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The Effect of Computed Tomography Perfusion (CTP) Scans on Acute Ischemic Stroke Patients at a Comprehensive Stroke Center

Sarah Holloway
seho245@uky.edu

Sarah Elizabeth Holloway
University of Kentucky, hollowaysd@yahoo.com

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Sarah Holloway and Sarah Elizabeth Holloway, Student

Dr. Melanie Hardin-Pierce, Advisor

The Effect of Computed Tomography Perfusion (CTP) Scans on Acute Ischemic Stroke Patients at a Comprehensive Stroke Center

Submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Nursing Practice at the University of Kentucky

By

Sarah Holloway

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Abstract

Objective: The DEFUSE 3 and DAWN trials have revealed that stroke patients may be eligible for mechanical thrombectomy up to 24 hours from symptom onset with appropriate perfusion imaging. The purpose of the study is to evaluate the impact CTP imaging will have patient selection and outcomes at a Comprehensive Stroke Center.

Methods: This study is a retrospective and prospective chart review comparing acute ischemic stroke patients evaluated for mechanical thrombectomy utilizing CT angiogram verses CT perfusion imaging from January 1, 2018- June 30th 2019 at a Comprehensive Stroke Center.

Results: Of the 129 patients who received CTAs, 36 patients received mechanical thrombectomy. This is compared to the 73 patients that received CTP scanning and 26 patients were found to be eligible for mechanical thrombectomy. There were no significant findings regarding patient selection for mechanical thrombectomy regarding the number of patients that received mechanical thrombectomy, complication rates, and change in NIHSS from admission to discharge.

Conclusion: The addition of CTP imaging at the Comprehensive Stroke Center demonstrated that patients can successfully be given mechanical thrombectomy in the extended intervention window of up to 24 hours from last known well.

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I wanted to take a moment to thank the institutions and people that have played a pivotal role in allowing me to successfully complete my Doctorate of Nursing Practice.

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Dedication

No one can make a successful completion of the DNP journey without help and support. This support did not just materialize upon my entering the University of Kentucky to complete my doctorial education. Instead, many different people have invested and pushed me to be the person that I was meant to be. I wanted to take a few minutes to acknowledge some of the people who have played a part in my successful completion of this DNP project.

First, I want to thank my mother. As a young girl, I struggled in school and had a hard time learning to read. My mom made the difficult decision to hold me back in school to ensure that I would have a better chance of success. As I have gotten older, she has pushed me to never accept average as acceptable and to push yourself to be the best. Throughout this program she has been a constant cheerleader and encourager, allowing me to believe that I was capable of completing this daunting journey.

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Background

In the United States, close to 795,000 people are impacted by an acute stroke diagnosis each year (Mozaffarian et al., 2016). According to Mozaffarian et al. (2016), one person dies from stroke in the U.S. every 240 seconds; in addition to the mortality risk, stroke often leaves patients with lifelong disabilities. In addition to the human cost of stroke, the financial cost is significant. For example, according to Chalouhi et al., (2013) it is estimated that the financial burden of stroke is approximately 30 billion dollars every year. A large reason that stroke remains such a significant cause of disability lies in the fact that stroke intervention has been limited to six hours from time of onset. This means that if a patient went to sleep normal and woke up the next morning exhibiting signs and symptoms of stroke, they would be ineligible for any type of acute stroke intervention. Research is now showing that with proper screening, some patients may be eligible for mechanical thrombectomy up to 24 hours from last known well with the help of computed tomography perfusion (CTP) scanning and diffusion and perfusion magnetic resonance imaging (Albers et al., 2018). This extension of the stroke intervention window is due to CTP's ability to "estimate the volume of irreversibly injured ischemic tissue and the volume of brain tissue that is ischemic but not yet infarcted" (Albers et al., 2018, p. 709).

As providers seek to allow more patients the opportunity for intervention, the role of neuroimaging has been magnified. The four major neuroimaging options are non-contrast CT(NCCT), CT angiogram (CTA), Diffusion MRI (DWI), and CT perfusion (CTP). A NCCT is the frontline modality that guides treatment and is an absolute for any patient presenting with acute signs and symptoms of stroke. Through NCCT, providers can determine if there is any sign of subarachnoid (SAH) or intracerebral bleeding (ICH), which would exclude a patient for IV tPA (Pavlina et al., 2018). In addition, NCCT can play a role in determining large vessel occlusion (LVO), in that "parenchymal findings of acute ischemic stroke (AIS) can be detected very early with NCCT with abnormalities for up to 75% of patients with middle cerebral artery strokes within 3 hours" (Pavlina et al., 2018, p. 412-413). Radiologist can also evaluate a NCCT for a hyperdense thrombus in an occluded artery (Pavlina et al., 2018). A hyperdense thrombus is an early signal to a radiologist that the patient has a large vessel occlusion. Also, they can use the Alberta Stroke Program Early CT Scale System (ASPECTS) to evaluate ischemic changes (Pavlina et al., 2018). The ASPECT score assigns a score of 1-10 evaluating the different vascular territories of the middle cerebral artery. Each area is evaluated for ischemic changes such as hypoattenuation or loss of grey-white differentiation (Pavlina et al., 2018). A patient who receives an ASPECTS score of 7 or less is seen as more likely to have poor outcomes (Pavlina et al., 2018). Research as shown through previous clinical trials that patients who receive an ASPECTS score of 5 or greater are appropriate candidates for endovascular therapy, with 7 being the cut off for treatment (Pavlina et al., 2018).

To further assess for LVO, CTAs can be used to find occlusions in the proximal vessels which can be retrieved through mechanical thrombectomy. It is also utilized to determine collateral circulation which is necessary to maintain a penumbra, and to allow the neurointerventionalist to determine a plan on how to proceed with the intervention (Pavlina et al., 2018). The significant draw back to CTA with ASPECTS scoring is its moderately low intrareader agreement (Pavlina et al., 2018). This means that based on the provider or radiologist's training or experience a significantly different ASPECTS score may be obtained. This may exclude patients from interventions that could have benefitted them.

It is for this reason that many clinical trials are adding CTP scanning to help determine appropriate patient selection for endovascular therapy. CTP works by enabling providers to differentiate between an ischemic core and the penumbra that can be revascularized. CTP is beneficial because not only can it be completed in conjunction with the CTA reducing the patient's contrast exposure but it is able to scan the entire brain (Pavlina et al., 2018). Another additional benefit that has long been lacking is CTP's ability to positively evaluate posterior circulation strokes (Becks et al., 2019). Additionally, it is found to be highly accurate with "high sensitivity (80%) and specificity of (95%)" (Furlanis et al., 2018, p. 2201). It is also beneficial due to the speed of CTP, where, the entire process of CTP from "scanning, reconstruction and interpretation of the whole-brain CTP can be done in less than 5 minutes on recent generation of CT scanners "(Becks et al., 2019, p. 128). The amount of time required to obtain imaging results is significant, since almost two million neurons die every minute the artery is not reperfused (Pavlina et al., 2018). However, CTP scanning does have limitations. MRI is more sensitive in detecting acute ischemic strokes of all sizes than CTP (Pavlina et al., 2018). In addition, some studies have found that CTP overestimates the size of the ischemic core and can exclude patients from treatment (Campbell et al., 2019).

In conclusion, each neuroimaging modality plays a unique role in evaluating ischemic stroke patients. As perfusion imaging evolves, it will only improve the amount of knowledge the providers are able to obtain prior to stroke intervention. This can be valuable in improving the selection criteria for acute ischemic stroke patients in the extended window.

Purpose

The aim of this study is to evaluate the effect of CTP scanning on acute ischemic stroke patients that presented to a Comprehensive Stroke Center. The aims of this study are as follows

1. To evaluate the percentage of patients that received CTP scans compared to CTA alone.
2. To evaluate the impact of CTP scanning on the frequency of mechanical thrombectomy.
3. To compare complication rates for patients selected for mechanical thrombectomy.
4. To determine the impact of CTP scans on improved neurological function as measured by the discharge National Institute of Health Stroke Scale (NIHSS).

Conceptual Framework

The conceptual framework guiding this study was based on Lippett's Theory of Planned Change. This theory is an adaption on Kurt Levin's Theory of Change. Lippett saw change as "deliberate, planned effort, which moves a system, an organization, or an individual in a new direction" (Manyibe, Aref, Hunter, Moore, & Washington, 2015, p. 26). Lippett's theory has seven steps which align with the nursing process (Mitchell, 2013). This theory is ideal for this project because it emphasizes both the change that is going to take place and the people and resources necessary to implement the change. Before the change is initiated, the problem is researched and the best solution is determined. Then the theory focuses on the current motivation to accept the change and determining the agents or people who will be responsible for the change. This step in the process is important, because if the right people are not chosen, buy-in may not occur and the change is less likely to be successful. Another key component of this theory that was significant to this project is the linear nature of this theory. Change agents are not able to go to the next step in the process without completing the one before. This allows for a clear understanding of the process prior to implementation. In bringing CTP scan to the Comprehensive Stroke Center (CSC), it was imperative that a clear protocol be developed to determine which patients were eligible for CTP scanning. In addition, building a clear communication plan into the protocol was necessary to ensure that imaging results were called to the stroke neurologist and further treatment decisions could be made in a timely fashion. Finally, this theory is beneficial because each key stakeholder is assigned their responsibility to ensuring the change is successful. This is imperative when problems arise, the team knows which person is responsible for that component of the process and can intervene and provide feedback.

The first phase is to diagnose the problem. The problem is what is the best way for the CSC to determine if a patient is a candidate for stroke intervention with the new treatment window extended to 24 hours for mechanical thrombectomy. The second step is to assess the motivation and the capacity for change. The CSC at which the study was conducted is forward thinking and looking for ways to improve stroke care in their community. They already have structures in place for planned change to be implemented. They also had both Administrative and Physician champions to bring CTP technology to their CSC in order to allow more patients to have access to life altering intervention for stroke.

The third step is to assess the change agents' motivation and resources. The system's stroke program goals and objectives are "to improve and sustain the quality of care that our stroke patients receive by transforming the current scientific evidence into clinical practice:

Delivering standardized care, hard wiring process, and utilizing systems of care" (Hundley, 2019, Slide 3). Also, this CSC, has stroke and neurointerventionalist coverage 24 hours a day, seven days a week. Additionally, the study site is the primary location where mechanical thrombectomies occur and thus have the technology and systems of care in place to implement this new change.

The fourth step is to select the progressive change objective. The objectives were to ensure that patients that presented to this CSC with an unknown last known well or presented after 4.5 hours were given CTP scanning. The stroke neurologist on call had to be called for patients who presented with a NIHSS of 6 < or exhibited signs and symptoms of LVO. In addition, patients who presented to other hospitals in this medical system with concerns for LVO, would have a NCCT and CTA at their facility and then would receive CTP on arrival to the CSC.

The fifth step is to determine the roles and responsibilities of each team member. Roles were determined based on current practice at the CSC. Education was provided to nursing, Emergency Department (ED) providers, and radiologist to improve understanding of the new process and to ensure the correct patients received CTP scanning. The sixth step is to implement the change. On October 1, 2018, CTP scanning went live at the CSC. Rapid technology software had been acquired and was the same technology that had been used in several of the large clinical trials in which CTP was used to evaluated patients for mechanical thrombectomy in the extended window. The seventh and final step is to evaluate the process change and to terminate the helping relationship. This DNP project is an evaluation of the effectiveness of CTP at the CSC from January 1, 2019- June 30th, 2019. The findings of this study will be communicated to key stakeholders in this process to remove any barriers to care and to provide feedback of patient outcomes.

Literature Review

A literature review was conducted using OVID and Clinical Key search engines utilizing the key word of CT perfusion and acute ischemic stroke. Twelve articles were reviewed that highlighted not only clinical trials that were evaluating CTP's role in extending the mechanical thrombectomy window, but also the impact on different radiological modalities and their impact on patient selection for stroke intervention. This review highlighted five key findings that were significant for this study. First, while IV tPA used to be the mainstay treatment for all eligible stroke patients, researchers are finding that for patients stricken with devastating strokes due to large vessel occlusion, IV tPA alone is not sufficient stand-alone therapy (Pavlina et al., 2018; Becks et al., 2019). In addition, many patients are not eligible to receive IV tPA due to presentation outside the 4.5-hour window or having medical contraindications. Finally, with IV tPA, "the rate of recanalization before thrombectomy (performed without delay) was <10% in recent randomized trials" (Sacks et al., 2018, p. 443).

This highlights the second major theme which is that for almost all eligible patients, endovascular therapy is better than medical management alone. Multiple trials have shown for patients with large vessel occlusions, that endovascular therapy provided as close to symptom onset, leads to the best patient outcomes (Pavlina et al., 2018; Sacks et al., 2018; Campbell et al., 2019; Sarraj et al., 2019). In fact, while many clinical trials used an ischemic core of 70mL as the cut off to treatment, one group of researchers found that "large ischemic core did not prevent benefit from endovascular therapy compared to standard medical therapy" (Campbell et al., 2019, p. 53).

The third key finding was the recent DAWN study and DEFUSE 3 trial demonstrated that the treatment window could be extended from the traditional window of 6 hours out to the extended window of 16-24 hours. The important caveat to this extended window, is that patients are selected with the help of perfusion imaging (Albers et al., 2018; Snelling et al., 2019; Sacks et al., 2018). However, some researchers also highlighted that imaging alone was not a stand-alone reason for patients to have mechanical thrombectomy. For example, in the DAWN trial, they looked not only at the volume of the ischemic core but also the severity of the patient's stroke resulting in a high NIHSS (Sacks et al., 2018). This idea highlights the importance of neurological assessment of the acute stroke patient. In one study that looked at correlations between NIHSS and perfusion imaging their key finding was "the strong correlation between the baseline NIHSS score and the ischemic volume in CTP imaging in the acute stroke phase" (Furlanis et al., 2018, p. 2205). Thus, a patient with a small ischemic core and a significant NIHSS is a good indicator the patient would benefit from endovascular therapy.

The fourth key message was regarding specific patient variables that impact the treatment decision. One of the largest debates in the literature revolved around patients with advanced age. Several studies found that patients who were older were more likely to have poor outcomes (Demeestere et al., 2018; Snelling et al., 2019; Sacks et al., 2018). However, multiple studies showed that age alone should not be used to exclude a patient from treatment (Sacks et al., 2018; Campbell et al., 2019; Snelling et al., 2019). Instead, some researchers encourage looking at the overall health and mobility of the patient instead of age alone in making a treatment decision. This idea was best highlighted by one group of investigators, who determined that "chronological age is not an ideal selection criterion and physiological robustness and functional reserves might be more valid in clinical practice" (Campbell et al., 2019, p. 53).

The final theme, which is a highlight of all stroke care is that time is brain and that no matter when the patient presents, it is imperative that intervention is given as quickly as possible (Campbell et al., 2019; Sacks et al., 2018). In fact, several researches have highlighted the impact of delay in treatment. With one noting that an analysis of pooled data from five different endovascular studies showed that delay from patient presentation to reperfusion led to increased patient disability (Sacks et al., 2018). Additionally, even a 30-minute delay can allow for significant increase in the ischemic core and was the equivalent of adding five years to the patient's brain (Campbell et al., 2019).

This literature review highlights the constantly evolving field of stoke intervention. While research is demonstrating the ability of endovascular intervention to be conducted safely up to 24 hours, there is still a great deal of discussion regarding what imaging should be used and what patients are most likely to benefit from these interventions. This is why it is important to evaluate CTP's impact on patient outcomes at Norton Brownsboro Hospital.

Agency Description

Setting

This study was conducted at CSC that is a 127-bed community hospital located in northeastern Jefferson County. This study aligns with the healthcare system's mission of providing high quality healthcare to our community. The CSC has a heliport for critical care transport and is a regional referral center for advanced neurosurgical conditions, specifically stroke care. They have 24/7 coverage of neurologists, neurovascular and neurosurgical physicians to provide the highest level of stroke intervention possible to patients in the region.

Target Population

The study will focus on adult patients 18 and older who present to Norton Brownsboro hospital for acute ischemic stroke within 24 from onset of stroke symptoms.

Congruence of Project

This DNP project aligns with the healthcare system's mission and vision statement in its desire to provide quality health care to the communities in which we serve. By evaluating the impact of extending the stroke intervention window with CTP, it is helping meet the value of setting the standard for quality and caring and continually improve care. Demonstrating stewardship of resources is another value that aligns well with this project as well. The cost to obtain the RAPID software and the CTP technology to the CSC was significant for the hospital. However, the decision to purchase the software for the CSC was already determined and was not a factor evaluated in this study. By evaluating the effectiveness of the technology, this project helps to ensure the money that was spent is being maximized to improve patient outcomes. In addition, the evaluation of patient outcomes in the extended time window is part of the system's values of accepting accountability for results. The CSC and System Stroke leaders will be able to take the results of this DNP project as a way to find opportunities for improvement and further strengthen the stroke program. Finally, this project shows how the CSC succeeds with integrity. They do not get great outcomes and success by only intervening on the patients with the highest chance of good outcomes. Instead, they work to provide the best outcomes to every patient they serve.

Stakeholders

There are five key stakeholders in this process. The CNO of the CSC is a stakeholder in approval of purchase of the CTP technology and software. In addition, she is able to remove barriers and facilitate discussion between all stakeholders. Additionally, she also gave approval for this DNP project to occur at her facility.

The system stroke coordinator will work to ensure the CTP process is written with the approval of key stakeholders. She is also responsible for educating all stroke coordinators at the system campuses on the CTP protocol and when to transfer their patients to the CSC. She is instrumental in implementing the CTP process and providing feedback to all key stakeholders.

The Stroke neurologist will be the one of the physician champion at the CSC. They will work to provide communication and update all of the stroke neurologist about the CTP process. They will work to educate colleagues on the current protocol and provide feedback to their peers on missed opportunities. They will also provide the team with provider feedback and concerns.

The stroke neurointerventionalist will be responsible for communicating with the stroke neurologist who received the stroke call and determine if the patient is a candidate for mechanical thrombectomy. In addition, they will be utilizing the CTP imaging to make treatment decision for patients who arrive to the CSC after 4.5 hours from last known well. They will be performing the mechanical thrombectomies and providing follow up care. They will also provide feedback to the group regarding missed opportunities and patient success stories.

The ED champion at the CSC will be the physician champion for the emergency department. They will be responsible for ensuring ED physicians are aware of the CTP protocol for acute ischemic stroke. They will be responsible for contacting the stroke neurologist on call if a patient presents to the ED with signs and symptoms of stroke. Also, they are responsible for ensuring the CTP is completed as quickly as possible after the order is given from the stroke neurologist.

The radiologist is a subject matter expert in reading and interpreting CTP scans. In addition, they are responsible for communicating with the ED physician when a patient has an abnormal CTP scan and the patient is evaluated to have a CTP mismatch with a small ischemic core with a large penumbra and is a possible candidate for mechanical thrombectomy.

Project Design

This will be a retrospective and prospective closed chart review comparing acute ischemic stroke patients selected for mechanical thrombectomy based on CT angiogram verses CT perfusion imaging from January 2018- June 2019 at Norton Brownsboro Hospital.

Project Methods

The CTP protocol that has been developed at the CSC for acute ischemic strokes has two different pathways, a last known well of less than 4.5 hours and then a last known well of 4.5-24 hours. If the patient presents to the CSC with a last known well of less than 4.5 hours, then an immediate phone call is made to the stroke neurologist to determine eligibility for administration of IV tPA and mechanical thrombectomy.

If the patient has an NIHSS of a 6 or greater, then the neurologist will order a NCCT, CTA head, CTA neck and CTP brain. If the NCCT is negative for hemorrhage, then the neurologist will determine if the patient is an IV tPA candidate based on past medical history, current medications, and recent surgeries. If the patient is eligible for tPA then it is immediately given. The next step is to determine if the patient has an LVO and is eligible for mechanical thrombectomy. The stroke neurologist and neurointerventionalist will discuss the findings of the CTA and CTP to determine if the patient is an eligible for mechanical thrombectomy.

However, if the patient presents after 4.5 hours but less than 24 hours from last known well then, the algorithm is determined based on the patient's admission NIHSS. If the patient has a NIHSS of 6 or greater, then a call is made to the stroke neurologist to determine if the patient is eligible for mechanical thrombectomy. These patients will also get a CTA head and neck and CTP brain. Then the decision will be made if the patient is eligible for intervention. Finally, if the patient presents in this window with a NIHSS less than 6 then they still receive a NCCT and CTA if they have adequate renal function. If the patient is not able to the have a CTA due to renal function, then an MRA without contrast is ordered. If after the initial imaging the patient has worrisome symptoms for LVO, then the neurologist must be notified to determine if a CTP is warranted. Worrisome symptoms have been defined in the protocol as: moderate to severe stenosis or occlusion of the internal carotid, middle cerebral artery at M1 or M2, basilar, vertebral, posterior cerebral artery at P1. This part of the protocol was developed to ensure adequate assessment of posterior circulation strokes which will present with low NIHSS.

Procedure

Approval was obtained from the University of Kentucky Institutional Review Board (IRB) and the Healthcare System's Office of Research prior to the start of data collection. The Retrospective chart review examined patients the received CTA for acute ischemic stroke between January 1, 2018 and June 30^{th,} 2018. A HIPPA waiver of informed consent was obtained due to the large number of patients that would be included and that this study was no more than minimal risk to the patient. A list of ICD 10 codes listed in Appendix B was provided to the Healthcare System's Office of Research to obtain a list of possible study candidates. The health care system research office approved the system's data analyst to run a report of patients that matched the ICD 10 codes provided. The prospective arm of this study examined patient who t received CTP for acute ischemic stroke between January 1, 2019 and June 30th, 2019. The data request was made for this group on August 1, 2019 to ensure that all patients had left the hospital and the study remained a closed chart review with no more than minimal risk for the patient. Once again, the principal investigator received a list of patients the matched the same ICD 10 codes provided in the retrospective arm of the study. Each medical record number was assigned a unique identifier that was de-identified to maintain patient confidentiality and necessary data for the study was stored independently from the original list provided. All de-identified data were stored on a password protected drive on the healthcare system's secure network.

Sample

In the retrospective period, 129 patients met the inclusion criteria of being aged 18 years or older, presenting to the CSC within 24 hours of last known well and having had a CTA to assess for possible mechanical thrombectomy for acute ischemic stroke. In the prospective arm of the study, 73 patients met the inclusion criteria of being aged 18 year or older, presenting to the CSC within 24 hours of last known well and having had a CTP to assess for possible mechanical thrombectomy for acute ischemic stroke. Demographic data are presented in Table 3 in the Appendix.

Statistical Analysis

Descriptive statistics were determined using SPSS version 26. Demographic data were described with means and standard deviation and frequencies and distributions. A two sample t-test was used to evaluate differences for the interval improvement of NIHSS from admission to discharge. Comparison between CTA and CTP with regard to number of mechanical thrombectomies and complication rates were analyzed with a Chi Square test of associated of Fisher's exact test. An alpha level of .05 was used throughout.

Results

Of the 202 patients who met the inclusion criteria for this study, 129 received CTA only to determine eligibility for mechanical thrombectomy verses 73 with received CTP scanning. The average age of the CTA group was 69.4 compared to 68.2 in the CTP group. The CTP group was found to have a larger percentage of men at 63% compared to 51.9% in the control group. The CTP group additionally had a larger percentage of African-Americans at 21.9% compared to the CTA group having only 10.1%. For both groups, hypertension was found in the highest frequency in at 65.9% and 74.0% respectively. Statistical significance was found in the difference in two groups regarding patients with a history of cancer. The control group had 6 patients or 4.7% compared to the CTP group that had 12 patients that represented 16.4% with a p-value of 0.015. The average patient admission NIHSS was 8.39 for the CTA group compared to 9.56 in the CTP group. Patients who were evaluated with CTA also were able to present to the hospital in a shorter time from symptom onset. The CTA group on average presented 4.79 hours from symptom onset compared to 5.34 for those evaluated with CTP.

With regard to objective 1, the incidence of patients who received CTP scan was 73 compared to 129 who received CTA in the baseline data. This demonstrates that 56.6% of patients received CTP compared to CTA. The findings for objective 2 were that the CTA group resulted in 36 patients receiving MT, representing 27.9% of the patients who were evaluated for LVO through CTA. The CTP group resulted in 26 patients receiving MT representing 35.6% of patient who received CTP. This was found to not be significant with a p value of 0.254, with statistical significance defined as a p- value of less than 0.05. Objective 3 evaluated the difference in complication rates between patients who received MT based on CTA verses CTP. The CTA group had 3 patients who experienced complications representing 8.3% of patients who received mechanical thrombectomy. The CTP group had 5 incidences of complications representing 19.2% of patients who received mechanical thrombectomy. Statistical significance was not found between the two groups regarding complication rates, with a p value of 0.262. Complications were defined as symptomatic intracerebral hemorrhage, stroke in a different territory or vessel damage. With regard to change in NIHSS from admission to discharge, a statistical significance was not achieved. The CTA group had a mean positive change of 3.48 points with a SD (7.23) where the CTP group had a mean change of 1.15 with a SD (10.06) with a p-value of 0.058.

Discussion

While this study did not find a statistically significant difference between patient selection through CTA verses CTP some important concepts were highlighted in the study findings. With regard to objective 1, which compared the number of CTP scans to CTA completed during the baseline data, 57% of patients received a CTP scan. This is in line with the healthcare systems protocol in which the majority of patients will receive a NCCT and CTA. A

CTP was performed in both windows for a NIHSS of 6<, however it was only added in patients with a NIHSS < 6, of if a CTA demonstrates a possible LVO. The full protocol can be referenced in Appendix A. The protocol was designed in a way that more patients will always receive CTA compared to CTP. It is also important to note, that the inclusion of CTP scanning was meant to add additional resources for providers to evaluate patients for stroke intervention. It was not added in an attempt to reduce the number of CTA performed on stroke patients.

Objective two did demonstrate that in this study, CTP scans allowed for a larger percentage of its patients to receive mechanical thrombectomy than CTA alone. A large component of this was due to CTP's ability to show salvageable penumbra even in patients presenting up to 24 from last known well. In fact, two patients in this study received mechanical thrombectomies after the 20-hour mark both without complications. These findings were in line with the DEFUSE 3 and DAWN trials which demonstrated that mechanical thrombectomies could be safely performed in the extended window of 16 hours and 24 hours respectively (Campbell et al., 2019). Both of these trials were stopped early due to overwhelming success of endovascular intervention in both trials (Bucke et al, 2018).

Complication rates between CTA and CTP were not found to be statistically significant, with a p value of 0.207, even though the CTP group had a higher percentage of complications. It is important to note that the CTP group complication rate is slightly higher than the national average. Even with the higher complication rate, CTP scans did allow two patients to receive MT in the 20-24-hour window from symptom onset without complications. These findings support the need for additional research to evaluate best practice screening tools with the new extended window. More research is needed to determine if additional exclusion criteria is necessary for patients receiving a mechanical thrombectomy in the extended window, following the same model as IV tPA.

Finally, the change in admission to discharge NIHSS was found not be statistically significant. However, the data favored the patients who were in the CTA group. This can be explained in part due to the CTA group on average presented earlier and had lower NIHSS scores. Literature supports the study findings, with their emphasis that increased time to reperfusion results in increased disability (Sacks et al., 2018; Campbell et al., 2018)). In addition, some in the CTP group originally presented with lower NIHSS scores and then developed worsening symptoms and that triggered endovascular intervention. This impacted the average improvement from admission to discharge in the CTP group by making some patients appear to have worsening neurological function post intervention.

Implications for Practice

The findings from this study are a promising start in showing the safety and efficacy for performing mechanical thrombectomies in the new extended window of up to 24 hours from last known well. Allowing more patients to have the opportunity to receive stroke intervention is a step in lowering the high disability rates related to stroke. In addition, several of the patients that underwent mechanical thrombectomies due to severe strokes had issues with dysphagia post mechanical thrombectomies; many patient's families did not want a surgically placed feeding tube, so patients were transitioned to comfort care and hospice. Developing a process to talk to families about long term recovery and possible surgical interventions post mechanical thrombectomy may allow for a better understanding of goals of care between providers and the patient's family.

Implications for Future Study

This research study highlights the necessity for additional research in evaluating the impact of CTP scan on acute ischemic stroke patients for intervention. Future research should analyze the financial impact of the extended mechanical thrombectomy window in comparison to medical management alone. This would allow for better understanding of the impact of the extended stroke intervention window on health care cost. Another area of research should focus on developing longitudinal data by following these stroke patients for one year to fully capture their neurological recovery. An extended research period would provide more comprehensive data on the impact of mechanical thrombectomy on the patient's overall quality of life in the extended verses the traditional intervention window.

Limitations

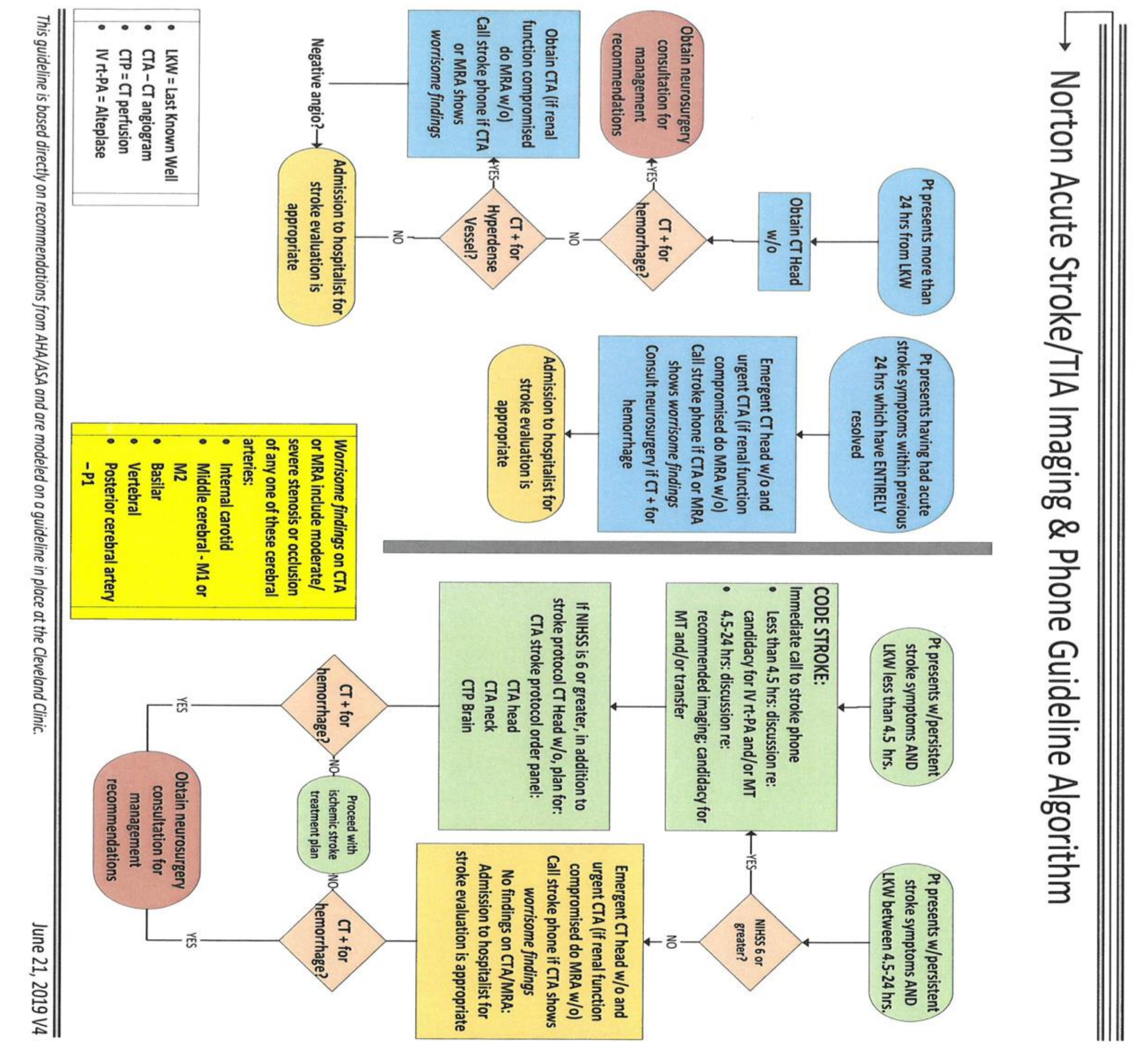
There are multiple limitations to this study. First, this was a small study from a single site in a community-based hospital. The majority of the patients who met the inclusion criteria were white, and while this represented the demographic of the community, these findings may not be generalizable in a large urban setting. Additionally, due to time limitations, we were unable to use a 90-day modified Rankin score (mRS) to measure functional neurological recovery. The mRS would have provided a more complete picture of each patient's neurological recovery post mechanical thrombectomy than the change in NIHSS from admission to discharge. Finally, due to the newness of the extended window for stroke intervention there are no longitudinal data to compare outcomes.

Conclusions

This data from this study suggests that patients can safely receive mechanical thrombectomies in the extended window of up to 24 hours with proper evaluation with use of CTP imaging and strong clinical exam. Additional research is need to continue to strengthen the evaluation process and to better understand perfusion imaging's role in patient selection. Lastly, even as healthcare researchers and clinicians work to extend the window for stroke intervention, it must be remembered that every moment counts and that stroke intervention should be completed as quickly as possible in a manner that is safe for the patient. This highlights the importance of CSCs in developing protocols and processes to evaluate and intervene for stroke patients in a timely fashion that follows best practices.

Appendix

A Norton Acute Stroke/TIA Imaging & Phone Guideline Algorithm



Norton Acute Stroke/TIA Imaging and Phone Guideline Algorithm Summary

- If patient presents more than 24 hrs from last known well (LKW), a stat CT brain w/o contrast and admission to hospitalist for routine stroke evaluation is appropriate. o If CT is + for hemorrhage — consult neurosurgery o If CT is + or suspicious for hyperdense vessel, obtain CTA (or MRA if renal function compromised). Call stroke phone for worrisome findings. If vessel imaging is negative admission to hospitalist for routine stroke evaluation is appropriate.

- If patient presents within 4.5 hours of LKW and has persistent symptoms, immediate call to stroke phone is appropriate with discussion re: candidacy for IV rt-PA and/or MT as well as recommend imaging. In addition to stroke protocol CT brain w/o contrast, plan for stroke protocol order panel CTA head/neck and CTP brain if NIHSS if greater than 6.

- If patient presents between 4.5 and 24 hrs from LKW AND has NIHSS 6 or greater, immediate call to stroke phone is appropriate for discussion re: candidacy for MT. In addition to stroke protocol CT brain w/o contrast, plan for stroke protocol order panel CTA head/neck and CTP brain.

- If patient presents between 4.5 and 24 hrs from LKW with NIHSS less than 6, stat CT brain w/o contrast and urgent CTA (if renal function is compromised do MRA w/o). Call to stroke phone if CTA/MRA shows worrisome findings.
- Worrisome findings on CTA/MRA include moderate/severe stenosis or occlusion of:
    - Internal carotid artery, Middle cerebral artery: Ml or M2, Basilar artery, Vertebral artery, Posterior cerebral artery: PI

- If patient presents having had acute stroke symptoms within 24 hrs prior to arrival which have entirely resolved, stat CT brain w/o contrast and urgent CTA (if renal function is compromised do MRA w/o). Call to stroke phone if CTA/MRA shows worrisome findings.
- Worrisome findings on CTA/MRA include moderate/severe stenosis or occlusion of:
- Internal carotid artery, Middle cerebral artery: Ml or M2, Basilar artery, Vertebral artery, Posterior cerebral artery: PI

This guideline is based directly on recommendations from AHA/ASA and are modeled on a guideline in place
at the Cleveland Clinic. June

Appendix B ICD 10 Codes for Acute Ischemic Stroke

ICD-IO-CM Code	Description
16300	Cerebral infarction due to thrombosis of unspecified precerebral artery
163011	Cerebral infarction due to thrombosis of right vertebral artery
163012	Cerebral infarction due to thrombosis of left vertebral artery
163019	Cerebral infarction due to thrombosis of unspecified vertebral artery
16302	Cerebral infarction due to thrombosis of basilar artery
163031	Cerebral infarction due to thrombosis of right carotid artery
163032	Cerebral infarction due to thrombosis of left carotid artery
163039	Cerebral infarction due to thrombosis of unspecified carotid artery
16309	Cerebral infarction due to thrombosis of other precerebral artery
16310	Cerebral infarction due to embolism of unspecified precerebral artery
163111	Cerebral infarction due to embolism of right vertebral artery
163112	Cerebral infarction due to embolism of left vertebral artery
163119	Cerebral infarction due to the embolism of unspecified vertebral artery
16312	Cerebral infarction due to embolism of basilar artery
163131	Cerebral infarction due to embolism of right carotid artery
163132	Cerebral infarction due to embolism of the left carotid artery
163139	Cerebral infarction due to embolism of unspecified carotid artery
16319	Cerebral infarction due to embolism of other precerebral artery
16320	Cerebral infarction due to unspecified occlusion or stenosis of unspecified precerebral artery
163211	Cerebral infarction due to unspecified occlusion or stenosis of right vertebral arteries
163212	Cerebral infarction due to unspecified occlusion or stenosis of left vertebral arteries
163219	Cerebral infarction due unspecified occlusion or stenosis of unspecified vertebral arteries
16322	Cerebral infarction due to unspecified occlusion or stenosis of basilar arteries
163231	Cerebral infarction due to unspecified occlusion or stenosis of the right carotid arteries

163232	Cerebral infarction due to unspecified occlusion or stenosis of left carotid arteries
163239	Cerebral infarction due to unspecified occlusion or stenosis of unspecified carotid arteries
16329	Cerebral infarction due to unspecified occlusion or stenosis of other precerebral arteries
16330	Cerebral infarction due to thrombosis of unspecified cerebral artery
163311	Cerebral infarction due to thrombosis of right middle cerebral artery
163312	Cerebral infarction due to thrombosis of left middle cerebral artery
163319	Cerebral infarction due to thrombosis of unspecified middle cerebral artery
163321	Cerebral infarction due to thrombosis of right anterior cerebral artery
163322	Cerebral infarction due to thrombosis of left anterior cerebral artery
163329	Cerebral infarction due to thrombosis of unspecified anterior cerebral artery
163331	Cerebral infarction due to thrombosis of right posterior cerebral artery
163332	Cerebral infarction due to thrombosis of left posterior cerebral artery
163339	Cerebral infarction due to thrombosis of unspecified posterior cerebral artery
163341	Cerebral infarction due to thrombosis of right cerebellar artery
163342	Cerebral infarction due to thrombosis of left cerebellar artery
163349	Cerebral infarction due to thrombosis of unspecified cerebral artery
16339	Cerebral infarction due to thrombosis of other cerebral artery
16340	Cerebral infarction due to embolism of unspecified cerebral artery
163411	Cerebral infarction due to embolism of right middle cerebral artery
163412	Cerebral infarction due to embolism of the left middle cerebral artery
163419	Cerebral infarction due to embolism of unspecified middle cerebral artery

163421	Cerebral infarction due to embolism of right anterior cerebral artery
163422	Cerebral infarction due to embolism of left anterior cerebral artery
163429	Cerebral infarction due to embolism or unspecified anterior cerebral artery
163431	Cerebral infarction due to embolism of right posterior cerebral artery
163432	Cerebral infarction due to embolism of the left posterior cerebral artery
163439	Cerebral infarction due to embolism of unspecified posterior cerebral artery
163441	Cerebral infarction due to embolism of right cerebellar artery
163442	Cerebral infarction due to embolism of left cerebellar artery
163449	Cerebral infarction due to embolism of unspecified cerebral artery
16350	Cerebral infarction due to unspecified occlusion or stenosis of unspecified cerebral artery
163511	Cerebral infarction due to unspecified occlusion or stenosis of right middle cerebral artery
163512	Cerebral infarction due to unspecified occlusion or stenosis of left middle cerebral artery
163519	Cerebral infarction due to unspecified occlusion or stenosis of unspecified middle cerebral artery
163521	Cerebral infarction due to unspecified occlusion or stenosis of right anterior cerebral artery
163522	Cerebral infarction due to unspecified occlusion or stenosis of left anterior cerebral artery
163529	Cerebral infarction due to unspecified occlusion or stenosis of unspecified anterior cerebral artery
163531	Cerebral infarction due to unspecified occlusion or stenosis of right posterior cerebral artery
163532	Cerebral infarction due to unspecified occlusion or stenosis of left posterior cerebral artery
163539	Cerebral infarction due to unspecified occlusion or stenosis of unspecified posterior cerebral artery
163541	Cerebral infarction due to unspecified occlusion or stenosis of right cerebral artery
163542	Cerebral infarction due to unspecified occlusion or stenosis of left cerebellar artery

163549	Cerebral infarction due to unspecified occlusion or stenosis of unspecified cerebral artery
16359	Cerebral infarction due to unspecified occlusion or stenosis of other cerebral artery
1636	Cerebral infarction due to cerebral venous thrombosis, nonpyogenic
1638	Other cerebral infarction
1639	Cerebral infarction, unspecified
16521	Occlusion and stenosis of right carotid artery
16522	Occlusion and stenosis of left carotid artery
16523	Occlusion and stenosis of bilateral carotid arteries
16529	Occlusion and stenosis of unspecified carotid artery
16601	Occlusion and stenosis of right middle cerebral artery
16602	Occlusion and stenosis of left middle cerebral artery
16603	Occlusion and stenosis of bilateral middle cerebral arteries
16609	Occlusion and stenosis of unspecified middle cerebral arteries
16611	Occlusion and stenosis of right anterior cerebral artery
16612	Occlusion and stenosis of left anterior cerebral artery
16613	Occlusion and stenosis of bilateral anterior cerebral arteries
16619	Occlusion and stenosis of unspecified anterior cerebral artery
16621	Occlusion and stenosis of right posterior cerebral artery
16622	Occlusion and stenosis of left posterior cerebral artery
16623	Occlusion and stenosis of bilateral posterior cerebral arteries
16629	Occlusion and stenosis of unspecified posterior cerebral arteries
1663	Occlusion and stenosis of cerebellar arteries

Tables

Table 1 Demographic characteristics and Past medical History

	Computed Tomography Angiogram (CTA) (n=129) Mean (SD) or n%	Computed Tomography Perfusion (CTP) (n=73)	p
Age	69.4(14.5)	68.23 (15.0)	.591
Gender			0.142
Male	67(51.9%)	46(63%)	
Female	62 (48.1%)	27(37%)	
Race			0.057
White	112(86.8%)	56 (76.7%)	
African American	13 (10.1%)	16 (21.9%)	
Hispanic	1 (0.8%)	0 (0%)	
Asian	0(0%)	1 (1.4%)	
Past Medical History			
Atrial Fibrillation	32(24.8%)	9 (12.3%)	0.075
Hypertension	85 (65.9%)	54 (74.0%)	0.403
Hyperlipidemia	53 (41.1%)	33 (45.2%)	0.656
Diabetes Mellitus	27 (20.9%)	21 (28.8%)	0.354
OSA	9 (7.0%)	7 (9.6%)	0.611
Smoking	23 (17.8%)	11 (15.1%)	0.655
Heart Failure	9 (7%)	12 (16.4%)	0.065
Stroke/TIA	27 (20.9%)	25(34.22%)	0.092
Substance Abuse	4 (3.1%)	3 (4.1%)	0.530
Cancer	6 (4.7%)	12 (16.4%)	0.015

Table 2. Clinical Characteristics

	CTA (n=129)	CTP (n=73)	P
Time from LKW	4.79 (5.27)	5.34(6.51)	0.543
Admission NIHSS	8.39 (8.02)	9.56(7.66)	0.305
Change in NIHSS	3.48(7.23)	1.15(10.05)	0.075

Table 3 Intervention Results

	CTA (n=129)	CTP (n=73)	P
Mechanical thrombectomy Rates	36(27.9%)	26(35.6%)	0.254
Complication Rates	3(8.3%) *	5(19.2%) *	0.262

*Complication rates were based on the number of patients that received mechanical thrombectomies with CTA (n=36) and CTP (n=26)

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