Telemedicine in Stroke Management

- systematic review

Ludwig Boltzmann Institut
Health Technology Assessment

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Projektleitung: Mag. Tim Johansson MSc
Projektbearbeitung: Mag. Tim Johansson MSc
Projektbegleitung: Dr. phil. Claudia Wild
Externe Begutachtung: Priv.-Doz. Dr.med. René Handschu MBA – Neurologische Klinik Universitätsklinikum Erlangen

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Responsible for Contents:

Ludwig Boltzmann Institute of Health Technology Assessment (LBI-HTA)
Garnisongasse 7/20, A-1090 Vienna
http://hta.lbg.ac.at/

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Executive Summary

need for rapid assessment

Background: Stroke is the third largest cause of death after cardiovascular disease and cancer in industrial countries and a major factor in permanent disability. Acute stroke care requires rapid assessment, including patients 'medical history and accurate diagnostics: "time is brain".

treatment in stroke center preferable prognosis

short treatment-window

Patients who receive organised stroke unit care are more likely to survive, return home and make a good recovery compared to patients treated with conventional care in general medical wards. Systemic tissue plasminogen activator (tPA) delivered within 3 hours after the onset of stroke symptoms for acute ischemic stroke patients has been shown to reduce subsequent morbidity and mortality. tPA dissolves the obstructing blood clot restoring blood flow before major brain damage has occurred. Telemedicine in stroke care allows a direct specialist consultation with a patient, patient monitoring and medical education. The putative advantages of telemedicine are improvements in the quality of stroke care and increased use of tPA, which is associated with better health outcomes.

Objective: the objective of this report is to assess the feasibility, acceptability, and treatment delivery reliability of telemedicine systems in acute stroke management. A secondary aim is to explore the feasibility and acceptability of telerehabilitation interventions in stroke management.

systematic literature analysis

Methods: A systematic literature search and evaluation of peer-reviewed literature was performed in Ovid Medline, Embase, DARE-NHSEED-HTA (INAHTA) and The Cochrane Library. The search was limited to the years 1995-2008. 144 references remained after the removal of duplicates. A further 8 articles were identified through handsearching, yielding a total of 152 references.

26 studies included

better health outcomes and reduced mortality

high level of satisfaction

Results: In total 26 studies were included in this systematic review. 19 studies assessed telemedicine technologies in acute stroke care. 7 studies used telemedicine technologies in stroke rehabilitation settings. There was wide variety in study designs, including randomized controlled trials, controlled clinical trials, qualitative analysis, and observational studies. Most studies on acute stroke care included data on tPA. In some cases the time from patient's admission in hospital to the start of thrombolysis, also called "door-to-needle time", was documented. "Onset-to-needle time" and "onset to admission" were other indicators that were measured. Transfer rate after consultation was commonly reported. Patients treated with tPA via telemedicine were often transferred to a stroke center for continuing monitoring and surveillance. Long term follow up at 6, 12 and 30 months of telestroke services demonstrated better functional health outcomes including reduced dependency and mortality, compared with conventional care. Patients and health care providers reported high levels of satisfaction, although no study had the assessment of this outcome as its main objective. There was limited evidence regarding the impact on resource utilization and cost-effectiveness.

7 telerehabilitation studies were identified in the literature. It appears that telerehabilitation interventions involving stroke patients and/or caregivers improve patient satisfaction and caregivers' mental health.

16 identified telestroke programs

16 telestroke programs worldwide were identified, with more than half of them in North America. Programs had different objectives and approaches regarding staffing, technology, and catchment areas. A wide range of total numbers of consultations was identified in the literature when comparing the interventions.

Conclusion: Although there is limited reliable evidence, observational studies indicated that telemedicine systems can be safe, feasible, and acceptable in acute stroke management. Telestroke interventions can bring therapeutic benefits, which are currently mainly available in specialized stroke centers. Telemedicine associations were associated with an increased delivery of systemic tPA, which improved patients' health outcomes. Economic studies on telemedicine interventions in stroke management are lacking. Some studies reported investment costs for technologies and education for health personnel and only one study reported cost-effectiveness. Studies of higher methodological quality are needed to explore the potential cost-effectiveness of telemedicine technologies in stroke management.

It is difficult to draw conclusions from the small sample of telerehabilitation studies included in this report. The few identified articles show promising results in terms of improving stroke patients' and/or caregivers' well-being. More research is necessary to determine the impact of telerehabilitation services.

lack of harmonization

Several programs have been identified as being at the forefront of telestroke. The lack of standardized measuring and reporting of resources and health outcomes constrain comparisons between telestroke networks and the determination of best practices. More research is needed to accurately measure the clinical and economic impact of telemedicine technologies in stroke management to support policy makers in making informed decisions.

Zusammenfassung

Hintergrund: In den industrialisierten Ländern zählt Schlaganfall zur dritthäufigsten Todesursache nach Herz-Kreislauferkrankungen und Krebs. Schlaganfall ist auch eine der häufigsten Ursachen für dauerhafte Behinderungen. Ein akuter Schlaganfall benötigt ein rasches Verfahren und eine präzise Diagnose („time is brain“) um Langzeitbehinderungen zu mindern.

„time is brain“

PatientInnen, die in spezialisierten Schlaganfallzentren, sog. „Stroke Units“ behandelt werden, haben eine bessere Überlebenschance und Gesundheitsprognose als konventionell behandelte Schlaganfallpatienten. Intravenöse Thrombolyse ist eine effektive Therapie, wenn sie innerhalb der ersten 3 Stunden nach den Schlaganfallsymptomen injiziert wird. Thrombolyse, der Tissue Plasminogen Activator (tPA) ist eine Substanz, die ein Blutgerinnsel auflösen kann und ist mit einer niedrigen Morbidität und Mortalität verbunden. Telemedizin ermöglicht es nun, dass neurologische ExpertInnen mit regionalen ÄrztInnen, ohne Verzögerung und geografische Barriere, kommunizieren können, und dadurch eine schnelle Betreuung der PatientInnen möglich wird. Die putativen Vorteile von Telemedizin sind zum einen die verbesserte Qualität des Schlaganfallmanagements und zum anderen die erhörte Rate von intravenösen Thrombolysen.

bessere Gesundheitsprognose in spezializierten Schlaganfallzentren

thrombolyse-kurze Behandlungsfenster

Zielsetzung: Die Zielsetzung dieses Berichts ist die Synthese von (publizierten) Erfahrungsberichten zur Realisierbarkeit, Akzeptanz und Zuverlässigkeit und Ergebnismessung von telemedizinischen Methoden im akuten Schlaganfallmanagement, ebenso wie von Tele-Rehabilitationsinterventionen im Rahmen des Schlaganfallmanagements.

Methode: Zur Beantwortung der HTA- Fragestellungen wurde eine systematische Übersichtsarbeit durchgeführt. Um relevante Artikel zu identifizieren, wurde eine elektronische Literatursuche in folgenden Datenbanken durchgeführt: Ovid Medline, Embase, DARE-NHSEED-HTA (INAHTA) und in der Cochrane Library. Die Literatursuche war auf die Zeit von 1995 bis 2008 begrenzt. Nach dem Aussortieren von Duplikationen verblieben 144 Zitate. Weitere 8 Publikationen wurden nach der Handsuche inkludiert. Insgesamt wurden 152 Zitate gefunden, 26 Erfahrungsberichte ausgewertet.

eine systematische Übersichtsarbeit

Ergebnis: Ingesamt wurden 26 Publikationen in dieser systematischen Übersichtarbeit eingeschlossen. 19 Publikationen berichteten von telemedizinischen Methoden bei akuten Schlaganfallmanagement und 7 Publikationen von Tele-Rehabilitationsinterventionen. Das Studiendesign in den Publikationen variiert von randomisiert kontrollierten Studien, kontrollierten Studien, qualitativen Analysen bis hin zu verschieden Beobachtungsstudien. Die Mehrzahl der Publikationen analysierte die Sicherheit und Durchführbarkeit von intravenöser Thrombolyse in telemedizinischen Netzwerken. Verschiedene Prozessabläufe wurden evaluiert. Zum Beispiel der Beginn der Symptomatik bis zur Thrombolyse (Onset – Lyse –Zeit) sowie der Zeitpunkt der stationären Aufnahme bis zur Thrombolyse (Pforte – Lyse – Zeit). Für die weitere Überwachung wurden Lyse behandelte PatientInnen oft zu Schlaganfallzentren transportiert. Follow-up von Telestroke PatientInnen nach 6, 12 und 30 Monten zeigte - im Vergleich zu PatientInnen mit konventionellen Behandlungen - eine reduzierte Wahrscheinlichkeit für Behinderung und Mortalität. PatientInnen und Personal berichteten von einer hohen Zufriedenheit mit telemedizinischen Interventionen, obwohl keine Publikation diesen Ansatz als Hauptforschungsziel hatte. Eine sehr begrenzte

26 Studien inkludiert

bessere Gesundheitsprognose, reduziert Behinderungen und Mortalität

hohe Zufriedenheit

Evidenz für die Nutzung von Ressourcen und Kosten-Effektivität ist vorhanden.

In den Publikationen zur Tele-Rehabilitation zeigt sich die Tendenz, dass Tele-Rehabilitationsinterventionen für Schlaganfallspatientinnen oder pflegende Angehörige die Gesundheitsversorgung verbessern können. Weiters gab es eine hohe Zufriedenheit mit den Interventionen.

16 Identifizierte Telestroke-Programme

16 Telestroke Programme wurden weltweit identifiziert. Mehr als die Hälfte sind in Nord-Amerika etabliert. Die Programme hatten verschiedene Zielsetzungen und Herangehensweisen bezüglich Personal, Technologie, und Einzugsgebiet. Die Anzahl von Konsultationen via telemedizinischer Technologien variiert stark in den Studien.

Schlussfolgerungen: Trotz der begrenzten Evidenz und dem Überwiegen von Beobachtungsstudien scheinen Telestroke-Interventionen sicher, zuverlässig und akzeptiert zu sein. Telemedizinische Interventionen können das Wissen und die Expertise von spezialisierten Schlaganfallzentren zu regionalen neurologisch unterversorgten Regionen verbreiten. Effektive Behandlungstherapien wie intravenöse tPA können häufiger eingesetzt werden, was eine bessere Gesundheitsprognose für die PatientInnen bedeutet. Ökonomische Studien zu Telestroke-Interventionen sind rar. Einige Studien präsentieren Investitions- und Bildungskosten für Technologie und Personal. Nur eine Studie hatte einen Kosten-Effektivitätsansatz.

Eine Schlussfolgerung bezüglich Tele-Rehabilitationsinterventionen ist schwer zu ziehen, da die Anzahl der inkludierten Studien zu gering ist. Die Tendenz weist jedoch eine verbesserte Gesundheit für pflegende Angehörige sowie PatientInnen auf.

mangel an standardisierten Qualitäts-Indikatoren

Die fehlende Ressourcendarstellung sowie der Mangel an standardisierten Qualitätsindikatoren, Abläufen, und Outcomeparameter macht es schwierig verschiedene Programmen zu vergleichen und ein „best practise" Model zu identifizieren. Eine Standardisierung der Ergebnismessung ist wünschenswert, um die klinischen und ökonomischen Aspekte von Telestroke-Interventionen genauer analysieren zu können.

1 Introduction

Stroke is one of the leading causes of morbidity and mortality worldwide. In the industrial countries stroke is the third largest cause of death after cardiovascular diseases and cancer, and a major factor in permanent disability [1]. Stroke is a sudden impairment of brain functions resulting either from a clot obstructing the flow of blood to the brain (known as ischemic stroke) or by a blood vessel rupturing and preventing blood flow to the brain (known as hemorrhagic stroke). When a stroke occurs, part of the brain cannot get the blood it needs and brain tissue starts to die. Ischemic stroke accounts for about 80 percent, and hemorrhagic stroke for about 20 percent, of all cases [2].

pathology:

Differences in incidence, prevalence and mortality between Eastern and Western Europe have been reported. They are likely due to differences in risk factors and environmental factors. Hypertension, alcohol and smoking are more common risk factors in Eastern Europe [3]. Overall, stroke accounts for about 10% of all deaths in most industrial countries [4]. In the European Union over 600.000 new strokes were reported in 2008. The prevalence of stroke survivors was estimated to about 2.4 millions [5]. The American Heart Association estimates that in the United States there are almost 4,7 million stroke survivors and approximately 795 000 people experience a new or recurrent stroke per year. Approximately 610 000 of these are first attacks, and 185 000 are recurrent attacks [6]. Stroke patients above 70 years account for half of all strokes. In all age groups up to the age of 85, males are more likely than women to suffer a stroke. Above 85, women are more likely to suffer a stroke [7]. Demographic changes which result in an ageing population will result in an increase in both the incidence and prevalence of stroke [8].

stroke responsible for 10% of all death in industrial countries

EU. 600,000 new cases

US. 610,000 new cases

The burden of stroke is heavy, for patients, family members and for society. Stroke is one of the most costly diseases in industrial countries. The costs of acute treatment, rehabilitation, and therapy put a major economic burden on health care systems. Indirect costs, such as persons' loss of productivity is a further burden on society [9].

direct & indirect costs

diagnostic, "time is brain"

treatment: good evidence for stroke-unit & tPA

problem of access to tPA

Helsingborg declaration 2006

telemedicine

An accurate diagnosis of stroke is dependent on a detailed patient history, neurological examination, imaging (computerised tomography or magnetic resonance imaging), and expert interpretation, all in a very time sensitive window: "time is brain". For more than a decade, two treatments for stroke patients have been shown to be effective; stroke-unit treatment and systemic thrombolytic treatment for ischemic stroke patients. The problem is, however, that most stroke patients do not have access to these therapeutic options. The main reasons for this are the lack of experts, (especially in non-urban areas) and financial factors. Another reason is that systemic thrombolytic therapy is recommended for ischemic stroke patients within 3 hours of onset and most patients are unable to access a hospital with the appropriate facilities within that time window. Thrombolysis treatment is primarily offered in stroke departments in university hospitals [10]. It is estimated that less than 2% of all stroke patients receive systemic thrombolysis in most industrial countries, primarily because of delayed admission to a stroke center [11]. In the last decade, with the development of information and communication technologies in medicine, there has been growing interest in the role that telehealth interventions could play in improving the quality of stroke management [12, 13]. The Helsingborg Declaration 2006 on European Stroke Strategies highlighted telemedicine systems as a prioritized research area in acute stroke management [14]. A broad definition of telemedicine is: 'the use of telecommunication technologies to provide medical information and services'[15]. Levine and Gorman have proposed the term 'telestroke' for the use of telemedicine in acute-stroke interventions [12]. It is important to realise that telemedicine is a heterogeneous notion and is not limited to a specific area of application. A distinction is made between real time (synchronous) and pre-recorded (asynchronous) telemedicine services. The latter enables the use of telemedicine regardless of time constraints. The supposed advantages of telemedicine in stroke care include:

putative advantages

- Real-time (visual or telephone) access to a remote specialist from any location
- Improved access of health services and quality of stroke care
- Increased use of thrombolytic therapy
- Reduction in costs (avoidance of patient transfer)
- Improvement in stroke education through the telemedical system
- Better efficiency in implementation of rehabilitation services

2 telemedicine models

The primary benefit of a telemedicine system is that areas with insufficient neurological services can be supported by a stroke expert through real-time telephone or videoconsulting. Specialists can apply their experience and expertise in stroke management. Two models of real-time videoconsulting systems can be identified:

- the fixed-site model: uses a dedicated, secure integrated services digital network (ISDN) or Digital Subscriber Line (DSL), with a 2-way audio- and videoconferencing link,
- a web-based system: need a specific software and Internet.

The advantage of a web-based model is that time can be saved by avoiding the travel of the consultant to hub sites, therefore shortening the onset-to-treatment time. Furthermore, a request can be answered by a neurological consultant from home or at hospital. A combination of telephone and video methods can be used [16]. Most symptoms can be assessed through a real-time audiovisual examination and the stroke severity can be verified using the National Institutes of Health Stroke Score (NIHSS) [17, 18]. Laboratory findings and radiological images (CT or MRT) can normally be transferred through a telemedicine system. Diagnostic images are important in excluding cerebral hemorrhage, which is one inclusion criterion for the use of thrombolytics (tPA). It is believed that telemedicine methods can spread the knowledge and expertise from stroke units, as well increase the use of systemic thrombolytic therapy for ischemic stroke patients. It is also expected that telemedicine will spread information about new stroke therapies and offer stroke patients more treatment options. Telemedicine also has the potential to play a role in stroke education and quality management [16, 19]. Telestroke seems to be a promising approach to reducing stroke care costs, above all reducing the subsequent costs by extending the use of thrombolytic drugs [20-23].

assessment of severity (NIHSS) laboratory fundings radiological images

high expectations in reducing costs in stroke care by extending use of tPA

1.1 Aims and Objectives

This systematic review aims:

systematic review

- to explore the effectiveness, cost-effectiveness and quality of telemedicine technologies in (acute) stroke management.
- to explore telestroke initiatives in relation to health outcomes, process of care (e.g., access to health services), health resources, and user and patient satisfaction/acceptance.
- to provide a synthesis of practices from organizations that provide telestroke services of relevance to policy makers.
- a secondary aim is to explore telemedicine technologies in stroke rehabilitation settings.

The main focus is on exploring the available interventions incorporating telemedical technologies in acute stroke management. Additionally the issue of whether telemedicine can achieve higher equality in health care by bringing new innovative therapies that are usually only available to urban populations into remote areas will be explored. For the purposes of this report the term “telestroke” is defined as: ‘the process by which electronic, visual, and audio communications (including the telephone) are used to provide diagnostic and consultation support to practitioners at distant sites, assist in or directly deliver medical care to patients at distant sites, and enhance the skills and knowledge of distant medical care providers’ [24]. According to the American Telemedicine Association, telemedicine is the use of medical information exchanged from one site to another via electronic communications to improve patients' health status. Videoconferencing, transmission of still images, e-health including patient portals, remote monitoring of vital signs, continuing medical education and nursing call centers are all considered part of telemedicine and telehealth [25]. Telerehabilitation is defined as the ability to provide, support, evaluation,

synthesis of reports from telestroke application focus on outcome, process & structure of telestroke initiatives

and intervention to persons who are disabled via telecommunication, and is a subcategory of the wider area of telemedicine [26]. Quality of care is based on the Donabedian concept [27], which take into account the outcome, process, and structure of care. The outcome of care indicates the effects of care on individuals, the process of care refers to the characteristics of available services, and the structure of care is the facilities, equipment, services and manpower available for care, and the credentials and qualifications of the health care professionals involved.

1.1.1 HTA Questioning

The report addresses several HTA questions:

improvements in outcome, quality, rescource –use

- Does the use of telemedicine improve quality, process and structure of care?
- What evidence exists that telemedicine systems improve health outcomes?
- Do telemedicine interventions affect health care resource utilization in stroke care?

user & patient satisfaction/ acceptance

- What is the level of user and patient satisfaction/acceptance of telemedical health services?

models of care

- What models of organization and best practices are at the forefront of telemedicine in acute stroke management?
- Are telemedicine technologies in acute stroke management cost-effective?

equity

- Can telemedicine in acute stroke management bring therapeutic benefits, which are today mainly available in urban environments (specialized stroke centers), to areas with limited neurological services, and therefore reduce inequalities and inequities in health?

2 Method

2.1 Literature Search

A systematic literature search was conducted on 12.11.2008 searching:

search in 4 databases

- Ovid Medline,
- Embase,
- DARE-NHSEED-HTA (INAHTA) and
- The Cochrane Library.

The search was limited to the years 1995-2008. 144 references remained after the removal of duplicates. A further 8 articles were identified through handsearching, yielding a total of 152 references. For detailed literature search strategies please contact LBI-HTA.

2.1.1 Selection Criteria

A PICO framework (Population, Intervention, Control, Outcome) was designed and its elements used as selection criteria. Articles were regarded as potentially eligible if they met all of the following criteria:

inclusion criteria

- Inclusion of stroke patients
- Evaluation of a telestroke service
- Inclusion of original data on health outcomes, process of care, user/patient satisfaction/acceptance/compliance, or resource utilization.
- Published since 1995, in a peer-reviewed journal.

stroke patients

telestroke service

orginal data

Articles on imaging modalities of telemedicine that focused exclusively on diagnostic concordance between telehealth and traditional face-to-face consultations were excluded as well as telemedicine interventions in stroke prevention and in pre-hospital stroke care.

exclusion: diagnostic concordance

2.1.2 Selection Method

Two reviewers independently screened each title and abstract of a potentially eligible report using Endnote, with the help of a standardised internal manual. Each article was categorized into one of three groups: “yes” (based on abstract, seems to meet inclusion criteria), “no” (does not meet the inclusion criteria) and “background” (useful background material).

two independent reviewers

2.2 Included Literature

152 citations identified, 26 included

Of the 152 articles identified in the literature search 51 articles were ordered for full text review and of these a total of 26 studies were included.

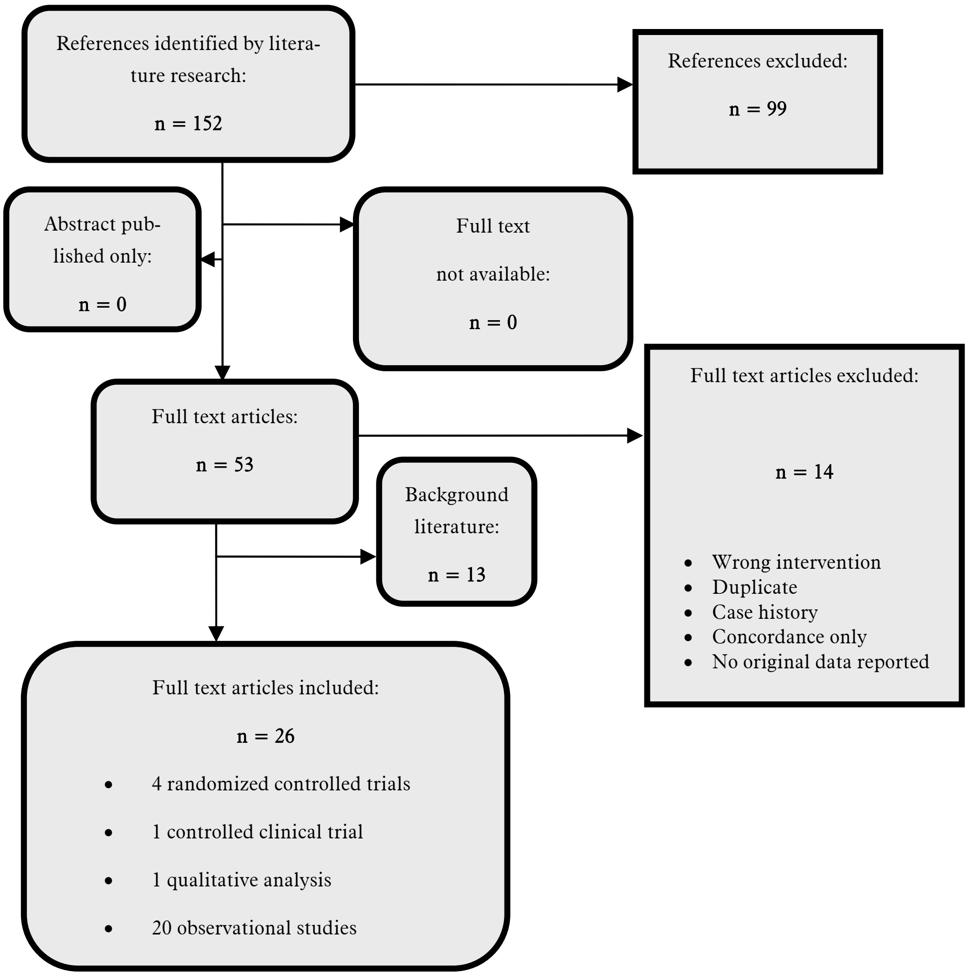

Figure 2.2-1: Illustration of selection of evidence (QUOROM tree)

2.3 Data Extraction

Extraction tables, including a set of parameters for extracting relevant information on telemedicine technologies in stroke management, were created. 4 tables were used for extracting data:

4 tables used in information extraction in information

- General characteristics of studies meeting the inclusion criteria (Appendix I),
- components and outcomes of included studies involving acute stroke care (Appendix II),
- systemic thrombolysis via telemedicine (Appendix III), and
- characteristics and outcomes of included studies involving tele-rehabilitation (Appendix IV).

3 Results

A total of 26 studies were included in this systematic review. 19 studies assessed telemedicine technologies in acute stroke settings. 7 studies used telemedicine technologies in stroke rehabilitation settings. All 24 studies were published after 2000. 14 articles originated from the United States [13, 28-40], 5 from Germany [41-45], 2 from Canada [46, 47] 2 from Hong Kong [26, 48], and one each from the Netherlands [49], Italy [50] and Finland [51]. 17 studies documented the source of funding, with only two reporting industry funding. There were 4 randomized controlled trials (RCT) [31, 34, 48, 49] one controlled clinical trial [43], and one qualitative analysis [35] 20 studies used an observational study design such as a case series or single prospective cohort (Appendix I).

26 studies

19 on acute stroke

7 on rehabilitation

USA, Germany, Canada, HongKong, Netherlands, Italy, Finland

16 networks with telemedical technologies in acute stroke settings were identified. 10 were located in the US, 3 in Germany, and one each in Canada, China and Finland (Table 3-1).

16 identified telestroke networks

Table 3-1: Identified acute telestroke networks

Author, Year	Source of Publication	Location, Network	Study Design	Objective	Settings	Funding
Canada						
Waite, 2006	Journal of Telemedicine and Telecare	Toronto, Ontario Telestroke project	Case series	To explore the feasibility of video consulting for acute stroke care	1 University and 2 community hospitals.	Canadian Stroke Network, Ontario Ministry of Health and IT Care, and North Network
China						
Wong, 2006	Neurosurgery	Hong Kong	RCT	To determine the differences among telephone consultation, teleradiology and video consultation on the basis of their process-of-care indicators, clinical outcomes, and cost-effectiveness.	District general hospital and a tertiary neurosurgical center.	Health Services Research Committee / Health Care and Promotion Fund
Finland						
Reponen, 2000	Journal of Telemedicine and Telecare	Finland	Case series	Effectiveness of wireless PDA to transmit computerized tomography.	Hospital, PDA device, remote neuroradiologist.	Not reported
Germany						
Audebert, 2006	Lancet Neurol	Bavaria,TEMPiS	CCT	Analyse the effects of a stroke network with telemedical support on quality of care, according to acute processes and long-term outcome.	2 academic stroke centers and 5 community hospitals.	German Federal Ministry of Research
Audebert, 2005	Stroke	Bavaria,TEMPiS	Prospective case series	Extend the use of tPA treatment in nonurban areas through telemedic support.	2 stroke centers and 12 local hospitals.	Health Insurance Company, Ministry of Employment and Social Order, Family and Women; German Stroke Foundation

Author, Year	Source of Publication	Location, Network	Study Design	Objective	Settings	Funding
Audebert, 2006	Stroke	Bavaria,TEMPiS	Prospective case series	Management and safety of tPA administration after telemedical consultation are equivalent in less experienced hospitals compared with tPA administration in academic stroke centers.	2 academic stroke centers and 12 regional hospitals.	Health Insurance Company, Ministry of Employment and Social Order, Family and Women; German Stroke Foundation
Handschu, 2008	J. Neurology	Bavaria, STENO	prospective study	Compare remote video-examination and telephone consultation in acute stroke.	2 district hospitals and 2 stroke centers.	Bavarian State Ministry of Labor and Social Welfare, Family and Women. "Competence Net Stroke"
Wiborg, 2003	Stroke	Swabia, TESS	Case series	To examine the feasibility, acceptance, and economic consequences of a telemedicine network including a special stroke training program.	1 Stroke unit and 7 rural community hospitals.	Bavaria, Germany, within the Bayern Online project
USA						
Choi, 2006	Joint commission on Journal on Quality and Patient Safety	Texas, StrokeSense	Prospective case series	To screen patient for rtPA via videoconferencing.	2 regional hospitals and 1 University stroke center.	US Department of Defense
Frey, 2005	Neurology	USA	Retrospective case series	Telephone network to support community EDs in the use of tPA.	Neurological stroke center and 43 hospitals.	Not reported
Hess, 2005	Stroke	Georgia, REACH	Case series	Bringing guideline driven stroke care to rural, underserved areas via a telestroke network.	8 rural hospitals and 1 medical College.	Medical College of Georgia Health Inc

Author, Year	Source of Publication	Location, Network	Study Design	Objective	Settings	Funding
Kuhle, 2006	Stroke	Califonia, 1-800 NOCLOTS	Case series	Telephone consultation given by pediatric neurologist or hematologists to physicians requesting advice on the management of children with stroke.	Telephone stroke pediatric consultation service.	Baxter Bioscience California
LaMonte, 2003	Stroke	Maryland	Prospective case series	Explore feasibility and safety of tPA during telemedicine consultation.	1 Brain Attack Center and 1 ED, regional hospital.	University of Maryland Medical System, St Mary's Hospital, Bell Atlantic, Vtel and a grant from Genentech.
Meyer, 2008	Lancet Neurol	San Diego, STRokE DOC	RCT	To increase the effective use of thrombolytics for acute stroke and to explore whether telemedicine or telephone consultation was superior for decision making for treatment with tPA.	1 academic stroke center and 4 regional hospitals.	National Institute of Neurological Disorders and Stroke; California Institute of Telecommunication s Technology; Department of Veterens' Affairs Research Division.
Schwamm, 2004	Academic Emergency Medicine	USA	Retrospective case series analysis	To determine eligibility for treatment with tPA and provide support to emergency departments without on-site stroke expertise.	Stroke experts and emergency physicians at an island-based critical access hospital.	Not reported
Rymer, 2003	Stroke	USA, Kansas City (Mo)	Case series	Increas tPA treatment in regional areas	1 stroke center and 18 regional hospitals	Genentech, Inc
Vaishnav, 2008	Clinical Neurology and Neurosurgery	Kentucky	Retrospective observational study	To determine the safety of telephonic guidance for use of intravenous rtPA in rural hospitals.	Rural hospitals and 1 University medical center.	Not reported
Wang 2004	Stroke	Georgia, REACH	Case series	To expand the use of tPA via telemedicine in Remote Evaluation for Acute Ischemic Stroke program.	1 medical college and 5 rural hospitals.	Not reported
Wang, 2000	Stroke	USA, Illinois OSF Stroke Network	Case series	Examine the safety and outcome of tPA delivery in a stroke network supported by a stroke center.	1 stroke center and 20 hospitals	Not reported

ED=emergency departments, CT= computer tomography, TC=telephone consultation, VC=video consultation (videoconference), tPA= tissue plasminogen activator, MRI = Magnetic resonance imaging, PDA=personal digital assistant, RCT= randomized controlled trails, CCT=controlled clinical trials

3.1 Aims and Interventions of Telemedicine Systems

3.1.1 Aims and Interventions of Telemedicine in Acute Stroke Care

The aims of the studies involving telemedicine in acute stroke care were mainly to explore the safety and feasibility of a telemedicine system in order to improve the quality of care or to increase the use of tissue plasminogen activator (tPA) therapy for patient s with an ischemic stroke.

techniqus, safety, and feasibility

In Bavaria, Germany, a telemedical stroke network (TEMPiS) was established between several community hospitals and 2 academic stroke centres in order to improve the quality of care. Acute processes indicators and long-term outcome indicators were analysed to assess the effects. The telemedical system consisted of a digital network that included a 2-way real time video conference system allowing the transfer of computer tomography (CT) and/or magnetic resonance imaging (MRI) with a high-speed data transmission up to 2 Mb/s. Each community hospital implemented stroke wards consisting of qualified stroke teams. Physicians in the participating hospitals were able to contact the academic stroke centers on a 24 hours basis [43]. Wiborg et al. aimed to assess the feasibility, acceptance, and economic consequences of a telehealth network. Seven rural hospitals in the southern part of Germany in Swabia were connected to the stroke unit of Günzburg via a videoconference link. All teleconsultations were rated in terms of transmission quality and relevance of telemedicine for stroke management [44].

identify eligible patients for tPA

Schwamm et al. aimed to explore the feasibility of a videoconferencing system to identify patients eligible for tPA and to provide support to emergency departments [13]. In Choi et al. a videoconsultation system was established in order to screen stroke patients that might be eligible for tPA infusion. A further goal was to analyse whether the decision making process for inclusion or exclusion was appropriate [29].

increased safety and feasibility of tPA delivery

via videoconsulting system

Audebert et al. explored the safety and feasibility of increasing the use of tPA via the TEMiS telemedicine system [41]. Another study analysed whether the management and safety of tPA administration after telemedical consultation are equivalent in less experienced hospitals compared with tPA administration in academic stroke centers [42]. A Canadian study aimed to explore the feasibility and use of tPA via a real time video consultation. The neurologist on duty either in hospital or at home supported emergency physicians in rural hospitals through a 2-way videoconsulting system. CT scans were tranferred via the system and interpreted by the neurologist [47]. LaMonte et al. aimed to explore the safety and feasibility of tPA treatment via real time video consultation or telephone consultation [33]. The Remote Evaluation for Acute Ischemic Stroke (REACH) program is based on real-time audio video consulting technologies with the aim to to expand the use of tPA and bring guideline driven stroke care to rural underserved areas via telemedicine [32, 38].

or telephone-based system

Vaishnav et al. explored the safety of telephone-based systems in guidance for the use of intravenous tPA in rural hospitals [37]. Frey et al. developed a telephone-based network to support community emergency departments in the use of tPA. The aim was to increase tPA use in areas lacking sufficient neurological services [30]. A physician based telephone hotline developed by Kuhle et al. intended to assist physicians in pediatric stroke management. Since clinical trials are lacking in pediatric stroke, physicians caring for children with stroke face significant challenges. Patient characteristics and the specific nature of clinical challenges should inform the design of and priorities for developing relevant clinical trials [46].

pediatric stroke management

comparison telephone vs. video consulting:

Wong et al. aimed to compare and determine the differences between three consultation methods, namely telephone consultation, telephone consultation with teleradiology and videoconferencing with radiology. The analysis was based on process of care indicators, clinical outcomes, and cost-effectiveness [48]. Handschu et al. compared traditional telephone consultation to modern audiovisual linkage within the "Stroke Care using Telemedicine in Northern Bavaria" (STENO) project [45]. One study explored whether video consulting or telephone consultation was superior in decision making for treatment with thrombolytics [34].

in the use of tPA

feasibility of PDAs

One study aimed to explore the accuracy of the current wireless personal digital assistant (PDA) technology in emergency teleradiology [51].

3.1.2 Aims and Interventions of Telemedicine in Rehabilitation Settings

home-based telehealth

4 studies explored the effect of a home-based telehealth intervention in stroke rehabilitation settings [28, 31, 49, 50]. One study developed a telerehabilitation program involving a 3D motion tracking system to help stroke patients with an arm deficit [50]. 2 studies aimed to improve the problem-solving skills of caregivers of stroke survivors in home settings. Boter et al. developed an outreach care program for stroke patients discharged to home. Nurses supported patients and carers according to their individual needs, information on stroke was distributed and advice on improving problem-solving skills was given. The program consisted of telephone contacts and visits to patients' homes [49]. Grant et al. aimed to quantify the impact of social problem-solving telephone partnerships on the primary family caregiver of stroke survivors. The intervention started with an initial face-to-face session, followed by weekly and biweekly telephone contact to develop and maintain problem-solving skills over a 12- week period [31]. Buckley et al. aimed to identify factors that influenced the receptiveness, use and acceptance of telehealth videophones by family caregivers of stroke patients in the home setting [28].

problem-solving

receptiveness and acceptance

community based stroke rehabilitation

Lai et al. aimed to explore the feasibility of using a videoconsulting system in a community based stroke rehabilitation program. The intervention included educational talks, exercise and psychosocial support, which were conducted by a physiotherapist via a videoconference link [26]. Schoop et al. explored the use of a video consulting system in enhancing care for persons with brain injuries or stroke in three areas: cognitive assessment, psychotherapy, and rural mental health training. In the cognitive assessment the neuropsychological evaluation was conducted either in person or via interactive video consulting among rural residents with cognitive dysfunction. In the psychotherapy study a psychotherapist delivered behavioural therapy to geriatric patients in a rural inpatient rehabilitation unit who had a brain injury or had had a stroke via videoconsulting. In the mental health training intervention a network was established and a neurophysiologist trained rural mental health providers in issues related to traumatic brain injury [36].

Internet education

One study aimed to assess the feasibility of providing Internet based education to support caregivers of stroke survivors in rural communities. A further goal was to explore the experience of caregiving. The participants were linked to customized educational care giving "tips of the month" and educational information. They also had the possibility to participate in an e-mail consultation with a nurse specialist or rehabilitation team. An e-mail discussion forum was established, which offered caregivers the opportunity to communicate with each other and exchange personal experiences [35].

3.2 Processes, Personal Resourses & Population

3.2.1 Processes and Patient Selection in Acute Stroke Care

emergency department

stroke protocols or symptom criteria for selecting patients

different guidelines used

NINDS, ASA, JCAHC

contact processes

Acute stroke patients in telemedicine programs are generally triaged by emergency physicians at the regional community hospitals. Clinical stroke protocols [32, 38, 41-43, 47, 52] or stroke symptoms criteria list [30] were used to triage stroke patients in community hospital (Table 3.2-2.). In most telestroke networks the stroke protocols include a guideline driven criteria list for systemic tissue plasminogen activator (tPA) treatment. In two video consulting studies [13, 47] and in two telephone based studies [37, 39] patient eligibility for tPA and post-treatment management was evaluated in accordance with The National Institute of Neurological Disorders and Stroke rt-PA Stroke Study Group (NINDS) guidelines [52]. Two telephone based studies [30, 40] used guidelines from the American Stroke Association (ASA)[53], another developed a thrombolysis algorithm, and disposition of tPA protocols [42] and one [29] used the Joint Commission on Accreditation of Healthcare Organisation criteria for tPA treatment [54]. In the TEMPiS telestroke network the systemic tPA treatment was based on the European guidelines [41-43]. Different processes in contacting the stroke center have been described in the literature. Some telemedical systems allow the emergency physicians to contact the stroke team directly by telephone when a suspected stroke patient is triaged [29, 37, 39-44, 47]. In 4 telestroke programs the emergency departments in rural hospitals triaged suspected stroke patients by contacting the stroke center through a digital pager system [29, 32, 34, 38, 41]. In two systems the emergency physician called a coordinator who contacted the neurologist on call [33, 47].

patient characteristics

criteria for tPA exclusion

informed consent

The patient characteristics' of patients treated with tPA via telemedicine are presented in table 3.2-1. One major reason for the restricted delivery of tPA in telemedical settings, was that the 3 hour treatment window was exceeded before telemedical consultation [29, 32, 38, 41]. Other reasons for the exclusion of tPA were unclear onset of symptoms, visible hypodensity in computer tomography, severe clinical syndromes, mild clinical deficits or rapid symptom regression, suspected epileptic origin, and pre-treatment with anticoagulation [39]. In some studies a severe concomitant illnesses and NIHSS score greater than 20 points was cause for exclusion [29, 41, 43]. Another study reported that the most common reasons for not treating with tPA were a rapid improvement in a patient's condition and insufficient stroke severity (less than 4 points on the NIHSS) [32]. Written informed consent was obtained from the patient or a family member, which also was an important inclusion criterion [13, 34, 41-43].

Table 3.2-1: Patient characteristics' of tPA treated patients via telemedicine.

Study & Time Period	No of Patients	Age (mean)	Sex, % Female	Median Pre- NIHSS (range)	Inclusion/Exclusion Criteria	stroke Care Protocols
Audebert, 2005 Feb. 2003 – Apr 2004	106	61	41	13 (2-23)	tPA, European approval. NIHSS ≥20	Yes
Audebert 2006 Jan 1, 2004 – Dec 31, 2004,	Intervention hospitals: 115	69,7	44	12 (4-24)	tPA, European approval. NIHSS ≥20	Yes
Audebert 2006 Jul 3003- Mar 2005	Intervention hospitals: 80	N/A	N/A	N/A	tPA, European approval. NIHSS ≥20	Yes
Frey, 2005 1998 - 2002	TC, 53	67,02	35,8	N/A	American Stroke Association	Yes
Hess, 2005 Mar 2003 - May 2005	*30*	62	60	12.5	N/A	Yes (stroke Pathways)
LaMonte, 2003 1999 - 2001	5	N/A	N/A	N/A	N/A	N/A
Meyer, 2008 Jan 2004- Aug 2007	VC, 31	N/A	N/A	N/A	18 years, symptoms of acute stroke. No specific exclusion criteria.	N/A
	TC, 25	N/A	N/A	N/A		
Rymer, 2003 30 months	142	N/A	N/A	N/A	NINDS	Yes
Schwamm, 2004 27-months	6	N/A	N/A	16.3 (8–22) (mean)	NINDS	Yes
Vaishnav, 2008 Nov 2003 - Sep 2006	TC, 123	63.64	39.8	N/A	NINDS	Yes
Waite, 2006 Jul 2002 -May 2005	27	N/A	N/A	N/A	NINDS	Yes
Wang, 2004 Mar 2003 – Apr 2004	12	N/A	N/A	11.5	N/A	Yes
Wang, 2000 Jun 1996- Dec 1998	57	71	40	14	American Stroke Association	Yes
Choi, 2006 Apr 2004- May 2005	14	68,5	50	10 (5-25)	Joint Commission on Accreditation of Healthcare Organisation	N/A

In a real-time video consultation the neurologist can conduct a full neurological examination. The NIHSS score can be determined, tPA eligibility analysed, laboratory findings and CT scans transmitted and interpreted by an stroke expert. In other models patients´ CT scans are viewed during the real-time video consultations [32, 38, 45, 48]. One telephone based system did not allow transfer of CT images. In this intervention the CT scans were interpreted by an onsite radiologist [30]. Based on the medical findings the stroke specialist can provide the physicians with recommendations for stroke care and stroke management [13, 29, 33, 44, 45, 47, 48]. Additional history from the patient and family can also be obtained through telemedicine [38]. The patient is then either treated, admitted, released, or transported on the basis of the results from the telemedicine consultation [29]. In some studies an infusion of tPA was initiated in the community hospitals' emergency departments with continued infusion during transport, including air transport [30]. Patients treated with tPA through a telemedical system were likely to be transferred from the rural site to the stroke center for continued monitoring and surveillance [32, 37, 38]. Some studies reported that follow-up teleconsultations were possible at any time [44] including transmission of follow-up imaging [41-43].

real-time consultation

transfer of CT and laboratory findings

evaluation and

treatment

patient transfer

follow-up

5 studies were based on supportive telephone consultations [30, 37, 39, 40, 46]. Benefits and risks of tPA treatment were discussed with the stroke expert, and recommendations for management of blood pressure, fluids, and other relevant medical problems were given. An onsite radiologist interpreted the CT scans in the emergency department [30]. In another study the on call neurologist conducted a structured interview with the requesting physician at the regional hospital by telephone, but did not examine the patient directly. Afterwards the consultant was given a treatment recommendation and a verbal report of CT findings, laboratory data, and the clinical examination including blood pressure. [37]. In the physician based telephone hotline a neurologist or haematologist supported physicians in stroke management for children. [46]. 2 studies compared telephone consultation with video consultation [34, 45]. In one telephone service the hub consultant questioned the stroke practitioner about the patient's medical history, physical assessment, the results of laboratory tests, and the local radiologist's report of the CT brain scans. The remote neurologist supported the local practitioner in the NIHSS examination [34]. In another study medical history, symptoms and clinical findings, including findings from CT (or sometimes MRI) scans, were verbally reported by the local physician to the remote stroke expert. To guide the discussion a standard checklist covering standard stroke symptoms and clues for history and stroke risk factors as well as concomitant medication was developed. Stroke severity was quantified using the NIHSS score. Recommendations for further diagnostics and treatment were also discussed by telephone [45].

telephone consultation

pediatric telephone consultation

3.2.2 Settings & Personal Resources in Acute Stroke Care

Community telestroke hospitals without any previous neurological expertise are in general supported by one or two academic stroke centers (table 3.2-2). The number of participating network hospitals ranged from 1 to 8 hospitals.

stroke center support

regional emergency departments

In one telephone-based intervention one stroke center supported 43 community hospitals [30].

Table 3.2-2: Settings and personal resources

Study, Consultation Method	Settings	Personal Resources	Distance, Telestroke Hospitals
Audebert, 2005 VC	2 stroke centers, 5 community hospitals with stroke ward	SC: 3 neurologists or 1 emergency physician CH: N/A	N/A
Audebert, 2006 VC	2 stroke centers, 12 community hospitals with stroke ward (2 hospital with neurological department)	SC: 5 fulltime neurologists CH: physicians, nurses, physiotherapists, occupational therapists, and speech therapists	8-60 km (5-37 miles).
Audebert, 2006 VC	2 stroke centers, 12 community hospitals with stroke ward (2 hospital with neurological department)	SC: 5 fulltime neurologists CH: physicians, nurses, physiotherapists, occupational therapists, and speech therapists	N/A
Choi, 2006 VC	1 stroke centers, 2 community hospitals	SC: N/A CH: N/A	144 and 209km (90 and 130 miles).
Frey, TC	1 stroke centers, 43 community hospital	SC: N/A CH: N/A	N/A
Handschu, 2008 VC and TC	2 stroke centers, 2 community hospitals	SC: N/A CH: N/A	N/A
Hess, 2005	1 stroke centers, 8 community hospitals	SC: N/A CH: N/A	51-148km (32-92 miles).
Kuhle, 2006 TC	Telephone stroke pediatric consultation service.	Responder: paediatric neurologist or paediatric haematologist No. of callers not reported	N/A
LaMonte, 2003 VC and TC	1 stroke centers, 1 community hospitals	SC: 2 neurologists and 2 stroke nurses CH: N/A	160km (100 miles).
Meyer, 2008 VC and TC	1 stroke centers, 4 community hospitals	SC: N/A CH: N/A	48-563km (30 to 350 miles)
Reponen, 2000	Hospital, PDA device, remote neuroradiologist.	Radiology department remote neuroradiologist with PDA	N/A
Rymer, 2003 TC	1 stroke center and 18 regional hospitals	SC: N/A CH: N/A	Within 160 km(100 miles)
Schwamm, 2004 VC	1 stroke centers, 1 community hospitals	SC: N/A CH: N/A	N/A
Vaishnav, 2008 TC	1 stroke centers, 1 community hospitals	SC: N/A CH: N/A	N/A
Waite, 2006 VC	1 stroke centers, 2 community hospitals	SC: 6 neurologists CH: N/A	345 km and 390km (214-242 miles).
Wang 2004 VC	1 stroke centers, 5 community hospitals	SC: 3 neurologists or 1 emergency physician, CH: N/A	64-160km (40-100 miles).
Wang, 2000 TC	1 stroke center and 20 hospitals	SC: N/A CH: N/A	24-209 km (15-130 mile)s
Wiborg, 2003 VC	1 stroke centers, 7 community hospitals	SC: N/A CH: N/A	53 to 136 km (33-85 miles).
Wong, 2006 VC	1 stroke centers, 1 community hospitals	SC: N/A CH: N/A	N/A

VC=video consulting, TC telephone consulting, SC=stroke center, CH=community hospital.

In a telemedical network in Germany, TEMPiS, 5 fulltime neurologists at 2 academic stroke centers supported regional stroke wards. The stroke wards involves dedicated stroke teams consisted of physicians, nurses, physiotherapists, occupational therapists, and speech therapists [41-43].

stroke center support regional stroke wards

10 studies reported the distance between stroke center and the network hospitals [29, 32-34, 38-40, 43, 44, 47]. The distances ranged from 8-563 km (5-350 miles).

distances 8-560 km

Some studies reported information on personnel resources. In one study 3 neurologists or 1 emergency physician (one on call) supported 5 rural hospitals [38]. In another study 2 attending neurologists and 2 acute care stroke nurses supported one community hospital [33]. Another telemedicine network involved 6 neurologists at a University clinic, which served 2 regional hospitals [47]. Most studies did not provide any detailed information on personnel resources [13, 29, 32, 34, 37, 44, 48].

personal resources in video consulting systems

stroke experts/ neurologists

In one telephone based study healthcare personnel and the attending stroke neurologist supported 43 regional emergency departments. An onsite radiologist interpreted the CT scans [30]. In the pediatric stroke telephone service the remote responder was either a paediatric neurologist or a paediatric haematologist [46].

personal resources in telephone-based systems

3.2.3 Processes, Personal Resources and Patient Selection in Rehabilitation Settings

7 studies explored telerehabilitation interventions in stroke care for survivors and/or caregivers [26, 28, 31, 35, 36, 49, 50]. Patients included in these studies generally suffered from mild impairment after stroke and were living in home settings. Patients with mild/worse impairment of cognitive function or significant communication barriers were excluded [26, 50]. 4 of these studies involved caregivers of stroke survivors. The inclusion critera in one study were: caregiver had to be related by blood or marriage, at least 18 years or older, and had to be able to read and speak English. Access to telephone and television for the installation of technologies was another inclusion criterion [28, 31, 35, 49].

stroke patients and/or caregivers

criteria: mild impairment

criteria: related by blood, married, 18 years, speak English

4 programs were home-based telehealth interventions [28, 31, 49, 50]. In one study involved 13 telenurses, which supported patients and caregivers according to their individual needs [49]. In another study a nurse performed weekly videophone contact with family caregivers over a 6 week period [28]. One social problem-solving telephone partnerships intervention consisted of an initial 3-hour face-to-face session with a trained nurse at patient's home. The initial session was followed by weekly and biweekly telephone contact, which aimed to develop and maintain social problem-solving skills over a 12-week period [31]. One study aimed to restore arm deficits resulting from a stroke with an arm motion rehabilitation intervention. Workstations equipped with a 3D motion tracking system to record the arm movements using a magnetic receiver attached to a physical object were installed in patients' homes. The therapist at the hospital could move an object, and the system software recorded it and change it into a moving virtual image on the patient's screen. Thereafter the patient moved the physical object following the trajectory of the corresponding virtual object displayed on the computer screen in accordance with the requested virtual task. In this way the therapist could provide the patient with different virtual tasks and give

home-based setting

arm motion tele-rehabilitation

information as to whether the task was being performed correctly through the video consulting system [50].

community based rehabilitation

In a community based rehabilitation intervention 21 stroke patients were recruited by a physiotherapist after discharge from either a geriatric hospital or from a community centre for seniors. The included participants had suffered from a stroke within the last 6 months and were able to walk independently, with or without walking aids. A physiotherapist held educational talks for a group in a community centre for seniors. The class size was about 6 to 8 persons. The subjects participated in an eight-week intervention programme (1 session per week and 1.5 h per session) at a community centre for seniors. A non-professional assistant was stationed at the community centre to support the programme. The education component included the pathophysiology of stroke, signs and symptoms, medical management, rehabilitation pathways, the identification and modification of risk factors, psychosocial impact, community support, and home and environmental safety. The exercise programme was designed to improve strength and balance, mainly in the leg muscles [26].

cognitive assessment, psychotherapy and mental health training

Schoop et al. explored the use of a video consulting system to enhance care for persons with brain injury in the following 3 areas: cognitive assessment, psychotherapy and rural mental health training. In the cognitive assessment study 52 patients were enrolled and 52 persons served as controls. All participants had cognitive dysfunction associated with traumatic brain injury, learning disabilities, multiple sclerosis or other disabilities. In the psychotherapy study a psychotherapist delivered behavioural therapy to geriatric to 13 patients living in a rural inpatient rehabilitation unit via a video consulting system. A secondary objective in the study was to improve access to behavioural health care for patients with a brain injury through a cognitive assessment. This intervention include a neuropsychological evaluation conducted either in person or via a video consultation conducted among rural residents with cognitive dysfunction. In the mental health training intervention, 39 health care providers were included on educational training in issues related to traumatic brain injury via telemedicine [36].

Internet-based education and support

In an Internet-based intervention caregivers of stroke survivors could be linked to customized educational care and support, giving “tips of the month” and further educational information. The participants could also directly contact a specialist nurse or a rehabilitation team via e-mail. A discussion forum was set up on the Internet, which gave caregivers the opportunity to communicate with each other and exchange personal experiences [35].

3.3 Telemedicine Technologies in Stroke Management

real-time 2-way video consulting

telephone based system

PDA

Different telemedicine technologies were identified in the literature search on telemedicine and stroke management. Most of the studies involve a stroke center, which supported community hospitals in stroke management through either a videoconferencing or telephone system. Other studies were based on different rehabilitation telemedicine services for stroke patients or caregivers of stroke survivors. 19 studies used telemedicine technologies in acute stroke settings. 10 of these studies used a 2-way real-time audio video conferencing system. 3 articles were published on the German telemedicine network, TEMPIS [41-43] and 2 on the REACH program [32, 38]. 3 studies compared telephone consultation with video consultation [34, 45, 48]. 5 interventions used traditional telephones to support community or regional hospitals in acute stroke management [30, 37] [39, 40] [46]. One further study explored the accuracy of personal digital assistant (PDA) technology in the interpretation of CT brain scans [51]. 7 studies usedtelemedicine technologies for stroke patients or caregivers of stroke survivors in a rehabilitation setting.

3.3.1 Technologies in Acute Stroke Care

There are two main approaches in the use of telemedicine technologies in acute stroke care:

- 2-way real-time video consulting or
- a telephone based support system

transfer of laboratory data and CT

Before initiating a video consultation a telephone call is made. In video consulting networks different technologies can be used. Computer tomography (CT) and laboratory testing are standard equipment which is needed in the remote hospitals. Laboratory results and CT scans can be transferred through most systems. The neurologist in the stroke center examines and interprets the images and gives advice on stroke treatment and management. In models where the CT scans are not transferred through the telemedicine system an onsite radiologist can interpret and report the findings of the images. CT scans are necessary to exclude intracerebral bleedings, the absence of which is, among others, one criterion for the use of intravenous thrombolysis (tPA).

ISDN/Internet connection

A 2-way videoconferencing system with a transfer of medical data such as laboratory test results and brain scans requires monitors, video cameras, and microphones located on-site and at the stroke center. The video consulting networks are based either on a fixed point-to-point connection system dependent on Integrated Service Digital Network (ISDN), DSL or on an Internet connection. ISDN lines guarantee bandwidth availability as well as consistent quality of service but restrict the accessibility of the telestroke system to the facilities where the dedicated lines are installed [38]. Another study used a web-based videoconference tool consisting of store and forward 2-way audio and 1-way video consulting broadband Internet access (512 kbp) [32]. Choi et al. used a video consulting system with secure transmission by a point-to-point VPN connection [29]. 3 telephone based systems were identified in the literature on telemedicine in acute stroke management [30, 37, 46].

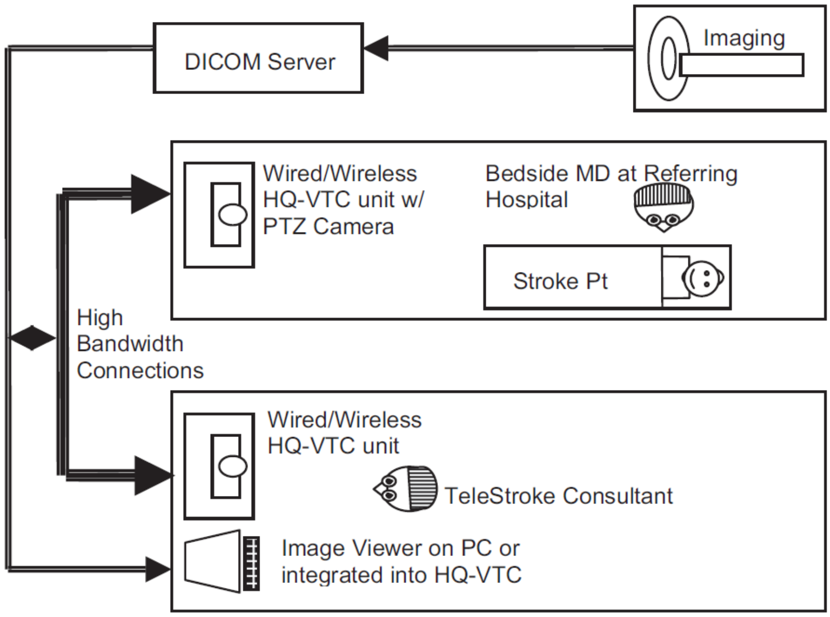

Figure 3.3-1: Telestroke schematic illustration. (Adapted from Rosenthal E, Schwamm LH. Telemedicine and stroke. In: Wooton R, Patterson V, eds. Teleneurology. London, England: Royal Society of Medicine Press, Ltd; 2005.)

telemedicine in decision taking on tPA

One study analysed whether real-time videoconferencing telemedicine or telephone consultation was superior in decision making for treatment with thrombolytics. It used a video consulting system based on laptops, with access to a 2-way real-time audiovideo internet connection. Brain CT images were viewed with a digital imaging and communications in medicine (DICOM) viewer. The hub consultant asked thepractitioner about the patient's medical history, the physical assessment, the results of laboratory tests and the local radiologist's report of the CT images [34].

PDAs in interpreting brain CT scans

One study explored the accuracy of the current technology of PDA/personal digital assistant in emergency teleradiology. Images were sent from a radiology department to a PDA. A transmission control protocol/Internet protocol connection between the PDA terminal and the teleradiology server of the hospital was established using the commercial GSM data service. The CT images (brain scans) were interpreted by a neurologist [51].

security

The privacy and security of the system can be maintained by using secure socket layer conditional access, data encryption, intruder alerts, and access logging and reporting. These security features ensure adherence to the Health Information Portability and Accountability Act for virtual telestroke consultations.

Most operating systems incorporate a remote pan-tilt-zoom interface to give a remote user full control over the transmitted image. Some systems have the possibility to record and store the consultation [55].

3.3.2 Technologies in Rehabilitation Settings

7 studies using telemedicine technologies in rehabilitation for stroke patients or caregivers of stroke survivors were found. 2 studies were based on a traditional telephone system [31, 49], one used a videophone system [28]. 3 studies used video consulting technologies [26, 36, 50] and one study used Internet for education and support via WebTV technologies [35].

real-time video consulting

Lai et al. used video consulting technologies between a hospital and a community centre for seniors for community-based stroke rehabilitation. The intervention was conducted by a physiotherapist who held educational talks, and exercise and psychosocial support sessions through a 2-way real-time video consulting system via a broadband connection [26]. Schopp et al. used a 2-way video teleconference system delivered over a T1 line to assess cognitive, psychotherapy and mental health training for persons with a brain injury living in rural areas. The videoconferencing systems were installed in patients' homes [36]. Pierce et al. used a WebTV with Internet access to provide Internet based education and support for caregivers in rural communities [35].

WebTV

3D motion tracking system

One study used a 3D motion tracking system, which aimed to restore arm deficits resulting from stroke. Workstations were equipped with a 3D motion tracking system to record the arm movements with a magnetic receiver attached to a physicall object. In addition, the therapist provided the patient with information as to whether the task was being correctly carried out through the video consulting system. The workstations were connected by ISDN lines [50].

telephone based system

One of the 2 studies using a telephone system was an outreach nursing care program for discharged stroke survivors at home. Nurses aimed to support patients and carers according to their individual needs e.g. advised them how to solve and cope with problems themselves [49]. The other study aimed to develop and maintain discharged stroke survivors' primary caregivers' problem-solving skills using telephone contacts partnership [31].

videophone system

In the videophone study caregivers of stroke survivors were supported by telehealth nursing services. The study aimed to identify factors that influenced the receptiveness to, use, and acceptance of telehealth technologies of caregivers of stroke patients in a home setting [28].

3.4 Outcome Categories Measured

3.4.1 In Acute Stroke Care

quality of care indicators

Different outcome indicators are in use to measure the quality of care. The most common quality of care indicators reported in the studies were [13, 43, 44]:

- mortality,
- rate of systemic thrombolysis,
- intracerebral hemorrhages (after tPA delivery),
- length of stay,

- rate of transfer and,
- use of different diagnostic procedures, and applied therapies including physiotherapy and occupational and speech therapy.

stroke severity

In the studies, different instruments are used to measure stroke severity. In TEMPiS, a cumulative number of neurological deficits were used [43]. 2 others used the modified Ranking scale/mRs to measure stroke severity [30] and effectiveness of treatment [44]. In some studies the NIHSS scale was used at baseline and sometimes post-treatment and in follow-up.

cormorbities

appropriate decision/ diagnostic accuracy

Some studies collected data on comorbities [42, 43] including cardiovascular history [44], arterial fibrillation, coronary disease, congestive heart failure, recurrent stroke, diabetes mellitus, hyperlipidemia, hypertension, patent foramen ovale, and active tobacco use [29]. One study explicitly analysed whether the decision to give thrombolytic treatment was appropriate [34]. Another study analysed diagnostic accuracy [48].

process indicators

Different process indicators were applied in the telestroke programs:

- time needed for the consultation process,
- transfer rate,
- unfit for interhospital transfers (critical ill patients),
- transportation time and
- if any adverse event during transfer, and
- if any transfer was unnecessary [48].

In TESS the time of admission and stroke onset, time span between first telephone call and start of the video consulting, and duration of teleconsultation was collected [44]. One study also registered data on avoidance of transfer. 11 Patients transfer to another hospital were avoided due to the telemedical intervention [13].

process quality indicators of tPA delivery

Most studies used at least one of the following indicators to measure processes in tPA delivery [13, 29, 30, 38, 41, 42]:

- time from onset of stroke symptoms to admission („onset-to-admission“ also called “onset-to-hospital”),
- time from admission to thrombolysis („door-to-needle“), and
- time from stroke symptoms onset to thrombolysis („onset-to-needle“).

Other process indicators identified in the literature were: admission to CT scan, CT scan to treatment time, [37, 42], and door to NIHSS evaluation [32, 38].

health outcome indicators

follow-up

Different stroke scales such as the Glasgow Coma Scale [48], NIHSS [13, 29, 34], modified Rankin scale [34], and Barthel Index [34] were used in some studies to determinein-/dependence after stroke care. Some studies also reported information on discharge disposition (home, rehabilitation facility, nursing home etc.), which can give some information on the health status after treatment [30, 38]. In TEMPiS the follow-up analysis was managed centrally and undertaken by a specially trained interviewer. 3 months after admission a standardised telephone interview or a postal questionnaire was sent to the patient. The patient or caregiver provided information about mortality, institutional care, Barthel index, and modified Rankin scale score. Patients' discharge destination was also documented [43]. At follow-up, CT or MRI scanning was also used [32].

3.4.2 In Rehabilitation Settings

7 telerehabilitation studies were identified in the literature search, all interventions used different outcome measures (Table 3.4-1). 4 studies were on home-based interventions [28, 31, 49, 50], one on a community based intervention, one on a Internet based Intervention and one on a satisfaction and acceptance intervention.

home-based

Table 3.4-1: Outcome categories measured in telerehabilitation studies.

Study, Intervention	Outcome Category Measured
Home-based telehealth	
Boter, 2004 Outreach care program consisting of telephone contacts and a visit to the patients in their homes.	Primary outcome measures: Satisfaction-With-Stroke-Care questionnaire and Short Form Health Survey /SF-36. Secondary outcome measures: the Hospital Anxiety and Depression Scale, Dissatisfaction with care, SASC-19, Barthel Index scale, modified Rankin scale, Caregiver Strain Index and Sense of Competence Questionnaire and Discrepancies, Social Support List–Discrepancies.
Buckley, 2004 Explore the receptiveness and utilization of telehealth call by caregivers of stroke survivors.	Information on Patient-Caregiver Functional Unit Scale, receptiveness, utilization Patterns. Nurses' and caregivers' acceptance of telephone intervention were collected through interviews.
Grant, 2002 To develop and maintain problem-solving skills over telephone partnerships intervention.	SF-36, Social Problem-Solving Inventory the Client Satisfaction Questionnaire, 20-item Center for Epidemiological Studies Depression Scale Preparedness for Caregiving Scale subscale of the Caregiving Burden Scale.
Piron, 2004 Restore arm deficits resulting from stroke via a telerehabilitation intervention.	Fugl-Meyer and Functional Independence Measure scale.

community based intervention

Internet based

satisfaction/ acceptance

Community based intervention	
Lai, 2004	Primary outcome measures: the Berg Balance Scale State, Self-Esteem Scale, SF-36, Knowledge test on stroke, a questionnaire to evaluate satisfaction Secondary outcome measures: the Geriatric Depression Scale/GDS-15 Elderly Mobility Scale, the Lawton Instrumental Activities of Daily Living Scale.
Internet based	
Pierce, 2004 Assess the feasibility of providing Internet based education and support for stroke caregivers in rural communities.	Functional Independence Scale. Qualitative methods to explore participants training and use of the intervention and Internet
Satisfaction/acceptance	
Schopp, 2000	Patient and provider satisfaction

satisfaction & acceptance

5 studies reported outcomes on user or patient satisfaction and acceptance of telemedicine technologies in stroke rehabilitation settings [26, 28, 31, 36, 49], one study explored this objective exhaustively [28].

3.5 Organisational and Institutional Outcomes

3.5.1 Technical Failures

human error

In 2 studies technical failures occurred due to human errors: a remote member of staff plugged the telemedicine machine into the wrong outlet. The treatment was continued over the telephone [29]. In another study a network configuration failure compounded by a human error was reported. On one occasion the neurologist could view the first image but not the following images. On another occasion the remote access software conflicted with the video conferencing software leading to a delay [47].

videotape archive

radiological interface

audio

In a video consulting intervention 6 of 24 (25%) consultations were not completely captured due to technical limitations in the videotape archive [13]. In another study, 2 videoconsultations out of a total of 23 consultations (10%) were aborted, because of technical difficulties [33]. In one study, of 77 video consultations performed 2 were aborted. Treatment could be continued by telephone [45]. The reason for the technical failure was not reported in these two studies [33, 45]. Another study reported 12 technical failures during video consultation: one case could not be completed, and in the other 11 cases 6 problems related to the radiological interface were reported. In 3 cases audio difficulties were reported. In one case the camera control had a failure, and in one case a delay in obtaining faxed consent was reported [34]. In a rehabilitation intervention the nurses reported audio- and video transmission problems in using the videophones [28].

logistical/ organisational problems

In one video consulting intervention logistical problems were the reason for the high failure rate of 30.1%. Lack of a dedicated team of medical personnel and the fix location of the telemedical technologies were mentioned as reasons for the failure. A further problem reported in the study was that intra-hospital transfer of critically ill patients was often regarded as harmful by the referring physician [48].

no adverse health effects

There were no adverse health outcome effects reported due to the technical failures [13, 29, 47].

3.5.2 Reported Organisational Hinderances, Advantages/Disadvantages

necessity: 24h service

Most telemedicine interventions in acute stroke care provided a 24-hour service [29, 32, 37, 38, 41-44, 47] or reported the need and importance of a 24-hour service [33]: This means a remote stroke expert is always available and that the community hospitals must have 24-hour access to diagnostic procedures including CT scans, laboratory exams, and sometimes doppler sonography [41-43]. In the Canadian telestroke network 63% of the incoming calls to the stroke center were outside normal business hours [47].

success factor: stroke protocols:

ASA,

NINDS

etc.

The implementation of stroke protocols for triaging patients and stroke care [13, 30, 32, 33, 37, 38, 41, 47] is reported as an essential part of successful telemedical interventions in acute care. In one telephone intervention the participating community hospitals were provided with evaluation and order forms by the stroke center. These protocols included guideline-driven tPA delivery based on the American Stroke Association (ASA) guidelines [30]. 3 studies used the inclusion and exclusion criteria for tPA based on The National Institute of Neurological Disorders and Strokert-PA Stroke Study Group (NINDS) [13, 37, 47]. The stroke care in TEMPiS hospitals was based on standardized stroke care protocols. Guidelines for tPA treatment was based on European guidelines [41]. In the American REACH program stroke care protocols and evidence-based stroke pathways and order sets were implemented in the rural hospitals [32, 38].

fix site system

web-based system

Both of the two technological real-time video consulting systems (fixed-site and one web-based) have advantages. The web-based model can be initiated from almost any location, provided that the device has access to public Internet and the software program is installed. The advantage of the web-based model is the flexibility and time that is saved by avoiding the travel of the consultant to the hub sites [33, 38, 47]. On the other hand, a dedicated link (ISDN) with a fiber optic system has a superior video and audio resolution compared to an Internet based system [29]. ISDN lines guarantee bandwidth availability and quality, but have restricted accessibility. When using a web-based system the connection to a specific Internet provider may fail. Congestion and dropped packets are further problems inherent to using the Internet, and bandwidth, downstream and upstream, are not always steady [38].

stroke education involvement of dedicated personnel

process improvements

Stroke education, initial training, and ongoing education for health personnel was reported as a key factor in the success of telestroke interventions [32, 33, 41-44]. The training in TEMPiS included training in the use of the National Institutes of Health Stroke Scale/NIHSS, the implementation of a thrombolysis algorithm, and the disposition of tPA protocols [41-43]. 3 studies reported shorter process times after the program had been running for some time compared to the early stages of implementation [29, 32, 41]. The onset to treatment time became shorter because of the educational efforts that improved the recognition of stroke and prompted an earlier activation of the system [32]. Another study reported an increase in the tPA rate in the second phase of the intervention. Increased public awareness and better pre-hospital stroke management achieved by the continuous educational activities in the regional hospitals were proposed as the reason for the increased use of tPA [41].

lysis box

To facilitate the utilization of tPA in the TEMPiS network hospitals a so-called stroke lysis box was distributed to all community hospitals. This box contained all the necessary tools and medications for tPA delivery [56].

air transport

excellent intra-transport care

logistics

shareing responsibility

The availability of emergency air transport was reported in one study as an important factor for success. One further key factor was the active involvement of paramedics personnel that appreciated the urgency of stroke making a rapid response and excellent intra-transport care possible [30]. In the TEMPiS network the establishment of a central organization of emergency interhospital transfers was reported as an additional important factor [41-43]. One study reported a high failure rate, which was due to logistical problems and that intrahospital transfer of critically ill patients was often regarded as unsafe by phycicians in the community hospital [48]. The stroke center's willingness to share responsibility for decision making and accept patients for transfer was an essential factor for good practice [30].

investments

One study mentioned the initial costs of equipment and staff training as potential barriers to implementing a telemedical system [33].

health providers' acceptance

TESS reported differences in the utilization of the telemedical service between the participating hospitals. One hospital represented 86% of the total number of consultations. Reasons for this were the additional time needed to transporta patient to the videoconference room and obtaining a patient's informed consent. The service needed more documentation, which was hard to obtain without additional medical staff in the local hospitals [44].

limitation in technology

The use of PDAs for interpreting brain CT images was not optimal. Disadvantages were found in the quality of pictures and the transmission time was not quick enough. Display technology, resolution and network speed must be improved before PDAs can be widely accepted in general teleradiology departments. The transmission bandwidth of GSM data was too slow (9600 bit/s) [51]. In the videophone intervention equipment failures were reported, and the the small size of the monitor was mentioned as the reason for limited utilization [28].

Other factors to ensure success reported were: the importance of a close relationship between the clinical staff and the technology support personnel [33], an appropriate compensation for physician consultation, the use of an existing physician referral call system which was familiar to referring emergency departments, and the integration of telestroke interventions into routine practice [47].

3.5.3 Satisfaction and Acceptance

in acute care: seldom reported

Only 3 studies reported on satisfaction with telemedicine interventions in acute stroke care. Overall patients and health care providers reported high levels of satisfaction and acceptance, but few studies had the evaluation of satisfaction and acceptance as a main objective [13, 33, 44]. In one study physicians reported that they believed that telestroke improved care in 95% of cases. Both stroke neurologists and emergency physicians frequently believed that telephone consultation alone would not have been equivalent to video consulting. In most cases patients reported that telemedicine was as good as a face-to-face meeting [13].

in rehab: convenience, decrease of isolation and stress

5 studies reported on user or patient satisfaction and acceptance of telemedicine technologies in stroke rehabilitation settings [26, 28, 31, 36, 49]. In one community based stroke rehabilitation program the patients considered the intervention to be good or excellent in 63% and 36% of cases respectively [26]. In the videophone intervention the telehealth nurses and caregivers accepted the new technology: the most frequently mentioned benefit of the videophones by both groups was that it offered a convenient method of communication and exchange of information. Some caregivers mentioned that home-based telehealth decreased their isolation and the stress associated with being at home and assuming the role of the primary caregiver. Almost all participants reported an easy use of equipment [28]. In the outreach care intervention, in both groups (intervention and control group), one-fifth of the patients reported that they were dissatisfied with care received in the hospital, and half were dissatisfied with care received after discharge [49]. In the problem-solving skills telephone partnerships intervention the satisfaction with healthcare services decreased over time in the control group while remaining similar in the intervention and sham intervention groups [31].

3.6 Costs

resource use

increase use of tPA=cost saving

initial investments

around $ 6000-8000 per set

Few studies assessed the impact of telestroke on resource utilization. Most studies only mentioned investment costs, but not maintenance costs, and only one study dealt with cost-effectiveness, e.g. the avoidance of other costs. Wong et al. a noted higher mean cost per patient in the video consulting group compared to the telephone group and teleradiology group, respectively, although none of the differences were statistically significant [48]. Audebert et al. reported that the TEMPiS service costs were approximately 300 000 € per year. Calculated savings for the network are between 3200 € to 4200 € per thrombolysis, the absolute increase of 76 tPA treatments within 1 year would produce a reduction of subsequent costs of between 243 200 € and 319 200 €. After the subtraction of the teleconsultation expenses, the net expenses varied between 56 800 € and 19 200 € per year. This means that the telestroke service is cost-effective only when screening tPA candidates via video consultation [41]. The total cost for one telemedical workstation is approximately 16,000 Euro [57]. In REACH the investment costs reported were moderate, consisting of a $ 6000 telemedicine cart and the establishment of adequate information technology to handle Internet connectivity. The costs to the rural hospital in this system are minimal and only involve maintaining broadband Internet access and a

DICOM-compatible computer tomography scanner. The additional personal cost for maintaining the system was not reported [32]. In Wiborg et al. all hospitals were provided with a video consulting system, which cost, approximately $ 8000. The system consisted of a portable device including a color video camera and microphone that could be connected to a commercial television monitor. Data were transmitted over 3 parallel integrated services digital networks (ISDN) [44].

In Buckley et al. where a telerehabilitation service for the caregivers of stroke patients was set up, the videophones cost approximately $500 per unit [28]. PDAs for interpretating CT brain scans cost 1000 € ($1000) per set [51].

additional technical personnel

Some studies reported the need of technical personal for installing, training and maintenance of the telemedical system [35].

3.7 Presented Results in the Telestroke Studies

3.7.1 Results of Acute Stroke Care Studies

quality of care

feasibility

The reported results after the implementation of telestroke programs are as follows. In TEMPiS the patients received physiotherapy, speech therapy and occupational therapy up to ten times more often in the telemedicine group than in the control group. There was a higher in-hospital mortality reported in the control hospitals than in the telemedicine group [43]. In Wiborg et al. a total of 623 strokes were registered in the participating hospitals, and 153 (25%) stroke patients were examined by teleconsultation. Relevant contributions could be made in >75% of the cases concerning diagnostic workup, CT assessment, and therapeutic recommendations. 40 patients were revealed to have a diagnosis other than stroke [44]. Another study reported that the physicians believed that videoconferencing improved care in 95% of the cases [13].

consultations times

3 studies reported total examination times of video or telephone consultations. In one study the mean time was 15 minutes for a video consultation [44] and in another study the median duration was 15 minutes including transmission of CT scans [41]. One study compared examination times of a telephone consultation and video consultation. The duration of the pure video examination was 17.8 min (9–35 min), and was 13.6 minutes (6–30 min) for the telephone consultation. Accounting for all directly related processes such as preparation and documentation, the video consultation took 49.8 minutes (29–62 min) at the stroke center and 44.2 minutes (35–60 min) at the local hospital. The telephone consultation took a mean time of 27.2 minutes (15–38 min) at the stroke center and 22.3 minutes (10–29 min) at the local hospital [45]. Wong et al. compared telephone consultation, video consultation and teleradiology in neurosurgical patients. The consultation process time for video consultation was 1.30 hours (SD 2.5 hours), which was longer than the telephone consultation, which took 0.70 (SD1.9 hours). On average, teleradiology consultation took 1.01 (SD1.8 hours) [48].

Handschu et al. reported that a change in diagnosis was more frequent in the telephone consultations group than in the video consulting group 17,6 % and 7,1 % of cases respectively [45]. One study aimed to determine the differences between 3 consultation methods (telephone consultation, and telephone consultation with teleradiology and videoconferencing with radiology) on the basis of their process-of-care indicators, clinical outcomes, and cost-effectiveness. The diagnostic accuracy of the telephone consultation service (63.8%) was significantly lower than that of teleradiology consultation (89.1%) and video consultation services (87.7%). There was a reduction in mortality (25%) and a trend toward more favorable outcomes (61%) in the teleradiology consultation group compared with the telephone (54% and 34%) and videoconference (54% and 33%) consultation groups. The mean cost per patient in the videoconference group ($ 16,300) was slightly higher than in the telephone consultation group ($ 14,000) and teleradiology group ($ 14,400), although the differences were not statistically significant [48].

diagnostic accuracy

costs

13 studies reported on the delivery of tPA treatment via telemedicine (table 3.7-1). 9 studies used video consulting technologies [13, 29, 32-34, 38, 41, 44, 47], 4 studies were based on telephone consultations [30, 37, 39, 40] and 2 studies used both telephone consultation and video consultation [33, 34]. The number of consultations differs widely in the studies with a range from 24 to 2182 consultations. In the included studies, a total of 829 patients were treated with tPA via telemedicine support. 2,4% to 30% patients consulted with telemedicine recived tPA treatment. 7 Studies provided information on the age of tPA treated patients. The mean age of the patients treated in the included studies was 66,2 years, females were less represented, 45%. Mortality ranged from 0-50%, although the small number of tPA treated patient in some studies strongly influence this high number. Intracerebral hemorrhages are a risk factor when giving tPA treatment. In the NINDS study intracerebral hemorrhages occured in 6,3% of the cases [52]. In a Cochrane Review symptomatic intracranial hemorrhage with thrombolysis occurred in 8.7% of the cases [10]. In the telestroke networks intracerebral hemorrhage was reported in between 0%-16,7 % of cases. In Meyer et al. the mortality was higher in the video consultation group (39%) compared to the telephone group (12%), but after adjustment for the imbalanced NIHSS score at baseline no statistical difference was found [34]. The median baseline NIHSS scores range from 10-14 in the telemedicine studies.

tPA delivery via telemedicine

2,4% to 30% tPA

intracerebral hemorrhages 0%-16,7%.

NIHSS in telestoke patients

Table 3.7-1: Systemic thrombolysis via video consulting and telephone consulting

Study	Numbers of Consultations	Receiving tPA	Population Characteristics (tPA)	Numbers Transported to SU	Outcomes				Processes
					Mortality	ICH	Hospital Stay	Discharge Destination	
Audebert, 2005	VC, 2182 (356 tPA candidates)	106 (30%)	Mean age: 68 Female (%):41 Median pre-NIHSS: 13	N/A	In-hospital mortality 11 (10.4 %) Mortality within 7 days, 6 (5.7%)	15 (8,5%)	12 days (median)	N/A	Door-to-needle: (mean) 76 min Onset-to-hospital (mean): 65 min Onset-to-needle: N/A
Audebert, 2006	VC, 709	80	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Audebert, 2006	VC, N/A	115	Mean age: 69,7 Female (%): 50 Median pre NIHSS: 12	N/A	In-hospital mortality 4 (3,5%) Mortality within 7 days, 4 (3.5%)	9 (7,8%)	10 days (median)	N/A	Door-to-needle (mean): 68 min Onset-to-hospital (mean): 64 min Onset-to-needle (mean): 134 min
Choi, 2006	VC, 328	14 (4,3%)	Mean age: 68,5 Female (%): 50 Median pre NIHSS 10	10	N/A	0	N/A	N/A	Door-to-needle: (median) 85 min Onset-to-hospital: N/A Onset-to-needle: N/A
Frey, 2005	TC, N/A	53	Mean age: 67,02 (36-89) Female (%):35,8 Median pre-NIHSS: N/A	53	4 (7%)	3 (6 %)	(Median) 5, (1-16)	Home: 16 Rehab.: 22 Skilled nursing facility: 11	Door-to-needle: (mean) 105 min. Onset-to-hospital: (mean) 60 min Onset-to-needle: (mean) 165 min
Hess, 2005	VC, 194	30 (23 %)	Mean age: 62 Female (%):60 Median pre-NIHSS:12,5	N/A	N/A	0	N/A	N/A	Door-to-needle: N/A Onset-to-hospital: N/A Onset-to-needle: (mean) 122 min

Study	Numbers of Consultations	Receiving tPA	Population Characteristics (tPA)	Numbers Transported to SU	Outcomes				Processes
					Mortality	ICH	Hospital Stay	Discharge Destination	
LaMonte, 2003	VC, 27	5 (18,5%)	Mean age: N/A Female (%):N/A Median pre-NIHSS: N/A	5	0	0	N/A	N/A	Door-to-needle: N/A Onset-to-hospital: N/A Onset-to-needle: N/A
	TC, 23	1 (4,3%)		1	0	0	N/A	N/A	
Meyer, 2008	VC, 111	31 (28%)	Mean age: N/A Female (%):N/A Mean pre-NIHSS: 16.,3(VC) 12,3(TC)	19	3 (12%)	2 (7%)	N/A	N/A	Door-to-needle: N/A Onset-to-hospital: N/A Onset-to-needle: N/A
	TC, 111	25 (23%)		18	12 (39%)	2 (8%)	N/A	N/A	
Rymer, 2003	TC, N/A	142	Mean age: N/A Female (%):N/A Mean pre-NIHSS: N/A	99	18 (12,7%)	9,2%	N/A	N/A	Door-to-needle: N/A Onset-to-hospital: N/A Onset-to-needle: 119
Schwamm, 2004	VC, 24	6 (25%)	Mean age: N/A Female (%):N/A Mean pre-NIHSS: 16.3 (8–22).	N/A	N/A	1 (16,7%)	N/A	N/A	Door-to-needle: (mean) 106 min Onset-to-hospital: N/A Onset-to-needle: N/A

Study	Numbers of Consultations	Receiving tPA	Population Characteristics (tPA)	Numbers Transported to SU	Outcomes				Processes
					Mortality	ICH	Hospital Stay	Discharge Destination	
Vaishnav, 2008	TC, N/A	123	Mean age: 63.64 Female (%): 39,8 Median pre-NIHSS: N/A	123	9 (7,5%)	3 (2,5%) symptomatic ICH 11 (9%) asymptomatic ICH	4 days (mean)	Home: 47%	Door-to-needle: N/A Onset-to-hospital: (mean) 54 min Onset-to-needle: (mean) 137 min
Waite, 2006	VC, 88	27 (30%)	Mean age: N/A Female (%):N/A Median pre-NIHSS: N/A	N/A	1 (3,7%)	0	N/A	N/A	Door-to-needle: N/A Onset-to-hospital: N/A Onset-to-needle: N/A
Wang, 2004	VC, 75	12 (16%)	Mean age: N/A Female (%):N/A Median pre-NIHSS: 11,5 (Mean 14.3)	N/A	N/A	0	N/A	Home: 5 Rehab: 3 Nursing home: 1	Door-to-needle: (mean) 104,9 min Onset-to-hospital: (mean) 70.9 min Onset-to-needle: (mean) 135.3 min
Wang, 2000	TC, N/A	57	Mean age: 71 Female (%): 40 Median pre NIHSS: 14	N/A	5 (9%)	5 (9%)	6,2 days	Home: 31 Rehab: 14 Nursing home: 7	Door-to-needle: N/A Onset-to-hospital: N/A Onset-to-needle: 155
Wiborg, 2003	VC, 153	2 (0,6%)	Mean age: 60 Female (%): 0 Median pre NIHSS: N/A	1	1 (50%)	N/A	N/A	N/A	Door-to-needle: N/A Onset-to-hospital: N/A Onset-to-needle: N/A

N/A=not applicable, VC=video consulting, TC, telephone consulting, CT=computer tomography, tPA.= tissue plasminogen activator, ICH=intracerebral hemorrhages, NIHSS= The National Institutes of Health Stroke Score, SU=stroke unit (stroke center)

Different process indicators were used reported in the studies (see appendix III). Most studies reported time from onset of stroke symptoms to admission („onset-to-hospital"), time from admission to thrombolysis („door-to-needle"), and time from stroke symptoms onset to thrombolysis („onset-to-needle"). The mean "onset-to-hospital" time ranged from 54-70,9 minutes, the mean "door-to-needle" time ranged from 76-106 minutes, and the mean "onset-to-needle" time range from 122-165 minutes.

onset-to-hospital

onset-to-needle

door-to-needle

The media length of hospital stay varied from 12 days in TEMPiS [41] to 5 days in a telephone based study [30]. Another study reported a mean length of hospital stay of 4 days [37]. In the STENO project the mean length of stay was 11,4 days in the video consulting group compared to 12,3 days in the telephone group [45]. In TEMPiS did one study explore patients' health at 3 months follow-up by comparing patients treated in telestroke hospitals with patients treated in hospitals without telemedical technologies. Mortality, institutional care, Barthel index, and modified Rankin, scale (MRS) score were analysed. Mortality in percentage of patients treated in the intervention hospitals who died within the first 3 months was 16% compared with 18% in the control group ($p=0{\cdot}20$). A total of 44% of patients in the intervention group had a poor outcome (modified Rankin score >3 or Barthel index <60.) after 3 months versus 54% in the control group ($p<0.0001$) [43]. In a RCT study, which compared video consultation with telephone consulting technologies reported no differences at 3-month follow up between the two groups. The functional outcomes were measured with Barthel Index and modified Ranking score [34].

length of stay

follow-up

In one telephone based program tPA treatment was initiated in the rural hospital and continued during a transfer to the stroke center [30]. In another intervention patients treated for intravenous thrombolysis in community hospitals 58 % of those consulted by telephone and 76 % by video consulting were thereafter transported to a tertiary medical center [34]. In other studies all patients treated with tPA via telemedicine were transported to the stroke center [33, 37]. In Audebert et al. 248 (13%) patients in the telemedicine group were transferred to other hospitals or departments and in the control group 146 were transferred (13%) [43]. In Wang 75 patients were given consultations using telemedicine and 54 were transferred (72%) to the stroke center [38]. In another study of 153 telestroke patients 8 (5%) were transferred to a stroke center [44]. One study compared the transfer rate between patients treated through video consulting and by telephone. 9,1 % from the video consulting group were transported to the stroke unit compared to 17,6 % from the telephone consultation group [45]. One video consulting study reported that transfer to another hospital was avoided in 11 cases [13].

transfer:

58% - 76 % of patients,

all tPA patients

9,1 % video consulting group

17,6 % telephone group

In one study 53 patients were treated with tPA via telephone consultation and of those 16 patients were discharged (30%), 22 moved to a rehabilitation clinic and 11 to a skilled nursing facility [30]. In another telephone based intervention 47% of 123 tPA treated patients were discharged [37]. In a video consulting intervention 12 patients received tPA treatment whereby 5 were discharged (42%), 1 was moved to a nursing home, 3 patients moved to a rehabilitation clinic, and in 3 cases was data missing [38]. Another study reported that 3 of 6 patients treated with tPA were independent 6 months after having a stroke [13].

discharge destination:

after tPA treatment 30% - 47% to home

correct treatment decisions:

more often correct in video consulting than in telephone

One RCT compared 111 telephone consultations and 111 video consultations in order to assess whether video consultation is better for decision making in acute telemedicine consultations. A correct treatment decision was more often reported in the telemedicine group than in the telephone group, 108 (98%) compared with 91 (82%). The overall tPA rate was 25%, 31 (28%) in the telemedicine group and 25 (23%) in the telephone group. Hemorrhage bleedings occurred in 2 (7%) tPA treated patients via telemedicine and in 2 cases (8%) in the telephone group. There was a difference in the unadjusted mortality (39% telemedicine vs 12% telephone, 4·6, 1·1–19·0; p=0·034); however, after adjustment for the imbalanced NIHSS score at baseline, the difference was not significant (p=0·17) [34].

safety of tPA delivery:

higher intracerebral hemorrhage rate after tPA in regional hospitals

One study explored the safe administration of tPA in an academic stroke center compared to in telemedical community hospitals. 115 of 4727 (2.4%) patients with an ischemic, hemorrhagic or TIA diagnosis received tPA in 12 participating community hospitals. 110 of 1889 (5.8%) patients were treated with tPA in 2 university hospitals. There were no statistically significant differences in mortality: 3.5% in the regional hospitals and 4,5% in the academic stroke centers. Thesymptomatic intracerebral hemorrhage rate was higher in the community hospitals 7,8% than in the stroke centers 2,7% [42]. In a stroke network of community hospitals located within 100 miles of a stroke center, 53 of 142 tPA-treated patients had tPA treatment initiated in the referring hospital after telephone consultation. These patients had an acceptable hemorrhage rate, 9,2% [39]. Comparing the patients transferred after intravenous tPA with those receiving intravenous tPA at the tertiary referral center showed that there were no differences in mortality, percentage with NIHSS <6, or length of stay [58]. Increased use of intravenous tPA has also been observed in a telephone based network of 20 hospitals. 57 recived tPA and 3 (5%) suffered from symptomatic intracranial hemorrhage [40].

improved process management

3 studies reported improvements in tPA delivery after the program had been run for several months [29, 32, 41]. In TEMPiS improvements in the organization of prehospital and in-hospital management were reported as reason for an increased use of tPA in the second phase. During the first 7 months only 42 patients were treated with tPA in the community hospitals, which increased to 63 patients in the following 6 months [41]. In the REACH program shorter process times were reported after the program had been running for some time compared with the early stages of the program. The onset to treatment time became shorter due to a reduction in the time between the patient being admitted to the emergency department and the time the stroke consultant logged on. The authors refer to the importance of educational measures, which improved the recognition of stroke and prompted an earlier activation of the system [32].

utilization: differences

The utilization of telestroke services differs widely in some studies when comparing the participating hospitals. One study reported that a single emergency department performed 55% of all consultations (121 consultations), while 3 other departments performed a total of 101 consultations. When analysing the number of consultations per physician, 18 (38%) practitioners carried out only one consultation, whereas 34 (71%) practitioners carried out between one and five consultations. Only 5 practitioners (10%) carried out more than ten consultations, and only 1 (2%) practitioner performed more than 12 consultations [34]. Another study reported that of 7 network hospitals, 1, represented 86% of all consultations. The reason for this was the additional time needed to transport patients to the videoconference room and obtaining patients' informed consent. The service required more documentation, which was hard to obtain without additional medical staff in the local hospitals [44].

3.7.2 Results of Rehabilitation Studies

home-based telehealth

In the outreach care intervention the SF-36 and a satisfaction questionnaire were used to measure the primary outcome. Patients in the intervention group reported better SF-36 scores than the controls. No statistical difference was found in satisfaction. For secondary outcomes measurements such as the Hospital Anxiety and Depression Scale, Barthel Index, modified Rankin scale, and use of secondary prevention drugs since discharge, no statistically significant differences were found. One exception was that intervention patients used fewer rehabilitation services and had lower anxiety scores [49]. Schopp et al. aimed to improve access to behavioural health care for patients with a brain injury. The multidimensional study involved a cognitive assessment, a psychotherapy study, and a training study. In the assessment study people seen via telemedicine were more likely than controls to want to repeat their experience and were more satisfied than the neuropsychologists who examined them. In the psychotherapy study neurorehabilitation patients were seen via videoconferencing for therapies related to brain injury or stroke. Persons receiving psychotherapy were less likely than persons receiving assessment services to want to repeat their experience. In the training study, 39 rural mental health providers were trained via videoconferencing, and trainees demonstrated a significant improvement when tested on their knowledge of brain injury [36].

motor-arm-deficite intervention

In Pirons et al. the intervention was a motor arm tele-rehabilitation intervention for post-stroke patients (5 persons). The participants underwent a 4 week tele-rehabilitation program. The therapy significantly improved the Fugl-Meyer mean score, the mean duration and the velocity of movement. No difference was seen in the Functional Independence Measure scale score [50].

social problem-solving

One study aimed to improve stroke caregivers' social problem-solving skills through a telephone-based intervention. Patients in the intervention group had better problem-solving skills, greater caregiver preparedness and less depression. The intervention group had significantly better scores in vitality, social functioning, mental health, and role limitations related to emotional problems compared to the controls [31].

tele-rehabilitation

In the community-based video consulting intervention the intervention group presented better scores on the Berg Balance Scale, State Self-Esteem Scale and knowledge test. Scores on all subscales of the SF-36 were also better. All the subjects accepted the use of videoconferencing for the delivery of the intervention. The pilot study reported the feasibility, efficacy and high level of acceptance of telerehabilitation in community-dwelling stroke patients [26].

education via telemedicine

In an educational intervention 39 rural mental health providers were trained in issues related to traumatic brain injury via video consulting by a neuropsychologist. After the sessions tests revealed a significant improvement in knowledge of brain injury. [36].

Internet for education & support

In the Internet based education and support intervention 9 adult caregivers of persons with stroke were enrolled. At the end of the 3 month study all the participants stated that they were satisfied with the Internet based intervention. 7 participants used the intervention 1-2 hours per week and 2 used it less than 1 hour per week. Participants viewed the web pages less frequently as the study progressed, but continued to use the e-mail function regularly throughout the study [35].

4 Discussion

disparities in stroke care led to telestroke initiatives

Disparities in access to healthcare services exist due to geographical barriers and limited resources. Rural locations often lack the resources for adequate emergency stroke treatment. The purpose of telestroke is to transfer knowledge and experienceof stroke management into areas with insufficient neurological services. Telemedicine networks usually seek to establish connections between remote locations and provide specialist support through different types of videoconferencing, telephone and clinical data transfer.

proven feasibility of telestroke processes

Based on the existing telestroke studies, it seems to be a feasible approach to build on dedicated stroke teams at specialist stroke centers – often at academic institutions - that support several community hospitals without pre-existing neurological services via video consulting. In telestroke programs neurologists, emergency physicians, nurses, and radiologists collaborate in the care of patients with acute stroke [55]. The remote stroke neurologist or a physician supported by a bedside nurse can quickly and reliably obtain a valid National Institutes of Health Stroke Scale (NIHSS) score through an audio video consulting system [17, 59, 60]. Radiology technologists ensure that neuroimaging (CT/MRI) is successfully transferred through the system. In some networks brain images are also interpreted by an onsite radiologist. Early accurate diagnosis can expand the knowledge and experiences from evidence-based stroke unit care, speed up treatment with Tissue plasminogen activator (tPA) and minimise unnecessary transfer to other hospital, although the majority of the studies report that patients receiving tPA treatment in a community telestroke hospital are transported to the stroke center for surveillance and monitoring or continuing treatment. Telestroke interventions can identify patients eligible for higly specialized treatments options such as intraarterial thrombolysis and mechanical thrombectomy (clot retrival) [16]. Involvement of a neurologist in stroke care has also been shown to be associated with better outcomes in non–lytic-treated patients. Management of intracerebral hemorrhage is improved by selected triage to centers with neurosurgical capability [61], although this outcome could not be verified in this review. More rapid diagnosis of the underlying mechanism of ischemic stroke may also lead to a more rapid application of secondary prevention therapy [61]. Studies on telestroke and long term outcome reported better health outcomes for patients treated in telestroke hospitals compared to conventional stroke care patients. This include reduced dependency and mortality at 6, 12 and 30 months follow-up [45, 62], Long-term mortality rates and functional outcomes of tPA treated telestroke patients were similar and comparable to the results from randomized trials [63]. A recently published study has shown that intravenous alteplase administered between 3 and 4.5 hours after the onset of stroke symptoms significantly improves clinical outcomes compared to placebo [64], although treatment between 3 and 4.5 hours is currently not included in the European regulations [65]. These results indicate potential for further development of telestroke interventions. If the treatment window for tPA expands from 3 hours to 4,5 hours, this would likely mean that more ischemic stroke patients would be eligible for this treatment through telemedicine, and the burden of illness would decrease.

identify patients for spezialized treatment

in question: transfer after tPA

better management of intracerebral hemorrhage in centers

long-term follow-up

discussion: transport all stroke patients to a stroke center

It can be debated whether it is better to transport all potential tPA patients directly to a stroke unit, when the distance is appropriate or whether telestroke services should be used. If a tPA candidate is directly transported to the stroke center time can be saved by avoiding a further hospital admission and by not performing the teleconsultation. Prehospital stroke intervention – such as the use of communication and information technologies in emergency transports - may improve the management of stroke care and may reduce the time from stroke onset to hospital admission[66, 67].

substantial capital investment

Telemedicine networks require a substantial capital investment in equipment, education and technical support. Components of the costs of the development and maintenance of a telestroke network include the telemedicine equipment, information technology support, the necessary clinical and administrative personnel, personnel training and accreditation, and allowances for on-call coverage [63]. Studies on cost and cost-effectiveness on telemedicine interventions in acute stroke management are rare. An increased use of tPA treatment indicates a cost reduction and cost-effectiveness [20-23].

less experiences in telerehabilitation

In addition to acute care, some identified studies explored telemedicine technologies in rehabilitation settings with regard to stroke survivors and their caregivers. These studies provide some preliminary evidence of satisfaction with and the feasibility of these technologies. However more work is needed to demonstrate the efficacy of these methods in promoting home-based telerehabilitation interventions.

factors for success: 24h service

stroke protocols

stroke education involvement of dedicated personnel

Most telemedicine interventions in acute stroke care provided a 24-hour service [29, 32, 37, 38, 41-44, 47] or reported the need for and importance of a 24-hour service [33]. This means a remote stroke expert is always available and that the community hospitals must have 24-hour access to diagnostic procedures including CT scans, laboratory exams, and in some cases doppler sonography [41-43]. It is reported that the implementation of stroke protocols for triaging patients and for standardization is essential to the success of telemedical interventions in acute care [13, 30, 32, 33, 37, 38, 41, 47]. These protocols normally also include guidelines for tPA delivery. Stroke education, initial training, and ongoing education for health personnel was reported as a key factor for success ful telestroke interventions [32, 33, 41-44]. The education in TEMPiS included training in the use of the National Institutes of Health Stroke Scale/NIHSS, the implementation of a thrombolysis algorithm, and the disposition of tPA protocols [41-43].

process improvements

air transport

excellent intra-transport care

3 studies reported that process times became shorter after the program had been running for some time [29, 32, 41]. The onset to treatment time became shorter, because of the educational efforts that improved the recognition of stroke and prompted an earlier activation of the system [32]. Another study reported an increased tPA rate in the second phase of the intervention. Increased public awareness and better prehospital stroke management achieved by the continuous educational activities in the regional hospitals were proposed as the reason for the increased use of tPA [41]. In one study, the availability of emergency air transport was reported as an important factor for success. One further key factor was the active involvement of paramedic personnel that appreciated the urgency of stroke and, making a rapid response and excellent intra-transport care possible [30]. The establishment of a central organization of emergency interhospital transfers

was reported as an important factor for success in some studies [41-43]. On the other hand, one study reported a high failure rate, which was due to logistical problems, the lack of a dedicated team of medical escort staff and the fixed position of the relevant technology in the emergency department. A further problem was that the intrahospital transfer of critically ill patients was regarded as unsafe [48]. The stroke center willingness to share responsibility for decision making and accept patients for transfer was an essential factor for good practice [30]. Collaboration between remote emergency departments and stroke centers is probably the most important element of a successful telestroke program [55].

logistics

sharing responsibility

collaboration

As interest in telestroke interventions has grown, numerous equipment options have been developed. Demaerschalk et al. identified different equipment and software packages (figure 4-1), such as the systems provided by Polycom (Pleasanton, CA), Tandberg (New York, NY), BF Technologies (San Diego, CA), and InTouch Health (Santa Barbara, CA), and published the results in a review. Other packages are REACH Call (Augusta, GA) and Specialists On Call (Westlake Village, CA). Most equipment features a high-resolution digital camera, microphone, speakers, server for scan storage, and a monitor for the patient to view the telestroke practitioner [55].

technologies

The systems presented by Demaerschalk are mainly used in U.S and North America. In Europe different systems exists. In STENO project in north Bavaria remote examination of patients was performed using the prototype of a novel audiovisual telesupport system (EVITA, ORI – Optics Research and Information Ltd), providing real-time transmission of video and audio sequences. The EVITA system use a special Internet protocol–based communication protocol with strong data security. The system allow to integrate other communication methods like DICOM, file transfer protocol (FTP), or hypertext transfer protocol (HTTP)[59]. In TEMPiS participating hospitals are equipped with a high speed videoconferencing system including a multiplex-ISDN transmission system and a branch office router (BINTEC®). This system allows data transfer rates of 2 Mbit/s. The telemedicine workstations consist of a Windows 2000-based videoconference system (VICON® VIGO Professional). The DICOM interface of the local CT scanners and MRI scanner is connected to the workstation and assessment of images is carried out using an Efilm workstation. The total cost for one workstation is approximately 16,000 Euro [57]. In TESS project all hospitals were provided with the videoconference system SONY® Contact (cost, approximately $8000), consisting of a portable device including a color video camera and microphone that can be connected to a commercial television monitor. Data were transmitted over 3 parallel integrated services digital network (ISDN) lines atspeeds up to 384 kilobits per second. All of the hospitals have the additional possibility of transmitting CT raw data by using a DICOM standard protocol [44]. In the German telestroke projects STENO, TEMPIS and TESS Digital Subscriber Line (DSL) connections are used in combination with ISDN connections. The rapid development of mobile technologies such as UMTS, WLAN and HSPA can offer a quality good enough for telestroke consultations. Ongoing clinical trials explore the safety of these technologies [68].

Figure 4-1: Telestroke systems after Demaerschalk et al., 2009

Factor	BF-Technologies	Polycom	Tandberg	In Touch Health	Reach Call	Specialists On Call
Product offering	AccessVideo™ Server	VSX™/HDX™ Practitioner Cart	TANDBERG Intern MXP	RP-7® Mobilethat integrate Robotic Platformaudio-visual	Web based tools that integrate audio-visual communication into clinical practice	Third party provider of physicians on call 24/7 via videoconference software
Hardware provided	Yes	Yes	Yes	Yes	No	No
Software	Yes	Yes	Yes	Yes	No	No
Web based	No	No	No	No	Yes	Yes
Annual cost (USA $)	~24,000	~25,000	~25,000	Varies	Based on monthly stroke volume	Based on monthly stroke volume
Maintenance fees	Yes	Yes	Yes	Yes	No	No
24/7 technology support	Phone	Phone and online	Phone and online	Continuously monitored	Phone and online	Phone and online request
Radiology transmission	Yes	Yes	Yes	Yes	No	No
Image					Not available	Not available
Website	*http://www. bf-technologies.com/*	*http://www. polycom.com/usa/en/ solutions/industry_ solutions/healthcare/ tele_medicine.html*	*http://www. tandberg.com/ ind_focus/ healthcare/ hc_solutions.jsp*	*http://www. intouchhealth.com/ products_rp7robot.html*	*http://www. reachcall.com/ company.html*	*http://www. brainsavingtech.com*

Two models are described in the literature. One is the fixed-site system, and the other the web-based system. The web-based model can be initiated from almost any location, provided that the device has access to the public Internet and the software program is installed. The advantage of the web-based model is the flexibility gained and the time that is saved by avoiding the travel of the consultant to the hub sites [33, 38, 47]. On the other hand, a dedicated link (ISDN) with a fiber optic system has a superior video and audio resolution compared to an Internet based system [29]. ISDN lines guarantee bandwidth availability and quality, but have restricted accessibility. A potential failure when using a web-based system is the connection to a specific Internet provider. Congestion and dropped packets are further problems inherent to using the Internet. Bandwidth, both downstream and upstream, is not always steady [38].

fixed site system

web-based system

Telephone based systems [30, 37] and video consulting technologies [41] are safe and feasible telestroke interventions, and provide support for tPA delivery. However, some studies have reported that video consulting methods are superior in diagnosis accuracy [48] and in giving correct treatment decisions [34], compared to telephone systems. Mortality is also reported to be lower in a video consulting system compared to a traditional telephone consultation [45]. It is hard to draw a final conclusion as to whether video consulting methods are superior to the telephone system in telestroke. In 3 studies the remote consultant was reliant on verbal reports of medical findings including results from CT scans [34, 37, 45]. It would have been interesting to analyse whether, a video consulting system with teleradiology is superior to a telephone based system with teleradiology. It can be assumed that, when the remote neurologist interprets the CT scans he or she may feel more confident when giving treatment advice (e.g. tPA delivery) than when an on-site radiologist interprets the CT scans. In a telephone based system, the accuracy of the diagnosis may also be better when a neurologist has access to CT images. In other words telephone based system with teleradiology might be more efficient than those telephone systems identified in the literature so far.

video consulting vs. telephone

The need for community based stroke information/campaigns to improve the public awareness of stroke was highlighted in some articles. This is important due to the fact that most stroke patients arrive after the 3 hour tPA treatment window, which means that most patients are not eligible for tPA because of late admission. Better recognition of stroke symptoms and improved understanding of this time sensitive illness may reduce time to admission. It should also be mentioned that the sooner an infusion of tPA can begin the better are the clinical outcomes.

public awareness: information on stroke

At the moment, telestroke seems to be the most promising intervention to improve access to and the quality of stroke care in areas with limited neurological services. Telestroke networks can expand the knowledge and experience of evidence-based stroke care. In stroke unit planning, it ought to be noted that the number of stroke patients treated in stroke centers might increase if tele-consultations are followed by transfers to the unit. Community hospitals might see telemedicine as a way of replacing health care workers. However, it must be underlined that telestroke services primarily aim to support health care providers in improving the quality of stroke care. Though their profile may change as a result, the service does not aim to replace health professionals in regional community settings.

expectations and realisations

service for support

standardized measurement

Each telestroke program is unique in terms of personnel resources, technology, the use of different health outcome measures and process management. Standardised outcome measures would allow increased harmonization, making it easier to compare programs and to determine which factors ensure the success of such programs [69].

Telemedical procedures must be regulated by national laws. The fact that teleconsultation in acute stroke is similar to face-to-face consultation should facilitate the development of such regulations. Physicians practicing telemedicine must be authorised to practice medicine in the country or state in which they are located [55].

the responsible physician

quality, security & safety

patient document

The physician asking for another physician's advice remains responsible for treatment and other decisions and recommendations given to the patient. When practicing telemedicine directly with the patient, the physician assumes responsibility for the case in question. The physician performing medical interventions via telemedice is responsible for those interventions. A physician practicing telemedicine is responsible for ensuring that the quality of the service is acceptable. The physician must carefully evaluate the data and other information received. Medical opinions and recommendations can be given and medical decisions made, only if the quality and quantity of data or other information received is sufficient and relevant for the case in question. When performing medical interventions at a distance, the physician must ensure the presence of sufficient and adequately trained staff to assist the patient and provide continuing care. All physicians using telemedicine must keep adequate patient records and document all cases correctly. Findings andrecommendations must be adequately documented [70].

4.1 Lessons to be Learnt for Telestroke Evaluations

indicators for monitoring/ evaluating impact of telestroke initiatives

To evaluate a telestroke network good data collection and storage are necessities. The TEMPiS telestroke network was the only project that stated that patient data was entered into a telemedicine database. Data collection was implemented within the Bavarian Stroke Register with predefined standards from the German Stroke Register Study Group [71] to ensure standardised data collection and data management [41-43]. To ensure "good practice" in evaluating telemedicine interventions, it is important that the collected data are valid, accessible and transparent. It is also important that the system is accepted and integrated into routine care, and therefore patient data should be entered into the hospital's CIS system. A potential barrier might be that most hospitals use different CIS systems and software programs, which do not always allow the transfer of data between hospitals. To obtain optimal data collection, and where possible, the telemedical patient data might be entered into a database or quality registry for stroke care. Quality registries contain individual-based data on diagnoses, treatment and outcomes, that allow evaluators to assess the quality of care, utilization and processes. Quality registries also provide benchmarking data.

for reporting the evaluation: general information

In the reporting oftelestroke program evaluations, general information should be presented. For example:

- settings,
- patient selection, inclusion and exclusion criteria,
- logistics,
- trigging stroke patients (stroke protocol),
- distances between stroke unit and telestroke hospials,
- information on technical resources and personnel resources,
- time and resources needed for education and training,
- patient characteristic (age, cormorbities, living situation, stoke severity etc.)
- cost, investments and maintenance of the service,
- number of consultations,
- numbers of registered stroke patients in the telestroke hospitals (area).

Based on the included studies in this systematic review a number of evaluation indicators related to the quality, utilization and processes of telestroke initiatives are proposed:

selection bias

quality indicators

- rate of systemic thrombolysis,
- intracerebral hemorrhages (after tPA delivery),
- mortality,
- length of stay,
- rate of transfer and,
- use of different diagnostic procedures, and applied therapies including physiotherapy and occupational and speech therapy.

Different process indicators were used in the telestroke programs. The following indicators provide appropriate information on processes:

process indicators

- time needed for the consultation process, with or without preparation,
- transfer rate,
- unfit for interhospital transfers (critical ill patients),
- transportation time,
- if any adverse event during transfer,
- if any transfer was unnecessary and,
- technical failures.

To analyse processes in tPA delivery the following indicators can be used:

process indicators

tPA treatment

- time from onset of stroke symptoms to admission („onset-to-admission“ also called “onset-to-hospital”),
- time from admission to CT scan,
- time from admission to thrombolysis („door-to-needle“), and
- time from stroke symptoms onset to thrombolysis („onset-to-needle“).

Indicators for measuring health outcomes are required in order to explore the health impact of the intervention. Information on the following indicators should be collected:

health outcome indicators

- mortality,
- disability, stroke scales (Glasgow Coma Scale, NIHSS, modified Rankin scale, and Barthel Index),
- discharge disposition,
- pre and post treatment NIHSS score.

follow-up

It is important to collect information on follow-up indicators in order to explore the long-term health outcome of the intervention:

- Bartel Index,
- modified Ranking scale
- follow up CT or MRI scanning
- living situation (before and after stroke)
- care needed after discharge.

legal issues
medical ethics
confidentiality
informed consent

In the practice of telemedicine, the principles of medical ethics should be followed. Rules of confidentiality and security apply to telemedicine documentation, and storage. Transmission methods should be used only where confidentiality and security can be guaranteed. Patient data and other information should only be sent to a physician or other health professional on patient request or with informed consent.

4.2 Final Recommendations

It is the primary intention of "telestroke" initiatives to bring the effective stroke therapies to peripheral and underserved areas and with this

- to improve quality of stroke care via supporting community services by stroke experts through telemedical interventions,
- to improve access to acute stroke interventions and to increase the use of thrombolytic therapy,
- to reduce direct costs by avoiding unnecessary patient transfers,
- to increase cost-effectiveness by decreasing long-term care costs, and finally to
- to improve stroke education and stroke rehabilitation services.

In order to evaluate telestroke initiatives and to proof the fulfilment of those expectations and – of course – big investments in telestroke technology, we recommend that new start-up telestroke projects should

1. learn from others: intensive networking between telestroke projects and detailed analyses and exchange of their strengths and weaknesses is recommended.
2. be evaluated regularly: telestroke projects should integrate intentionally "feedback-loops". After a predefined pilot phase, followed by a first evaluation, the roll-out phase should not start after reflection on possible changes in organization, documentation, techniques, etc. Regular re-evaluation – even after roll-out - is recommended.
3. be documented: documentation of (process and outcome) indicators are essential for proofing effectiveness of telestroke initiatives and for self-learning organisations and for benchmarking with others. We recommend a "wise balance" between over-collection of unnecessary data and lack of indicator-oriented documentation.

4.3 Study Limitation

This systematic review had several limitations. Articles on imaging modalities of telemedicine that focused exclusively on diagnostic concordance between telehealth and traditional face-to-face consultations were excluded. This area is covered with relative good evidence so including these studies was beyond the resources available for this review. Studies on telemedicine interventions in stroke prevention and in pre-hospital stroke care, which is a part of telemedicine interventions in stroke management was also excluded due to limitation in resources available for this review.

Reports on telerehabilitation were identified in the literture search strategy, which focused on telemedicine in stroke care. A specified systematic review on telerehabilitation in stroke management might have identified more articles.

5 Conclusion

Stroke is a time sensitive neurological condition with high morbidity and mortality rates, resulting in socioeconomic costs. Telemedicine technologies in acute stroke care, whether they are based on a telephone-based system or a real-time video consulting system, are safe and feasible in acute stroke management. Some studies in acute stroke settings reported an improvement in health outcomes, including reduced dependency and mortality at 6, 12 and 30 months follow-up. Standardized measures regarding the assessment of telestroke services would assist in the comparison between telestroke and standard care, and would allow comparisons across telestroke studies. Telemedicine technologies can be used to support regional hospitals without neurological expertise, but with an access to computer tomography and laboratory. The use of intravenous thrombolysis, which has been shown to significantly reduce the burden of illness, should be increased. Telestroke interventions can support areas with insufficient neurological services, and increase equality and equity by providing evidence-based stroke care.

safety & feasibility

improved health
reduced mortality

standardized measurement

increase use of tPA

equality & equity

Obtaining evidence on the use of telemedicine in rehabilitation settings related to stroke survivors and caregivers was not a main objective. This evidence was therefore not thoroughly reviewed, and therefore no conclusions could be drawn. The few identified articles show promising results in improving patients' and/or stroke survivors' caregivers' well-being. More research is required to determine the impact of telerehabilitation services.

telerehabilitation

Economic studies on telemedicine technologies in stroke management are rare. Some studies reported investment costs and only one study reported cost-effectiveness. More studies of higher methodological quality are needed to give greater insights into the potential cost-effectiveness of telemedicine interventions in stroke management.

cost-effectivness

Numerous organizations have been identified as being at the forefront of telestroke, but the lack of standardized reporting of resources and outcomes prevents comparisons across organisations and the clarification of best practices. More research is required to explore the clinical and economic impact of telemedicine technologies in stroke management, so as to support policy makers in making informed decisions.

lack of harmonization

6 References

[1] Lopez AD, Mathers CD, Ezzati M, Jamison DT, Murray CJ. Global and regional burden of disease and risk factors, 2001: systematic analysis of population health data. Lancet. 2006 May 27;367(9524):1747-57.

[2] Rohkamm R. Color Atlas of Neurology. Stuttgart: Georg Thieme Verlag 2004.

[3] Brainin M, Bornstein N, Boysen G, Demarin V. Acute neurological stroke care in Europe: results of the European Stroke Care Inventory. Eur J Neurol. 2000 Jan;7(1):5-10.

[4] Lewis P. Rowland HHM. Merritt's neurology: Lippincott Williams & Wilkins 2005.

[5] SITS. Safe Implementaion of Thrombolysis in Stroke. 2009 [cited 24.04.2009]; Available from: http://www.acutestroke.org/index.php?module=ContentExpress&func=display&ceid=40&meid=7

[6] Lloyd-Jones D, Adams R, Carnethon M, De Simone G, Ferguson TB, Flegal K, et al. Heart disease and stroke statistics--2009 update: a report from the American Heart Association Statistics Committee and Stroke Statistics Subcommittee. Circulation. 2009 Jan 27;119(3):480-6.

[7] Hacke W in Diener H.C Putzki N (ed.). Leitlinien der Deutschen Gesellschaft für Neurologie. 4th ed. Stuttgart: Thieme Verlag 2008.

[8] Olsen TS, Langhorne P, Diener HC, Hennerici M, Ferro J, Sivenius J, et al. European Stroke Initiative Recommendations for Stroke Management-update 2003. Cerebrovascular diseases (Basel, Switzerland). 2003;16(4):311-37.

[9] Berger K in Hartmann A Heiss WD (ed.). Der Schlaganfall : Pathogenese, Klinik, Diagnostik und Therapie akuter zerebrovaskulärer Erkrankungen. Darmstadt: Steinkopff 2001.

[10] Wardlaw JM, Zoppo G, Yamaguchi T, Berge E. Thrombolysis for acute ischaemic stroke. Cochrane database of systematic reviews (Online). 2003(3):CD000213.

[11] Albers GW, Olivot JM. Intravenous alteplase for ischaemic stroke. Lancet. 2007 Jan 27;369(9558):249-50.

[12] Levine SR, Gorman M. "Telestroke" : the application of telemedicine for stroke. Stroke. 1999 Feb;30(2):464-9.

[13] Schwamm LH, Rosenthal ES, Hirshberg A, Schaefer PW, Little EA, Kvedar JC, et al. Virtual TeleStroke support for the emergency department evaluation of acute stroke. Academic Emergency Medicine. 2004 Nov;11(11):1193-7.

[14] Kjellstrom T, Norrving B, Shatchkute A. Helsingborg Declaration 2006 on European stroke strategies. Cerebrovascular diseases (Basel, Switzerland). 2007;23(2-3):231-41.

[15] Perednia DA, Allen A. Telemedicine technology and clinical applications. Jama. 1995 Feb 8;273(6):483-8.

[16] Fisher M, Fisher M. Developing and implementing future stroke therapies: the potential of telemedicine. Annals of Neurology. 2005 Nov;58(5):666-71.

[17] Shafqat S, Kvedar JC, Guanci MM, Chang Y, Schwamm LH, Shafqat S, et al. Role for telemedicine in acute stroke. Feasibility and reliability of remote administration of the NIH stroke scale. Stroke. 1999 Oct;30(10):2141-5.

[18] Wang S, Lee SB, Pardue C, Ramsingh D, Waller J, Gross H, et al. Remote evaluation of acute ischemic stroke: reliability of National Institutes of Health Stroke Scale via telestroke.[see comment]. Stroke. 2003 Oct;34(10):e188-91.

[19] Audebert H, Audebert H. Telestroke: effective networking. Lancet neurology. 2006 Mar;5(3):279-82.

[20] Demaerschalk BM, Yip TR. Economic benefit of increasing utilization of intravenous tissue plasminogen activator for acute ischemic stroke in the United States. Stroke. 2005 Nov;36(11):2500-3.

[21] Sandercock P, Berge E, Dennis M, Forbes J, Hand P, Kwan J, et al. Cost-effectiveness of thrombolysis with recombinant tissue plasminogen activator for acute ischemic stroke assessed by a model based on UK NHS costs. Stroke. 2004 Jun;35(6):1490-7.

[22] Fagan SC, Morgenstern LB, Petitta A, Ward RE, Tilley BC, Marler JR, et al. Cost-effectiveness of tissue plasminogen activator for acute ischemic stroke. NINDS rt-PA Stroke Study Group. Neurology. 1998 Apr;50(4):883-90.

[23] Sinclair SE, Frighetto L, Loewen PS, Sunderji R, Teal P, Fagan SC, et al. Cost-Utility analysis of tissue plasminogen activator therapy for acute ischaemic stroke: a Canadian healthcare perspective. PharmacoEconomics. 2001;19(9):927-36.

[24] Lambrecht CJ. Emergency physicians' roles in a clinical telemedicine network. Annals of emergency medicine. 1997 Nov;30(5):670-4.

[25] American Telemedicine Association Web site. ATA Defining Telemedicine. 2009 [cited 05.05.2009]; Available from: http://www.americantelemed.org/i4a/pages/index.cfm?pageid=3333

[26] Lai JC, Woo J, Hui E, Chan WM, Lai JCK, Woo J, et al. Telerehabilitation - a new model for community-based stroke rehabilitation. Journal of Telemedicine & Telecare. 2004;10(4):199-205.

[27] Donabedian A. Evaluating the quality of medical care. The Milbank Memorial Fund quarterly. 1966 Jul;44(3):Suppl:166-206.

[28] Buckley KM, Tran BQ, Prandoni CM, Buckley KM, Tran BQ, Prandoni CM. Receptiveness, use and acceptance of telehealth by caregivers of stroke patients in the home. Online Journal of Issues in Nursing. 2004 Sep 30;9(3):9.

[29] Choi JY, Porche NA, Albright KC, Khaja AM, Ho VS, Grotta JC, et al. Using telemedicine to facilitate thrombolytic therapy for patients with acute stroke. Joint Commission Journal on Quality & Patient Safety. 2006 Apr;32(4):199-205.

[30] Frey JL, Jahnke HK, Goslar PW, Partovi S, Flaster MS, Frey JL, et al. tPA by telephone: extending the benefits of a comprehensive stroke center. Neurology. 2005 Jan 11;64(1):154-6.

[31] Grant JS, Elliott TR, Weaver M, Bartolucci AA, Giger JN, Grant JS, et al. Telephone intervention with family caregivers of stroke survivors after rehabilitation.[see comment]. Stroke. 2002 Aug;33(8):2060-5.

[32] Hess DC, Wang S, Hamilton W, Lee S, Pardue C, Waller JL, et al. REACH: clinical feasibility of a rural telestroke network. Stroke. 2005 Sep;36(9):2018-20.

[33] LaMonte MP, Bahouth MN, Hu P, Pathan MY, Yarbrough KL, Gunawardane R, et al. Telemedicine for acute stroke: triumphs and pitfalls. Stroke. 2003 Mar;34(3):725-8.

[34] Meyer BC, Raman R, Hemmen T, Obler R, Zivin JA, Rao R, et al. Efficacy of site-independent telemedicine in the STRokE DOC trial: a randomised, blinded, prospective study.[see comment]. Lancet neurology. 2008 Sep;7(9):787-95.

[35] Pierce LL, Steiner V, Govoni AL, Hicks B, Cervantez Thompson TL, Friedemann ML, et al. Internet-based support for rural caregivers of persons with stroke shows promise. Rehabilitation Nursing. 2004 May-Jun;29(3):95-9.

[36] Schopp LH, Johnstone BR, Merveille OC, Schopp LH, Johnstone BR, Merveille OC. Multidimensional telecare strategies for rural residents with brain injury. Journal of Telemedicine & Telecare. 2000;6 Suppl 1:S146-9.

[37] Vaishnav AG, Pettigrew LC, Ryan S, Vaishnav AG, Pettigrew LC, Ryan S. Telephonic guidance of systemic thrombolysis in acute ischemic stroke: safety outcome in rural hospitals. Clinical Neurology & Neurosurgery. 2008 May;110(5):451-4.

[38] Wang S, Gross H, Lee SB, Pardue C, Waller J, Nichols FT, 3rd, et al. Remote evaluation of acute ischemic stroke in rural community hospitals in Georgia. Stroke. 2004 Jul;35(7):1763-8.

[39] Rymer MM, Thurtchley D, Summers D, America Brain and Stroke Institute Stroke T, Rymer MM, Thurtchley D, et al. Expanded modes of tissue plasminogen activator delivery in a comprehensive stroke center increases regional acute stroke interventions. Stroke. 2003 Jun;34(6):e58-60.

[40] Wang DZ, Rose JA, Honings DS, Garwacki DJ, Milbrandt JC, Wang DZ, et al. Treating acute stroke patients with intravenous tPA. The OSF stroke network experience.[see comment]. Stroke. 2000 Jan;31(1):77-81.

[41] Audebert HJ, Kukla C, Clarmann von Claranau S, Kuhn J, Vatankhah B, Schenkel J, et al. Telemedicine for safe and extended use of thrombolysis in stroke: the Telemedic Pilot Project for Integrative Stroke Care (TEMPiS) in Bavaria. Stroke. 2005 Feb;36(2):287-91.

[42] Audebert HJ, Kukla C, Vatankhah B, Gotzler B, Schenkel J, Hofer S, et al. Comparison of tissue plasminogen activator administration management between telestroke network hospitals and academic stroke centers: The telemedical pilot project for integrative stroke care in Bavaria/Germany. 2006:1822-7.

[43] Audebert HJ, Schenkel J, Heuschmann PU, Bogdahn U, Haberl RL, Telemedic Pilot Project for Integrative Stroke Care G, et al. Effects of the implementation of a telemedical stroke network: the Telemedic Pilot Project for Integrative Stroke Care (TEMPiS) in Bavaria, Germany.[see comment]. Lancet neurology. 2006 Sep;5(9):742-8.

[44] Wiborg A, Widder B, Telemedicine in Stroke in Swabia P, Wiborg A, Widder B, Telemedicine in Stroke in Swabia P. Teleneurology to improve stroke care in rural areas: The Telemedicine in Stroke in Swabia (TESS) Project.[see comment]. Stroke. 2003 Dec;34(12):2951-6.

[45] Handschu R, Scibor M, Willaczek B, Nuckel M, Heckmann JG, Asshoff D, et al. Telemedicine in acute stroke: remote video-examination compared to simple telephone consultation. Journal of Neurology. 2008 Nov;255(11):1792-7.

[46] Kuhle S, Mitchell L, Andrew M, Chan AK, Massicotte P, Adams M, et al. Urgent clinical challenges in children with ischemic stroke: analysis of 1065 patients from the 1-800-NOCLOTS pediatric stroke telephone consultation service.[see comment]. Stroke. 2006 Jan;37(1):116-22.

[47] Waite K, Silver F, Jaigobin C, Black S, Lee L, Murray B, et al. Telestroke: a multi-site, emergency-based telemedicine service in Ontario. Journal of Telemedicine & Telecare. 2006;12(3):141-5.

[48] Wong HT, Poon WS, Jacobs P, Goh KY, Leung CH, Lau FL, et al. The comparative impact of video consultation on emergency neurosurgical referrals. Neurosurgery. 2006 Sep;59(3):607-13; discussion -13.

[49] Boter H, Group HS, Boter H, Group HS. Multicenter randomized controlled trial of an outreach nursing support program for recently discharged stroke patients. Stroke. 2004 Dec;35(12):2867-72.

[50] Piron L, Tonin P, Trivello E, Battistin L, Dam M, Piron L, et al. Motor tele-rehabilitation in post-stroke patients. Medical Informatics & the Internet in Medicine. 2004 Jun;29(2):119-25.

[51] Reponen J, Ilkko E, Jyrkinen L, Tervonen O, Niinimaki J, Karhula V, et al. Initial experience with a wireless personal digital assistant as a teleradiology terminal for reporting emergency computerized tomography scans. Journal of Telemedicine & Telecare. 2000;6(1):45-9.

[52] The National Institute of Neurological Disorders and Stroke rt-PA Stroke Study Group. Tissue plasminogen activator for acute ischemic stroke. The National Institute of Neurological Disorders and Stroke rt-PA Stroke Study Group.[see comment]. New England Journal of Medicine. 1995 Dec 14;333(24):1581-7.

[53] Adams HP, Jr., Adams RJ, Brott T, del Zoppo GJ, Furlan A, Goldstein LB, et al. Guidelines for the early management of patients with ischemic stroke: A scientific statement from the Stroke Council of the American Stroke Association.[see comment]. Stroke. 2003 Apr;34(4):1056-83.

[54] Manual D-SCC. 2nd ed. ed: Oakbrook Terrace IL: Joint Commissions Resources 2005.

[55] Demaerschalk BM, Miley ML, Kiernan TE, Bobrow BJ, Corday DA, Wellik KE, et al. Stroke telemedicine. Mayo Clinic proceedings. 2009;84(1):53-64.

[56] Ickenstein GW, Horn M, Schenkel J, Vatankhah B, Bogdahn U, Haberl R, et al. The use of telemedicine in combination with a new stroke-code-box significantly increases t-PA use in rural communities. Neurocritical Care. 2005;3(1):27-32.

[57] Audebert HJ, Wimmer ML, Hahn R, Schenkel J, Bogdahn U, Horn M, et al. Can telemedicine contribute to fulfill WHO Helsingborg Declaration of specialized stroke care? Cerebrovascular Diseases. 2005;20(5):362-9.

[58] Rymer MM, Thrutchley DE, For the Stroke Team at the Mid America Brain and Stroke I, Rymer MM, Thrutchley DE, For the Stroke Team at the Mid America Brain and Stroke I. Organizing regional networks to increase acute stroke intervention. Neurological Research. 2005;27 Suppl 1:S9-16.

[59] Handschu R, Littmann R, Reulbach U, Gaul C, Heckmann JG, Neundorfer B, et al. Telemedicine in emergency evaluation of acute stroke: interrater agreement in remote video examination with a novel multimedia system. Stroke. 2003 Dec;34(12):2842-6.

[60] Meyer BC, Lyden PD, Al-Khoury L, Cheng Y, Raman R, Fellman R, et al. Prospective reliability of the STRokE DOC wireless/site independent telemedicine system.[see comment]. Neurology. 2005 Mar 22;64(6):1058-60.

[61] Schwamm LH, Holloway RG, Amarenco P, Audebert HJ, Bakas T, Chumbler NR, et al. A Review of the Evidence for the Use of Telemedicine Within Stroke Systems of Care. A Scientific Statement From the American Heart Association/American Stroke Association. 2009:STROKEAHA.109.192360.

[62] Audebert HJ, Schultes K, Tietz V, Heuschmann PU, Bogdahn U, Haberl RL, et al. Long-term effects of specialized stroke care with telemedicine support in community hospitals on behalf of the Telemedical Project for Integrative Stroke Care (TEMPiS). Stroke. 2009 Mar;40(3):902-8.

[63] Schwab S, Vatankhah B, Kukla C, Hauchwitz M, Bogdahn U, Furst A, et al. Long-term outcome after thrombolysis in telemedical stroke care.[see comment]. Neurology. 2007 Aug 28;69(9):898-903.

[64] Hacke W, Kaste M, Bluhmki E, Brozman M, Davalos A, Guidetti D, et al. Thrombolysis with alteplase 3 to 4.5 hours after acute ischemic stroke. The New England journal of medicine. 2008 Sep 25;359(13):1317-29.

[65] The European Stroke Organization (ESO) Executive Committee and the ESO Writing Committee. Guidelines for Management of Ischaemic Stroke and Transient Ischaemic Attack 2008. 2008 [cited 01.05.2009]; Available from: http://www.eso-stroke.org/pdf/ESO%20Guidelines_update_Jan_2009.pdf

[66] Ziegler V, Rashid A, Muller-Gorchs M, Kippnich U, Hiermann E, Kogerl C, et al. [Mobile computing systems in preclinical care of stroke. Results of the Stroke Angel initiative within the BMBF project PerCoMed]. Anaesthesist. 2008 Jul;57(7):677-85.

[67] LaMonte MP, Xiao Y, Hu PF, Gagliano DM, Bahouth MN, Gunawardane RD, et al. Shortening time to stroke treatment using ambulance telemedicine: TeleBAT. J Stroke Cerebrovasc Dis. 2004 Jul-Aug;13(4):148-54.

[68] Audebert HJ, Haberl RL, Hacke W, Handschu R, Schenkel J, Scibor M, et al. [Telemedicine in acute stroke care: current status and developments]. Deutsche Medizinische Wochenschrift. 2007 Mar 2;132(9):431-6.

[69] Deshpande A, Khoja S, McKibbon A, Rizo C, Jadad AR. Telehealth for acute stroke management (Telestroke): systematic review of analytic studies and environmental scan of relevant initiatives. Ottawa: Canadian Agency for Drugs and Technologies in Health (CADTH) 2008.

[70] Standing Committee of European Doctors (CPME). CPME guidelines for Telemedicine. 2002.

[71] Heuschmann PU, Kolominsky-Rabas PL, Roether J, Misselwitz B, Lowitzsch K, Heidrich J, et al. Predictors of in-hospital mortality in patients with acute ischemic stroke treated with thrombolytic therapy. 2004:1831-8.

Appendix I) General characteristics of studies meeting the inclusion criteria

Author, Year	Source of Publication	Country, Location	Study Design	Objective	Settings	Funding
Audebert, 2006	Lancet Neurol	Germany, Bavaria	CCT	Analyse the effects of a stroke network with telemedical support on quality of care, according to acute processes and long-term outcome.	2 academic stroke centers and 5 community hospitals.	German Federal Ministry of Research
Audebert, 2005	Stroke	Germany, Bavaria	Prospective case series	Extend the use of tPA treatment in nonurban areas through telemedic support.	2 stroke centers and 12 local hospitals.	Health Insurance Company, Ministry of Employment and Social Order, Family and Women; German Stroke Foundation
Audebert, 2006	Stroke	German, Bavaria	Prospective case series	Management and safety of tPA administration after telemedical consultation are equivalent in less experienced hospitals compared with tPA administration in academic stroke centers.	2 academic stroke centers and 12 regional hospitals.	Health Insurance Company, Ministry of Employment and Social Order, Family and Women; German Stroke Foundation
Boter, 2004	Stroke	The Netherlands, districts of Amsterdam and Utrecht	RCT	Explore the effectiveness of an outreach nursing care program for stroke survivors discharged at home.	2 university hospitals and 10 general hospitals.	Netherlands Heart Foundation
Buckley, 2004	Online Journal of Issues in Nursing	USA	Exploratory descriptive study	To explore the receptiveness, use, and acceptance of telehealth technologies by caregivers of stroke patients in home setting.	Videophone products placed at patients homes, telehealth nurse.	National Institute of Disabilities and Rehabilitation of US. Dept of Education
Choi, 2006	Joint commission on Journal on Quality and Patient Safety	USA, Texas	Prospective case series	To screen patient for rtPA via videoconferencing.	2 regional hospitals and 1 University stroke center.	US Department of Defense

Author, Year	Source of Publication	Country, Location	Study Design	Objective	Settings	Funding
Frey, 2005	Neurology	USA	Retrospective case series	Telephone network to support community EDs in the use of tPA.	Neurological stroke center and 43 hospitals.	Not reported
Grant, 2002	Stroke	USA, south eastern	RCT	To quantify the impact of social problem-solving telephone partnerships on primary family caregiver outcomes after stroke survivors were discharged home from a rehabilitative facility.	General hospital as core of excellence and patients at home.	Not reported
Handschu, 2008	J. Neurology	Bavaria	prospective study	Compare remote video-examination and telephone consultation in acute stroke.	2 district hospitals and 2 stroke centers.	Bavarian State Ministry of Labor and Social Welfare, Family and Women. "Competence Net Stroke"
Hess, 2005	Stroke	USA	Case series	Bringing guideline driven stroke care to rural, underserved areas via a telestroke network.	8 rural hospitals and 1 medical College.	Medical College of Georgia Health Inc
Kuhle, 2006	Stroke	Canada	Case series	Telephone consultation given by pediatric neurologist or hematologists to physicians requesting advice on the management of children with stroke.	Telephone stroke pediatric consultation service.	Baxter Bioscience California
Lai, 2004	Journal of Telemedicine and Telecare	China (Hong Kong)	Case series	Explore the feasibility of using videoconferencing for community-based stroke rehabilitation between a hospital and a community centre for seniors.	1 hospital and 1 community centre for seniors.	Not reported
LaMonte, 2003	Stroke	USA, Maryland	Prospective case series	Explore feasibility and safety of tPA during telemedicine consultation.	1 Brain Attack Center and 1 ED, regional hospital.	University of Maryland Medical System, St Mary's Hospital, Bell Atlantic, Vtel and a grant from Genentech, Inc.

Author, Year	Source of Publication	Country, Location	Study Design	Objective	Settings	Funding
Meyer, 2008	Lancet Neurol	USA, San Diego	RCT	To increase the effective use of thrombolytics for acute stroke and to explore whether telemedicine or telephone consultation was superior for decision making for treatment with tPA.	1 academic stroke center and 4 regional hospitals.	National Institute of Neurological Disorders and Stroke; California Institute of Telecommunications Technology; Department of Veterens' Affairs Research Division.
Pierce 2004	Rehabilitation nursing	USA, Ohio	Qualitative analysis	Explore the feasibility of providing Internet-based education and support intervention to caregivers.	Rehabilitation center linked with caregivers homes.	Not reported
Piron, 2004	Medical Informatics & The Internet in Medicine	Italy	Case series	To evaluated the effects of a tele-rehabilitation system for the therapy of arm motor impairments due to a stroke.	Computers placed at patient's home were connected to a computer in a rehabilitation hospital.	Veneto Region, Italy
Reponen, 2000	Journal of Telemedicine and Telecare	Finland	Case series	Effectiveness of wireless PDA to transmit computerized tomography.	Hospital, PDA device, remote neuroradiologist.	Not reported
Rymer, 2003	Stroke	USA, Kansas City (Mo)	Case series	Increas tPA treatment in regional areas	1 stroke center and 18 regional hospitals	Genentech, Inc
Schopp, 2000	Journal of Telemedicine and Telecare	USA	Observational study	To explore the use of videoconferencing to enhance cognitive assessment, psychotherapy and mental health training. care for persons with brain injury in rural areas.	1) Rural residents 2) Rural rehabilitation inpatient unit 3) Rural mental health providers	National Institute on Disability and Rehabilitation Research (NIDRR)
Schwamm, 2004	Academic Emergency Medicine	USA	Retrospective case series analysis	To determine eligibility for treatment with tPA and provide support to emergency departments without on-site stroke expertise.	Stroke experts and emergency physicians at an island-based critical access hospital.	Not reported

Author, Year	Source of Publication	Country, Location	Study Design	Objective	Settings	Funding
Vaishnav, 2008	Clinical Neurology and Neurosurgery	USA, Kentucky	Retrospective observational study	To determine the safety of telephonic guidance for use of intravenous rtPA in rural hospitals.	Rural hospitals and 1 University medical center.	Not reported
Waite, 2006	Journal of Telemedicine and Telecare	Canada, Toronto	Case series	To explore the feasibility of telemedicine for acute stroke care (video consulting).	1 University and 2 community hospitals.	Canadian Stroke Network, Ontario Ministry of Health and IT Care, and North Network
Wang 2004	Stroke	USA, Georgia	Case series	To expand the use of tPA via telemedicine in Remote Evaluation for Acute Ischemic Stroke program.	1 medical college and 5 rural hospitals.	Not reported
Wang, 2000	Stroke	USA, Illinois OSF Stroke Network	Case series	Examine the safety and outcome of tPA in the stroke network	1 stroke center and 20 hospitals	Not reported
Wiborg, 2003	Stroke	Germany, Swabia	Case series	To examine the feasibility, acceptance, and economic consequences of a telemedicine network including a special stroke training program.	1 Stroke unit and 7 rural community hospitals.	Bavaria, Germany, within the Bayern Online project
Wong, 2006	Neurosurgery	China (Hong Kong)	RCT	To determine the differences among telephone consultation, teleradiology and video consultation on the basis of their process-of-care indicators, clinical outcomes, and cost-effectiveness.	District general hospital and a tertiary neurosurgical center.	Health Services Research Committee / Health Care and Promotion Fund

ED=emergency departments, CT= computer tomography, TC=telephone consultation, VC=video consultation (videoconference), tPA= tissue plasminogen activator, MRI = Magnetic resonance imaging, PDA=personal digital assistant, RCT= randomized controlled trails, CCT=controlled clinical trials

Appendix II) COMPONENTS AND OUTCOMES OF INCLUDED STUDIES INVOLVING ACUTE STROKE CARE

Study	Intervention & Time Period	Population	Technology Resources	Personal Resources/Distance	Process Management	Outcome, Category Measured	Result
Audebert, 2006	Assess the quality of care using a telestroke network according to acute processes and long-term outcome. Jul 2003 - Mar 2005	3122 stroke patients	High-speed VC system (ISDN data transfer rates up to 2 Mb/s) to examine patients and transfer radiological data of CT and MRI.	12 community hospital implemented stroke wards with a stroke team consisting of doctors, nurses, physiotherapists, occupational therapists, and speech therapists (up to 8 beds, 3 to 4 with monitors). 5 fulltime neurologists at 2 academic stroke centers served on a 24h basis the stroke teams. Distances to stroke center 8-60km (5-37 miles).	Patients possible for tPA in the community hospitals were sent for CT scanning. During the CT investigation, the telemedic consultant was informed by telephone. CT scans were transmitted to and evaluated in the stroke center. After evaluation the VC begun. The investigation was assisted by the attending physicians of the regional hospitals.	Diagnostic procedures: Rapid brain imaging†, Carotid artery sonography, Standardised test for dysphagia. Treatment: tPA, Physiotherapy, Speech therapy, Occupational therapy. Discharge destination: Mean length of stay, Home, Rehabilitation unit, Nursing or residential home, Transferred to other hospital or department, Dead. Vital status, living situation and disability after 3 months (BI, mRS).	Physiotherapy, speech therapy, and occupational therapy was up to ten times more frequent in the intervention than in the control hospitals. 44% of patients in the intervention group had a poor outcome after 3 months versus 54% in the control group (p<0·0001). Higher In-hospital mortality in the control hospitals.
Audebert, 2005	To investigate the procedural quality and safety of tPA administration after telehealth evaluation. Feb 1, 2003 - Apr 7, 2004.	4178 stroke patients.	High-speed VC system (ISDN data transfer rates up to 2 Mb/s) to examine patients and transfer teleradiological data of CT and MRI.	5 fulltime neurologists at 2 academic stroke centers served stroke teams in community hospitals.	Patients possible for tPA in the community hospitals were sent for CT scanning. During the CT investigation, the telemedic consultant was informed by telephone. CT scans were transmitted to and evaluated in the stroke center. After evaluation the VC begun. The investigation was assisted by the attending physicians of the regional hospitals.	Median NIHSS Symptomatic hemorrhage In-hospital mortality, Mortality within 7 days, Onset to admission mean, min. Mean door-to-needle time, min. Mean time to treatment, min. Percentage of tPA administered within 90 min.	106 reciving tPA via VC. During the first 12 months, tPA rate 2.1%. Mean time between onset to admission 65 min., door-to needle 76 min. Mean time for eleconsultation 15 min. Symptomatic hemorrhage occurred in 8.5% of patients, and in-hospital mortality was 10.4%.

Study	Intervention & Time Period	Population	Technology Resources	Personal Resources/Distance	Process Management	Outcome, Category Measured	Result
Audebert, 2006	Investigate the impact of telemedical networking on processes of tPA administration in community hospitals compared with academic hospital. Jan 1, 2004 – Dec 31, 2004,	4727 stroke patients	High-speed VC system (ISDN data transfer rates up to 2 Mb/s) to examine patients and transfer teleradiological data of CT and MRI.	5 fulltime neurologists at 2 academic stroke centers served stroke teams in community hospitals consisting of doctors, nurses, physiotherapists, occupational therapists, and speech therapists	Patients possible for tPA in the community hospitals were sent for CT scanning. During the CT investigation, the telemedic consultant was informed by telephone. CT scans were transmitted to and evaluated in the stroke center. After evaluation the VC begun. The investigation was assisted by the attending physicians of the regional hospitals. Patients treated with tPA in the community hospitals had a telemedical follow-up including transmission of follow-up imaging.	tPA patients living in the catchment area of >35 km, tPA patients admitted within 90 min of onset, Patients receiving tPA within 3h, 120 and 90 min. Processes of tPA Management Onset to admission, Admission to CT time, CT to treatment time, Admission to treatment time, Onset to treatment Highest systolic blood pressure during 24 hours after tPA (mean), Highest diastolic blood pressure during 24 hours after tPA (mean) Length of stay Complications After tPA: Intracranial bleedings, Mortality within 7 days, In-hospital mortality	115 of 4727 ischemic and hemorrhagic stroke and TIA patients (2.4%) received tPA in 12 regional hospitals, and 110 of 1889 (5.8%) cases were treated with tPA in the 2 stroke hospitals. There were no statistically significant differences in mortality and ICHs rate, time to admission and time from admission to first CT was shorter in the community hospitals, whereas latency from CT to tPA bolus and total door to needle time was shorter in the stroke centers. Overall time from symptom onset to treatment was similar in both groups. Mortality rate 3.5% in the regional hospitals 4,5% in stroke centers.

Study	Intervention & Time Period	Population	Technology Resources	Personal Resources/Distance	Process Management	Outcome, Category Measured	Result
Choi, 2006	Screen stroke patient for systemic tPA via VC. Apr 2004- May 2005	14 ischemic stroke patients.	Real time 2-way VC with secure transmission by a point-to-point VPN	2 rural hospitals, 144 and 209km (90 and 130 miles).	ED trigged suspected stroke patients with a pager system. Preliminary information was gathered by telephone to determine whether the patient is suitable for tPA. For candidates was a VC initiated. The consultant assesses a rapid neurological evaluation and CT scans are interpreted. The patient is then treated, admitted, released, or transferred.	of onset to admission, NIHSS before and after tPA, door to needle, blood pressure parameters, intracranial bleedings	In the preceding 13 months Jan 2003–Mar 2004, 2 (0.8%) of 327 received rtPA, compared with 14 (4.3%) of 328 patients during Apr 2004–May 2005. Door to median needle time 85 min (27-165) NIHSS Median pre-treatment 10. 7 of 14 patients NIHSS improvement of ≥4 at 24h post-treatment while 3 worsened. No ICHs. Transfer to stroke center after tPA.
Frey, 2005	To increase tPA use through a telephone network consisting of a stroke center and community EDs. Between 1998-2002	126 patients.	TC	An emergency physician in the regional hospital and the stroke team on-call consisting of a resident, stroke fellow, and the attending stroke neurologist. Radiologists on site interpreted CT scans in EDs.	ED presented their cases by telephone to an on-call stroke team. In accordance with ASA Guidelines, the attending physician checked the inclusion and exclusion criteria's for tPA, discussed benefits and risks of tPA, and give recommendations for management of blood pressure, fluids, and other relevant medical problems. A on site radiologists interpreted the CT scans in the ED. Infusion of tPA was initiated in the outside ED then transported to stroke center.	Onset to ED Door to needle Onset to treatment mRS before and after tPA and at discharge. Hemorrhage Length of stay Discharge home or rehabilitation	53 patients were treated with tPA by telephone and 73 in a stroke center. tPA-treatment increased with 72%, from 31 to 53 due to TC. Requirements included willingness of community EDs to use tPA and willingness of the stroke center to provide support. average flight time of 30min

Study	Intervention & Time Period	Population	Technology Resources	Personal Resources/Distance	Process Management	Outcome, Category Measured	Result
Handschu, 2008	Compare remote video-examination and telephone consultation in acute stroke. One year study period	152 stroke patients	VC provided by live audiovisual communication and access to brain images; TC was done via standard telephone using a structured interview. There was a weekly rotation of the two methods.	N/A	ED trigges stroke patients using a stroke protocol. Clinical examination by the remote neurologist, NIHSS, interpreteing CT/MRI scans. Afterexamination, a written statement was given concerning treatment and recommendation. TC: History, symptoms and clinical findings, CT or MRI imaging were verbally reported to the stroke expert. A standard checklist covering symptoms and clues for history and risk factors as well as concomitant medication was used.	Primary outcomes: the rate of transfer to the stroke center after consultation. Other key objectives: short-term outcome, such as death and dependency 10 days after stroke. Quality parameters: discharge destination, length and type of hospital stay, and change in diagnosis.	77 patients were seen by RVE and 74 by TC. Total examination times were 49.8 min for RVE and 27.2 min for TC ($p < 0.01$). Patients were more frequently transferred to the stroke center after TC consultation (9.1 % vs. 14.9 %, $p < 0.05$) and had a higher mortality 10 days after stroke (6.8 % vs. 1.3 %, $p < 0.05$). Diagnosis made by TC had to be corrected more frequently (17.6 % vs. 7.1 %; $p < 0.05$).
Hess, 2005	Expand the use of tPA and to bring guideline driven stroke care via VC system to neurological underserved areas. Mar 2003 to May 2005	194 stroke patients	Web-based telestroke tool consisting of SF+2-way VC. 2-way audio and 1-way video consulting. Broadband Internet access (512 kbp)	1 stroke center served 8 community hospitals on a 24h basis. Distance to stroke center, 51-148km (32-92 miles).	Regional hospital activates the system when a suspected stroke patient arrives within 4h of symptoms onset. The communication center then contacts the stroke specialist on call which logs on the REACH Website and initiated the session. A decision to treat or not to treat with tPA is made. In addition, recommendations for diagnostic evaluation and therapy and arrangements for transfer to stroke center are done.	tPA rate, NIHSS, hemorrhages, OTT, onset to door, REACH login to tPA, mortality, follow-up imaging (CT or MRI)	30 patients were treated with tPA, 23% (7) were treated in 90 minutes and 60% (18) were treated within 2 hours. There were no ICHs The mean OTT 122min. The OTT dropped from 143 min in the first 10 patients treated to 111 min in last 20.

Study	Intervention & Time Period	Population	Technology Resources	Personal Resources/Distance	Process Management	Outcome, Category Measured	Result
Kuhle, 2006	Physician based telephone hotline to assist in management of pediatric stroke Jan 1995 to Jan 2004	718 physicians placed 1131 stroke calls on 1113 children.	TC	Responder: paediatric neurologist or paediatric haematologist.	Physicians initiating the consultation service accepted a legal disclaimer to reach the answering service. The answering service paged the appropriate physician. The responding physician made telephone contact with the calling physician within minutes or hours of the consult, discussed the patient, and provided relevant information. Patient characteristics and treatment was entered into a computerized database.	Patient documentation: geographic location stroke type, timing, and associated thromboses age and sex, diagnostic tests, vascular territory, risk factors, cardiac disorders, other chronic diseases, acute illnesses, prothrombotic disorders vasculopathy.	In 60% of patients, callers had not initiated antithrombotic therapy. Callers' questions for both stroke types usually concerned treatment selection (83%), but for AIS, questions more frequently concerned the selection and interpretation of etiological investigations.
LaMonte, 2003	Feasibility for acute stroke management using telemedicine. 1999 and 2001	50 stroke patients.	SF+2-way VC system transmitted via ISDN. System allow transfer of laboratory data and CT scans.	Stroke team, 2 neurologists and 2 acute care nurse. Distance to stroke center 160km (100 miles).	The onsite physician calls the coordinator, who then transfers the call to the on-call stroke team. The coordinator establishes the request for VC. Informed consent before telemedicine evaluation is obtained from the patient or family member by the on-site emergency department. Transfer of laboratory data, vital signs, CT scans is possible during the consultation. A full neurological examination is then performed by the stroke specialist. tPA patients transferred to stroke center.	Nummbers of tPA and complications (bleedings)	50 consultations, 23 were attempted through telemedicine linkage, and 27 were by traditional telephone conversation, followed by transfer. Of the 23 VC, 2 were aborted because of technical difficulties. Of the patients evaluated by traditional means, 1 of 27 (3.8%) received intravenous rtPA; 5 of 21 (23.8%) received rtPA after telemedicine consultation. No complications.

Study	Intervention & Time Period	Population	Technology Resources	Personal Resources/Distance	Process Management	Outcome, Category Measured	Result
Meyer, 2008	To explore whether telemedicine or telephone consultation was superior for decision making for treatment with thrombolytics. Jan 2004 - Aug 2007	222 stroke patients. VC (n=111) TC (n=111).	VC Laptops, independent access to 2-way audio and high-resolution video, over standard internet connection. TC	4 ED, remote sites that were located 48-563km (30 to 350 miles) from an academic hub.	VC: suspected patient trigged in the EDs. Hub stroke team was contacted by a pager system. The hub consultant took a medical history NIHSS examination. CT images were viewed with DICOM viewer. TC: Hub consultant queried the spoke practitioner about history, physical assessment, the results of laboratory tests, and the local radiologist's report of the CT, and directed the local practitioner in the NIHSS examination. CT images were not viewed by the consultant.	The primary outcome measure: decision to give tPA was appropriate (multistage, masked adjudication process). Secondary outcomes were: rates of tPA use, NIHSS and mRS before and after treatment, 90-day functional outcomes (BI mRS), rates of ICHs, the completeness of the data, and technical observations.	Correct treatment decisions were made more often in the telemedicine group than in the telephone group (108 (98%) *vs* 91 (82%). tPA was used at an overall rate of 25%, 31 (28%) telemedicine *vs* 25 (23%) telephone. 90-day functional outcomes were not diff erent for BI or for mRS score. There was no diff erence in mortality or rates of ICHs after treatment with tPA, 2 (7%) telemedicine *vs* 2 (8%) telephone.
Reponen, 2000	Explore the accuracy of PDA technology in emergency teleradiology.	21 patients.	Mobile Store and forward only using dial-up to local LAN and PPP	A junior radiologist (hospital), a remote neuroradiologist	Patients were screened with a CT scanner and the images transferred to a workstation. Transfer of CT was provided through a dial-in connection to the local-area network of the radiology department, a private point-to-point protocol server was set up using a remote access service. A transmission control protocol/Internet protocol connection between the PDA terminal and the teleradiology server of the hospital was established using the commercial GSM data service.	Connection initializing time, transmission time of images. Time needed for interpretation, mean total work time. Gained essential and beneficial information was also quantified by the neuroradiologist.	In 1 case the image quality was good enough for a final report and in 20 cases the quality was suitable for a preliminary report. The transmitted images gave essential information in 5 cases (24%), beneficial information in 13cases (62%) and were of minor benefit in 3 cases (14%) compared with an ordinary telephone discussion. The neuroradiologist considered that the image consultation saved a hospital visit in 15 cases (71%).

Study	Intervention & Time Period	Population	Technology Resources	Personal Resources/Distance	Process Management	Outcome, Category Measured	Result
Rymer, 2003	Increase tPA delivery in neurologically underserved via a comprehensive stroke center, TC 30 months,	781 stroke patients	TC	Not reported	tPA protocols, NINDS. tPA candidates consulteted via phone with a neurologists.	onset to treatment admission NIHSS in-hospital mortality Symptomatic hemorrhage	142 of 781 (18,2%) received tPA: IV tPA in 36% (52 of 142), IV followed by IA tPA in 25% (35 of 142), and IA tPA in 39% (55 of 142). 70% (99 of 142) were referred from hospitals within 100 miles of the stroke center.
Schwamm, 2004	Increase tPA delivery in neurologically underserved facilities via telemedicine. 27- months period	24 patients.	SF+2-way VC system and transfer of teleradiological data of CT transmitted at 256–384 kbps.	Emergency physicians at 4 regional hospital and neurologists at a tertiary care center.	The emergency physicians trigged patients with symptoms of acute ischemic stroke, which were potential eligible for tPA. All patients were examined by a stroke neurologist who documented NIHSS, tPA eligibility, CT scans analysed, and provided recommendations on stroke management.	NIHSS, CT interpretations clinical characteristics, protocol violations, symptoms of stroke onset to admission, mean consult-to-needle time of minutes and door to-needle time of minutes. Transfer avoidance.	24 patients were evaluated by a stroke neurologists via VC. Mean (SD) consult-to-needle time of 36 (±15) min and door to-needle time of 106 (±22) min. Transfer was avoided in 11 cases.

Study	Intervention & Time Period	Population	Technology Resources	Personal Resources/Distance	Process Management	Outcome, Category Measured	Result
Vaishnav, 2008	To determine the safety of telephonic guidance for use of intravenous tPA in rural hospitals. Nov 2003 - Sep 2006	123 ischemic stroke, patients.	TC	Emergency physicians at remote hospitals and a tertiary care center	ED in rural hospitals contacted the stroke team through a 24-h paging system when a stroke patient possible eligible for tPA. The neurologist conducted a structured interview of the requesting physician from the regional hospital by telephone but did not examine the patient directly. After the consultant was given verbal reports of CT findings, laboratory data, and the clinical examination including blood pressure, decision to treat was made according to the NINDS tPA inclusion and exclusion criteria. After tPA the patient was transferred by ground or helicopter to the Medical Center for follow-up.	Primary outcome measures: symptomatic ICH and in-hospital mortality. Primary outcome measures: Mean ET from stroke onset to admission, mean ET from ED to time of CT scan, mean ET from stroke onset to tPA, mean time from arrival in the ED to tPA.	123 patients were treated with tPA. ET from stroke onset to community hospital arrival was 54±30 min. ET from stroke onset to tPA bolus was 133±37 min. 3 patients (2.5%) had symptomatic ICH, 11 (9%) had asymptomatic ICH, 9 patients (7.5%) died. Mean length of stay was 4±3 days; 47% were discharged to their homes. All patients were transfer to stroke center after tPA. Delivery.
Wang, 2000	To examine the safety and outcome of intravenous tPA for acute ischemic stroke in the OSF Stroke Network. Jun 1996-Dec 1998	57 ischemic stroke, patients.	TC	Not reported	Emergency physician, primary care physician, and/or neurologist have the option of consulting 1 neurologists on call. AHA tPA protocol. transfer is an option if concerns exist aboutneurosugery/ neurological backup or if access to blood products I needed.	baseline and discharge NIHSS, mRs, discharge disposition, mortality, and length of immediate hospitalization.	No statistically significant differences in the variables recorded for patients treated at the community hospitals versus those who received tPA at the stroke center. At discharge, 47% of the patients had minimal or no disability (MRS, 0 to 1), 44% had an NIHSS score of 0 or 1, 54% went home, 25% were transferred to in-patient rehabilitation, 12% went to a nursing or skilled-care facility. 9% died. ICH 9%;

Study	Intervention & Time Period	Population	Technology Resources	Personal Resources/Distance	Process Management	Outcome, Category Measured	Result
Wang, 2004	Remote evaluation for acute Ischemic stroke stroke. Mar 2003 - Apr 2004	75 patients.	SF+2-way VC system delivered over Internet. CT images transmitted by the local radiology staff.	5 rural hospitals in east Georgia were connected via a VC system with a medical center. Distance to stroke center 64-160km (40-100 miles).	ED in regional hospital trigged stroke patient eligible for tPA. Neurologist on duty, login to the REACH Website and initiated the 2-way audio and 1-way VC. NIHSS is measured, CT scans transmitted and interpreted, med. history from the patient and family is obtained. The neurologist makes a recommendation regarding tPA and any other needed therapy. Patients are likely to be transfer after tPA.	For patients evaluated with telemedicine: onset to ED, door to consult callback was registered, door to NIHSS and the NIHSS score was registered. In management of tPA NIHSS score, the time needed from admission to NIHSS evaluation, ICHs, mean door to needle time and mean onset to needle time. discharge dispositions: home, rehab, nursing home.	12 patients received tPA, all without ICHs complications. NIHSS scores ranged from 0 to 30, with a mean of 14.3. Mean onset to door time was 70.9 minutes. Mean door to consult time was 45.1 minutes and the mean door to NIHSS completion was 62.9 minutes. Mean onset to needle time was 135.33 minutes.
Wiborg, 2003	Assess feasibility, acceptance, and economic consequences of a telehealth network. Mar 2001 - Sep 2002	153 stroke patients.	Technology: SF+2-way VC system transmitted via ISDN. CT scans was transferred via telemedicine link.	1 stroke unit and 7 community hospitals. Distances to stroke center 53 to 136 km (33-85 miles).	EDs present stroke patients and their CT images to the stroke unit. Local physician calls the neurologist, who then establishes the VC. Patient's history, symptoms, and the actual medical findings are reported. The remote neurologist examine the patient and interpret CT scans. The results and therapeutic implications are discussed with the physician and a written protocol containing presumptive diagnosis, diagnostic/ therapeutic implications and recommendations is transmitted to the local department by fax.	Date and time of admission, date and time of stroke onset, Time span between first telephone call and start of the presentation. Data on primary care: symptomatology on admission, mRS score, mBI, relevant cardiovascular history, diagnostic procedures, monitoring, applied therapies (including physiotherapy and occupational and speech therapy), complications, stroke classification and localization, code, and date of discharge. Rating of VC quality.	153 stroke patients were examined by teleconsultation. Mean age was 67.5 years. 87 patients had an ischemic stroke, 9 had an ICHs, and 17 suffered a TIA. 40 patients were revealed to have a diagnosis other than stroke. Duration of teleconsultation was 15 min on average. User satisfaction was good concerning imaging and audio quality, and patient satisfaction was good in all cases. Relevant contributions could be made in >75% of the cases concerning diagnostic workup, CT assessment, and therapeutic recommendations.

Study	Intervention & Time Period	Population	Technology Resources	Personal Resources/Distance	Process Management	Outcome, Category Measured	Result
Wong, 2006	Comparison 3 telemedical consultations systems; telephone consulting, teleradiology, and video consulting Oct. 1998 to Sep. 2001	710 patients	SF+2-way VC system via broadband (10Mbit/s)	District general hospital with 1400 beds and a tertiary neurosurgical center in a teaching hospital also with 1400 beds (serve a population of 1,5 million). Travelling time between the hospitals approx. 30 min.	TC: The referring physician was required to TC and discuss in detail with the on-call neurosurgical specialist the case history, physical signs, and relevant investigations. TR: In addition to the telephone consultation, CT brain scan images were transferred from the district general hospital to the neurosurgical center via a Windows-based software. VC: Patients and any relevant radiological images could be visualized at the same time, using the low-cost commercial real-time interactive VC equipment installed in the Accidental and EDs of the two hospitals, connected by one Integrated Services Digital Network line transmitting information at 256 kbps.	process-of-care indicators: consultation process time, median admission Glasgow Coma Scale transfer rate Consultation failure rate, unfit for transfer, transportation time, transfer adverse event, unnecessary transfer, diagnostic accuracy 1 month and 6 months after admission, Clinical outcomes: Glasgow Coma Scale; Mortality. Cost-effectiveness: ratio between the net differences in costs and the net differences in outcomes.	Consultation process time for VC (1.30 SD2.5 h) was longer when compared with TC (0.70 SD1.9 h; pP <0.003), but comparable to TR (1.01 SD1.8 h; pP <0.147). Diagnostic accuracy of TC mode (63.8%) was significantly lower than TR (89.1%; pP 0.0005) and VC modes (87.7%; pP 0.0005). There was a reduction in the 6- months mortality (24.7 versus 34.0%; pP < 0.025) and a trend (pP<0.121) toward more favorable outcomes in patients from the TR group compared with the TC group.

ED=emergency departments, CT= computer tomography, TC=telephone consultation, VC=video consultation (videoconference), tPA (rtPA)= tissue plasminogen activator, MRI = Magnetic resonance imaging, PDA=personal digital assistant, mRs=modified Ranking scale, BI=Barthel Index, NIHSS= The National Institutes of Health Stroke Score, OTT=onset to treatment time, TIA=transient ischemic attack, POTS=Plain old telephone system, VC=Videoconference/video teleconference, SF=Store and forward, ISDN=Integrated services digital network, ICH=intracerebral hemorrhages, ISDN=(Integrated Service Digital Network), ET=elapsed time, DICOM= digital imaging and communications in medicine, NINDS= The National Institute of Neurological Disorders and Stroke rt-PA Stroke Study Group, SF =store and forward, AHA=American Heart Accosiation.

Appendix III) Systemic thrombolysis via telemedicine

Study	Intervention and Time Period	Population Characteristics	Numbers of Consultations	Receiving tPA	Outcome	Result	Comments
Audebert, 2005	To extend the use of tPA treatment in nonurban areas through telemedicine support. Feb. 2003 – Apr 2004	Mean age: 68 Female 41 % Median NIHSS 13	2182	106	Protocol violations occurred in 15 cases (15%). ICHs (8.5%), In-hospital mortality 10.4% Mortality within 7 days, 5,7%. The average (median) in-hospital stay was 12 days. 9 patients had a ICHs within 36h and 2 patients died.	106 stroke patients received tPA via VC. During the first 12 months, tPA rate 2.1% of all stroke patients. Mean delay between onset and hospital admission was 65 min, and door-to-needle time in average 76 min. Median duration for VC, including transmission of CT scans, was 15 min. ICH occurred in 8.5% of patients, and in-hospital mortality was 10.4%.	Increase rate of tPA in the second phase after implementation. Improvement related to increased public awareness, better prehospital stroke management achieved by the continuous educational activities at the regional hospitals. A telemedicine databank was establiched.
Audebert, 2006	To assess the effects of a stroke network with telemedical support on quality of care, according to acute processes and long-term outcome. Jul. 2003 – Mar. 2005	Not reported	709	80	Not reported	All indicators related to quality of acute stroke care were more commonly met in the network than in the control hospitals. After 3 months, 44% of patients treated in network hospitals versus 54% treated in control hospitals had a poor outcome.In multivariate regression analysis, treatment in network hospitals independently reduced the probability of a poor outcome	

Study	Intervention and Time Period	Population Characteristics	Numbers of Consultations	Receiving tPA	Outcome	Result	Comments
Audebert, 2006	To explore if tPA treatment via telemedical consultation are equivalent in less experienced hospitals compared to academic stroke centers.	Mean age: 69,7 Female (%): 50 Median pre NIHSS: 12	Not reported	115	In-hospital mortality 4 (3,5%) Mortality within 7 days, 4 (3.5%) ICHs 9 (7,8%) Length of stay (median)10 days	Prehospital latencies were shorter in the regional hospitals despite longer distances. Door to needle times were shorter in the stroke centers.Door-to-needle (mean): 68 min. Onset-to-hospital (mean): 64 min. Onset-to-needle (mean): 134 min	
Choi, 2006	Screen stroke patient for tPA via telemedicine VC. April 2004 – May 2005	Mean age 74 (41-89) Female 50% Median pre NIHSS 10	328	14 (4,3%)	Median pre-treatment NIHSS was 10.7. In 14 patients NIHSS improvement of ≥4 at 24h post-treatment while 3 worsened. No ICHs.	In the preceding 13 months Jan 2003–Mar 2004, 2 of 327 received tPA (0.8%), compared with 14 of 328 (4.3%) patients during Apr 2004–May 2005. Door to median needle time 85 min (27-165).	Telemedicine facilitated tPA for acute stroke patients intended not to replace care provided by remote-site providers but rather to address a time- and spatially related emergency need.
Frey, 2005	Telephone network to support community ED in the use of tPA. Between 1998 - 2002	Mean age 67,02 (36-89) Sex female (%) 35,8	Not reported	53 (73 in house. Intervention group)	Haemorrhages 6% Mortalaity 7%. Length of stay (Median) 5, (1-16) Discharge disposition: 16 home 22 rehab. 11 Skilled nursing facility.	tPA-treated by phone increased with 72%, from 31 to 53. Onset to ED (mean) 60 min ED to tPA (mean) 105 min. Onset to tPA (mean) 165 min. Average flight time of 30min.	Factors for good practice, air transport. Paramedics, rapid response and excellent intratransport care. Willingness of the stroke center to share the responsibility for decision making.

Study	Intervention and Time Period	Population Characteristics	Numbers of Consultations	Receiving rtPA	Outcome	Result	Comments
Hess, 2005	Expand the use of tPA and to bring guideline driven stroke care via VC to rural underserved areas. March 2003 – May 2005	Mean age: 62 Sex 60 female	194	30 (23 %)	No ICHs.	30 patients were treated with tPA. The mean NIHSS was 15.4, median 12.5. The mean OTT was 122 min. The OTT dropped from 143 min in the first 10 patients treated to 111 min in last 20 patients. Of the 30 patients treated with tPA, 23% (7) were treated in<90 min and 60% (18) were treated within 2 hours.	OTT dropped from 143 min in the first 10 patients treated to 111 min in last 20 patients This was likely due to an educational effort that improved the recognition of stroke and prompted an earlier activation of the system even before the CT scan was completed.
LaMonte, 2003	Acute stroke management using telehealth January 1999 - December 2001.	Not reported	50	5 (all transported to the stroke center)	Not reported	50 consultations, 23 were attempted through VC, and 27 by telephone consultation, followed by transfer. Of the 23 VC, 2 were aborted because of technical difficulties. Of the patients evaluated by traditional means, 1 of 27 (3.8%) received intravenous tPA; 5 of 21 (23.8%) received tPA after VC. No complications.	Factors for good practice: clarity of data transmission and easy to use. Close relationship between the clinical support staff and the technology personnel. Initial training and ongoing mentoring on management of stroke patients. Potential barriers: initial costs of equipment and staff training. Lack of 24h service. Fixed location of equipment. Mobile system, optimal.

Study	Intervention and Time Period	Population Characteristics	Numbers of Consultations	Receiving tPA	Outcome	Result	Comments
Meyer, 2008	To increase the effective use of thrombolytics for acute stroke and to explore whether telemedicine or telephone consultation was superior for decision making for treatment with tPA. Januar 2004 – August 2007	234 patients were enrolled and 222 were randomly assigned to telemedicine or telephone-only consultations.	222 (111 Telephone and 111 Telemedicine)	25 (23%) Telephone 31 (28%) Telemedicine	Post-thrombolytic ICHs 2 (7%) 90-day BI score (95–100) 10 (33%) 90-day mRS score (dichotomised 0–1) 9 (30%) Subgroup mortality 12 (39%)	Mean NIHSS at presentation was 9,5 in the VC group vs 7,7 points in the TC group. One VC was aborted for technical reasons. Correct treatment decisions VC group: 108 cases (98%) TC group: 91 cases (82%). tPA overall rate 25%. 31 (28%) patients in VC group and 25 (23%) in TC group. 90-day functional outcomes were not different for BI or for mRS score. No difference in mortality or ICHs after reciving tPA, 2 (7%) VC and 2 (8%) TC.	Low technical complications, and favourable time requirements all support the efficacy of telemedicine for making treatment decisions.
Rymer, 2003	neurologically underserved via a comprehensive stroke center, TC	Not reported	781	142	Overall in-hospital mortality rate was 12.7% (18 of 142): IV tPA, 5.8%; IA tPA, 14.2%; and IV/IA, 20%.Symptomatic hemorrhage occurred in 9.2%: IV tPA, 1.9%; IV/IA tPA, 11.4%; IA tPA, 14.6%	The mean times from onset to treatment were as follows: IV (0.9 mg/kg), 119 minutes; IV (0.6 mg/kg) followed by IA tPA, 120.5 minutes; and IA tPA, 210.6 minutes.	
Schwamm, 2004	To determine eligibility for treatment with tPA and provide support to Emergency departments without on-site stroke expertise. 27-month period	24 patients Mean age 68.7 (31–92) Female, 15 White, 23 NIHSS score, mean 5.7	24	6	1 patient had a ICH, and another had a minor asymptomatic hemorrhagic. One half of the tPA treated patients were independent by 6 months poststroke.	Mean NIHSS 16.3 (8–22). 6 tPA patients Mean Consult-to-needle timef 36 (±15) min. Mean door to-needle time 106 (±22) min. Transfer was avoided in 11 patients.	Physicians believed that VC improved care in 95% of the cases.

Study	Intervention and Time Period	Population Characteristics	Numbers of Consultations	Receiving tPA	Outcome	Result	Comments
Vaishnav, 2008	To determine the safety of telephonic guidance for use of intravenous tPA in rural hospitals. Nov 2003 - Sep 2006	39,8 % female Mean age 64	Not reported	123	3 patients (2.5%) symptomatic ICH. 2 of these patients were released to rehab, 1 died. 11 patients (9%) had an asymptomatic ICH. All of these patients survived, 4 were able to return at home and 7 were released to rehab. Of the 123 patients, 9 patients (7.5%) died.	ET from stroke onset to community hospital arrival was 54±30 min. ET from stroke onset to tPA bolus was 133±37 min. 3 patients (2.5%) had symptomatic ICH, 11 (9%) had asymptomatic ICH, 9 patients (7.5%) died. Mean length of stay was 4±3 days; 47% were discharged to their homes.	
Waite, 2006	To explore the feasibility of video consulting for acute stroke care 34 months, July 2002 - may 2005	Not reported	88 VC	27 (30%)	haemorragic bleedings: no Motalaity: 1	27 patients received tPA. No haemorrhagic complications. 1 patient died. Mortality was attributed to the severity of the stroke rather than to the administration of t-PA. 63% of calls happen after hours requiring a 24-hour service.	Calls were placed for VC mainly outside normal opening hours, which requires a 24h VC service. Factors for success include infrastructure; use of an existing physician referral call system; development and use of harmonized clinical protocols; approach to training and ongoing support of staff to integrate telehealth into clinical practice; and compensation for physician consultation

Study	Intervention and Time Period	Population Characteristics	Numbers of Consultations	Receiving tPA	Outcome	Result	Comments
Wang, 2004	To expand the use of tPA via VC to rural underserved areas. March 2003 – April 2004	Not reported	75	12	No hemorrhages NIHSS Discharge disposition: Home, 5 Nurs. home, 1 Rehab, 3 (Data on 3 patients missing).	12 patients received tPA, no ICHs. NIHSS 0-30, mean 14.3. Mean onset to door time 70.9 min. Mean door to consult time 45.1 min and the mean door to NIHSS 62.9 min. Mean onset to needle time 135.33 min.	
Wang, 2000	To examine the safety and outcome of intravenous tPA for acute ischemic stroke in the OSF Stroke Network. Jun 1996-Dec 1998	Mean age 71 Females 40% Basline NIHSS: 14	Not reported	57	At discharge, 47% of the patients had minimal or no disability (MRS, 0 to 1), 44% had an NIHSS score of 0 or 1, 54% went home, 25% were transferred to in-patient rehabilitation, 12% went to a nursing or skilled-care facility. Mortality 9 %, ICHs 9%	≈900 ischemic stroke patients were treated at the OSF Comprehensive Stroke Center. 57 (6.3%) were treated with tPA.	
Wiborg, 2003	Establishment of a telemedicine network including transfer of CT scans between a stroke center and regional hospitals. March 2001 – March 2002	76 female (50 %) Mean age 67,5	153 (a total of 623 strokes were registered in the hospitals)	2	Not reported	153 VC. Mean age 67.5 years. 87 patients with ischemic stroke, 9 had an ICHs, and 17 suffered a TIA. 40 patients were revealed to have a diagnosis other than stroke. Duration of VC was 15 min on average. User satisfaction was good concerning imaging and audio quality, and patient satisfaction was very good. Relevant contributions could be made in >75% of the cases concerning diagnostic workup, CT assessment, and therapeutic recommendations.	The importance of teleconsultation is underscored by the fact that 26% of the patients had diagnoses other than stroke, which had been suspected by the emergency physician.

VC=Videoconference/video teleconference, POTS=plain old telephone system, CT=computer tomography, ED=emergency department, tPA. (rtPA)= tissue plasminogen activator, ICH=intracerebral hemorrhages, NIHSS= The National Institutes of Health Stroke Score, BI=Barthel Index, MRS=modified Rankin scale, ET=elapsed time, OTT=onset to treatment time, TIA=transient ischemic attack

Appendix IV) CHARACTERISTICS AND OUTCOMES OF INCLUDED STUDIES INVOLVING TELEREHABILITATION

Study	Intervention & Time Period	Population	Technology Resources	Personal Resources	Process Management	Outcome Category Measured	Result
Boter, 2004	Outreach care program consisting of telephone contacts and a visit to the patients in their homes.	536 patients: randomized 263 (with 211 carers) to standard care with outreach care and 273 (with 230 carers) to standard care only.	TC	13 trained stroke nurses.	Nurses supported patients and carers according to their individual needs. Brochures on stroke or informal care were discussed and distributed. Instead of actively solving problems, which may induce a passive attitude the nurses aimed to support patients and carers and advised how to solve the problems themselves or cope with them.	Primary outcome measures: Satisfaction-With-Stroke-Care questionnaire and SF-36. Secondary outcome measures: the Hospital Anxiety and Depression Scale, Dissatisfaction with care, SASC-19, BI, mRS, Caregiver Strain Index and Sense of Competence Questionnaire and Discrepancies, Social Support List–Discrepancies	Interventional group better scores on the SF-36 domain than controls. Patients in the intervention used less rehabilitation services and had lower anxiety scores than controls. No statistically significant differences were found on other outcomes.
Buckley, 2004	Explore the receptiveness and utilization of telehealth call by caregivers of stroke survivors. 6 week intervention	21 caregivers of patients who had had a stroke in the previous 6 months	Videophone technology	Telehealth nurses and biomedical engineer who installed the equipment.	A nurse made 2 initial home visits weekly telehealth visits with each caregiver over a 6-week period. During the initial home visit was information on patient's medical history and medication profile collected and equipment installed.	Patient-Caregiver Functional Unit Scale Receptiveness, Utilization Patterns. Nurses' and Caregivers' Acceptance of POTS were done by interviews.	Acceptance related to moderate dependence of patient on caregiver, comfort with technology and timing of introduction (earlier better). Nurse rapport and availability was key factor in actual use of the system.

Study	Intervention & Time Period	Population	Technology Resources	Personal Resources	Process Management	Outcome Category Measured	Result
Grant, 2002	To develop and maintain problem-solving skills over telephone partnerships intervention. 12- week period.	74 ischemic stroke survivors and their primary family caregivers.	TC	1 research nurse, a graduate research assistant and a academic health scientist.	The intervention consisted of an initial 3-hour face-to-face session with a trained nurse in patients´ home. The initial session was followed by weekly and biweekly telephone contacts to develop and maintain these skills. The trained nurse assisted family caregivers in applying problem-solving skills and provided feedback on the appropriateness of techniques used.	SF-36 Social Problem-Solving Inventory the Client Satisfaction Questionnaire 20-item Center for Epidemiological Studies Depression Scale Preparedness for Caregiving Scale subscale of the Caregiving Burden Scale	Intervention group ha better problem-solving skills, greater caregiver preparedness, less depression ($p<0.001$), and significant differences in vitality, social functioning, mental health, and role limitations related to emotional problems.
Lai, 2004	Feasibility of using VC in a community based stroke rehabilitation program. 8-week intervention	21 stroke patients	Two-way VC system only via broadband (10Mbit/s)	A remote physiotherapist, a non-professional supportative assistant in the community centre.	21 patients living at home participated in the intervention programme at the community centre for seniors. A physiotherapist hold educational talks, exercise and psychosocial support. Class size 6 to 8 persons. The education involved pathophysiology of stroke, signs and symptoms, medical management, rehabilitation pathways, the identification and modification of risk factors, psychosocial impact, community support, and home and environmental safety.	Primary outcome BBS SSES SF-36 Knowledge test on stroke A questionnaire to evaluate satisfaction Secondary outcome GDS-15 EMS Lawton IADL	Improvement noted on the Berg Balance Scale, State Self-Esteem Scale, knowledge and SF-36 Satisfaction was rated good/excellent in 63%/ 37% of cases.

Study	Intervention & Time Period	Population	Technology Resources	Personal Resources	Process Management	Outcome Category Measured	Result
Pierce, 2004	Assess the feasibility of providing Internet based education and support for stroke caregivers in rural communities 3 months intervention.	9 adult caregivers (5 men and 4 women)	Internet access via television (WebTV) delivered over dial-up	A nurse specialist and a computer technician who installed the equipment and trained the participants (technical support).	The participations can be linked to a customized educational care giving "tip of the month" and educational information. They also can participate in an e-mail consultation with a nurse specialist or rehabilitation team. An e-mail discussion forum was established, which offered caregivers to communicate with each other and exchange personal experiences.	Functional Independence Scale. Qualitative methods to explore participants training and use of the intervention and Internet	All participants were satisfied with Caring-Web. 8 of 9 strongly agreed or agreed They required this services. 7 subjects used the intervention 1-2h per week and 2 used it less than 1h per week. 3 Participants reported technical failures. 5 participants posted message in the discussion group. All used the "tipp" educational link once a week.
Piron, 2004	Restore arm deficits resulting from stroke via a telerehabilitation intervention. 4 week intervention.	5 patients (2 men and 3 women)	VC through a TCP/IP protocol and point-to-point ISDN	Therapist at a rehabilitation hospital	Workstations with a 3D motion tracking system to record arm movements were installed in patients´ homes. On a remote workstation did the therapist move an object and the system software transformed it into a virtual image that changed position on the screen in response to the receiver movement. Creating virtual tasks. During performance, the patient could see not only his movement but also the correct trajectory, as prerecorded by the therapist. In addition, the therapist provided the patient with information about the task correctness through the VC system.	Fugl-Meyer and Functional Independence Measure scale.	Improved Fugl-Meyer score, mean velocity and duration of movement; no change on ADLs ($p<.05$); a lack of physical presence did not hamper motor learning

Study	Intervention & Time Period	Population	Technology Resources	Personal Resources	Process Management	Outcome Category Measured	Result
Schopp, 2000	Improving access to behavioural health-care for brain injury via telemedicine	3 separate studies: Cognitive assessment study: 52 patients and 52 case controls Psychotherapy study: 13 patients seen via VC Educational training study: 39 health care providers.	2-way VC system only delivered over T1 line	The cognitive assessment and psychotherapy study was supported by neuropsychologists. In the training study 39 rural mental health providers was trained by the neuropsychologists.	Cognitive assessment the neuropsychological evaluation was conducted either in person or via interactive VC among rural residents with cognitive dysfunction. Psychotherapy study a psychotherapist delivered behavioural therapy via VC and in-person visits to geriatric patients living in a rural rehabilitation unit. Mental health training, a network was established between rural mental health providers who were trained by neurophysiologists in issues related to traumatic brain injury.	Patient and provider satisfaction	Persons seen via telemedicine were more likely than controls to want to repeat their experience and more satisfied than were the neuropsychologists who examined them. Persons receiving psychotherapy were less likely than persons receiving assessment services to want to repeat their experience. In the training study, 39 rural mental health providers were trained via VC, and trainees demonstrated significant improvement on tests of knowledge about brain injury.

VC=Video consulting, TC=Telephone consulting, POTS=Plain old telephone system, SASC-19=Satisfaction-With-Stroke-Care questionnaire, BBS=The Berg Balance Scale, SSES=State Self-Esteem Scale, SF-36=Medical Outcomes Study 36-item Short Form, GDS-15=Geriatric Depression Scale 15-item, EMS=Short Form, the Elderly Mobility Scale, Lawton IADL=The Lawton Instrumental Activities of Daily Living Scale, SF=Store and forward, ISDN=Integrated services digital network, BI=Barthel Index, MRS=modified Rankin scale