% (n=32)	
Female	45.5% (n=20)	52.2% (n=35)	0.484
Race * (n=98)			
White	87.2% (n=34)	89.8% (n=53)	
Other	12.8% (n=5)	10.2 % (n=6)	0.663
Mean Initial NIHSS score (n=111)	9.98 ± 7.63	10.52 ± 8.94	0.740
Mode of arrival (n=110)			
EMS	81.4 % (n= 35)	71.6% (n=48)	
Private Vehicle	18.6 % (n= 8)	28.4% (n=19)	0.246
Treated on the Weekend (n=44)	29.5% (n=13)	46.3% (n=31)	0.078

NIHSS= National Institute of Health Stroke Scale
* 13 patients with race listed as unable to determine and therefore excluded from race analysis
** 1 patient without identified mode of transportation and therefore excluded from mode of transportation analysis

Table 2C

Demographics and characteristics of post-intervention CT versus traditional telestroke

Parameter	CT Telestroke (n=26)	Traditional Telestroke (n=30)	P-Value
Mean Age in years (n=56)	68.46 ± 14.92	68.80 ± 17.08	0.938
Gender (n=56)			
Male	53.8% (n=14)	36.7% (n=11)	
Female	46.2% (n=12)	63.3% (n=19)	0.197
Race* (n=50)			
White	87.0% (n=20)	96.3% (n=26)	
Other	13.0% (n=3)	3.7% (n=1)	0.225
Mean Initial NIHSS score (n=56)	11.38 ± 9.84	9.90 ± 8.93	0.566
Mode of arrival (n=56)			
EMS	65.4 % (n= 17)	73.3% (n=22)	
Private Vehicle	34.6 % (n= 9)	26.7% (n=8)	0.519
Treated on the Weekend (n=56)	30.7% (n=8)	46.7% (n=14)	0.224

NIHSS=National Institute of Health Stroke Scale
* 6 patients with Race listed as unable to determine and therefore excluded from race analysis

Table 3C

Median Door to Needle Time (DTN)

	Pre-Intervention	Post-Intervention	P-value (Mann-Whitney U test)
Door to Needle Time (minutes)	44.0 (n=44)	44.0 (67)	0.909
PPMC DTN (minutes)	49.0 (n=19)	41.0 (n=32)	0.158
PSVMC DTN (minutes)	43.0 (n=25)	46.0 (n=35)	0.233
DTN Without delays (minutes)	43.0 (n=40)	41.0 (n=53)	0.568

Table 4C

Door to Needle Target Stroke Goals

	Pre-Intervention	Post-Intervention	P-value
Treated ≤30 minutes	15.9% (n=7)	23.9% (n=16)	0.311
Treated ≤45 minutes	56.8% (n=25)	56.7% (n=38)	0.992
Treated ≤60 minutes	77.3% (n=34)	76.1% (n=51)	0.888
PPMC	n= 19	n= 32	
Treated ≤30 minutes	15.8% (n=3)	28.1% (n=9)	0.315
Treated ≤45 minutes	36.8% (n=7)	65.6% (n=21)	0.046
Treated ≤60 minutes	68.4% (n=13)	84.4% (n=27)	0.180
PSVMC	n= 25	n= 35	
Treated ≤30 minutes	16.0% (n=4)	20.0% (n=7)	0.693
Treated ≤45 minutes	72.0% (n=18)	48.6% (n=17)	0.070
Treated ≤60 minutes	84.0% (n=21)	68.6% (n=24)	0.174

Table 5C

Door to Needle Times (DTN) for CT Telestroke versus Traditional Telestroke

	Telestroke Camera Used				P value (Mann Whitney U test)
Patient cohort	CT	Median DTN (minutes)	Traditional	Median DTN (minutes)	
Pre-intervention vs. post-intervention (n=69)	37.7% (n=26)	38.5	62.3% (n=43)	44.0	0.128
Post-Intervention (n=56)	46.4% (n=26)	38.5	53.6% (n=30)	48.0	0.011
PPMC Post-Intervention (n=27)	48.1% (n=13)	32.0	51.9% (n=14)	50.5	0.014
PSVMC Post-Intervention (n=29)	44.8% (n=13)	43.0	55.2% (n=16)	47.5	0.308

**Patients evaluated at bedside were removed for this analysis