



REVIEW ARTICLE

# Emergency Medical Services and Stroke Management: A Review of Current Guidelines and Practices

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Published online: 17 February 2025

## Abstract

The worldwide occurrence of strokes reaches around 15 million cases per year while these conditions persist in more than 100 million patients at once. Worldwide stroke stands as the second main cause of mortalities since 88% of all stroke deaths occur within low- and middle-income countries (LMICs). Emergency Medical Services establish critical intervention paths because they detect strokes early while providing immediate on-scene treatment and quick response times that directly affect patient recovery. The effectiveness of proposed quality indicators to improve prehospital stroke treatment remains unknown independently from other indicators. The research tackles the developing EMS functions in stroke management through an analysis which shows how prehospital triage tools together with telehealth integration and mobile stroke services shorten the door-to-needle period and improve patient treatment results. The potential of point-of-care diagnostic tools for stroke subtype identification gets investigated to identify their contribution to optimizing prehospital decision-making processes. The text examines crucial issues within prehospital stroke care such as restricted EMS service accessibility and minimal training support and inadequate evidence-based protocol data. The reduction of stroke mortality and improvement of patient recovery requires future research to focus on EMS collaboration with multilevel stakeholders through technology innovation and policy equality to optimize stroke management in underserved healthcare environments.

Keywords: EMS, Stroke, Afib, Ischemic Stroke, Hypertension, etc.

## INTRODUCTION

Stroke remains a leading cause of disability, mortality, and morbidity, particularly in developed nations such as

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the United States (Vos et al., 2016). Beyond its devastating impact on individual patients, stroke imposes significant financial burdens on society due to lost labor productivity and long-term nursing care requirements. With an ageing and growing population, the economic consequences of stroke are expected to escalate in the coming years (Writing Group Members, 2016). Given these challenges, emergency medical services (EMS) play a crucial role in the early recognition, triage, and management of stroke patients, directly influencing patient outcomes. EMS serves as the critical link between stroke onset and hospital intervention. Rapid identification and prehospital treatment can significantly improve patient prognosis by reducing delays in definitive care. Current guidelines from the American Heart Association (AHA) and the American Stroke Association (ASA) emphasize the importance of prehospital notification, allowing stroke centers to prepare for incoming patients, thereby optimizing assessment, testing, and treatment times (Morris et al., 2000). Traditionally, EMS response involved initial assessment by paramedics followed by transportation to the nearest hospital, where a neurologist, CT scan, and emergency room evaluation would take place (Alkhotani et al., 2022).

However, recent technological advancements have revolutionized stroke management within the EMS framework.

Innovations such as mobile stroke units (MSUs), telemedicine, artificial intelligence (AI)-driven diagnostics, and advanced prehospital imaging technologies have significantly enhanced EMS capabilities. MSUs, equipped with onboard CT scanners and stroke specialists via telemedicine, allow for immediate stroke diagnosis and thrombolysis administration before reaching the hospital, significantly reducing time-to-treatment (Schooley & Horan, 2015). AI-powered diagnostic tools assist EMS personnel in real-time decision-making by analyzing patient data to predict stroke severity and determine optimal treatment pathways. Additionally, cloud-based data sharing enables seamless communication between EMS teams and hospital stroke specialists, ensuring that resources are allocated efficiently before the patient's arrival. Given the evolving landscape of stroke care, EMS must continuously adapt to integrate these technological advancements. The future of EMS in stroke management lies in leveraging state-of-the-art computational tools, deep learning algorithms, and real-time remote monitoring to enhance prehospital decision-making and streamline hospital workflows. Addressing these opportunities will enable EMS to play a pivotal role in achieving and exceeding current stroke treatment goals, ultimately improving patient outcomes (McKinney et al., 2013).

## OVERVIEW OF STROKE

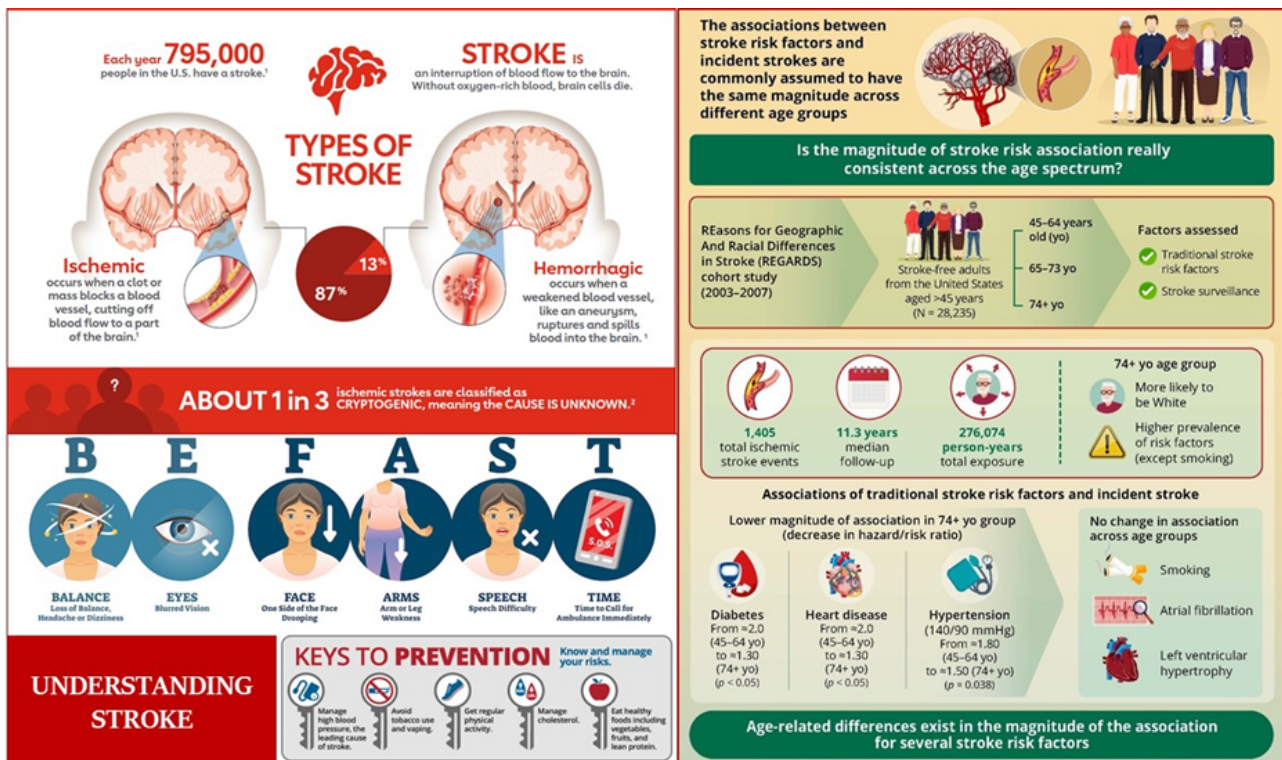
Stroke is the second largest cause of mortality worldwide and the third greatest cause of death and disability (GBD Stroke Collaborators, 2021). The number of incident strokes increased by 70%, prevalent strokes by 85%, stroke fatalities by 43%, and disability-adjusted life-years (DALYs) by 32% from 1990 to 2019 (Béjot et al., 2016). While age-standardized incidence rates have decreased, prevalence and incidence rates have grown by 22% and 15%, respectively, among those aged < 70. In addition to aggregate worldwide statistics, national and regional assessments show an increasing youth stroke burden (Bako et al., 2022). These "premature strokes" reduce productive years of life and predispose younger persons to longer-term sequelae and problems, including recurrent cerebrovascular episodes (Boot et al., 2020).

Current literature uses "premature stroke," "early-onset stroke," and "stroke among the young/young stroke" interchangeably. This may be because early stroke is not well-defined. Additionally, "young" and "juvenile" ages are not clearly defined. Lower restrictions are consistent at 18, while higher limitations span the decade between 45 and 55 years old, with 45 and 50 being the most popular. After 55, stroke incidence doubles every decade (Yousufuddin & Young, 2019). They also make up the lowest quartile of stroke age distribution, with a median of 60–65 years. We will analyze the subject using the 18–55 age range, which encompasses most relevant studies, to be more inclusive. As with older populations, IS accounts for 44–65% of incidence strokes in younger patients, followed by ICH (17–39%) and SAH (16–20%) (Kissela et al., 2012). To ensure inclusivity and comparability with prior studies, we selected the 18–55 age range, which aligns with most existing research on young stroke patients (Marini et al., 2010). Recent estimates show 11–28 strokes per 100,000 person-years

under 44, up from 5–17 in the 1990s (Madsen et al., 2020). This breakdown allows for a more nuanced analysis of risk factors, disease patterns, and sex-based differences within the young stroke population.

10–15% of stroke sufferers are young. However, significant youthful heterogeneity may make analysis difficult (Maaijwee et al., 2014). Although easy, considering the 18–55 age range as a monolith may ignore risk factor and etiology changes during adulthood. Even in young people, stroke incidence climbs exponentially between 15 and 50 (Putala et al., 2009). Thus, studying stroke epidemiology in young people aged 18–34, 35–45, and 46–55 may be useful. Stroke in the 18–34 age group is rare (Leppert et al., 2020), although women had a 26–56% greater risk of pre-mature IS than males, depending on stroke subtype (Tang et al. After 35, stroke incidence rises, with men at greater risk than females. Traditional risk factors drive this age-related stroke risk rise in men (Larrue et al., 2011). Stroke subtype changes with age. Patients over 40 had more lacunar and big artery strokes and less cardioembolic, cryptogenic, and "other" strokes (Jafari et al., 2021). Patient incidence rates in the 18–44 and 45–64 age groups have increased significantly during the last two decades in ICH populations (Kim, 2016). Sex modifies age and stroke risk in young people, especially in high-income nations. The worldwide statistics may show differing stroke risk trends for men and women.

The variable occurrence of stroke throughout different regions of the world depends upon multiple socioeconomic elements and environmental aspects and healthcare variables. Close to 89% of stroke-related DALYs together with 86% of stroke-related deaths occur within low-income to upper-middle-income countries. Private health care service deficiencies for treating acute strokes as well as poor public understanding among people and higher vulnerability to risk factors like hypertension, diabetes, and tobacco use are responsible for this unequal health gap (Owolabi et al., 2018). The world saw an increase in stroke burden during recent decades because population changes combined with growing metabolic risk factors together with environmental elements such as pollution and temperature variations. The pathologies of stroke differ between low-income nations where intracerebral hemorrhage frequently occurs and high-income nations with higher rates of subarachnoid hemorrhage (Feigin et al., 2021). Outside the United States, Boot et al. have shed light on early stroke distribution worldwide. Twenty per 100,000 person-years is the average rate of young stroke in North America, Australia, and Asia. European research shows a little lower incidence, whereas African cohorts treble it (Niu et al., 2014). Although stroke prevalence is greater in African nations, smoking rates have declined over the last several decades (van et al., 2018), and it is unclear how this may affect premature stroke rates. Asian youth had higher rates of large-vessel thrombosis and intra-cranial atherosclerosis than US youth (Handke et al., 2007). Moyamoya disease, a rare cerebrovascular illness, is frequently observed in Asian populations (Divišová et al., 2020), however it is unlikely to be the only cause of the rise in stroke among young people. Finally, a small Saudi Arabian cohort had significant rates of dyslipidemia (71.4%) and small vessel blockage (31.7%). Attributes may vary among foreign cohorts, but vascular risk factors are generally constant, with many risk variables in stroke patients (Tatlisumak et al., 2018). This universal risk-factor profile supports global youth intervention and improvement of modifiable vascular hazards.



**Figure 1: An overview of stroke. Type of strokes and prevention ways. Role of Risk Factors for Ischemic Stroke (Howard et al., 2004).**

Unlike older patients, most premature Ischemic stroke (IS) is cryptogenic (24–53%), followed by cardio-embolism (10–34%), big artery atherosclerosis (4–29%), and small vessel disease (12–26%) (George, 2020). Young people have up to 35% IS due to cervicospinal dissection (Parikh et al., 2020). Patent foramen ovale (PFO) is found in 40–56% of young cryptogenic strokes (Markidan et al., 2018), and hyperlipidaemia, hormonal contraception, and migraine with aura may increase cryptogenic stroke risk (Aigner et al., 2017). Young Intracerebral Hemorrhage (ICH) is usually caused by vascular malformation or hypertension, depending on the cohort (Roger et al., 2012). These data indicate significant variations in stroke aetiology and presentations between preterm and older populations.

Similar modifiable risk factors are related with premature IS and older populations. Smoking, hypertension, inadequate physical activity, and hyperlipidemia are major concerns for young people (Mszar et al., 2020). Even at this younger age, stroke incidence is rising with accumulated comorbidity. Risk factors and premature stroke features are covered (Mitchell et al., 2015).

Young IS aetiologies may vary from normal age groups, although their associated vascular risk factors are more similar. Smoking may be the biggest vascular danger for young individuals. According to Menet et al. (2018), smoking is prevalent in premature cohorts, with up to 44% of young IS patients smoking, compared to just 24% of elder stroke patients. Smoking enhances atherosclerotic and cardioembolic strokes dose-dependently (Ruixing et al., 2009). Smoking interacts with other IS factors such oral contraception and migraine to increase risk (Gialeraki et al., 2018).

Hypertension and inadequate physical exercise enhance IS risk like smoking (Li et al., 2019). Risks are higher in males and rise in the 35–44 and 45+ age groups, reflecting the shift in stroke risk from women to men (Kent

et al., 2013). Hypertension is less prevalent in young individuals, but its risk is increased (Chen et al., 2016), probably due to poor detection and treatment (Kottloor & Arora, 2018). Various obesity studies have produced conflicting outcomes. Recent research reveals that obesity increases IS risk in young adults (Kamel et al., 2016). After correcting for various factors, some studies revealed no relationship between obesity and stroke risk (Kuybu et al., 2020). High rates of dyslipidemia, another vascular risk factor for premature IS, are seen in men and children (MacClellan et al., 2007; Ortiz et al., 2018). Despite this relationship, the mechanism connecting lipid profiles to stroke is unclear (Ghaffari-Rafi et al., 2020).

Smoking causes hypertension and hyperlipidemia, and hypertension and hyperlipidemia are strongly linked (Yahya et al., 2020). Note that each of these characteristics is more prevalent in men and has the largest influence in the 35–55 age group, when stroke is more common in men (Vanakker et al., 2011). Young women may face additional dangers. Although pregnancy represents a gender-specific risk in younger age groups, it is currently linked to <5% of strokes in young women (Stack & Cole, 2021). Oral contraception and hormone replacement treatment enhance stroke risk via thromboembolic pathways (Bevan et al., 2012). A meta-analysis found a dose-dependent connection between oral contraceptive and stroke, with a 20% increase in IS risk for every 10- $\mu$ g dosage increase and 5 years of use (Lees, 2010). These variables provide age-dependent hazards for women, increasing stroke prevalence in younger age groups.

From this debate, modifiable risk factors for young IS are mostly hypertension- and pregnancy/hormone-related. These hazards are independent but may increase genetic and chronic illness risk (Gache et al., 2013). Since cryptogenic or other causes account for many IS in the young, various underlying disorders may increase IS risk. PFO, migraine with aura, Atrial Fibrillation (AFib), Fabry

disease, Moyamoya, and connective tissue diseases are of interest.

Patent Foramen Ovale is frequent. Most estimates imply that may affect 27% of the general population with variable sex differences (Gache et al., 2013). Cryptogenic stroke is more common, occurring in up to 62.6% of juvenile strokes of unclear cause (Lees et al., 2010). PFO also affects pregnancy and thrombosis (Bouckaert et al., 2009). PFO is common in the general population, therefore its causation with IS in young people is unclear (Li et al., 2018). However, observational findings link PFOs to stroke in individuals without additional risk factors (Mahawish et al., 2018), and surgical closure may lower young patients' recurrent stroke risk. PFO closure and anticoagulation diminish IS, however long-term anticoagulation at a young child may increase bleeding problems (Al-Jehani et al., 2020).

AFib, like PFO, disrupts blood flow and increases embolism risk, possibly aggravated by other systemic anomalies (Bayona et al., 2017). There is evidence that PFO increases atrial susceptibility and arrhythmia risk. Young stroke patients have decreased AFib rates, but it still poses a risk for IS. As with older populations, paroxysmal events may make Afib diagnosis difficult, leading to underreporting. Compared to migraine without aura, Afib is associated with migraine with aura. Due to vascular dysfunction, migraineurs are at risk for cardioembolic stroke. Young women are more likely to have migraine with aura, and smoking and oral contraceptives increase IS risk (Lindsay et al., 2014).

Fabry disease thickens bigger arteries due to lysosomal storage (Jin & Wang, 2016). The overall population has 1 stroke per 100,000, whereas 24–48% of Fabry disease patients have one, especially at 28–54 years old (Alexandrov & Alexandrov, 2020). Unlike hereditary Fabry disease, Moyamoya diagnosis is unknown. Moyamoya, which narrows cranial arteries, is more common in low-income and urban adults under 50 (Hersh et al., 2006). Females, 18–44-year-olds, and Asian/Pacific Islanders are also at risk, with Japanese cohorts being particularly high (Kane-Gill & Rincon, 2019). Moyamoya increases hemorrhage risk and IS risk (Demaerschalk et al., 2009).

As PFO is connected to cryptogenic stroke, Fabry Disease and Moyamoya to atherosclerosis, connective tissue diseases may cause cervicospinal dissection. Here, Ehlers-Danlos, fibromuscular dysplasia, and Marfan syndrome may be examined (Varughese et al., 2021). These genetic abnormalities enhance blood vessel fragility and stroke risk (Xiao et al., 2000). This raises trauma risks and cervical artery dissection. While there are few ways to reduce these risks, a new view suggests assessing traumatic triggers in young stroke patients. 2000 (Lumley et al.).

Even without genetic abnormalities, early stroke risk is heritable. The Framingham Heart Study found that children with parents with a history of early stroke (<65 years) had a more than doubled risk of IS (Wells et al., 2021), but genome-based variability only explains 38% of IS risk (Ketelaars et al., 2013). While there is little direct evidence linking family history to stroke in the young, premature IS patients are more likely to have a positive family history than older patients (Murphy et al., 2015), and family history is strongest in the youngest age group (15–24 years) compared to 25–34 (Coutinho, 2019). This heritability is consistent across IS subtypes (Harston et al., 2015).

## ROLE OF EMERGENCY MEDICAL SERVICES (EMS)

Stroke survivors should respond instantly to reduce possible mortality and disability (Harston et al., 2015). Emergency Medical Services serve as critical components by allowing timely intervention through rapid home-to-clinic transportation. Recovery of blood flow through rt-PA administration faces severe restrictions due to its time-sensitive parameters including a three-hour treatment window and expanded possibilities for four and a half or up to six hours after symptom onset (as indicated by Wardlaw, 2009). Emergency medical services need to evaluate stroke patients en route to the hospital since rapid therapeutic interventions yield better results according to Wintermark et al. (2013). EMS participation provides better triage services than self-transport due to statistics showing unacceptable patient brain imaging delays but faster interventions (Jaeger et al., 2023).

Multiple strategies should be implemented to improve EMS operational efficiency. The expansion of EMS stroke education programs will help emergency medical staff identify stroke in the field thus shortening the time to start stroke treatment. Quick patient management improvements in EMS routing protocols and direct hospital pre-notifications will enhance EMS response efficiency (Katz et al., 2015). Stroke specialists using telemedicine capabilities in pre-hospital care can fill expertise gaps by providing remote assessment and real-time guidance to EMS personnel which improves both treatment speed and patient outcomes for thrombolysis decisions. Stroke unit technology included CT imaging devices along with telemedicine infrastructure resulted in quicker medical interventions through shorter door-to-treatment intervals (Janerka et al., 2023).

EMS has created a substantial difference in stroke care but additional innovations and systemic advancements need to be explored. Pre-hospital stroke management can be improved by enhancing EMS hospital stroke team integration together with optimized triage protocols and telemedicine applications to achieve better patient survival and limited disability outcomes.

## CURRENT GUIDELINES FOR PREHOSPITAL STROKE CARE

National guidelines have not been issued by the majority of governments throughout the globe. Acute ischemic stroke care does not, however, lack organized procedures and workflows. The ESO Stroke Guidelines, put into action by European nations, have been a smashing success since their inception. Australia and New Zealand are likewise working towards a uniform strategy by adopting the 2017 Australian Clinical Guideline for Stroke Management (Weerts et al., 2018). Wu et al. (2017) note that the Middle East and North Africa Stroke and Interventional Neurotherapies Organization has also developed a unified strategy for stroke management throughout the pandemic.

The majority of the proposed standards are revisions of earlier ones, most often drawn from nations with relatively high per capita incomes. Stroke clinical practice guidelines (CPGs) from low-income nations showed certain quality compromises, according to a systematic analysis comparing these two groups of countries. Accordingly, the World Stroke Organization developed the WSO Global Stroke Services Guideline and Action Plan in 2014 for precisely this reason (Ayub 2017). To obtain high-quality, evidence-based recommendations and to guarantee that results are assessed to encourage a milieu for continuous

improvement, this effort seeks to assist country-level health authorities in setting up or improving current stroke frameworks (Brown, 2015).

Since emergency medical services professionals are often the first to assess stroke victims, their knowledge and efficiency are crucial to the success of prehospital treatment and evaluation. Li et al. aimed to shed light on the obstacles that hinder the efficient assessment and provision of these services (Li et al., 2019). Initial access to patients upon dispatch was one of the factors mentioned as a barrier. Involvement of the fire department was often secondary when it came to forcing locked doors open. Another significant obstacle was communication. Patients'

inability to communicate effectively could be due to a lack of English skills or other issues including cultural, ethnic, or health literacy. However, the nature of the communication obstacles in this investigation remained unclear. Patients suffering from motor weakness, changed perception, or altered degree of consciousness sometimes have difficulty moving about after a stroke, making extraction more challenging. Additional focused assessment in the form of a prospective research into each of the highlighted components is necessary to resolve these issues. It is worth mentioning that the group without obstacles did not experience a significant delay in obtaining intravenous alteplase compared to the one with considerable hurdles.

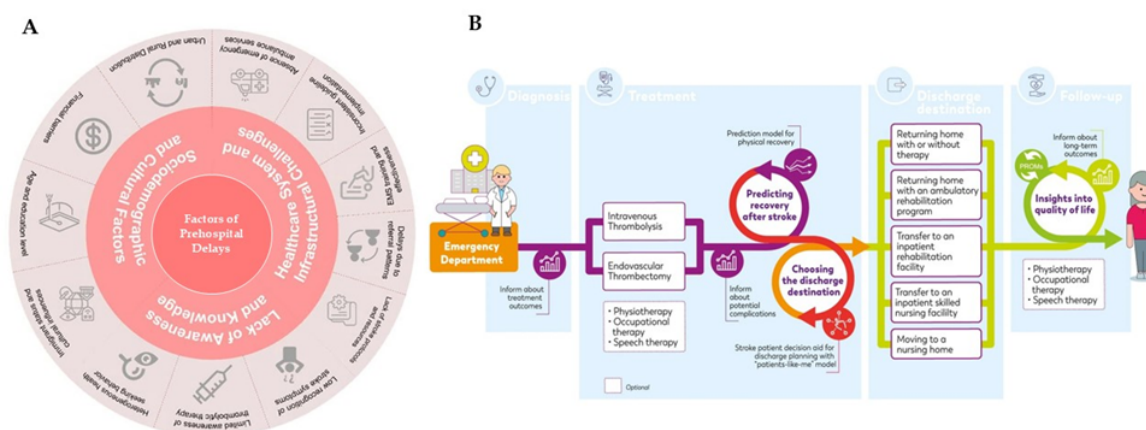


Figure 2: Factors contributing to prehospital delays in stroke care. The patient journey of patients with stroke in the developed countries (Wiyarta et al., 2024).

## ADVANCED TECHNOLOGIES IN STROKE DIAGNOSIS AND TREATMENT

### Mobile stroke unit (MSU)

An administration-equipped emergency van known as a mobile stroke unit can examine, evaluate, and treat symptoms of a severe stroke. It might include a state-of-the-art lab, a standard rescue vehicle equipped with a CT scanner, and telemedicine collaboration between the rescue vehicle and the emergency clinic via videoconferencing, recorded exchange of patient evaluations, and CT investigations. At the scene of an emergency, this rescue vehicle is equipped with everything needed to conduct a hyperacute evaluation and treat stroke victims (Farcas et al., 2022). The concept of a mobile stroke unit was born out of a need to address the problem of postponing stroke treatment by allowing for immediate identification and treatment of patients at the scene of the incident, rather than having to wait for them to reach an emergency clinic. The pre-clinic appearance time may be used by EMS workers to home in on a person with suspected stroke by bringing imaging innovation and stroke clinical experience to the scene. An evaluation with the distant VN via telemedicine, documentation of the patient's neurological and laboratory examinations, a CT scan (if necessary), and a case history are all tasks that fall under the purview of the MSU team at the emergency site. Thrombolysis may be administered on-site if necessary. Standard of care for thrombolysis in acute ischemic stroke therapy according to the 2015 Canadian Stroke Best Practice Recommendations is t-PA and screening by the stroke physician. It is essential to administer the t-PA as

soon as possible upon arriving at a healthcare facility and no later than 4.5 hours following the start of symptoms. The prompt administration of endovascular treatment for acute ischemic stroke requires a well-coordinated system that incorporates emergency medical services (EMS), rapid imaging, and in-hospital coordination among the emergency room, radiology, and a stroke team with extensive experience in stroke patient care (Denecke et al., 2020).

### Tele-stroke

The use of media communications technology for clinical indicative, checking, and beneficial reasons when distance and time separate the members is what telemedicine is defined as. Although the use of video-to-sound for neurological patient evaluations, particularly severe stroke cases, was initially shown in the mid-1990s, the phrase "tele stroke" was coined by Levine and Gorman to describe the actual application of highly intuitive telemedicine for the evaluation and intervention of severe stroke cases. The two discussed how video-teleconferencing connects vascular neurological specialists on a daily basis with emergency doctors and their patients, allowing for unlimited access to immediate stroke therapy. Due of the high initial investment required, telemedicine networks are notoriously expensive to launch. Davidson et al. (2022) break down these costs into many categories, including telemedicine equipment, data innovation support, key clinical and authoritative individuals, workforce training and credentialing, and, in the event of a total session financing, the workforce. Office size, technological preferences, and other factors affect the

estimated yearly expenditure of \$46,000, which may range from less than \$10,000 to over \$200,000. Research grants and governmental subsidies may sometimes cover these initial expenses, especially in rural or underprivileged areas. Consequently, the majority of tele stroke networks are associated with large academic ecosystems in major urban areas that service rural and remote areas.

From the perspectives of emergency medical services and remote doctors using a variety of methods, around eleven studies have evaluated the acceptability of tele-stroke systems. While a small number of studies have shown minor connection concerns, the overall result shows that tele-stroke systems are well-received for their good picture quality, use, dependability, and overall safety. Due to concerns about clinicians' capacity to utilize tele-stroke devices and incorporate them into normal care processes, just 25% of EMS nurses thought that tele-stroke may enhance emergency assessments and minimize time-to-treatment, according to one research (Walsh, 2019).

### ***Prehospital imaging device***

Prehospital imaging plays a crucial role in the early diagnosis and treatment of stroke. Prehospital ultrasound stands as a crucial device that paramedics use for on-site patient assessments. Role-based assessment techniques of traditional methods prove less effective than ultrasound imaging because it shows direct observations of soft tissue structures together with bones and muscles helping achieve accurate assessments. Quick imaging enables faster stroke diagnoses at the same time it boosts prehospital emergency services decision-making processes. Prehospital ultrasound demonstrates restricted performance because it struggles to detect structures behind bones especially when trying to image the brain. Obtaining high-quality medical images becomes challenging because most emergency medical service organizations have small numbers and frequent personnel changes. The development of structured training sessions linked with AI image interpretation systems aims to boost usability and diagnostic precision for these imaging instruments (Amaral et al., 2020).

Prehospital imaging is enhanced through the utilization of the diagnostic tool called Electroencephalography (EEG). The ELCTRA-STROKE study employed EEG technology with 'dry' electrode caps to identify anterior circulation large vessel occlusion (LVO) in patients deemed at risk for stroke. The implementation of EEG-based emergency assessment technologies exists at a fundamental level of algorithm development though the method is established as a medical technology. Results are reviewed in hospitals exclusively which delays prehospital evaluation as the main drawback of the method. Automated data signal processing combined with remote neurologist interpretation shows potential as a solution for using this tool in prehospital environments (Amaral et al., 2020).

Prehospital assessment of stroke cites infrared-based imaging as one of its evaluated detection methods. Scientists at the US institution discovered that infrared-based devices successfully distinguished between hemorrhagic and ischemic strokes accepting 71% patients but misidentified 57% cases (Gonzalez et al., 2011). Research demonstrates that these devices have potential in prehospital stroke screening but their low specificity restricts their clinical use. Sensor technology improvements alongside AI-driven analytical methods promise to increase their accuracy and reliability which

could establish them as valuable stroke differentiation tools at the emergency stage.

### ***Biomarkers***

Biomarkers serve as an alternative method for stroke diagnosis to occur rapidly. Scientific progress in imaging biomarkers better explains the mechanisms through which ischemic stroke occurs. Using biomarkers in randomized clinical trials faces significant barriers due to the mixed clinical responses and insufficient imaging protocol standards among patients. The SMART-Chip biosensor functions as a promising tool by detecting purines in finger-prick blood through rapid analysis which takes 3 to 5 minutes. Immediately after a hypoxic event purines increase rapidly which enables their detection as an early warning sign of stroke. The device shows promise although it requires paramedic training because it needs widespread validation through numerous large-scale studies (Sarissa Biomedical Ltd., UK).

The investigation of S100B and neuron-specific enolase (NSE) and glial fibrillary acidic protein (GFAP) and brain-derived neurotrophic factor (BDNF) and matrix metalloproteinase-9 (MMP-9) and C-reactive protein (CRP) and D-dimer continues in terms of clinical biomarkers for identification. Medical studies have connected these biomarkers to severe stroke conditions as well as brain tissue damage and inflammatory patterns. The shortage of portable laboratory devices remains the main obstacle to effectively determine these biomarkers at the scene of medical emergencies. The required solution to this challenge involves funding biosensor development jointly with improved biomarker validation methods and methods to integrate biomarker results with current imaging techniques for better diagnostics accuracy (Ahmad et al., 2023).

Stroke diagnostic advances have not produced sufficient treatment solutions for patients who experience severe ischemic conditions. The poor adoption rate of neuroprotectant and reperfusion therapy drugs stems from poor outcome standardization together with variable patient conditions. Research imaging methods developed important applications for overcoming healthcare challenges through standardized clinical study testing while selecting appropriate treatment candidates and enhancing safety evaluations. Penumbra imaging was included in late-stage acute stroke trials to establish the Acute Stroke Imaging Research Roadmap II which works on standardizing disease marker assessment in stroke research. Future research should concentrate on optimizing current imaging methods while combining them with biomarker testing and enhancing their availability during prehospital stroke care within resource-constrained regions to enhance stroke treatment results worldwide.

### **CHALLENGES & FUTURE DIRECTIONS OF EMS IN PREHOSPITAL STROKE CARE**

The essential need for ongoing clinical research and technological growth lies in improving patient care during stroke incidents in emergency settings. Numerous obstacles have not impeded scientific progress which has enabled better patient results along with better therapeutic methods. Studies in this field generate new technologies and prehospital stroke management methods which enable better identification of emergency response standards and disease-specific treatment protocols.

Evidence-based care delivery by prehospital care professionals depends on sustained innovations and research activities in these critical life-saving events.

The achievement of clinical research goals depends on thorough planning and execution strategies which consider the built-in limitations and difficulties found in prehospital

medical services. Research methodologies necessitate both healthcare practitioners and emergency medical services (EMS) organizations to work together for designing secure and ethical methodologies. Researchers need to use current technologies and diverse data sources for successful data collection and analysis within prehospital care areas.

**Table 1: Several solutions that can be implemented to improve clinical research in prehospital care (Cimino & Braun, 2023).**

<b>Solutions</b>	<b>Description</b>
Collaboration	Collaboration between prehospital care providers, hospitals, and research institutions can improve the quality of research in prehospital care. This collaboration can lead to better study design, more robust data collection, and stronger analysis.
Technology	Technology can be leveraged to improve data collection and analysis. For example, the use of electronic health records (EHRs) can help standardize data collection and make it easier to share data between prehospital care providers and researchers. Additionally, the use of mobile apps and wearables can provide real-time data that can be used for research purposes.
Training	Prehospital care providers should receive training on research methods and data collection to ensure they are collecting data in a standardized and accurate manner. This training can also help providers understand the importance of research and the impact it can have on patient care.
Funding	Increased funding for prehospital care research can help support larger, more comprehensive studies. This funding can also be used to develop new technologies and research methods to improve data collection and analysis.
Ethics committees	Ethical considerations must be addressed when conducting research in prehospital care. Establishing ethics committees that review research proposals and ensure that patient privacy and safety are maintained can help improve the quality and trustworthiness of research in prehospital care.
Public awareness	Greater public awareness of the importance of prehospital care research can help increase funding and support for this area of study. It can also help improve patient participation in research studies and increase the overall impact of the research.

The essential need for ongoing clinical research and technological growth lies in improving patient care during stroke incidents in emergency settings. Numerous obstacles have not impeded scientific progress which has enabled better patient results along with better therapeutic methods. Studies in this field generate new technologies and prehospital stroke management methods which enable better identification of emergency response standards and disease-specific treatment protocols. Evidence-based care delivery by prehospital care professionals depends on sustained innovations and research activities in these critical life-saving events.

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Emergency medical services gain substantial opportunities to advance through implementing artificial intelligence (AI) in their prehospital emergency systems. The combination of AI predictive models assesses patient information consisting of vital signs together with medical records and patient demographics for determining which patients have high cardiac arrest dangers and need quick EMS response. AI optimizes resource utilization along with automated triage procedures and diagnostic assistance which collectively improves prehospital stroke treatment

(Fontanellaz et al., 2021). Combining artificial intelligence systems with telemedical services along with simulation programs helps optimize EMS system operations as well as patient outcome results.

The effective solution of these challenges involves three approaches which include making telemedicine more prevalent in EMS operations and providing emergency responders with opportunities for simulation training and implementing standardized prehospital protocols. The advancement of instrument technologies depends on government action through healthcare organization investments in infrastructure along with staff training and medical research initiatives. Technological advances together with resource solutions will lead to substantial improvement of prehospital stroke care that improves patient survival rates and outcomes during recovery.

## CONCLUSION

Medical attention needs immediate intervention when stroke manifests as a critical emergency condition. This minimizes its adverse outcomes in patients. The delivery of emergency medical services plays an essential part in providing fast medical assessments and the proper treatments to stroke victims before transporting them quickly to medical facilities. The study strengthens EMS knowledge by showing that researchers need to develop innovative standards that speed up medical responses. The connection between established protocols and

recommendations will enhance EMS operations by ensuring immediate and equal stroke patient care. Strategic planning with integrated new technologies remains the key to EMS development which will lead to global improvement of emergency response systems.

## DECLARATIONS

### Ethics approval and consent to participate

Institutional Review Board approval is not required.

### Competing/Conflict of interests Statement

The authors declare no conflict of interest

### Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors

### Authors' contributions

*Abdullah Alsamhari*: Supervised the Data Collection Process, And Checked Writing, Approved Methodology, Manuscript Editing and Supervised All Steps, Final Editing;  
*Rafiulla Gilkaramenthi*: Researched Literature, Web-Survey Design, Coordinate and Monitor the Data Collection Process with Collaborators, Wrote the First Draft of The Manuscript;  
*Saad M. Mushawwah, Lara Altaezi*: Paper Revision;  
*Hamdi Hasan Abdulbari*: Interpret Data, Checked Writing;  
*Albaraa Jebreeel*: Manuscript Editing;  
*Bader Hussain Alamer*: Final Editing, Reviewing, And Supervising the Steps.

### Acknowledgment

The authors would like to express their deepest gratitude to “AlMaarefa University”.

### Availability Of Data And Materials

The article and supplementary materials contain the original contributions discussed in the study. Original datasets are available upon reasonable request from the corresponding author.

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