BioSCIENCE Review Article
DOI: https://doi.org/10.55684/2025.83.e00019

Telemedicine as a tool for stroke management: up to date 2024

Telemedicina como ferramenta para o manejo do AVC: up to date 2024

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ABSTRACT

Introduction: Teleneurology, which involves the use of telecommunication technologies to provide remote medical assistance in neurology, is becoming increasingly relevant in the treatment of stroke due to its ability to connect patients in remote areas to stroke specialists in real time.

Objective: To investigate whether teleneurology offers sufficient benefits to justify its regulation and implementation in stroke treatment services.

Method: The systematic review was conducted following a series of methodological steps. First, the theme "Teleneurology and its role in stroke therapy" was established and the guiding question "Does teleneurology have sufficient benefit to be regulated and used in stroke treatment services?" was formulated. Next, inclusion and exclusion criteria for articles were defined, as well as the information to be extracted from the selected studies. A comprehensive search was conducted in academic databases using a combination of telemedicine and stroke-related descriptors.

Result: The review identified 782 relevant articles, of which 35 were selected for analysis. The results highlight the importance of telemedicine in stroke treatment, especially in early thrombolysis and post-treatment monitoring. Additionally, the ethical implications of telemedicine, technological advancements including the use of artificial intelligence and telemetry, and telemedicine-based care models such as mobile stroke units and telestroke networks were discussed.

Conclusion: Teleneurology offers significant benefits in stroke treatment, including reducing the time to treatment initiation and improving clinical outcomes. However, further research is needed to fully explore the potential of telemedicine in stroke management and address ongoing ethical and technological issues.

KEYWORDS: Stroke. Telehealth technologies. Telemedicine. Teleneurology

Central Message

Telemedicine employs digital, information, and communication technologies to facilitate remote medical practice, encompassing care, education, research, prevention, management, and health promotion. In the context of stroke management, it stands out as an essential tool, allowing for up-to-date diagnoses and treatments.

Perspective

Recent studies show that telemedicine is essential to improve stroke management. It contributes significantly to the reduction of sequelae, optimization of medical intervention time and equitable access to neurovascular care, incorporating the latest guidelines and clinical practices.

RESUMO

Introdução: A teleneurologia, que envolve o uso de tecnologias de telecomunicação para fornecer assistência médica remota em neurologia, está se tornando cada vez mais relevante no tratamento do AVC devido à sua capacidade de conectar pacientes em áreas remotas a especialistas em AVC em tempo real.

Objetivo: Investigar se a teleneurologia oferece benefícios suficientes para justificar sua regulamentação e implementação nos serviços de tratamento de AVC.

Método: A revisão sistemática foi conduzida seguindo uma série de etapas metodológicas. Primeiro, foi estabelecido o tema "Teleneurologia e seu papel na terapia de AVCs" e formulada a questão norteadora "A teleneurologia tem benefício suficiente para ser regulamentada e utilizada em serviços de tratamento de AVCs?". Em seguida, foram definidos os critérios de inclusão e exclusão dos artigos, bem como as informações a serem extraídas dos estudos selecionados. Ampla pesquisa foi realizada em bases de dados acadêmicas usando combinação de descritores relacionados à telemedicina e ao AVC.

Resultado: A revisão identificou 782 artigos relevantes, dos quais 35 foram selecionados para análise. Os resultados destacam a importância da telemedicina no tratamento do AVC, especialmente na trombólise precoce e na monitorização pós-tratamento. Além disso, foram discutidas as implicações éticas da telemedicina, os avanços tecnológicos, incluindo o uso de inteligência artificial e telemetria, e os modelos de cuidados baseados em telemedicina, como unidades móveis de AVC e redes de telestroke.

Conclusão: Resultados sugerem que a teleneurologia oferece benefícios significativos no tratamento do AVC, incluindo a redução do tempo até o início do tratamento e a melhoria dos resultados clínicos.

PALAVRAS-CHAVE: AVC. Tecnologias de telessaúde. Telemedicina. Teleneurologia.

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Conflict of interest: None | Funding: None | Received: 06/05/2025 | Accepted: 02/08/2025 | Publication date: 29/08/2025 | Correspondence: gisolan@yahoo.com.br | Associate Editor: Jurandir Marcondes Ribas Filho

How to cite:
Nogueira GN, Gonçalves RF. Pykocz AH, de Oliveira NB, Giudice Junior FDP, Bonzato CV, Isolan GR. Telemedicina como ferramenta para o manejo do AVC: up to date 2024. BioSCIENCE. 2025;83:e00019

INTRODUCTION

Telemedicine, according to the World Health Organization, is related to the care of health services, by professionals who use information and communication technologies not only to validate the diagnosis, treatment and prevention of diseases, but also to research and carry out the continuing education of professionals to be trained for this purpose. This technology has the potential to increase medical assessments, minimize disparities in access to healthcare, and reduce the time between follow-up visits. These benefits can redesign clinical work, which can streamline the management of complex medical conditions both between tertiary referral centers and in primary care.[1]

It allows the provision of health services at a distance using connectivity technologies; for this, it can involve teleconsultation, teleconferencing or even teleeducation.[2] Telemedicine offers medical care to patients with difficult access to health professionals responsible for their treatment and follow-up. In addition, the use of telemedicine is safe to support the outpatient follow-up of some patients, including those who are postoperative, those who do not have access to quality hospitals, and those who have difficulty moving or in whom the process of leaving their homes can be expensive (elderly patients or those with dementia).[3]

In the last 2 decades, teleneurology has been developing with the expansion of technological resources and the COVID-19 pandemic has intensified this process. Different modalities of telemedicine are studied in various areas of neurology, including teleconsultation, teleconsultation, telerehabilitation, telemonitoring and teleeducation. The advances achieved by teleneurology in this period stimulated technological innovations and health processes that created opportunities to improve the care provided to patients treated through this system.[2]

Current evidence indicates that telemedicine is a potential tool to be used as a complement to face-to-face consultations in various areas of neurology.[2] It is clear that the number of neurologists per inhabitant is unequal worldwide1, which often causes problems for the access of patients outside the large metropolitan centers, and teleneurology is crucial to avoid these difficulties. In this context, neurological consultation through real-time online video platforms is useful for both outpatients and inpatients, so that consultations and follow-ups can be carried out. With the right technical support, teleconsultations work well when it comes to diagnostic accuracy, in part because telemedicine-enabled neurological testing can be just as good as bedside testing, and it also reduces hospital stays. Patient satisfaction with teleconsultation, as assessed by questionnaires1, is high, although some patients have concerns about confidentiality, which can be an important point in the evaluation of the services provided by telemedicine.

In light of these considerations, the importance of this theme for the medical literature is perceived. Nevertheless, the present study aimed to review the literature to validate this theme with pertinent ideas that put practicality and efficiency of telemedicine applied to the treatment of strokes.

METHOD

This article is a systematic review of the literature. To carry out the present study, the following methodological steps were followed: identification of the theme and guiding question of the research; definition of inclusion and exclusion criteria; identification of the information to be extracted from the selected articles; analysis and interpretation of the results and presentation of the review.

At first, the theme "Teleneurology and its role in stroke therapy" was established. Subsequently, the guiding question was defined "Does teleneurology have sufficient benefit to be regulated and used in stroke treatment services?".

The DeCS/MeSH descriptors "Telemedicine", "Teleneurology", "Brain Stroke", "Rehabilitation", "CVA units", "SMASH-U", "Telestroke", "Cardiovascular risk" and "Cerebrovascular Accident" were searched using the DeCS/MeSH descriptors, intersecting with the Boolean operators "AND" and "OR", for the search in the PubMed, BVS, Google Scholar and ScienceDirect databases. Thus, 782 articles were found, according to the inclusion criteria, language in English, or Portuguese or Spanish, publication period from 2009 to 2024, free text in full and relevant aspects on the guiding question, such as the main foundations of stroke, as well as its diagnosis, management and treatment, being related to telemedicine, so that this technology can not only improve medical conduct but also improve the prognosis of patients. At the end of the articles analyzed, 35 were selected to compose the present review.

The search results were selected based on the exclusion and exclusion criteria that were applied to the articles made available in full. Only original studies related to the theme were included, focusing on clinical trials and randomized studies that answered the guiding question in English and Spanish. At the same time, duplicate articles, review articles, and those that did not fit the theme of this review were excluded.

DISCUSSION

Telemedicine: importance related to stroke

Stroke treatment is one of the most frequent and consolidated conditions in the telemedicine-assisted model, having been the first area of neurology to effectively use and implement telemedicine. There are not enough trained neurologists to treat stroke patients in all locations in the world4, so that the emergence and consolidation of teleneurology are closely linked to the responses of stroke patients treated with the aid of teleneurology. Increasing the

risk of complications is a crucial point that can be managed by telemedicine.

During the last 2 decades, the concept of telestroke has spread around the world and has been perfected. Mobile stroke units have been developed to optimize pre-hospital care. They are specially equipped ambulances with CT scans, a laboratory at the point of care for blood analysis, medications and interdisciplinary staff. Telemedicine allows the support of a stroke specialist and, if indicated, thrombolysis can be started in the ambulance, before arrival at the hospital.[5] In this context, in which every effort is made to reduce the time between the onset of symptoms and the start of reperfusion therapy6, telestroke allows remote specialists to indicate thrombolysis through information provided by the hospital physician, close to the patient.[7] Scientific evidence shows that stroke treatment has benefited from the digital health revolution. The use of teleneurology for stroke has had a significant impact on the acute treatment of cerebrovascular diseases in many countries.[2]

Cerebrovascular disorders require periodic evaluations to verify the effectiveness, dose, and side effects of medications. Mobile platforms and real-time online video platforms have been used in secondary and tertiary prevention, with the aim of encouraging the monitoring of hypertension, body weight, waist circumference, blood lipid profile, smoking and blood glucose.[8] In this context, telemedicine is used by videoconference, providing remote contact with health professionals, as well as monitoring of this data1 for thrombolysis and for the general management of stroke. It can be of special use in rural areas and/or in need of this specialized service.

Telestroke is an "audio-visual communication network and computer systems that provide the basis for a model of collaboration and interprofessional care focused on acute stroke patients."[9] Developments in telestroke have led to recommendations for the implementation of these programs based on the existing evidence base.[10] Telestroke networks are designed in a "hub and spoke" system in which the stroke center (hub) provides high-quality care to distant locations that do not have [stroke center (spokes). For instance, the Remote Evaluation for Acute Ischemic Stroke (REACH) telehealth network is a telehealth program that aims to improve stroke outcomes in rural hospitals in Georgia and South Carolina, through more efficient diagnoses and treatments for patients with acute ischemic stroke.[11] There is a growing amount of evidence to suggest that telestroke is feasible, safe, and effective in the treatment of acute ischemic strokes. Stroke mortality rates in hospitals that use it are similar to those in specialized stroke centers.[7]

In addition, the use of telestroke can dramatically increase the number of patients treated in non-specialized settings, especially in the critical 4.[5-hour] window.[12] When assessing the impact of telestroke on mortality, it was found that participation in a telestroke network significantly decreases the chances of death compared to hospitals without it.[12] Participation in telestroke also seems to reduce the impact of length of hospital stay on mortality, with a marginal smaller difference in hospitals with it.

In general, the size of the hospital seems to have a great impact on the association between in-hospital mortality, time of arrival, and participation in telestroke. Patients admitted to small/medium-sized hospitals are more likely to die, regardless of arrival time or participation in telestroke. In addition, the impact of participation in it was lower in small/medium-sized hospitals compared to larger hospitals.[12] Its networks are designed to increase the specialist's reach to all hospitals in the network2, but the impact appears to be greater in larger hospitals. This suggests that differences in hospital staffing, resources, and structure between larger and small/medium-sized hospitals have an impact on the clinical outcomes of stroke patients, and that telehealth networks do not affect all hospitals in the same way.[12]

Telemedicine in stroke diagnosis

Telemedicine operates in the context of stroke with diverse models of care, with the main one being Hub and Spoke, in which the Hub is a central hospital that offers telestroke consultations to smaller hospitals, usually without neurology or neurosurgery services. In this model, the health professional of the satellite hospital receives the guidance of a teleneurologist of the central hospital about the case, as well as the opinion of a teleradiologist about the patient's imaging studies, most commonly non-contrast CT. If the ambulance has the appropriate equipment, the video call can start on the way to the hospital.[13]

For the proper functioning of this model, the DICOM (Digital Imaging and Communications in Medicine) server is essential, which allows the rapid remote visualization of non-contrast CT images of the head obtained during telestroke consultations.[13] In addition, it is crucial to perform a rapid review of these images to identify conditions that may mimic focal neurological deficits, such as abscesses or masses, and to rule out contraindications for intra-arterial thrombolysis with tPA, such as hemorrhage or metastatic cerebral malignancy, since the application of this is more effective up to 4.[5] h after the onset of symptoms. Additionally, some telestroke hospitals have the ability to perform CT angiograms of the head and neck, which provides additional information about the location of clots that can be removed through thrombectomy procedures.[13]

One of the main factors that impact the mortality of stroke cases is the delay in diagnosis and treatment, which includes the delay in the patient's admission to the hospital, with studies indicating that the pre-hospital delay prevents between 40% and 85% of patients from arriving at the hospital in less than 3 h after the onset of symptoms.[14] This model, therefore, allows smaller hospitals access to patient evaluation by a specialist in a shorter time, reducing the door-

to-needle time15 with studies indicating a significant reduction in stroke mortality in hospitals that are part of a telestroke network compared to those that do not, due to telemedicine providing a reduction in the influence of admission time on the patient's risk of death.[16]

In other models, such as Mobile Stroke Units (MSU) or Mobile Stroke Treatment Units (MSTU), the ambulances responsible for performing the first care are not only equipped to perform the video call, but also to perform exams such as non-contrast CT and the application of IV tPA.[13-17] In the MSUs, the teleneurologist evaluates the patient on the way to the hospital, having access to the imaging tests performed in the vehicle, making a reliable diagnosis and being able to guide the start of treatment in cases in which thrombolysis should be performed6, resulting in a significantly lower mean time from port to thrombolysis.[14]

In addition, after the neurologist's opinion, the patient can be referred to the most appropriate treatment center for the case, whether this emergency service is prepared for stroke treatment or a specialized hospital for more complex procedures.[18] Another positive point pertinent to MSUs is their low cost compared to a specialized center for stroke treatment, allowing quality care in rural or less favored regions.[14]

Another technological advance that allows an increase in the accessibility of Telemedicine for the diagnosis of stroke are the tools to be used for neuroimaging analysis; studies show that portable devices such as tablets, iPads and smartphones allow equally adequate analysis of imaging exams by professionals, using applications that do not store the images in the device, Providing greater patient safety, these devices obtained sensitivity, specificity and accuracy of 100% in making the diagnosis. In addition, another possible advance for the future of neuroimaging in telemedicine is the use of artificial intelligence (AI) for the analysis of imaging exams, resulting in a fully automated system.[13] In addition, the use of helicopters equipped as Air Mobile Stroke Units (Air-MSU) has been used as an alternative in Australia to allow rapid access to patients in more distant regions.[18]

The main obstacles to the use of telemedicine in the diagnosis of stroke, in turn, are, in general, linked to infrastructure, given the need for high-quality mobile internet network access to send images in real time and make video calls in good quality, which may be inaccessible in regions far from large urban centers.[13] However, according to studies, loss of connection has been shown to be rare and, in most cases, brief, both in hub and spoke models and in MSUs, with a 4G connection being sufficient to carry out the consultation with satisfactory quality and with the possibility of quick switching to a 3G connection if necessary.[6,17-19] In addition, a satellite telemedicine network was successfully implemented in India in order to circumvent possible infrastructural and connection problems.

In addition, another factor that hinders the approach to stroke in relation to telemedicine is the limitation of non-contrast-enhanced CT for diagnosis, since some changes perceptible in other imaging studies, such as magnetic resonance imaging and CT angiography, only begin to become clear in normal CT scans after the onset of symptoms.[13] However, this obstacle has been overcome after the successful implantation of CT angiography and CT perfusion devices in MSUs, which are effective for observing the intracranial circulation.[17]

Telemedicine in stroke management

Telemedicine acts in the management of stroke aiming to reduce the time until the start of treatment and in this the MSTUs and In-Transit Telestroke stand out, in which the patient's consultation with the teleneurologist takes place while still in the ambulance, resulting in a reduction in the door-to-needle time.[20] Regarding safety and efficacy, studies have shown that patients with acute ischemic stroke who received thrombolytic therapy through telemedicine had similar results to patients who received the same treatment in person at a medical facility. These findings provide additional evidence that telemedicine can be effectively used to support regional hospitals with limited experience in treating stroke patients through thrombolytic therapy, as well as contributing to raising the standard of care and reducing inequalities in access to treatment.[21-24]

Another care model that employs telemedicine in stroke is the hubless or horizontal model, in which hospitals are part of a network and telemedicine consultations are carried out with specialized professionals belonging to different centers in this network, without having a specific hospital that serves as a reference.[13-16] The horizontal network-based telemedicine model for hyperacute care delivery has several advantages over the more common center-satellite model. By relying on shared resources of stroke clinicians, the system becomes more sustainable, as opposed to relying on a single center team. In addition, this approach promotes a sense of collaborative partnership, benefiting cooperation between different service locations.

Telemedicine and post-stroke rehabilitation

As already defined, telehealth aims to outline and carry out health practices, making it possible to exchange information for the diagnosis, prevention, and treatment of diseases. It can be used for continuing education of health professionals, as well as for research and evaluation purposes.[25] In addition to the risk of death, stroke also has a prognosis with a potential limiting factor for daily activities, causing permanent sequelae if the patient does not undergo rehabilitation. Many individuals after the event become dependent to perform basic and instrumental activities of daily living.[26] Cognitive impairment is a frequent sequela, which directly affects functionality and well-being, and can cause difficulty in staying

employed, being independent, maintaining relationships and driving vehicles.[27,28]

Disabilities are usually alleviated if rehabilitation is carried out within the time window of 3 to 6 months after the stroke. Due to the high frequency of people who are affected worldwide, and the disabilities they may present after the episode, stroke is considered a public health and economic problem in Brazil.[26]

The goal of rehabilitation is to maximize communication, develop the cognitive and motor functioning of patients; therefore, it does not only aim to recover, but to reintegrate the individual.[29]

To recover from the damage caused by stroke, it is necessary to have a multidisciplinary team, composed of physiatrists, physiotherapists, speech therapists and occupational therapists. However, limitations in the health service are common, often with these professionals not being available to rehabilitate the patient after stroke, in addition to other situations, which can limit patients to access these services, which are essential for their recovery. In this way, causing recovery with extensive motor and cognitive limitations.[30]

Telerehabilitation is the application of communication and digital technologies in order to provide rehabilitation therapy to patients, through specialists, to post-stroke patients.[31] In addition to expanding access to care, enabling professionals from other places to monitor and treat the person after suffering a stroke, complying with the policies of universality, equity and integrity that are fundamental for good care.[32]

It is important to understand that expanding and advancing existing possibilities through telerehabilitation is a way to increase the effectiveness, adherence and positive results of rehabilitation. Because investment in communication technologies is required in order to provide rehabilitation at a distance, this method has not yet been widely explored. Despite this, it has demonstrated efficiency in relation to conventional methods.[33]

The moment when telehealth was most heard about was during the COVID-2019 pandemic, a time when, mainly, stroke rehabilitation services could not be suspended. In this way, the Federal Council of Physical Therapy and Occupational Therapy released teleconsultation, synchronously or asynchronously. It sought to evaluate balance training through telerehabilitation in patients with neurological dysfunction. However, previous studies are still considered heterogeneous in relation to the sample, patient profile, and service platform. Most of the participants suffered stroke, being considered one of the most prevalent neurological disorders, in addition to Parkinson's disease, multiple sclerosis and motor neuron diseases.[34]

According to technological advances, telerehabilitation becomes more accessible and viable, making it easier for the individual in relation to place and time. The synchronous form of care allows the techniques to be applied in real time, evaluating the patient's performance and condition; therefore, it has been the most used. In this way, it enables the patient to actively participate in the recovery process, motivating the continuity of rehabilitation care.[35]

Despite the benefits, the method still has limitations that must be corrected, such as the possibility of technical problems occurring during the service, which may require the presence of someone in person due to their severe neurological dysfunction, in addition to the lack of home structure. Unfortunately, this can be a reality for many patients who need telerehabilitation.[35]

It is clear from the analyzed studies that telemedicine can offer important advantages in the management of stroke patients, from diagnosis to management, such as reducing the need to travel, faster access to specialized care, and improving patient satisfaction, among others. Scientific evidence shows that stroke treatment has benefited from the digital health revolution. The use of stroke-related teleneurology has had a significant impact on the acute treatment of cerebrovascular diseases in many countries, as this technology provides individualized treatment, addressing the specific needs of each person, in order to promote greater follow-up of the therapeutic plan and, consequently, the prognosis of patients. In addition, telemedicine emerges as an ally in the treatment of stroke due to the increased possibility of complying with stroke windows (care up to 4.[5] h) providing a reduction in sequelae, increasing quality of life.

CONCLUSION

The advances achieved by teleneurology in this period stimulated technological innovations that, when incorporated into health processes, created opportunities to improve the care provided to patients treated through this system. However, the reliability of patients when it comes to data security is a fact to be analyzed for the full consolidation of the use of telemedicine combined with stroke treatment. Thus, understanding that the present review is not enough to give the final verdict on telemedicine, there is a need to search for strategies that guarantee this reliability and clinical studies that prove these ideas.

Authors' contributions

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REFERENCES

1. Aquino ER da S, Suffert SCI. Telemedicine in neurology: advances and possibilities. Arq Neuropsiquiatr. 2022;80(5 Suppl 1):336–41. https://doi.org/10.1590/0004-282x-anp-2022-s127
2. Domingues RB, Mantese CE, Aquino E da S, Fantini FGMM, do Prado GF, Nitrini R. Telemedicine in neurology: current evidence. Arq Neuropsiquiatr. 2020;78(12):818–26. https://doi.org/10.1590/0004-282X20200131

3. Chirra M, Marsili L, Wattley L, Sokol LL, Keeling E, Maule S, et al. Telemedicine in neurological disorders: opportunities and challenges. Telemed e-Health. 2019;25(7):541–50. https://doi.org/10.1089/tmj.2018.0101
4. Larner AJ. Teleneurology: an overview of current status. Pract Neurol. 2011;11(5):283–8. https://doi.org/10.1136/practneurol-2011-000090
5. Hatcher-Martin JM, Adams JL, Anderson ER, Bove R, Burrurs TM, Chehrenama M, et al. Telemedicine in neurology. Neurology. 2019;93(10):e1–e8. https://doi.org/10.1212/WNL.0000000000008708
6. Lin CH, Lee KW, Chen TC, Lin JH, Liaw KR, Hsiao PJ, et al. Quality and safety of telemedicine in acute ischemic stroke: early experience in Taiwan. J Formos Med Assoc. 2022;121(1 Pt 2):314–8. https://doi.org/10.1016/j.jfma.2021.04.024
7. Heemskerk JL, Domingo RA, Tawk RG, Vivas-Buitrago TG, Huang JF, Rogers A, et al. Time is brain: prehospital emergency medical services response times for suspected stroke and effects of prehospital interventions. Mayo Clin Proc. 2021;96(6):1446-1457. https://doi.org/10.1016/j.mayocp.2020.08.050
8. Mosconi MG, Paciaroni M. Treatments in ischemic stroke: current and future. Eur Neurol. 2022;85(5):349-66. https://doi.org/10.1159/000525822
9. Sarfo FS, Ulasavets U, Opare-Sem OK, Ovbiagele B. Tele-rehabilitation after stroke: an updated systematic review of the literature. J Stroke Cerebrovasc Dis. 2018;27(9):2306–18. https://doi.org/10.1016/j.jstrokecerebrovasdis.2018.05.013
10. Weber J, Ebinger M, Audebert HJ. Prehospital stroke care: telemedicine, thrombolysis and neuroprotection. Expert Rev Neurother. 2015;15(7):753–61. https://doi.org/10.1586/14737175.2015.1051967
11. Evans NR, Sibson L, Day DJ, Agarwal S, Shekhar R, Warburton EA. Hyperacute stroke thrombolysis via telemedicine: a multicentre study of performance, safety and clinical efficacy. BMJ Open. 2022;12(1):e057372. https://doi.org/10.1136/bmjopen-2021-057372
12. Rubin MN, Demaerschalk BM. The use of telemedicine in the management of acute stroke. Neurosurg Focus. 2014;36(1):E4. https://doi.org/10.3171/2013.11.focus13428
13. Cramer SC, Dodakian L, Le V, See J, Augsburger R, McKenzie A, et al. Efficacy of home-based telerehabilitation vs in-clinic therapy for adults after stroke. JAMA Neurol. 2019;76(9):1079–87. https://doi.org/10.1001/jamaneurol.2019.1604
14. Itrat A, Taqui A, Cerejo R, Briggs F, Cho SM, Organek N, et al. Telemedicine in prehospital stroke evaluation and thrombolysis. JAMA Neurol. 2016;73(2):162–8. https://doi.org/10.1001/jamaneurol.2015.3849
15. Fassbender K, Grotta JC, Walter S, Grunwald IQ, Ragoschke-Schumm A, Saver JL. Mobile stroke units for prehospital thrombolysis, triage, and beyond: benefits and challenges. Lancet Neurol. 2017;16(3):227–37. https://doi.org/10.1016/s1474-4422(17)30008-x
16. Mathur S, Walter S, Grunwald IQ, Helwig SA, Lesmeister M, Fassbender K. Improving prehospital stroke services in rural and underserved settings with mobile stroke units. Front Neurol. 2019;10:159. https://doi.org/10.3389/fneur.2019.00159
17. Geisler F, Kunz A, Winter B, Rozanski M, Waldschmidt C, Weber JE, et al. Telemedicine in prehospital acute stroke care. J Am Heart Assoc. 2019;8(6):e010343. https://doi.org/10.1161/jaha.118.011729
18. Puetz V, Bodechtel U, Gerber JC, Dzialowski I, Kunz A, Wolz M, et al. Reliability of brain CT evaluation by stroke neurologists in telemedicine. Neurology. 2013;80(4):332–8. https://doi.org/10.1212/wnl.0b013e31827f07d0
19. Solenski NJ. Telestroke. Neuroimaging Clin N Am. 2018;28(4):551–63. https://doi.org/10.1016/j.nic.2018.06.012
20. Kircher C, Kreitzer N, Adeoye O. Pre and intrahospital workflow for acute stroke treatment. Curr Opin Neurol. 2016;29(1):14–9. https://doi.org/10.1097/wco.0000000000000281
21. Zhai Y, Zhu WJ, Hou HL, Sun DX, Zhao J. Efficacy of telemedicine for thrombolytic therapy in acute ischemic stroke: a meta-analysis. J Telemed Telecare. 2015;21(3):123–30. https://doi.org/10.1177/1357633x15571357
22. Legris N, Hervieu-Bègue M, Daubail B, Daumas A, Delpont B, Osseby GV, et al. Telemedicine for the acute management of stroke in Burgundy, France: an evaluation of effectiveness and safety. Eur J Neurol. 2016;23(9):1433-40. https://doi.org/10.1111/ene.13054
23. Alberts MJ, Wechsler LR, Jensen MEL, Latchaw RE, Crocco TJ, George MG, et al. Formation and function of acute stroke–ready hospitals within a stroke system of care: recommendations from the Brain Attack Coalition. Stroke. 2013;44(12):3382–93. https://doi.org/10.1161/strokeaha.113.002285
24. Bladin CF, Cadilhac DA. Effect of telestroke on emergent stroke care and stroke outcomes. Stroke. 2014;45(6):1876-80. https://doi.org/10.1161/strokeaha.114.003825
25. Belt GH, Felberg RA, Rubin J, Halperin JJ. In-transit telemedicine speeds ischemic stroke treatment. Stroke. 2016;47(9):2413–5. https://doi.org/10.1161/strokeaha.116.014270
26. Burgos PI, Lara O, Lavado A, Rojas-Sepúlveda I, Delgado C, Bravo E, et al. Exergames and telerehabilitation on smartphones to improve balance in stroke patients. Brain Sci. 2020;10(11):773. https://doi.org/10.3390/brainsci10110773
27. Subbarao BS, Stokke J, Martin SJ. Telerehabilitation in acquired brain injury. Phys Med Rehabil Clin N Am. 2021;32(2):223–38. https://doi.org/10.1016/j.pmr.2021.01.001
28. Witrick B, Zhang D, Switzer JA, Hess DC, Shi L. The association between stroke mortality and time of admission and participation in a telestroke network. J Stroke Cerebrovasc Dis. 2020;29(2):104480. https://doi.org/10.1016/j.jstrokecerebrovasdis.2019.104480
29. Lopez-Pedrera C, Oteros R, Ibáñez-Costa A, Luque-Tévar M, Muñoz-Barrera L, Barbarroja N, et al. The thrombus proteome in stroke reveals a key role of the innate immune system and new insights associated with its etiology, severity, and prognosis. J Thromb Haemost. 2023;21(10):2894-907. https://doi.org/10.1016/j.jtha.2023.04.015
30. Aramini R, Brignone M, Mestriner D, Pastorino M, Procopio R, Rachidi F, et al. Computation of the attenuation function of the lightning return-stroke current from electromagnetic fields measured in a short-duration time-window, Part I: theoretical investigation. Electr Power Syst Res. 2023;221:109392. https://doi.org/10.1016/j.epsr.2023.109392
31. Schumm L, Lamale CL, Major S, Hecht N, Nieminen-Kelhä M, Zdunczyk A, et al. Physiological variables in association with spreading depolarizations in the late phase of ischemic stroke. J Cereb Blood Flow Metab. 2021;42(1):121–35. https://doi.org/10.1177/0271678x211039628
32. Dromerick AW, Geed S, Barth J, Brady K, Giannetti ML, Mitchell A, et al. Critical Period After Stroke Study (CPASS): a phase II clinical trial testing an optimal time for motor recovery after stroke in humans. Proc Natl Acad Sci U S A. 2021;118(39):e2026676118. https://doi.org/10.1073/pnas.2026676118
33. Bernstein RA, Kamel H, Granger CB, Piccini JP, Sethi PP, Katz JM, et al. Effect of long-term continuous cardiac monitoring vs usual care on detection of atrial fibrillation in patients with stroke attributed to large- or small-vessel disease: the STROKE-AF randomized clinical trial. JAMA. 2021;325(21):2169–77. https://doi.org/10.1001/jama.2021.6470
34. Stevens ER, Roberts E, Kuczynski HC, Boden-Albala B. Stroke warning information and faster treatment (SWIFT): cost-effectiveness of a stroke preparedness intervention. Value Health. 2019;22(11):1240–7. https://doi.org/10.1016/j.jval.2019.06.003
35. Chae SH, Kim Y, Lee KS, Park HS. Development and clinical evaluation of a web-based upper limb home rehabilitation system using a smartwatch and machine learning model for chronic stroke survivors: prospective comparative study. JMIR Mhealth Uhealth. 2020;8(7):e17216. https://doi.org/10.2196/17216