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Optimizing the Care of Pediatric Patients with Stroke and Stroke-like Symptoms Using a Pathway that Supports Efficient Use of Expertise Across Multiple Disciplines for Time-Sensitive Response

Pediatric stroke is a critical health concern that demands urgent attention and comprehensive diagnostic measures due to its potential for severe morbidity and mortality in children. The incidence of pediatric stroke in the United States has been estimated to be approximately ten cases per 100,000 children. However, the true prevalence is likely higher, given the diverse and often subtle ways stroke can manifest in pediatric patients. Unlike in adults, where the signs of stroke are well-known and widely publicized, the heterogeneity of presentations in children, combined with a lack of widespread suspicion for stroke, poses a significant challenge to accurate diagnosis.

While the typical adult stroke presents as a sudden focal deficit in speech or movement, pediatric strokes can take on a variety of forms, including seizures, altered mental status without a clear focal deficit, or headaches. Moreover, the high-risk population for pediatric stroke is itself heterogeneous, encompassing those with congenital heart disease, history of veno-arterial life support (ECLS) where the carotid artery is ligated, a host of congenital malformations, trauma, and infections unique to children. The combination of a heterogeneous presentation and heterogeneous high-risk population in combination with the rarer occurrence of stroke in pediatrics makes pediatric stroke patients particularly vulnerable to misdiagnosis and delayed identification, both of which contribute to unfavorable outcomes.

Adding to the complexity, management strategies that have been proven to be effective for stroke care rely on timely diagnosis and interventions that need to be implemented within a very small window of time from onset of symptoms. The urgency to educate pediatric providers and establish efficient processes for diagnosis and management is heightened, given the potential for high morbidity if strokes are overlooked. The consequences of overlooking or delaying the diagnosis of pediatric stroke can be devastating, as early intervention is crucial for mitigating long-term effects and improving outcomes. Recognizing acute stroke promptly and activating pathways for swift evaluation and intervention poses a persistent challenge for children's hospitals, emphasizing the critical need for enhanced awareness and streamlined protocols in pediatric stroke care.

The focal point of this project aims to specifically address pediatric stroke identification, diagnosis and treatment. By establishing a pediatric code stroke protocol that can be used to urgently bring expert attention to the bedside with speed and efficiency, pediatric patients identified as having acute stroke can potentially benefit from timely interventions and prevent a lifetime of severe neurologic sequelae. Just as it was important to educate that heart disease is not just a disease of males and breast cancer is not just a disease of females, it is important to educate that stroke is not just a disease of adults. In fact, stroke is more challenging to diagnose in children because of the diversity of high-risk populations and the variety of presentation features. Understanding and addressing these differences are crucial for accurate and timely diagnosis and to decrease the risk of oversight. These differences in diagnosis as compared to adults combined with the long-term morbidities associated with survivors of pediatric stroke make having a system in place to efficiently address this issue a must and is currently a gap in our clinical care. This population requires specialized attention due to the unique nature of their symptoms

and the potential for misdiagnosis underscoring the need for a sensitive and well-coordinated healthcare system capable of swiftly identifying children at high risk. Establishing protocols that enhance awareness among healthcare professionals, caregivers, and the community is imperative. This involves recognizing stroke as an emergency, educating healthcare providers about the unique signs of pediatric stroke, and ensuring timely access to specialized care. By prioritizing the development of such a system, we can significantly reduce the impact of pediatric stroke on the lives of affected children and their families, ultimately safeguarding the well-being of this particularly vulnerable population.

I am interested in addressing this critical issue here at UNC for several compelling reasons. Firstly, we are fortunate to possess a wealth of expertise within our institution, encompassing a multidisciplinary team of specialists in pediatric neurology, pediatric critical care medicine, pediatric interventional radiology, and various other disciplines. While this expertise is a valuable asset, the urgency and complexity of stroke management demands the creation of a streamlined process to leverage this knowledge effectively. Secondly, I am interested in improving clinical outcomes for this vulnerable patient population. Drawing on over a decade of experience as a faculty member at UNC, particularly in critical care initiatives, I recognize the need for a structured support system to implement innovative ideas successfully. In the past couple of years, I have been spearheading the pediatric neurocritical care consortium where I have been consistently astounded by the passion and expertise of the members in the group while being humbled by the need for more support to help implement ideas and foster growth. The Improvement Scholars Program would provide the platform to address this critical need and provide an invaluable opportunity for me to hone my skills in implementing a sustainable multi-disciplinary improvement project.

Our team has initiated the process of a pediatric code stroke protocol at UNC. We have identified representatives from each of the crucial areas involved in stroke care to cover the pager. These areas include adult neurology given their expertise as well as their in-house staffing, pediatric neurology for pediatric specific considerations, pediatric critical care for patient management and implementation of neuroprotective care measures, pediatric anesthesiology as pediatric patients often need anesthesia to complete imaging, pediatric radiology for assistance in obtaining rapid imaging, and pediatric pharmacy to assist with medications such as thrombolytics which are often difficult to dose in pediatrics. As part of the process, we have attempted to educate staff across all areas of the children's hospital including emergency room, wards, and clinics as well as those physicians who triage phone calls for admission from outside hospitals. We acknowledge the challenge given the breadth of spaces where children at risk of stroke may be cared for and the ever-constant staffing changes. Finally, the group has created and published a guideline for management of acute stroke at UNC to guide staff in the process.

With or without a process, pediatric patients with acute stroke will continue to present to UNC. In order to prevent patient harm and reduce morbidity, it is imperative that we establish as efficient a process for diagnosis and management of these patients. There are established expert-recommended strategies and approaches to pediatric stroke care, but they are time sensitive and reliant on a multi-disciplinary approach to be able to work together effectively. It is also important to recognize that as we are an adult stroke center, adult protocols may be extrapolated to our pediatric patients even though those protocols do not meet expert recommendations as set forth by national societies for pediatric stroke. As an example, many pediatric patients are rushed to CT imaging as opposed to MRI as the recommended imaging of choice exposing pediatric patients to unnecessary testing, unnecessary exposure to radiation, and delay in diagnosis and treatment.

Since its inception in late 2021, the pediatric code stroke system has been activated approximately 50 times. In 2023, there were 25 code stroke calls that our team is aware of. Eight of these calls identified an acute stroke. Encouragingly, our efforts have yielded notable successes, exemplified by a recent case involving a 12-year-old displaying signs and symptoms of acute stroke. The code stroke process facilitated the rapid administration of thrombolytic therapy, resulting in timely treatment and the patient's subsequent recovery and discharge. However, the process is far from effective to the extent that is necessary for the safety and well-being of our pediatric patients. Looking at the number of consults placed to the pediatric neurology service where stroke was on their differential, we know that the number of code stroke calls during this time period should have been higher. The case of a nine-year-old patient with sickle cell disease and chronic pain issues serves as a poignant illustration of the critical need for an efficient and well-coordinated system for code stroke response. Despite the red flags in the patient's history, such as a recent retinal artery occlusion and a worsening headache accompanied by a change in mental status, the lack of an organized process led to significant delays in her care. The absence of a swift recognition-to-intervention pathway resulted in ordering a CT with contrast, which, while not the ideal initial study for stroke, was pursued without consultation with pediatric neurology. The failure to establish timely intravenous access further prolonged the diagnostic process, as hours passed before completing the necessary imaging. Ultimately, nine hours passed from the time of severe headache to first seizure which is what prompted a pediatric rapid response that then led to a pediatric code stroke activation. The delay in stroke care for this patient led in part to her devastating and ultimately fatal neurologic outcome. The failure to engage key stakeholders, such as neurology, radiology, and the pediatric ICU, highlights the necessity of fostering a culture that encourages early and proactive pediatric code stroke activation. Such a system would prioritize expert consultation, rapid diagnostic measures, and collaborative efforts to ensure the timely implementation of appropriate interventions for our vulnerable pediatric patients, thereby enhancing the chances of a positive outcome for patients with heightened stroke risk.

Some of the challenges we have seen facing the pediatric code stroke protocol here at UNC involve the dissemination of information. As many are familiar with the adult code stroke protocol and many staff cross cover adult and pediatric units, it is a challenge to educate regarding a dedicated pediatric pathway and clarifying the distinctions between the pediatric and adult code stroke processes. There exist many differences between the two protocols including the composition of the code stroke team which includes some adult providers further adding to confusion, imaging modalities, inclusions and exclusions for treatment, and types of stroke specific to pediatric populations. Additionally, tracking pediatric code stroke calls, identifying missed opportunities, and establishing clear metrics for success have presented ongoing challenges that need to be better defined. Other challenges include the fact that our adult colleagues are tasked with the responsibility of attending to adult code strokes but also to assist in pediatric code stroke calls. Unlike in free standing children's hospitals, it remains challenging for our adult colleagues to recognize the nuances between the two protocols during their response which further underscores the need for broad education. Recognizing the need for a systematic approach to identify bottlenecks and issues, we are committed to developing a well-structured plan for the efficient rollout and sustained success of our pediatric code stroke program, ensuring that all team members are well-equipped to handle these critical situations.

In fostering a proactive and patient-centric healthcare environment, it is imperative to cultivate a culture within the organization that encourages the early and frequent activation of a pediatric code stroke without the fear of blame. Aligning with the principles of Carolina Quality Initiatives, we aim to establish a just culture that prioritizes learning and improvement over assigning blame. Creating an atmosphere where healthcare professionals feel empowered to call a pediatric code stroke without hesitation fosters

rapid response and timely intervention, ultimately benefiting the patient's outcome. This cultural shift requires a collective commitment to putting aside hierarchical structures and egos, emphasizing collaboration and shared responsibility. By promoting open communication, mutual respect, and a focus on continuous learning, we can create a unified medical system that prioritizes patient well-being and ensures that every member of the team plays a crucial role in optimizing stroke care. Clear and concise communication with adequate mutual support and just culture are also ingrained in the children's hospital through TeamSTEPPS training. Just as with other emergency response systems already in place at UNC, TeamSTEPPS will be an integral part of the pediatric code stroke process.

Pediatric patients with symptoms of acute stroke can present in various hospital settings including the pediatric emergency room, pediatric oncology clinic, referrals from outside hospitals, and even inpatient areas. Furthermore, patients often need to transition between these different care settings as they undergo evaluation and treatment, for example presentation to the clinic, transfer to the ER, and ultimately admission to the PICU. A comprehensive process is needed to ensure standardized care across these diverse settings. To improve care delivery and minimize misdiagnosis and harm, stroke must remain ever present on the differential for a variety of presenting symptoms and for a breadth of underlying medical conditions in the pediatric population. Over the course of the last two years as our group has been looking over cases here at UNC, we have seen an average of one to two cases per month necessitating urgent evaluation and management. Unfortunately, it is exactly these cases that are both urgent in nature and just rare enough to necessitate a strong, efficient process requiring ongoing education and training. Implementing a standardized care pathway will ensure that each pediatric patient falling within the defined criteria receives prompt and appropriate attention no matter their initial point of contact. We have seen such endeavors work well in other children's hospitals such as CHOP but also within our own institution on the adult side. A pediatric process would align with the high standards set by the comprehensive stroke center for adults while encompassing features unique to pediatric stroke.

When I think about process measures for pediatric code stroke, I break it down into four parts. In this table, I am attempting to evaluate each of these parts.

- 1) **Recognition** of stroke (second process measure)
- 2) **Communication**: Knowing the process of calling a code stroke (fourth process measure)
- 3) **Evaluation**: Expert neurologic evaluation at the bedside (first process measure)
- 4) **Diagnosis**: Time to imaging/correct imaging (third process measure)

MEASURE NAME	MEASURE TYPE	MEASURE CALCULATION	MEASURE EXCLUSION	DATA SOURCE	BASELINE	GOAL	COLLECTION FREQUENCY
Time to patient assessment (NIH scoring) from code stroke call/admission	Outcome	NIH score documentation in chart – time of code stroke call	Time of code stroke call for patients who are en route to hospital will be arrival time to UNC	EMR	60 mins	15 mins	Monthly
Time from admission/arrival to ED/floor/ICU to calling code stroke	Outcome	First documentation of mental status changes in the EMR that should trigger stroke as a differential		EMR	Baseline for ED is 15 mins. Baseline for inpatients is 60 mins	15 mins	Monthly
Time to imaging from code stroke call/admission	Outcome	MRI (CT will also count) start time –	Time of code stroke call for patients who are	EMR	120 minutes	60 mins	Monthly

		time of code stroke call	en route to hospital will be arrival time to UNC				
% of patients with acute stroke diagnosis without code stroke call	Process	Numerator: # of code stroke calls positive for stroke Denominator: # of patients diagnosed with acute stroke		EMR (billing, peds neuro consults for stroke)	50%	75 – 100 %	Monthly
% of patients with code stroke call without stroke (balancing the culture of calling often/not missing acute stroke vs resource utilization)	Balancing	Numerator: # of code stroke calls diagnosed with stroke Denominator: # of code stroke calls		Code stroke calls through operator	30%	30- 50%	Monthly

Once established here at UNC, a comprehensive pediatric stroke evaluation and management system could then be expanded to include other UNC Health system facilities and then ultimately to outlying hospitals in our catchment area. We have commitment from the departments of neurology, critical care medicine, and neurosurgery as evidence by our pediatric neurocritical care consortium that meets monthly. The key stakeholders in this monthly meeting include:

1. Casey Olm-Shipman, MD, MS. Vice Chair, Quality Improvement. Medical Director, Neuroscience ICU.
2. Varina Boerwinkle, MD. Division Chief, Child Neurology.
3. Valerie Jewells, DO. Professor of Neuroradiology

The pediatric critical care medicine division is also highly invested in the success of this project. As faculty in the division, I spearhead the pediatric neurocritical care monthly meetings and activities. My supervisor, Benny Joyner, MD, MPH also supports this endeavor not only as the chief of the division but also in his role as the Vice Chair of Quality and Safety in the department of pediatrics. Project team members would include those named here as well as others that attend our monthly meetings (nursing, nurse educators, other pediatric neurologists and pediatric intensivists, etc). Such a process would help close the gap in pediatric stroke care and promote collaboration across multiple subspecialties for enhanced patient as well as clinician and staff experience. There is clinical expertise here in both the division of child neurology and pediatric critical care. However, expertise does not translate to expert care. Staff want to deliver their best care when representing this hospital and our patients deserve our best as well. A well-established quality improvement project in this area could then also open the door to further research endeavors in this field.

Several factors will contribute to the success of the improvement project focused on code stroke for pediatric patients, while certain challenges may pose hindrances. One significant fostering factor is the wealth of expertise already present at the hospital. Leveraging the skills and knowledge of healthcare professionals, especially those with experience in pediatric care and stroke management, can significantly enhance the project's effectiveness. Passion for improving health outcomes in the pediatric patient population is another driving force. The shared commitment among team members to enhance care for young patients facing strokes will fuel the initiative and sustain momentum throughout the project. This collective dedication provides a solid foundation for overcoming challenges and driving positive change.

On the other hand, inherent complexities within a multidisciplinary team structure can present obstacles. Coordinating efforts across various specialties requires effective communication and collaboration. Overcoming silos and streamlining communication channels will be essential to ensuring a cohesive and efficient response to pediatric code stroke situations. Another potential hindrance is the existing culture of hesitancy, particularly when calling a pediatric code stroke involves mobilizing numerous experts during a period of limited resources. Addressing this challenge requires a cultural shift, transforming hesitancy into advocacy for the patient. Emphasizing the critical importance of early intervention for potential stroke cases, coupled with ongoing education and training, can help reshape the mindset, highlighting the urgency of not missing a treatable diagnosis. This cultural shift towards prioritizing patient outcomes over resource concerns will be pivotal in successfully implementing and sustaining improvements in the code stroke response system.

Our ultimate goal is to progress towards achieving the designation of a Comprehensive Stroke Center as outlined by the Joint Commission. Recognizing the distinctive challenges posed by pediatric stroke cases, we aspire to establish a robust pediatric stroke program within our healthcare system. We acknowledge that possessing expertise alone is insufficient; successful programs necessitate a solid foundation in guidelines and processes specifically tailored for recognizing, managing, and treating pediatric strokes. Drawing inspiration from successful models in children's hospitals, we understand that the creation of a pediatric stroke program is not a one-size-fits-all endeavor. While national guidelines provide a framework, the unique characteristics of each hospital demand a meticulous design of processes, taking into account local nuances, resources, and collaborative efforts. Our commitment extends beyond acquiring expertise; it involves the conscientious development of protocols and procedures that align with the distinctive needs of pediatric stroke patients and position us as a leader in providing comprehensive and specialized care.

Sustaining a successful and efficient code stroke process requires a dynamic approach encompassing continuous review, improvement, and ongoing education efforts. The first aspect involves establishing a dedicated team, as we have, that consistently reviews and reassesses the process. Regular monthly meetings, where pediatric stroke is a recurring agenda item, occur on the second Tuesday of each month at 1pm and serve as a valuable platform for discussing any emerging issues, evaluating recent cases, and identifying opportunities for refinement. This practice ensures that the process remains adaptable and responsive to the evolving needs of the patient population.

The second challenge, ongoing education efforts, can be addressed through a multifaceted approach. Regular lectures directed primarily towards physicians can provide updated information on best practices, new research, and advancements in stroke care. Additionally, on-the-ground simulations, conducted on a set schedule, offer hands-on experience and reinforce the procedural aspects of the code stroke response, enhancing preparedness among healthcare providers. Strategic signage placed around different units can serve as visual reminders, reinforcing the importance of the code stroke process and providing quick references for key steps. Quarterly participation in nursing and physician meetings allows for face-to-face engagement, fostering a sense of collaboration and shared responsibility. These interactions provide an opportunity to address any concerns, gather feedback, and ensure that the entire healthcare team is aligned with the established protocols.

In summary, sustaining an efficient code stroke process involves a combination of consistent process review within the existing team structure and a proactive approach to ongoing education. By implementing these measures, the healthcare system can maintain a high standard of care, ensuring that every team member is well-equipped and motivated to respond effectively to pediatric stroke cases.

Certainly, when addressing concerns about the time commitment for an improvement project focused on pediatric code stroke, it's important to emphasize that the team is already actively engaged in efforts to study and enhance the current process. By acknowledging that pediatric patients continue to present with strokes to the hospital, it becomes clear that the initiative is not only necessary but also urgent. Expressing a willingness to welcome the improvement project reinforces the team's commitment to optimizing the existing efforts and streamlining the system for greater efficiency. The goal is to effectively communicate that the team recognizes the importance of dedicating time to this initiative and views it as an opportunity to better organize and refine the current procedures, ultimately leading to improved outcomes for pediatric patients experiencing strokes.

In conclusion, my participation in the Improvement Scholars Program is fueled by a genuine commitment to advancing pediatric stroke care. The proposed project addresses a critical gap in quality, aligns with UNC Health's improvement priorities, and offers a structured approach to implementation. I am eager to contribute to this transformative initiative and leverage the mentorship and resources provided by the program to make a lasting impact on patient outcomes.

References:

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3. Letters of Support
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