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Recognition and Early Assessment of Acute Stroke Using the FAST and BE FAST Approach-An Updated Review.

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Abstract

Background: Acute stroke requires rapid recognition and referral to improve access to time-dependent treatments and reduce mortality and long-term disability. Delays in symptom identification, emergency response, and hospital referral remain major challenges across healthcare systems.

Aim: This systematic review aimed to evaluate the effectiveness of stroke recognition tools and referral strategies in primary and emergency care and examine their effects on treatment timeliness and patient outcomes.

Methods: A systematic review was conducted of 33 studies published between 2003 and 2025. The included studies investigated conventional stroke recognition scales, dispatcher-based triage systems, emergency medical services interventions, mobile stroke units, and artificial intelligence-based approaches. Evidence was synthesized narratively because of heterogeneity in study designs, populations, diagnostic accuracy measures, and reported outcomes.

Results: FAST, CPSS, ROSIER, and NIHSS were frequently evaluated, with conventional screening tools generally demonstrating sensitivity above 80%, although specificity varied. PreHAST and FAST-ED showed potential for identifying severe stroke and large vessel occlusion. Dispatcher-based systems improved emergency prioritization and reduced referral delays by approximately 12–20 minutes. Mobile stroke units reduced time to imaging by 8–17 minutes and increased reperfusion eligibility by 7–12%. Improved recognition and referral were associated with greater treatment access and functional independence. However, rural and resource-limited settings continued to experience delays related to transportation, imaging availability, and EMS capacity. AI-based approaches showed promising diagnostic performance but require further validation.

Conclusion: Structured recognition tools and coordinated referral pathways improve early stroke management. Their effectiveness depends on appropriate implementation, healthcare infrastructure, and equitable access to emergency services.

Keywords: Acute stroke; FAST; stroke recognition; emergency medical services; prehospital triage; referral pathways; mobile stroke units; artificial intelligence.

Introduction

Stroke remains one of the leading causes of death and long-term disability worldwide, representing a major public health challenge and placing substantial burdens on healthcare systems, patients, and their families. It occurs when the blood supply to a specific area of the brain becomes interrupted or reduced, preventing brain tissue from receiving sufficient oxygen and nutrients. This interruption may result from an arterial blockage (ischemic stroke) or the rupture of a cerebral blood vessel (hemorrhagic stroke). Both types can cause permanent neurological damage, depending on the affected brain region, the extent of tissue injury, and the time required to initiate appropriate medical intervention. Epidemiological evidence indicates that approximately one in four adults may experience a stroke during their lifetime. The majority of stroke cases occur in low- and middle-income countries, although high-income countries also face considerable challenges associated with population aging and the increasing prevalence of cardiovascular risk factors, including hypertension, diabetes mellitus, obesity, smoking, and physical inactivity [1]. The clinical and socioeconomic consequences of stroke extend beyond the acute phase of illness. Survivors may experience persistent neurological impairments, including muscle weakness, paralysis, speech and language difficulties, swallowing disorders, cognitive impairment, visual disturbances, and psychological problems. These complications can interfere with activities of daily living, reduce

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independence, and negatively affect overall quality of life. Furthermore, stroke-related disability frequently requires prolonged rehabilitation, continuous medical supervision, and family support. Consequently, early recognition, timely diagnosis, and appropriate management are essential components of effective stroke prevention and treatment strategies.

Time represents one of the most important determinants of outcomes following acute stroke. During cerebral ischemia, inadequate blood flow deprives neurons of oxygen and glucose, initiating a cascade of metabolic disturbances, cellular injury, and neuronal death. It has been estimated that approximately 1.9 million neurons are lost every minute during an untreated large-vessel ischemic stroke [2]. This progressive neurological injury explains the importance of rapid identification and emergency intervention. Reperfusion therapies, particularly intravenous thrombolysis and endovascular thrombectomy, aim to restore cerebral blood flow and preserve potentially salvageable brain tissue. Intravenous thrombolysis is generally recommended within 4.5 hours of symptom onset in eligible patients, whereas endovascular thrombectomy may benefit selected patients with large-vessel occlusion within 6 hours and, following appropriate clinical and imaging assessment, up to 24 hours after symptom onset [3]. Therefore, delays in symptom recognition, emergency activation, transportation, and hospital assessment may reduce treatment eligibility and increase the risk of mortality and long-term disability [4]. Early stroke recognition is particularly important because the initial symptoms may develop suddenly and vary according to the location and severity of the affected cerebral region. Common manifestations include unilateral facial weakness, weakness or numbness affecting one arm or leg, sudden speech difficulties, visual disturbances, loss of balance, dizziness, and severe unexplained headache. Some patients present with subtle neurological symptoms that may be overlooked by family members, bystanders, or healthcare professionals. In particular, posterior circulation strokes may produce dizziness, ataxia, visual disturbances, and coordination problems without the typical facial or arm weakness associated with anterior circulation strokes. This clinical variability emphasizes the importance of structured recognition approaches and comprehensive neurological assessment.

The Face, Arm, Speech, Time (FAST) assessment is one of the most widely used screening approaches for identifying potential stroke symptoms. It provides a simple and rapid method that can be performed by healthcare professionals, emergency medical services (EMS) personnel, patients' relatives, and members of the public. The assessment focuses on three major neurological indicators. Facial weakness is evaluated by asking the patient to smile and observing whether one side of the face appears to droop. Arm weakness is assessed by asking the patient to raise both arms and identifying whether one arm drifts downward or cannot be maintained in position. Speech abnormalities are evaluated by asking the patient to repeat a simple sentence and observing slurred speech, incorrect word use, or difficulty understanding and producing language. The final component, Time, emphasizes the importance of immediately activating emergency medical services and recording the time when symptoms first appeared or when the patient was last known to be neurologically normal. An extended version, known as BE-FAST, incorporates Balance and Eyes to improve recognition of symptoms associated with posterior circulation strokes. Balance assessment focuses on sudden loss of coordination, gait instability, or unexplained dizziness, whereas Eye assessment considers sudden visual loss, double vision, or visual field disturbances. These additional components may help identify patients who do not present with the conventional FAST symptoms. Nevertheless, FAST and BE-FAST remain screening approaches rather than definitive diagnostic methods. A negative screening result does not completely exclude stroke, particularly in patients presenting with atypical neurological manifestations.

Other standardized assessment instruments are also used in prehospital and emergency settings. These include the Cincinnati Prehospital Stroke Scale (CPSS), Recognition of Stroke in the Emergency Room (ROSIER) scale, and National Institutes of Health Stroke Scale (NIHSS). The CPSS evaluates facial drooping, arm weakness, and speech abnormalities, providing a rapid method for identifying suspected stroke. The ROSIER scale incorporates neurological findings such as facial weakness, arm weakness, leg weakness, speech disturbance, visual field defects, and loss of consciousness or syncope. The NIHSS provides a more comprehensive assessment of neurological impairment through standardized evaluation of consciousness, gaze, visual fields, facial movement, limb strength, sensation, language, articulation, and neglect [5]. Evidence indicates that the FAST assessment has high sensitivity, commonly reported at approximately 94–95%, although specificity may range between 55% and 60%, depending on the population and clinical setting [6]. This relatively high sensitivity supports its use as an initial screening instrument, while its limited specificity means that some patients without stroke may be incorrectly identified as suspected cases. Conditions that may resemble acute stroke include hypoglycemia, seizures, migraine, vestibular disorders, metabolic disturbances, and functional neurological disorders. Consequently, patients identified through FAST screening require further clinical assessment and diagnostic investigations. The ROSIER and CPSS instruments also demonstrate useful diagnostic

performance, although their accuracy varies according to the patient population, healthcare setting, and experience of the healthcare professional performing the assessment [7].

Emergency departments play a central role in confirming the diagnosis and initiating appropriate treatment. Initial assessment should include evaluation of airway, breathing, and circulation, measurement of vital signs, assessment of blood glucose, and documentation of neurological findings. Particular attention should be given to identifying the exact time of symptom onset or the last-known-well time, as this information directly influences eligibility for reperfusion therapy. Non-contrast computed tomography (NCCT) is generally the initial imaging investigation because it can rapidly identify intracranial hemorrhage and help distinguish hemorrhagic from ischemic stroke. Computed tomography angiography (CTA) may subsequently identify large-vessel occlusion and support decisions regarding endovascular thrombectomy. Magnetic resonance imaging (MRI), particularly diffusion-weighted imaging, can provide additional information about early ischemic changes when clinically indicated and available. Despite advances in stroke assessment and emergency treatment, several barriers continue to delay recognition and management. These include limited public awareness of stroke symptoms, inadequate professional training, delayed emergency calls, transportation difficulties, insufficient access to diagnostic imaging, and unequal distribution of specialized stroke services. Rural communities and resource-limited healthcare settings may experience additional challenges related to the availability of EMS, neurologists, imaging facilities, and stroke units [8]. Organizational barriers, including inconsistent emergency department protocols, inadequate communication between prehospital and hospital teams, and delays in neurological consultation, may further affect treatment timelines [9].

Misdiagnosis represents another important challenge in acute stroke management. Previous evidence suggests that approximately 10–25% of stroke cases may initially be misdiagnosed, particularly when patients present with mild, atypical, or posterior circulation symptoms [10]. Failure to recognize these presentations can result in inappropriate treatment, delayed imaging, and missed opportunities for reperfusion. Improving the knowledge and practical assessment skills of emergency healthcare professionals is therefore essential for reducing diagnostic errors and improving patient outcomes. Regular training, simulation-based education, standardized assessment protocols, and continuous evaluation of clinical performance can strengthen the ability of healthcare professionals to identify suspected stroke cases. The role of EMS personnel is particularly important in reducing prehospital delays. Early recognition at the scene, appropriate prioritization during transportation, and prenotification of the receiving hospital allow emergency teams to prepare for immediate assessment and treatment. EMS prenotification and dispatcher-supported triage have been associated with reductions in onset-to-door times of approximately 12–22 minutes and improvements in reperfusion eligibility of 7–12% [11]. Furthermore, early communication between prehospital providers and hospital stroke teams can facilitate direct transfer to imaging facilities and reduce unnecessary delays in emergency department procedures [12].

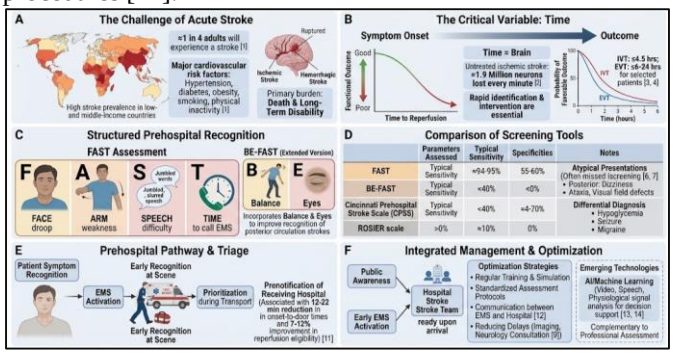


Figure-1: Recognition and Early Assessment of Acute Stroke Using the FAST.

Emerging technologies may provide additional opportunities to improve stroke recognition. Artificial intelligence (AI)-based systems using video analysis, speech recognition, clinical information, and neuroimaging data are being investigated to support early identification of neurological abnormalities. Some approaches have reported sensitivities exceeding 79% and specificities exceeding 84%, although performance varies according to the technology, study population, and validation methods [13]. Machine-learning approaches involving physiological signals, biomarkers, and imaging characteristics may also contribute to clinical decision-making and patient prioritization [14]. Although these technologies cannot replace professional assessment or established diagnostic procedures, they may complement existing screening methods and improve the efficiency of emergency stroke pathways. Ultimately, successful stroke management depends on an integrated approach involving public awareness, early symptom recognition, rapid EMS activation, standardized neurological assessment, timely diagnostic imaging, and access to appropriate treatment. The FAST assessment remains an important first-line screening approach because of its simplicity, accessibility, and suitability for different healthcare settings. However, healthcare professionals should understand its limitations and recognize the importance of additional neurological findings, particularly in patients with atypical presentations. Improving knowledge and competency in FAST assessment

among emergency healthcare professionals may contribute to earlier stroke recognition, more efficient referral, reduced treatment delays, and improved clinical outcomes. Therefore, understanding the principles of stroke recognition, identifying common and atypical clinical manifestations, and applying standardized assessment methods are essential competencies for healthcare professionals working in emergency departments and prehospital care settings.

Diagnostic Accuracy of Stroke Recognition Tools and Emerging Assessment Models

The diagnostic accuracy of stroke recognition tools represents a major determinant of effective prehospital assessment, emergency referral, and timely treatment of patients with suspected acute stroke. Early identification is particularly important because the clinical benefits of reperfusion therapies depend on rapid recognition and access to appropriate medical intervention. Several standardized screening instruments have therefore been developed to assist healthcare professionals and emergency medical services (EMS) personnel in identifying patients who may have experienced an acute cerebrovascular event. These tools differ in their assessment components, diagnostic thresholds, sensitivity, and specificity. Recent studies have also investigated artificial intelligence (AI) and machine-learning models as potential approaches to improving stroke recognition and supporting clinical decision-making. Sensitivity and specificity are two essential indicators used to evaluate the diagnostic performance of stroke recognition instruments. Sensitivity represents the proportion of patients with confirmed stroke who are correctly identified by the screening tool. A highly sensitive instrument reduces the likelihood of false-negative results, which is particularly important in emergency settings because missed stroke cases may experience delays in treatment. Specificity represents the proportion of patients without stroke who are correctly classified as negative. Higher specificity reduces false-positive results and unnecessary emergency referrals. However, these two measures frequently involve a trade-off, particularly when screening tools use low diagnostic thresholds to maximize the identification of potential stroke cases. The FAST assessment remains one of the most investigated instruments because of its simplicity and suitability for prehospital and emergency environments. Harbison et al. (2003), in a prospective cohort study conducted in the United Kingdom, reported a sensitivity of 86% and specificity of 60% for FAST when compared with computed tomography (CT)-confirmed diagnoses. These findings demonstrate that FAST can identify a substantial proportion of patients with stroke, although its moderate specificity indicates that a considerable number of patients without stroke may also produce positive screening results. In comparison, Saberian et al. (2021), in an Iranian study using magnetic resonance imaging (MRI) as the diagnostic reference standard, reported a sensitivity of 94.8% and specificity of 55.1%. The higher sensitivity suggests that FAST may be particularly useful as an initial screening instrument when the primary objective is to avoid missing suspected stroke cases. However, its relatively limited specificity highlights the importance of subsequent neurological assessment and diagnostic imaging.

Other standardized instruments have demonstrated different diagnostic performance profiles. The FAST-ED scale, which extends conventional FAST assessment by incorporating additional clinical indicators associated with large-vessel occlusion, demonstrated a sensitivity of 88.0% and specificity of 57.5% at a cutoff score of ≥2 in the study by Nasr-Esfahani et al. (2021). The scale may provide additional information for identifying patients who require urgent assessment for potential endovascular treatment. Nevertheless, its diagnostic accuracy depends on the selected cutoff, patient characteristics, and clinical setting. Similarly, the Prehospital Acute Stroke Severity Scale (PreHAST) demonstrated a sensitivity of 93.2% and specificity of 46.5% at a cutoff score of ≥1 in the study by Karimi et al. (2020). Although its high sensitivity supports its potential application in early stroke screening, its low specificity suggests that the selected threshold may identify a considerable number of patients who do not have confirmed stroke. This finding illustrates the importance of selecting appropriate diagnostic thresholds according to the intended clinical purpose. A lower threshold may be preferable when screening aims to identify nearly all suspected cases, whereas higher thresholds may be considered when the objective involves prioritizing patients with more severe neurological impairment. The Recognition of Stroke in the Emergency Room (ROSIER) scale demonstrated a sensitivity of 95.0% and specificity of 60.1% in the study by Saberian et al. (2021). Its performance indicates that it can identify a high proportion of patients with stroke while maintaining moderate specificity. The inclusion of several neurological findings, including facial weakness, limb weakness, speech abnormalities, and visual field disturbances, may contribute to its diagnostic performance. These characteristics make ROSIER a useful instrument for structured emergency department assessment, particularly when healthcare professionals need to distinguish suspected stroke from common clinical mimics.

The same study evaluated several additional screening instruments, including the Los Angeles Prehospital Stroke Screen (LAPSS), Cincinnati Prehospital Stroke Scale (CPSS), Med PACS, Ontario Prehospital Stroke Scale (OPSS), and Melbourne Ambulance Stroke Screen (MASS). LAPSS demonstrated a sensitivity of 71.9% and specificity of 82.8%, indicating a different balance between identifying stroke cases and excluding

patients without stroke. Its relatively high specificity may reduce unnecessary stroke alerts, although its lower sensitivity raises concerns regarding missed cases. In contrast, CPSS demonstrated a sensitivity of 95.0% and specificity of 54.3%, supporting its use as a sensitive initial screening instrument. Med PACS produced a sensitivity of 95.7% and specificity of 50.6%, representing the highest sensitivity among the conventional recognition instruments reported in this comparison. OPSS demonstrated a sensitivity of 80.8% and specificity of 59.5%, whereas MASS showed a sensitivity of 86.7% and specificity of 61.8%. These differences indicate that no single conventional screening instrument provides optimal performance across all diagnostic conditions and healthcare environments. Recent developments in artificial intelligence have introduced additional approaches to stroke recognition. AI-based systems may analyze clinical observations, physiological signals, medical images, and other patient-related information to identify patterns associated with cerebrovascular events. Cai et al. (2022) evaluated DeepStroke, an AI-based approach in an emergency department setting and reported a sensitivity of 78.61% and specificity of 51.61% compared with clinician assessment. Although these findings indicate the potential usefulness of automated recognition systems, the relatively limited specificity and sensitivity suggest that further development and validation are necessary before such approaches can be considered reliable alternatives to established clinical assessment.

Goda et al. (2025) investigated a machine-learning model based on photoplethysmography (PPG) signals in a multicenter diagnostic feasibility study. The model demonstrated a sensitivity of 66% and specificity of 74%. PPG technology measures changes in blood volume within peripheral tissues and may provide physiological information that can be analyzed using computational approaches. Although the reported sensitivity was lower than that of several conventional stroke screening instruments, the findings suggest that physiological signal analysis may contribute to the development of complementary diagnostic approaches. Kuzan et al. (2025) evaluated the diagnostic performance of ChatGPT-4V using retrospective MRI analysis and reported a sensitivity of 79.57% and specificity of 84.87%. These findings indicate a different diagnostic profile from that of conventional FAST-based screening, with relatively higher specificity. The ability of multimodal AI systems to process medical images may offer opportunities for supporting image interpretation and clinical decision-making. However, retrospective diagnostic performance should not be interpreted as evidence of equivalent effectiveness in real-time emergency environments. Prospective studies involving larger and more diverse patient populations are required to establish clinical reliability. Among the emerging computational approaches, the hemodynamic machine-learning model investigated by García-Terriza et al. (2023) demonstrated a sensitivity of 98.0% and specificity of 97.8%. These results represent the highest reported diagnostic performance among the models included in the presented comparison. The model was based on hemodynamic monitoring, suggesting that physiological measurements may provide useful information for identifying abnormalities associated with acute cerebrovascular events. Nevertheless, these findings should be interpreted according to the study design, patient selection, monitoring conditions, and external validation procedures. High diagnostic accuracy in a particular study does not necessarily guarantee similar performance across different healthcare settings.

Another approach, DARE-PACE, evaluated by Yiang et al. (2022) in Taiwan, demonstrated a sensitivity of 85.4% and specificity of 97.7% among patients with an NIHSS score ≥8. The study used registry-based data and CT angiography (CTA) confirmation. Its high specificity suggests potential value in identifying selected patients with substantial neurological impairment and supporting the prioritization of further vascular assessment. However, its performance in patients with NIHSS scores ≥8 should not be generalized to all suspected stroke patients, particularly those presenting with mild neurological deficits. Overall, the findings presented in Table 1 demonstrate considerable variation in the diagnostic performance of conventional stroke screening instruments and emerging AI-based models. Conventional tools such as FAST, CPSS, and ROSIER generally demonstrate high sensitivity, supporting their role in initial stroke recognition and emergency referral. However, their moderate specificity highlights the need for further diagnostic investigations to distinguish true stroke cases from clinical mimics. Conversely, instruments such as LAPSS and emerging models such as ChatGPT-4V and DARE-PACE demonstrate higher specificity in their respective study populations, although their sensitivity and applicability differ. The comparison also highlights the importance of interpreting diagnostic accuracy within the context of study design and reference standards. Studies using MRI, CT, CTA, clinician assessment, or selected severity thresholds do not necessarily evaluate identical diagnostic outcomes. Differences in patient populations, stroke severity, assessment settings, and diagnostic cutoffs may explain some of the observed variations. Therefore, direct comparisons between these instruments should be approached cautiously.

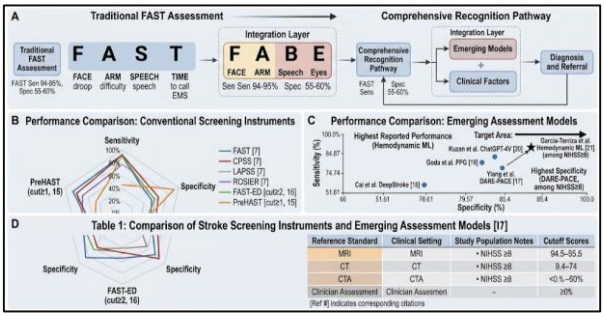


Figure-2: FAST Approach.

From an emergency care perspective, the most appropriate recognition instrument depends on its intended application. FAST and CPSS remain practical options for rapid initial screening by EMS personnel and emergency healthcare professionals because they are simple and require limited assessment time. ROSIER may be particularly useful during emergency department assessment, whereas FAST-ED and other severity-oriented approaches may assist in identifying patients who require assessment for large-vessel occlusion. AI-based systems may eventually complement these instruments by supporting clinical triage, physiological monitoring, and diagnostic imaging interpretation. Ultimately, stroke recognition should follow an integrated clinical pathway rather than depend on a single screening score. Positive screening results should trigger immediate emergency evaluation, documentation of symptom onset or last-known-well time, blood glucose measurement, neurological examination, and appropriate neuroimaging. Healthcare professionals should also remain alert to atypical presentations and recognize that a negative FAST result does not exclude stroke. Combining standardized clinical assessment with appropriate diagnostic investigations and emerging technological approaches may improve early recognition, reduce inappropriate referrals, and increase access to time-dependent stroke treatment.

Characteristics of Included Studies

The systematic review included studies investigating stroke recognition, prehospital assessment, emergency referral pathways, and interventions designed to improve the timely identification and management of patients with suspected acute stroke. The included studies varied considerably in their research designs, patient characteristics, stroke classifications, assessment settings, and referral outcomes. This variation provides a broad overview of the factors influencing early stroke recognition and the effectiveness of different approaches to improving emergency care pathways.

Study Designs and Methodological Characteristics

The included studies employed several methodological approaches, reflecting the complexity of evaluating stroke recognition and referral interventions. Randomized controlled trials, prospective and retrospective observational studies, diagnostic accuracy investigations, multicenter clinical trials, registry-based analyses, and cross-sectional studies were represented. Randomized controlled trials evaluated interventions intended to improve the recognition and management of acute stroke. For example, De Luca et al. (2009) conducted a cluster randomized controlled trial involving patients aged 80 years or younger to investigate the effects of an intervention on stroke-unit referral. The intervention group demonstrated a higher proportion of stroke-unit referrals than the control group, with 646 of 2,656 patients (24.4%) referred in the intervention group compared with 293 of 2,239 patients (13.1%) in the control group. Similarly, Denti et al. (2017) employed a stepped-wedge cluster randomized design to investigate the effect of an intervention on early stroke recognition and hospital arrival. However, the study did not demonstrate a significant effect of the campaign on early arrival, despite 635 of 1,622 patients (39.2%) arriving within two hours of symptom onset. Other investigations evaluated emergency treatment pathways and prehospital interventions. Ebinger et al. (2015) conducted a randomized-week clinical trial involving the Stroke Emergency Mobile Unit (STEMO), reporting a reduction in mean alarm-to-treatment time from 76.3 minutes in the control group to 51.8 minutes in the intervention group. Intravenous thrombolysis was administered to 33% of patients in the STEMO group compared with 21% in the control group. These findings demonstrate the potential contribution of specialized emergency services to improving treatment timeliness. Prospective and retrospective observational studies also contributed substantially to the evidence. Harbison et al. (2003) investigated stroke recognition in a prospective observational cohort, while Oostema et al. (2015) examined the relationship between EMS recognition and emergency department processes. Registry-based studies, including those conducted by Govindarajan et al. (2015), Manawadu et al. (2014), and Yiang et al. (2022), provided additional information regarding referral patterns, treatment utilization, and diagnostic pathways. Furthermore, diagnostic accuracy studies by Karimi et al. (2020), Saberian et al. (2021), and Goda et al. (2025) evaluated the performance of conventional and emerging recognition approaches.

Demographic and Clinical Characteristics

The populations investigated were predominantly older adults, reflecting the increased incidence of stroke with advancing age. Reported mean ages generally ranged from approximately 64 to 78 years, while studies reporting median ages showed similar patterns. For example, Behrndtz et al. (2023) reported a median age of 74 years, Berg et al. (2023) reported a mean age of 67.4 years, and Dela Ossa et al. (2022) reported a mean age of 75 years. Other studies, including those conducted by Saver et al. (2015) and Sundström et al. (2017), reported mean

ages of 69 and approximately 78 years, respectively. The representation of older patients was particularly evident in studies examining emergency referral and treatment pathways. Govindarajan et al. (2015) specifically investigated patients aged 80 years and older, highlighting the importance of assessing stroke recognition and treatment among elderly populations. This age distribution is clinically relevant because older patients may present with multiple comorbidities, atypical symptoms, and increased risks of complications, potentially complicating early recognition and emergency management. Regarding sex distribution, most studies reported a higher proportion of male participants. For instance, Behrndtz et al. (2023) included 103 male patients among 171 participants (60%), while Berg et al. (2023) reported 163 male patients among 290 participants (56%). Karimi et al. (2020) reported 462 male participants among 804 patients (57.5%), and Saberian et al. (2021) reported 463 male participants among 926 patients (57.5%). However, some investigations demonstrated different distributions. Oostema et al. (2015) reported that males represented 41.2% of participants, while Karliński et al. (2015) reported a male proportion of 26.2%. These variations indicate differences in the demographic composition of the populations investigated.

Distribution of Stroke Types and Diagnostic Outcomes

The included studies examined different cerebrovascular conditions, including acute ischemic stroke (AIS), intracerebral hemorrhage (ICH), transient ischemic attack (TIA), and stroke mimics. Ischemic stroke represented the predominant clinical diagnosis in most investigations reporting specific stroke classifications. Denti et al. (2017), for example, included 1,175 ischemic stroke cases (72.4%), 114 hemorrhagic stroke cases (7%), and 195 TIA cases (12%) among 1,622 participants. Similarly, Berg et al. (2023) reported 151 ischemic strokes (52%), 17 hemorrhagic strokes (6%), and 120 TIAs (41%) among 290 patients. In the study by Dela Ossa et al. (2022), ischemic stroke and TIA represented 452 of 654 cases (69%), while intracranial hemorrhage accounted for 150 cases (22.9%) and stroke mimics accounted for 50 cases (7.7%). The inclusion of stroke mimics is particularly important when evaluating recognition instruments. Conditions that resemble acute stroke may produce neurological manifestations that lead to incorrect screening results or unnecessary emergency referrals. For example, Behrndtz et al. (2023) reported 16 stroke mimics among 171 participants (9%), while Goda et al. (2025) identified 27 mimics among 88 participants (31%). These findings emphasize the importance of distinguishing genuine cerebrovascular events from alternative diagnoses during initial assessment.

Onset-to-Recognition Time and Emergency Referral Outcomes

The time between symptom onset, initial recognition, and hospital arrival represented an important component of the investigations included. Several studies demonstrated that early recognition and appropriate prioritization were associated with improvements in emergency treatment processes. Berglund et al. (2021) reported a median admission time of approximately 210 minutes among patients receiving high-priority transportation compared with approximately 240 minutes among those receiving low-priority transportation. High-priority classification was also associated with increased utilization of intravenous thrombolysis and endovascular thrombectomy. Similarly, Oostema et al. (2015) demonstrated an association between EMS stroke recognition and shorter CT completion times. Patients recognized by EMS underwent CT assessment after a mean of 34.6 minutes compared with 84.7 minutes among patients without prehospital recognition. Other investigations reported improvements in treatment eligibility following early referral. Manawadu et al. (2014) reported that early referrals were associated with substantially greater intravenous thrombolysis utilization, with 74 of 77 patients (96%) receiving treatment compared with 31 of 103 patients (30%) in the comparison group. Furthermore, Gude et al. (2023) reported that recognized acute ischemic stroke patients were more frequently admitted than unrecognized patients, with corresponding proportions of 85.8% and 74.5%, respectively. The importance of appropriate referral pathways was also demonstrated by Helwig et al. (2019), who reported secondary transfers in 68 of 165 patients (41.2%) managed through the conventional pathway compared with no secondary transfers among 210 patients managed through the mobile stroke unit pathway. These findings suggest that specialized prehospital services may improve access to appropriate stroke facilities and reduce additional transfers.

Emerging Technologies and Advanced Diagnostic Approaches

Recent studies have expanded stroke recognition research beyond conventional clinical screening instruments. Artificial intelligence, machine-learning algorithms, physiological monitoring, and advanced imaging have been investigated as potential approaches to supporting early diagnosis and clinical triage. Cai et al. (2022) evaluated an AI-based diagnostic approach using an emergency department dataset and reported that screening could be completed in less than six minutes. Goda et al. (2025) investigated a machine-learning model based on photoplethysmography (PPG) signals, with a screening duration of approximately 30 seconds. The study included patients with large-vessel occlusion, non-large-vessel

occlusion, and stroke mimics, demonstrating the feasibility of investigating physiological signals for early stroke identification. Yiang et al. (2022) investigated a registry-based approach involving CT angiography and reported that unnecessary CTA examinations were avoided in 98 of 147 patients (66.6%). García-Terriza et al. (2023) also investigated a machine-learning approach for differentiating ischemic from hemorrhagic stroke, demonstrating the growing interest in computational technologies for improving emergency triage.

Overall Interpretation

Collectively, the included studies demonstrate that stroke recognition and referral pathways involve several interconnected clinical, organizational, and technological factors. Patient age, stroke severity, symptom presentation, transportation priority, availability of diagnostic imaging, and communication between prehospital and hospital teams may influence the effectiveness of emergency stroke management. The evidence also indicates that interventions targeting early recognition and referral can improve important clinical processes, including CT assessment, stroke-unit admission, thrombolysis utilization, and treatment timelines. However, the findings were not uniformly positive, as some interventions failed to demonstrate significant improvements in early hospital arrival. The methodological and clinical heterogeneity across the included studies should be considered when interpreting their findings. Differences in study designs, diagnostic criteria, patient populations, stroke classifications, and definitions of recognition and referral outcomes limit direct comparisons between investigations. Nevertheless, the collective evidence supports the importance of standardized stroke recognition procedures, appropriate EMS prioritization, early hospital notification, and efficient referral pathways. Integrating conventional clinical assessment with emerging diagnostic technologies may further strengthen early stroke identification and improve access to time-dependent treatment.

Diagnostic Accuracy of Recognition Tools

The diagnostic accuracy of stroke recognition tools represents a central component of the evaluation of early stroke identification and referral pathways. Accurate recognition at the prehospital and emergency department levels can reduce delays in clinical assessment, diagnostic imaging, and initiation of appropriate treatment. The studies included in this review evaluated a range of recognition strategies, including structured clinical scales, symptom-based assessment, dispatcher protocols, physician judgment, mobile stroke units, and emerging artificial intelligence (AI) approaches. However, the availability and reporting of quantitative diagnostic accuracy measures varied considerably across the included studies. While some investigations reported sensitivity and specificity, others focused primarily on clinical workflow, referral performance, or treatment-related outcomes without providing sufficient data to calculate diagnostic accuracy. Among the conventional recognition instruments, the Face Arm Speech Time (FAST) approach was one of the most frequently evaluated methods. Harbison et al. (2003) investigated FAST as a clinical recognition strategy, reflecting its role in identifying common stroke symptoms through assessment of facial weakness, arm weakness, and speech disturbance. Its simple structure makes it suitable for use by emergency medical services (EMS) personnel and other first-contact healthcare providers. The approach can support rapid identification and referral without requiring advanced neurological assessment. Nevertheless, its reliance on a limited number of clinical signs may reduce its ability to identify patients presenting with atypical symptoms or neurological deficits that do not involve the three principal FAST components. This limitation is relevant when considering patients with posterior circulation stroke or less characteristic clinical presentations.

Other established assessment instruments included the Cincinnati Prehospital Stroke Scale (CPSS), the Recognition of Stroke in the Emergency Room (ROSIER), the Los Angeles Prehospital Stroke Screen (LAPSS), the Med PACS, the Ontario Prehospital Stroke Scale (OPSS), and the Melbourne Ambulance Stroke Screen (MASS). Saberian et al. (2021) evaluated several of these instruments within the same diagnostic accuracy investigation. The inclusion of multiple tools in one study provides an opportunity to examine differences in their performance under comparable assessment conditions. These scales differ in their clinical components, assessment requirements, and intended settings. CPSS and FAST are designed to facilitate rapid prehospital recognition, whereas ROSIER is primarily associated with emergency department assessment. LAPSS and other structured screening instruments incorporate additional clinical criteria that may help distinguish suspected stroke from alternative diagnoses. However, the performance of these instruments depends on the characteristics of the population being assessed, the experience of the healthcare provider, and the reference standard used to confirm the diagnosis. The National Institutes of Health Stroke Scale (NIHSS) also contributed to the recognition and assessment framework, particularly in emergency departments. De Luca et al. (2009) reported the use of CPSS in EMS settings and NIHSS during emergency department assessment. Unlike brief screening instruments, NIHSS provides a structured assessment of neurological impairment and helps characterize stroke severity. It can also support clinical evaluation of patients with suspected large vessel occlusion when interpreted alongside other clinical and imaging findings. Nevertheless, its administration requires training and additional

assessment time, which may limit its suitability as an initial screening instrument in some prehospital environments. Its role is therefore more closely related to detailed neurological assessment following initial recognition than to replacing rapid screening tools.

Several studies evaluated newer or modified recognition approaches. Karimi et al. (2020) assessed Prehospital Acute Stroke Severity (PreHAST), while Nasr-Esfahani et al. (2021) investigated FAST-ED. These instruments extend the assessment beyond basic symptom recognition by incorporating clinical features that may help identify patients with more severe neurological deficits or suspected large vessel occlusion. Their development reflects the need to improve the identification of patients who may require specialized stroke services or transfer to comprehensive stroke centers. However, the diagnostic performance of these instruments must be considered in relation to their intended purpose. A tool designed to identify severe stroke or large vessel occlusion does not necessarily have the same diagnostic objective as a general stroke screening scale. The findings also demonstrate increasing interest in technology-assisted stroke recognition. Cai et al. (2022) evaluated DeepStroke, an AI-based recognition approach. Goda et al. (2025) investigated a machine-learning model using photoplethysmography (PPG) signals alongside the Hunter-8 approach. These methods explore the possibility of identifying stroke-related patterns through automated analysis of clinical or physiological information. PPG-based assessment is of particular interest because it can obtain pulse waveform information through relatively accessible monitoring technology. Machine-learning algorithms may identify patterns that are difficult to recognize through conventional clinical assessment alone. However, the results of these approaches should be interpreted cautiously because diagnostic accuracy estimates from feasibility or validation studies do not necessarily demonstrate effectiveness in routine clinical practice.

Additional AI-based approaches were reported by Kuzan et al. (2025) and Terriza et al. (2023). Kuzan et al. examined ChatGPT-4V in relation to MRI interpretation, while Terriza et al. investigated machine-learning models based on hemodynamic signals. These approaches represent different applications of computational methods in stroke assessment. Imaging-based AI may support the interpretation of radiological findings, whereas models based on hemodynamic signals may contribute to early identification before definitive imaging is available. Although these methods demonstrate potential for supporting clinical decision-making, their performance requires evaluation across larger and more diverse patient populations. External validation, standardized reference diagnoses, and assessment under real-world clinical conditions are necessary before their routine adoption can be justified. Importantly, not all recognition strategies were evaluated through conventional sensitivity and specificity measures. Behrndtz et al. (2023), Berglund et al. (2021), Blauenfeldt et al. (2023), Denti et al. (2017), and several other investigators examined approaches such as PASS, symptom-based EMS triage, PreSS, public education campaigns, and dispatcher-based recognition systems. Their inclusion indicates that stroke recognition extends beyond the performance of an individual screening scale. It also depends on how symptoms are identified by the public, communicated to emergency dispatchers, interpreted by ambulance personnel, and transferred to hospital teams. Similarly, studies by Karliński et al. (2015, 2022) evaluated physician or EMS professional judgment, while other investigations examined the Danish Index Dispatcher, the Dispatcher Medical Index, RETTS, and RLS-85. These approaches provide information about the broader recognition pathway, although the absence of reported diagnostic accuracy metrics limits direct comparison with validated screening instruments.

The available findings indicate that reported sensitivity across conventional recognition approaches generally ranged from approximately 79% to 95%, while specificity ranged from approximately 52% to 84%. These ranges suggest that several tools can identify a substantial proportion of patients with stroke, although their ability to distinguish stroke from other conditions varies. Sensitivity is particularly important in initial screening because missed cases may delay access to time-dependent treatment. Specificity is also relevant because false-positive recognition can increase unnecessary emergency referrals, diagnostic investigations, and demands on specialized stroke services. Therefore, selecting a recognition tool requires consideration of both measures rather than relying on sensitivity alone. The variability in reported diagnostic performance also highlights the importance of study design and assessment setting. Differences in patient characteristics, stroke severity, prevalence of stroke mimics, healthcare provider training, and diagnostic reference standards may influence the reported results. Furthermore, studies that did not report sensitivity and specificity cannot be directly ranked against investigations that provided these measures. Their contribution should instead be interpreted through their findings on recognition processes, referral decisions, and clinical outcomes. Overall, the evidence supports the continued use of established screening instruments such as FAST, CPSS, and ROSIER within appropriate clinical settings, while recognizing the potential contribution of severity assessment tools and emerging AI-based approaches. No single

instrument can be assumed to provide optimal performance across all stages of the stroke pathway. A coordinated approach that combines rapid symptom recognition, structured neurological assessment, appropriate EMS triage, and timely hospital evaluation is therefore essential. Future research should prioritize prospective multicenter validation, standardized diagnostic reference criteria, and direct comparisons between conventional and technology-assisted recognition methods. Such investigations would help establish whether emerging approaches can improve early detection, reduce missed stroke cases, and support more appropriate referral decisions in routine healthcare practice.

Referral Patterns

Timely referral is a fundamental component of effective acute stroke management because delays during the prehospital phase can affect access to diagnostic imaging and time-dependent treatments, including intravenous thrombolysis and endovascular thrombectomy. The studies included in this review investigated several strategies to improve referral pathways, including structured emergency dispatcher systems, prehospital triage scales, mobile stroke units, and training interventions for emergency medical personnel. Overall, the findings indicate that referral efficiency depends on the coordination of different healthcare professionals and the ability of emergency systems to recognize suspected stroke, assign an appropriate priority level, and transport patients to suitable stroke facilities without unnecessary delays. Dispatcher-based systems represented an important intervention for improving the early stages of the referral pathway. The Danish Index Dispatcher and the Rapid Emergency Triage and Treatment System (RETTS) were evaluated as structured approaches for identifying suspected stroke and determining the appropriate emergency response. Sundström et al. examined the use of RETTS alongside the Dispatcher Medical Index, with findings indicating improvements in priority assignment and a reduction in under-triage. These systems provide dispatchers with standardized criteria for interpreting reported symptoms and assigning an appropriate level of urgency. Their use may reduce variability in decision-making and help ensure that patients with suspected stroke receive an appropriate emergency response. Similarly, Gude et al. and Berg et al. investigated the Danish Index Dispatcher in relation to prehospital stroke recognition and referral. The reported findings associated dispatcher-based prioritization with shorter onset-to-door intervals and improved access to hospital assessment. Earlier arrival may increase the proportion of patients evaluated within the therapeutic time windows for reperfusion treatment. In particular, early recognition and appropriate ambulance prioritization can facilitate timely neurological assessment and imaging after hospital arrival. Across the studies summarized in this review, dispatcher-based systems were associated with reductions in onset-to-door times of approximately 12–22 minutes. These findings support the role of structured dispatcher protocols as an important component of an integrated stroke referral system [19].

Mobile stroke units provided another approach to reducing delays in the prehospital pathway. The Stroke-Einsatz-Mobile (STEMO) system, evaluated by Ebinger et al., represents a specialized ambulance-based model that brings selected diagnostic and treatment capabilities closer to the patient. Unlike conventional ambulance services, mobile stroke units can facilitate earlier assessment and imaging before arrival at the receiving hospital. This approach may allow healthcare professionals to identify eligible patients and initiate appropriate treatment decisions during the prehospital phase. The reported findings demonstrated reductions in time to computed tomography (CT) and improvements in reperfusion treatment rates. Across the reviewed evidence, reductions in time to CT ranged from approximately 8 to 17 minutes, while reperfusion eligibility increased by approximately 7–12%. These results suggest that mobile stroke units may improve the efficiency of the referral pathway by reducing the interval between initial emergency contact and diagnostic assessment [20]. Nevertheless, the effectiveness of mobile stroke units depends on their availability, geographical coverage, operational costs, and integration with existing emergency medical services. Their implementation may be more challenging in rural or geographically dispersed areas, where specialized units may not be readily accessible. Therefore, although this model offers potential advantages, its application should be considered within the context of local healthcare resources and the organization of regional stroke services. Training and protocol-based interventions were also investigated as methods of improving prehospital recognition and referral. The Paramedic Acute Stroke Treatment Assessment (PASTA) trial, reported by Price et al., evaluated an enhanced paramedic assessment and management approach. However, the findings did not demonstrate a significant reduction in treatment delays compared with standard care. This result indicates that additional training and assessment procedures do not necessarily translate into shorter referral intervals. The effectiveness of training interventions may depend on the complexity of the protocol, the time required to complete additional assessments, the availability of hospital resources, and the coordination between ambulance personnel and receiving stroke teams [21].

In contrast, the integration of the Prehospital Acute Stroke Severity Scale (PreHAST) into EMS assessment was associated with improvements in identifying patients with suspected large vessel

occlusion (LVO). PreHAST provides a structured approach to evaluating neurological deficits and estimating stroke severity. Its use may help emergency personnel identify patients who require rapid referral to facilities capable of providing advanced stroke interventions. The reviewed findings indicated that PreHAST-based triage improved LVO detection by approximately 9–15% and shortened referral intervals by approximately 5–12 minutes. These findings highlight the potential value of incorporating stroke severity assessment into prehospital decision-making, particularly when selecting the appropriate destination hospital. Karimi et al. investigated PreHAST in the prehospital setting, while the findings summarized in the review also indicate that structured severity assessment can support more appropriate referral decisions [22]. The PASS scale, evaluated by Behrndtz et al., provided another example of structured prehospital triage. Its application was associated with a moderate improvement in LVO triage. This finding suggests that structured assessment may support the identification of patients who require specialized stroke services. However, the degree of improvement should be interpreted in relation to the characteristics of the study population and the diagnostic criteria used. Prehospital scales should support, rather than replace, clinical judgment and subsequent diagnostic imaging. Despite improvements associated with several interventions, important barriers to timely referral remain. Secondary transfers represent one of the main challenges, particularly when patients initially arrive at hospitals without the facilities required for advanced stroke treatment. The need for additional assessment, imaging, stabilization, and interhospital communication can increase the time required to reach a comprehensive stroke center. Rural access is another concern because longer travel distances and limited availability of specialized emergency services may delay hospital arrival. Furthermore, differences in dispatcher experience and accuracy can affect the recognition of stroke symptoms and the assignment of appropriate emergency priorities.

The findings also demonstrate that no single intervention can address all sources of prehospital delay. Dispatcher systems primarily influence emergency call assessment and ambulance prioritization, whereas mobile stroke units target delays in prehospital diagnosis and treatment. Severity assessment scales support the identification of patients who may require specialized referral, while paramedic training aims to improve clinical recognition and decision-making. Combining these approaches within a coordinated referral pathway may provide greater benefits than relying on an individual intervention. Overall, the evidence indicates that structured dispatcher systems, mobile stroke units, and prehospital severity assessment can contribute to more efficient stroke referral. However, the inconsistent findings from training interventions demonstrate the importance of evaluating the actual impact of each strategy on patient outcomes and treatment intervals. Future improvements should focus on standardized referral protocols, accurate prehospital recognition, effective communication between EMS and receiving hospitals, and efficient interhospital transfer arrangements. These measures may reduce avoidable delays and improve access to appropriate stroke care.

Subgroup Analyses

Subgroup analyses were conducted to examine variations in stroke recognition accuracy and referral patterns according to healthcare setting, geographical region, and the recognition tools used. These comparisons provide insight into how differences in healthcare organization, emergency service capacity, and assessment methods may influence early stroke identification and access to appropriate treatment. The analysis included 33 studies, comprising investigations conducted in primary care, emergency care, and different geographical regions.

Subgroup Analysis by Healthcare Setting

The analysis by healthcare setting included nine primary care studies and 24 emergency care studies. The primary care studies mainly evaluated FAST and PreHAST as initial recognition instruments. Reported sensitivity ranged from 70% to 90%, while specificity ranged from 45% to 60%. These findings indicate that primary care recognition strategies were able to identify a considerable proportion of patients with suspected stroke. However, the relatively low specificity suggests that some patients without stroke may also be incorrectly classified as suspected cases, potentially increasing unnecessary referrals. A major finding in this subgroup was the frequency of referral delays exceeding 4.5 hours. Such delays may reduce the opportunity for patients with ischemic stroke to receive intravenous thrombolysis within the conventional treatment window. The findings suggest that recognition at the primary care level does not always translate into timely access to specialized stroke services. Delays may occur during initial clinical assessment, referral decisions, transportation, or communication with receiving hospitals. In comparison, the 24 emergency care studies demonstrated sensitivity ranging from 80% to 95% and specificity ranging from 55% to 85%. These studies evaluated approaches including NIHSS, artificial intelligence-based tools, and structured emergency referral protocols. Emergency care settings generally demonstrated higher treatment eligibility and shorter referral intervals. Studies involving dispatcher-supported emergency systems reported referral acceleration of approximately 12–20 minutes. This improvement may reflect more

efficient emergency prioritization, earlier recognition, and better coordination between prehospital services and hospital teams. Nevertheless, the differences between primary and emergency care should be interpreted in relation to the distinct roles of these settings in the stroke pathway.

Subgroup Analysis by Geographical Region

Regional analysis demonstrated differences in the organization and availability of prehospital stroke services. Fourteen European studies evaluated structured emergency systems, including FAST and dispatcher-based recognition approaches. Reported sensitivity ranged from 82% to 95%, while specificity ranged from 55% to 75%. The main finding was faster referral associated with dispatcher protocols. The availability of organized emergency response systems and structured assessment procedures may contribute to earlier recognition and more efficient transportation of patients with suspected stroke. The combined Asia and Middle East subgroup included 12 studies, with reported sensitivity ranging from 70% to 88% and specificity ranging from 50% to 65%. These studies mainly investigated PreHAST and ROSIER. The principal challenges identified were limited imaging availability and variability in EMS capacity and training. Such limitations may affect both the initial identification of stroke and the ability to transfer patients rapidly to facilities providing advanced diagnostic and therapeutic services. The findings highlight the importance of strengthening emergency response infrastructure and improving access to appropriate diagnostic imaging. Seven North American studies evaluated approaches that included AI-based DeepStroke and ChatGPT-4V. Sensitivity ranged from 75% to 85%, while specificity ranged from 70% to 80%. These studies demonstrated promising specificity and reflected the growing interest in applying AI technologies to stroke recognition and assessment. However, the findings do not establish that AI-based approaches are superior to conventional scales across all clinical settings. Their performance requires further validation before widespread implementation.

Subgroup Analysis by Recognition Tool

The analysis according to recognition tool identified differences between conventional clinical scales, advanced neurological assessment instruments, and AI-based methods. Traditional screening tools, particularly FAST, CPSS, and ROSIER, demonstrated sensitivity ranging from approximately 80% to 95%, with specificity generally between 50% and 65%. Their relatively high sensitivity supports their use in initial stroke screening, particularly in prehospital settings where rapid assessment is essential. However, their lower specificity may result in false-positive referrals and increased demands on emergency services. PreHAST and other structured severity assessment approaches provide additional information that may support the identification of patients requiring specialized stroke care. Their usefulness is particularly relevant when the referral decision involves selecting hospitals with different levels of stroke treatment capability. AI-based models demonstrated promising specificity, with reported values exceeding 75% in some investigations. These approaches may help distinguish stroke from alternative conditions through automated analysis of imaging or physiological data. However, the available evidence remains limited by the need for external validation and evaluation in larger patient populations. Their clinical value will depend on whether they can improve recognition accuracy without introducing additional delays or increasing the complexity of emergency assessment. The NIHSS provides a more comprehensive assessment of neurological impairment and can support clinical evaluation in emergency departments. Nevertheless, its administration requires more time and training than brief screening instruments, making it less practical for routine initial prehospital assessment. Overall, the subgroup findings demonstrate that recognition accuracy and referral efficiency vary according to healthcare setting, geographical region, and the assessment method used. Emergency care studies generally reported higher sensitivity and better treatment eligibility than primary care studies, while regional differences reflected variations in emergency service capacity and diagnostic resources. Although conventional scales remain important for rapid recognition, emerging AI-based approaches may provide additional support.

Patient Outcomes, Barriers, and Facilitators

Improved stroke recognition and timely referral were associated with better clinical outcomes, including increased access to reperfusion treatment, reduced mortality, and greater functional independence. EMS prenotification, dispatcher-based triage, and mobile stroke units shortened treatment delays and improved reperfusion rates. STEMO-supported pathways increased thrombolysis rates and the proportion of patients achieving functional independence, defined as a modified Rankin Scale score ≤2 at 90 days. Mobile stroke units reduced door-to-needle times by approximately 8–17 minutes and increased reperfusion eligibility by 7–12%. Dispatcher-supported systems, including the Danish Index, were associated with reported mortality reductions of 8–12% [23,24]. PreHAST, FAST-ED, and PASS supported the identification of patients with large vessel occlusion. PreHAST-based triage increased LVO detection by 9–15% and reduced referral delays by 5–12 minutes. However, the PASTA trial did not demonstrate significant functional outcome improvements despite enhanced paramedic training, highlighting that improvements in assessment protocols do not always translate into measurable patient benefits [12,24]. Several barriers affected stroke care. System-level challenges

included rural location, limited access to stroke centers, insufficient mobile stroke unit coverage, and delays during interhospital transfers. Organizational barriers involved inaccurate dispatcher assessments, inconsistent EMS triage, and differences in protocol implementation. Clinician-related factors included inadequate training and variable adherence to established procedures. At the patient level, limited awareness of stroke symptoms, atypical presentations, and delayed decisions to seek medical attention contributed to late hospital arrival [22]. Facilitators included structured referral protocols, EMS training, dispatcher support, and technological innovations. Public education campaigns increased symptom recognition by approximately 10–18%, although this improvement did not produce equivalent reductions in onset-to-door times. AI-based tools offered potential decision support, particularly in resource-limited settings, while mobile stroke units enabled earlier imaging and treatment initiation. However, their cost limits widespread implementation. Overall, early recognition and coordinated referral improved access to treatment and patient outcomes. Addressing rural access, workforce training, public awareness, and imaging availability remains essential to reducing disparities in acute stroke care.

DISCUSSION

This systematic review synthesized evidence from 33 studies published between 2003 and 2025, examining early recognition and referral pathways for acute stroke in primary and emergency care. The findings demonstrate that structured recognition tools, efficient emergency referral systems, and coordinated healthcare services contribute to earlier diagnosis, improved access to reperfusion treatment, and better patient outcomes. Traditional recognition instruments, including FAST, ROSIER, CPSS, and NIHSS, demonstrated generally high sensitivity, although specificity varied across studies [19,22,23]. FAST and CPSS remained useful for rapid prehospital screening, while ROSIER supported emergency department assessment. PreHAST and FAST-ED offered additional value in identifying patients with severe neurological deficits and suspected large vessel occlusion. However, the relatively low specificity of some screening instruments highlights the risk of false-positive referrals and the importance of confirmatory imaging. AI-based diagnostic approaches also showed potential, particularly through automated analysis of imaging and physiological signals, but their clinical application remains limited by insufficient external validation. Referral organization was another major determinant of patient outcomes. Structured dispatcher systems, including the Danish Index and RETTS, improved emergency prioritization and facilitated timely hospital access [19,24]. Mobile stroke units, particularly STEMO, reduced diagnostic and treatment delays through prehospital imaging and early treatment decisions [20]. These interventions were associated with increased reperfusion treatment and improved functional independence. In contrast, the PASTA trial demonstrated that enhanced paramedic training alone did not produce significant improvements in treatment delays or functional outcomes. This suggests that training must be supported by effective communication, appropriate infrastructure, and coordinated referral protocols.

Despite these improvements, geographical and socioeconomic disparities remain important challenges. Rural and resource-limited settings frequently experience longer transportation times, limited access to diagnostic imaging, shortages of trained emergency personnel, and delays in interhospital transfers. These barriers are particularly relevant in low- and middle-income countries, where implementing mobile stroke units and advanced imaging services may not be financially or operationally feasible. Public education campaigns increased stroke symptom recognition by approximately 10–18%, but this improvement did not consistently translate into shorter onset-to-door times. Therefore, public awareness initiatives must be integrated with accessible emergency services and clear referral pathways. The findings support international efforts to standardize early stroke recognition and management. Frameworks such as the WHO Global Stroke Action Plan and American Stroke Association recommendations provide opportunities to strengthen emergency assessment and referral systems. Practical strategies include simplified screening protocols, dispatcher-assisted triage, community health worker training, telemedicine consultation, and mobile health applications. These approaches may offer feasible alternatives for healthcare systems with limited specialist availability. This review has several strengths. It included evidence spanning more than two decades and covered different geographical regions, healthcare settings, and recognition technologies. It also considered both conventional clinical scales and emerging AI-based methods. However, inconsistent reporting of sensitivity, specificity, and referral outcomes limited direct comparisons. Differences in study design, patient populations, diagnostic standards, and healthcare infrastructure prevented quantitative meta-analysis. Furthermore, the predominance of studies from high-income countries limits the generalizability of the findings to resource-limited settings.

The practical implications include incorporating validated recognition tools, EMS prenotification, dispatcher protocols, and coordinated referral arrangements into routine stroke services. Future research should prioritize multicenter validation of conventional and AI-based tools, alongside evaluations of cost-effectiveness,

feasibility, and scalability. Mobile stroke units and telemedicine should also be assessed across different socioeconomic settings. Implementation studies are particularly needed to determine how these interventions can be integrated into national stroke pathways while reducing inequalities in access to reperfusion treatment. Overall, early recognition and efficient referrals contribute to improved survival, treatment access, and functional outcomes after acute stroke. However, achieving these benefits across different healthcare systems requires more than introducing screening tools. Sustainable improvements depend on coordinated emergency services, trained personnel, accessible diagnostic facilities, and referral strategies adapted to local resources.

Conclusion:

This systematic review demonstrates that early stroke recognition and efficient referral pathways are essential for improving access to reperfusion treatment and patient outcomes. Conventional screening tools, including FAST, CPSS, and ROSIER, support rapid identification of suspected stroke, while PreHAST and FAST-ED provide additional information for assessing stroke severity and identifying large vessel occlusion. Dispatcher-based protocols and mobile stroke units improve referral efficiency and reduce delays in diagnostic assessment and treatment. Emerging AI-based approaches offer further potential but require multicenter validation before routine clinical implementation. Despite these advances, significant disparities persist, particularly in rural and resource-limited healthcare settings. Limited imaging facilities, transportation delays, and inadequate EMS training continue to affect timely care. Future improvements should prioritize standardized referral protocols, workforce training, telemedicine, and cost-effective recognition strategies adapted to local resources. Integrating these interventions into national stroke pathways may improve equitable access to timely treatment and reduce the global burden of stroke.

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