Archives of Academic Emergency Medicine. 2025; 13(1): e57

OPEN ACCESS

ORIGINAL RESEARCH

Real-Time Telemedical Oversight Improves Prehospital Stroke Metrics: A Five-Year Cohort Study

Ponlawat Kanchayawong[1], Kasamon Aramvanitch[2], Chaiyaporn Yuksen[2*], Satariya Trakulsrichai[2], Pungkava Sricharoen[2], Sureerat Suwatcharangkoon[3], Patcharaporn Sirintaranont[3], Jesada Keandoungchun[3], Promphet Nuanprom[1], Chetsadakon Jenpanitpong[1], Suthap Jaiboon[1]

1. Division of Paramedicine, Department of Emergency Medicine, Faculty of Medicine Ramathibodi Hospital, Mahidol University, Bangkok, Thailand

2. Department of Emergency Medicine, Faculty of medicine, Ramathibodi hospital, Mahidol University, Bangkok, Thailand

3. Division of Neurology, Department of Medicine Faculty of Medicine Ramathibodi Hospital, Mahidol University, Bangkok, Thailand

Received: April 2025; Accepted: May2025; Published online: 25 June 2025

Abstract: **Introduction:** By enabling direct consultation with neurologists, Real-Time Telemedical Oversight (ReTMO) can facilitate rapid stroke assessment and decision-making. This study aimed to assess the efficacy of prehospital stroke management before and after ReTMO implementation. **Methods:** A single-center retrospective before-and-after study was conducted at Ramathibodi Hospital, Bangkok, Thailand, from January 2020 to December 2024. In March 2022, a structured prehospital stroke protocol was integrated with the ReTMO system in this hospital. We evaluated its impact by comparing stroke patients transported by emergency medical services (EMS) before and after protocol implementation. Neurological outcomes at hospital discharge were analyzed using multivariable ordinal logistic regression. In contrast, door-to-treatment times in the emergency department (ED) and hospital length of stay were assessed using multivariable Gaussian regression. **Results:** The study included 91 prehospital stroke patients, with 36 in the pre-protocol group and 55 in the post-protocol group. Implementation of the structured prehospital stroke protocol was associated with a significant reduction in door-to-computed tomography (CT) scan time by 10.47 (95% confidence interval (CI): -17.62 to -3.3) minutes and door-to-laboratory result time by 15.90 (95% CI: -30.48 to -1.33) minutes. Additionally, adjusted ordinal logistic regression analysis demonstrated a significant improvement in neurological outcomes at hospital discharge (odds ratio (OR) = 0.14, 95% CI: 0.02–0.99, P = 0.049). However, reductions in ED stroke treatment time and hospital length of stay were not statistically significant. **Conclusion:** Implementing ReTMO alongside a structured prehospital stroke protocol significantly reduced in-hospital delays in door-to-CT and door-to-laboratory result times while also improving neurological outcomes at hospital discharge.

Keywords: Stroke; Emergency medical services; Telemedicine; Treatment outcome; Time-to-treatment

Cite this article as: Kanchayawong P, Aramvanitch K, Yuksen C, et al. Real-Time Telemedical Oversight Improves Prehospital Stroke Metrics: A Five-Year Cohort Study. Arch Acad Emerg Med. 2025; 13(1): e57. https://doi.org/10.22037/aaemj.v13i1.2693.

1. Introduction

Stroke is a critical medical emergency and a leading cause of mortality and long-term disability worldwide (1). According to the American Heart Association (AHA), stroke remains a significant public health concern, with mortality rates continuing to rise in the United States and other countries over the past decade (1, 2). Rapid evaluation, accurate diagnosis, and timely treatment are crucial for improving stroke patient outcomes (3), as the effectiveness of interventions such as intravenous thrombolysis (IVT) and mechanical thrombectomy (MT) is highly time-dependent (4, 5).

Stroke mortality rates vary significantly across Asia, with the highest rates reported in Mongolia and Indonesia, while the lowest are observed in Japan and Singapore (6). In Thailand, stroke is the second leading cause of death, and its mortality rate has been steadily increasing. In 2020, the incidence rate was reported at 105.9 (98.3–114.6) per 100,000 population, while the mortality rate reached 45.9 (41.5–51.5) per 100,000 population (7, 8). Recognizing this burden, the Thai Ministry of Public Health has implemented several initiatives to enhance stroke care, including emergency department (ED) and emergency medical services (EMS) improvements and the introduction of the Stroke Fast Track System. This system facilitates the rapid assessment and transport of stroke patients to specialized stroke units or hospitals with appropriate capabilities (8). These strategies aim to reduce delays and optimize access to neurology specialists, improving overall stroke management. Prehospital stroke care plays a pivotal role in the management of acute stroke, offering the poten-

*Corresponding Author: Chaiyaporn Yuksen; Division of Emergency Medicine, Department of Emergency Medicine, Faculty of Medicine, Ramathibodi Hospital, Mahidol University, Bangkok 10400, Thailand. E-mail: chaipool0634@hotmail.com, ORCID: https://orcid.org/0000-0002-4890-7176.

tial to significantly improve outcomes through early recognition, rapid transport, and timely intervention (9, 10). Prehospital notification has been shown to increase IVT administration rates by 3.2% to 44.0%, significantly reducing door-to-imaging times (10-14). However, challenges such as prehospital delays, protocol inconsistencies, resource limitations, inadequate training, and lack of synchronization with specialized neurological units remain key barriers to optimizing stroke care (9, 10, 15).

To address these limitations, Mobile Stroke Units (MSUs) have emerged as an innovative prehospital stroke care model, enabling on-site stroke diagnosis and treatment (16). In Thailand, the Siriraj Mobile Stroke Unit has demonstrated success in delivering immediate stroke care using ambulances equipped with onboard CT scanners and specialized stroke teams. These advanced mobile units have been shown to significantly reduce door-to-needle times and improve functional outcomes by enabling the administration of time-sensitive treatments, such as IVT, at the scene (17).

Dispatcher-assisted interventions are another essential component of prehospital stroke care, contributing to improved outcomes across various medical emergencies (18). Studies have shown that the integration of teleconsultation and prehospital stroke triage systems can enhance stroke triage accuracy, leading to faster mechanical thrombectomy (MT) delivery while maintaining timely IVT administration (19). Furthermore, several studies suggest that telemedicine, including video instructions, can improve the accuracy and efficiency of prehospital stroke management by providing real-time visual guidance to bystanders and EMS personnel (10, 18-23).

Recent trends indicate a growing reliance on EMS ambulance services among stroke patients, as EMS transport has been shown to significantly reduce the time to imaging and treatment compared to walk-in patients (24, 25). Studies evaluating the implementation of prehospital stroke protocols have reported that EMS-facilitated access to stroke evaluations, CT scans, neurologist notifications, and treatment administration significantly shortens treatment times (19, 23, 24). However, the most valuable outcome measure remains improved neurological function and recovery in stroke patients (26, 27).

This study aimed to evaluate the impact of implementing a Real-Time Telemedical Oversight protocol alongside a structured Prehospital Stroke Protocol by examining neurological outcomes at hospital discharge using the modified Rankin Scale (mRS, 0–6). It also assessed key time-sensitive care metrics, including door-to-CT and door-to-IVT times, as well as hospital length of stay, to determine the overall effectiveness of protocol optimization on stroke management and recovery.

2. Methods

2.1. Study design and setting

We conducted a retrospective single-center before-and-after protocol at Ramathibodi Hospital, a tertiary university hospital in Bangkok, Thailand. The study period spanned from January 2020 to December 2024, encompassing the implementation of the Ramathibodi Prehospital Stroke Protocol, which was initiated in March 2022. We evaluated its impact by comparing stroke patients transported by EMS before and after protocol implementation. Neurological outcomes at hospital discharge, door-to-treatment times in the ED, and hospital length of stay were among the studied outcomes. The Ramathibodi Emergency Medical Operation (RAMA EMO) unit, operating under 24-hour emergency physician supervision, was responsible for executing the protocol and managing prehospital stroke care.

The Institutional Review Board of the Faculty of Medicine at Ramathibodi Hospital approved this observational study (COA No. MURA2024/718).

2.1.1 Pre-protocol implementation

Before the implementation of the Ramathibodi Prehospital Stroke Protocol (figure 1), EMS at Ramathibodi Hospital, established in 2008, operated under a conventional emergency response system. In emergency situations, the emergency unit provided medical advice, gathered patient information, and obtained patient history via telephone consultation. The emergency medical team, consisting of emergency physicians, registered nurses, and practical nurses, worked alongside ambulance services to assess patients for life-threatening conditions. Stroke assessments were conducted using standardized prehospital stroke diagnostic tools, including the Cincinnati Prehospital Stroke Scale (CPSS) and the Los Angeles Prehospital Stroke Screen (LAPSS). The team determined the appropriate on-site treatment and coordinated with the medical director to notify the ED, ensuring rapid patient transport to the hospital for immediate medical intervention following standardized treatment protocols.

2.1.2 Post-protocol implementation

In March 2022, the RAMA EMO unit was established to provide dedicated EMS under 24/7 supervision by emergency physicians. This restructuring aimed to improve prehospital stroke care efficiency by ensuring a multidisciplinary, technology-integrated response system. The dispatch and command team plays a critical role in EMS operations by ensuring efficient coordination and rapid response. This team consists of a medical director, a supervisor emergency medical dispatcher (SEMD), and an emergency medical dispatcher (EMD), both of whom are paramedics. Their primary responsibilities include assessing emergency calls, dispatching appropriate medical units, and facilitating real-time communication between field teams and hospital emergency departments. The EMS operation team is structured into two levels based on the severity of the emergency:

1. Doctor-Led Team (DLT) – Composed of emergency physicians, paramedics, and ambulance-driving paramedics, who are certified to drive ambulances for rapid response. This team ensures immediate coordination with the emergency room for critical cases requiring urgent intervention.

2. **Paramedic-Led Team (PLT)** – Comprised of two paramedics and ambulance-driving paramedics, this team is responsible for urgent emergency cases that require prompt medical attention but do not require physician-led transport. This structured EMS framework ensures timely prehospital care, enhancing stroke patient outcomes through optimized triage, dispatch efficiency, and emergency interventions. Additionally, the RAMA EMO unit enforces specific protocols for major emergency conditions, including trauma, out-of-hospital cardiac arrest, and acute stroke management.

The Ramathibodi Prehospital Stroke Protocol leverages advanced telemedicine technologies to support EMS personnel in identifying stroke symptoms and providing timely interventions (figure 1). This protocol was developed as a multidisciplinary collaboration among multiple healthcare agencies and underwent a lean process to optimize speed, efficiency, and ease of implementation for EMS operators. The primary objective was to enhance prehospital stroke recognition, streamline communication, and facilitate early intervention to improve patient outcomes. The EMD introduced a video-assisted dispatcher instruction system to aid in early stroke symptom detection before the EMS team arrived at the scene. This two-way communication system provided real-time visual guidance to bystanders, allowing them to assist in stroke identification and initial care. The video instruction system was used when two or more bystanders were available, and the caller had a smartphone with video call capability.

On-scene EMS operations incorporated real-time communication and data transmission to the SEMD. This continuous data exchange included stroke diagnostic assessments, patient evaluations, and evidence-based treatment interventions. The prehospital stroke team performed both basic and advanced life support interventions, with simultaneous transmission of 12-lead electrocardiogram (ECG) data and activation of the pre-notification protocol.

Validated clinical assessment tools were systematically documented and transmitted to the receiving in-hospital stroke team and radiologist, facilitating early neuroimaging preparation and ensuring a seamless stroke care continuum. These assessments included the National Institutes of Health Stroke Scale (NIHSS), Los Angeles Motor Scale (LAMS), Glasgow Coma Scale (GCS), and stroke-specific symptom evaluations. In addition to comprehensive stroke assessments.

The Ramathibodi Prehospital Stroke Protocol systematically recorded critical time metrics to monitor and enhance stroke care efficiency. Key time intervals documented in this process included door-to-CT scan time, door-to-IVT time, door-to-laboratory result time, and door-to- MT time. Furthermore, prehospital management time intervals were recorded to assess EMS notification efficiency and stroke team activation, including first medical contact (FMC) to stroke detection, FMC to stroke team activation, and FMC to CT brain imaging. To further optimize prehospital stroke care, the Ramathibodi Prehospital Stroke Protocol was developed as a standardized system designed to improve early stroke recognition, expedite EMS response, and ensure timely in-hospital treatment. A comprehensive overview of the protocol's implementation and workflow is provided in Supplement 1.

2.2. Participants

All retrospective patient data were retrieved from the electronic medical records (EMR) system of Ramathibodi Hospital. This study included patients admitted to the ED of Ramathibodi Hospital between January 2020 and December 2024. Patients with suspected stroke who arrived at the ED without EMS transport or were transported by EMS from other hospitals were excluded from the study (figure 2).

2.3. Data gathering and outcome measures

The study variables included baseline characteristics and clinical profiles of stroke patients, such as age, gender, and initial vital signs, including systolic blood pressure (SBP), heart rate (HR), respiratory rate (RR), Glascow coma scale (GCS), and capillary blood glucose levels. Additional data collected included prehospital stroke assessments, such as the NIHSS score and stroke diagnosis outcome, as well as prehospital EMS time metrics, including activation time, response time, scene time, and transport time. Prehospital operation records, consisting of FMC, prehospital interventions, and treatment measures performed by EMS teams, were also obtained from the EMR system.

The primary outcome was neurological status at hospital discharge, assessed using the mRS. The mRS scores were compared between the pre-protocol and post-protocol groups to evaluate the impact of the Ramathibodi Prehospital Stroke Protocol on functional outcomes. Secondary outcomes included time-to-treatment metrics related to stroke management, such as door-to-time intervals and hospital length of stay.

2.4. Definitions

2.4.1 Emergency medical services (EMS) time metrics

• Activation time: The interval between receiving the emergency call and the departure of the EMS team from their base, reflecting the efficiency of EMS mobilization and readiness (28).

• Response time: The interval from receiving the emergency call to the arrival of the EMS team at the scene, serving as a key measure of EMS efficiency in reaching patients (13).

• Scene time: The duration from EMS arrival at the scene to departure with the patient, encompassing assessment, stabilization, and transport preparation. Guidelines recommend minimizing this time to under 15 minutes for suspected stroke cases (13, 29).

• Transport time: The interval from EMS departure from the scene to arrival at the hospital ED, evaluating the efficiency of patient transport to a definitive care facility (28).

2.4.2 Initial prehospital vital signs

The initial recorded physiological parameters of the stroke patient upon EMS arrival, including:

• Systolic Blood Pressure (SBP): An indicator of stroke severity and the risk of hemorrhagic transformation.

• Heart Rate (HR): Assessed to evaluate circulatory status and detect potential arrhythmias.

• Respiratory Rate (RR): Monitored to identify respiratory distress or compensatory mechanisms.

• Glasgow Coma Scale (GCS): A neurological assessment tool used to determine the level of consciousness and severity of impairment.

• Capillary Blood Glucose: Measured to rule out hypoglycemia or hyperglycemia, which can mimic stroke symptoms or worsen outcomes.

2.4.3 Pre-arrival dispatcher assistance

Pre-arrival dispatcher-assisted evaluation and guidance before EMS arrival includes:

• Phone Assistance: Traditional voice-based dispatch, where emergency personnel collect patient history and provide initial management instructions.

• Video-Call Assistance: Real-time visual assessment, allowing dispatchers to guide bystanders in early stroke recognition and triage to improve accuracy.

2.4.4 First medical contact (FMC) time intervals

Time intervals measured from the FMC, defined as the patient's first interaction with medical personnel (EMS)

• FMC to Detection: The interval from first medical contact to stroke recognition, enabling early intervention planning. (Due to the use of telemedicine in some cases, stroke may be detected before EMS arrival, resulting in negative time values.)

• FMC to Stroke Team Activation: The time from first medical contact to in-hospital stroke team notification, ensuring pre-arrival readiness. (In some instances, telemedical assessment allows stroke team activation prior to patient arrival, which may yield negative time intervals.)

• FMC to CT scan: The time from first medical contact to the initiation of CT brain imaging upon hospital arrival.

• FMC to Laboratory Result: The interval from first medical contact to the availability of essential blood test results, aiding treatment decisions.

• FMC to IVT: The time from first medical contact to administration of intravenous thrombolysis (IVT) for eligible ischemic stroke patients.

• FMC to MT: The time from first medical contact to initiation of mechanical thrombectomy (MT) in patients with large vessel occlusion (LVO).

2.4.5 National institutes of health stroke scale (NIHSS) (30)

• NIHSS Score (Prehospital): A neurological assessment conducted by EMS before hospital arrival to evaluate stroke severity using a prehospital-adapted NIHSS tool. (Not assessment of pre-protocol period)

• NIHSS Score (ED): A reassessment performed in the ED after CT brain imaging to confirm stroke severity and guide treatment decisions.

• NIHSS Score (Stroke Unit): A follow-up assessment conducted upon admission to the stroke unit to monitor neurological status and inform ongoing care plans.

2.4.6 Modified Rankin scale (mRS) at hospital discharge (31)

The mRS is a widely used measure of functional outcomes after stroke, assessed at hospital discharge. A detailed evaluation of this outcome measure is provided in Supplement 2.

2.4.7 Door-to-time intervals (from ED visit) (32)

• Door-to-CT scan: The interval from ED arrival to the initiation of CT brain imaging.

• Door-to-IVT: The interval from ED arrival to the administration of intravenous thrombolysis (IVT) for eligible stroke patients.

• Door-to-Laboratory Result: The interval from ED arrival to receipt of essential blood test results.

• Door-to-MT: The interval from ED arrival to the initiation of mechanical thrombectomy (MT) for LVO cases.

2.5. Statistical analyses

All data were analyzed using Stata version 16 (Stata Corp LLC, College Station, TX, USA). Descriptive statistics were used to summarize the baseline characteristics of patients. Categorical variables were presented as percentages and analyzed using the exact probability test. Continuous variables were assessed for normality; if normally distributed, they were expressed as means with standard deviations (SD) and compared using the two-sample t-test. If non-normally distributed, they were presented as medians with interquartile ranges (IQR) and analyzed using the Wilcoxon rank-sum test. To evaluate the association between the pre- and post-protocol implementation phases, multivariable models were applied. Neurological outcomes were assessed using multivariable ordinal logistic regression, with the mRS (0–6) as the dependent variable. The model was adjusted for age, GCS, capillary blood glucose, endotracheal intubation, response time, scene time, initial SBP, NIHSS score at ED, hemorrhagic stroke, and transport time to ED. Results were reported as odds ratios (OR) with 95% confidence intervals (CI), and the proportional odds assumption was tested and confirmed.

For door-to-time intervals, which are continuous variables, multivariable Gaussian regression was employed, adjusting for gender, age, GCS, NIHSS, response time, scene time, and transport time to ED. Results were reported as mean differences with 95% CI. Similarly, hospital length of stay (LOS) was analyzed using multivariable Gaussian regression with robust standard errors to account for heteroscedasticity, adjusting for gender, age, GCS, NIHSS, hemorrhagic stroke, response time, scene time, and transport time to ED. LOS results were also presented as mean differences with 95% CI. All statistical analyses were performed using appropriate statistical software, with a significance level set at $p < 0.05$.

2.6. Sample size estimation

Sample size estimation was performed using Stata version 16, based on data collected from stroke patients in the RAMA EMO unit between May 2021 and August 2022. This pilot study determined the required sample size for a two-sample comparison of proportions for favorable neurological outcomes, with a statistical power of 0.80 and a significance level (alpha) of 0.05, utilizing a one-sided test. A total of 101 cases were included in the study, with 39 patients in the pre-protocol group and 62 in the post-protocol group. The sample size estimation was designed to ensure sufficient statistical power to detect clinically meaningful differences in stroke outcomes before and after the implementation of the Ramathibodi Prehospital Stroke Protocol.

3. Results

3.1. Baseline patients' characteristics

As shown in Figure 3, there was a notable upward trend in the proportion of stroke patients arriving via EMS from 2020 to 2024, increasing from 4.91% to 14.52% (P < 0.001). Concurrently, the composition of EMS providers shifted, with a relative decrease in the proportion of patients transported by the RAMA EMO unit, particularly after 2021, as compared to other EMS agencies.

Of the 6,831 stroke patient visits, 6,389 cases were excluded as they were non-EMS arrivals, while 351 cases were excluded as they were transported by EMS from other hospitals. The study included 91 stroke patients who were transported by EMS to Ramathibodi Hospital's ED between January 2020 and December 2024, as shown in Figure 2. The final study cohort consisted of 36 patients in the pre-protocol group and 55 in the post-protocol group.

As shown in Table 1, there were no statistically significant differences between the pre-protocol and post-protocol groups in terms of: gender (p = 0.825), age (p = 0.275), initial prehospital vital signs such as SBP (p =0.247), HR (p =0.778), RR (p =0.148), Capillary blood glucose (p=0.351), GCS scores (p = 0.292), stroke diagnosis (p = 0.280), or NIHSS scores at ED (p = 0.416), and NIHSS scores at stroke unit (p = 0.699). This indicates that baseline characteristics and stroke severity were comparable between the two groups prior to the implementation of the prehospital stroke protocol.

Following protocol implementation, significant changes were observed in EMS time intervals. Activation time increased from 3 (IQR: 2–7 min) minutes to 5 (IQR: 3–7) minutes (p = 0.037), and scene time increased from 20 (IQR: 16–23) minutes to 25 (IQR: 21–33) minutes (p = 0.002). However, response time and transport time showed no statistically significant differences between the two groups.

3.2. Prehospital stroke protocol characteristics and interventions

The implementation of the Ramathibodi Prehospital Stroke Protocol introduced several key assessments and interventions during the prehospital phase, as detailed in Table 2. Pre-arrival dispatcher assistance was provided in all cases, with 74.55% (n = 41) of patients receiving video-call assistance, while 25.45% (n = 14) received only phone assistance.

Time metrics from FMC to critical interventions demonstrated rapid stroke identification, with a median time of 0 (IQR: -8, 4) minutes from FMC to stroke detection. The notification process was expedited, with a median time of 1 (IQR: -2, 6) minutes from FMC to stroke team activation. Negative time intervals observed in some cases were attributed to early stroke detection during the pre-arrival phase via video-call assistance, allowing stroke identification before EMS arrival. In certain instances, initial stroke assessments were performed remotely, enabling stroke team activation before on-scene evaluation by EMS personnel.

Essential laboratory testing required a mean time of 84.51 ± 27.69 minutes from FMC to laboratory result availability. Neuroimaging was performed in a median of 46 (IQR: 38, 59) minutes. The administration of IVT required a mean time of 79.6 ± 27.22 minutes, while MT in eligible patients was initiated within a mean time of 175.71 ± 27.55 minutes.

Prehospital blood sampling was successfully performed in 78.18% (n = 43) of cases, ensuring expedited laboratory processing upon hospital arrival. ECG data transmission (12-lead ECG) was successfully completed in 79.63% (n = 43) of patients to aid in prehospital cardiovascular assessment.

3.3. Door-to-treatment time and length of stay

The implementation of the Ramathibodi Prehospital Stroke Protocol significantly improved key door-to-treatment time metrics, particularly by reducing imaging and laboratory processing times, as shown in Table 3. The protocol significantly shortened the door-to-CT scan time from 26 (IQR: 16–36) minutes pre-protocol to 7 (IQR: 5–10) minutes post-protocol (p < 0.001). While the reduction in door-to-IVT time from 44.5 to 35.5 minutes did not reach statistical significance (p = 0.231), the observed 9-minute decrease may represent a clinically meaningful improvement. Reductions in door-to-laboratory result and door-to-mechanical thrombectomy (MT) times were also observed but did not reach statistical significance.

There was a significant improvement in door-to-CT scan times, with a mean reduction of 10.47 (95% CI: -17.62 to -3.3, p = 0.041) minutes. Similarly, door-to-laboratory result times decreased by 15.90 (95% CI: -30.48 to -1.33, p = 0.032) minutes according to multivariable analysis. However, other door-to-treatment time metrics remained unchanged. In contrast, door-to-IVT time did not significantly change, with a mean difference of -1.64 (95% CI: -21.47 to 18.16, p = 0.871) minutes, indicating that while some prehospital and ED workflows were optimized, the IV thrombolysis process was not markedly impacted in this cohort.

Despite the improvements in prehospital and early in-hospital stroke care processes, the protocol did not lead to a statistically significant reduction in overall hospital length of stay. The ED length of stay increased by an average of 6.12 (95%CI: -3.65 to 15.89, p = 0.220) hours in the post-protocol group compared to the pre-protocol group, suggesting a potential delay in in-hospital stroke management, though this difference was not statistically significant. The stroke unit length of stay showed a median reduction of 1.49 (95%CI: -9.09 to 6.10, p = 0.700) days, indicating a modest improvement, although this change did not reach statistical significance. Similarly, the overall hospital length of stay decreased by 2.30 (95%CI: -11.25 to 6.65, p = 0.614) days, but again without achieving statistical significance.

3.4. Neurological outcomes in stroke patients before and after protocol implementation

Multivariable ordinal logistic regression analysis demonstrated a significant association between protocol implementation and improved neurological outcomes. The adjusted odds ratio for the mRS was 0.14 (95% CI: 0.02–0.99, p-value = 0.049), indicating that patients in the post-protocol group were more likely to achieve lower mRS scores at hospital discharge compared to those in the pre-protocol group.
The proportional odds assumption was validated, confirming that the odds ratio remained constant across all ordinal categories of the mRS scale (0–6). We tested the proportional odds assumption using the Likelihood Ratio (LR) test. The model yielded LR $chi^2(12) = 27.34$ with a p-value of 0.0069. Despite the statistical significance, we reviewed individual variable contributions and found no substantial violation of the proportional odds assumption. Therefore, the ordinal logistic regression model was considered appropriate for analyzing neurological outcomes. This trend suggests that following protocol implementation, patients had a higher likelihood of achieving better functional outcomes, with a lower probability of severe disability or mortality. The findings highlight that the Ramathibodi Prehospital Stroke Protocol was significantly associated with improved neurological recovery at hospital discharge, emphasizing its role in enhancing prehospital stroke management and patient outcomes.

4. Discussion

The implementation of the Ramathibodi Prehospital Stroke Protocol significantly improved key stroke care metrics and patient outcomes. Door-to-CT scan time and door-to-laboratory result time were significantly reduced, demonstrating statistically significant improvements in both measures. These advancements were primarily attributed to the prehospital notification system and streamlined workflows, which enabled faster imaging and laboratory processing upon patient arrival at the hospital. However, other time interval metrics did not exhibit statistically significant changes. In contrast, neurological outcomes at hospital discharge improved significantly, with patients in the post-protocol group being more likely to achieve lower mRS scores, reflecting reduced disability and better functional recovery. Despite these improvements, hospital length of stay metrics, including ED stay and overall hospitalization duration, did not demonstrate statistically significant reductions.

4.1. Treatment timeline improvements

The Ramathibodi Prehospital Stroke Protocol significantly improved door-to-treatment times, particularly in neuroimaging and laboratory result processing. The door-to-CT scan time showed a mean reduction of 10.47 minutes (95% CI: -17.62 to -3.30, p = 0.004). Similarly, the door-to-laboratory result time decreased by 15.90 minutes (p = 0.032), enhancing overall diagnostic efficiency. These improvements are critical in stroke care, where timely intervention is essential. Rapid neuroimaging is a key determinant of eligibility for time-sensitive treatments such as IVT and MT, both of which lose efficacy as treatment delays increase (33). The Ramathibodi protocol's 7-minute door-to-CT scan time exceeds the AHA recommendation of under 20 minutes, underscoring its effectiveness (34). Comparatively, a systematic review on prehospital stroke workflow optimizations (PSWO) reported that prehospital notification and workflow streamlining resulted in door-to-imaging time reductions of 10 to 40 minutes, depending on hospital efficiency and protocol adherence (35). A study conducted in Iran found that simple process modifications reduced the median door-to-CT time from 75 minutes to 20 minutes, highlighting the potential for further efficiency gains (36).
Similarly, the 15.90-minute reduction in door-to-laboratory result time demonstrates enhanced efficiency in prehospital blood sample preparation and in-hospital processing workflows. This improvement aligns with large-scale multicenter studies in Europe and the U.S., which have reported that prehospital interventions, including blood draws during EMS transport, can reduce laboratory processing times by 15 to 20 minutes (35). Despite these improvements, the Ramathibodi Prehospital Stroke Protocol did not result in statistically significant reductions in door-to-IVT or door-to-MT times. The median door-to-IVT time in the post-protocol group was 35.5 minutes, which is within global benchmarks but did not demonstrate a statistically significant reduction compared to the pre-protocol phase. Similarly, door-to-MT time remained unchanged, indicating that while prehospital workflow optimizations expedited early imaging, further in-hospital process improvements are required to accelerate treatment initiation (35).
These findings are consistent with international studies, which suggest that prehospital notification alone does not consistently lead to significant reductions in door-to-IVT time without concurrent in-hospital workflow optimizations (35). Research indicates that prehospital notification reduces door-to-imaging times and has been associated with an increase in thrombolysis rates ranging from 3.2% to 44.0%, findings that align with our study (12, 37, 38). Many European countries have implemented quality improvement initiatives to meet these targets, with high-volume stroke cen-

ters now reporting median door-to-IVT times of 50–60 minutes (39).

The Ramathibodi protocol's median door-to-IVT times of 35.5 minutes is comparatively faster than European and U.S. benchmarks, suggesting that prehospital optimizations effectively streamlined early stroke workflows. However, the lack of a statistically significant reduction suggests that bottlenecks remain within the in-hospital workflow, potentially due to delays in IVT administration post-imaging or additional diagnostic steps before thrombolysis initiation (39). Furthermore, MSU interventions in high-income settings such as the U.S. and Germany have demonstrated reductions in door-to-IVT times of 15–30 minutes, highlighting the need for additional prehospital capabilities beyond notification (16, 17).

Following protocol implementation, activation time increased by approximately 2 minutes due to added preparation for prehospital interventions. Scene time also rose from 20 to 25 minutes ($p = 0.002$), largely from tasks like IV access, blood sampling, and ECG. Although this exceeded the AHA's <15-minute recommendation, the extended time supported faster in-hospital workflow (34). Consistent with Chowdhury et al. (2021), our findings suggest that slightly prolonged scene time may be acceptable when offset by improved coordination and treatment efficiency (35).

4.2. Neurological outcome findings

The modified Rankin Scale (mRS) is a key measure of functional recovery in stroke patients, with lower scores indicating greater functional independence. In this study, multivariable ordinal logistic regression analysis demonstrated that the implementation of the Ramathibodi Prehospital Stroke Protocol was significantly associated with improved neurological outcomes, as reflected in a lower adjusted odds ratio (OR = 0.14, 95% CI: 0.02–0.99, $p = 0.049$) for worsening mRS scores at discharge. This suggests that patients in the post-protocol group were more likely to achieve better functional independence compared to those in the pre-protocol phase. The wide confidence interval approaching 1.00 reflects a degree of statistical uncertainty. This borderline result raises the possibility of a Type I error, in which a statistically significant effect is observed despite the null hypothesis being true. Given the limited sample size and the small number of outcome events, this finding should be interpreted with caution. However, these findings contrast with the meta-analysis by Chowdhury et al. (2021), which did not demonstrate a statistically significant improvement in favorable neurological outcomes (RR = 1.04, 95% CI: 0.97 to 1.12) following prehospital workflow optimizations (35). The significant reduction in door-to-CT time—from 26 minutes pre-protocol to just 7 minutes post-protocol—likely played a critical role in the observed improvements by enabling faster clinical decision-making for urgent interventions such as IVT and MT. This finding reinforces the well-established principle that "time is brain" in stroke care, where each minute saved contributes to the preservation of neurological function (34).

Our study suggests that dispatcher-assisted prehospital stroke triage, as integrated into the protocol, contributed to particularly favorable neurological outcomes. Prior research has shown that prehospital notification systems enhance stroke recognition and expedite treatment initiation, allowing for real-time assessment and hospital preparation before EMS arrival. These systems may eliminate delays associated with conventional protocols, potentially explaining the improved functional outcomes observed in our mRS data (31, 32). Furthermore, our results align with previous findings that structured prehospital stroke protocols enhance coordination between EMS and hospital stroke teams. Improved communication and early activation of stroke teams, as observed in this study, represent critical factors that have consistently been associated with better patient management and improved neurological recovery. These findings add to the growing body of evidence highlighting the essential role of structured prehospital care in optimizing stroke patient outcomes (3, 34).

4.3. Hospital length of stay

The Ramathibodi Prehospital Stroke Protocol improved critical door-to-treatment metrics and neurological outcomes; however, it did not result in a statistically significant reduction in hospital or ED length of stay (LOS). This finding is consistent with global studies on stroke care efficiency, where improvements in prehospital workflow do not always translate to shorter hospitalization durations. In our study, ED-LOS increased by 6.12 hours post-protocol, while stroke unit LOS decreased by 1.49 days and overall hospital LOS decreased by 2.30 days, though these changes were not statistically significant.

The increase in ED-LOS despite protocol-driven improvements aligns with challenges observed in resource-limited settings. While dedicated stroke units in tertiary care centers globally have been shown to reduce ED-LOS (e.g., 3.7 hours vs. 8.2 hours in general wards) (40), our hospital's ED-LOS increased by 6.12 hours post-protocol, likely due to limited stroke unit bed availability. With high patient volumes and restricted stroke unit capacity, many patients required prolonged ED observation before admission, creating bottlenecks in patient flow. This contrasts with studies in which streamlined stroke unit workflows directly reduced ED boarding times through guaranteed bed access.

In Thailand, where stroke unit beds are often prioritized for severe cases, high patient volumes necessitate early discharges or transfers to general wards, limiting the potential for LOS reductions. This differs from high-income healthcare systems, such as the United States, where dedicated stroke units reduce LOS by an average of four days through the use of specialized rehabilitation teams and structured post-acute care pathways. In the U.S., the average LOS for stroke patients is six days, with an associated total cost of approximately US$1,041 per hospitalization (41). Additionally, prolonged ED stays impose hidden financial burdens on healthcare facilities, highlighting how hospital bed shortages indirectly increase hospitalization expenses, even when protocol-driven improvements enhance imaging and laboratory turnaround times.

Our findings are consistent with hospitalization trends observed across Europe and Asia. In the Netherlands, the mean LOS ranges from 25 to 28 days, largely due to delays in discharge placement to long-term care facilities (42). In contrast, Japan reports significantly longer hospitalizations, with acute stroke patients averaging 3–4 weeks in hospital, and some facilities extending care up to three months in rehabilitation settings (43, 44). However, the median hospital LOS in our study was 4 days, which falls within the lower range of international standards. The absence of a significant reduction in LOS suggests that factors beyond prehospital workflow efficiency—such as in-hospital complications, rehabilitation availability, and discharge planning—play a more significant role in determining total hospitalization duration. These findings underscore the need for comprehensive stroke care strategies that extend beyond prehospital and acute-phase interventions, incorporating enhanced inpatient stroke unit capacity, rehabilitation pathways, and efficient discharge planning to optimize patient outcomes and hospital resource utilization.

4.4. Video-instructed dispatcher innovation

The implementation of video-instructed dispatcher assistance, utilized in 74.55% of cases, represents a significant advancement in prehospital stroke care, enabling real-time visual assessment before EMS arrival. Similar telemedicine-based approaches have demonstrated improved prehospital stroke triage and treatment decision-making (45). A study by Itrat et al. demonstrated that telemedicine interventions enhance diagnostic accuracy and reduce delays in stroke management (46). Our findings support the integration of video-assisted technology in dispatcher protocols, reinforcing its role in early stroke identification and improved patient outcomes.

4.5. Protocol implementation insights

The increase in scene time post-protocol implementation (25 vs. 20 minutes, p = 0.002) reflects a strategic redistribution of prehospital time rather than a process limitation. This additional time allowed for key interventions, such as prehospital blood collection and ECG acquisition, which contributed to reducing in-hospital delays. A similar approach was observed in the STEMO (Stroke Emergency Mobile) study by Ebinger et al., which demonstrated that investing additional prehospital time resulted in greater overall treatment efficiency (47).

Although stroke subtype distribution varied between groups, the difference was not statistically significant (p = 0.280). However, the proportion of LVO cases was higher post-protocol implementation (8.33% vs. 3.12%), potentially reflecting improved recognition of severe stroke symptoms through enhanced prehospital assessments, including video-assisted evaluations. (48) These findings suggest that our protocol may be particularly beneficial for identifying severe stroke cases that require advanced interventions such as MT (48, 49).

4.6. Endotracheal intubation in stroke care: protocol analysis

Endotracheal intubation (ETT) was performed in only 1.82% of cases in the prehospital stroke protocol cohort, indicating that most stroke patients did not require advanced airway management before hospital arrival. This aligns with standard stroke care guidelines, which recommend ETT primarily for patients with severe neurological deterioration, compromised airway protection, or GCS 8 (50). While prehospital ETT can be lifesaving in select cases, studies suggest that prolonged intubation attempts may delay definitive stroke treatment, including intravenous thrombolysis (IVT) and mechanical thrombectomy (MT). Future research should explore whether enhanced airway management protocols could further optimize outcomes for critically ill stroke patients while minimizing prehospital delays.

4.7. Study strengths

This study evaluates a comprehensive, multidisciplinary prehospital stroke protocol that integrates multiple evidence-based components to address critical bottlenecks in stroke care. The protocol was developed through close collaboration among the ED, EMS, the stroke team, and radiologists, ensuring seamless communication and expedited stroke management. EMS teams played a pivotal role in prehospital stroke recognition, rapid triage, and pre-arrival notification, allowing ED staff and stroke specialists to prepare for immediate intervention. Radiologists were pre-alerted to facilitate faster CT scan acquisition and interpretation, significantly reducing imaging-related delays. The improvements observed in key stroke care metrics through this integrated approach surpass those reported in previous studies, providing real-world evidence supporting the effectiveness of advanced prehospital stroke protocols in Thailand, where stroke remains the second leading cause of death.

4.8. Limitations

The retrospective design of this study introduces potential selection bias and unmeasured confounding factors, along with the possibility of missing data due to reliance on electronic medical records (EMR). Incomplete documentation, particularly for prehospital assessments and EMS time metrics, may have affected the accuracy of the findings. Additionally, the relatively small sample size, particularly in the pre-protocol group (n = 36), limits the statistical power to detect differences in clinical outcomes. This may explain why trends observed in mRS scores did not reach statistical significance.

Another limitation is that stroke severity may have influenced outcomes, as patients presenting with milder symptoms inherently have better prognoses, while those with severe strokes may require longer hospital stays, regardless of prehospital interventions. Since stroke severity was primarily assessed using NIHSS scores, the lack of additional stratification may have influenced the observed effects of the protocol.
Furthermore, this study was conducted in a single-center, tertiary university hospital, which is equipped with specialized resources and 24-hour emergency physician supervision. This setting may limit the generalizability of the findings, particularly in rural areas where EMS capabilities and transport times differ significantly. Lastly, neurological outcomes were assessed at discharge, rather than at standardized long-term follow-up time points (e.g., 90 days), potentially missing long-term recovery patterns that could provide a more comprehensive assessment of the protocol's impact.
Although improvements in stroke care metrics were observed following protocol implementation, we acknowledge that these changes may have been influenced in part by secular trends, such as system adaptations and stroke-unit learning curves. As calendar year was not included in the multivariable models, the potential impact of time-related confounding cannot be entirely ruled out.
Future research should incorporate prospective, multicenter study designs, long-term functional assessments, and detailed stroke severity adjustments to enhance the validity and applicability of findings, ensuring broader clinical and policy implications for prehospital stroke care.

5. Conclusions

The Ramathibodi Prehospital Stroke Protocol significantly improved neurological outcomes at hospital discharge, demonstrating the effectiveness of structured prehospital stroke care. The protocol led to substantial reductions in door-to-CT and door-to-laboratory result times; however, it did not significantly impact door-to-IVT, thrombectomy times, or hospital length of stay, emphasizing the need for further in-hospital workflow optimizations.
The integration of real-time telemedical oversight with a standardized prehospital stroke protocol enhances stroke recognition and care coordination, ensuring more timely and efficient treatment initiation. These findings support the implementation of structured prehospital stroke protocols to optimize acute stroke care and potentially improve patient outcomes through enhanced prehospital efficiency and streamlined care pathways.

6. Declarations

6.1. Acknowledgments

None.

6.2. Authors' contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work. All authors read and approved the final version of manuscript.

6.3. Conflict of interest

The authors declare that they have no competing interests.

6.4. Funding and supports

No funding was obtained for this study.

6.5. Availability of data

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

6.6. Using artificial intelligence chatbots

During the preparation of this work the author(s) used ChatGPT4.5 in order to check and correct grammatical errors during the manuscript writing process. After using this tool/service, the author reviewed and edited the content as needed and take full responsibility for the content of the publication.

References

1. Feigin VL, Brainin M, Norrving B, Martins S, Sacco RL, Hacke W, et al. World Stroke Organization (WSO): Global Stroke Fact Sheet 2022. Int J Stroke. 2022;17(1):18-29.
2. Martin SS, Aday AW, Almarzooq ZI, Anderson CAM, Arora P, Avery CL, et al. 2024 Heart Disease and Stroke Statistics: A Report of US and Global Data From the American Heart Association. Circulation. 2024;149(8):e347-e913.
3. Powers WJ, Rabinstein AA, Ackerson T, Adeoye OM, Bambakidis NC, Becker K, et al. 2018 Guidelines for the Early Management of Patients With Acute Ischemic Stroke: A Guideline for Healthcare Professionals From the American Heart Association/American Stroke Association. Stroke. 2018;49(3):e46-e110.
4. Roaldsen MB, Lindekleiv H, Mathiesen EB. Intravenous thrombolytic treatment and endovascular thrombectomy for ischaemic wake-up stroke. Cochrane Database Syst Rev. 2021;12(12):Cd010995.
5. Tsivgoulis G, Katsanos AH, Sandset EC, Turc G, Nguyen TN, Bivard A, et al. Thrombolysis for acute ischaemic stroke: current status and future perspectives. Lancet Neurol. 2023;22(5):418-29.
6. Venketasubramanian N. Stroke Epidemiology in Asia. Cerebrovasc Dis Extra. 2025;15(1):81-92.

7. Suwanwela NC. Stroke epidemiology in Thailand. J Stroke. 2014;16(1):1-7.
8. Kumluang S, Wu O, Langhorne P, Geue C. Stroke resource utilisation and all-cause mortality in Thailand 2017-2020: A retrospective, cross-sectional study. BMJ Open. 2023;13(6):e072259.
9. Zachrison KS, Nielsen VM, de la Ossa NP, Madsen TE, Cash RE, Crowe RP, et al. Prehospital Stroke Care Part 1: Emergency Medical Services and the Stroke Systems of Care. Stroke. 2023;54(4):1138-47.
10. Yperzeele L, Van Hooff RJ, De Smedt A, Valenzuela Espinoza A, Van de Casseye R, Hubloue I, et al. Prehospital stroke care: limitations of current interventions and focus on new developments. Cerebrovasc Dis. 2014;38(1):1-9.
11. Jauch EC, Saver JL, Adams HP, Jr., Bruno A, Connors JJ, Demaerschalk BM, et al. Guidelines for the early management of patients with acute ischemic stroke: a guideline for healthcare professionals from the American Heart Association/American Stroke Association. Stroke. 2013;44(3):870-947.
12. McKinney JS, Mylavarapu K, Lane J, Roberts V, Ohman-Strickland P, Merlin MA. Hospital prenotification of stroke patients by emergency medical services improves stroke time targets. J Stroke Cerebrovasc Dis. 2013;22(2):113-8.
13. Patel MD, Brice JH, Moss C, Suchindran CM, Evenson KR, Rose KM, et al. An evaluation of emergency medical services stroke protocols and scene times. Prehosp Emerg Care. 2014;18(1):15-21.
14. Patel MD, Rose KM, O'Brien EC, Rosamond WD. Prehospital notification by emergency medical services reduces delays in stroke evaluation: findings from the North Carolina stroke care collaborative. Stroke. 2011;42(8):2263-8.
15. Baldereschi M, Piccardi B, Di Carlo A, Lucente G, Guidetti D, Consoli D, et al. Relevance of prehospital stroke code activation for acute treatment measures in stroke care: a review. Cerebrovasc Dis. 2012;34(3):182-90.
16. Navi BB, Audebert HJ, Alexandrov AW, Cadilhac DA, Grotta JC, Group PW. Mobile Stroke Units: Evidence, Gaps, and Next Steps. Stroke. 2022;53(6):2103-13.
17. Nilanont Y, Chanyagorn P, Shukij K, Pengtong W, Kongmuangpuk M, Wongmayurachat K, et al. Comparing performance measures and clinical outcomes between mobile stroke units and usual care in underserved areas. Neurol Sci. 2023;44(4):1261-71.
18. Bielski K, Böttiger BW, Pruc M, Gasecka A, Sieminski M, Jaguszewski MJ, et al. Outcomes of audio-instructed and video-instructed dispatcher-assisted cardiopulmonary resuscitation: a systematic review and meta-analysis. Ann Med. 2022;54(1):464-71.
19. Mazya MV, Berglund A, Ahmed N, von Euler M, Holmin S, Laska AC, et al. Implementation of a Prehospital Stroke Triage System Using Symptom Severity and Teleconsultation in the Stockholm Stroke Triage Study. JAMA Neurol. 2020;77(6):691-9.
20. Lee SY, Song KJ, Shin SD, Hong KJ, Kim TH. Comparison of the effects of audio-instructed and video-instructed dispatcher-assisted cardiopulmonary resuscitation on resuscitation outcomes after out-of-hospital cardiac arrest. Resuscitation. 2020;147:12-20.
21. Lee SGW, Kim TH, Lee HS, Shin SD, Song KJ, Hong KJ, et al. Efficacy of a new dispatcher-assisted cardiopulmonary resuscitation protocol with audio call-to-video call transition. Am J Emerg Med. 2021;44:26-32.
22. Lee HS, You K, Jeon JP, Kim C, Kim S. The effect of video-instructed versus audio-instructed dispatcher-assisted cardiopulmonary resuscitation on patient outcomes following out of hospital cardiac arrest in Seoul. Sci Rep. 2021;11(1):15555.
23. Richards CT, Oostema JA, Chapman SN, Mamer LE, Brandler ES, Alexandrov AW, et al. Prehospital Stroke Care Part 2: On-Scene Evaluation and Management by Emergency Medical Services Practitioners. Stroke. 2023;54(5):1416-25.
24. Phongphuttha W TS. Outcome of Stroke Fast-Track Patients Arrival by Emergency Medical Services. Journal of the Medical Association of Thailand. 2021;104(Suppl. 1):S88-S93.
25. Yang H, Wu Z, Huang X, Zhang M, Fu Y, Wu Y, et al. In-Hospital Emergency Treatment Delay Among Chinese Patients with Acute Ischaemic Stroke: Relation to Hospital Arrivals and Implications for Triage Pathways. Int J Gen Med. 2023;16:57-68.
26. Sangari A, Akhoundzadeh K, Vahedian M, Sharifipour E. Effect of pre-hospital notification on delays and neurological outcomes in acute ischemic stroke. Australas Emerg Care. 2022;25(2):172-5.
27. Shkirkova K, Saver JL, Starkman S, Wong G, Weng J, Hamilton S, et al. Frequency, Predictors, and Outcomes of Prehospital and Early Postarrival Neurological Deterioration in Acute Stroke: Exploratory Analysis of the FAST-MAG Randomized Clinical Trial. JAMA Neurol. 2018;75(11):1364-74.
28. Tansuwannarat P, Atiksawedparit P, Wibulpolprasert A, Mankasetkit N. Prehospital time of suspected stroke patients treated by emergency medical service: a nationwide study in Thailand. Int J Emerg Med. 2021;14(1):37.
29. Cash RE, Richards CT. Emergency Medical Services Data: An Unexpected Source of Variation in Stroke Care Performance. J Am Heart Assoc. 2023;12(1):e028491.
30. Oostema JA, Nickles A, Luo Z, Reeves MJ. Emergency Medical Services Stroke Care Performance Variability in Michigan: Analysis of a Statewide Linked Stroke Registry. J Am Heart Assoc. 2023;12(1):e026834.
31. Saver JL, Chaisinanunkul N, Campbell BCV, Grotta JC, Hill MD, Khatri P, et al. Standardized Nomenclature for Modified Rankin Scale Global Disability Outcomes: Consensus Recommendations From Stroke Therapy Academic Industry Roundtable XI. Stroke. 2021;52(9):3054-

62.
32. Oostema JA, Nickles A, Allen J, Ibrahim G, Luo Z, Reeves MJ. Emergency Medical Services Compliance With Prehospital Stroke Quality Metrics Is Associated With Faster Stroke Evaluation and Treatment. Stroke. 2024;55(1):101-9.
33. Sloane B, Bosson N, Sanossian N, Saver JL, Perez L, Gausche-Hill M. Is Door-to-Needle Time Reduced for Emergency Medical Services Transported Stroke Patients Routed Directly to the Computed Tomography Scanner on Emergency Department Arrival? J Stroke Cerebrovasc Dis. 2020;29(1):104477.
34. Powers WJ, Rabinstein AA, Ackerson T, Adeoye OM, Bambakidis NC, Becker K, et al. Guidelines for the Early Management of Patients With Acute Ischemic Stroke: 2019 Update to the 2018 Guidelines for the Early Management of Acute Ischemic Stroke: A Guideline for Healthcare Professionals From the American Heart Association/American Stroke Association. Stroke. 2019;50(12):e344-e418.
35. Chowdhury SZ, Baskar PS, Bhaskar S. Effect of prehospital workflow optimization on treatment delays and clinical outcomes in acute ischemic stroke: A systematic review and meta-analysis. Acad Emerg Med. 2021;28(7):781-801.
36. Sadeghi-Hokmabadi E, Taheraghdam A, Hashemilar M, Rikhtegar R, Mehrvar K, Mehrara M, et al. Simple In-Hospital Interventions to Reduce Door-to-CT Time in Acute Stroke. Int J Vasc Med. 2016;2016:1656212.
37. Lin CB, Peterson ED, Smith EE, Saver JL, Liang L, Xian Y, et al. Emergency medical service hospital prenotification is associated with improved evaluation and treatment of acute ischemic stroke. Circ Cardiovasc Qual Outcomes. 2012;5(4):514-22.
38. Binning MJ, Sanfillippo G, Rosen W, D’Ambrosio M, Veznedaroglu E, Liebman K, et al. The neurological emergency room and prehospital stroke alert: the whole is greater than the sum of its parts. Neurosurgery. 2014;74(3):281-5; discussion 5.
39. Giorelli M, Leone R, Aniello MS, Altomare S, Colonna I, Liuzzi D, et al. Bringing door-to-needle times within the European benchmarks results in better stroke patients outcomes in a spoke hospital from the Apulian Region. Neurol Sci. 2023;44(9):3199-207.
40. Minaeian A, Patel A, Essa B, Goddeau RP, Jr., Moonis M, Henninger N. Emergency Department Length of Stay and Outcome after Ischemic Stroke. J Stroke Cerebrovasc Dis. 2017;26(10):2167-73.
41. Huang YC, Hu CJ, Lee TH, Yang JT, Weng HH, Lin LC, et al. The impact factors on the cost and length of stay among acute ischemic stroke. J Stroke Cerebrovasc Dis. 2013;22(7):e152-8.
42. Kang JH, Bae HJ, Choi YA, Lee SH, Shin HI. Length of Hospital Stay After Stroke: A Korean Nationwide Study. Ann Rehabil Med. 2016;40(4):675-81.
43. Poll M, Martins RT, Anschau F, Jotz GP. Length of Hospitalization and Mortality among Stroke Patients before and after the Implementation of a Specialized Unit: A Retrospective Cohort Study Using Real-World Data from One Reference Hospital in Southern Brazil. Healthcare. 2024;12(8):836.
44. Shimozuru Y, Matsushima Y, Ochi M, Itoh H, Hachisuka A, Saeki S. Survey of patients with stroke in the Kitakyushu Area, Japan: a 12-year retrospective analysis of the critical pathway. J Stroke Cerebrovasc Dis. 2024;33(2):107525.
45. Brandler ES, Sharma M, McCullough F, Ben-Eli D, Kaufman B, Khandelwal P, et al. Prehospital Stroke Identification: Factors Associated with Diagnostic Accuracy. J Stroke Cerebrovasc Dis. 2015;24(9):2161-6.
46. Itrat A, Taqui A, Cerejo R, Briggs F, Cho SM, Organek N, et al. Telemedicine in Prehospital Stroke Evaluation and Thrombolysis: Taking Stroke Treatment to the Doorstep. JAMA Neurol. 2016;73(2):162-8.
47. Ebinger M, Winter B, Wendt M, Weber JE, Waldschmidt C, Rozanski M, et al. Effect of the use of ambulance-based thrombolysis on time to thrombolysis in acute ischemic stroke: a randomized clinical trial. JAMA. 2014;311(16):1622-31.
48. Barrett KM, Pizzi MA, Kesari V, TerKonda SP, Mauricio EA, Silvers SM, et al. Ambulance-based assessment of NIH Stroke Scale with telemedicine: A feasibility pilot study. J Telemed Telecare. 2017;23(4):476-83.
49. Turc G, Bhogal P, Fischer U, Khatri P, Lobotesis K, Mazighi M, et al. European Stroke Organisation (ESO)-European Society for Minimally Invasive Neurological Therapy (ESMINT) guidelines on mechanical thrombectomy in acute ischemic stroke. J Neurointerv Surg. 2019;11(6):535-8.
50. Mullhi RK, Singh N, Veenith T. Critical care management of the patient with an acute ischaemic stroke. Br J Hosp Med (Lond). 2021;82(1):1-9.

Table 1: Comparing the baseline characteristics of studied patients before and after implementation of pre-hospital stroke management protocol in Ramathibodi Hospital

Characteristics	Protocol implementation		P-value
	Before (n=36)	**After (n=55)**	
Gender			
Male	24 (66.67)	35 (63.64)	0.825
Age (year)			
Mean ± SD	60.81 ± 13.65	64.18 ± 14.76	0.275
Initial Glasgow Coma Scale			
13-15	20 (55.56)	32 (58.18)	0.292
9-12	8 (22.22)	17 (30.91)	
3-8	8 (22.22)	6 (10.91)	
Diagnosis outcome			
Ischemic Stroke	13 (40.62)	23 (47.92)	0.280
Hemorrhagic stroke	17 (53.12)	16 (33.33)	
Large vessel occlusion	1 (3.12)	4 (8.33)	
Transient ischemic attack	1 (3.12)	5 (10.42)	
Other#	4 (11.11)	7 (12.73)	
Initial Prehospital Vital sign			
SBP (mmHg)	160.09 ± 44.29	154.29 ± 39.47	0.247
HR (/minute)	88.65 ± 22.84	89.92 ± 18.60	0.778
RR (/minute)	20.38 ± 2.83	19.56 ± 2.29	0.148
Capillary Blood Glucose (mg/dl)	147.42 ± 38.63	156.84 ± 46.38	0.351
Time of EMS (minutes)			
Activation time	3 (2 - 7)	5 (3 - 7)	0.037
Response time	13.5 (9 - 18)	14 (11 - 22)	0.089
Scene time	20 (16 - 23)	25 (21 - 33)	0.002
Transport time	7.5 (6 - 10)	7 (5 - 12)	0.985
NIHSS Score			
Prehospital	N/A*	11 (5 - 18)	N/A
ED	13 (6 - 19)	10.5 (4 - 20.5)	0.416
Stroke unit	18.5 (6 - 23)	17.5 (11.5 - 25.5)	0.699

Data are presented as mean ± standard deviation (SD), frequency (%), or median (interquartile range (IQR)).
SBP: Systolic blood pressure; HR: Heart rate; RR: Respiratory rate; EMS: Emergency medical service;
NIHSS: National Institutes of Health Stroke Scale; ED: Emergency department.
*N/A: Not assessment of pre-protocol period; #Other: Non-stroke diagnosis outcome.

Table 2: Stroke management characteristics after implementation of the Ramathibodi prehospital stroke protocol (n = 55)

Management characteristics	Number (%)
Pre-arrival dispatcher assistance	
Phone assistance	14 (25.45)
Video-call assistance	41 (74.55)
FMC intervals times to (minutes)	
Detection	0 (-8, 4)
Activate stroke team	1 (-2, 6)
Laboratory Result	84.51 ± 27.69
Brain computed tomography scan	46 (38, 59)
Intravenous thrombolysis	79.6 ± 27.22
Mechanical thrombectomy	175.71 ± 27.55
Prehospital intervention	
Endotracheal intubation	1 (1.82)
Intravenous access	50 (90.91)
Complete blood Lab	43 (78.18)
Transfer 12 leads ECG data	43 (79.63)

Data are presented as mean ± standard deviation (SD), frequency (%), or median (interquartile range (IQR)).
FMC: First medical contact; ECG: Electrocardiography.

Table 3: Comparing the outcomes of stroke patients before and after implementation of Ramathibodi Prehospital Stroke Protocol

Outcome	Protocol implementation		P-value
	Before (n=36)	After (n=55)	
Modified Rankin Scale (mRS) at hospital discharge			
0 (Normal)	0 (0)	4 (7.69)	0.055
1	7 (19.44)	3 (5.77)	
2	1 (2.78)	2 (3.85)	
3	3 (8.33)	4 (7.69)	
4	4 (11.11)	12 (23.08)	
5	19 (52.78)	18 (34.62)	
6 (Death)	2 (5.56)	9 (17.31)	
Favorable neurological outcome (mRS = 0-2)			
Yes	8 (22.22)	9 (17.31)	0.593
Length of stay			
Emergency department (hours)	2.42 (2.00 – 5.08)	3.35 (2.05 – 6.80)	0.153
Stroke unit (days)	5 (3 - 9)	4.5 (2 - 8.5)	0.795
Hospital (days)	5.5 (2 - 14)	4 (2 - 8)	0.169
Door-to- time intervals (minutes)			
Brain computed tomography scan	26 (16 – 36)	7 (5 – 10)	< 0.001
Intravenous thrombolysis (n= 6 vs. 10)	44.5 (32 – 63)	35.5 (18 – 45)	0.231
Laboratory results	39 (23 – 51)	36 (28.5 – 43)	0.601
Mechanical thrombectomy (n= 3 vs. 7)	143.33 ± 20.82	135.57 ± 22.43	0.633

Data are presented as mean ± standard deviation (SD), frequency (%), or median (interquartile range (IQR)).

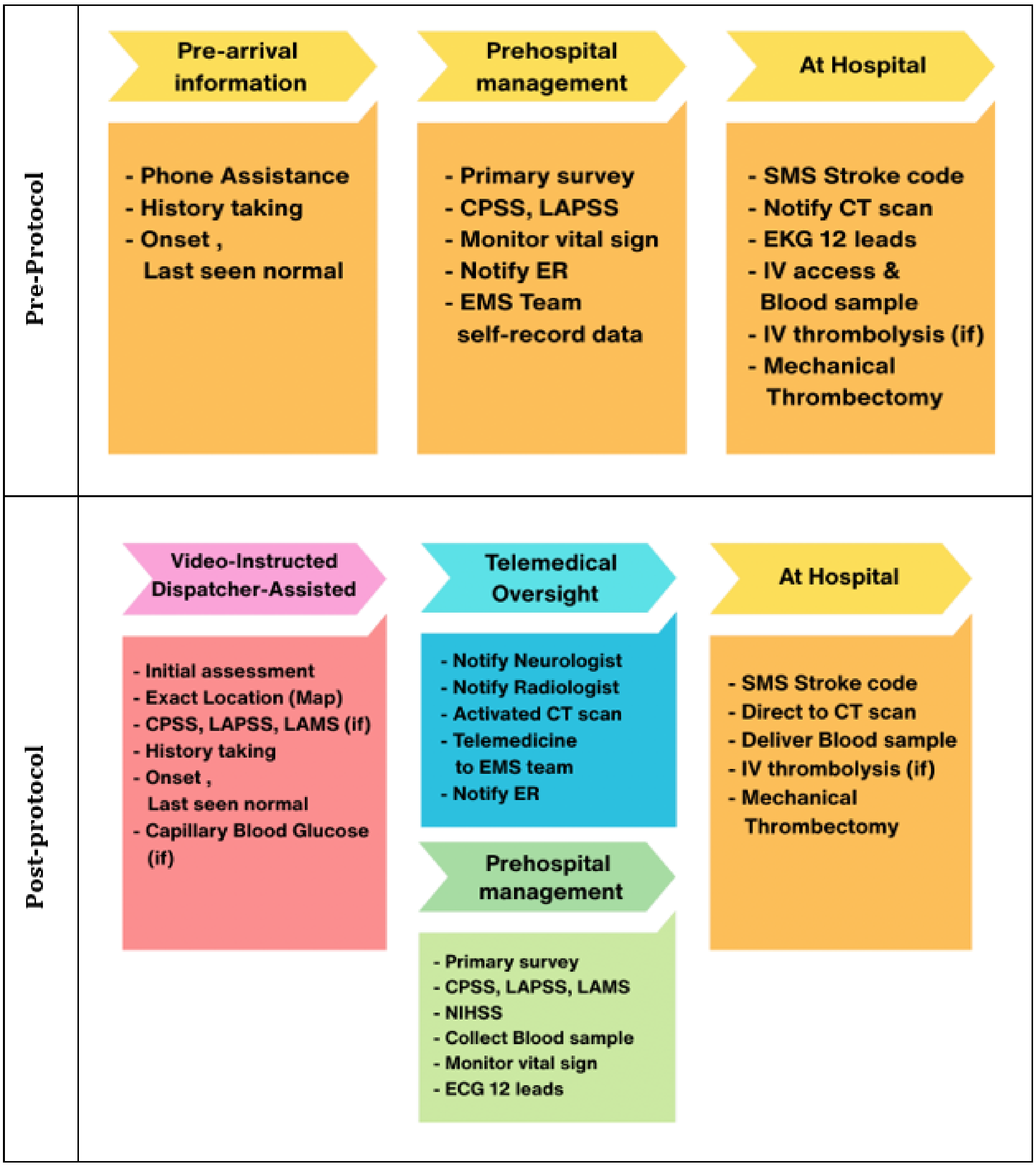

Figure 1: Stroke patient management in Ramathibodi Hospital. CT: computed tomography; IV: intravenous; CPSS: Cincinnati Prehospital Stroke Scale; LAPSS: Los Angeles Prehospital Stroke Screen; LAMS: Los Angeles Motor Scale; NIHSS: National Institutes of Health Stroke Scale; ECG/EKG: electrocardiography; EMS: emergency medical services; ER: emergency room.

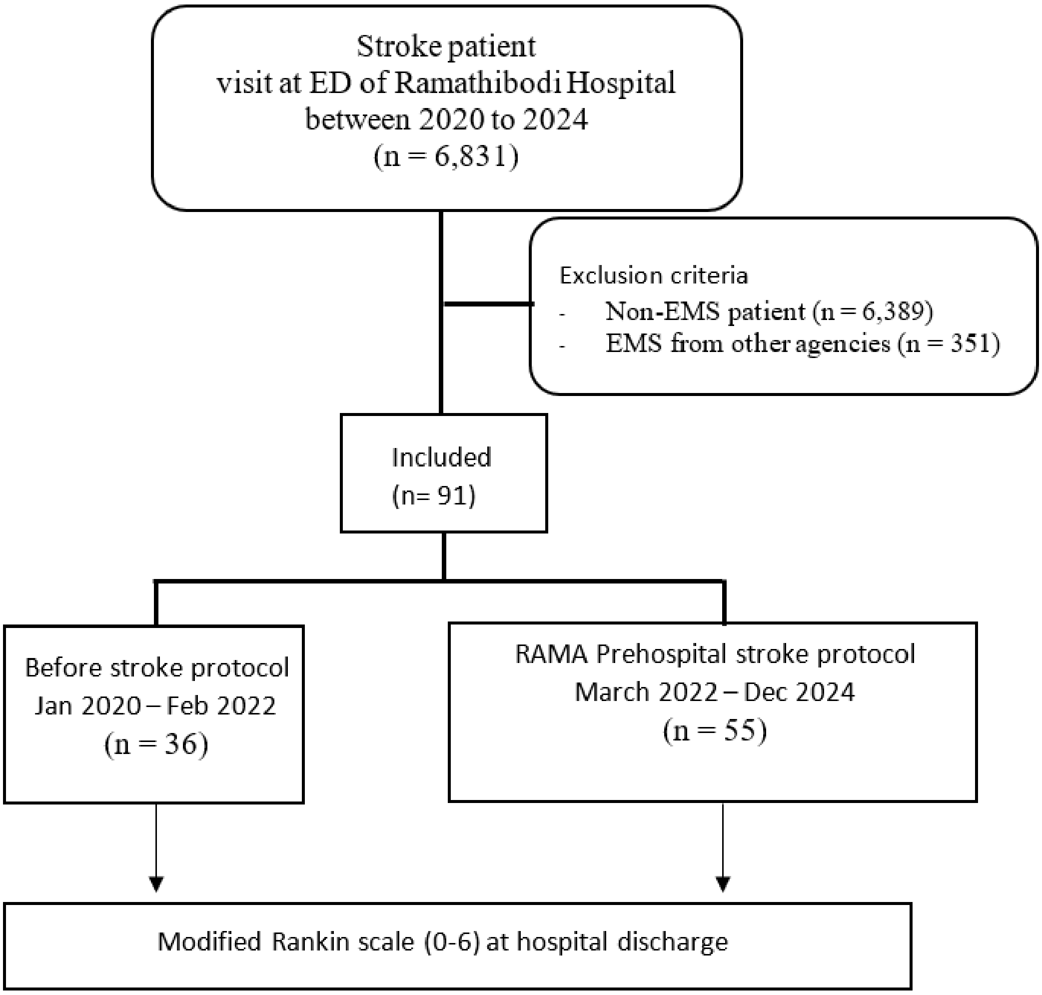

Figure 2: Study flow diagram. ED: emergency department; EMS: emergency medical services; RAMA: Ramathibodi.

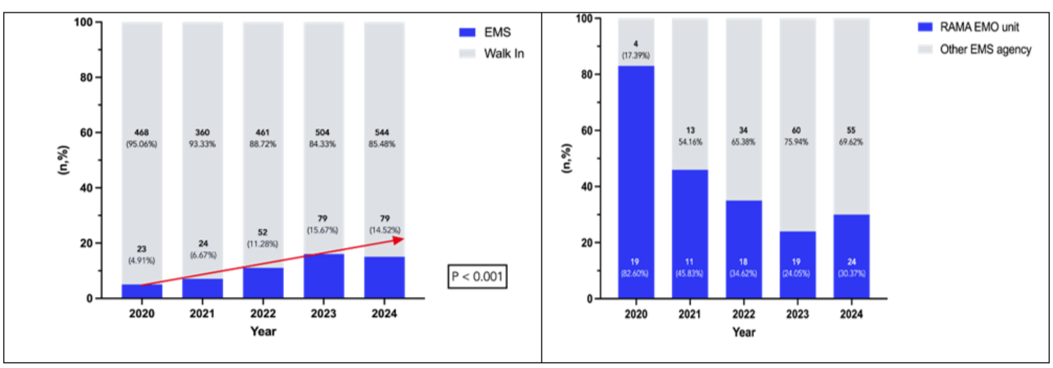

Figure 3: Type of emergency department arrival and emergency medical services (EMS) agency in studied stroke cases. RAMA EMO: Ramathibodi Emergency Medical Operation.