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The use of digital technologies in stroke management in the world: an analysis of examples

Technologie cyfrowe wykorzystywane w opiece nad pacjentami z udarami – analiza przypadków na świecie

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S u m m a r y

The aim of this publication is to illustrate the realistic potential of digital technologies – mobile applications, telemedicine, automated analysis systems applied in the several key elements in stroke patient management. According to data provided by WHO, it is estimated that strokes have caused 5.78 million deaths in 2016.

Review has been conducted searching for digital health technologies used for stroke management in PubMed database, and several references have been snowballed from the search terms.

More and more scientific evidence speak for the efficiency of using digital technologies in care of stroke patients. Unfortunately, most of the recommendations linked to digitalization of patient care are part of guidelines provided by American associations, with no European or Polish equivalents. The chosen technologies (and especially those making primary and secondary prevention feasible) can be easily applied by wide groups of patients and healthcare practitioners. However, more publicly targeted informational and educational campaigns are necessary, together with the development of specific recommendations.

S t r e s z c z e n i e

Celem tej publikacji jest zilustrowanie realistycznego potencjału technologii cyfrowych – aplikacji mobilnych, telemedycyny, zautomatyzowanych systemów analitycznych stosowanych w kilku kluczowych elementach zapobiegania i terapii udaru. Na podstawie danych Światowej Organizacji Zdrowia szacuje się, że udar był przyczyną 5,78 miliona zgonów na świecie w 2016 roku.

Baza PubMed została przeszukana pod kątem stosowanych metod cyfrowych w zapobieganiu i terapii udaru. Po wstępnym przeszukaniu identyfikowano kierunki dalszych poszukiwań w oparciu o najpopularniejsze słowa kluczowe odnoszące się do technologii cyfrowych.

Coraz więcej dowodów naukowych przemawia za skutecznością wykorzystania cyfrowych technologii w opiece nad pacjentem z udarem. Niestety, większość związanych z ucyfrowieniem opieki rekomendacji zawartych jest w wytycznych tworzonych przez towarzystwa amerykańskie, bez europejskiego czy polskiego odpowiednika. Wybrane technologie (zwłaszcza te umożliwiające prewencję pierwotną i wtórną) mogą być z łatwością zastosowane przez szerokie grupy pacjentów i pracowników ochrony zdrowia, potrzeba jednak szeroko zakrojonych kampanii informacyjnych, edukacji i rekomendacji w tym zakresie.

INTRODUCTION

The World Health Organization (WHO) defines stroke as the "interruption of the blood supply to the brain, usually because a blood vessel bursts or is blocked by a clot. This cuts off the supply of oxygen and nutrients, causing damage to the brain tissue" (1).

According to data provided by WHO, it is estimated that strokes have caused 5.78 million deaths in 2016, being the world's second biggest killer (2).

Nowadays the majority of the strokes occurs in the younger age, unlike 30 years ago when they affected mostly people over 75 (3). The INTERSTROKE case-control study led in 32 nations around the world provided evidence that 10 risk factors represented 90% of the population-attributable risk for all stroke (4).

Guidelines written by The European Stroke Organisation (ESO) (5) distinguish a few key components to enhance stroke care:

1. Public Awareness and Education.
2. Primary Prevention.
3 Secondary Prevention.
4. Referral and Patient Transfer.
5. Emergency Management.
6. Stroke Services and Stroke Units.
7. Diagnostics.
8. General Stroke Treatment.
9. Specific Treatment.
10. Prevention and Management of Complications.
11. Rehabilitation.

In this paper the authors explore the most prominent developments in stroke care with a special focus on recent progress in the use of new and digital technologies. Multiple new definitions have been introduced to the public health domain. For instance, mHealth (mobile health) can be defined as a practice of medicine and public health services combined with the use of mobile devices (6). This term, however, is being replaced with broader term of "Digital Health" covering healthcare interventions delivered via digital technologies – telemedicine, Web-based strategies, e-mail, mobile phones, mobile applications, text messaging, and monitoring sensors (7). After a two-year process to update and standardize the typology, in December 2017 WHO released a revised classification scheme for digital health interventions, which "aims to promote an accessible and bridging language for health program planners to articulate functionalities of digital health implementations" (tab. 1) (8).

The aim of this publication is to illustrate the realistic potential of digital technologies – mobile applications, telemedicine, automated analysis systems applied in the several key elements in stroke patient management.

In addition, another at-desk review has been conducted searching for digital health technologies used for stroke management in PubMed database, and several references have been snowballed from the search terms.

REVIEW

Mobile applications

By 2019, the number of smartphone users is estimated to raise to 2.5 billion people. A little more than 36 percent of the total population is anticipated to possess and use a smartphone by 2018, up from around 10 percent in 2011 (9). Mobile applications can be used to raise awareness among patients and healthcare professionals, therefore reducing financial burden from numerous disorders.

Mobile applications – Public Awareness and Education

Several mobile stroke applications can increase stroke awareness and help to perform early detections on mild stroke symptoms.

Some of the existing mobile health awareness applications are designed to raise knowledge and awareness around stroke and its consequences, including FAST Test (10), The Mayo Clinic Acute Stroke Evaluation App (11), Stroke 119 (12).

Mobile applications – Emergency Management

The National Institute of Health Stroke Scale (NIHSS) is the most widely used scale for the evaluation of basic neurological function in acute ischemic stroke, both initially and during its evolution. The scale can be used as a guideline for the development of both self-check (13) assessment for detecting mild stroke symptoms and by trained members of Emergency Medical Service staff (14). Several apps can be used to assist

Tab. 1. Selected elements of stroke care according to ESO and the corresponding WHO digital health typology including examples

Element of stroke care	Digital functionaity for addresing the health system challenge
Public awareness and education	1.6.1. Client look-up of health information – *mobile applications* 2.8.1. Provide training content and reference material to healthcare provider(s) – *mobile applications*
Primary prevention	4.1.4. Automated analysis of data to generate new information or predictions on future events – *mobile applications* 1.4.2. Self monitoring of health or diagnostic data by client – *mobile applications*
Secondary prevention	1.4.3. Active data capture/documentation by client – *mobile applications*, *wearable devices*
Referral and patient transfer	2.3.2. Provide checklist according to protocol – *mobile applications* 2.4.1. Consultations between remote client and healthcare provider – *telemedicine* 2.6.1. Coordinate emergency response and transport – *telemedicine*
Emergency management	2.4.4. Consultations for case management between healthcare providers – *telemedicine* 2.8.1. Provide training content and reference material to healthcare provider(s) – *mobile applications*
Diagnostics	2.7.2. Schedule healthcare provider's activities – *workflow management systems* 4.1.4. Automated analysis of data to generate new information or predictions on future events – *artificial intelligence system* 2.4.3. Transmission of medical data (e.g. images, notes, and videos) to healthcare provider – *telemedicine* 2.4.4. Consultations for case management between healthcare providers – *telemedicine*
Rehabilitation	2.4.1. Consultations between remote client and healthcare provider – *telemedicine* 1.4.2. Self monitoring of health or diagnostic data by client – *virtual reality*

EMS staff in the application of the NIHSS in clinical practice (15).

Mobile applications – Primary Prevention, Secondary Prevention

In hope of increasing stroke awareness and improving stroke and NCD prevention (on an individual level), a new app was recently created by The National Institute for Stroke and Applied Neurosciences (AUT University) called the Stroke Riskometer™. The app is using recent studies from the field of risk presentation/communication and international guidelines on stroke and cardiovascular disease prevention which makes it a potentially important tool in general stroke prevention. Its algorithm is based on the Framingham Stroke Risk Score (FSRS) prediction algorithm (16) and is additionally improved by including several major risk factors based on the INTERSTROKE study (4). Stroke Riskometer™ estimates the absolute risk of stroke within the next 5 and 10 years for people aged ≥ 20 years (17).

Compared to the conventional risk-estimation charts, electronic interactive systems offer a substantial advantage in that as many risk factors as necessary can be incorporated. The disadvantage is the increase in the complexity of the system, which can have an impact on use in clinical practice (18).

TELEMEDICINE

Telemedicine is defined as “the use of electronic information and communications technologies to provide and support health care when distance separates the participants” (19). This covers all aspects of medicine practiced at a distance, using telephone, fax, and electronic mail technology, as well as the use of interactive full-motion video and audio, that brings together patients and providers separated by distance (20).

Nowadays, among neurological disorders, telemedicine is most commonly applied in emergency stroke and neurocritical care (21). In 1999, the term “Telestroke” was proposed for the use of state-of-the-art video telecommunications in managing patients care (22).

The evaluation of several existing applications of telestroke services is positive.

Telemedicine – Emergency Management

Researchers conducted a multicentre observational study to test the feasibility of telestroke consulting over a wired broadband. Neurologists in the academic centre in Ontario carried 88 consults with 24 patients receiving t-PA for two peripheral emergency departments, demonstrating that telestroke consulting was feasible (23).

Another example of telestroke system was successfully applied in the test of reliability of simplified National Institutes of Health Stroke Scale done remotely (over a cellular videophone on a 3G network) by a physician assisted locally by an emergency medical technician compared with bedside examination by the physician. 480 paired comparisons were done. The authors concluded that assessment over videophone was as reliable as bedside and could be a timely method for remote patient assessment (24).

Telemedicine – Diagnostics

Computer Tomography (CT) imaging plays a critical role in evaluating and decision making for patients suspected of acute stroke, especially prior to initiating treatment (25). When images are transmitted in the digital imaging and communications in medicine (DICOM) standard, imaging quality at a remote site can be equivalent to that on site (26). The rate of overall agreement for the presence of radiological contraindications to thrombolysis does not differ substantially between trained neurologists and radiologists (27).

Although the size of the screens of iOS devices (iPhone, iPod) are much smaller than radiology workstations, the accuracy of CT image interpretation with a specific smartphone client-server teleradiology system was almost as good as the accuracy of a medical diagnostic workstation (28).

Telemedicine – Rehabilitation

Telemedicine-enabled delivery of rehabilitation services (also called telerehabilitation) can potentially be offered to patients with stroke after they are discharged from the hospital. This kind of service delivery can address health workforce shortages, long distances to the nearest facility and reduce the costs of care delivery, while staying beneficial for patients with limited mobility. Numerous studies clearly show that telerehabilitation (e.g. physical, occupational, or speech therapy services) can be a suitable alternative to usual rehabilitation care in poststroke patients (29).

AUTOMATED ANALYSIS OF DATA – DIAGNOSTICS

The term Machine Learning (ML) was defined by Arthur Samuel in 1959 to describe the subfield of computer science that involves the “programming of a digital computer to behave in a way which, if done by human beings or animals, would be described as involving the process of learning” (30). As a field of computer science and engineering, it facilitates extraction of data based on recognition of patterns, in which a computer learns from previous mistakes after repeated analysis of data and masters tasks that were previously considered too complex for a machine to process. The evolution of using these systems to interpret data in neuroimaging has provided valuable information for research in matters of interaction, structure, and mechanisms of the brain and behavior in certain neurological disorders (31).

In 2012, a team of researchers from the University of Toronto published a – as it turned out later – quite revolutionary work in the field of machine learning, establishing the foundation for most modern image analysis systems based on AI. In their work, the researchers used machine learning based on Deep Convolutional

Neural Network (CNN) on a subset of 1.2 million images of the same image base as their predecessors, but limited to still a small number of 1000 classes. The result of this task was obtaining 83.6% accuracy of classification, beating the next best result of another classifier at the level of 73% (32).

By now, machine learning algorithms have been used to assist in the process of diagnosis and personalizing treatment decisions in acute ischemic stroke. Numerous implementations of machine learning algorithms can improve early identification of imaging diagnostic findings, estimate time of onset, analyse cerebral edema, predict complications and patient outcomes after treatment (33).

VIRTUAL REALITY – REHABILITATION

Virtual reality (VR) can be defined as simulated interactions with different environment and events that are presented to the performer with the aid of technology. These so-called virtual environments may mirror aspects of the real world or represent spaces that are far removed from it, while allowing various forms of user interaction through movement and/or speech. Virtual reality based rehabilitation and interactive video gaming have emerged as recent treatment approaches in stroke rehabilitation with commercial gaming consoles in particular, being rapidly adopted in clinical settings (34).

VR has the potential to target a wide range of motor, functional, and cognitive issues, affords methods that automatically record and track patient performance, and offers a high level of flexibility and control over therapeutic tasks. This scalability allows patients to train at the highest intensity that would be possible for their individual ability, while keeping the experience of interaction with therapeutic tasks enjoyable and compelling. At the same time, VR may enable patients with a neurodisability (like stroke) to practice without excessive physical fatigue which otherwise may deter continued effort and engagement in therapy.

According to the systematic review published in Cochrane Database, the use of virtual reality and interactive video gaming was not more beneficial than conventional therapy approaches in improving upper limb function. Virtual reality may be beneficial in improving upper limb function and activities of daily living function when used as an adjunct to usual care (to increase overall therapy time) (35).

CONCLUSIONS

The scope of use of new technologies is expanding in the medical field for preventive, diagnostic, management and rehabilitation purposes. There is a particular need for technological solutions in this field, which is facing challenges in providing rapid and complex solutions with limited human expertise. More and more scientific evidence speak for the efficiency of using digital technologies in care of stroke patients. Unfortunately, most of the recommendations linked to digitalization of patient care are part of guidelines provided by American associations, with no European or Polish equivalents. The chosen technologies (and especially those making primary and secondary prevention feasible) can be easily applied by wide groups of patients and healthcare practitioners. However, more publicly targeted informational and educational campaigns are necessary, together with the development of specific recommendations.

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