TeleStroke Units Serving as a Model of Care in Rural Areas
10-Year Experience of the TeleMedical Project for Integrative Stroke Care

Peter Müller-Barna, MD*; Gordian J. Hubert, MD*; Sandra Boy, MD; Ulrich Bogdahn, MD; Silke Wiedmann, PhD; Peter U. Heuschmann, MD, MPH; Heinrich J. Audebert, MD

Background and Purpose—Stroke Unit care improves stroke prognosis and is recommended for all patients with stroke. In rural areas, population-wide implementation of Stroke Units is challenging. Therefore, the TeleMedical Project for integrative Stroke Care (TEMPiS) was established in 2003 as a TeleStroke Unit network to overcome this barrier in Southeast Bavaria/Germany. Evaluation of its implementation between 2003 and 2005 had revealed improved process quality and clinical outcomes compared with matched hospitals without TeleStroke Units. Data on sustainability of these effects are lacking.

Methods—Effects on the stroke care of the local population were analyzed by using data from official hospital reports. Prospective registries from 2003 to 2012 describe processes and outcomes of consecutive patients with stroke and transient ischemic attack treated in TEMPiS hospitals. Quality indicators assess diagnostics, treatment, and outcome. Rates and timeliness of intravenous thrombolysis as well as data on teleconsultations and secondary interhospital transfers were reported over time.

Results—Within the covered area, network implementation increased the number of patients with stroke and transient ischemic attack treated in hospitals with (Tele-)Stroke Units substantially from 19% to 78%. Between February 2003 and December 2012, 54,804 strokes and transient ischemic attacks were treated in 15 regional hospitals, and 31,864 teleconsultations were performed. Intravenous thrombolysis was applied 3331 stroke cases with proportions increasing from 2.6% to 15.5% of all patients with ischemic stroke. Median onset-to-treatment times decreased from 150 (interquartile range, 127–163) to 120 minutes (interquartile range, 90–160) and door-to-needle times from 80 (interquartile range, 68–101) to 40 minutes (interquartile range, 29–59).

Conclusions—TeleStroke Units can provide sustained high-quality stroke care in rural areas. (*Stroke. 2014;45:2739-2744.)

Key Words: quality indicators, health care ■ stroke ■ telemedicine ■ thrombolytic therapy

Organized care in Stroke Units is considered the most effective intervention for patients with acute stroke.1,2 The World Health Organization declared the aim of treating all patients with stroke on dedicated Stroke Units.3 The short time window for recanalization therapies4 and the preference particularly of elderly patients to be treated in their familiar local hospital favor a decentralized system of care. However, implementation of Stroke Units requires multidisciplinary stroke expertise which is not sufficiently available in many, often rural, areas. Therefore, delivering appropriate stroke care in such regions is a major public health challenge.5 A possible approach is to establish TeleStroke Unit networks: Stroke Units in rural areas supported by stroke centers in terms of education, quality management, and teleconsultations.

The TeleMedical Project for integrative Stroke Care (TEMPiS) in Bavaria, Germany, was one of the first TeleStroke projects. The evaluation of its implementation phase between February 2003 and December 2005 showed to be effective in providing safe and extended thrombolysis6,7 and in improving stroke outcomes compared with matched hospitals without TeleStroke Units.8,9 However, little is known about sustainability of such networks in terms of structures, quality of care provided, and outcome.
Therefore, we analyzed changes in structures as well as processes and patient outcomes within the TEMPiS network for a 10-year period regarding our aim of providing evidence-based acute care for all patients with stroke within the network area.

Methods

TEMPiS comprises 2 neurological stroke centers and 15 regional hospitals in Southeast Bavaria/Germany (Figure 1). Detailed descriptions of the concept were published previously. None of the regional hospitals had a Stroke Unit before network start in 2003. Local stroke care is provided by internal medicine departments in 11 hospitals and by neurological departments in 4 hospitals. The concept requires a neurologist on site at least during working days (part or full time). In the remaining times, the 11 hospitals without neurological departments have access to neurological expertise via telemedicine only. The 4 hospitals with neurological departments use the teleconsultation service for second opinion and organization of emergency interhospital transports.

The core elements of TEMPiS are as follows:

1. Implementation of a TeleStroke Unit in each hospital with formation of a multidisciplinary stroke team and implementation of standardized stroke care protocols. Intravenous thrombolysis (IVT) is provided as a 24/7 service with IVT routinely delivered in regional hospitals. The size of TeleStroke Units is planned to cover a volume of ≥250 patients with stroke and transient ischemic attack (TIA) per year.

2. Continuing training for all stroke team members provided by a multidisciplinary education team provided by the 2 stroke centers. The comprehensive quality management system also comprises audits, compulsory participation in the Bavarian routine data registry and the TEMPiS IVT registry, benchmarking, and certification procedures.

3. Implementation of telemedicine for 24/7 availability of acute neurological stroke expertise. Telemedicine comprises a telephone contact between the on-site physician and the vascular neurologist at the stroke center, transmission of digital brain images to the vascular neurologist (forwarded to a neuroradiologist/neurosurgeon if indicated) and, on request of the vascular neurologist, a real-time clinical examination of patients via videoconferencing. The teleconsultation team based in the stroke centers consists of 5 to 7 full-time vascular neurologists who must not be in charge of other clinical tasks during their teleconsultation shift. Teleconsultations are always performed as a physician-to-physician communication. The system runs on dedicated stationary and mobile workstations also allowing consultations from home. Mandatory indications for teleneurological assessment were predefined. They include eligibility for IVT, decreased consciousness, brain stem symptoms, intracranial hemorrhage, severe stroke (National Institute of Health Stroke Scale score >12), and progressive stroke. A telemedical follow-up can be requested at any time of the in-hospital stay. Written summaries are sent electronically to the enquiring hospital shortly after finishing teleconsultations.

Geographical Selection of Regional Hospitals

At network implementation, the target area in Southeast Bavaria comprised 16 administrative districts with 1.90 million inhabitants covering an area of 14,538 km² (Figure 1). To enable IVT administration for all suitable patients, we aimed at prehospital transport distances of no longer than 30 minutes. This approach resulted in 12 TeleStroke Units with ≥250 strokes per year. By the end of 2012, 3 additional hospitals within 3 new administrative districts entered the network. The coverage rose to 2.28 million inhabitants and 17,887 km² resulting in a population density of 127 inhabitants/km². Another hospital with a high stroke volume was member from 2006 until 2011 but then left the network to run an autonomous neurological Stroke Unit (data not included in analyses).

Data Collection

All data for this 10-year analysis refer to the TEMPiS TeleStroke Unit hospitals; data from the 2 centers are not included. Data were collected from several sources: data from the general local health insurance (AOK), routine data for administrative purposes, data of the TEMPiS teleconsultation, and IVT registries and the Bavarian stroke registry.

Health Insurance Data

The AOK is the largest health insurance in Bavaria with a market share of ~40% and provided data to assess the trend in proportions of patients with stroke treated in hospitals with specialized stroke care. Because we wanted to demonstrate the effect of our network in rural areas, we restricted this analysis to the rural TEMPiS region (Figure 1) excluding therefore 1 regional hospital in the city of Munich (Pasing). Annual numbers of AOK-insured patients with stroke and TIA admitted to acute hospitals with a (Tele-) Stroke Unit (regardless of TEMPiS participation) were compared with all AOK-insured patients with stroke and TIA living in this region.

Routine Data

The financial departments of the regional hospitals provided numbers of stroke and TIA admissions per year that were collected for administrative purposes. Cases with hospital main diagnoses ischemic, hemorrhagic, and undefined stroke and TIA (International Classification of Diseases, Tenth Revision codes G45, 161, 163, and 164) were included.
**TEMPiS Teleconsultation Registry**

Data from all teleconsultations were collected prospectively by the 2 stroke centers including date and time of request. Analysis of transfer recommendations to a stroke center was restricted to the years 2003 (February 1, 2003, to January 31, 2004) and 2012.

**TEMPiS IVT Registry**

All TeleStroke Units use a uniform IVT protocol for documentation of times (onset, admission, and treatment). National Institute of Health Stroke Scale, and formal contraindications. All protocols are sent to the network coordination center for plausibility checks before entering the data into the registry. Completeness of protocols is ascertained by random samples taken by the network coordinator and comparison with the teleconsultation registry and the Bavarian stroke registry. If onset of stroke symptoms was not observed, the last-time-seen-well was defined as onset. In-hospital strokes were excluded from analyses of timelines. Data from 2006 to 2008 were not collected and are therefore not included in the analyses. IVT rates are expressed as number of IVT compared with number of ischemic strokes (ISs) admitted to the hospitals.

**Bavarian Stroke Registry**

All patients with stroke and TIA of the participating hospitals were prospectively registered using anonymized data sets. The annual documentation rate compared with routine data has continuously been >95% since 2008, but lacked some completeness until 2007 (62.9%–87.1%). The data set covers information on baseline characteristics of patients with index stroke, diagnostics, treatment, and outcome. The data sets are checked for plausibility by the Bavarian Working Group for Quality Management in Inpatient Health Care. Evidence-based stroke quality (for definitions, see Table I in the online-only Data Supplement) is assessed, and target values for Stroke Units are used according to the independent German Quality Indicator Board.11

**Statistical Analysis**

The Mann–Whitney U test was used to test differences in continuous variables, and the χ² test was used for those in proportions. Data are presented by year for demonstrating trends over time. We calculated the P for trend adjusted for age and sex by adding year of admission as continuous variable with the respective indicator as outcome to a logistic regression model for categorical and a generalized linear model for continuous variables. All tests were 2 tailed, and statistical significance was determined at an α-level of 0.05. Analyses were performed on IBM SPSS Statistics 22 and SAS 9.2.

**Ethics**

The TEMPiS teleconsultation and IVT registries have been approved by the institutional review board in Munich. Basis for the Bavarian stroke registry is a German law (§137 SGB V). According to German legislation, no patient consent is required for documentation in routine observational quality registries. Retrospective analysis of anonymized health insurance data was approved by the data protection officer of the AOK.

**Results**

**Impact of the Network on the Regional System of Stroke Care**

The average number of the AOK-insured patients with stroke and TIA living in the TEMPiS region during the years 2002 to 2012 was 5095 per year. The annual proportions of patients with stroke and TIA admitted to hospitals with a dedicated Stroke Unit increased from 19% (995/5292) before network implementation (2002) to 52% (2585/4907; P<0.001) in 2003 and to 78% (4039/5151) in 2012 (P<0.001; Table). From 2003 onward, the majority of patients treated in hospitals with a Stroke Unit were admitted to TEMPiS hospitals (71% in 2003 and 72% in 2012).

**Stroke Care in TEMPiS Regional Hospitals**

Between February 1, 2003, and December 31, 2012, a total of 54,804 patients with stroke and TIA were documented in the TEMPiS hospitals. The number of patients with stroke and TIA increased from 4109 (in 2003) to 7207 (in 2012) (Figure 2). The mean number of patients with stroke and TIA per hospital per year increased from 342 to 480 (2003 and 2012). Table II in the online-only Data Supplement shows demographic and clinical characteristics of patients with stroke over time. Time trends show a better differentiation of stroke subtypes, increasing age, and less severe symptoms (decreasing National Institute of Health Stroke Scale) on admission over time.

**Table. Patients With Stroke and TIA Treated in Hospitals With Dedicated (Tele-)Stroke Units as Proportion of All Patients Living in the TEMPiS Area**

<table>
<thead>
<tr>
<th>Year</th>
<th>Patients With Stroke and TIA Living in the TEMPiS Region</th>
<th>Patients With Stroke and TIA Admitted to Any Hospital With a Stroke Unit</th>
<th>Patients With Stroke and TIA Admitted to TEMPiS Hospitals</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>5292</td>
<td>995 (19%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>2003</td>
<td>4907</td>
<td>2585 (53%)</td>
<td>1844 (38%)</td>
</tr>
<tr>
<td>2004</td>
<td>5156</td>
<td>2845 (55%)</td>
<td>2078 (40%)</td>
</tr>
<tr>
<td>2005</td>
<td>5125</td>
<td>2921 (57%)</td>
<td>2069 (40%)</td>
</tr>
<tr>
<td>2006</td>
<td>5064</td>
<td>2992 (59%)</td>
<td>2103 (42%)</td>
</tr>
<tr>
<td>2007</td>
<td>5083</td>
<td>3293 (65%)</td>
<td>2325 (46%)</td>
</tr>
<tr>
<td>2008</td>
<td>5054</td>
<td>3574 (71%)</td>
<td>2611 (52%)</td>
</tr>
<tr>
<td>2009</td>
<td>5068</td>
<td>3587 (71%)</td>
<td>2559 (50%)</td>
</tr>
<tr>
<td>2010</td>
<td>5032</td>
<td>3700 (74%)</td>
<td>2607 (52%)</td>
</tr>
<tr>
<td>2011</td>
<td>5109</td>
<td>3847 (75%)</td>
<td>2705 (53%)</td>
</tr>
<tr>
<td>2012</td>
<td>5151</td>
<td>4039 (78%)</td>
<td>2903 (56%)</td>
</tr>
</tbody>
</table>

The analysis is restricted to members of the general local health insurance (AOK). TEMPiS indicates TeleMedical Project for integrative Stroke Care; and TIA, transient ischemic attack.
Teleconsultations

By the end of 2012, the total number reached 31,864. During the past decade, numbers of teleconsultations per year have steadily increased from 1,928 (in 2003) to 4,513 (in 2012; Figure 2). In 2003, videoconferencing was done in 988 of 1,928 teleconsultations (51%) with the rest of the teleconsultations restricted to evaluation of brain images and telephone consultation. This proportion of video-comprising teleconsultations slightly decreased to 47% (2,134/4,513) in 2012 ($P=0.004$). Recommendations of secondary transfers from the regional hospitals to stroke centers decreased from 11.5% (252/2,182 teleconsultations) in 2003 to 7.0% (317/4,513) in 2012 ($P<0.001$).

Quality of Stroke Care

The absolute numbers of IVT per year steadily increased from 10 before network implementation (2002) and 63 in the first year of the network (2003) to 685 in 2012, totaling 3,331 IVT since 2003. IVT rate as the proportion of all patients with IS admitted to the hospitals increased from 2.6% (63/2,466) in 2003 to 15.5% (685/4,409) in 2012 ($P<0.001$; Figure 3). Median onset-to-treatment times decreased from 150 minutes (interquartile range [IQR], 130–165) in 2003 to 120 minutes (IQR, 87–160) in 2012 ($P<0.001$). Median door-to-needle times also decreased from 80 (IQR, 68–101) to 40 minutes (IQR, 29–59; $P<0.001$). Median onset-to-door times remained stable (60 minutes [IQR, 45–79] in 2003 and 68 minutes [IQR, 48–105] in 2012; $P=0.63$). The percentage of IVT treatments administered within the first hour after admission improved from 26% (15/57) in 2003 to 80% (543/675) in 2012 ($P<0.001$).

Figure 3. Numbers, rates, and door-to-needle times (including interquartile range [IQR]) of intravenous thrombolysis (IVT) performed in all patients with ischemic stroke. The IVT rate in 2002 indicates the status before network implementation. Door-to-needle times were not available for 2002 and 2006 to 2008.

Data from the Bavarian stroke registry about diagnostics, treatment, and outcome procedures for the 10-year period are presented in Table II in the online-only Data Supplement. Most parameters show clear improvement over time, whereas length of in-hospital stay decreased. Seven-day in-hospital mortality in all patients with IS has decreased from 5.0% (74/1,469) in 2003 to 3.1% (145/4,618) in 2012, whereas 7-day mortality after IVT remained stable (mean, 6.3%; $P$ for trend=0.122).

Table III in the online-only Data Supplement shows nationwide defined stroke quality indicators for 2012. TEMPiS hospitals achieved quality-of-care levels above target values in 9 indicators with 4 indicators slightly below target (all within 1% difference from targets).

Discussion

The main findings of 10-year experience of TEMPiS showed that this type of telemedical Stroke Unit network is sustaining, offers state-of-the-art acute stroke care by increasing access to Stroke Units and improving thrombolysis service, and is associated with long-term improvement in terms of quality indicators of acute hospital care.

Many TeleStroke networks were established during the past few years worldwide. In contrast to most other networks with a focus on telemedicine-enabled stroke thrombolysis or referral to tertiary hospitals,12,13 TEMPiS integrates the Stroke Unit concept in regional hospitals.

According to local health insurance data, the proportion of patients with stroke and TIA being admitted to a hospital with a dedicated Stroke Unit increased from 19% to 78% in the source population. Apart from establishing the new TeleStroke Units, many efforts have been made to convince the population, ambulance services, and primary care physicians about the better prognosis of patients with stroke treated in a Stroke Unit. This strategy was reinforced by the positive result of the TEMPiS efficacy analysis.8 However, a Stroke Unit admission rate of 78% does still not appear satisfactory because the goal...
should be close to 100%. In Germany, emergency medical services are usually organized within administrative districts and seem to be less inclined to bring patients to a TeleStroke Unit of the adjacent district even if it could be reached within 30 minutes. This has led to a change of our strategy. In consensus with health authorities, in 2013, we started to set up further TeleStroke Units in administrative districts so far lacking a (Tele-)Stroke Unit.

Despite the primary focus on Stroke Unit care, the IVT rate from all patients with IS admitted to TEMPiS hospitals rose from 0.4% to 15.5%, reflecting a high rate compared with other systems of care. Although IVT rates in TeleStroke networks are usually reported as tissue-type plasminogen activator rates of teleconsultations only, we could not find any comparable published IVT rate (IVT per IS) other than the 9.6% reported from Spain. During the 10 years, onset-to-treatment times and door-to-needle times decreased remarkably. Eighty percent of all IVT in the TEMPiS Stroke Units are delivered within 60 minutes of admission, thus being clearly beyond the target of the American Stroke Association of 50%.

Decrease of secondary transfers is mainly attributable to more careful recommendations regarding surgical treatment in hemorrhagic strokes and improved local stroke care. The increase in patients with minor stroke may also contribute.

Costs for regional hospitals and centers in our TeleStroke Unit concept are substantial and need adequate reimbursement. In 2002, health policy authorities decided to support telemedicine networks. When the controlled study showed that the TEMPiS concept was both improving clinical outcomes and cost effective when compared with conventional care (higher costs during acute care were fully compensated by lower rehabilitation and long-term care costs), ongoing support by health insurances covering the teleconsultation service and the quality management program was decided in 2006. Meanwhile, the running costs of the TeleStroke Units for the regional hospitals are reimbursed within the German diagnosis related groups system. Teleconsultants are employed by the network and paid according to German tariffs. However, cost-effectiveness is only given, if numbers of patients with stroke and TIA per hospital and the number of teleconsultations exceed critical limits. Use of mobile (laptops or tablet) devices for teleconsultants may reduce costs and may enable networks with lower numbers of teleconsultations, especially beyond normal working hours.

Participation in such a comprehensive network requires ongoing motivation. In our opinion, the most important incentives include the everyday experience of obtaining fast and clinically relevant recommendations and the conviction in the regional hospitals that participation in the network is beneficial for patients and hospitals alike. Patients benefit from improved outcome. Hospitals experience the advantages of specialization in treatment of one of the most frequent and devastating diseases.

The study has limitations. Because of nonmodifiable regional structures, the transfer of our concept to other rural regions meets limitations. The population density in the rural TEMPiS area of 127 inhabitants/km² allows annual stroke volumes of >250 patients with stroke and TIA per TeleStroke Unit. With substantially lower population densities like, for example, in Georgia, United States (63/km²) or Alberta, Canada (6/km²), TeleStroke networks also reported benefits, mainly by increasing numbers of IVT. Our single-network data represent prospectively collected registry data, routine data, and data of 1 health insurance. Therefore, selection and coding biases as well as data collection errors cannot be excluded. However, cross-checking of the data between different sources ensured plausibility. Documentation rate for the Bavarian stroke registry compared with routine data lacked some completeness in the years 2003 to 2007 but improved in more recent years. A control group is lacking. We are therefore not able to separate network effects from general improvements of stroke care over time in the past decade.

The analysis of secondary transfers is based on the recommendations of physicians providing teleconsultation services. In some cases, transfers may not have been carried out and some patients may have been transferred against recommendation of a teleconsultation. The presented proportion of patients treated in a hospital with a (Tele-)Stroke Unit in relation to all hospitalized patients with stroke and TIA living in the TEMPiS region might have several biases. First, the analysis is restricted to patients of 1 health insurance. Although the AOK is the largest health insurance in Bavaria with a proportion of ≈40%, this may produce a selection bias. Second, all patients with stroke and TIA registered in the TEMPiS region are included but not all of them may have experienced their stroke while staying in this area. Third, to be treated in a hospital with a Stroke Unit does not inevitably mean to be treated in a Stroke Unit. A minority may have been treated on other wards for comorbidities or complications (eg, intensive care units), but each TEMPiS hospital has medical and financial incentives to treat patients with stroke preferably on their TeleStroke Unit.

Conclusions

The TeleStroke Unit network TEMPiS is an example of how the challenges of area-wide implementation of Stroke Units in rural areas can be met. Although network structures have to be adapted to regional features, for example, population densities, geographical and administrative borders, and hospital infrastructures, we think that many of the experiences gained in the TEMPiS concept might be used as a role model for other rural areas.

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**SUPPLEMENTAL MATERIAL:**

| **Information to patient and/or next of kin** | Numerator: Patients or next of kin that were informed about the progress and prevention of the disease by the doctor and that were informed about social help by the social worker or a nurse.  
Denominator: All patients that were not discharged or transferred at the day of admission. Patients with TIA and those who died are excluded. |
|---|---|
| **Early physio-/occupational therapy for patients with motor disability** | Numerator: Patients that received treatment by physiotherapy or occupational therapy within the first 2 days.  
Denominator: All patients with a paresis and clear functional deficit (modified Rankin Scale (mRS) ≥ 3 or Barthel Index ≤ 70 within the first 24h after admission). Patients with TIA, those unconscious and those that were discharged, transferred or died on the first day are excluded. |
| **Early mobilization of patients with severe disability** | Numerator: Patients that were mobilized within the first two days after admission.  
Denominator: Patients that needed help with transfer from bed to chair (Barthel Index 0-10). Patients that were discharged, transferred or died on the first day, those with TIA and those unconscious, with mechanical ventilation or with increased intracranial pressure on admission are excluded. |
| **Dysphagia screening** | Numerator: Patients with dysphagia screening per protocol.  
Denominator: All patients with stroke. Patients with TIA, impaired consciousness, or those where dysphagia screening was not possible or those that were discharged/transferred or died on the day of admission are excluded. |
| **Early speech and language therapy for patients with dysphagia/dysphasia/dysarthria** | Numerator: Patients that received treatment by speech and language therapy within the first 2 days.  
Denominator: All patients with dysphagia/dysarthria/dysphagia. Patients with TIA, those unconscious and those that were discharged, transferred or died on the first day are excluded. |
| **Early cerebral imaging (<60 min after admission) in patients eligible for thrombolysis** | Numerator: Patients with cerebral imaging (CCT/MRI) within the first hour of admission.  
Denominator: All patients within the age range 18-80 and with onset-admission ≤ 2 h and NIHSS of 4-25. |
| **Extracranial carotid artery diagnostic in patients with IS or TIA** | Numerator: Patients with imaging of extracranial vessels (dopplersonography / duplexsonography / DSA / CT-angiography / MR-angiography).  
Denominator: All patients with TIA or cerebral infarction. |
| **Revascularization of symptomatic carotid stenosis in patients with IS or TIA** | Numerator: Patients where revascularization of carotid artery was initiated or recommended.  
Denominator: Patients with TIA or cerebral infarction with ipsilateral stenosis of carotid artery (>50% NASCET) and with mRS 0-3. |
| **Platelet inhibitor given within 48h in patients with IS or TIA** | Numerator: All patients that were given platelet inhibition within 48h after onset.  
Denominator: All patients with TIA and cerebral infarction. Patients that receive anticoagulation or where onset to admission is >48h are excluded. |
| **Platelet inhibitor given at discharge in patients with IS or TIA and no anticoagulation** | Numerator: All patients that receive platelet inhibition at discharge/transfer.  
Denominator: All patients with TIA or cerebral infarction. Patients on anticoagulation and those who died are excluded. |
| **Anticoagulation given in patients with IS or TIA and atrial fibrillation** | Numerator: Patients with therapeutic anticoagulation at discharge/transfer or with the recommendation for it in the discharge letter.  
Denominator: All patients with TIA or cerebral infarction and atrial fibrillation that are mobile or slightly impaired (defined by 10-15 points in the Barthel-Index items transfers and mobility and mRS 0-3 at discharge) and that were discharged home or to a rehabilitation clinic. |
| **Early IVT given in patients with indication for IVT** | Numerator: Patients that received IVT.  
Denominator: Patients with cerebral infarction, age 18-80 and with onset-admission ≤ 2 h and NIHSS 4-25. Patients with intra-arterial thrombolysis are excluded. |
| **Door-to-needle time <60 min in patients with IVT** | Numerator: Patients with door-to-needle time <60 minutes.  
Denominator: Patients with cerebral infarction and IVT. |
| **Mortality after IVT** | Numerator: Patients that died.  
Denominator: Patients with cerebral infarction and IVT. |
| **Pneumonia in patients with IS** | Numerator: Patients with pneumonia as a complication from stroke.  
Denominator: All patients with cerebral infarction. |
| **Deaths in patients with IS** | Numerator: Patients that died within 7 days of hospital stay.  
Denominator: All patients with cerebral infarction. Patients discharged or transferred before day 7 are excluded. |
| **Discharge in rehabilitation clinic** | Numerator: Patients where post hospital rehabilitation was initiated.  
Denominator: All patients without previous nursing care with mRS 2-5 at discharge. Patients that were transferred or died during the hospital stay are excluded. |
| **Cerebral imaging** | Numerator: Patients that received cerebral imaging (CCT or MRI).  
Denominator: All patients with stroke. |

Table I: Definitions of the German quality indicators in acute stroke care as defined by the Quality Indicator Board of the German Stroke Registers Study Group.
<table>
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<td>number of participating hospitals, n</td>
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<td>number of stroke or TIA patients, n</td>
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<tr>
<td>Ischemic stroke, n (%)</td>
<td>1469 (49.1)</td>
<td>2438 (59.0)</td>
<td>2394 (62.6)</td>
<td>1915 (63.4)</td>
<td>2958 (65.1)</td>
<td>3464 (62.4)</td>
<td>3437 (61.2)</td>
<td>3753 (63.3)</td>
<td>4174 (64.9)</td>
<td>4618 (63.4)</td>
</tr>
<tr>
<td>Intracerebral hemorrhage, n (%)</td>
<td>219 (7.3)</td>
<td>284 (6.9)</td>
<td>282 (7.4)</td>
<td>187 (6.2)</td>
<td>340 (7.5)</td>
<td>384 (6.9)</td>
<td>410 (7.3)</td>
<td>371 (6.3)</td>
<td>402 (6.3)</td>
<td>535 (7.3)</td>
</tr>
<tr>
<td>Transient ischemic attack, n (%)</td>
<td>839 (28.1)</td>
<td>1191 (28.8)</td>
<td>1122 (29.3)</td>
<td>850 (28.2)</td>
<td>1169 (25.7)</td>
<td>1586 (28.6)</td>
<td>1637 (29.1)</td>
<td>1770 (29.8)</td>
<td>1754 (27.3)</td>
<td>2085 (28.6)</td>
</tr>
<tr>
<td>Undefined Stroke, n (%)</td>
<td>464 (15.5)</td>
<td>223 (5.4)</td>
<td>28 (0.7)</td>
<td>67 (2.2)</td>
<td>77 (1.7)</td>
<td>114 (2.1)</td>
<td>136 (2.4)</td>
<td>39 (0.7)</td>
<td>98 (1.5)</td>
<td>48 (0.7)</td>
</tr>
<tr>
<td>Age (years), Median (IQR)</td>
<td>74 (66-81)</td>
<td>75 (66-82)</td>
<td>75 (67-82)</td>
<td>76 (67-83)</td>
<td>76 (67-83)</td>
<td>76 (68-83)</td>
<td>76 (68-83)</td>
<td>76 (68-83)</td>
<td>76 (68-84)</td>
<td>76 (68-84)</td>
</tr>
<tr>
<td>Female sex, n (%)</td>
<td>1509 (52.7)</td>
<td>2087 (52.4)</td>
<td>1900 (50.9)</td>
<td>1495 (51.5)</td>
<td>2259 (50.2)</td>
<td>2831 (51.0)</td>
<td>2893 (51.5)</td>
<td>3071 (51.8)</td>
<td>3234 (50.3)</td>
<td>3620 (49.7)</td>
</tr>
<tr>
<td>NIH-SS on admission, Median (IQR)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>6 (2-9)</td>
<td>4 (1-8)</td>
<td>3 (1-8)</td>
<td>3 (1-7)</td>
<td>3 (1-7)</td>
<td>3 (1-7)</td>
<td>3 (1-7)</td>
</tr>
<tr>
<td>Onset to admission &lt; 3 hours, n (%)</td>
<td>1066 (37.4)</td>
<td>1335 (34.6)</td>
<td>1328 (36.3)</td>
<td>1124 (41.5)</td>
<td>1148 (32.4)</td>
<td>2037 (40.7)</td>
<td>2068 (41.1)</td>
<td>2339 (44.6)</td>
<td>2467 (43.0)</td>
<td>2876 (44.1)</td>
</tr>
<tr>
<td>Brain imaging, n (%)</td>
<td>2917 (97.5)</td>
<td>4026 (97.3)</td>
<td>3732 (97.5)</td>
<td>2859 (94.7)</td>
<td>4345 (95.6)</td>
<td>5486 (98.9)</td>
<td>5574 (99.2)</td>
<td>5894 (99.3)</td>
<td>6391 (99.4)</td>
<td>7251 (99.5)</td>
</tr>
<tr>
<td>Brain imaging &lt; 1 hour, n (%)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1980 (84.2)</td>
<td>3526 (87.4)</td>
<td>4390 (87.9)</td>
<td>4632 (88.9)</td>
<td>5252 (89.1)</td>
<td>5535 (86.6)</td>
<td>6777 (88.0)</td>
</tr>
<tr>
<td>Vascular imaging in IS and TIA, n (%)</td>
<td>1798 (79.8)</td>
<td>2730 (75.2)</td>
<td>2774 (78.9)</td>
<td>2344 (90.9)</td>
<td>706 (94.3)</td>
<td>4619 (91.5)</td>
<td>4803 (94.7)</td>
<td>5216 (94.4)</td>
<td>5583 (94.2)</td>
<td>6364 (94.9)</td>
</tr>
<tr>
<td>Standardized test for dysphagia, n (%)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1819 (64.9)</td>
<td>2901 (62.7)</td>
<td>3555 (63.3)</td>
<td>4130 (73.8)</td>
<td>4780 (81.3)</td>
<td>5338 (85.2)</td>
<td>6006 (84.5)</td>
</tr>
<tr>
<td>In-hospital stay (days), Median (IQR)</td>
<td>9 (6-13)</td>
<td>8 (5-11)</td>
<td>7 (5-11)</td>
<td>8 (5-11)</td>
<td>7 (5-11)</td>
<td>7 (5-11)</td>
<td>7 (4-10)</td>
<td>7 (4-10)</td>
<td>6 (4-9)</td>
<td>6 (4-9)</td>
</tr>
<tr>
<td>Speech &amp; Swallowing therapy, n (%)</td>
<td>978 (66.8)</td>
<td>1499 (74.3)</td>
<td>1287 (77.5)</td>
<td>1377 (86.1)</td>
<td>846 (83.6)</td>
<td>2482 (87.5)</td>
<td>2611 (90.2)</td>
<td>2735 (91.1)</td>
<td>2893 (93.3)</td>
<td>3245 (94.5)</td>
</tr>
<tr>
<td>Physiotherapy / Occupational therapy, n (%)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2339 (84.6)</td>
<td>3549 (86.0)</td>
<td>4351 (86.2)</td>
<td>4459 (87.9)</td>
<td>4867 (88.1)</td>
<td>5162 (87.1)</td>
<td>5839 (87.1)</td>
</tr>
<tr>
<td>Platelet inhibitor given within 48h in IS and TIA, n (%)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Anticoagulation given in IS and TIA with atrial fibrillation, n (%)</td>
<td>-</td>
<td>394 (46.6)</td>
<td>376 (46.4)</td>
<td>356 (52.7)</td>
<td>599 (53.9)</td>
<td>828 (57.9)</td>
<td>807 (56.2)</td>
<td>900 (58.8)</td>
<td>1061 (64.0)</td>
<td>1231 (67.8)</td>
</tr>
<tr>
<td>7-day in-hospital mortality in pat. with IS, n (%) ††</td>
<td>74 (5.0)</td>
<td>100 (4.1)</td>
<td>111 (4.6)</td>
<td>83 (4.3)</td>
<td>108 (3.7)</td>
<td>137 (4.0)</td>
<td>150 (4.4)</td>
<td>148 (3.9)</td>
<td>143 (3.4)</td>
<td>145 (3.1)</td>
</tr>
<tr>
<td>7-day mortality after IVT, n (%)</td>
<td>5 (10.9)</td>
<td>4 (3.7)</td>
<td>7 (5.3)</td>
<td>11 (6.6)</td>
<td>17 (6.7)</td>
<td>21 (5.9)</td>
<td>34 (8.7)</td>
<td>33 (7.0)</td>
<td>33 (6.3)</td>
<td>32 (4.8)</td>
</tr>
</tbody>
</table>

Table II: Baseline characteristics of all patients admitted to TEMPiS hospitals and their index strokes as well as diagnostics, treatment and outcome over time. Data obtained from the Bavarian stroke registry. * Adjusted for age and sex by adding year of admission as continuous variable with the respective indicator as outcome to a logistic regression model for categorical and a generalized linear model for continuous variables. † Data missing for 845 patients (19%). ‡ Data missing for 1003 patients (22%). § CT- and MR-angiograms excluded due to missing data. ‖ All patients with aphasia, dysarthria or dysphagia and in-hospital stay >1 day. # Patients with dysphagia excluded due to missing data. ** All patients with motor deficits and in-hospital stay >1 day. †† Excluded are patients discharged to other acute care hospitals before day 7.
<table>
<thead>
<tr>
<th>Quality indicator</th>
<th>TEMPiS TeleStroke Units</th>
<th>target</th>
<th>on target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information to patient and/or next of kin</td>
<td>4,120/4,629 (89.0%)</td>
<td>&gt;= 90%</td>
<td>-</td>
</tr>
<tr>
<td>Early physio-/occupational therapy for pat. with motor disability</td>
<td>2,352/2,470 (95.2%)</td>
<td>&gt;= 90%</td>
<td>+</td>
</tr>
<tr>
<td>Early mobilization of pat. with severe disability</td>
<td>2,762/2,978 (92.7%)</td>
<td>&gt;= 90%</td>
<td>+</td>
</tr>
<tr>
<td>Dysphagia screening</td>
<td>3,872/4,355 (88.9%)</td>
<td>&gt;= 90%</td>
<td>-</td>
</tr>
<tr>
<td>Early speech and language therapy for pat. with dysphagia/dysphasia/dysarthria</td>
<td>2,661/2,854 (93.2%)</td>
<td>&gt;= 80%</td>
<td>+</td>
</tr>
<tr>
<td>Early cerebral imaging (&lt;60 min after admission) in pat. eligible for thrombolysis</td>
<td>570/588 (96.9%)</td>
<td>&gt;= 90%</td>
<td>+</td>
</tr>
<tr>
<td>Extracranial carotid artery diagnostic in pat. with IS or TIA</td>
<td>6,359/6,697 (95.0%)</td>
<td>&gt;= 90%</td>
<td>+</td>
</tr>
<tr>
<td>Revascularization of symptomatic carotid stenosis in pat. with IS or TIA</td>
<td>159/225 (70.7%)</td>
<td>not defined</td>
<td></td>
</tr>
<tr>
<td>Platelet inhibitor given within 48h in pat. with IS or TIA</td>
<td>3,747/3,971 (94.4%)</td>
<td>&gt;= 95%</td>
<td>-</td>
</tr>
<tr>
<td>Platelet inhibitor given at discharge in pat. with IS or TIA and no anticoagulation</td>
<td>4,557/4,805 (94.8%)</td>
<td>&gt;= 95%</td>
<td>-</td>
</tr>
<tr>
<td>Anticoagulation given in pat. with IS or TIA and atrial fibrillation</td>
<td>808/967 (83.6%)</td>
<td>&gt;= 80%</td>
<td>+</td>
</tr>
<tr>
<td>Early IVT given in pat. with indication for IVT</td>
<td>287/439 (65.4%)</td>
<td>&gt;= 60%</td>
<td>+</td>
</tr>
<tr>
<td>Door-to-needle time &lt;60 min in pat. with IVT</td>
<td>535/664 (80.6%)</td>
<td>&gt;= 80%</td>
<td>+</td>
</tr>
<tr>
<td>Mortality after IVT</td>
<td>51/664 (7.7%)</td>
<td>not defined</td>
<td></td>
</tr>
<tr>
<td>Pneumonia in pat. with IS</td>
<td>180/4,615 (3.9%)</td>
<td>not defined</td>
<td></td>
</tr>
<tr>
<td>Deaths in pat. with IS</td>
<td>145/3,900 (3.7%)</td>
<td>not defined</td>
<td></td>
</tr>
<tr>
<td>Discharged to rehabilitation clinic</td>
<td>1,148/2,540 (45.2%)</td>
<td>not defined</td>
<td></td>
</tr>
<tr>
<td>Cerebral imaging</td>
<td>7,245/7,280 (99.5%)</td>
<td>&gt;= 95%</td>
<td>+</td>
</tr>
</tbody>
</table>

Table III: Quality indicators in acute stroke care (as defined by the Quality Indicator Board of the German Stroke Registers Study Group; see Table I) for the 15 TEMPiS TeleStroke Units in 2012. Target values were predefined by the independent German Quality Indicator Board.