Multidisciplinary Research in Neurosciences

The nursing role in the mobile stroke unit for the treatment of ischemic stroke. A review of the literature

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Abstract. *Introduction:* Ischemic stroke is one of the most frequent causes of disability and death worldwide and includes huge social and financial costs of rehabilitation, long-term care and loss of patient productivity. Mobile Stroke Units (MSUs) are ambulances equipped with a computed tomography (CT) scanner and equipped with a stroke team that allows for pre-hospital stroke assessment. MSUs are generally set up with an anesthetist connected in telemedicine with the neurologist of the hospital of reference to whom the patient will be entrusted, a paramedic team and radiologist technicians who follow the event. The objective of this review is to identify the role of the nurse in the mobile stroke unit (MSU) and in particular to describe the skills, training and collaborative role in these mobile units. *Evidence acquisition:* 13 studies were included in the review and highlighted the nurse as the central figure in MSUs with organizational, nursing and management skills. *Evidence synthesis:* Studies show that early identification of acute ischemic stroke is vital to provide timely treatment through intravenous thrombolysis, which can improve clinical outcome and reduce resulting complications. *Conclusions:* Technologies such as telestroke, mobile stroke units are playing an increasingly important role in the identification and treatment of stroke. Trained and specialized nursing staff who, together with the MSU team, carry out the recognition of ischemic stroke and subsequent thrombolytic treatment (r-tPa) in less time, provide better patient outcomes and efficient future functional recovery.

Keywords: Mobile Stroke Unit, Nurse, Thrombolysis.

Introduction

Ischemic stroke is one of the most frequent causes of disability and death worldwide. Acute ischemic stroke has enormous social and financial costs due to the patient's rehabilitation, long-term care, and loss of work and social productivity. Thanks to the rapid progress of the past few decades, there are now safe and effective treatments for ischemic stroke. However, the main therapeutic modalities remain intravenous thrombolysis (r-tPa) often associated with mechanical thrombectomy treatment which are extremely time-dependent (1). Treatment with r-tPA in the golden hour (preferential time of drug administration) versus treatment within 61-270 minutes is associated with an increased likelihood of home discharge, independent walking to discharge, freedom from disability to discharge and reduction of bleeding complications or hospital mortality (2). Stroke has gone from the third to the fifth leading cause of death in the past decade due to advances in prevention and treatment. Organizations including the American Heart Association and the American Stroke Association have raised community awareness of stroke symptoms by popularizing the acronym "FAST" and "BE-FAST". Therefore, hospitals have made stroke care a priority by implementing policies that have significantly improved (reduced) the door-to-needle, i.e. the time that

elapses between the recognition of the stroke and the administration of the thrombolytic drug (3). The process of transporting acute stroke patients to the hospital for this imaging often delays therapy by more than an hour, the equivalent of 120 million neurons dying per minute (4).

Technologies such as telestroke and mobile stroke units are playing an increasingly important role in the identification and treatment of ischemic stroke (2). The World Health Organization recently defined mobile health as "medical and public health practice supported by mobile devices, such as cell phones, patient monitoring devices, personal digital assistants, and other wireless devices" (5).

The mobile stroke units (MSUs) are ambulances equipped with a computed tomography (CT) scanner and equipped with a stroke team that allows a pre-hospital assessment directly at the stroke site. MSUs are generally established with an anesthetist in telemedical connection with the neurologist of the reference hospital who will be entrusted with the patient a paramedical team and a technician for imaging CT, achieving better results and an increase in thrombolytic rates in the hour of In particular, it is a standard ambulance that is equipped with a portable CT scanner and supports all the necessary equipment for the acute evaluation and treatment of a patient with stroke (3,6).

The objective of the review is to identify the role of the nurse in the mobile stroke unit (MSU) and to describe the skills, training and collaborative role. In particular, we want to outline the nursing procedures that take place in MSU and the elements that depict the nurse who relates to the patient and the team following the stroke event, the communication skills in telemedicine with the reference hospital to which he will be entrusted the patient and the skills / knowledge that must be possessed in order to belong to the specialized personnel of these mobile units.

Materials and Methods

Study design

To conduct the review, a research question was outlined using the Population, Intervention, Outcome (PIO) methodology (Table 1).

Table 1. The PIO instrument to literature review conduction.

Population	Patient candidates for intravenous thrombolysis on MSU
Interventation	Nurse on MSU administering intravenous thrombolytics
Outcomes	Nurse administering intravenous thrombolytics to candidate patients in less time on MSU.

A search and subsequent bibliographic consultation was carried out by consulting the MEDLINE databases (through Pubmed), The Cochrane Library, Scopus, Google Scholar and articles pertinent to the topic were found.

Articles written in both English and Italian were considered. The search strategy envisaged the use of the following terms, both for free search and using the MeSH database, individually and in combination with the Boolean operators AND and OR: "mobile stroke unit", "nurse", "thrombolysis". The same terms were used for the search on the Google Scholar database (Table 2)

Item selection process

Through an initial bibliographic search on electronic databases, all the articles considered potentially relevant for the purposes of the review were identified. Following the removal of duplicate titles, an initial screening of titles and abstracts was performed to identify the number of articles potentially eligible for review. The reviewers (LP and LT) carried out a new selection of the articles, thus identifying potentially relevant studies in relation to the initial search objective and evaluating the related full-text.

Inclusion-exclusion criteria

All studies that met the following criteria were included in the review:

1. studies that aimed to investigate the role of nurses in MSUs as a primary objective;
2. the role of the nurse in collaboration with the MSU team and in particular training and skills;
3. adult population (≥ 18 years old); 4) full text available in English or Italian.

Table 2. Combination of keywords used with the Boolean AND operator.

Database	String	Limits	Results
Medline (Pubmed)	("mobile"[All Fields] OR "mobiles"[All Fields]) AND ("stroke"[MeSH Terms] OR "stroke"[All Fields] OR "strokes"[All Fields] OR "stroke s"[All Fields]) AND "unit"[All Fields] AND ("nurse s"[All Fields] OR "nurses"[MeSH Terms] OR "nurses"[All Fields] OR "nurse"[All Fields] OR "nurses s"[All Fields]) AND "thrombolysis"[All Fields]	None	5
Medline (Pubmed)	"tpa"[All Fields] AND ("nurse s"[All Fields] OR "nurses"[MeSH Terms] OR "nurses"[All Fields] OR "nurse"[All Fields] OR "nurses s"[All Fields]) AND (("mobile"[All Fields] OR "mobiles"[All Fields]) AND ("stroke"[MeSH Terms] OR "stroke"[All Fields] OR "strokes"[All Fields] OR "stroke s"[All Fields]) AND "unit"[All Fields])	None	5
Scopus	((mobile stroke unit) AND (nurse)) AND (thrombolysis)	None	5
Scopus	(TITLE -ABS-KEY (tpa) AND TITLE-ABS-KEY (mobile AND stroke AND unit) AND TITLE-ABS-KEY (nurse))	None	5
Cochrane library	Mobile stroke unit in All Text AND "nurse" in All Text AND "thrombolysis" in All Text	None	16
Google Scholar	mobile stroke unit and nurse and thrombolysis	None	1280

Studies were excluded:

1. those that report only the description of the staff administering intravenous thrombolysis in hospital;
2. studies that concerned only the content and quality of CT images in mobile stroke units;
3. studies that reported the use of MSUs for other events such as intracranial hemorrhages and epileptic seizures;
4. results of studies relating only to the use of telestroke;
5. studies relating to the MSU as a description of the cost of the vehicle and in which the nursing figure is not mentioned (Figure 1) (7).

Results

Table 3 reports the 13 articles included in the review, including authors, year of publication, number and type of patients, evaluation of the parameters studied, objectives and results.

Studies show that early identification of acute ischemic stroke is vital to provide timely treatment through intravenous thrombolysis, which can improve clinical outcome and reduce resulting complications. The only acute systemic treatment for stroke that has been shown to be effective is the recombinant tissue plasminogen activator (r-tPA), but its window of use is recommended within 3-4.5 hours after the onset of symptoms. stroke. An MSU, also known as a stroke emergency mobile or mobile stroke treatment unit, combines a specially trained team, conventional emergency equipment, telemedicine capabilities, a CT scanner, and diagnostic tools used to make an urgent decision for or against thrombolysis directly in the patient's location (4,8). MSU models and services can be adapted to improve stroke services for these patients. In addition to acute stroke triage, MSUs can provide telemedicine services to patients who are candidates for r-tPa treatment (6). On board the MSU, the team includes an anesthetist and some studies report the presence of a neurologist, the latter usually connected with telemedicine. The presence of the nurse plays a key role supported by paramedics and radiologist technicians. Other studies report the tasks, training and general organization of the MSU ambulance (1,2,9).
A study conducted on the MSU in Melbourne describes the nursing role related to the administration of drugs in a shorter time compared to other hospital reference scenarios by improving patient outcomes (10). The treatment of ischemic stroke with r-tPa requires time reduction and administration at the site of the event to ensure the brain recovery of patients (11-13). Further studies have shown how much the technology present on the MSU helps the trained team to communicate with the reference hospital to which the patient will be entrusted (3,5,14).

Discussion

The aim of the study is to identify the nursing figure in MSUs and to outline the skills and knowl-

Table 3. Studies included in the review (n=13).

Database Author(s), year	Objective	Design	Setting and Sample	Results
PubMed				
Bowry et al., 2015 (14)	Optimizing pre-hospital triage using mobile stroke units (MSUs) can accelerate treatment times.	Randomized, observational	Of 130 alarms, 24 MSU and 2 MS patients were enrolled. Twelve of the 24 MSU patients received tPA on board; 4 they were treated within 60 minutes of the last normal view and 4 passed to endovascular treatment.	The run-in phase provided a tPA treatment rate of 1.5 patients per week, ensuring that treatment within 60 minutes from onset are possible and allows for patient enrollment in the MS weeks.
Scopus				
Lin et al., 2018 (4)	Initial experience with Mercy Health MSU and institutional protocols implemented to facilitate rapid treatment of acute stroke patients.	Descriptive, observational	The MSU was sent 248 times and transported 105 patients after on-site examination with imaging. Intravenous (IV) tissue plasminogen activator (tPA) was administered to 10 patients.	The world's first 24/7 MSU has been successfully implemented with IV-tPA delivery rates and times comparable to other MSUs nationwide.
Cochrane Library				
Larsen et al., 2021(6)	Treatment of acute stroke in mobile stroke units (MSUs) is feasible and reduces treatment time, but the optimal staffing pattern is unknown.	Non-randomized, prospective and controlled study	440 patients were included. The median time to treatment initiation of MSU (IQR) was 101 (71-155) minutes compared with 118 (90-176) minutes in controls, p = 0.007	Integrating AIS thrombolysis into anesthetist-based EMS reduces treatment times without negatively affecting the outcomes
Google Scholar				
Calderon et al., 2018 (9)	To provide a look at the evolution of the MSU in its current state and in future directions.	Observational, descriptive	Initially hypothesized in 2003, the first MSUs were launched in Germany and adopted worldwide in the management of pre-hospital acute stroke.	MSU crew description, timing and administration of the thrombolytic drug.
Bowry et al., 2017 (8)	Mobile Stroke Unit (MSU) can accelerate tPA treatment and facilitate faster triage of patients to hospitals	Prospective, randomized, multicentre	More than 50% of patients had a decision on treatment time within the first "golden hour" of the onset of stroke symptoms.24 time from initial treatment call) were seen in the Pre-Hospital Acute Neurological study Treatment and Optimization	Feasibility and safety of the operation of the MSU in the United States and the reliability of telemedicine to evaluate stroke patients for eligibility for tPA.
Mathur et al., 2019 (1)	Time is the brain, as the therapeutic windows narrow for both intravenous thrombolysis and mechanical thrombectomy depend on appropriate and specialized treatment	Observational, descriptive	Times from symptom onset to hospitalization have been reported in rural hospital from 5 to 30 hours (59,60). These transport delays contribute to the low thrombolysis rate of 1-6% for patients in the rural areas around the world	Mobile Stroke Units (MSUs) provide a valuable resource prehospital to rural and remote facilities where patients may not have an easy time access to hospital stroke care.

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Database Author(s), year	Objective	Design	Setting and Sample	Results
Ehntholt et al., 2020 (2)	(MSU) have revolutionized emergency stroke care by providing pre-hospital thrombolysis faster than conventional ambulance transport	Observational, descriptive	Two German studies suggest that the MSU model is cost-effective as it reduces disability and improves adapted quality of life after stroke. The ongoing BEST-MSU study will be the first multicenter, randomized, controlled study that will shed light on the impact of MSUs on long-term neurological outcomes and cost-effectiveness.	MSUs are effective in reducing treatment time in acute ischemic stroke without increasing the adverse events.
Zhao et al., 2021 (10)	Mobile Stroke Units (MSUs) are specially designed ambulances with CT imaging capabilities that can provide faster pre-hospital care to patients in the community.	Observational, descriptive	The Melbourne Mobile Stroke Unit is the first MSU service in the Australian region, commencing operations in 2017 in Melbourne's central metro.	The challenges of creating MSU in a unique Australian environment and the initial clinical efficacy of pre-hospital treatment of MSU and triage on ischemic and haemorrhagic stroke
Fassbender et al., 2021 (13)	It summarizes the current knowledge in this young field of stroke research, discussing topics such as the benefits of reduction delay before treatment, imaging-based triage	Observational, descriptive	The ambulance, the basis of the MSU, varies around the world in size according to the specific needs of various regions and health systems allowing adequate space for triage nurses	Current research, therefore, focuses on safety, long-term medical benefits, better setting ed cost efficiency as crucial determinants for the sustainability of this new acute stroke management strategy.
Liaw et al., 2020 (3)	Technologies like telestroke, mobile stroke units and artificial intelligence stand playing an increasingly important role in identification and treatment stroke.	Observational, descriptive	The Central Hospital of the University of Helsinki has developed the Helsinki Fundamental Protocol at its own institution, leading to average DTN times of 20 minutes.	MSUs are ambulances equipped with CT imaging technology and equipped of nurses, technicians and doctors so that the tPA can be delivered to the patient in the field after the initial assessment and imaging. In this way, the time taken during the transfer from EMS to hospital is eliminated and decision making can be done directly by the stroke team
John et al., 2015 (11)	A paradigm shift in the use of mobile CT is was its installation in ambulances for the management of acute stroke.	Observational, descriptive	Two separate MSU projects in Saarland and Berlin have demonstrated safety and security feasibility of this concept for pre-hospital stroke care, showing an increase in the rate of intravenous thrombolysis and a significant reduction in treatment time compared to conventional care.	MSU has also improved patient triage to appropriate and specialized hospitals. Although numerous problems still remain unanswered with the concept of MSU, including the clinical outcome and cost-effectiveness, the MSU company is visionary and allows to provide a life-saving and ameliorative treatment for ischemic stroke and hemorrhagic.

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Database Author(s), year	Objective	Design	Setting and Sample	Results
Nam et al., 2013 (5)	Rapid detection and triage are essential for effective thrombolytic treatment.	Observational, descriptive	A mobile telemedicine scoring system from the National Institutes of Health Stroke Scale showed higher correlation and rapid assessment than the face-to-face method. Since the benefits of thrombolytic treatment are time-dependent, treatment should be started as quickly as possible.	Computing and mobile health are useful tools for managing stroke patients from acute to rehabilitation.
Asad et al., 2020 (13)	The important primary step in maintaining stroke is the initial identification of stroke patients and triage to centers that can deliver the appropriate treatment, as quickly as possible.	Observational, descriptive	Auxiliary data from prehospital care and emergency stroke care, counting the use of emergency medical facility protocols for documentation of stroke patients, and counting thrombectomy and thrombolysis that transformed patient care with ischemic stroke.	Tele stroke and artificial intelligence are playing a cumulative role in stroke recognition and treatment. Stroke care system models remain to simplify the distribution of definitive revascularization in the mechanical thrombectomy age.

edge to be able to support the stroke event in these mobile units. The only acute systemic treatment for ischemic stroke that has been shown to be effective is recombinant tissue plasminogen activator (r-tPA), but its recommended window of use is within 3-4-5 hours of onset of symptoms (9). The Prehospital Stroke Treat-ment Organization (PRESTO) was therefore established in 2016 to improve patient outcomes and promote research in the various spheres of pre-hospital stroke care. The PRESTO organization has facilitated the expansion of MSU programs around the world to establish a global and cohesive stroke care network that can connect patients, public / municipal resources. Worldwide, MSUs hold great promise, with the potential to improve patient outcomes and provide care by improving hospital costs / benefits and r-tPA drug delivery times (8). Fassbender et al in Homburg, Germany, were the first to propose and execute the concept of Mobile Stroke Unit (MSU) (ambulance equipped with a CT scanner (TAC), laboratory tests, telemedicine connection to the hospital and appropriate drugs on board the MSU) which enables pre-hospital diagnosis and treatment of stroke in a relatively rural setting. The results of their study showed that pre-hospital management achieved a median treatment decision time between symptom onset and therapy of 56 minutes versus 104 for the classic stroke in hospital (8). In these MSUs there is the presence of a nurse trained in intensive care, a radiologist for CT and a paramedic. A neurologist (VN) can also physically travel with the MSU or participate on the scene using telemedicine technology. The BEST-MSU study in Houston is determining whether it is beneficial to have a VN onboard instead of just availability through telemedicine, as well as the feasibility of cross-training MSU team members to complete multiple tasks, including nurse training such as technician to scan the CT images. The composition of the staff can be adapted to meet the needs of rural structures and according to the economic needs of the hospital to which the ambulance belongs. Particularly in Norway, in the smaller urban areas, the MSU is made up of an anesthetist, a paramedic and a paramedic nurse. Anesthesiologists have been trained to identify and

treat stroke. The anesthetist can also provide resuscitation and perform invasive emergency procedures to any unstable or critically ill patient. The evolution of telestroke technology requires that staff have continuous, intermittent or simulated training (1,12). Nurses and paramedics place suitable patients for r-tPA administration on a stretcher which is then raised to align the patient's head with the scanner when the CT scan is performed. For each patient, a standard configuration of 8 plates and 5 mm is obtained, available for immediate viewing on a laptop readily transmissible to the destination hospital via an i-cloud-based image storage and communication system (telemedicine) to the neurologist and the stroke unit team for image evaluation. Studies show that telemedicine is a fundamental element and the nurse has a central role as they must have adequate training in order to allow the functioning of these communication tools on the MSU between the territory and the reference hospital (9). To safeguard radiation exposure and ensure quality CT (CT) images, the MSU requires the staff of a CT technologist. As a cost-saving measure, CT technologists can be trained as "emergency technicians" to assist the MSU paramedic / nurse when a neurologist / anesthetist is not available in the ambulance and / or they can also become highly skilled in other forms of modality. imaging or nurse support (8). In one study it is described in detail that the nurse on arrival with the MSU prepares the patient for possible intravenous thrombolytic treatment. She performs the gluco-stick test, i.e. fingertip glucose, to rule out significant variations in blood glucose ranges (8). The nurse reports the value to the anesthetist and the neurologist in connection to correct the insulin value or exclude conditions such as hypo or hyper glycaemia that simulate and are often confused with the stroke event. With the point-of-care laboratory presents in MSU analyzes, after the execution of the blood sampling, the haematological parameters (thrombocytes, erythrocytes, leukocytes, hemoglobin), INR coagulation parameters, activated partial thromboplastin time aPTT, clinical chemistry parameters such as gamma-glutamyltransferase, pancreatic amylase, creatinine, glucose (1,8). Personnel on board including nursing staff must be adequately trained in the use of lead vests and personal radiation detectors in MSUs and use of protocols for people outside the MSU exposed to radiation (2).

In Melbourne, the nurse aboard the MSU administers support medications early on a doctor's prescription. This includes antihypertensive agents before and after intravenous thrombolysis to ensure suitable blood pressure values before thrombolysis and idarucizumab inactivators to eliminate the anticoagulant action and allow the administration of thrombolysis. This is because drugs are always stored in a known location on the vehicle, relative to the drug supply in a large emergency room (and may require pre-approval from another medical specialty, wasting time). MSU staff are also particularly trained to administer these drugs more effectively (being trained in drug infusion rate / knowledge), while in the hospital it may be necessary to administer such drugs by a less experienced general emergency nurse (10,11). In one study, the MSU staff consists of a paramedic, an anesthetist and a specialist nurse with training in the critical area and has dealt not only with dynamics related to the stroke event but also those related to deferred events such as intracranial hemorrhage and seizures epileptics. It has been shown that the nurses on medical prescription could in advance administer antihypertensive drugs and perform resuscitation maneuvers if the stroke event resulted in unfavorable complications (6). In detail, the drugs that are administered in the MSU by the nurse are: Aspirin, Lorazepam, Nicardipina D 50, levetiracetam, Labetalol, Mannitol, Clopidogrel, tPA, midazolam, Ondansetron (4).

MSUs vary worldwide in size depending on the specific needs of various regions and health systems. Some MSUs focus on small and light standard solutions, thus reducing costs, facilitating speed in the narrowest streets of the city. However, larger vehicles may be more advantageous as the additional space allows relatives to accompany the patient into the MSU, ensures suitable spaces for a nursing history and signing informed consent for subsequent medical procedures; they can also incorporate larger scanners and their more robust construction allows them to cope with difficult road conditions (13). These on-site assessments allow to obtain more precise information and allow the nurse and doctor to perform accurate triage and also allow people who have witnessed the patient's stroke event by chance to tell the details that often in

the hospital they cannot be detected (4). In Australia, a study is conducted with an Air Mobile Stroke Unit (Air-MSU); with this approach, the MSU concept is extended to another transport vehicle by equipping a helicopter or airplane with CT scanners and telemedicine connectivity (1). The evolution of these means should be implemented in greater numbers in hospitals, as they have shown how they reduce company time and costs. The MSU has improved the triage of stroke patients to appropriate and specialized hospitals but equipment backup problems are the responsibility of the team and in particular of the nurse who prepares and sets up the MSU daily and above all is careful to ensure that the ISTAT point care does not expose itself to hot and cold temperatures and that the infusion pumps for the thrombolytic drug are replaced if not functioning (14).

Conclusion

Early identification of acute ischemic stroke is vital to provide timely treatment through intravenous thrombolysis, which can improve clinical outcome and reduce complications. From the results of this review, it emerges that the healthcare of the future is mobile and at the same time the central role in the MSU of the professional nurse. The included studies highlight a roundup of concepts and situations and innovations that can be used in the pre-hospital setting where even the seconds alone count more than one can imagine. Innovations that are also taking hold in our European countries which from time to time tend to improve health services and shorten the execution times of the maneuvers to ensure the protection of a life and act in what is called the "GOLDEN HOUR". Future Italian multicentre studies must investigate this rescue system, still unexplored to date, integrating the necessary role of the nurse in team work.

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