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Recommendations on telestroke in Europe

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Abstract

Lack of stroke specialists determines that many European rural areas remain underserved. Use of telemedicine in stroke care has shown to be safe, increase use of evidence-based therapy and enable coverage of large areas of low population density. The aim of this article is to summarise the following recommendations of the Telestroke Committee of the European Stroke Organisation on the setup of telestroke networks in Europe: Hospitals participating in telestroke networks should be chosen according to criteria that include population density, transportation distance, geographic specifics and in-hospital infrastructure and professional resources. Three hospital categories are identified to be part of a hub-and-spoke network: (1) the Telemedicine Stroke Centre (an European Stroke Organisation stroke centre or equivalent with specific infrastructure and setup for network and telemedicine support), (2) the telemedicine-assisted stroke Unit (equivalent to an European Stroke Organisation stroke unit but without 24 h onsite stroke expertise) and (3) the telemedicine-assisted stroke ready hospital (only covering hyperacute treatment in the emergency department and transferring all patients for further treatment).

Keywords

Telemedicine, telestroke, network, stroke, stroke care system, remote area

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Introduction

Telemedicine refers to the use of telecommunication technology to provide health care from the distance. In 1999, Levine and Gorman introduced the term 'telestroke' as the use of telemedicine to provide neurological consultation for stroke in hospitals lacking this level of expertise.[1] Since late 1990s, multiple telestroke projects have been developed worldwide, mainly in Western countries, for the management of stroke patients. Several studies have demonstrated increasing thrombolysis rates after telestroke implementation without significant differences in safety or efficacy (class of recommendation IIb, level of evidence B).[2–4]

Currently, there is a wide difference in stroke care between European countries. This lack of uniformity is the consequence of the organisational models adopted at local and national levels, and the uneven distribution of resources that may determine an irregular adherence

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to current European Stroke Organisation (ESO) guidelines.[5] Telestroke can help harmonising stroke care between urban and rural areas since it addresses existing workforce gaps in the expert management of stroke patients. Early telestroke project developed in Europe at the beginning of the century and published network structures and outcomes, barriers and legal issues in telemedicine thus leading to further development of networks across Europe.[6–9] Recently, an analysis of the first 10 years' experience of a large telestroke network in Germany demonstrated that telestroke lead to increasing numbers of stroke patients being treated in hospitals with (tele)stroke units (19–78%), significantly higher intravenous thrombolysis (IVT) rates (2.6–15.5%), and a 40-min drop in door-to-needle times (80, interquartile range: 68–101, to 40, interquartile range: 29–59). Thus, telestroke units (TSUs) can provide sustained high-quality stroke care in rural areas (Level of evidence C).[10]

To achieve the goals of the second Helsingborg Declaration,[11] and the more recent Action Plan for stroke in Europe 2018–2030, regarding mortality, independence and accessibility to specific treatments, main aims of telestroke are expert coverage of Stroke Unit care, delivery of IVT and selection of potential candidates for endovascular treatment (EVT) across all regions and countries in Europe where onsite expertise is not available. This article, written by the Telestroke Committee of the ESO aims to propose a set of recommendations on the establishment of telestroke networks for the management of acute stroke patients. These recommendations are largely based on expert opinions.

Organisation of telestroke networks

The most common telestroke system is the so-called hub-and-spoke model where a telemedicine stroke centre (TSC) (hub) provides expert stroke knowledge to a variable number of regional or community hospitals (spokes). On the spoke side, the need of external coverage and expertise may vary according to the in-house structural and professional resources. Particularly at regional hospitals that cannot provide around-the-clock stroke expertise, the stroke unit depends on telestroke to provide expert care (telemedicine-assisted stroke unit (TSU)).[12] In other cases small community hospitals without stroke-dedicated facilities may play a role only as for patients' initial assessment, diagnostic, identification of IVT candidates and eventually thrombolysis treatment. In such case, the network provides telemedicine hyperacute stroke services.

A 'hubless' horizontal network of community hospitals is another possible telestroke system. Teleconsultations during off-hours are performed by local neurologists of all hospitals involved in the network in rotation.[9]

Depending on every specific network protocol and spoke hospitals resources, patients either stay at the spoke hospital if endovascular or neurosurgical treatment is not required, and the spoke is sufficiently resourced to expertly care for the patient ('drip-and-keep') or are transferred to the hub centre after IVT ('drip-and-ship').

Telemedicine can not only facilitate rapid case assessment and treatment decision but it also makes regular training, case discussions and audits possible.

This article will focus mainly on the most widely used hub-and-spoke model.

The hub-and-spoke telestroke network

In the so-called 'hub-and-spoke' model, there can be three hospital types involved: (1) the telemedicine stroke center (TSC), (2) the TSU and (3) the telemedicine-assisted stroke ready hospital unit (TSRH). The hub covers the full pathway of a stroke centre, including IVT, endovascular and neurosurgical interventions. TSUs are capable of administering IVT with the support of a stroke specialist by telemedicine, and provide subsequent stroke unit care. TSRH are able to manage stroke patients acutely, such as administering IVT but do not provide further stroke unit care (see Table 1). For patients requiring more advanced procedures, such as endovascular or neurosurgical treatment, telestroke may play an important role in triaging acute stroke patients.[13]

Telemedicine Stroke Center, the hub

Generally, TSC should fulfill all requirements for ESO Stroke Centres.[14] The ESO Stroke Centre is a hospital infrastructure that covers the entire chain of care, including neurosurgical and vascular interventions.[14] In addition, the TSC of a telestroke network should take responsibility for a region-wide stroke care concept including: (1) coverage of telemedical consultations for all spoke hospitals dependent on remote expertise 24 h/d, 7 days/week, (2) definition of the standard operating procedures for stroke care at all participating hospitals, (3) development and maintenance of a network-wide, quality-focused stroke registry and (4) continuous education programmes for staff of the spoke hospitals.

Recommendations for the organisation of a TSC

1. Central stroke care
   a. TSC should be a large hospital with region-wide importance and should include all structural

Table 1. Key features of the three telemedicine units in a stroke network.

	TSC	TSU	TSRH
Stroke care	All structural elements identified in the ESO criteria for stroke centres	All infrastructural elements identified in the ESO Stroke Unit category, except for onsite 24 h/7 d availability of stroke physician. Expert assessment and treatment of acute stroke patients provided onsite at least part time.	Embedded in a hospital with 24 h ED, 24 h CT scanning and 24 h laboratory. Expert assessment and treatment of acute stroke patients based on teleconsultation.
Teleconsultation	Provides teleconsultations service with videoconference and imaging transfer; teleconsultants are specialised in stroke care teleconsultantations are readily available (<3 min).	Sufficiently staffed to manage acute stroke patients with telemedicine support.	Sufficiently staffed to manage acute stroke patients with telemedicine support.
SOPs	Provides written standard operating procedures for: • Prehospital care; • Hyperacute in-hospital care at the Emergency Departments; • Multidisciplinary follow-up management on stroke unit.	Implements SOPs of TSC for: • Prehospital care; • Hyperacute in-hospital care at the Emergency Department; • Multidisciplinary follow-up management on stroke unit.	Implements SOPs of TSC for: • Prehospital care; • Hyperacute in-hospital care at the Emergency Department.
Training	Offers regular multidisciplinary training for all spoke hospitals.	Participates in TSC training.	Participates in TSC training.
Quality improvement	Provides or is involved in a quality improvement initiative (registry).	Participates in quality improvement initiative of TSC.	Participates in quality improvement initiative of TSC.

TSC: Telemedicine Stroke Centre; TSU: Telemedicine-assisted Stroke Unit; TSRH: Telemedicine assisted Stroke Ready Hospital; ESO: European Stroke Organization; ED: Emergency Department; CT: Computertomography; SOP: Standard Operating Procedures.

elements and health professionals identified in the ESO criteria for stroke centres, ensuring high-level 24 h/d stroke management along the entire chain of care.

2. Teleconsultation service
   a. TSC should provide teleconsultations with videoconference and imaging transfer;
   b. teleconsultants should be specialised in stroke care and should have been trained on a stroke unit with region-wide importance;
   c. teleconsultants should be readily available (<3 min) at all times and should be free from other urgent care.
3. Transfer options
   a. TSC should provide capacity for stroke patients being secondarily transferred from spoke hospitals for more elaborate treatment, or provide cooperation with other stroke centres for this purpose.
4. Standard operating procedures
   a. The hub should provide written protocols for all spoke hospitals, addressing acute stroke processes and treatments in the following areas:
      i. Prehospital care;
      ii. Hyperacute in-hospital care at the emergency departments (EDs);
      iii. Multidisciplinary follow-up management on stroke unit.
5. Professional training
   a. The hub should offer regular multidisciplinary training for all spoke hospitals.
6. Quality monitoring
   a. The hub and spoke hospitals (the telestroke network) should be involved in a quality improvement initiative based on regular checks of a series of pre-established quality metrics.

Spoke hospitals

Selection of hospitals. When setting up a network with the aim to ensure complete stroke unit coverage of an area, location of hospitals to include in stroke care must be carefully chosen. Not all hospitals in a country/region should provide stroke care. Instead, it should be offered in a number of selected hospitals distributed across a given territory taking into account geographic and demographic features. It is known that larger volume of patients leads to a decrease in mortality[15] and to improvement of in-hospital processes.[16]

$$\frac{200}{\text{population/km}^2 \times \text{number of strokes/100.000/year}} = \text{area (km}^2\text{)}$$

Figure 1. Minimum size of an area to be covered by a single stroke unit. Size is inversely related to population density (population/km^2) and stroke incidence (number of strokes/100.000/year).

A stroke unit seems effective (and cost effective), when at least 200 stroke patients are treated per year as outlined in the ESO Stroke Unit recommendations.[14] Therefore, size of area covered by a single stroke unit should be large enough to ensure effective stroke unit treatment. On the other hand, stroke treatments, especially causative treatments are heavily time dependent.[17,18] Therefore, thoughtful consideration should be given to ensuring acceptable transportation times from peoples' home to the next stroke care facility.

When choosing the right hospitals for a telestroke network two rules should be applied: (1) the TSU should treat at least 200 stroke patients per year and (2) acute stroke care should be within reach of 45 min for 90% of the population.

Population density and stroke incidence will allow calculating number of stroke units needed for an area to fulfill rule No.1.

Minimum size of an area to be covered by a single stroke unit can be calculated by the following formula (Figure 1):

Rule No.2 is dependent on geography, infrastructure and transportation systems.

These rules are usually both applicable in areas with population densities of $\geq$120 inhabitants/km^2. Difficulties arise in very scarcely populated areas where size of the area to be covered by a single stroke unit will have to be very large to ensure 200 patients per year. In this situation, the 45-min transport rule is jeopardised. Conversely, if in such low-density areas rule No. 2 is prioritised, TSUs will be undersized. It is therefore in such areas where TSRHs are meaningful. TSRHs do not need to ensure 200 patients per year, as they do not keep patients for further treatment. Moreover, they should be reachable within 45 min and should be ready to rapidly deliver IVT before transferring all stroke patients to the next (tele-) stroke unit (Figure 2).

Telestroke unit (TSU). Benefit of organised stroke unit care covers all stroke subtypes.[19] It is not surprising therefore, that the backbone of organised stroke care is the stroke unit.[20] The ESO Stroke Unit refers to an intermediate level of care for stroke patients that satisfies evidence-based requirements, and is organised to provide acute and post-acute care with a multiprofessional specially trained and skilled team, including physicians, nurses, physiotherapists, speech therapists, occupational therapists, social workers and neuropsychologists (optional). In case of staff constraints, the stroke unit will need external assistance when it comes to the decision-making process in the acute stroke patient and general knowledge transfer. In this context, stroke physicians would be made available through telemedicine.

Recommendations for the organisation of TSUs. The TSU should include all infrastructural elements identified in the ESO Stroke Unit category, except for onsite 24 h/7 d availability of stroke physician. Instead TSU should have a responsible physician and nurse involved in stroke care.

1. The TSU must be sufficiently staffed to manage acute stroke patients with telemedicine support.
2. Expert assessment and treatment of acute stroke patients should be provided onsite at least part time.
3. The TSU should implement the written protocols, provided by network centre addressing the following stages of acute stroke care:
   a. Prehospital care;
   b. Hyperacute in-hospital care at the ED;
   c. Multidisciplinary follow-up management on stroke unit;
4. Professional training
   a. TSU should participate in network-wide multidisciplinary training sessions
5. The TSU should participate in the national and network-specific stroke registry.

The telemedicine-assisted stroke ready hospital unit (TSRH). Over a quarter of European citizens live in rural areas where timely access to an ESO Stroke Unit or Stroke Centre is not possible.[21] Defining care facilities that meet the needs of acute stroke patients living in these areas is relevant to guarantee quality of acute care and outcomes after stroke. Hospitals and centres included in the TSRH level of care would typically be small community hospitals covering distant and sparsely populated areas and offering first line management. Infrastructure and staff of this level of care are detailed in Tables 1 and 2. This level of care would be equivalent to the Brain Attack Coalition Acute Stroke-Ready Hospital or Stroke-Ready Hospital.[22] This unit does not cover ongoing stroke treatment, therefore after hyperacute care has been initiated, all patients must

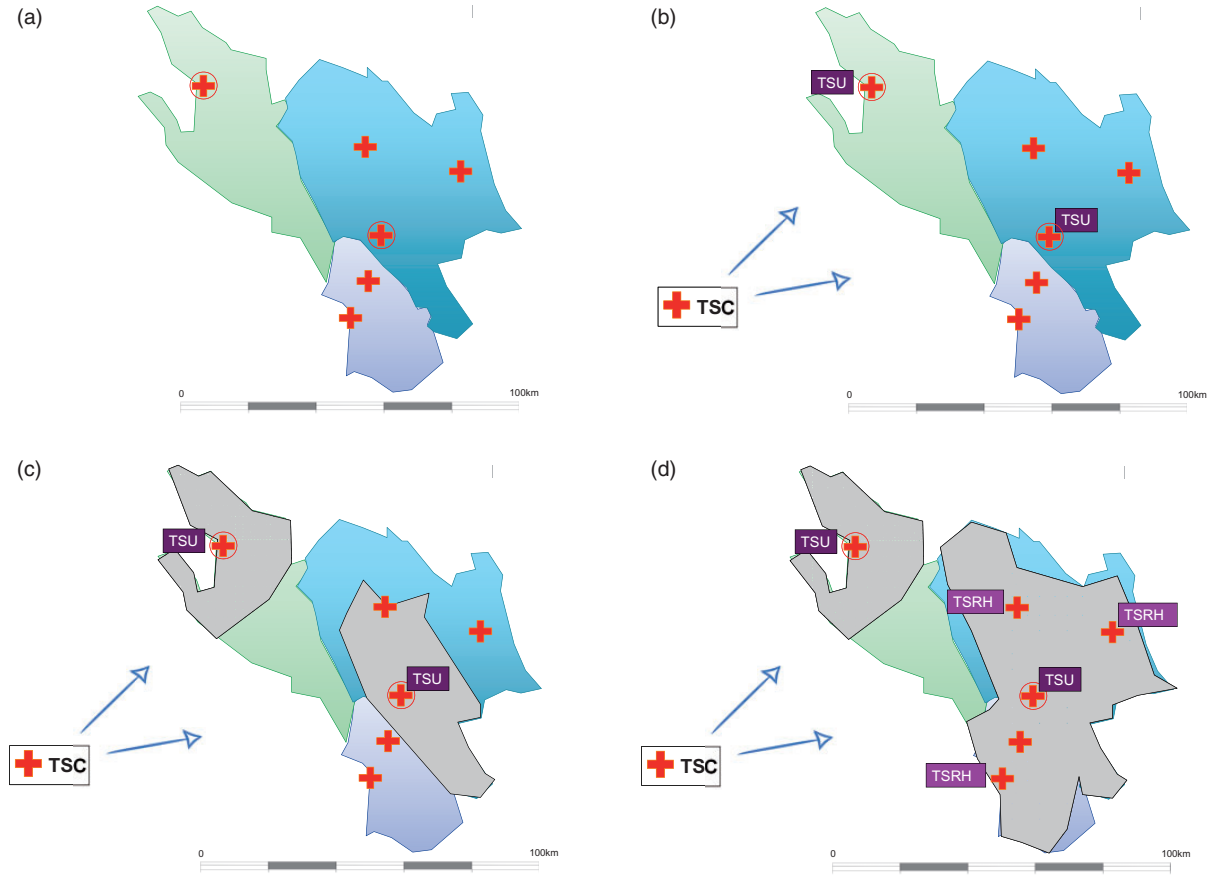

Figure 2. Fictional development of a telestroke network in an example European mountainous area with three provinces of low population density and no current specific stroke care. Area size and population density in green, blue and purple provinces are 1748 km^2 and 65/km^2, 2884 km^2 and 25/km^2, 904 km^2 and 64/km^2, respectively. Stroke incidence is 270/100.000 in all three provinces. (a) There are two existing regional hospitals (cross with circle) and four small provincial hospitals. TSC would be located remotely from these provinces. (b) Applying the formula to account for rule No. 1 (size of region for one stroke unit), allows setup of two telemedicine assisted stroke units (TSU). One for green province, one for blue and purple province together (minimum area in green province 1140 km^2, in blue province 2963 km^2, in purple province 1157 km^2). (c) Applying rule No. 2 (travel distance $<$ 45 min) of these two TSU shows an inadequate coverage of only half of the provincial area (grey). (d) Set up of further three TSRH allows for timely coverage of three quarters of the area. No adequate coverage can be obtained in South of green province, as there are no health care facilities in this very mountainous landscape.
TSC: Telemedicine Stroke Centre, TSU: Telemedicine assisted Stroke Unit, TSRH: Telemedicine assisted Stroke Ready Hospital.

be transferred to a (tele-)stroke unit, regardless whether they received IVT or not.

Recommendations for the organisation of TSRH

1. The TSRH must be embedded in a hospital with 24 h ED, 24 h Computertomography scanning and 24 h laboratory.
2. ED must be sufficiently staffed to manage acute stroke patients with telemedicine support.
3. Expert assessment and treatment of acute stroke patients should be provided onsite based on teleconsultation.
4. The TSRH should implement the written protocols, provided by network centre addressing the following stages of acute stroke care:
   a. Prehospital care;
   b. Hyperacute in-hospital care at the ED.
5. Professional training
   a. TSRH should participate in network-wide multi-disciplinary training sessions.
6. The TSRH should participate in the national and network specific stroke registry.

Structural requirements for a stroke unit (and the telemedicine system) should be in place before including the hospital in the network. Staff specialisation and quality of processes can be trained and supported by

Table 2. Professional and structural requirements for TSC and spoke hospital types involved in telestroke networks.

Resources	TSC	TSU	TSRH
Emergency department	✓	✓	✓
24-h/day laboratory	✓	✓	✓
24-h/day head CT (plain)	✓	✓	✓
24-h/day head CT angiography	✓	✓	✓/×
24-h/day CT perfusion	✓	×	×
Acute stroke unit (semi-intensive dedicated beds, stroke nurses)	✓	✓	×
Intensive care unit	✓	✓/×	×
General neurology ward	✓	×	×
24-h/day stroke physician	✓	×	×
24-h/day neuroradiologist and neurosurgeon on call	✓	×	×
Early physiotherapy	✓	✓	×
Early rehab assessment and establishment of rehab goals	✓	✓	×
Early swallowing assessment	✓	✓	✓
Angiography suite	✓	×	×
Vascular surgery	✓	×	×
Doppler sonography	✓	✓	×

TSC: telemedicine Stroke Centre; TSRH: Telemedicine-assisted Stroke Ready Hospital; TSU: Telemedicine-assisted Stroke Unit; CT: Computertomography.

network centre staff during and after the telestroke network setup. Generally, a newly setup TSU needs three to five years to reach quality levels of a well-established stroke unit.

Technical aspects of the telemedicine equipment

The backbone of a high-quality teleconsultation service is a stable technical system that allows instant 24 h/d videoconference and rapid imaging transfer. Insufficient telesignal quality may lead to inferior quality of information. Various publications have shown that telemedicine for stroke is safe,[23] but little is known about low quality telemedical systems and their specific impact on patients' health. Therefore one should aim for high-quality systems and perform constant evaluation (e.g. by judging video- and audioquality separately for each videoconference on a 5-point scale). Systems should comprise the following features:

1. Connection
   a. Virtual private network (VPN) connection between hospitals allows individual identification, encryptions and data integrity;
   b. Connection speed above 1 Mbps;
   c. Advanced Encryption Standards (AES) up to 256 bit.
2. TSC equipment
   a. Telemedicine computer, equipped with camera and microphone is not a medical device and can be placed in a normal office;
   b. Bidirectional audio–video streaming guarantees appropriate dialogue between hub and spoke personnel and patient;
   c. Audio filter for background sound and echocancelling;
   d. Connection of the system with the radiology information system network and/or the picture archiving and communication systems of spoke hospital for sharing brain images;
   e. Software for planning, documenting and storing teleconsultation reports.
3. Spoke hospital equipment
   a. Remote systems, equipped with a camera, microphone and monitor may be medical devices (type Ia since they have no direct contact with patient) (individually appointed by national health authority);
   b. Audio filter for background sound and echocancelling;
   c. Availability of a zoom (up to 20 fold) for the camera remotely controlled by the specialist. Cameras usually are robotic devices with autofocus and panning/tilting systems.

Ethical aspects of telemedicine

In the age of new technologies such as telemedicine, physicians' fundamental ethical responsibilities have not changed. The practice of medicine is itself a moral activity established in a 'commitment to trust' between a patient and a doctor, taking into account the Oath of Hippocrates.[24]

There are a number of ways in which legal and ethical aspects are relevant to telemedicine. These include the responsibilities and potential liabilities of health professionals, the duty to maintain the confidentiality and privacy of patient records, the jurisdictional problems associated with cross-border consultations, the reliability of equipment, the offering of opinions only when possessing necessary information.

Telemedicine, i.e. telestroke, is justified because of its speed (the duty of timely communication serves ethical goals of beneficence and justice) and its capacity to reach patients with limited access to medical assistance (ethical principle, or duty, of beneficence), in addition to its power to improve health care (World Medical Association (WMA) statement on the ethics of telemedicine).[25]

Telemedicine should primarily be employed in situations in which a physician/expert cannot be physically present within a safe and acceptable time.

The European Union's Directive on Data Protection (95/46/EC) lays down data protection principles, which must be complied in relation to all personal data.

Patient's consent to the use of information can only be assumed for the direct provision of treatment.

The 2009 policy article[23] outlined a set of general recommendations that defined how telestroke should be implemented and laid the foundation for identifying measures of quality appropriate to telestroke providers and recipients of those services.[13] Implementation requires compliance with all applicable laws and statutes and continuous quality improvement that should include an assessment of the adoption and use of the technology, rates of technical and human failures related to the system and needs for training and maintaining competency. The use of widely accepted industry technology standards is encouraged, and the care provided during telestroke consultation should be similar to that given during on-site consultation. For doctors who provide clinical services through telemedicine, it is compulsory to meet all the competence for providing care for patient with cerebrovascular diseases and to be trained in the use of appropriate technologies and to ensure a satisfactory use of the technology to interact with patients. A mechanism for a uniform national licensure process for telestroke consultants limited to telemedicine practice should be adopted by national medical associations, and a uniform streamlined credentialing and privileging process for telestroke consultants should be adopted by telestroke centres.

A detailed record should be kept of the advice the teleconsultant delivers as well as the received information on which the advice was based. A physician asking for another physician's advice or second opinion remains responsible for treatment and other decisions and recommendations given to the patient.

There are many questions about the legal and ethical aspects of telemedicine. Health care professionals who undertake telemedicine should act in a prudent manner to minimise the possibility of medicolegal complications.[26]

Quality improvement

The aim of any telestroke network is to improve quality of stroke care. Apart from bringing stroke expertise to remote patients via telemedicine, quality improvement is achieved by setting up standard operating procedures, by performing constant professional training for all spoke hospitals and by giving regular quality feedback through registry data analyses.

Standard operating procedures (SOPs)

SOPs are written to standardise stroke treatment. Detailed protocols for regular processes in stroke care covering the entire chain of acute stroke care, from onset of symptoms to discharge from hospital, should be written by the network centre and implemented at the spoke hospitals.

Common SOPs should cover each of the following stages:

1. Pre-hospital care (in agreement with Emergency Medical Service (EMS): Protocols should include standards for recognition of stroke patients at dispatcher and the EMS staff level, for rapid transportation to appropriate hospital and for pre-notification of the destination hospital.
2. Hyperacute stroke management at ED: protocols should include priority triage of suspected stroke patients, Computertomography priority, alert and process of teleconsultation, workflows for delivery of IVT and for rapid inter-hospital transfer (in cooperation with EMS).
3. Stroke management on stroke unit: protocols should include recommendations for all professionals involved in stroke care regarding diagnostic and treatment of all stroke subtypes and all aetiologies, and should include management in case of acute neurological deterioration or other complications.

Professional training

As some staff members of TSU and usually all of TSRH are not stroke experts, professional training is indispensable to assure high quality stroke care on site. As staff rotation and change can be expected, this training will need to be offered regularly. This should include training sessions on general knowledge of acute stroke care and latest news on evidence-based care provided on site (spoke hospital) or via teleconference by specialised centre staff of each profession and for each profession at least two times/year. This includes doctors, nurses, physiotherapists, speech and language therapists, occupational therapists (in case of missing occupational therapist, staff alternatively providing cognitive assessment).

Quality data analyses

Prospective data collection should be guaranteed at any acute care hospital involved in stroke care (spoke and hub hospitals). Data should be regularly analysed either by each hospital site that is part of the network or by a central entity.

Quality parameters should include the following items:

4. All generally recommended parameters in stroke care:
5. baseline characteristics, stroke subtype, stroke severity, rate of IVT and EVT, time delays in acute patients, complications and outcomes during hospital stay.
6. Specific telestroke quality parameters
7. time delays of telemedicine workflows (door-videoconference, duration of videoconference, videoconference decision on treatment); transfer time delays, quality of recommendation by teleconsultant (stroke mimic/chameleon rate, complications) and of technical system (video- and audioquality, imaging transfer).

Conclusions

Setup of high-quality stroke care is demanding in rural areas. Telestroke network structure can help to overcome lack of expertise in remote regions. Hub and spoke model is the most commonly used structure with one or two network centres and variable amount of participating provincial hospitals.

Network centres should provide all levels of stroke care and have a district-wide importance. Inclusion of spoke hospitals must be chosen with care to adequately cover a whole region. A TSU should treat at least 200 stroke patients/year and hyperacute stroke treatment should be within close reach (<45 min) for 90% of the population. Spoke hospitals should either be setup as TSUs, providing acute treatment including stroke unit care, or as TSRHs, only providing ED care, including IVT and identification of candidates for thrombectomy and transfer options for all patients.

Quality improvement has to be ensured by standardising stroke treatment throughout the network, performing intensive multiprofessional training and by setting up feedback mechanisms with analyses of a network specific stroke registry.

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