SYSTEMATIC REVIEW

Application of Telemedicine in the Ambulance for Stroke Patients: A Systematic Review

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Abbreviations:
CPSS: Cincinnati Prehospital Stroke Scale
CT: computerized tomography
ECG: electrocardiogram
EMS: Emergency Medical Services
NIHSS: National Institutes of Health Stroke Scale
PRISMA: Preferred Reporting Item for Systematic Reviews and Meta-Analyses
STROBE: Strengthening the Reporting of Observational Studies in Epidemiology

Abstract

Introduction: The use of telemedicine for the prehospital management of emergency conditions, especially stroke, is increasing day by day. Few studies have investigated the applications of telemedicine in Emergency Medical Services (EMS). A comprehensive study of the applications of this technology in stroke patients in ambulances can help to build a better understanding. Therefore, this systematic review was conducted to investigate the use of telemedicine in ambulances for stroke patients in 2023.

Methods: A systematic search was conducted in PubMed, Cochrane, Scopus, ProQuest, Science Direct, and Web of Science from 2013 through March 1, 2023. The authors selected the articles based on keywords and criteria and reviewed them in terms of title, abstract, and full text. Finally, the articles that were related to the study aim were evaluated.

Results: The initial search resulted in the extraction of 2,795 articles. After review of the articles, and applying the inclusion and exclusion criteria, seven articles were selected for the final analysis. Three (42.85%) studies were on the feasibility and intervention types. Also, randomized trials, feasibility, feasibility and prospective-observational, and feasibility and retrospective-interventional studies were each one (14.28%). Six (85.71%) of the studies were conducted in the United States. The National Institutes of Health Stroke Scale (NIHSS) and RP-Xpress were the most commonly used tools for neurological evaluations and teleconsultations.

Conclusion: Remote prehospital consultations, triage, and sending patient data before they go to the emergency department can be provided through telemedicine in ambulances. Neurological evaluations via telemedicine are reliable and accurate, and they are almost equal to in-person evaluations by a neurologist.

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Introduction

Stroke is one of the most serious health care issues,[1] which is known as the second leading cause of death and the third cause of premature death and disability in the world.[2] Stroke imposes a great health and economic burden on society,[2] including a major part of health care costs, medicine, and unemployment, especially in developing countries.[1,2]

Sixty minutes from the onset of symptoms to the treatment of the disease is known as the "golden hour."[3] Treatment during this time is associated with a high rate of discharge, patient independence, relief from disability, and a reduction of hemorrhagic complications and mortality.[4] Therefore, successful triage, evaluation, and timely intervention are crucial for longer survival, improved patient outcomes, reduced disabilities, and fewer treatment complications.[1,3,5]

In emergencies such as stroke, the integration of prehospital and hospital interventions is particularly important. Indeed, the focus should be on initial assessment, diagnosis, and sometimes treatment by Emergency Medical Services (EMS) personnel and subsequently by

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physicians in the hospital emergency department. Prehospital assessment is important to save time and helps in preparation, prioritization of resources, and quick treatment of the patient.[6]

Timely care depends on how quickly patients are diagnosed and call for help; it also depends on the response time of the ambulance from the onset of symptoms to reaching the hospitals, the distance from the scene to the hospital, and the accuracy in identifying real patients from patients who are suspected of having a stroke.[7] Quick identification of the patient, triage to proper care, and improvement of in-hospital measures lead to receiving more services, and communication between paramedics and stroke centers helps speed up the treatment process.[8] Therefore, ambulance services play an important role in identifying and transferring suspected stroke patients to health care centers.[7]

Although steps have been taken to optimize stroke management, reviews have shown that only 10.6% of 6,483 patients were treated within 90 minutes and 1.4% within 60 minutes of symptom onset. One of the main reasons for the delay in treatment is that many patients arrive at the hospital too late.[4]

The use of telemedicine in ambulances offers the potential to improve patient care and facilitate remote consultation by connecting neurologists or nurses with EMS personnel until arrival at the hospital. Telemedicine refers to the use of information and communication technology to remotely connect a patient to a therapist, where the patient and therapist communicate virtually through technology platforms.

Telemedicine's goal is to distribute health services equitably, improve quality, reduce time, review tests and diagnoses, and manage emergency conditions. The process of caring for stroke patients with ambulance-based telemedicine includes the provision of EMS, interviews, and examinations through interactive video conferencing, which perform a quick assessment of the patient and inform the hospital about the patient's condition. Telemedicine improves the triage process and increases the accuracy of diagnosis.[1,3,5,9,10]

Therefore, it is suggested as a suitable and affordable method, especially for deprived areas. In acute stroke, clinical symptoms along with imaging results determine the appropriate treatment. Since treatment is highly time-dependent, shortening the time for proper physician evaluation may improve patient outcomes.[11]

Therefore, prehospital management of stroke plays an important role in the treatment and post-disease outcomes. Recovery depends on accurate and timely triage, adequate care, and post-stroke rehabilitation. Prehospital delay is one of the main and most frequent reasons patients do not receive treatment for stroke. One of the most effective ways to overcome this problem is to use telemedicine in the ambulance.[3] This technology enables specialists to record the relevant history and examination during the transfer of the patient. In addition, it helps to prioritize laboratory and imaging processes.[12]

Several studies have used telemedicine as a tool for ambulance intervention. For example, in the fields of stroke, cardiology, and trauma, they have used it to record and send electrocardiograms (ECGs), vital signs, and computerized tomography (CT) scan images, for emergency consultations, diagnoses, monitoring patients, and managing the disease.[13–15]

Although the number of prehospital interventions using telemedicine is increasing, their use is limited due to communication challenges, legal issues, security and privacy, insurance strategy, technology literacy, cultural barriers, equipment compatibility, lack of infrastructure, system cost, device flexibility, poor quality videos and images sent, and such are limited[9,16,17] and depend on long-term clinical benefits, cost-effectiveness, and the best setting.[3,4]

As a result, the applications of this technology for stroke patients, especially during ambulance transport, have not yet been accurately determined and need more studies. It is expected that by conducting this study, ambulance-based telemedicine interventions will increase even more, especially in the field of stroke. Also, laws, guidelines, and insurance institutions should support these types of interventions. Therefore, this systematic review was conducted to investigate the use of telemedicine in ambulances for stroke patients in 2023.

Methods

Eligibility Criteria and Search Strategies

First, the study protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO) database (Centre for Reviews and Dissemination, University of York; York, United Kingdom) with the identification number CRD42023408643. Then, a general and rapid search of the Cochrane Library (Wiley; Hoboken, New Jersey USA) was performed to ensure that no similar study existed. This systematic review was conducted based on the 2020 version of the Preferred Reporting Item for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Due to the advancement of technology in the last 10 years,[18–20] the search period was chosen from 2013 through March 1, 2023 and the search was conducted by two authors (AFA and ZZ) in: PubMed (National Center for Biotechnology Information, National Institutes of Health; Bethesda, Maryland USA); Cochran (Wiley; Hoboken, New Jersey USA); Scopus (Elsevier; Amsterdam, Netherlands); Science Direct (Elsevier; Amsterdam, Netherlands); ProQuest (Ann Arbor, Michigan USA); and Web of Science (Clarivate Analytics; London, United Kingdom). The "AND" operator was used between separate concepts, the "OR" operator was used among synonyms, and the search filter was selected "Title, Abstract, and Keyword." The keywords were selected from the "Medical Subject Headings (MESH) Terms" section of PubMed and related studies. The search strategy is shown in Table 1.

Inclusion Criteria

All English studies with full texts were included. These included clinical trials, cross-sectional, case-control, observational, feasibility, and case studies. All the studies that were in line with the study goal and related to the research question "What are the uses of telemedicine in the ambulance for stroke patients?" were also evaluated during the peer-review process and were chosen without any restrictions.

Exclusion Criteria

All non-English studies, studies whose keywords were not in all three sections of the title, abstract, and full text, and studies that were not related to the research question, as well as review studies, editorials, conferences, and brief reports, were deleted.

Screening

The step-by-step screening was performed based on the 2020 PRISMA guideline. The studies identified from the data sources were entered into an X9 EndNOTE (Clarivate Analytics; Philadelphia, Pennsylvania USA) library, and duplicates were removed. At the same time, two authors (FS and AFA) independently screened the studies based on the eligibility criteria in three steps: (1) title; (2) abstract; and (3) full text. Disagreements

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Strategy	#1 AND #2 AND #3
#1	Stroke **OR** Acute Stroke **OR** Brain Stroke **OR** Ischemic Stroke **OR** Cerebrovascular Accident **OR** CVA
#2	Telemedicine **OR** Tele medicine **OR** Tele-medicine **OR** Telestroke **OR** Tele Stroke **OR** Tele-stroke **OR** Teleneurology **OR** Tele- CVA
#3	Ambulance **OR** Rapid Response Vehicle **OR** Emergency Services **OR** Emergency Medical System **OR** EMS **OR** Helicopter Emergency Medical System **OR** HEMS **OR** Rescue **OR** Air Ambulance **OR** Prehospital

Table 1. Search Strategy

were shared between two authors (FS and AFA) and resolved through a third author (MAM), if necessary. Also, the articles that had a lot of citations were carefully checked so that there was no bias in their selection.

Assessing the Risk of Bias

After screening the studies, the two authors (FS and MAM) discussed on the quality of each study. Therefore, the citation and printing bias were also considered, and the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist was used to evaluate the articles. This STROBE checklist has 22 items. Each item is given a score between zero and one. Studies that obtained 75% of the items were selected for the final analysis.[21]

Data Extracting

After assessing the quality of the studies, two authors (FS and MAM) independently extracted data. Data extraction was done based on the researcher's form that was set in the Word 2016 software (Microsoft Corp.; Redmond, Washington USA).

Ethics Approval

The study was approved by the ethics committee of Shiraz University of Medical Sciences (Shiraz, Iran) with ID number IR.SUMS.REC.1402.195.

Results

The search resulted in 2,795 articles. However, 520 items were removed as they were duplicates. Screening the titles of 2,275 articles resulted in removing 2,096 (irrelevant objectives). The abstracts of the remaining 179 articles were assessed, and 171 articles were removed (irrelevant objectives). Eventually, the full texts of eight articles were studied, and seven were selected. Figure 1 demonstrates the study flow diagram.

Table 2 presents a summary of the study design, country, most common hardware, and scale in the selected studies. The randomized trial, feasibility, feasibility and prospective-observational, and feasibility and retrospective-interventional studies were each one (14.28%). Also, feasibility and interventional studies were three (42.85%).

The United States and Germany were the most common countries that used telemedicine for prehospital interventions. Each of them accounted for six (85.71%) and one (14.28%) of the studies, respectively. The most common telemedicine hardware used in studies were In-Touch RP-Xpress health devices (In-Touch Health, Teladoc Health, Inc.; New York USA), CT scanners, laptops, and tablets. Each of them accounted for four (57.14%), three (42.85%), two (28.57%), and two (28.57%) of the studies, respectively.

Also, the most common scales used in the studies were the National Institutes for Health Stroke Scale (NIHSS) with four (57.14%) and two (28.57%) with the Cincinnati Prehospital Stroke Scale (CPSS), respectively.

The information presented in the Supplementary Table S1 (available online only) was summarized after a thorough examination of the full text of these seven studies.

Discussion

A stroke is considered an emergency, and prehospital care is very important in the first hour from the onset of symptoms to the treatment of the disease. Various methods have been considered for prehospital stroke interventions, but their use has been limited for some reasons. Among these methods, telemedicine has more capabilities and emphasizes the equitable distribution of health services while saving time, strengthening communication between specialists, and optimizing treatment with a multi-team approach. The present systematic review study was conducted to investigate the use of telemedicine in ambulances for stroke patients in 2023.

The results of the study show that rapid management, triage, neurological evaluations, diagnosis, decision making, and prehospital care of stroke are possible with this technology. Telemedicine has been used to provide consultations, record and send vital signs and diagnostic tests, as well as interpret the results of CT scans, magnetic resonance imaging/MRI, and ECGs.[12,22–27]

Emergency care is an integral part of any care system. Rapid response and treatment with a focus on higher survival rates are the hallmarks of prehospital care systems. Therefore, searching for effective and efficient ways to save time and provide maximum care is necessary before reaching hospitals.[28]

Telemedicine can play an effective role in this field. In fact, by simultaneously sending patient information from the ambulance to the remote medical specialist in the treatment center or dispatch, it helps to make decisions and take timely action in different situations.[29] People who have had a stroke are not exempt from this rule.

Previous studies[28–34] have also shown the successful application of using telemedicine for prehospital emergency care. The findings of these studies are in line with the present study, and telemedicine has been used for consultation;[30] consultation and sending vital data, ECG, and radiology images;[31] triage;[32] consultation, examination, monitoring of vital signs, and airway management of children;[33] evaluation, diagnosis, and treatment;[28] evaluation and transmission of radiological images;[34] as well as evaluation and transmission of ultrasound images.[29]

However, fully understanding the potential of this technology for stroke patients requires providing adequate training, raising awareness about the nature of illness, clarifying the benefits of using technology, and conducting more clinical trials and interventional studies.

Stroke is the most common neurological disease, accounting for approximately one-third of all deaths world-wide. Almost 17 million new stroke cases are reported annually. More than 50% of survivors become chronically disabled, which affects their daily activities and quality of life. Therefore, a multi-team treatment approach is recommended.[35]

For most acute stroke sufferers, the first line of communication with care systems is EMS personnel in ambulances. However,

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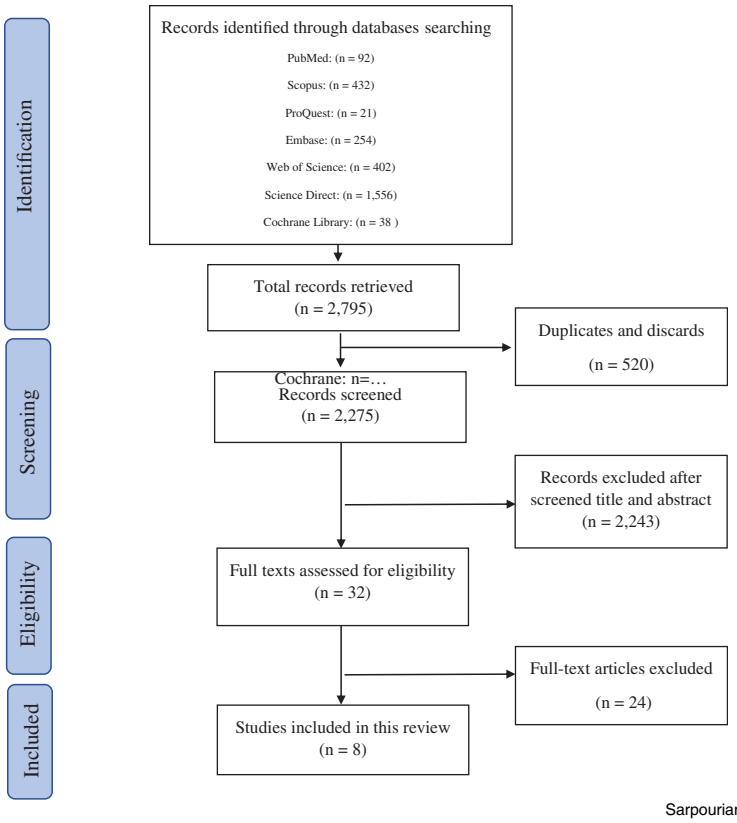

Figure 1. PRISMA Flow Diagram.

Study Design	Percentage (%)	Number	References
Randomized Trial Study	14.28	1	(22)
Feasibility Study	14.28	1	(23)
Feasibility and Interventional Study	42.85	3	(12, 24, 25)
Feasibility and Prospective-Observational Study	14.28	1	(26)
Feasibility and Retrospective-Interventional Study	14.28	1	(27)
Country			
United States	85.71	6	(12, 22, 23, 25-27)
Germany	14.28	1	(24)
Most Common Hardware			
RP-Xpress Device	57.14	4	(12, 22, 25, 26)
CT Scanner	42.85	3	(22, 24, 26)
Laptop	28.57	2	(22, 24)
Tablet	28.57	2	(26, 27)
Most Common Stroke Scale			
NIHSS	57.14	4	(12, 22-24)
CPSS	28.57	2	(25, 27)

Table 2. Summary of the Study Design, Country, Most Common Hardware, and Scale in the Selected Studies
Abbreviations: CT, computerized tomography; NIHSS, National Institutes of Health Stroke Scale; CPSS, Cincinnati Prehospital Stroke Scale.

accurate identification of patients before reaching the hospital is challenging due to heterogeneous clinical presentations, time constraints, and a lack of diagnostic technologies. On the other hand, the quality of quick communication between prehospital personnel and stroke treatment centers is very important. Currently, prehospital paramedics use scales to assess patients, but they are less accurate compared to hospital assessments.

In some situations, evaluations are performed in well-equipped ambulances (mobile stroke units), which require an ambulance-based neurologist. Therefore, telemedicine can help to strengthen the

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multi-team care and solve these problems by improving the quality of communication between rescuers and medical centers, and even dispatching and sharing patient information.[8,36] All seven studies[12,22–27] were conducted in developed countries. It seems that the interest of developed countries in telemedicine is more due to appropriate infrastructure, high computer literacy, and special government laws.[16]

Six studies were conducted in the United States[12,22,23,25–27] and only one study was conducted in Germany.[24] Yang, et al's study showed that the United States has the highest number of publications and citations in the field of digital health literacy and telemedicine.[37] Also, there are several successful and active models of telemedicine in this country,[38] and one-third of United States' hospitals use telemedicine, which is most commonly used for stroke, neurology, psychology, and pediatrics.[39]

Since more than 80% of American adults use the internet and own a personal cell phone, and the first source of medical information for most of them is an internet search, the American society is more technologically equipped than other societies. Therefore, it is expected that there will be a greater tendency to use telemedicine in response to health issues.[40]

The most common hardware used in the studies were the RP-Xpress device and CT scanner, respectively. The RP-Xpress device was used in four studies in the United States.[12,22,25,26] This device is a mobile communication platform that provides remote communication over the internet using a 175-degree fisheye camera with six-times zoom and a high-quality hyper-cardioid microphone and full-range speaker. It enables patient monitoring and connection to medical devices. Therefore, it has been used in many studies. Two studies in the United States[22,26] and one study in Germany[24] used portable CT scanners to evaluate and treat acute stroke. These CT scanners are small and simple, transfer the images to distant places for interpretation, and can be used in emergencies.[41]

The NIHSS scale was used in four studies to evaluate stroke patients in ambulances. One study in Germany[24] and three studies in the United States[12,22,23] used it. This scale has a good reputation and is used in cases of acute stroke as a relevant and sensitive tool to assess the severity of the disorder and make informed decisions. It includes 15 independent items with a score of zero to 42. A score of zero indicates no neurological abnormality and a score greater than 20 usually indicates dense paralysis with impaired consciousness. Since the scores of this scale are related to the mortality and functional results of patients, it has been used in most studies.[42,43]

Three studies carried out the feasibility and intervention through telemedicine in the ambulance.[12,24,25] Of these three studies, only Geisler, et al's[24] has used the Vimed Car and Vimed Doc systems (Meytec GmbH; Werneuchen, Germany) for remote consultation and radiology. Also, three studies used the stroke simulation scenario on healthy people.[12,23,26] In general, telemedicine-assisted prehospital care has been performed in limited areas such as neurology, cardiology, and trauma. According to the present study, this is the first comprehensive study that accurately describes the applications of telemedicine in ambulances for stroke patients. Therefore, setting up telemedicine systems, especially in low- and middle-income countries that face more emergencies, should be given high priority by health system managers and policymakers.

Limitations

This study had several limitations. Firstly, it included articles in the form of simulations, which limited the assessment of telemedicine's exact application to real patients. Consequently, further investigation into the clinical aspects of these studies was required. Additionally, another limitation was that only English language studies were included in the analysis.

To better understand the applications and improve the use of telemedicine in prehospital stroke interventions, the following suggestions are recommended: (1) Conducting clinical trials and intervention studies on real stroke patients and using fewer simulation scenarios should be the main priority of researchers in this field; (2) It is recommended to use low-cost equipment, compatible devices, and flexible and user-friendly platforms in ambulances; (3) Equipping ordinary ambulances with the internet and technology is the need of the day; (4) Training and persuading EMS personnel, ambulances, and neurologists to use this technology should be on the agenda; (5) Removing security, political, legal, insurance, and cultural barriers, especially in developing and under-developed countries; (6) It is recommended to use telemedicine to perform emergency interventions in other fields to better understand its applications; and (7) The support of universities, growth centers, and accelerators for new and practical projects in this field should be done.

Conclusion

Remote prehospital consultations, triage, and sending patient data before they go to the emergency department can be provided through telemedicine in ambulances. Agreement on diagnoses, neurologic examinations, and treatment decisions is almost equal to in-person evaluations by a neurologist. Video examinations facilitate the processes as soon as the patient arrives at the hospital emergency unit, which leads to a reduction in the time of receiving CT scan services and improves treatment decisions for patients. In fact, telemedicine supports and complements in-person assessments. However, technical difficulties remain a limitation associated with the prehospital telemedicine-based approach.

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Supplementary Material

To view supplementary material for this article, please visit https://doi.org/10.1017/S1049023X23006519

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