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Research Article

Prehospital Identification of Middle Cerebral Artery Occlusion - A Stroke Education Program and Transcranial Ultrasound for Paramedics

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Abstract

Objective: Pre-hospital stroke scales imperfectly distinguish between acute ischemic stroke including large intracranial vessel occlusion, hemorrhagic stroke, and stroke mimics. Current point-of-care diagnostics include serum biomarkers, telemedicine, mobile computed tomography units and ultrasound equipment. The aim of our study was to evaluate a web-based stroke education program for paramedics including Transcranial Color-Coded Duplex Sonography (TCCS).

Method: We designed a two-part web-based 7-week curriculum with a theoretical part including four web based theoretical tutorials and a practical part with 3 hands-on seminars. Pre- and post-test (29 questions, pictures and videos) were generated for knowledge gain assessment. Test results of 10 paramedics were compared with those of six young neurology residents. The post-educational test included a stroke examination followed by a symptom-oriented TCCS examination in the intervention group.

Results: Pre- and posttest results showed a significant increase in the number of correctly answered questions and a clear approach to the control group (intervention group: pre mean: 14.3/29 questions; post mean 19.4/29; p=0.004; controls mean 23.4/29; p=0.002). In addition, a safer handling of stroke patients in the preclinical setting was noted. The level of improvement in TCCS did not reach significance (p=0.1875).

Conclusion: The proposed web based educational training course may enable paramedics to perform not just a short neurological examination but also good quality TCCS, a combination highly suitable for patient selection for endovascular embolectomy. Further studies implementing in the field performance tests, novel portable ultrasound technology and telemedical support from stroke neurologists are needed before the impact on stroke treatment can be studied.

Keywords: LVO; Ultrasound; Stroke; Education; Prehospital; Paramedics

Abbreviations

NIHSS: National Institutes of Health Stroke Scale; TCCS: Transcranial Color-Coded Duplex Sonography; LVO: Large Vessel Occlusion; ICH: Intracerebral Hemorrhage; LAMS: Los Angeles Motor Scale; CPSS: Cincinnati Prehospital Stroke Scale; MASS: Melbourne Ambulance Stroke Screen; LAPSS: Los Angeles Prehospital Stroke Screen; PASS: Prehospital Acute Stroke Severity Scale; FAST-ED: Field Assessment Stroke Triage for Emergency Destination; RACE: Rapid Arterial Occlusion Evaluation; POC: Point-of-Care; GFAP: Glial Fibrillary Aacid Protein; MSU: Mobile Stroke Units; POCUS: Point-of-Care Ultrasound; MCOA: Middle Cerebral Artery Occlusion; FAST: Face Arm Speech Time; MCA: Middle Cerebral Artery; GCS: Glasgow Coma Scale; CNS: Central Nervous System; RCT: Randomized Controlled Trials

Introduction

Recognition of acute stroke symptoms and the delay until decision to call the emergency dispatcher are still the major limiting factor for effective treatment in acute stroke [1]. Yet, other prehospital delays such as time from dispatch to arrival, time on scene and transport to the hospital still contribute with an estimate time of 25 to 50 min. especially in rural areas [2-4]. In addition a subset of stroke, patients with Large Intracranial Vessel Occlusion (LVO) or Intracerebral Hemorrhage (ICH), require neurointerventional or neurosurgical treatment in neurovascular centers requiring site specific emergency approach obviating potential time consuming secondary interhospital transfer.

A recent meta-analysis suggests that some prehospital scoring systems including cortical signs may have enough accuracy to predict stroke due to LVO but these signs may be difficult to investigate by paramedics [5]. Overall, no scale predicted LVO with both high sensitivity and specificity to justify bypassing primary stroke units and more prospective studies are needed to assess the accuracy of LVO prediction instruments in the prehospital setting in all patients with suspected stroke, including patients with hemorrhagic stroke and stroke mimics [6]. In a recent study performed under emergency

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conditions in the field, 94 acute stroke patients were examined using seven prehospital stroke scales. After hospital admission final diagnoses were ICH in 19%, stroke mimics in only 5% and cerebral ischemia 76% with almost half of patients diagnosed with LVO (48%). In this specific stroke study the LAMS showed an accuracy of 0.72 for LVO and an accuracy for patients with ICH and LVO that would be directly transported to a comprehensive stroke center with neuroradiological and neurosurgical capacity, and was slightly superior to all other scales [7].

Point-of-Care (POC) diagnostics can significantly enhance stroke diagnosis and differentiation. Blood serum analysis has drawn significant interest in pre-hospital stroke care and to date only Glial Fibrillary Acid Protein (GFAP) specific level detection can separate hemorrhagic stroke from ischemic stroke and stroke mimics [8,9]. Mobile Stroke Units (MSU) allow for pre-hospital thrombolysis with significantly shorter symptom-to-needle times but are highly limited in range and require specialized staff [10]. The quality and use of POCUS devices (point-of-care ultrasound devices) has increased considerably over the years and is currently used to assess various prehospital cases e.g. trauma patients [11-13]. A previous study using TCCS by qualified stroke neurologists in the field showed 90% sensitivity and 98% specificity for identification of Middle Cerebral Artery Occlusion (MCAO), indicating high potential for identification of LVO in stroke patients [14]. In addition, other significant findings also included reversal of flow in the anterior cerebral artery indicating critical internal carotid artery stenosis but also high rates of patent cerebral arteries, probably excluding patients from interventional embolectomy [15]. However, POCUS requires a pathological concept for a directed diagnostic approach, i.e. left sided hemiparesis with gaze to the right consistent with right MCAO that is not present in any stroke scales.

Material and Methods

Ethics and study design

This study was designed as a prospective educational interventional cohort study with the aim to improve neurological knowledge especially in relation to stroke TCCS in paramedics. The study protocol was approved by the local Ethics Committee at the University of Regensburg according to the declaration of Helsinki (Ethic committee Nr. 09/135).

Timeline and Curriculum

The enlisted paramedics were offered a 7-week education program covering basic neuro- and neurovascular anatomy of the brain, stroke pathophysiology (etiology, symptoms, risk factors), diagnosis, pre-hospital management, documentation, use of stroke Face Arm Speech Time (FAST) Test), National Institutes of Health Stroke Scale (NIHSS) [16], Glasgow Coma Scale (GCS) [17] and TCCS. The hands-on seminars had a duration of 45 minutes and were offered over a period of one week. During the first two hands-on tutorials, the paramedics received instructions how to use TCCS and perform neurological exam including the FAST test. In the final hands-on seminar, they executed the whole procedure (neurological examination, FAST test, TCCS) under supervision on their own. The entire and final test contained 29 questions with 4 subgroups for the different lecture topics and 3 short video clips with real stroke patients and 3 questions related to the video material. In addition, the participant had to perform a FAST Test and TCCS of the proposed vessel (Figure 1). Shows a sketch of the education program and tests.

In order to connect the theory with real live experience, videos of real patients, who consented with video documentation, videos of a structured neurological examination on healthy volunteers and videos of performing a TCCS were uploaded as clinical examples. The theoretical tutorials were separated into basic neuroanatomy, anatomy of the brain supplying vessels, stroke syndromes with stroke prehospital therapy and support, and TCCS. Each of them was available online. They were able to access additional literature and videos anytime and without time limitation. Every person received a personalized account to access to the online platform specifically designed for this study. The participants were trained during work shift. Due to the structured setting of the training, the participants were able to pursue their work without interruption. Only for the hands-on exercises, they had to be released from their work.

Transcranial color-coded sonography

In the TCCS online lectures and prior hands-on sessions, instructions focused on image acquisition and identifying satisfactory views. There was formal instruction on probe orientation, identifying B-mode brain structures (such as contralateral skull and mesencephalic brain stem), Doppler functionality, or image quality adjustments, as these were necessary to obtain and interpret ultrasound images for the purposes of identifying the vessels including presence or absence of occlusion. Paramedics performed the hands-on session until they were satisfied, could acquire adequate views, but no longer than 45 minutes per session. Hands on sessions with ultrasound equipment and data acquisition were performed using the Sonosite Micromaxx (Sonosite Inc., Bothell, Wash., USA) portable duplex ultrasound device equipped with a phased-array transducer (P17, transmit frequency 2.0 MHz) for transcranial imaging. The protocol requested for visualization and flow measurements of the Middle Cerebral Artery (MCA) on both sides starting with the vessel assumed most likely affected. After MCA visualization using Color Doppler mode, flow measurements were performed in the MCA mainstream (M1-segment, depth 54 mm) segment using spectral Doppler sonography. Images and video clips were stored as DICOM files for off-line analysis.

Performance review

All paramedics were asked to complete a multiple-choice questionnaire with 29 questions to ascertain baseline knowledge (see supplement). Questions were assessing knowledge of "neuroanatomy" (n=9), "stroke pathophysiology" (n=13), "pre-hospital management of stroke" (n=4, including performance of FAST score) and "theory and interpretation of TCCS findings" (n=3; three of the questions consisted of videos showing stroke patients with varying symptoms and affected territories. The aim was to identify the symptom and to assign the supplying blood vessel to the corresponding anatomic Central Nervous System (CNS) region. Prior to testing, a panel of medical experts for clarity, relevance, and usefulness reviewed the questions.

All paramedics had no prior ultrasonography training. At the end of the training curriculum, the same test and objectively

Figure 1: Timeline of the curriculum of paramedics to optimize the pre-hospital management of stroke.

structured clinical examination with aim to correctly identify stroke patients (distinguish stroke mimic), identify the vessel assumed to be with restricted blood supply and acquire quality ultrasound image of both MCA vessel with TCCS were administered to evaluate knowledge gained. This last part of the exam was performed under the supervision of two experienced physicians in stroke and TCCS (FS and DB). Neurology residents in their first and second year of training served as a control group. No participants were compensated in any way.

Statistical analysis

Wilcoxon matched-pairs signed rank test and Kruskal-Wallis test was used to determine the differences between groups.

Results

Overall, 10 paramedics and 6 neurology residents in the first or second year of their training participated in this study. The web-based curriculum was well accepted, as there were no queries regarding to technical difficulties, connectivity, setup and access to the platform. All ten paramedics took the initial test; a single participant was excluded from the evaluation, because he did not participate in the final test. The results of nine paramedics were compared with six neurology residents in their first or second year as control group. Every participant learned how to perform NIHSS, FAST and TCCS within a satisfactory time (47 seconds mean for FAST in post-test)

The paramedics group was able to improve their knowledge through the training measures but did not reach the total value of the control group. Further improvements within the subgroups "stroke pathophysiology", "preclinical stroke management" and "TCCS interpretation" were achieved (Figure 2 a-b).

In detail, the results achieved can be summarized as follows. While 144 questions (10 participants, mean value 14.38; n=29 questions) were answered correctly by all participants in the initial test, the total number of correctly answered questions in the final test increased to 175 (9 participants, mean value 19.39; P=0.0039, Wilcoxon matched pairs signed rank test). Despite this clear improvement, paramedics did not quite achieve control group level with 23.38 correctly answered questions on average (p >0.05, Mann-Whitney U-test). With regard to the subgroups, the following results were shown in the topics specifically relevant for preclinical application. In the subgroup "Preclinical Stroke Management", 19 questions were answered correctly by all participants in the initial test (mean value 1.9; n=four questions), in the final test 34 (mean value 3.78).

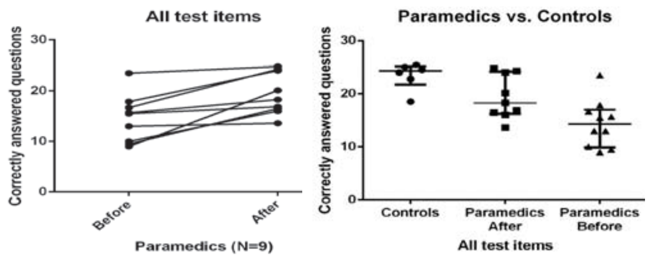

Figure 2 a-b: Number of correctly answered questions of all test questions. Comparison to the control group (p=0.0039).

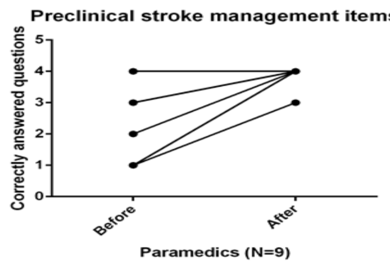

Figure 3: Test results in the subgroup analysis "Preclinical Stroke Management" (p=0,0078).

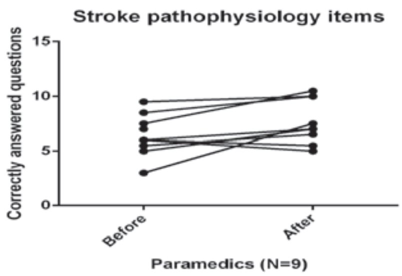

Figure 4: Test results for the subgroup "Stroke Pathophysiology" (p=0.0508).

The statistical analysis shows a highly significant increase (p=0.0078), (Figure 3).

In the subgroup "Stroke Pathophysiology", there were 64 correctly answered questions in the initial test (mean value 6.4; n=13 questions), in the final test 69 (n=13 questions; mean value 7.67). Although the results between pre- and post-test improved for most participants, the evaluation (in the Wilcoxon Match-paired Signed Rank Test) showed a p-value of 0.0508, just above the significance

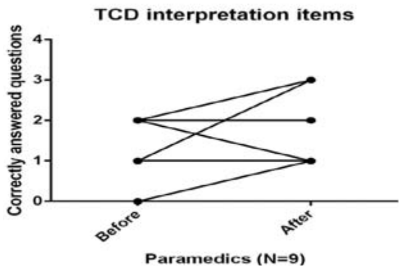

Figure 5: Test results in the subgroup analysis "TCD Interpretation" (p=0.1875).

level (Figure 4).

In the subgroup "TCCS Interpretation", the number of correctly answered questions was initially 12 (mean value 1.2; n=3 questions), in the post-test it was 17 questions (mean value 1.89). The results in the subgroup analysis showed a mixed picture among the participants, which is also reflected in the *p*-value, which was not significant at 0.1875 (Figure 5).

The mean value for the time required for the entire test was 16 minutes in the initial test. This time did not change even though the total time required by all participants improved from 2h 40min to 2h 24min. During the final exam, an experienced neurologist simulating neurological deficits tested pathophysiological and neuroanatomic knowledge. Through a focused examination, all participants were able to correctly identify the affected brain area along with the corresponding vessel with the presumed restricted blood flow within a short time and then perform a targeted TCCS examination. All participants were able to obtain representative TCCS pictures in good quality.

Discussion

In this educational training course, we could enable paramedics to perform not just a short neurological examination but also good quality TCCS, a combination highly suitable for patient selection for endovascular embolectomy. As patients with LVO may be better served by direct transfer to centers with endovascular capacity, hazardous delays due to secondary interhospital transfer between primary and comprehensive stroke centers may be avoided [18].

Currently, the use of stroke scales enables identification of stroke patients, but is not recommended for the prehospital triage of patients with large vessel occlusion [6]. A brief overview of the most important scores currently available reveals deficits regarding the preclinical application. For example, doctors in the hospital trained with NIHSS scoring or Stroke Unit doctors who are familiar with stroke symptoms and patients evaluated the FAST-ED, CPSS, LAMS and RACE. The LAMS score is one of the scores evaluated in the field by paramedics. In a recent study in 94 patients, this score lead to the diagnosis of acute ischemic stroke in 76% with a surprisingly high proportion of 48% LVO and non-LVO in only 28%, intracranial hemorrhage in 19%, and stroke mimic in 5%.

Yet, we opted to use the FAST score for our study because paramedics in the preclinical setting are already using it. Recently, the use of LAMS was compared to management in MSU and accurate triage decisions for LVO embolectomy was achieved in only 70% of patients compared to 100% in the MSU [19]. However, all these scales show a low specificity for prehospital recognition of LVO [20]. Thus, there is a high risk of misclassification of, especially in the hands of untrained personnel with the possibly causing excessive harm due to prolongation of symptom to needle time by bypassing the next stroke unit for a distant comprehensive stroke unit [21].

The only mobile neuroimaging technique other than the MSU approach is ultrasound based, and in the hand of the experienced neurologist yields high diagnostic confidence in LVO diagnosis [23,24]. In order to streamline stroke treatment special prehospital diagnostic tools such as CPSS, FAST, MASS, LAPSS, PASS, FAST-ED, RACE have been developed with the aim to help paramedics and emergency doctors to correctly distinguish stroke mimics from real strokes, but are deemed to be insufficient for pre-hospital selection of stroke patients [22-29]. Paramedics or first aid doctors have not validated most of these scores in the field, but only after arrival in a stroke unit, after exclusion of brain hemorrhage, ischemic stroke database analysis and by NIHSS-trained doctors and neurologists, thus presenting a severe selection bias.

In other preclinical emergency settings (for example FAST: Focused Assessment with Sonography for Trauma), ultrasound is regarded as a valuable tool for emergency medicine. In pilot study in 2010, Heegaard et al. showed that paramedics were able to perform and interpret FAST in a preclinical setting after a 6h-hour training [24]. In more than 100 patients, the preclinical use of US by paramedics was performed and with a dropout rate of only 7.4% considered useful with 100% proportion of agreement with the physician supervisors. Also, Walcher et al. and Heegaard W et al. demonstrated a potential improvement in POCUS diagnostics in educated paramedics in abdominal trauma patients, but there were still difficulties with the interpretation of the findings [13,30].

For stroke patient diagnosis using TCCS a basic neurological understanding and the pathophysiological concepts are required to accurately link absent vessel identification to stroke symptoms. Using the Learning platform and additional TCCS training in our department, we enabled paramedics to identify stroke patients and especially LVO using a focused examination applying targeted use of TCCS. In contrast to Heegaard et al. who applied 6 hours of training with a subsequent refresher phase, we offered the participants a 7-week, structured and web-based course, which they completed alongside their everyday work as paramedics.

Telemedicine as well as intelligent stroke algorithms software have evolved significantly over the past years offering additional support for stroke therapy in hospitals lacking a dedicated stroke unit [30-33]. Considering these current developments, the consultation of experienced stroke neurologists offering telemedical support in the field is a consequent strategy. Employment of echo-enhancing agents in patients with absent sufficient temporal bone window (up to 20% of stroke patients) may be facilitated by telemedical supervision and help to increase the number of clinically useful TCCS studies, but also to decrease examination time and increase diagnostic confidence [34-36]. While paramedics are uniquely placed to deliver early treatment, their experience of participating in Randomized Controlled Trials (RCTs) to evaluate interventions is scarce, and legal and ethical requirements are high [37]. Future studies under these conditions will show whether stroke patients can be reliably identified faster and can be transported to an appropriate hospital in a timely manner [38].

Some difficulties showed up and were discussed: for example, loss of motivation after a hard workday, higher shift frequency during some of the weeks prevented paramedics from being able to study as planned. Even so, acceptance and results speak for the successful structure of the lectures (form, language and amount of information per training) and the hands-on training. The online platform allows a feedback on daily basis that possibly played a role on the level of motivation.

Our study has some limitations: First, some participants showed a negative result regarding to individual questions in both the pre- and post-tests. This may be an indication for an insufficient treatment of the topic in the theoretical part of the training, but it may also be due to an unclear formulation of the question. On the other hand, some questions seem to be too superficial or not very relevant in clinical practice. In summary, the curriculum and test questions for subsequent groups need to be revised and adapted after application and validation "in-the-field". Second, Secondly, it can be discussed whether the training period of seven weeks is not too long and whether it is possible to provide targeted training within a shorter time. A shorter training period would save resources, but might mean that more content would have to be learned per time unit.

In summary, this project advocates a focused stroke diagnosis and transcranial ultrasound curriculum designed for paramedics and aimed to accelerate stroke treatment especially in patients suited for embolectomy. Telemedical support by stroke specialists in the comprehensive stroke unit, novel portable ultrasound equipment as well as evaluation of the performance in the field are warranted.

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