Off-Hours Admission and Acute Stroke Care Quality  
A Nationwide Study of Performance Measures and Case-Fatality  
Nina Sahlertz Kristiansen, MHSc; Jan Mainz, MD, PhD; Bente Mertz Nørgård, PhD, DMSc; Paul D. Bartels, MD; Grethe Andersen, DMSc; Søren Paaske Johnsen, MD, PhD

Background and Purpose—Studies have reported higher risks of death and other adverse outcomes in acute stroke patients admitted off-hours; however, little is known about the underlying mechanisms. According to time of admission, our aim was to examine compliance with performance measures for acute stroke care processes, including the effect of a systematic quality improvement program, and to examine 30 days case-fatality.

Methods—A population-based historical cohort study, including patients admitted to Danish hospitals with a first ever acute stroke (January 1, 2003, to December 31, 2011; N=64,975). Off-hours were weekends and evening and nighttime shifts on weekdays. Compliance with performance measures was compared using general linear modeling, and odds ratios for 30 days case-fatality were obtained using multivariable logistic regression.

Results—Patients admitted off-hours had a lower chance of compliance with 8 out of 10 performance measures; however, these differences diminished over time. Unadjusted odds ratio for 30 days case-fatality, for patients admitted off-hours compared with patients admitted on-hours, was 1.15 (95% confidence interval, 1.09–1.21). Adjusting for patient characteristics (in particular, stroke severity) decreased the odds ratio to 1.03 (95% confidence interval, 0.97–1.10). Additional adjustment for hospital characteristics and compliance with performance measures had no effect on the odds ratio.

Conclusion—Patients admitted off-hours received a poorer quality of care. However, the admission time–related differences in care were substantially reduced over time, and the differences in 30 days case-fatality appeared primarily to be explained by differences in stroke severity. (Stroke. 2014;45:00:00.)

Key Words: case-fatality ■ quality of care ■ stroke

During the last 20 years, studies have reported that patients admitted with acute stroke, during off-hours or during weekends, experience a higher risk of death1–11 and other adverse outcomes, such as delayed medical interventions and poorer rehabilitation outcomes.4–7,11 However, the mechanisms driving these variations remain to be clarified. Differences in patient characteristics, as well as differences in the quality of the care provided, seem to be plausible explanatory factors, but large-scale population-based studies with detailed data on unselected patients are needed to disentangle the role of these factors and further to examine the effectiveness of quality improvement interventions aimed at reducing the variation. The aim of our study was first to determine whether compliance with performance measures for acute stroke care differed according to time of admission. Second, we examined whether such differences, if any, changed following implementation of a systematic quality improvement program. Third, we examined whether time of admission was associated with differences in 30 days case-fatality and whether such differences could be explained by patient characteristics, hospital characteristics, and compliance with acute stroke care performance measures.

Methods

The Danish National Health Services provides tax-supported healthcare for the entire population (~5.6 million), including free access to hospital care. All Danish residents are assigned a unique civil registration number that is used in all healthcare registries and ensures unambiguous individual-level record linkage. This study was based on data from the Danish Stroke Registry (DSR),11 linked with data from the Danish National Patient Register,12 the Danish Civil Registration System,13 the Danish National Database of Reimbursed Prescriptions, and the Integrated Database for Labor Market Research, which are all population-based registries. The study was approved by The Danish Data Protection Agency (J.no. 2012-41-0578).
The Danish Stroke Registry
The DSR was established as a nationwide quality improvement project in 2003. Participation is mandatory for all hospital units treating patients with acute stroke. The DSR monitors quality of care performance measures, which reflect recommendations from the national clinical guidelines on acute stroke care.12 The performance measures are selected by a multidisciplinary expert panel consisting of experienced clinicians. Data are prospectively collected upon hospital admission by the care-taking staff, according to detailed data specifications. A DSR-trained clinician is responsible for processing the data to the DSR database. After data analyses, which is managed by the DSR organization, the results are reported on a monthly basis to the individual units, in order for the managers and clinicians to monitor their performances, and to take action when improvement is needed. Annual regional and national structured audits are performed to facilitate learning and exchange of experience. All results are made publically available. Completeness and quality of the data are continuously ensured, that is, by comparison with local hospital discharge registries, registrations of hospital contacts in the Danish National Registry of Patients, and through the audits. For a graphical representation of the quality improvement process used in the DSR, please see Figure I in the online-only Data Supplement at http://stroke.aha.journals.org.

Study Population
From the DSR, we identified all patients admitted with first ever acute stroke (intracerebral hemorrhage, ischemic stroke, or unspecified stroke) from January 1, 2003, to December 31, 2011 (N=64,975). All adults with acute stroke, who have been admitted to a Danish hospital, must be registered in the DSR, regardless of length of stay. Acute stroke is defined as occurrence of symptoms within the last week in accordance with the WHO’s criteria. The recordings are commenced at the unit to which the patient is first admitted, regardless of the type of the unit.

Time of Admission
In Danish hospitals, it is common practice that the care-taking staff works in the following 3 shifts: daytime 7.00 AM to 3:00 PM, evening 3:00 PM to 11:00 PM, and nighttime 11:00 PM to 7:00 AM. During the study period, 7:00 AM to 3:00 PM was the only time during the day where the units in general were fully staffed, with the different health-care professionals required in modern interdisciplinary stroke care. Outside this time-frame, the nurse ratio was typically lower and the access to occupational therapists and physiotherapists restricted. To capture the time of day where the setting for acute stroke care was most likely to differ, off-hours admission was defined as admission during weekends (Friday 11.00 AM to Monday 6.59 AM) and during evenings and nighttime shifts on weekdays. Admission at all other times during the week was defined as on-hours admission.

To examine whether admission-related differences reflected a general off-hours problem, we performed additional analyses using 2 alternative definitions of off-hours admission: (1) restricted to patients admitted on weekdays and comparing admissions during evenings or nighttime shifts with admissions during daytime shifts and (2) including all patients and comparing patients admitted during weekends regardless of shift (Friday 11.00 AM to Monday 6.59 AM) and during evenings and nighttime shifts on weekdays. Admission at all other times during the week was defined as on-hours admission.

Performance Measures
Acute stroke care quality was assessed according to compliance with performance measures for 10 specific processes of care. A time frame was defined for each measure to capture the timeliness of the processes. For an overview of the performance measures, please see Table I in the online-only Data Supplement at http://stroke.aha.journals.org. Patients were classified as eligible or ineligible for the specific performance measures depending on whether the clinicians treating the patient identified contraindications. The quality of care was further summarized using 2 composite performance measures: the all-or-one composite measure and an opportunity-based composite measure. Both measures were based on the performance measures 1, 2, 4, 5, 6, 8, and 10 (because these were monitored throughout the study period) and included only patients eligible to comply with ≥3 performance measures. For each patient, the total number of relevant performance measures was defined as the denominator, and the number of performance measures actually complied with was defined as the numerator, and the proportion of relevant performance measures the single patient met was determined. Conducting the all-or-none measure, the number of patients meeting all relevant performance measures was calculated (not taking partial credits into account) and further summarized as the percentage of patients meeting all relevant performance measures. Conducting the opportunity-based measure, the percentage of relevant performance measures, that the single patient met, was calculated and further summarized as the mean percentage of met performance measures across all included patients.13

30 Days Case-Fatality
30 days case-fatality was assessed using data from the Danish Civil Registration System, in which information on date and place of birth, residence, emigration, and vital status are recorded. Information on vital status is daily updated, and follow-up on mortality using the Civil Registration System can be considered fully complete.14

Patient and Hospital Characteristics
At the time of hospital admission, data were collected on the following patient characteristics: age, sex, body mass index, marital status, housing, myocardial infarction, atrial fibrillation, hypertension, diabetes mellitus, intermittent claudication, smoking, and alcohol intake. Stroke severity was assessed using the Scandinavian Stroke Scale and categorized as very severe (0–14 points), severe (15–29 points), moderate (30–44 points), and mild (45–58 points).15 From the Danish National Registry of Patients, to which all Danish nonpsychiatric hospitals must report every patient–hospital contact, we collected data concerning discharge diagnosis and comorbidity; the latter expressed using the Charlson Comorbidity Score Index, based on hospital contacts recorded within the last 10 years before admission.16–18 From the Danish National Database of Reimbursed Prescriptions, we collected data on treatment, with the following type of drugs, within the last 90 days before admission: antihypertensive drugs, platelet inhibitors, vitamin K antagonists, statins, selective serotonin reuptake inhibitors, non-selective serotonin reuptake inhibitor antidepressants, and hormone replacement therapy (women). From the Integrated Database for Labor Market Research, we collected data on level of education, occupational status, and level of income. Through the Danish Health and Medicines Authority and according to the official Danish Classification of Hospitals and Departments, we identified hospital characteristics in terms of the hospitals location (which Danish region), the type of hospital, and the type of unit. For an overview of all patient and hospital characteristics, please see Tables IIa, IIb, and IIc in the online-only Data Supplement at http://stroke.aha.journals.org.

Statistical Analyses
According to time of admission, we first compared patient and hospital characteristics using χ² test. Second, the proportion of patients receiving the 10 processes of care in compliance with the performance measures was calculated, as were the all-or-none composite measure and the opportunity-based composite measure. Relative risks were computed and adjusted for stroke severity and clustering by stroke unit, using generalized linear models. The opportunity-based composite measure was compared according to time of admission using multiple linear regressions. To ensure that possible variation in compliance with performance measures was not caused by variation in the proportion of patients with ischemic stroke admitted off-hours, we made additional analyses stratified according to type of stroke. To identify possible changes over time, the analyses of the performance measures (1, 2, 4, 5, 6, 8, and 10) and of the 2 composite measures
were further performed in strata for each of the years in the study period. In all of the analyses, only patients who were classified as eligible for the specific performance measure were included. To examine the risk of bias caused by admission-time-variation in the determination of ineligibility, the proportion of patients being deemed ineligible was calculated for patients admitted on- and off-hours, respectively, and relative risks were computed using χ² test. Third, we used multivariable logistic regression to obtain odds ratios (OR) for 30 days case-fatality according to time of admission, while adjusting for clustering by stroke unit, patient, and hospital characteristics, as well as compliance with the 10 performance measures. Because data on some of the patient characteristics (eg, alcohol intake, smoking habits, and stroke severity) were missing among 1% to 32% of the patients (please see Table IIa in the online-only Data Supplement at http://stroke.ahajournals.org), the multivariable logistic regression analyses were conducted both as complete case analyses and, because data were likely to be missing at random, as analyses after multiple imputations. Missing values were imputed using multiple imputations by chained equations. Twenty imputed data sets were created by replacing missing values with simulated values from a set of imputation models, constructed from all complete potential prognostic factors, and the outcome variables. Missing values for binary factors were imputed from logistic models, missing values for categorical nominal factors were imputed from multinomial logistic models, and missing values for categorical ordinal factors were imputed from ordinal logistic models. The Monte Carlo error was estimated to ensure a sufficient amount of imputations.

All of the above mentioned statistical analyses were first performed using the primary definition of time of admission and then repeated twice using the 2 additional definitions of time of admission. All statistical analyses were performed using Stata I/C 12.0 (StataCorp).

### Results

**Patient and Hospital Characteristics**

Forty-five units at 36 hospitals reported data to the DSR during the study period 2003 to 2011. A total of 64,975 patients were included in the study, and of these, 39,072 were admitted off-hours, whereas 25,903 were admitted on-hours. Patients admitted off-hours were more likely to have severe or very severe stroke (according to the Scandinavian Stroke Scale). Otherwise, there were no substantial differences between the groups. For the distribution of all of the patient and hospital characteristics, please see the Tables IIa, IIb, and IIc in the online-only Data Supplement at http://stroke.ahajournals.org.

### Table 1. Chance of Compliance With Performance Measures of Acute Stroke Care According to Time of Admission

<table>
<thead>
<tr>
<th>Performance Measures (N=64,975)</th>
<th>Admitted Off-Hours (n=39,072)</th>
<th>Admitted On-Hours (n=25,903)</th>
<th>RR (95% CI)</th>
<th>RR† (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Admission to a specialized stroke unit within 48 h</td>
<td>33,589/36,153 (93.0%)</td>
<td>22,483/24,036 (93.5%)</td>
<td>0.99 (0.99–1.00)</td>
<td>0.99 (0.99–1.00)</td>
</tr>
<tr>
<td>2. Antiplatelet therapy initiated among patients with ischemic stroke without arterial fibrillation within 48 h</td>
<td>22,118/26,335 (84.0%)</td>
<td>15,684/18,123 (86.5%)</td>
<td>0.97 (0.96–0.98)</td>
<td>0.97 (0.96–0.98)</td>
</tr>
<tr>
<td>3. IV thrombolysis initiated within 1 h after admission (door-to-needle time)</td>
<td>487/34,585 (14.1%)</td>
<td>273/22,227 (12.3%)</td>
<td>1.15 (1.00–1.32)</td>
<td>1.13 (1.01–1.27)</td>
</tr>
<tr>
<td>4. Examination with CT/MR scans within 24 h</td>
<td>22,586/38,384 (58.8%)</td>
<td>17,812/25,475 (69.9%)</td>
<td>0.84 (0.83–0.85)</td>
<td>0.85 (0.82–0.88)</td>
</tr>
<tr>
<td>5. Assessment by a physiotherapist within 24 h</td>
<td>20,872/31,618 (66.0%)</td>
<td>15,461/20,775 (74.4%)</td>
<td>0.99 (0.88–0.90)</td>
<td>0.89 (0.86–0.93)</td>
</tr>
<tr>
<td>6. Assessment by an occupational therapist within 24 h</td>
<td>19,657/31,869 (61.7%)</td>
<td>15,056/21,087 (71.4%)</td>
<td>0.86 (0.85–0.87)</td>
<td>0.87 (0.84–0.89)</td>
</tr>
<tr>
<td>7. Mobilization within 24 h</td>
<td>15,262/21,118 (72.0%)</td>
<td>11,833/14,343 (82.5%)</td>
<td>0.87 (0.84–0.90)</td>
<td>0.90 (0.86–0.94)</td>
</tr>
<tr>
<td>8. Assessment of nutritional risk within 24 h</td>
<td>20,077/30,249 (66.4%)</td>
<td>14,271/20,175 (70.7%)</td>
<td>0.94 (0.93–0.95)</td>
<td>0.95 (0.93–0.97)</td>
</tr>
<tr>
<td>9. Indirect examination of swallowing function within 24 h</td>
<td>20,422/26,191 (78.0%)</td>
<td>1464/1676 (87.3%)</td>
<td>0.89 (0.87–0.92)</td>
<td>0.89 (0.86–0.93)</td>
</tr>
<tr>
<td>10. Direct examination of swallowing function within 24 h</td>
<td>10,862/18,001 (60.3%)</td>
<td>8016/11,463 (69.9%)</td>
<td>0.86 (0.85–0.88)</td>
<td>0.87 (0.84–0.91)</td>
</tr>
<tr>
<td>11. Compliance with all performance measures (all-or-none composite measure)</td>
<td>10,378/36,981 (28.1%)</td>
<td>9851/24,691 (39.9%)</td>
<td>0.70 (0.69–0.72)</td>
<td>0.73 (0.69–0.76)</td>
</tr>
<tr>
<td>12. Proportion of relevant performance measures met (opportunity-based composite measure)</td>
<td>n=36,835; Mean (SD), 70.6% (2.8)</td>
<td>n=24,610; Mean (SD), 77.0% (2.8)</td>
<td>Diff. (95% CI), 6.4% (5.95–6.85)</td>
<td>Diff.‡ (95% CI), 6.3% (5.79–6.72)</td>
</tr>
</tbody>
</table>

CI indicates confidence interval; CT, computed tomography; DSR, Danish Stroke Registry; MR, magnetic resonance; and RR, relative risk.

*The amount of patients varied between the different performance measures. This was because of variation in the amount of patients for whom the individual performance measures were clinically relevant. The performance measures (3) IV Thrombolysis within 1 h after admission, (7) mobilization within 24 h, and (9) indirect examination of swallowing function within 24 h were not implemented in the DSR until 2011; thus, the relatively lower amount of patients seen for these 3 measures.

†RR adjusted for clustering by stroke unit and for admission stroke severity (Scandinavian Stroke Scale).

‡Coefficient (difference) after multiple linear regression analysis adjusting for clustering by stroke unit and for admission stroke severity (Scandinavian Stroke Scale).
As presented in Table 1, off-hours admission was associated with a lower compliance with the performance measures for the majority of the processes of acute stroke care. Though, in relation to IV thrombolysis, compliance with the performance measure was higher among the patients admitted off-hours (absolute difference 1.8%, adjusted relative risks 1.13 (95% confidence interval [CI], 1.01–1.27)). The overall quality of care, summarized in terms of the all-or-none composite measure, was lower among patients admitted off-hours (absolute difference 11.8%, adjusted relative risks 0.73 (95% CI, 0.69–0.76)), as was the overall quality of care, summarized in terms of the opportunity-based composite measure, where the mean proportion of received relevant processes of care was found to be 6.3% (95% CI, 5.8–6.7) lower among the patients admitted off-hours. Adjusting for stroke severity had no substantial effect on the differences in the chance (relative risks) of compliance with the performance measures. Additional analyses showed no systematic differences in compliance with the performance measures when stratifying according to stroke type (ischemic and unspecified stroke versus intracerebral hemorrhage). For results, please see the Table III in the online-only Data Supplement at http://stroke.aha.journals.org.

Development Over the Time Period 2003 to 2011

Figures 1 and 2 show the development over time in the compliance with the performance measures of care, the all-or-none composite measure, and the opportunity-based composite measure for patients admitted off-hours versus on-hours. For all of the individual performance measures, as well as the 2 composite measures, we found a positive development in the level of compliance over the assessed time period, indicating that the quality of acute stroke care improved significantly between 2003 and 2011 for patients admitted off-hours versus on-hours.

30 Days Case-Fatality

Table 2 presents the results of the 30 days case-fatality analyses, showing estimates from the complete case analyses and the analyses after multiple imputations. We found a higher case-fatality rate among off-hours patients (unadjusted OR after multiple imputations 1.15 [95% CI, 1.09–1.21]). Adjusting for patient characteristics lowered the OR (adjusted OR after multiple imputations 1.03 [95% CI, 0.97–1.10]). Further adjustment for hospital characteristics and compliance with performance measures, respectively, had no additional effect (OR adjusted further for hospital characteristics 1.03 [95% CI, 0.97–1.10]; OR adjusted further for quality of care 1.05 [95% CI, 0.97–1.12]).

Additional Analyses

The results of the analyses using the 2 alternative definitions of off-hours were, in all, similar to those using the primary definition (data not shown).
We found patients admitted off-hours to have higher levels of stroke severity at the time of admission. Off-hours admission was associated with a lower compliance with the performance measures for 8 out of 10 acute stroke care processes. However, the absolute differences between patients admitted off-hours and on-hours were in general modest, and the variation in care was substantially reduced after implementation of a national systematic quality improvement program. The 30 days case-fatality was significantly higher among patients admitted off-hours; however, this appeared to be explained by the differences in stroke severity and not by differences in care.

Performance Measures

Only a few other studies have addressed the association between time of admission and acute stroke care performance measures. Rudd et al and Rose et al found examination with computed tomography/magnetic resonance scans to be delayed for patients admitted during weekends, whereas Fang et al, in contrast, found no differences in use of computed tomography/magnetic resonance scans and dysphagia screening. Regarding the latter, Reeves et al found a minor reduction in the proportion of patients receiving dysphagia screening, and of patients receiving thrombolysis, among patients admitted during weekends. Overall, we found a lower quality of care provided to patients admitted off-hours; however, it should be noted that the absolute differences were modest (<10 percentage points) for the majority of the examined performance measures. Furthermore, the vast majority (>95%) of the patients, who was not compliant with the performance measures within the defined time frames, received the processes at a later phase during their admission. Still, previous studies based on data from the DSR have found that compliance with the performance measures is associated with a lower risk of medical complications during hospitalization, a lower length of stay, and a lower case-fatality. These findings underline the importance of timeliness of multidisciplinary stroke care and support a rather aggressive approach toward eliminating even modest insufficiencies in the quality of care.

The admission time–related variation in quality of care diminished over time in our study period. Between 2003 and 2001, all Danish hospitals, treating patients with acute stroke, participated actively in quality work through the activities related to the DSR. We are not able to isolate the effect of this national quality improvement program, and a causal association between the program and the improvement in the quality of care cannot be conclusively determined. However, it is a fact that establishing the DSR is the most significant initiative in Danish acute stroke care in this specific period, and there is a national consensus, among stroke clinicians, that the activities related to the registry have been a driving force in optimizing the care pathways at stroke units in Denmark.

30 Days Case-Fatality

Similar to our findings, Jauss et al found no difference in short-term mortality after adjusting for clinical condition (Modified Rankin Scale at admission, disturbance of conscience, presence of motor deficits, dysarthria, aphasia, and swallowing-disorder), which was found to be more severe among the patients admitted during off-hours. Other studies have not found differences in short-term mortality when restricting to patients admitted to specialized stroke centers, indicating that organizational factors may be important in understanding the weekend- or off-hours effect. Across patient populations, the body of scientific work supporting the existence of a weekend- or off-hour-effect is substantial. However, comparing the literature across different types of medical conditions, as well as different cultures and organizational structures, is problematic because of, for example, differences in patient selection, control for confounding, and completeness in follow-up. More studies addressing the consequences of time of admission and in particular the possible underlying explanations are needed.

Strength and Limitations

The main strengths of our study include its size, the national population-based design, the detailed prospective data collection, and the complete follow-up on survival status. Detailed registration of the exact time of admission enabled the definition of off-hours to reflect the work flow in every day clinical practice. Only patients without contraindications for the specific performance measure were included in the analyses of the
Table 2. Odds Ratio for 30 Days Case-Fatality According to Time of Admission

<table>
<thead>
<tr>
<th>Time of Admission</th>
<th>Proportion (%)</th>
<th>Unadjusted OR (95% CI)</th>
<th>Adjusted OR* (95% CI)</th>
<th>Adjusted OR† (95% CI)</th>
<th>Adjusted OR‡ (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete case analysis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On-hours</td>
<td>2244/25,903 (8.66%)</td>
<td>1.00 (ref.)</td>
<td>1.00 (ref.)</td>
<td>No estimates because of missing data leading to model collapse</td>
<td>No estimates because of missing data leading to model collapse</td>
</tr>
<tr>
<td>Off-hours</td>
<td>3838/39,072 (9.82%)</td>
<td>1.15 (1.09–1.21)</td>
<td>1.06 (0.99–1.14)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Analysis after multiple imputations

<table>
<thead>
<tr>
<th>Time of Admission</th>
<th>Proportion (%)</th>
<th>Unadjusted OR (95% CI)</th>
<th>Adjusted OR* (95% CI)</th>
<th>Adjusted OR† (95% CI)</th>
<th>Adjusted OR‡ (95% CI)</th>
</tr>
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<tr>
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<td>2244/25,903 (8.66%)</td>
<td>1.00 (ref.)</td>
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<td>1.00 (ref.)</td>
<td>1.00 (ref.)</td>
</tr>
<tr>
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<td>3838/39,072 (9.82%)</td>
<td>1.15 (1.09–1.21)</td>
<td>1.03 (0.97–1.10)</td>
<td>1.03 (0.97–1.10)</td>
<td>1.05 (0.99–1.12)</td>
</tr>
</tbody>
</table>

CI indicates confidence interval; BMI, body mass index; CT, computed tomography; MR, magnetic resonance; and OR, odds ratio.

*Adjusted for clustering by stroke unit and for patient characteristics: sex, age group, BMI, marital status, housing, alcohol intake, smoking habits, level of education, working status, level of income, diabetes mellitus, atrial fibrillation, acute myocardial infarction, hypertension, intermittent claudication, medication 90 days before admission, admission stroke severity (Scandinavian Stroke Scale), comorbidity (Charlson Comorbidity Index), discharge diagnosis, and year of admission.

†Adjusted for clustering by stroke unit, the above mentioned patients characteristics, and for hospital characteristics: region, type of hospital, type of unit, and unit volume.

‡Adjusted for clustering by stroke unit, the above mentioned patients characteristics, and for compliance with performance measures: admission to a specialized stroke unit, antiplatelet therapy initiated, IV thrombolysis initiated, examination with CT/MR scans, assessment by a physiotherapist, assessment by an occupational therapist, assessment of nutritional risk, and indirect and direct examination for swallowing function.

quality of care, decreasing the risk of confounding (eg, by higher levels of stroke severity). Further, the possibility of bias caused by admission-time-variation in the determination of ineligibility was refuted after additional analyses. Our study was highly dependent on the validity of the registries that were used. In this context, it is relevant to consider whether the identification of patients with acute stroke, and the documentation of the performance measures, could be biased by the time of admission. However, the risk appear small because the physicians working off- and on-hours shifts were the same, and we do not have reason to believe that the clinical practice changed during off-hours to an extent where the physicians ability to make valid stroke identification and documenting the case-taking was affected. Also, extensive efforts are made to ensure the validity of the DSR data. For instance, the quality of the data sets is regularly assessed through structured audit processes, and the completeness of the patient registration is ensured through comparison with local hospital discharge registries and the Danish National Registry of Patients. A recent study confirms that the overall validity of the registration of patients with acute stroke in the DSR is high, with a sensitivity and a positive predictive value >90%. Another potential limitation was the lack of access to clinical outcomes beyond case-fatality (eg, Modified Rankin Score). Case-fatality is not necessarily a sensitive measure, and a casual linkage between variation in quality of care and variation in mortality can be difficult to establish.

In conclusion, we found that Danish patients with acute stroke, admitted off-hours, had a lower chance of compliance with most of the recommended performance measures of acute stroke care. Much of the variation according to time of admission was eliminated during the period 2003 to 2011, following implementation of a national systematic quality improvement program. Higher 30-day case-fatality among patients admitted off-hours appeared to be explained by more severe strokes at the time of admission.

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Disclosures

None.

References


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SUPPLEMENTAL MATERIAL

Off-hours Admission and Acute Stroke Care Quality:
A Nationwide Study of Performance Measures and Case-fatality
### Methods

**Performance Measures**

**Supplementary table I) Overview of the quality of acute stroke care performance measures**

<table>
<thead>
<tr>
<th>Performance measure</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Admission to a specialized stroke unit within 48 hours.</td>
<td>A Specialized stroke unit was defined as a unit that exclusively or primarily is dedicated to patients with stroke and which is characterized by having multidisciplinary teams, a staff with a specific interest in stroke, involvement of relatives and continuous education of the staff.</td>
</tr>
<tr>
<td>2. Antiplatelet therapy initiated among patients with ischemic stroke without arterial fibrillation within 48 hours.</td>
<td>Initiation of antiplatelet therapy was defined as continuous use of the drugs and not merely a single dose.</td>
</tr>
<tr>
<td>3. IV thrombolysis initiated within one hour after admission.</td>
<td>Time from admission to the hospital to IV thrombolysis is initiated (“door-to-needle” time).</td>
</tr>
<tr>
<td>4. Examination with CT/MR scans within 24 hours.</td>
<td>Examination with CT/MR scans performed within 24 hours.</td>
</tr>
<tr>
<td>5. Assessment by a physiotherapist within 24 hours.</td>
<td>Assessment by a physiotherapist and an occupational therapist was defined as a formal bed-side assessment of the patient’s need of rehabilitation.</td>
</tr>
<tr>
<td>6. Assessment by an occupational therapist within 24 hours.</td>
<td></td>
</tr>
<tr>
<td>7. Mobilization within 24 hours.</td>
<td>Early mobilization was defined as unassisted or assisted mobilization from bed to either sitting in a chair or standing upright or walking, depending on the patient’s general condition.</td>
</tr>
<tr>
<td>8. Assessment of nutritional risk within 24 hours.</td>
<td>Assessment of nutritional risk was defined as an assessment following the recommendations of the European Society of Parenteral and Enteral Nutrition, i.e. calculation of a score which accounted for nutritional status as well as for the stress induced by the stroke.</td>
</tr>
<tr>
<td>9. Indirect examination of swallowing function within 24 hours.</td>
<td>Indirect swallowing assessment was defined as a formal bed side assessment performed before the patient was offered food and drink. Indirect testing included assessment of the alertness of the patient and the patient’s ability to cough and swallow saliva.</td>
</tr>
<tr>
<td>10. Direct examination of swallowing function within 24 hours.</td>
<td>Direct swallowing assessment was defined as a formal bed-side swallowing test, performed before the patient was offered food and drink. Direct testing included test of the ability to swallow water with and without thickener and the ability to swallow solid food.</td>
</tr>
<tr>
<td>11. Compliance with all relevant performance measures (all or none composite measure)</td>
<td>Compliance with all of the, for the single patient clinically relevant and not contra-indicated, performance measures. Based on the performance measures 1, 2, 4, 5, 6, 8 and 10 (since these measures were monitored throughout the study period).</td>
</tr>
<tr>
<td>12. Proportion of relevant performance measures met (opportunity-based-composite measure)</td>
<td>Proportion of the, for the single patient, clinically relevant and not contra-indicated, performance measures met. Based on the performance measures 1, 2, 4, 5, 6, 8 and 10 (since these indicators were monitored throughout the study period).</td>
</tr>
</tbody>
</table>
Results

Patient- and hospital characteristics

The following tables IIa, IIb and IIc show the distribution of patient- and hospital characteristics based on the original data before multiple imputations were applied.

Supplementary table IIa) Distribution of patient characteristics according to time of admission

<table>
<thead>
<tr>
<th>N = 64.975</th>
<th>Admitted off-hours (n =39.072)</th>
<th>Admitted on-hours (n =25.903)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n (%)</td>
<td>n (%)</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-65</td>
<td>12,002 (30.7)</td>
<td>8,132 (31.4)</td>
</tr>
<tr>
<td>65-80</td>
<td>15,042 (38.5)</td>
<td>10,222 (39.5)</td>
</tr>
<tr>
<td>&gt; 80</td>
<td>12,028 (30.8)</td>
<td>7,549 (29.1)</td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Women</td>
<td>18,793 (48.1)</td>
<td>12,278 (47.4)</td>
</tr>
<tr>
<td>Men</td>
<td>20,279 (51.9)</td>
<td>13,625 (52.6)</td>
</tr>
<tr>
<td><strong>Marital status</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Living with partner, family or friend</td>
<td>20,805 (53.3)</td>
<td>14,282 (55.1)</td>
</tr>
<tr>
<td>Living alone</td>
<td>16,305 (41.7)</td>
<td>10,326 (39.9)</td>
</tr>
<tr>
<td>Other</td>
<td>930 (2.4)</td>
<td>605 (2.3)</td>
</tr>
<tr>
<td>Unknown</td>
<td>1,032 (2.6)</td>
<td>690 (2.7)</td>
</tr>
<tr>
<td><strong>Housing</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Own home</td>
<td>34,345 (87.9)</td>
<td>23,004 (88.8)</td>
</tr>
<tr>
<td>Nursing home / other institution</td>
<td>2,135 (5.5)</td>
<td>1,356 (5.2)</td>
</tr>
<tr>
<td>Other</td>
<td>863 (2.2)</td>
<td>499 (1.93)</td>
</tr>
<tr>
<td>Unknown</td>
<td>1,729 (4.4)</td>
<td>1,044 (4.0)</td>
</tr>
<tr>
<td><strong>Level of education</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Short (Primary and lower secondary school)</td>
<td>16,676 (42.7)</td>
<td>10,996 (42.5)</td>
</tr>
<tr>
<td>Medium  (Vocational education and upper secondary school)</td>
<td>4,728 (12.1)</td>
<td>3,280 (12.7)</td>
</tr>
<tr>
<td>Long (Short-, medium-, and long-term higher education)</td>
<td>12,098 (31.0)</td>
<td>8,091 (31.2)</td>
</tr>
<tr>
<td>Unknown</td>
<td>5,570 (14.3)</td>
<td>3,536 (13.7)</td>
</tr>
<tr>
<td><strong>Occupation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unemployed or student</td>
<td>858 (2.2)</td>
<td>567 (2.2)</td>
</tr>
<tr>
<td>Working</td>
<td>8,881 (22.7)</td>
<td>6,199 (23.9)</td>
</tr>
<tr>
<td>Early retiree</td>
<td>5,001 (12.8)</td>
<td>3,389 (12.7)</td>
</tr>
<tr>
<td>Pensioner</td>
<td>24,317 (62.2)</td>
<td>15,837 (61.1)</td>
</tr>
<tr>
<td>Unknown</td>
<td>15 (0.04)</td>
<td>11 (0.04)</td>
</tr>
<tr>
<td><strong>Level of income</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. quartile (&lt;= 116.422 dkk.)</td>
<td>9,604 (24.6)</td>
<td>6,524 (25.2)</td>
</tr>
<tr>
<td>2. quartile (116.423 - 148.866 dkk.)</td>
<td>9,786 (25.1)</td>
<td>6,473 (25.0)</td>
</tr>
<tr>
<td>3. quartile (148.867- 239.450 dkk.)</td>
<td>10,027 (25.7)</td>
<td>6,334 (24.5)</td>
</tr>
<tr>
<td>4. quartile (&gt;=239.451 dkk.)</td>
<td>9,639 (24.7)</td>
<td>6,560 (25.3)</td>
</tr>
<tr>
<td>Unknown</td>
<td>16 (0.04)</td>
<td>12 (0.05)</td>
</tr>
<tr>
<td><strong>Alcohol intake</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;= 14/21 drinks per week</td>
<td>30,791 (78.8)</td>
<td>20,588 (79.5)</td>
</tr>
<tr>
<td>&gt; 14/21 drinks per week</td>
<td>3,036 (7.8)</td>
<td>1,974 (7.6)</td>
</tr>
<tr>
<td>Unknown</td>
<td>5,245 (13.4)</td>
<td>3,341 (12.9)</td>
</tr>
<tr>
<td><strong>Smoking habits</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td>12,869 (32.9)</td>
<td>8,440 (32.6)</td>
</tr>
<tr>
<td>On occasion</td>
<td>429 (1.1)</td>
<td>296 (1.1)</td>
</tr>
<tr>
<td>Former (&gt; six months)</td>
<td>7,867 (20.1)</td>
<td>5,359 (20.7)</td>
</tr>
<tr>
<td>Never</td>
<td>11,779 (30.2)</td>
<td>7,883 (30.4)</td>
</tr>
<tr>
<td>Unknown</td>
<td>6,128 (15.7)</td>
<td>3,925 (15.2)</td>
</tr>
<tr>
<td><strong>BMI</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;18.5</td>
<td>1,221 (3.1)</td>
<td>741 (2.9)</td>
</tr>
<tr>
<td>18.5-25</td>
<td>11,511 (29.5)</td>
<td>7,700 (29.7)</td>
</tr>
<tr>
<td>25+</td>
<td>13,647 (34.9)</td>
<td>9,199 (35.5)</td>
</tr>
<tr>
<td>Unknown</td>
<td>12,693 (32.5)</td>
<td>8,263 (31.9)</td>
</tr>
</tbody>
</table>

### Diabetes mellitus

| Yes | 4,958 (12.7) | 3,178 (12.3) |
| No | 33,674 (86.2) | 22,425 (86.6) |
| Unknown | 440 (1.1) | 300 (1.2) |

### Atrial fibrillation

| Yes | 6,174 (15.8) | 3,984 (15.4) |
| No | 32,287 (82.6) | 21,482 (82.9) |
| Unknown | 611 (1.6) | 437 (1.7) |

### AMI

| Yes | 3,207 (8.2) | 2,142 (8.3) |
| No | 35,091 (89.8) | 23,298 (89.9) |
| Unknown | 774 (2.0) | 463 (1.8) |

### Hypertension

| Yes | 18,513 (47.4) | 12,332 (47.6) |
| No | 19,552 (50.0) | 12,893 (49.8) |
| Unknown | 1,007 (2.6) | 678 (2.6) |

### Intermittent claudication

| Yes | 1,035 (2.7) | 675 (2.6) |
| No | 30,758 (78.7) | 20,492 (79.1) |
| Unknown | 7,279 (18.6) | 4,736 (18.3) |

### Admission stroke severity (SSS)

| Very severe (0-14 pt.) | 3,460 (8.9) | 2,090 (8.1) |
| Severe (15-29 pt.) | 3,470 (8.9) | 2,053 (7.9) |
| Moderate (30-44 pt.) | 6,499 (16.6) | 3,726 (14.4) |
| Mild (45-58 pt.) | 21,037 (53.8) | 15,141 (58.5) |
| Unknown | 4,606 (11.8) | 2,893 (11.2) |

### Charlson Comorbidity Index

| No comorbidity (0 pt.) | 21,356 (54.7) | 14,379 (55.5) |
| Low comorbidity (1-2 pt.) | 13,553 (34.7) | 8,869 (34.2) |
| High comorbidity (>2 pt.) | 4,163 (10.7) | 2,655 (10.3) |

### Discharge diagnosis

| Intracerebral hemorrhage | 4,528 (11.6) | 2,408 (9.3) |
| Ischemic stroke | 28,434 (72.8) | 19,415 (75.0) |
| Stroke without specifications | 6,110 (15.6) | 4,080 (15.8) |

### Year of admission

| 2003 | 3,233 (8.3) | 2,238 (8.6) |
| 2004 | 4,284 (11.0) | 3,038 (11.7) |
| 2005 | 4,287 (11.0) | 2,978 (11.5) |
| 2006 | 4,492 (11.5) | 3,120 (12.0) |
| 2007 | 4,383 (11.2) | 2,922 (11.3) |
| 2008 | 4,259 (10.9) | 2,725 (10.5) |
| 2009 | 4,717 (12.1) | 2,955 (11.4) |
| 2010 | 4,745 (12.1) | 2,977 (11.5) |
| 2011 | 4,672 (12.0) | 2,950 (11.4) |
### Supplementary table IIb) Distribution of patient characteristics according to time of admission - medication

<table>
<thead>
<tr>
<th>Treatment within the last 90 days before admission</th>
<th>Admitted off-hours (n = 39,072)</th>
<th>Admitted on-hours (n = 25,903)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anti-hypertensive drugs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>15,776 (40.4)</td>
<td>10,621 (41.0)</td>
</tr>
<tr>
<td>No</td>
<td>23,296 (59.6)</td>
<td>15,282 (59.0)</td>
</tr>
<tr>
<td>Platelet inhibitors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>8,929 (22.9)</td>
<td>5,755 (22.2)</td>
</tr>
<tr>
<td>No</td>
<td>30,143 (77.2)</td>
<td>20,148 (77.8)</td>
</tr>
<tr>
<td>Vitamin K antagonists</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>1,771 (4.5)</td>
<td>1,134 (4.4)</td>
</tr>
<tr>
<td>No</td>
<td>37,301 (95.5)</td>
<td>24,769 (95.6)</td>
</tr>
<tr>
<td>Statins</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>5,121 (13.1)</td>
<td>3,422 (13.2)</td>
</tr>
<tr>
<td>No</td>
<td>33,951 (86.9)</td>
<td>22,481 (86.8)</td>
</tr>
<tr>
<td>SSRI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>2,534 (6.5)</td>
<td>1,666 (6.4)</td>
</tr>
<tr>
<td>No</td>
<td>36,538 (93.5)</td>
<td>24,237 (93.6)</td>
</tr>
<tr>
<td>Non-SSRI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>2,119 (5.42)</td>
<td>1,331 (5.14)</td>
</tr>
<tr>
<td>No</td>
<td>36,953 (94.58)</td>
<td>24,572 (94.86)</td>
</tr>
<tr>
<td>Hormone replacement therapy – women</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>1,746 (4.5)</td>
<td>1,214 (4.7)</td>
</tr>
<tr>
<td>No</td>
<td>17,047 (43.6)</td>
<td>11,064 (42.7)</td>
</tr>
<tr>
<td>Unknown (= men)</td>
<td>20,279 (51.9)</td>
<td>13,625 (52.6)</td>
</tr>
</tbody>
</table>

### Supplementary table IIc) Distribution of hospital characteristics according to time of admission

<table>
<thead>
<tr>
<th>Region</th>
<th>Admitted off-hours (n = 39,072)</th>
<th>Admitted on-hours (n = 25,903)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital</td>
<td>10,340 (26.5)</td>
<td>6,870 (26.5)</td>
</tr>
<tr>
<td>Sealand</td>
<td>6,601 (16.9)</td>
<td>3,786 (14.6)</td>
</tr>
<tr>
<td>Southern Denmark</td>
<td>9,212 (23.6)</td>
<td>6,461 (24.9)</td>
</tr>
<tr>
<td>Central Denmark</td>
<td>8,648 (22.1)</td>
<td>6,035 (23.3)</td>
</tr>
<tr>
<td>Northern Jutland</td>
<td>4,271 (10.9)</td>
<td>2,751 (10.6)</td>
</tr>
<tr>
<td>Type of hospital</td>
<td></td>
<td></td>
</tr>
<tr>
<td>University hospital</td>
<td>14,014 (35.9)</td>
<td>8,681 (33.5)</td>
</tr>
<tr>
<td>Non-university hospital</td>
<td>25,058 (64.1)</td>
<td>17,222 (66.5)</td>
</tr>
<tr>
<td>Type of unit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specialized stroke unit</td>
<td>13,360 (34.2)</td>
<td>9,479 (36.6)</td>
</tr>
<tr>
<td>Other type of unit</td>
<td>25,712 (65.1)</td>
<td>16,424 (63.4)</td>
</tr>
<tr>
<td>Unit volume</td>
<td>(Average admissions pr. year)</td>
<td></td>
</tr>
<tr>
<td>0-200</td>
<td>13,374 (34.2)</td>
<td>8,734 (33.7)</td>
</tr>
<tr>
<td>201-400</td>
<td>15,468 (39.6)</td>
<td>10,983 (42.4)</td>
</tr>
<tr>
<td>401-600</td>
<td>10,230 (26.2)</td>
<td>6,186 (23.9)</td>
</tr>
</tbody>
</table>
### Supplementary table III) Chance of compliance with performance measures according to time of admission - stratified according to type of stroke

<table>
<thead>
<tr>
<th>Performance measure</th>
<th>Intracerebral hemorrhage</th>
<th>Ischemic stroke or Stroke without specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Admitted off-hours (n =4,528)</td>
<td>Admitted on-hours (n =2,408)</td>
</tr>
<tr>
<td>1. Admission to a specialized stroke unit within 48 hours.</td>
<td>3,631/4,065 (89.3 %)</td>
<td>1,969/2,180 (90.3 %)</td>
</tr>
<tr>
<td>2. Examination with CT/MR scans within 24 hours.</td>
<td>3,262/4,446 (73.4 %)</td>
<td>1,197/2,363 (80.9 %)</td>
</tr>
<tr>
<td>3. Assessment by a physiotherapist within 24 hours.</td>
<td>1,799/3,072 (58.6 %)</td>
<td>1,084/1,631 (66.5 %)</td>
</tr>
<tr>
<td>4. Assessment by an occupational therapist within 24 hours.</td>
<td>1,697/3,057 (55.5 %)</td>
<td>1,042/1,635 (63.7 %)</td>
</tr>
<tr>
<td>5. Mobilization within 24 hours</td>
<td>92/141 (61.7 %)</td>
<td>66/87 (75.9 %)</td>
</tr>
<tr>
<td>6. Assessment of nutritional risk within 24 hours.</td>
<td>1,722/2,936 (58.7 %)</td>
<td>956/1,557 (61.4 %)</td>
</tr>
<tr>
<td>7. Indirect examination of swallowing function within 24 hours.</td>
<td>183/247 (74.1 %)</td>
<td>133/128 (88.3 %)</td>
</tr>
<tr>
<td>8. Direct examination of swallowing function within 24 hours.</td>
<td>914/1,784 (51.2 %)</td>
<td>546/890 (61.4 %)</td>
</tr>
</tbody>
</table>

* The amount of patients varied between the different performance measures. This was due to variation in the amount of patients for whom the individual measures were clinically relevant. The performance measures 7) Mobilization within 24 hours and 9) Indirect examination of swallowing function within 24 hours, were not implemented in the DSR until 2011, thus the relatively lower amount of patients seen for these performance measures.

** RR adjusted for clustering by stroke unit and for admission stroke severity (Scandinavian Stroke Scale).
### Supplementary table IV: Risk of being deemed ineligible for the individual performance measures according to time of admission

Unmarked online supplement

<table>
<thead>
<tr>
<th>Performance measure</th>
<th>Admitted off-hours</th>
<th>Admitted on-hours</th>
<th>RR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Admission to a specialized stroke unit within 48 hours</td>
<td>2,919/39,072 (7.5%)</td>
<td>1,867/25,903 (7.2%)</td>
<td>1.04 (0.98-1.10)</td>
</tr>
<tr>
<td>2. Antiplatelet therapy initiated among patients with ischemic stroke without arterial fibrillation within 48 hours</td>
<td>12,737/39,072 (32.6%)</td>
<td>7,780/25,903 (30.0%)</td>
<td>1.09 (1.06-1.11)</td>
</tr>
<tr>
<td>3. IV thrombolysis initiated within one hour after admission (&quot;door-to-needle time&quot;).</td>
<td>35,614/39,072 (91.2%)</td>
<td>23,676/25,903 (91.4%)</td>
<td>1.00 (0.99-1.00)</td>
</tr>
<tr>
<td>4. Examination with CT/MR scans within 24 hours</td>
<td>688/39,072 (1.8%)</td>
<td>428/25,903 (1.7%)</td>
<td>1.07 (0.95-1.20)</td>
</tr>
<tr>
<td>5. Assessment by a physiotherapist within 24 hours</td>
<td>7,454/39,072 (19.1%)</td>
<td>5,128/25,903 (19.8%)</td>
<td>0.96 (0.93-0.99)</td>
</tr>
<tr>
<td>6. Assessment by an occupational therapist within 24 hours</td>
<td>7,203/39,072 (18.4%)</td>
<td>4,816/25,903 (18.6%)</td>
<td>0.99 (0.96-1.02)</td>
</tr>
<tr>
<td>7. Mobilization within 24 hours</td>
<td>36,954/39,072 (94.6%)</td>
<td>24,469/25,903 (94.5%)</td>
<td>1.00 (1.00-1.01)</td>
</tr>
<tr>
<td>8. Assessment of nutritional risk within 24 hours</td>
<td>8,823/39,072 (22.6%)</td>
<td>5,728/25,903 (22.1%)</td>
<td>1.02 (0.99-1.05)</td>
</tr>
<tr>
<td>9. Indirect examination of swallowing function within 24 hours</td>
<td>36,453/39,072 (93.3%)</td>
<td>24,227/25,903 (93.5%)</td>
<td>1.00 (0.99-1.00)</td>
</tr>
<tr>
<td>10. Direct examination of swallowing function within 24 hours</td>
<td>21,071/39,072 (53.9%)</td>
<td>14,440/25,903 (55.8%)</td>
<td>0.97 (0.95-0.98)</td>
</tr>
</tbody>
</table>
Figure legend for Supplementary figure I

*Supplementary figure I*) Quality improvement cycle in the Danish Stroke Registry