J Neurol (2014) 261:2003–2008
DOI 10.1007/s00415-014-7450-4

ORIGINAL COMMUNICATION

Teleneurology in stroke management: costs of service in different organizational models

René Handschu · Mateusz Scibor · Martin Nückel · Dirk Asshoff · Barbara Willaczek · Frank Erbguth · Stefan Schwab · Frank Daumann

Received: 2 May 2014 / Revised: 17 July 2014 / Accepted: 18 July 2014 / Published online: 1 August 2014

Abstract Telemedicine is in increasing use in clinical neuroscience such as acute stroke care, especially by applying remote audiovisual communication for patient evaluation. However, telephone consultation was also used linking stroke centres to smaller hospitals. We compared costs of telestroke services using audiovisual and telephone communication in different organizational models. Within a small network in Northern Bavaria video-based teleconsultation (VTC) and telephone advice (TA) was provided for evaluation of acute stroke patients on a weekly rotation. The costs of the admissions process with or without one of both methods of telemedicine were calculated and compared from the perspective of the spoke hospital. Different levels of service and network size were modelled and costs of transfers as well as loss of revenues were calculated. Yearly total labour costs were 415,000 € for an on-site service VTC-service compared to 61,000 € in an on-call service. Additional costs for one teleconsultation were 109.55 € in VTC and 49.82 € in TA (VTC/TA ratio 2.2). The ratio decreased to 0.8 when accounting for costs of transfer and loss of reimbursement for all patients transferred as transfer of patients to the stroke centre was more frequent after TA (9.1 vs. 14.9 %full-time on-site ser). Costs of one QALY gained by using VTC instead of TA ranged from 115.00 € to 515.86 € depending on the different models. In the first view TA looks like the less expensive method as it is easy to access and works without additional costs. When accounting for all disadvantages TA becomes slightly more expensive. In telestroke care VTC should be recommended as the method of choice also from an economic perspective.

Keywords Acute stroke · Costs · Telemedicine · Stroke management

Electronic supplementary material The online version of this article (doi:10.1007/s00415-014-7450-4) contains supplementary material, which is available to authorized users.

R. Handschu (✉)
Department of Neurology, Klinikum Neumarkt, Nürnberger Str.12, 92318 Neumarkt/OPf, Germany
e-mail: rene.handschu@klinikum.neumarkt.de

M. Scibor · S. Schwab
Department of Neurology, Universitaetsklinikum Erlangen/ Friedrich Alexander Universitaet Erlangen-Nürnberg, Erlangen, Germany

M. Nückel · F. Erbguth
Department of Neurology, Klinikum Nürnberg, Nürnberg, Germany

D. Asshoff
Department of Internal Medicine, Kreisklinik Roth, Roth, Germany

B. Willaczek
Department of Internal Medicine, Klinikum Forchheim, Forchheim, Germany

F. Daumann
Division of Sports and Health Economy, Friedrich-Schiller-Universitaet Jena/MBA Program "Health Care Management", University of Bayreuth, Bayreuth, Germany

Introduction

Use of telemedicine is rapidly growing in acute stroke care. Telemedicine has been demonstrated to be a safe and effective way to support administration of thrombolysis in smaller hospitals [1]. First guidelines and Health Technology Assessment (HTA) reports are published on the basis of upcoming evidence [2] while studies on costs and

economic impact of Telemedicine in stroke care are limited. There are reports on cost-effectiveness of telestroke in general stroke care [3, 4], especially with respect to enforcement of thrombolysis. Herein telestroke service was found to save costs for the overall healthcare system and reduce costs for the spoke hospital [3]. In these studies telestroke service was based on use of direct audiovisual communication. Nevertheless, telephone advice was also reported as a method to guide thrombolysis in remote hospitals [5]. Thus it is not clear which method of telemedicine is mandatory and feasible for guiding acute stroke care. While telephone consultation was reported to be equal to telestroke in safety of thrombolysis [6], remote video consultation was found to be superior to telephone contact regarding several outcome parameters [7] and in enforcing use of tPA [8]. We compared several types of service using video-based teleconsultation (VTC) to traditional telephone advice (TA) in acute stroke care within a telestroke project. Herein we aimed to calculate net costs of different methods and systems of service including their various impacts on costs and revenues of the local "spoke" hospitals.

Materials and methods

The study was conducted within the Project for "Stroke Care using Telemedicine in Northern Bavaria" (STENO), a small pilot study of a stroke care network consisting of two stroke centres at Nuremberg and Erlangen and two local hospitals (district hospitals at Roth and Forchheim, Bavaria, Germany). The STENO project was funded by the Bavarian State Government. Meanwhile, STENO has expanded to a network with 3 stroke centres (hubs) and 17 local hospitals (spokes) from this pilot project.

Within the study period of 1 year all stroke patients admitted to the two local hospitals were included in the study. On a week to week rotation there was a switch between pure telephone advice (TA) and full audiovisual consultation using remote video examination called video-based teleconsultation (VTC). Details of the study methodology are described in a prior paper [7].

VTC was performed using a novel audio-visual telesupport system (EVITA, Optics Research and Information Ltd, Erlangen, Germany) fulfilling the recommendations of the American Heart Association Stroke Council [2]. Details of the EVITA-system and its technical features were previously reported [7, 9]. Due to availability of high bandwith lines and needs of data safety, the system was accessible only at one personal computer at the stroke unit of each centre.

Clinical examinations of patients at the local hospital were performed based on a standard procedure applying the National Institutes of Health Stroke Scale by the remote examiner. Assistance at bedside was provided by the local physician on call. Images of computed tomography (CT) scans of the brain were reviewed by the remote examiner at the stroke centre. After the examination, a hand-written statement was given by the consulting expert concerning assessment and treatment recommendation and sent to the local hospital by fax.

Telephone advice (TA) was conducted via standard telephone lines or in some cases GSM-cell phones. History, symptoms and clinical findings as well as findings from CT-imaging were reported orally by the local physician to the stroke expert in the centre. Recommendations for further diagnostics and treatment were also discussed by telephone only. Only experienced stroke neurologists were qualified for providing teleconsultation in both modes.

During the whole study all workflow of the admission process was monitored, all workload and material of the admissions and teleconsultation process was registered and used for complete accounting of all variable costs of each consultation. Teleconsultation is included in the admissions process. Therefore, costs of the normal admissions process from door to stroke unit (or transfer to the stroke centre) were calculated as well as the costs for the admissions process including VTC or including TA, respectively.

Fixed overhead costs were partially included. Total costs of labour were calculated by average salaries and on-call fees of an experienced physician and an emergency room nurse. A summary of calculation input data is given in the appendix (supplementary material). From these data a calculation of total costs at the local hospital for VTC and TA was performed considering different models of service:

(A) an on-call service (consulting stroke expert is at home and gets involved on demand) for a small network including two hospitals and one centre (140 consultations per hospital per year). In an on-call model TA can be done from home or any other place. For every VTC the expert has to drive to the stroke centre as there is only one telestroke unit on site (a maximum delay of 30 min was accepted from call to start of consultation).

(B) Full-time on-site service (consulting expert is in hospital all time) for a small network of the same size.

(C) Full-time on-site service (consulting expert is in hospital all time) for a larger network of 11 hospitals and 1 centre (ca. 2,000 consultations per year).

Full expenses of the telemedicine service at the stroke centres were accounted to the local (spoke) hospitals in each model. For model (A) a further calculation for VTC and TA was made including the costs of patient transfer

Table 1 Fixed costs of telemedicine service at the stroke centre (hub)

	VTC	TA
Full-time on-site service	Labour costs: 415,905.73 €	Labour costs: 415,905.73 €
	Data line rental: 3,205.80 €	Fixed costs/year: 415,905.73 €
	Technical service: 2,160.00 €	
	Fixed costs/year: 421,271,53 €	
On-Call service	Labour costs ca.: 60,910.00 €	Labour costs ca.: 57,010.00 €
	Data line rental: 3,205.80 €	Mobile phone: 168.36 €
	Technical service: 2,160.00 €	Fixed costs/year: 57,178.36 €
	Fixed costs/year: 66,275.80 €	

and loss of reimbursement (at the local hospital) for patients being transferred to the centre.

For sensitivity analysis we calculated the model including costs of transfer and loss of reimbursement by stepwise alteration of case rate by 100 € steps from 2,243 € to 4,243 € and alteration of network capacity (number of teleconsultations per year) from 1,000 to 3,000 consultations.

To estimate cost effectiveness the incremental costs of VTC for one life saved was calculated. The cost rates are not discounted as they were fixed amounts at one time point or spent over some weeks, respectively. Cost-effectiveness by life years and quality adjusted life years (QALY) saved were calculated by data of the Bavarian Bureau of Statistics on average life expectancy [10]. There are no data on health utilities from our study. Thus we used data from the Oxford Vascular Study for estimation of QALYs achieved [11].

Results

In a prior paper [7] we reported medical outcomes and baseline data of the pilot study: while the two groups of 77 VTC and 74 TA were comparable in demographic and medical characteristics of patients (mean age 68.6 years) there were more patients with intracerebral hemorrhage in VTC ($n = 9$) than in TC ($n = 5$). Patients with a need for thrombolysis were not included in the evaluation as there was a special pathway for them. Duration of the pure video examination was 17.8 min (9–35 min) while the phone call itself took 13.6 min (6–30 min). Accounting for all directly related processes like preparation and documentation VTC took 49.8 min (29–62 min) at the stroke centre and 44.2 min (35–60 min) at the local hospital, while for TA a mean time of 27.2 min (15–38 min) was spent at the stroke centre and 22.3 min (10–29 min) at the local hospital. After VTC 9.1 % of all patients were transferred compared to 14.9 % after TA, in-hospital mortality was higher in patients after TA (6.8 %) than after VTC (3.9 %) [7]. Calculated costs for one transfer were 881.91 €. For reimbursement of one stroke case an average case rate of 3,243 € was accounted for according to the German Diagnosis Related Groups system (DRG) (2012 release).

The yearly total personnel costs calculation sums up for 415,000 € for hospital-based full service VTC at the stroke centre. An on-call service would cost about 61,000 € per year at the hub. Table 1 lists the total costs at the hub for both methods.

The teleconsultation is included in the admission process. Therefore, costs of the normal admission process from door to stroke unit (or transfer) were calculated (100.36 € per case) as well as costs of admission process including TA (150.06 € per case) or VTC (209.91 € per case). See Appendix (supplementary material) for cost accounting of these variables. For further analysis the additional costs of each mode of teleconsultation are given as the difference of normal and teleconsultation-based admission process. Additional costs of one video-based teleconsultation (VTC) or one telephone advice (TA) in the different models of service are given in Table 2 as well as the ratio VTC/TA. A differentiation of costs including costs of transfer and loss of reimbursement within model A and C is shown in Table 2 as well.

On sensitivity analysis alteration of case rate and network capacity proofed the dominant effect of including transferred cases by a stable VTC/TA ratio of 0.78 (0.75–0.81) for model C and 0.84 (0.80–0.89) for model A.

Moreover, as transfer rates may differ between networks and will change within one network over time, we calculated transfer rates that set both methods equal (cost ratio VTC/TA 1.0) when costs of transfer and case rate are stable: If transfer rates of VTC and TA converge a rate of 10.9 % for VTC and 12.1 % for TA will produce the same costs per consultation. If the transfer rate of 14.9 % for TA remains stable a transfer rate of 13.6 % in VTC is required, while a transfer rate of only 10.4 % in TA compares to a stable rate of 9.1 % in VTC.

Based on the different mortality rates 100 VTCs will reduce mortality by 2.9 %. Accordingly, incremental costs of one life saved were 3,714.18 € in model A (additional costs of VTC over TA), 2,422.56 € in model B

Table 2 Costs for one teleconsultation in various models of service

	VTC (€)	TA (€)	VTC/TA cost ratio
Additional costs for telemedicine within the admissions process (additional minutes of physician and nurse, material, telephone charges)	109.55	49.70	2.2
Total costs for model A) (on-call service, 2 hospitals one centre 140/280 consults p.a.)	330.57	222.85	1.5
Total costs for model B) (full-time on-site service, 2 hospitals one centre 140/280 consultations p.a.)	1,560.80	1,490.54	1.1
Total costs for model C) (full-time on-site service, 11 hospitals one centre 2,000 consultations p.a.)	266.90	212.60	1.3
Total costs for model A) (on-call service, 2 hospitals one centre 140/280 consultations p.a.) plus Costs of patient transfers (0.09/0.14 × 881.91 €)	410.82	354.25	1.2
Total costs for model A) (on-call service, 2 hospitals one centre 140/280 consultations p.a.) plus costs of patient transfers and loss of reimbursement (lost reimbursement for cases transferred 0.09/0.14 × 3,243 €)	705.93	837.46	0.8
Total costs for model C) (full-time on-site service, 11 hospitals, one centre, 2,000 consultations p.a.) plus costs of patient transfers and loss of reimbursement	642.26	827.21	0.78

and 1,872.26 € in model C. Life-expectancy in our patients (mean age 68.8 years) is estimated for 16.28 years [10]. Subsequently incremental costs of one life year saved were 228.14 € for model A, 148.80 € for model B and 115.00 € for model C. Quality adjusted life expectancy depends on health-related utilities for a lifetime in a condition of illness or disability. A recent publication from the Oxford Vascular Study notes a health utility of 0.7 for a life after stroke [11]. The authors also combined utilities with data for 5-year life expectancy that was 2.21 quality adjusted life years (QALY) for the 5-year period. Going from these data costs for one QALY saved by VTC would be 515.86 € for model A, 336.47 € for model B and 260.04 € for model C. A summary of these data is shown in Table 3.

Discussion

Telemedicine has been already used for stroke care and its beneficial effect in terms of, e.g. enforcing thrombolysis has been shown [1, 12]. However, telemedicine can be established with different modes of communication. In a prior paper we reported a study comparing traditional telephone communication with full-size audiovisual linkage in acute stroke care [7]. This work reports the comparison of costs of these two methods in various models and estimation of cost-effectiveness of VTC.

This is one of the first reports on a prospective evaluation of costs of telestroke service and its impact in different service models. The study was not truly randomized but due to the weekly rotation the group of patients and its demand of care in the admission process the study is supposed to be equal as is the composition of teams in terms of human resources.

Comparing the two methods TA is far less time-consuming. It takes about half of the time spent on VTC at the stroke centre and as well at the local hospital. However, the time at the local hospital does not include the time for the neurological examination done by the local physician. In case of video examination the local physician could do just a quick first look while a precise neurological examination is done together with the stroke expert during the video communication (and taken into account for the total time of the consultation). TA is not only faster but also easier as access to a telephone is available almost everywhere at least when using mobile phones. In contrast due to data safety and technical reasons, VTC in our study was only possible at one defined place at each stroke centre. Thus an on-call service is much easier with TA than with VTC. However, technical advantages will outweigh these disadvantages of VTC in the future with newer technology and high bandwith wireless connectivity. Accordingly first

Table 3 Data of cost-effectiveness and estimated cost utility for VTC compared to TA

	Costs of one life saved by using VTC instead of TA (34.5 VTC may help saving 1 life) (€)	Costs of one life year gained (life expectancy 16.28 years) (€)	Costs of one QALY gained (16.28 years × 0.44[a] = 7.2 years) (€)
Model A	3,714.18	228.14	515.86
Model B	2,422.56	148.80	336.47
Model C	1,872.26	115.00	260.04

[a] 2.21 years QALY in 5 years life-expectancy [11] = 2.21/5.00 = 0.44

reports of mobile audiovisual examination in telestroke were already published [13]. Overall additional costs for telemedicine service mainly depend on the type of service provided because the main part of costs is derived from fixed costs such as labour costs. Costs of labour certainly differ between an on-call or on-site service.

Subsequently using TA, like in model A, is the far less expensive method as it is easily provided on an on-call basis with lower costs of labour and has also lower or almost no technical costs. The decision for full-service or on-call teleconsultation is primarily based on quality parameters, especially the acceptable delay until a teleconsultation can be started. If an on-site service that is exclusively on duty for teleconsultation is mandatory as stated in the guidelines and standards of the German Stroke Society [14], costs of labour will certainly increase. As a consequence a minimum size of the network is required to provide adequate cost-efficiency. Thus the difference in costs of TA compared to VTC decreases in a larger network like model C. Subsequently the ratio of direct costs VTC/TA declines from 2.3 in model A to 1.3 in model C.

Contrary to the advantages of TA the data of the pilot study have already shown that teleconsultation using VTC provides a higher level of quality [7]. Especially there was a higher in-hospital mortality in TA compared to VTC and a trend to a higher rate of transfer to the stroke centre after TA, indicating that consultation by telephone was not sufficient for a reliable assessment in more cases than when using VTC.

When taking into account this disparencies by including costs of transfers and the loss of reimbursement for the local hospital in every case transferred to the stroke centre the ratio turns over and TA becomes slightly more expensive than VTC from the viewpoint of the spoke hospital as it will lose patients and thus reimbursement and moreover will have to pay for the transfer costs. Additionally, TA may produce more overall costs for the health care system at all as stroke treatment may be more expensive in huge stroke centres. An increase in patient transfer was already reported to reduce cost-effectiveness of a telestroke network [15]. However, telestroke in general was reported to be cost-effective by providing the benefit of improved stroke care lifelong [16].

Our Study has several limitations: the cost ratio finally depends mainly on the frequency of transfer after teleconsultations that remains stable. Due to a small number of patients in each group the reliability of the data such as the frequency of transfer is limited. Therefore, we modelled transfer rates that will set both methods on the same costs to provide basis for further calculation. However, the "value" of a patient transferred or a case lost for the hospital depends on the regulations of reimbursement for these cases and for the transportation fees. These regulations are subject to constant changes that could alter the rating of "transferring patients". Moreover, the motivation for referring patients to the stroke centre may also be driven by other factors, e.g. a transfer of patients with severe stroke or unclear diagnosis to the stroke centre could also minimize treatment costs or spare scarce intensive care capacity at the local hospital. It should be noted that our view is from the perspective of the spoke hospital. At the hub a case transferred will gain proceeds. If so the network partners could agree on discounts for cases transferred of arrange retransfer. Finally, one should bear in mind that our comparison is about the costs of telemedicine service only. An effect of telemedicine in acute stroke care is proven only when combined with a network structure including training and quality management for all partners within the network [2]. Our analysis does not include costs for training or network management. However, these costs might be equal for TA and VTC if the same level of quality is to be achieved. Subsequently, our data are more a basis for costs calculation in telestroke services of different type and size. Even more calculation of cost-effectiveness is based on estimations and data from the literature that cannot necessarily be adopted to a telestroke setting.

To summarize, our study may suggest that when estimating the economic effect of telemedicine systems participants should take into account not only the pure costs of the teleconsultation service. From our data smaller hospitals that will participate in stroke care networks should use audiovisual communication for remote clinical examination and image transfer to be cost-effective also on the basis of their cost and reimbursement ratio.

Accordingly, VTC and video-based telecommunication seems to be the preferable method for teleconsultation in acute stroke not only in the light of higher quality of stroke service but also from an economic perspective.

Acknowledgments We are very grateful to Mrs Andrea Handschu, MSc, who reviewed all calculations and accountings in this manuscript and to Mrs Sonja Heinloth for editing the manuscript. The STENO-project was supported by a public grant of the Bavarian State Ministry of Health and Social Welfare.

Conflict of interest None of the authors has any conflict of interest or any financial relationship to companies or products named in this article.

References

1. Audebert HJ, Kukla C, Clarmann von Clarnau S et al (2005) Telemedicine for safe and extended use of thrombolysis in stroke: the Telemedic Pilot Project for Integrative Stroke Care (TEMPiS) in Bavaria. Stroke 36:287–291
2. Schwamm LH, Holloway RG, Amarenco P et al (2009) 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. Stroke 40:2616–2634

3. Switzer JA, Demaerschalk BM, Xie J, Fan L, Villa KF, Wu EQ (2013) Costeffectiveness of hub-and-spoke telestroke networks for the management of acute ischemic stroke from the hospitals' perspectives. Circ Cardiovasc Qual Outcomes 6:18–26
4. Ehlers L, Müskens WM, Jensen LG, Kjølby M, Andersen G (2008) National use of thrombolysis with alteplase for acute ischaemic stroke via telemedicine in Denmark: a model of budgetary impact and cost effectiveness. CNS Drugs 22:73–81
5. Majersik JJ, Meurer WJ, Frederiksen SA et al (2012) Observational study of telephone consults by stroke experts supporting community tissue plasminogen activator delivery. Acad Emerg Med 19:E1027–E1034
6. Pervez MA, Silva G, Masrur S et al (2010) Remote supervision of IV-tPA for acute ischemic stroke by telemedicine or telephone before transfer to a regional stroke center is feasible and safe. Stroke 41:e18–e24
7. Handschu R, Scibor M, Willaczek B, for the STENO Project et al (2008) Telemedicine in acute stroke: remote video examination compared to simple telephone consultation. J Neurol 255: 1792–1797
8. Meyer BC, Raman R, Hemmen T, Obler R, Zivin JA, Rao R, Thomas RG, Lyden PD (2008) Efficacy of site-independent telemedicine in the STRokE DOC trial: a randomised, blinded, prospective study. Lancet Neurol 7:787–795
9. Handschu R, Littmann R, Reulbach U et al (2003) Telemedicine in emergency evaluation of acute stroke: interrater agreement in remote video examination with a novel multimedia system. Stroke 34:2842–2846
10. Bavarian Bureau of Statistics: life expectancy by year. https://www.statistikdaten.bayern.de/genesis/online?language=de&sequenz=tabelleErgebnis&selectionname=12621-001z
11. Luengo-Fernandez R, Gray AM, Bull L, Welch S, Cuthbertson F, Rothwell PM (2013) Oxford Vascular Study. Quality of life after TIA and stroke: ten-year results of the Oxford Vascular Study. Neurology 81:1588–1595
12. Zaidi SF, Jumma MA, Urra XN et al (2011) Telestroke-guided intravenous tissue-type plasminogen activator treatment achieves a similar clinical outcome as thrombolysis at a comprehensive stroke center. Stroke 42:3291–3293
13. Audebert HJ, Boy S, Jankovits R et al (2008) Is mobile teleconsulting equivalent to hospital-based telestroke services? Stroke 39:3427–3430
14. Audebert H, Busse O (2010) Updates by the Stroke Society. Nervenarzt 81:776
15. Demaerschalk BM, Switzer JA, Xie J, Fan L, Villa KF, Wu EQ (2013) Cost utility of hub-and-spoke telestroke networks from societal perspective. Am J Manag Care 19:976–985
16. Nelson RE, Saltzman GM, Skalabrin EJ, Demaerschalk BM, Majersik JJ (2011) The cost-effectiveness of telestroke in the treatment of acute ischemic stroke. Neurology 77:1590–1598