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ORIGINAL ARTICLE

A one-to-one telestroke network: the first Italian study of a web-based telemedicine system for thrombolysis delivery and patient monitoring

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Abstract Over 10 years after European approval, thrombolysis is still limited by a restricted time window and non-optimal territorial coverage. Implementation of telestroke can give a growing number of patients access to treatment. We hereby present the first Italian telemedicine study applied to both the acute and the monitoring phase of stroke care. From January 2011 to December 2013, we tested a web-based, drip, and treat interaction model, connecting the cerebrovascular specialist of one hub center to the Emergency Department of a Spoke center. We then compared thrombolysis delivered using the telestroke model with thrombolysis provided at the Hub Stroke Unit at the time when the telemedicine program was activated. Telethrombolysis data were then compared with data from the two main international telestroke projects (TEMPiS and REACH), and other European telestroke studies performed at the time of writing. We collected a total of 131 thrombolysis procedures (25 telethrombolysis and 106 thrombolysis patients at the Stroke Unit). Statistical analysis with the *t* test yielded no statistically significant differences between the two populations in door-to-scan, door-to-needle (DTN), and onset-to-treatment times (OTT). Our OTT and DTN pathway times were longer than the TEMPiS and REACH studies but comparable with other European telemedicine trials, despite different models of interaction and number of centers. Our study in a northeastern province of Italy confirms the potential of applying telemedicine to a cerebrovascular pathology.

Keywords Acute Stroke · Iv thrombolysis · Telemedicine

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Introduction

From the very first studies, reperfusion therapy with rtPA demonstrated a time-dependent efficacy for treating cerebrovascular events: the number needed to treat rose from 4.5, when therapy is administered within 3 h of symptoms onset, to 14, when administered between 3 and 4.5 h [1]. Rapid thrombolysis delivery thus becomes one of four interventions that have to date proved to improve outcome after stroke onset [2]. Nevertheless, despite being approved in Europe since 2002, the use of thrombolysis remains limited by the restricted time window and non-optimal territorial coverage, and today, less than 5 % of eligible patients are treated [3]. Applying telemedicine to stroke can give more patients access to expert care, even in remote areas, and can reduce transfers, and consequently, consultation times, costs, and discomfort for patients with severe stroke [4]; it can also lead to a reduction in the elevated running costs of highly specialized stroke units and patient centralisation, releasing resources for a few referral centers [5–8]. To date, several telestroke experiences have been conducted in Europe and the USA [9–28]. Here, we present the results of the first Italian telemedicine study applied to the acute and monitoring phase of stroke care. Health optimum (HEALTHcare delivery

OPTIMIsation throUgh teleMedicine) is a European telemedicine project approved and cofinanced by the European Union with the aim of enhancing the availability of best medical practices through the application of digital communication systems to medicine. The first phase of the project was centered on telelaboratory and neurosurgical teleconsultation services for traumatic brain injury. During the second phase, telemedicine was applied to the treatment of acute cerebrovascular pathology ("telestroke") modelled on the Bavarian-based TEMPiS project [11]. Specifically, for the first time in Italy, we piloted a neurologic teleconsultation service for acute stroke patients eligible for thrombolytic therapy, based on a "drip and treat" model of interaction between the Neurology Department of Treviso Hospital (Hub center) and the Emergency Department of Conegliano community hospital (Spoke center). The aims of our study were to make acute phase therapies available to a wider population and to achieve uniform stroke care standards by means of a common training pathway shared by ER physicians and stroke specialists. During the first 3 years of our study, we tested the feasibility, timing, and safety of thrombolytic treatment delivery through a web-based telestroke system, analysing two populations: patients undergoing telethrombolysis versus patients treated with thrombolysis at the Hub center at the same time as the telemedicine program was activated.

Materials and methods

From January 2011 to December 2013, we piloted a web-based interaction model connecting the cerebrovascular neurologist at the Hub center (Treviso Hospital) to the ER physician of the Spoke center (Conegliano Hospital), located at a distance of 33 km. Conegliano community hospital does not have a Neurology Department but a Neurology Service is available from 8 am to 5 pm during working days. The Conegliano Emergency Department has a wide catchment area and is unable to transfer acute stroke patients to the Hub hospital within the appropriate time window. Treviso hospital has a second level Stroke Unit, with stroke specialists, a neurologic ward providing 24 h/day, 7 days/week standardized stroke care, stroke pathway protocols, and continuing stroke training.

For the purposes of the trial, we set up the following:

- an emergency consulting room with video cameras at the Spoke center;
- a consulting room with a video camera at the Spoke intensive care unit (ICU);
- a consulting room for the on-duty neurologist at the Hub center, with a computer, video camera, and audiovisual system connected to the Spoke center cameras (a two way interactive audio–video connection). Data transmission required a broadband system between the two hospitals: telestroke consultations transmission was protected by personal usernames and passwords, and by digital signature with personal smart card. Teleconsultant referrals and responses required an electronic form (file XML-CDA2) for reporting time of symptoms onset, teleconsultant referral time, SITS-MOST protocol with inclusion/exclusion criteria, and the NIH stroke scale. CT scan Dicom images were attached. The project required two participants: the ER physician at the Spoke hospital, who identified patients with symptoms/signs suggestive of a cerebrovascular event, potentially eligible for thrombolytic therapy, and the neurologist on duty at the Hub center. When there was no on-duty neurologist at the Spoke center (5 pm–8 am on working days, weekends and holidays), the ER physician advised the Hub center neurologist by telephone that a request for teleconsultation had been transmitted. The ER physician examined the blood tests, CT scan report, 12-lead ECG, and checked the indications for thrombolytic therapy as described in the SITS-MOST protocol (within 3 h of symptoms onset). The ER physician then filled in the teleconsultant referral form and sent it to the neurologist accompanied by the CT scan. The neurologist examined the CT scan images and, via the webcam connected to the ER consulting room, viewed the patient's neurological exam, and assessed the NIH stroke scale. The neurologist then gave his recommendations, filled in a response form signed with the personal smart card, and sent them to the community ER. The following recommendation options were possible:

  - patient is eligible for thrombolytic treatment, and tPA must be administered;
  - patient is eligible for thrombolytic treatment and must be transferred to the Hub center (for two main reasons, either because there was a tPA protocol violation or because subsequent endovascular treatment was a potential option);
  - patient is not eligible for thrombolytic treatment;
  - other.

Reperfusion therapy with tPA was administered in the ER room, and after treatment, the patient was transferred to the Spoke ICU for the following 24 h. When a second opinion was required (e.g., the patient's neurological picture had worsened), a second videoconference was held at the ICU. Statistical analysis: data values were expressed as mean ± DS or medians, and comparison between the two groups was performed with *t* test.

Results

In our analysis, a total of 131 patients received systemic thrombolysis. From 2011 to 2013, the number of thrombolysis procedures doubled in both populations (telethrombolysis vs thrombolysis delivered at the Hub center) (see Table 1). During the three-year pilot, 38 videoconferences were conducted. During these, thrombolysis was recommended in 25 cases (66 % of the total telestroke evaluations). In the telestroke group, mean patient age was 68.5 years (range 39–79). Specifically, two patients younger than 45 years underwent therapy, while no patient older than 80 years was treated. Regarding pathway indicators, median symptoms onset to ER arrival time (onset-to-door time) was 57 min (Ist quartile 32 min, IIIrd quartile 72 min); median ER arrival to CT scan performance time (door-to-scan time) was 24 min (Ist quartile 14 min, IIIrd quartile 38 min), while median ER arrival to therapy (door-to-needle time, DTN time) was 73 min (Ist quartile 98, IIIrd quartile 121 min) (see Table 2). Mean NIH stroke scale score was 10 (range 3–20) (see Table 2). Regarding outcome, 48 % of patients treated with systemic thrombolysis through the telestroke system had significant clinical improvement after 24 h of therapy (a decrease in the NIHSS score of 4 points or more). After 24 h, 8 % of patients showed significant clinical deterioration (an increase in the NIHSS score of 4 points or more), and the NIHSS score was unchanged in 28 % (data not available in 16 %). Two patients (8 % of patients treated via telestroke) developed a symptomatic haemorrhage (sICH according to the NINDS definition). The disability evaluation at 3 months showed: an mRS score <2 at 3 months in 12 patients treated via telestroke (42.8 %), an mRS score of 3–4 at 3 months in 8 patients (28.5 %), an mRS score of 6 at 3 months in 3 patients (10.7 %). Data were not available in two cases (7.1 %). In the video consultations where tPA administration was not recommended (34 %), 6 had a diagnosis of transient ischemic attack (NIHSS score at discharge: 0), 3 had a non-cerebrovascular diagnosis ("stroke mimics"), 3 had a diagnosis of "stroke"; in 1 case, the discharge diagnosis was unknown. Ten thrombolysis procedures were performed in the Spoke center when the neurologist was on duty (working days from 8 am to 5 pm) throughout the 3 years of the telestroke project. No patient has been transferred to the Hub center.

We compared these results with those of patients undergoing systemic thrombolysis in the Hub center at the same time as the telemedicine program was activated (working days from 5 pm to 8 am, weekends and holidays), throughout the three project years (see Table 2). From January 2011 to December 2013, 108 systemic thrombolysis procedures were conducted at the Hub Stroke Unit (information not available in two cases). The mean age of patients treated with systemic thrombolysis at the Hub center was 67.8 years (range 25–92); 20 patients were older than 80, and 13 were younger than 45. Regarding the pathway indicators, median onset-to-door time was 55 min (Ist quartile 39 min, IIIrd quartile 74 min); median door-to-scan time was 23 min (Ist quartile 16 min, IIIrd quartile 38 min); and median DTN time was 95 min (Ist quartile 82, IIIrd quartile 125 min) (see Table 2). Mean NIHSS score was 11.6 (range 2–25) (see Table 2). As concerns patient outcomes, significant clinical improvement was observed after 24 h of therapy (a 4 or more points decrease in NIHSS score) in 50 % of patients treated with systemic thrombolysis at the Hub center; significant clinical deterioration was recorded at 24 h (an increase in the NIHSS score of 4 or more points) in 6 % of patients; the NIHSS score was unchanged in 34 % of patients. Data are not available in 10 %. Three patients developed symptomatic hemorrhage (2 %). The three-month disability assessment was not performed in 62 % of patients (the two populations

Table 1 Number of thrombolysis per year in the Hub center and in the telestroke program

Year	Thrombolysis				Total	Total
	Stroke unit		Telestroke			
	N	%	*N*	%	*N*	%
2011	24	22.7	5	20	29	22.1
2012	40	37.7	10	40	50	38.2
2013	42	39.6	10	40	52	39.7
Total	106	100	25	100	131	100

Table 2 Characteristics of patients and times of treatment

	Age		Baseline NISSS		Onset to door (min), median	Door to scan (min), median	Door to needle (min), median
	Mean (±SD)	Median	Mean (±SD)	Median			
Stroke unit	67.8 (±14.4)	71.5	11.6 (±6.1)	11	55 (I quartile 39, III quartile 74)	23 (I quartile 16, III quartile 38)	95 (I quartile 82, III quartile 125)
Telestroke	68.5 (±10.7)	72	10.4 (±5.0)	9	57 (I quartile 32, III quartile 72)	24 (I quartile 14, III quartile 38)	73 (I quartile 98, III quartile 121)

cannot, therefore, be compared). In terms of the two pathway indicators, mean DTN time in the Hub center was 104.1 min (standard deviation, SD 36.3), and 96.8 min for the telestroke patients (SD 29.6), while mean OTT time was 165.8 min at the Hub center (DS 44.2) and 151.4 min for the telestroke patients (SD 44.1). As regards quality, at the Hub Stroke Unit, eight thrombolysis procedures were performed with a DTN time ≤60 min (7.5 %) compared with two telestroke patients (8 %); two thrombolysis procedures had an OTT time ≤90 min (1.8 %) at the Hub center compared with two telestroke patients (8 %). Statistical time analysis performed with the *t* test yielded no statistically significant differences between the two populations in door-to-scan ($t = 0.8$, $p = 0.4$), DTN ($t = 0.9$, $p = 0.4$), and OTT times ($t = 1.3$, $p = 0.1$).

Telethrombolysis data collected during our study were then compared with data from two key international telestroke studies (TEMPiS and REACH, see Table 3) and with other European telestroke studies performed to date (see Table 4).

Discussion

This is the first Italian telestroke study. Sample size is comparable with other such European and US trials (see Tables 3 and 4), considering that the interaction between the Hub and Spoke centers in our study is one-to-one. In addition, the number of treated patients doubled during the study, most likely due to raised physician awareness and to

Table 3 Comparison with the two main international telestroke programs: telestroke models and telethrombolysis data

	TEMPiS [1]	TEMPiS [2]	REACH	Treviso-Conegliano
Area	Regional	Regional	Regional	Provincial
Hub/spoke	Drip and treat 2/12	Drip and treat 2/12	Drip and ship 1/8	Drip and treat 1H/1S
Number of thrombolysis procedures	106	115	50	25
Mean age	68	69.7	63	68.5
Median NIHSS	12	12	12	9
Onset-to-treatment time	141	134	127.6	151.4
Door-to-needle time	76	68		96.8
% hemorrhage	8.5	7.8 %	2 %	8
mRankin 3 months <2 (%)	nk	nk	nk	42.8 %
Period	February 2003–April 2004	2004	February 2003–March 2006	2011–2013

Table 4 Comparison of published representative European telestroke programs: telestroke models and telethrombolysis data

	TEMPiS [1]	TEMPiS [2]	EoE telestroke	Meuse (east france)	Finnish telestroke	Barcelona Spain	Madrid Spain	Italy
Model of interaction; hub/spoke	Drip and treat; 2/12	Drip and treat; 2/12	na (hubless model)	Drip and ship; 1/1	Drip and treat; 1H/5S	Drip and treat; 1H/1S	Drip and ship 1H/1S	Drip and treat 1H/1S
Number of thrombolysis	106	115	74	21	61	46	18	25
Mean age	68	69.7	69	72	70	nk	68	68.5
Median NIHSS	12	12	10	Mean 16	10	nk	6.5	9
Onset-to-treatment time (min)	141	134	170.1	169	130	nk	155	151.4
Door-to-needle time (min)	76	68	94.9	69	24	53.4	66	96.8
% hemorrhage	8.5	7.8 %	7.3	14	6.7 %	8,69 %	0	8
mRankin 3 months <2 (%)	nk	nk	nk	29 %	29.4 %	53.65 %	55.6 %	42.8 %
Period	February 2003–April 2004	2004	2010–2011	October 2010–February 2012	2007–2009	2007–2010	2010–2013	2011–2013

pathway improvement: this enhances patient recruitment potential and achieves one of the main aims of telemedicine, which is to treat an increasing number of patients, irrespective of residence. Our study demonstrates that patients suffering from acute stroke can be treated safely and rapidly using a web-based specialist neurologic examination and a drip and treat protocol. Two distinctive innovative aspects differ our study from the others: we included only two hospitals, connected by a Hub and Spoke model of interaction, telematically extending neurologic coverage and consultations for thrombolytic therapy to times when there was no neurologist on duty at the spoke hospital (evenings, weekends, and holidays). Support is, thus, provided for in-loco neurologists by extending the time available for neurologic examinations at the Spoke center. Moreover, the possibility of monitoring patients in the community-hospital ICU via web allows stroke specialists to deliver neurologic indications for both thrombolysis and the important follow-up phase. Analysis of pathway times shows satisfactory onset-to-door times and door-to-scan times for both hospitals and procedures (telemedicine and non-telemedicine pathway), but the time taken to start therapy is still too long, especially at the Hub center. As reported in other studies, there is no statistically significant trend toward lower OTT in the Spoke compared with the Hub center [8, 11, 12]. At the Hub center, despite the presence of an in-loco stroke specialist round the clock, OTT is rather long compared with door-to-scan time, which is instead satisfactory. This is because Hub centers often seek the second-level confirmation (i.e., brain MRI or ultrasound scans) to gain a more precise diagnostic picture before treating patients in the acute phase, causing treatment delay. Moreover, in community hospitals with less ER admissions, patients are often evaluated more rapidly by the entire staff, and the diagnostic pathway starts earlier. There were no violations of the thrombolysis protocol in the web-based evaluations by virtue of the trial design. Whenever it was decided to violate the protocol, the patient was centralized prior to treatment. Compared with the main telemedicine trials (TEMPiS and REACH), our OTT and DTN pathway times were longer, but comparable with other European telemedicine trials, despite different interaction models and numbers of centers.

Conclusions

Our study in the northeast of Italy confirms the potential of a web-based approach to acute cerebrovascular care, even when the distances involved are small. In addition, the availability of web-based patient follow-up allows specialists to offer "stroke-unit-like" care during the important hours post thrombolysis (i.e., proper blood pressure or blood sugar monitoring).

The progressive increase in the number of treated patients marks achievement of one of the key aims of telemedicine, namely, to increase the number of patients receiving expert care, regardless of where they live.

Compliance with ethical standards

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Disclosures None.

Conflict of interest None.

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