Long-Term Effects of Specialized Stroke Care With Telemedicine Support in Community Hospitals on Behalf of the Telemedical Project for Integrative Stroke Care (TEMPiS)

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Background and Purpose—Stroke unit treatment is effective in reducing death and dependency after stroke but is not available in many, particularly rural, areas. The implementation of a stroke network with telemedicine support was associated with improved outcome at 3 months. We report follow-up results at 12 and 30 months after acute stroke.

Methods—Telemedical Project for Integrative Stroke Care (TEMPiS) consists of the set-up of specialized local stroke wards, continuous medical education, and telemedical consultation for patients with acute stroke by 2 stroke centers. In a prospective, nonrandomized, intervention study, 5 community hospitals participating in the network were compared with 5 matched control hospitals without specialized stroke facilities or telemedical support. All patients with consecutive ischemic or hemorrhagic stroke admitted between July 2003 and March 2005 were evaluated. Outcome “death and dependency” was defined by death, institutional care, or disability (Barthel index <60 or Rankin scale >3).

Results—We followed-up 3060 patients (1938 in TEMPiS and 1122 in control hospitals). Follow-up rates were 97.2% after 12 months and 95.9% after 30 months for death or institutional care, and 96.5% after 12 months and 95.7% after 30 months for death and dependency. In multivariable regression analysis, there was no significant effect of the TEMPiS intervention for reduced “death or institutional care” at 12 months (OR, 0.89; 95% CI, 0.75–1.07; P=0.23) and 30 months (OR, 0.93; 95% CI, 0.78–1.11; P=0.40) but a significant reduction of “death and dependency” at 12 months (OR, 0.65; 95% CI, 0.54–0.78; P<0.01) and 30 months (OR, 0.82; 95% CI, 0.68–0.98; P=0.031).

Conclusions—Implementing a system of specialized stroke wards, continuing education, and telemedicine in community hospitals offers long-term benefit for acute stroke patients. (Stroke. 2009;40:902-908.)

Key Words: organized stroke care ■ outcome ■ stroke ■ stroke unit ■ telemedicine

With the aging population in developed and developing countries, the burden of stroke on society is anticipated to increase substantially over the next decades.1–3 Specialized inpatient stroke services (stroke unit treatment) have been proven to be highly effective in reducing mortality and dependency after stroke.4 Despite this evidence and existing recommendations,5–7 in many countries only a minority of patients with acute stroke have access to specialized facilities.8 There is insufficient coverage, particularly in rural areas, and stroke care is often delivered at local hospitals without specialized stroke care.9 A major barrier for the implementation of stroke units is the shortage of experienced stroke physicians in those hospitals. Telemedicine offers a new approach to provide continuously available stroke expertise and can be used to facilitate the set-up of specialized stroke services in general community hospitals.

The Telemedical Project for Integrative Stroke Care (TEMPiS) was designed to improve quality of stroke care in a large area of Southeast Bavaria.10 A prospective, nonrandomized, intervention study showed a significant improvement of acute in-hospital stroke treatment in terms of quality indicators such as rapid brain imaging, thrombolysis rate, assessment of swallowing disorders, and early rehabilitation therapy. The network implementation was also associated
with a reduction in the outcome “death and dependency” defined by death, institutional care, or severe disability after 3 months. Because the TEMPiS intervention focused only on acute in-hospital treatment including telemedical consultation predominantly in the hyperacute phase, it remained unclear whether these effects would also affect the medium-term and long-term prognosis.

Materials and Methods
The TEMPiS concept has been described in detail previously. In summary, TEMPiS is a cooperation of 2 academic stroke centers with community hospitals not providing specialized stroke care before network implementation. Stroke wards were established in all hospitals including formation of multidisciplinary stroke teams and installation of monitoring facilities. The stroke teams were trained via onsite and center-based courses and received continuous bedside teaching by specialized neurologists, nurses, and therapists. Standardized treatment protocols were developed as consented operating procedures. Quality of care was assessed through regular audits and continuous participation in the Bavarian stroke register. The 24/7 teleconsultation service was provided by the 2 stroke centers and was staffed with full-time neurologists. Indications for teleconsultations were predefined as: patients potentially suitable for thrombolysis, intracranial hemorrhages, severe strokes with National Institutes of Health Stroke Scale score >10, reduced level of consciousness, brain stem symptoms, progressive strokes, and uncertainty about diagnostic or therapeutic procedures. The telemedical consultation consisted of a joined video examination of the patient and the interpretation of the locally conducted CT or MRI brain scans by the neurologist teleconsultants. All physicians of the department responsible for stroke care have access to the teleneurology service and to the consulting neurologist onsite.

Network preparations including set-up of stroke wards and training of stroke teams were accomplished from August 2002 until January 2003. The telemedical network started in February 2003.

Study Design
We designed a nonrandomized intervention study comparing 5 TEMPiS hospitals in a distance of up to 75 kilometers from Munich with 5 control hospitals in the same area but without specialized stroke services and telemedical networking. All hospitals are general acute hospitals serving the population of their local catchment area. The hospitals were well-balanced regarding predefined matching criteria such as bed capacity, equipment, in-house neurology department, and distance to the next established stroke unit. One hospital in each group was in private ownership, whereas all other hospitals were owned by public authorities. In both groups, the general treatment responsibility remained with the local doctors. In hospitals without neurology department, patients could be reviewed by consulting neurologists on-site after request by the treating medical physicians. The brain scans were reported by the local radiologists.

The prospective recruitment of consecutive stroke patient started in July 2003 and ended in March 2005, with a delayed enrollment in 1 intervention and 1 control hospital starting in January 2004. All patients with acute neurological deficits and suspected cerebrovascular etiology were recorded either by local physicians or trained study nurses. The documented baseline parameters included sociodemographic characteristics, risk factors, and vascular comorbidities, subtype of stroke, and stroke severity. As the National Institutes of Health Stroke Scale score was only available for ~80% of the patients (89% in TEMPiS hospitals [median, 5]; 67% in control hospitals [median, 6]), we measured stroke severity as the cumulative number of the following neurological symptoms: limb weakness, dysphasia, dysarthria, and disturbances of consciousness. The cumulative number of neurological deficits was classified into mild (no or 1 deficit), moderate (with 2 of these symptoms), severe (with 3 of these symptoms), and very severe (with 4 symptoms demonstrated to be a strong predictor of short-term mortality). All analyses were performed on an intention-to-treat basis and compared patients with acute stroke admitted to intervention hospitals and to the hospitals of the control group irrespective of whether they were subsequently transferred to another acute hospital facility (10.9% in the TEMPiS group and 11.5% in the control group).

An onsite monitor who was not otherwise involved in patient recruitment reviewed discharge diagnoses. The final decision whether the patient fulfilled the inclusion criteria was made by the local physicians. The baseline parameters, in-hospital procedures, and discharge destinations are described in another publication. There were significant imbalances in baseline parameters regarding diabetes mellitus, previous stroke, and stroke severity. Diabetes (29% vs 22%) and previous stroke (23% vs 17%) were more common in the control group. Mild (51% vs 46%) but also very severe strokes (4% vs 7%) were less frequent in the TEMPiS group.

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**Figure.** Cumulative survival in both hospital groups (unadjusted).

<table>
<thead>
<tr>
<th>Numbers at risk</th>
<th>Admission</th>
<th>305 days</th>
<th>900 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intervention group</td>
<td>1938</td>
<td>1604</td>
<td>1439</td>
</tr>
<tr>
<td>Control group</td>
<td>1132</td>
<td>926</td>
<td>813</td>
</tr>
</tbody>
</table>
All a priori defined indicators of acute stroke care quality were met more commonly in the intervention hospitals during the study period.

Patient follow-up was managed centrally and performed by specially trained interviewers 12 and 30 months after admission by a standardized telephone interview or by administering postal questionnaires to the patient. The patient or caregiver or the patient’s general practitioner provided information about death, institutional care, Barthel index, and modified Rankin scale. The interviewers were trained using the training DVD, “Modified Rankin Scale. A Training & Certification Resource” (University of Glasgow). If a patient had died, then the exact date of death was recorded. Institutional care was defined as patients living in residential/nursing homes and patients in acute and rehabilitation hospitals at time of follow-up.

Two outcome scenarios were defined a priori: The combined outcome death and institutional care included case fatality and living in institutional care regardless of whether patients were treated in hospitals or lived in residential or nursing home or other care institutions. Death and dependency were defined as patients living in residential/nursing homes and patients in acute and rehabilitation hospitals at time of follow-up.

Statistical Analysis
Statistical analyses were a priori defined in an analysis plan and were used identically to the previous evaluation of in-hospital procedures and 3 months’ outcome. The t test was used to test differences in continuous variables and the χ² test was used for differences in binary data. Multivariable logistic regression analyses were performed to adjust the effect of the TEMPIS intervention on outcome for potential confounders. Odds ratios and corresponding 95% confidence intervals of the TEMPIS network effect were calculated after adjustment for age, sex, living in partnership, comorbidities, and stroke severity (all listed in the Tables showing the predictors of outcome) stroke subtypes by performing different regression models for outcome “death and dependency” and combined outcome death and institutional care. Statistical significance of the resulting coefficients was tested using the likelihood ratio test. Variables in multivariate analyses were eliminated using backward-elimination procedure. The probability values given are the values of each factor just before the particular factor was removed from the model during backward modeling. The final models of the outcome scenario “death or institutional care” (Table 4) include the nonsignificant factor “intervention hospital” as a forced-in factor. All other nonsignificant factors were removed from the model.

All tests were 2-tailed, and statistical significance was determined at a level of 0.05. Statistical analyses were performed with SPSS 14.1 software package (SPSS Inc).

Ethics Committee Approval
The design of this nonrandomized study was approved by the ethics committee of the Bavarian Board of Physicians. Patients gave their written informed consent for study participation and follow-up interviews.

Role of the Sponsors: Funding/Support
The present data analysis was funded by the German Federal Ministry of Research (BMBF) within the Competence Net Stroke. TEMPIS was supported as a pilot project by the Bavarian Health

### Table 1. Death Rates and Adjusted ORs for Death at Various Times After Stroke Admission

<table>
<thead>
<tr>
<th>Time After Stroke Admission</th>
<th>Intervention Group Deaths (%)</th>
<th>Control Group Deaths (%)</th>
<th>Adjusted* OR</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 days</td>
<td>143 (7.4)</td>
<td>101 (9.0)</td>
<td>0.86</td>
<td>0.64–1.15</td>
</tr>
<tr>
<td>30 days</td>
<td>200 (10.4)</td>
<td>141 (12.7)</td>
<td>0.84</td>
<td>0.65–1.09</td>
</tr>
<tr>
<td>90 days</td>
<td>289 (15.1)</td>
<td>186 (16.8)</td>
<td>0.93</td>
<td>0.74–1.17</td>
</tr>
<tr>
<td>365 days</td>
<td>430 (22.7)</td>
<td>268 (24.5)</td>
<td>0.98</td>
<td>0.80–1.19</td>
</tr>
<tr>
<td>900 days</td>
<td>599 (32.0)</td>
<td>373 (34.5)</td>
<td>0.95</td>
<td>0.79–1.14</td>
</tr>
</tbody>
</table>

*If treated in the intervention group and adjusted for all baseline parameters as listed in Table 3.

<table>
<thead>
<tr>
<th>Table 2. Combined Outcomes After 12 and 30 Months (Unadjusted)</th>
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</thead>
<tbody>
<tr>
<td><strong>12 Months</strong></td>
</tr>
<tr>
<td>Death or Institutional Care</td>
</tr>
<tr>
<td>At home</td>
</tr>
<tr>
<td>Institutional care</td>
</tr>
<tr>
<td>Dead</td>
</tr>
<tr>
<td>At home without severe disability</td>
</tr>
</tbody>
</table>

*Unadjusted outcome “at home” was tested against the combined outcome of “death and institutional care.”
†Unadjusted outcome “at home without severe disability” was tested against the combined outcome of “death and institutional care and at home with severe disability.”
Insurance Companies and has become part of regular stroke care with ongoing reimbursement. The Bavarian State Ministry for Employment and Social Order, Family, and Women funded part of the technical equipment, and the German Stroke Foundation (Stiftung Deutsche Schlaganfall-Hilfe) supported the first part of the outcome analysis. Boehringer Ingelheim Pharma GmbH & Co KG had dispensed stroke lysis boxes in intervention hospitals at the start of the project.

The sponsors had no role in study design, data collection, data analysis, data interpretation, or writing the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit the publication.

Results

A total of 3060 (1938 in intervention and 1122 in control hospitals) patients fulfilled the inclusion criteria for the outcome analysis. Mean intervals from admission to 12 months follow-up were 358 (SD, 29) days for the intervention group and 359 (SD, 39) days for the control group (P=0.43). For 30 months’ follow-up, mean intervals were 920 (SD, 36) and 914 (SD, 37) days, respectively (P<0.01).

Mortality

Follow-up rates for vital status were 97.7% for the intervention group vs 97.5% for control group after 12 months and 96.4% vs 96.3% after 30 months. Survival plots for the 2 groups are shown in the Figure. The cumulative survival rates after 900 days were 68.0% in the intervention group and 65.5% in the control group (log rank test: P=0.271). Death rates and adjusted odds ratios for mortality at different time intervals are shown in Table 1.

Death and Institutional Care

Follow-up rates for the combined outcome of death or institutional care were 92.2% for the intervention group vs...
96.7% for the control group at 12 months and 96.0% vs 95.8% at 30 months. Predictors of outcome are shown in Table 3. The statistically significant difference in univariate analysis at 12 months in favor of the TEMPiS group (Table 2) did not remain significant after correction for possible confounders (Table 3). There was only a trend in favor of the intervention group at 30 months without significance in multivariable analysis (Table 3).

**Death, Institutional Care, or Severe Disability**

Follow-up rates for this combined outcome were 96.8% for the intervention group vs 96.0% for the control group at 12 months and 95.7% vs 95.6% at 30 months. The outcome “death and dependency” was significantly less frequent in the intervention group at both follow-up times (Table 2), and these differences remained statistically significant after correction for possible confounders (Table 4).

**Discussion**

Similar to the 3-month evaluation, a substantially lower proportion of patients treated in TEMPiS hospitals had a combined outcome “death and dependency” after 12 and 30 months. The absolute difference between the 2 hospital groups for this outcome declined from 10.4% at 3 months over 9.3% at 12 months to 5.2% at 30 months (Table 2). The adjusted corresponding probabilities to be dead or dependent at the 3 follow-up times suggest a long-lasting beneficial effect of specialized acute stroke care in community hospitals with continuous medical education and telemedicine consultation. The decreasing absolute difference in long-term outcome might be attributed to an increasing impact of other factors such as age and other diseases with time. Although tending toward improved outcome, there was no significant difference in case fatality or combined death and institutional care. With smaller absolute differences, our study was clearly
underpowered to detect a significant difference in these outcomes. Our results are in line with randomized trials such as the Helsinki acute stroke study, yielding shorter in-hospital length of stay and a significantly improved functional outcome but no difference in mortality at 1 year.

Because most of the reported trials about effectiveness of organized stroke care derived from comprehensive or rehabilitation stroke units, there are only few published controlled trials comparing acute stroke treatment in specialized and general settings. The most similar setting regarding acute admission and early treatment (although not including acute monitoring and telemedicine) is described in the single center randomized study in Akershus, Norway, with mean lengths of in-hospital stay of 9.1 days in stroke unit and 8.5 days in general medical ward. A significantly lower 1-year mortality was reported but another evaluation of the same group in Akershus could not show a significant improvement of functional status or need of long-term care but showed a tendency in favor of the stroke unit setting.

A large-scale observational study comparing acute treatment in stroke units and conventional wards in Italy yielded significant reductions of mortality, institutional care, and disability after correction for possible confounders. Daffertshofer et al reported results of another observational study within the context of the German Stroke Unit model. They found a similar reduction of death and dependency after 6 months for ischemic stroke patients treated in acute stroke units (OR, 0.63; 95% CI, 0.46–0.87).

To our knowledge, TEMPiS is the first study showing that the benefit of acute specialized stroke care can be extended to community hospitals by implementation of specialized stroke wards, ongoing quality management, and providing 24/7 access to neurological expertise via telemedicine including provision of a thrombolysis service.

Our study has several strengths and limitations. Information was collected prospectively from a large number of patients with high follow-up rates. The control group is recruited in matched hospitals offering the option to compare network data with conventional care. Observing the network effects in a multicenter community setting may provide better information about effectiveness in routine clinical care as compared with randomized clinical trials. However, in contrast to randomized, controlled trials that balance observed and unobserved confounders between treatment and control groups, we cannot rule out that some unobserved differences in patient characteristics between the intervention group and the control group contributed to our results. We were not able to blind the telephone interviewers for the hospital identity of each patient and, thus, knowledge of adherence to intervention or control arm might have influenced the interviewers. In addition, a higher proportion of patients were treated in intervention hospitals. This difference was caused at least in part by altered admission algorithms. Some counties with TEMPiS-linked hospitals recommended admitting all patients to the hospital with a TEMPiS unit and omitting other hospitals in the same ownership and catchment area. We cannot exclude that the implementation of the TEMPiS network might have influenced the characteristic of patients admitted to the intervention hospitals. However, observed outcome differences between TEMPiS and control hospitals remained statistically significant after adjustment for potential confounders. Presently, all reported effects have to be contributed to the complete network concept including set-up of stroke wards, quality management, and telemedical consultation. With the study design we used, it is not possible to determine the impact of telemedicine on stroke outcome. Because only 36% of all admitted stroke patients in TEMPiS hospitals underwent telemedical consultations, the observed effect on outcome cannot be attributed to telemedicine alone. A recently published randomized study has shown that stroke telemedicine consultations result in more accurate decision-making compared with telephone consultations. However, the study was not powered to show differences in clinical outcome. A second randomized controlled trial analyzing these specific effects of telemedical consultation for individual patients is currently underway (ClinicalTrials.gov NCT00279149).

In summary, the present data suggest that the set-up of stroke wards in community hospitals with appropriate facilities and education supported by telemedicine-linked academic stroke centers offers a new way to provide specialized stroke care in smaller hospitals. This seems to be associated with a long-term benefit for patients with acute stroke revealed by reduced death and dependency during follow-up of 30 months.

Acknowledgments
The authors thank all physicians, therapists, and nurses of the participating hospitals, all members of the TEMPiS study team, and, not least, the patients and their family members, without whose cooperation and help this study would not have been possible.

Disclosures
The following institutions participated in this study. Stroke centers: Department of Neurology, Klinikum Harlaching, Städtisches Klinikum München GmbH, and Department of Neurology, University of Regensburg; TEMPiS hospitals: Asklepios Stadtiklinik Bad Tölz, Kreisklinik Ebersberg gGmbH, Kreisklinik München-Pasing, Klinikum Freising, and Klinikum Rosenheim; Control group hospitals: Krankenhaus Landshut-Achendorf, Klinikum Landshut gGmbH, Ilmtalklinik Pfaffenhofen GmbH, Klinikum Neuperlach; Städtisches Klinikum München GmbH, and Kliniken St. Elisabeth Neuburg a.d. Donau.

Sources of Funding
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Disclosures
H.J.A. has received speaker fees from Meytec GmbH (distributor of the telemedicine devices). J.S. is member of an advisory board of Boehringer Ingelheim Pharma GmbH. All other authors state that there are no conflicts of interest. The statistical analysis was conducted by H.J.A. and J.S.

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