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APPLYING HUMAN ERROR IDENTIFICATION TO ENHANCE STROKE CARE: A BRAZILIAN EXPERIENCE

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ABSTRACT
Stroke is the second leading cause of death and the third leading cause of combined death and disability worldwide, with a global cost exceeding $721 billion. In Brazil, it is one of the main causes of death, resulting in 11 deaths per hour. Stroke is a medical emergency that requires prompt treatment, as up to 1.9 million neurons can be lost every minute without intervention. Ischemic stroke can be treated with medications and procedures, positively impacting mortality, and disability rates. Chemical thrombolysis should be performed within 4.5 hours of symptom onset, while mechanical thrombectomy may be indicated between 8 to 24 hours if medication fails. Stroke patient care is complex and Human Reliability Analysis techniques, SHERPA, help identify vulnerabilities and improve the care process.
Results: Seventeen critical activities were identified and classified during the service. The most frequent errors were A2 (23%) and C4 (14%). The most critical activities occurred in opening the patient's medical record for the incorrect specialty (activity 1.1), making decisions about thrombolysis (activity 7), and the unavailability of technology (activity 10).
Actions: The protocol was updated and redesigned. The training model was restructured and included individual feedback. Signage was also implemented on the patient arrival form and a communication system with the internal regulatory center to ensure differentiated reception in the emergency room for patients with potential for thrombolysis. The application of the method and systemic changes resulted in improvements in service flow and response time in critical tasks (1 to 9). Although the number of patients is still small, in the first half of 2024, 11 patients were treated at the hospital and 10 received care according to the protocol.
Conclusion: HTA and SHERPA structured the prediction of human errors and reorganized activities with ergonomic principles, optimizing the implementation of the stroke protocol in the health service.

Keywords: Stroke Protocol, Stroke Care, HTA, SHERPA, Human Reliability Analysis, Human Reliability Tools, Patient Safety, Safety in Healthcare, Human Factors in Healthcare, Risk Assessment.

Topics A.17 Healthcare and Medical Industry, M.17 Human Reliability, M.25 Risk Assessment.

INTRODUCTION

In 2019, stroke was identified as the third leading combined cause of death and disability, as measured by disability-adjusted life years (DALYs), and the second-leading cause of death in the world, according to the Global Burden Disease (GBD) study. The economic impact was also alarming, with global costs exceeding 721 billion dollars (Abbasifa et al., 2021; Feigin et al., 2022). Despite a reduction in age-adjusted rates, the 2019 GBD analysis revealed a substantial increase in the annual number of strokes and related deaths between 1990 and 2019. These data reinforce the urgency of implementing effective primary prevention, rapid recognition, appropriate treatment, and rehabilitation strategies to address the growing impact of stroke on global health. In Brazil, the scenario is equally worrying. Stroke is one of the leading causes of death, resulting in 11 deaths per hour the Civil Registry of Brazil, in 2024 110.827 deaths from stroke were recorded, surpassing those caused by heart attack (CRC do Brasil, 2025).

Clinical definition Ischemic stroke is characterized by the sudden onset of focal or global neurological deficits, resulting from cerebral ischemia. This condition results from spontaneous obstruction of arterial flow in blood vessels that supply the brain, spinal cord, or retina. Diagnostics is confirmed by imaging tests, such as computed tomography (CT) or magnetic resonance imaging (MRI) (Caplan, 2019).

The expression "Time is brain" emphasizes the rapid loss of neural tissue during ischemia, with an estimated 1.9 million neurons lost per minute without treatment (Saver, 2006). Although each patient experiences an individual rate of neuronal loss over time without treatment, there is no doubt that faster intervention provides better outcomes (Gomez et al., 2018).

As recommended by the European Stroke Organization (ESO), the therapeutic window for thrombolysis can be extend up to 4.5 hours and window for thrombectomy varies between 6 and 12 hours. Furthermore, some scientific evidence points to the possibility of extension up to 24 hours treatment window, despite prompt intervention maximize long term benefits (Wardlaw et al, 2014; Oliveira-Filho et al, 2024).

The fragmentation and growing complexity of the socio-technical system widens the distance between the ideal and the practice. Guidelines from the American Heart Association (AHA) (William et al., 2019), European Stroke Organization (ESO) (Turc et al., 2022), and Brazilian Ministry of Health (BRASIL, 2021) emphasize the importance of early recognition, efficient screening, access to advanced therapies, and immediate rehabilitation.

As Hollnagel (Hollnagel, 2014) explains, Work as Imagined (WAI), the idealized version of tasks described in protocols, often diverges significantly from Work as Done (WAD), the reality of how tasks are performed in day-to-day practice. WAD reflects the continuous adaptations made to address challenges such as resource shortages, workload pressures, delays, and organizational barriers. In the context of ischemic stroke, this entails making decisions based on incomplete information, prioritizing limited resources, and modifying protocols to meet the specific needs of patients effectively.

Phipps et al. (Phipps et al., 2008) examined human errors in anesthetic practice, emphasizing the value of systematic methods like Hierarchical Task Analysis (HTA) and Systematic Human Error Reduction and Prediction Approach (SHERPA) to analyze tasks, predict failures, and address vulnerabilities. The combination of the two tools allowed a detailed overview of the tasks, identify areas of vulnerability, and propose improvements in the safety and effectiveness of care.

Ashour, Phipps, and Ashcroft demonstrated the effectiveness of SHERPA in identifying errors in community pharmacy dispensing, offering a more detailed analysis compared to FMEA, and highlighting its potential to enhance pharmaceutical care (Ashour, Phipps, & Ashcroft, 2022).

Guirro (Guirro, 2017) applied SHERPA to map infusion processes, demonstrating its effectiveness in identifying vulnerabilities and proposing mitigation strategies. The study emphasized the potential of systematic approaches like HTA and SHERPA to enhance safety and resilience in healthcare processes.

The integration of analysis tools, such as HTA and SHERPA, can contribute to the planning and implementation of specific actions, identifying system failures and promoting sustainable improvements. This approach could save lives and improve quality of life.

OBJECTIVE

Given the criticality of stroke, its high morbidity and mortality, the time-sensitive nature of its treatment as well as the complexity of care process, the use of tools to improve safety and efficiency is essential. These challenges become even more relevant in Brazilian National Public Health System (*Sistema Único de Saúde - SUS*) context, characterized by high volumes of care and limited resources. Tools such as HTA and the SHERPA can play a key role in identifying vulnerabilities and implementing improvements in critical processes in high-complexity environments, such as the emergency room, contributing to patient safety and operational efficiency. However, its applicability within healthcare domain remains inadequately explored, highlighting the need for further research to investigate its potential use in this context. In our hypothesis, the integration of human factors engineering tools in ischemic stroke care enables a comprehensive understanding of real-world clinical activities and enable analysis of interactions involved. Additionally, it allows for the estimation of possible failures, the redesign of processes and facilitation of steps. Finally, it also enhances the care team’s awareness of the inherent risks and variability within clinical context. This study aims to investigate the applicability of the HTA and SHERPA methodologies in the identification of critical tasks susceptible to human errors in stroke care workflow in the emergency room of a tertiary public hospital in Sao Paulo, Brazil. It seeks to gain a more detailed understanding of the identified vulnerabilities, supporting more effective adaptations and development of new stages in care protocol.

METHODS

This study was conducted between 2021 and 2024, in a public hospital in Sao Paulo, Brazil, which provides medium and high-complexity care, where the average number of eligible patients for treatment ranged from one to five per month.

The first work team was formed by a neurologist, a general practitioner, a physician specialized in continuous improvement and an emergency room clinical nurse.

This work team assessed 64 cases of patients eligible for thrombolysis, reviewing their care delivery and clinical histories, step by step, by examining medical records. Through collaborative meetings, using the brainstorming technique, team mapped the patient flow and care process as outlined in clinical guidelines (William et al., 2019; Turc et al., 2022; BRASIL, 2021). This mapping served as basis to enumerate HTA tasks and subtasks.

The continuous improvement physician and the neurologist carried out an on-site audit and multidisciplinary team discussions, determining HTA's final consensus, through a standard approach, adapted from Lane, Stanton and Harrison (Lane et al., 2006).

The literature review, data analysis and qualified application of tools were carried out by a second work team: two continuous improvement physicians specializing in human factors engineering, a physician specializing in emergency medicine and an HSE (Safety) Engineer.

HIERARCHICAL TASK ANALYSIS (HTA)

The method was applied based on its three fundamental principles (Annett & Stanton 2000; Stanton, 2006):

- First level (tasks): Identification of the overall objective, clinical decision-making and safe application of the proposed treatment. The work team evaluated patient's journey, from facility arrival, diagnosis, decision-making and treatment.
- Second level (subtasks): detailing the tasks that contribute to the system's goal. The team described actions that make up the main tasks, including transport between the phases of care, monitoring technique, safe administration of the recombinant intravenous human tissue plasminogen activator (rTPA). The level of detail required was determined by consensus among the first work team based on the relevance of actions, studying incidents and potential incidents in patient care at the institution.
- Review of hierarchical relationships: the work team ensured that subtasks were sequential, taking to account the system dynamics. They recognized the potential changes in the system's understanding, modifications in care flow, in the scientific relevance of recommendations in protocols, and shifts in epidemiology of both population and disease.

SYSTEMATIC APPROACH TO REDUCING AND PREDICTING HUMAN ERRORS (SHERPA)

SHERPA covers the interaction of human-machine systems, using cognitive models and recommendations on procedures and human performance (Embrey, 1986).

HTA tasks and subtasks were examined and classified according to the SHERPA tool.

1. Classification of behavior: action; recovery; verification; selection; communicate information.
2. Determination of possible credible errors: classification of the error's types. The error classification employed in SHERPA was adapted from the framework proposed by Baber & Stanton (Baber & Stanton, 2002).
3. Description of each error's consequences.
4. Determining the "recovery potential".
5. Assessing the likelihood of each error occurring, including where it is "recovered." These estimates were based on case analyses and incident reports from the institution. In evaluating the probabilities, the team considered specific aspects of institutional context, such as values, safety culture, epidemiological profile of patients, and sociocultural characteristics of the local health system (Phipps et al., 2008; Reddy et al, 2020).
6. Criticality assessment. The same method was used by, both in classification, probability and criticality of the error (Phipps et al., 2008; Reddy et al, 2020). Potentially fatal or permanent tasks and subtasks were characterized as critical and marked with the "!" symbol.
7. Suggestion of possible treatment and prevention strategies to avoid the occurrence or propagation of errors (equipment, training, guidelines and organizational flows).

The team reached consensus on the range for probability and criticality based on their collective experience. Once an error was identified, preventive and/or mitigating actions were determined and subsequently tested.

RESULTS

In developing the HTA, the team identified 17 tasks and 48 subtasks, covering the entire process from the patient's arrival at the healthcare facility to the outcome of the first care intervention, specifically thrombolysis and/or thrombectomy. Table 1 presents the steps at the hierarchical care level.

Table 1. HTA of acute and hyperacute stroke care tasks in a tertiary hospital in São Paulo, Brazil.

Table 1. HTA of acute and hyperacute stroke care tasks in a tertiary hospital in São Paulo, Brazil.

Identifier	Care Episode Tasks and Subtasks
1	File opening and screening
1.1	Reception opens file for Medical Clinic Doctor
1.2	Reception delivers form to triage nurse
1.3	Nurse performs reception
1.4	Nurse performs brief anamneses
1.5	Nurse performs Manchester classification
1.6	Nurse checks vital signs
1.7	Nurse writes down vital signs in the electronic medical record and form
2	Allocation of patients in the shock room
3	Patient monitoring
3.1	Electrocardiogram
4	Communication for medical care
4.1	Nurse communicates with clinical Doctor of Emergency Care
5	Initial medical attention (within 10 minutes)
5.1	Physical and neurological examination
5.2	Assessment of vital signs and blood glucose
5.3	Ordering laboratory tests
5.4	Evaluate electrocardiogram
5.5	Request CT scan
6	Non-contrast tomography (within 25 minutes)
6.1	Transport of the monitored patient to the CT room
6.2	Conducting the exam
6.3	Evaluation of the images in the CT room by the emergency physician
6.4	Transport of the monitored patient to the shock room
7	Clinical decision making - physician managing multiprofessional team, indication of thrombolysis
	If CT without bleeding and port symptom time <= 4.5 hours
7.1	Maintain Blood Pressure (BP) < 185 x 110 mm Hg
7.1.1	Nursing measures BP every 15 minutes
7.1.2	Nursing records BP measurement every 15 minutes
7.1.3	Doctor prescribes antihypertensive if BP < 185 x 110 mm Hg
7.2	Checking blood glucose
7.3	Check EGC - in the impossibility of previous evaluation
7.4	Check for thrombolysis contraindications
7.5	Ensure peripheral venous access
7.6	Apply NIHSS
7.7	Request thrombolysis / thrombolytic box (rTPA)
8	Thrombolysis within 60 minutes of hospital admission
8.1	Prescribe thrombolytic - 0.9 mg/kg IV, maximum 90 mg, 10% bolus and 90% in 60 minutes
8.2	Thrombolytic preparation (rTPA)
8.3	Preparation of the infusion pump
8.4	Dose bolus
8.5	Attack dose
8.6	Monitor SSVV with 15-minute interval
8.7	Nursing records BP measurement every 15 minutes
9	Conclusion of thrombolysis apply NIHSS scale
9.1	Secure record of other information in the medical record
	If thrombolysis reperfusion failure, signs of stroke between 4.5 h and 20h
10	CT angiography of intracranial and extracranial vessels
10.1	Transport of the monitored patient to the CT room
10.2	Conducting the exam
10.3	Evaluation of the images in the CT room by the emergency physician of the medical clinic
10.4	Transport of the monitored patient to the shock room

11	Clinical decision making - physician managing multiprofessional team
11.1	Evaluate CT angiography report
11.2	Evaluate time symptoms of symptoms
11.3	Indicate thrombectomy
12	Thrombectomy request via the São Paulo State Regulation Center and the Internal Regulation Center
12.1	Doctor actively activates controller duty to request a place for thrombectomy via the Regulation Center
12.2	Doctor fills out request for emergency external procedure
12.3	Doctor fills out requests for ambulance transport
13	Acceptance of the vacancy and preparation of the patient
13.1	Doctor prepares the patient's medical record
13.2	Nursing prepares equipment for patient transport
14	Safe Patient Wrapping in Transport Ambulance
15	Patient Exit by Ambulance for External Procedure
16	Bed reservation for patient return
17	Secure record of other information in the medical record

Table 1 (continued).

For each HTA task and subtask, SHERPA was applied. When the moderate and high probability tasks combined with the critical task, risk treatment measures were established (Table 2).
The most frequent errors were A2 (23%) and C4 (14%), followed by A7 (12%). The other errors had a frequency of less than 7% (see Table 4). Regarding probability, 54% were classified as low, 41.5% as moderate, of which 29.5% of the errors were of type A2. Errors with high probability were found in 4.5% of the tasks (types A3, I1 and A8, in subtasks 1.1, 1.7 and activity 10, respectively).
47.5% of the activities were classified as critical. Of these, 71% had a low probability, 22.5% moderate and 6.5% high.

Table 2. SHERPA simplified outcome (critical medium and high probability task) for stroke patient care.

Task	Task Classification and Human Error Identification	Error Description	Consequence	Recovery	Ordinal Probability Analysis (P)	Criticality Analysis (C)	Remedial Strategy
1.1	A3	Opening of form for Neurosurgery or for SADT Computed Tomography	Delay in protocol opening and potential loss of therapeutic window	None	H	!	Change in the communication of the Internal Regulation Center with the Regulation Center and concierge, reception, and emergency room employees.
1.6	C2	Nurse does not measure all vital signs (manual measurement)	Error in decision-making (hypoglycemia as a cause of neurological symptom), or failure to control systemic blood pressure (potential bleeding in thrombolysis or enlarged area of cerebral infarction)	Immediate task 1.6	M	!	Individual educational approach in all cases of failure
3	C2	Equipment unavailability (crowded emergency room, no backup)	Failure to recognize clinical deterioration	None	M	!	Handling for Technology Backup
5.2	C2	Nurse does not measure all vital signs (manual measurement)	Failure to recognize clinical deterioration	Immediate task 5.2	M	!	Individual educational approach in all cases of failure

6.3	C4	Insufficient medical expertise, inadequate assessment	Failure in decision-making	None	M	!	Individual educational approach in all cases of failure
7	S1 e S2	Insufficient medical expertise (doubts about indications and contraindications of thrombolysis)	Failure in decision-making	None	M	!	Individual educational approach in all cases of failure
7.1	A4	Failure to treat blood pressure disorder	Aggravation of the clinical syndrome, side effect bleeding.	7.1	M	!	Individual educational approach in all cases of failure
10	A8	Equipment unavailable (lack of resources)	Failure in decision-making	10	H	!	Patient referral by Regulation in Treatment Center
11.3	C4	Insufficient medical expertise, inadequate assessment	Failure in decision-making (indication of thrombectomy), increasing lethality and reducing the prevention of disabling sequelae)	11.3	M	!	Annual training in the protocol and Individual educational approach in all cases of failure

Table 2 (continued).

Table 3: Percentage of errors by classification.

HTA	N	Percentage
A1	1	2%
A2 Operation out of time due	15	23%
A3	2	3%
A4	1	2%
A5	3	5%
A7 Wrong operation on correct object	8	12%
A8	3	5%
A9	5	8%
C1	2	3%
C2	4	6%
C4 Wrong check on the correct object	9	14%
I1	3	5%
I3	4	6%
R2	1	2%
S1	2	3%
S2	4	6%

Of the critical activities, 67.5% were classified as low probability, 22.5% moderate and 9.5% high probability. Most of the critical activities occurred in the type A7 error (16%), although all of them had low probability. The sub activities of the action "thrombolysis within 60 minutes of admission to the hospital" (activity 8) were crucial point in the execution of the protocol.

The critical activities with high probability occurred in error related to the opening of the patient's medical record to the correct specialty (activity 1.1); in decision-making about thrombolysis (activity 7) and in the unavailability of technology (activity 10).

Subtask 1.1 (opening of the patient's medical record of the incorrect specialty) and task 10 (unavailability of technology: CT angiography) were classified as critical and high probability.

Based on the findings of SHERPA, Remedial Strategies were implemented (Table 2) among the critical errors:

- A communication mechanism was implemented, defining "time alert" eligible cases. The streamlining of internal flow, expedite care and reduce risk of misallocation to the wrong medical specialty, improved communication.
- Implementing an individualized approach and coaching sessions with on-site training prevents failure in decision-making.

- A contingency protocol was developed for the impossibility of using CT angiography.

The changes contributed to improve response time and greater adherence to best practices. In 2024, 91% of eligible patients received treatment according to guidelines, reflecting a positive impact on safety and quality of care. A comprehensive evaluation of results is currently underway, with ongoing analysis to ensure sustainable improvements.

DISCUSSION

The study explored the potential applicability of the HTA and SHERPA tools in analyzing critical tasks in management of acute ischemic stroke. The findings informed adjustments to activities associated with the clinical protocol, aiming to better align them with the institutional context. This approach suggests possible improvements in the design of care workflows and responses to critical tasks, such as screening and thrombolysis, highlighting areas for further investigation and optimization.

This integrated use is particularly valuable in overly complex tasks, such as the management of critical technologies or clinical protocols in the emergency, allowing us to identify not only where failures may occur, but also how interactions between different actors and devices need to be optimized. Hierarchical task analysis helps to understand dependencies and interrelationships between subtasks, while SHERPA allows predicting potential flaws specific to the design of institutional reality.

The approach can help to reduce redundant steps, facilitate communication, simplify workflow, and strengthen teamwork. The feedback to the operational team and the collaborative construction of a redesign brought many insights, creating more intuitive and safe flows, based on the detailed analysis of tasks and possible failures and greater collective awareness of interdependence and necessary adjustments.

The integration between HTA and SHERPA enables effective analysis of both task structures and human interactions. This method of information gathering, and team collaboration promotes a comprehensive perspective that goes beyond the simple identification of vulnerabilities, allowing for the collaborative development of a more resilient environment.

LIMITATIONS

Despite efforts to minimize subjectivity in assessing the probability and criticality (considering case discussions, incident reports, systemic cultural issues and specific characteristics of the epidemiological profile), the central component of the evaluation still presents a significant degree of subjectivity. This dependes on team's perception and methodological limitation in local audits, which restrict the generalizability of the obtained results.

The sample size proved to be limiting for significant quantitative and qualitative results to demonstrate improved on patients' health outcomes.

Another relevant point is the dependence on historic institutional data for steps validation, subject to information's collection or recording biases. The absence of robust data, such as multicenter analyses (study restriction to a single tertiary-level hospital), also limit the universal application of the proposed interventions, which hinders the findings generalizability to other contexts or populations.

POSSIBILITIES

The replication of the methodology in other scenarios and health networks can expand the evidence base on the use of human reliability analysis tools.

Incorporating quantitative analyses into future studies offers a valuable opportunity to refine and strengthen the proposed methodology. Expanding the sample size and increasing demographic diversity will enable the research to produce more robust and comprehensive insights into clinical outcomes and operational efficiencies associated with HTA and SHERPA.

Additionally, the integration of emerging technologies such as artificial intelligence, could improve error identification and failure prediction, thereby elucidating vulnerabilities in system interaction.

Another possibility is the expansion of tools application in other critical conditions such as acute myocardial infarction and sepsis, promoting systematic improvements in other clinical syndromes.

Finally, it is important to point out that, although tools such as HTA and SHERPA play a crucial role in improving hospital care, they are only part of a necessary systemic effort towards health. Comprehensive interventions including primary prevention and reducing complexity in interactions are key to ensuring better patient outcomes. Progress in this direction depends on interdisciplinary collaboration and institutional commitment to quality and safety in healthcare.

CONCLUSION

HTA and SHERPA were applied to structure the acute and subacute stroke patient care activities for human errors prediction and reorganize them

to ergonomic principles. This approach led to optimized implementation of clinical protocol within the hospital emergency department.
The study reinforces the importance of human factors management in the healthcare, particularly in highly complex environments.

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