A Structured Reading Algorithm Improves Telemetric Detection of Atrial Fibrillation After Acute Ischemic Stroke

Bernd Kallmünzer, MD*; Lorenz Breuer, MD*; Christiane Hering, MD; Dorette Raaz-Schrauder, MD; Rainer Kollmar, MD; Hagen B. Huttner, MD; Stefan Schwab, MD; Martin Köhrmann, MD

Background and Purpose—Anticoagulation is a highly effective secondary prevention in patients with cardioembolic stroke and atrial fibrillation/flutter (AF). However, the condition remains underdiagnosed, because paroxysmal AF may be missed by diagnostic tests in the acute phase. In this study, the sensitivity of AF detection was assessed for serial electrocardiographic recordings and continuous stroke unit telemetric monitoring with or without a structured algorithm to analyze telemetric data (SEA-AF).

Methods—Three hundred forty-six consecutive patients with acute ischemic stroke were prospectively included and subjected to standard telemetric monitoring. In addition, telemetric data were separately analyzed following SEA-AF, consisting of a structured evaluation of episodes with high risk for AF and a chronological beat-to-beat screening of the full registration. Serial electrocardiograms were conducted in 24-hour intervals.

Results—Median effective telemetry monitoring time was 75.5 hours (interquartile range 64–86 hours). Overall, AF was diagnosed in 119 of 346 patients (34.4%). The structured reading algorithm was the most sensitive method to detected AF. Conventional telemetry and serial electrocardiographic assessments were less effective. However, only 35% of patients with previously documented paroxysmal AF and negative baseline electrocardiogram demonstrated AF episodes during monitoring.

Conclusions—Continuous stroke unit telemetry using SEA-AF shows a significantly higher detection rate for AF compared with daily electrocardiographic assessments and standard telemetry without structured reading. The low overall probability to detect paroxysmal AF with either method during the first days after stroke demonstrates the urgent need for complementary diagnostic strategies such as long-term monitoring and frequent follow-up assessments.

Clinical Trial Registration—URL: www.clinicaltrials.gov. Unique identifier: NCT01177748.

(Stroke. 2012;43:994-999.)

Key Words: arrhythmia ■ atrial fibrillation ■ ECG ■ monitoring ■ stroke ■ telemetry

Atrial fibrillation (AF) is the most common sustained cardiac arrhythmia in the general population and bears a high risk for vascular complications, including ischemic stroke.1,2 The early identification of underlying cardioembolic etiology is of particular relevance for patients with cerebral ischemia, because the risk for stroke recurrence is high and the initiation of adequate therapy with oral anticoagulation represents one of the most effective strategies in secondary stroke prevention.3,4 AF may occur in paroxysmal, persistent, or permanent forms,1 all of them displaying similar stroke risk.1,6 However, paroxysmal forms pose special diagnostic challenges: silent episodes may recur in timely clusters1,5 and escape a single electrocardiogram (ECG) on admission.7,8 Current guidelines recommend cardiac monitoring for at least 24 hours after an acute cerebrovascular event,9,10 but evidence for a clear superiority among different modalities of monitoring is lacking. In clinical practice, evaluation of telemetric data is often not standardized and AF episodes may remain unrecognized although being captured by the monitoring. A competing approach to telemetry proposes the assessment of serial ECGs in regular time intervals.11 Guidelines considered this concept as sufficient for a stroke unit setting10 and it could represent a cost-effective alternative.11,12

In this study, efficacy to detect AF was compared for: (1) serial ECG assessments; (2) standard stroke unit telemetry; and (3) a structured comprehensive evaluation algorithm of monitoring data (SEA-AF). In addition, sensitivity of the methods was calculated in patients with a known history of documented AF.
Methods

Study Setting and Patient Inclusion

This prospective, single-center observational trial was conducted on consecutive patients with acute ischemic stroke, who were admitted to the stroke unit of the University Medical Centre Erlangen, Germany, within 3 days after symptom onset. The study period covered May to December 2010. The study was approved by the local ethics committee and was registered with www.clinicaltrials.gov (NCT 01177748). The diagnosis of stroke was established on the basis of clinical findings and diagnostic imaging in accordance with current guidelines.9,10 A cardiovascular stroke unit work-up, including echocardiography, sonography of cerebral arteries, risk-factor stratification, and laboratory testing, was performed following current recommendations.10 Overall prevalence of AF in our cohort was calculated adding patients in whom AF was detected during stroke unit monitoring and patients with a history of documented and verified AF (paroxysmal and permanent AF). For the latter, the patients’ general practitioners and/or cardiologists were contacted and the results of past examinations and ECGs were reviewed by study personnel to confirm the AF diagnosis. Patients were divided into 2 groups for analysis: (1) patients without previous AF; and (2) patients with a history of confirmed AF.

Modalities for AF Detection

All patients received a standard 12-lead ECG (MAC 1200 ST; General Electric) on admission. Three modalities for AF detection were compared during treatment at the stroke unit.

Serial ECG Assessments

Serial standard 12-lead ECGs were conducted by the study personnel in 24-hour intervals starting at 8:00 AM on the day after baseline ECG. Paper print was performed with a speed of 25 mm/s. If AF or any other significant arrhythmia was suspected, the diagnosis was confirmed by a cardiologist.

Standard Telemetric Monitoring

As a standard of care, patients on our 14-bed dedicated stroke unit were connected to a multimodal monitoring system (Dräger; Infinity Delta Series, Lübeck, Germany) including a 6-lead continuous ECG registration, which was displayed with 2 traces on 2 different screens, 1 positioned next to the patient and a second at a central control station. If feasible, patients with acute cerebral ischemia at our institution receive telemetric monitoring of at least 72 hours. An automatic alarm signal is given in cases of flat line, ventricular arrhythmia, tachycardia >120 beats/min, or bradycardia <40 beats/min. The system does not automatically recognize episodes of AF. If a member of the stroke unit personnel suspected AF from the continuous ECG traces, a 12-lead ECG was conducted and reviewed by a cardiologist.

Structured Evaluation Algorithm for AF

Continuous telemetry data were saved to a central hard disk. The records were daily reviewed by a study investigator (B.K. or L.B.), including a structured evaluation of episodes with high risk for AF followed by a chronological review of the full registration (SEA-AF; Figures 1 and 2) in analogy to Holter ECG evaluation guidelines.13 The 6 steps of this algorithm were: (1) a graphical 24-hour heart rate spectrum was generated and paper printed; (2) paroxysmal drops and boosts in heart rate >20 beats/min were identified and evaluated at the corresponding ECG strips; (3) changes in the amplitude of heart rate variation were identified and evaluated: (4) all tachycardia >120 beats/min or bradycardia <40 beats/min were identified and evaluated; (5) episodes of arrhythmia (tachy-bradycardia, flat line, ventricular arrhythmia) detected by the monitoring system were identified and the corresponding ECG was evaluated; and (6) the 24-hour “beat-to-beat” registration overview was analyzed for irregularities in RR intervals and AF episodes.

All detected episodes were paper-printed as 2-trace ECG strips and reviewed by a cardiologist in case of suspected arrhythmia. For the diagnosis of AF, an arrhythmic episode had to comply with all ECG criteria of current guidelines and last for >30 seconds.1

Patients and the clinical stroke unit personnel were blinded to the results of the SEA-AF for up to 48 hours. Theretofore, significant arrhythmia detected by the SEA-AF was reported to the clinicians to allow the initiation of an adequate therapy. Previously unrecognized potentially life-threatening arrhythmia was reported immediately. The expenditure of time to perform SEA-AF was measured for 100 consecutive 24-hour registrations and is reported as median and range.

Statistical Analysis

Data were processed using the PASW Statistics 18 (SPSS Inc) software package. For the baseline data, normality of distribution was tested using the Shapiro-Wilk and Kolmogorov-Smirnov tests. Normally distributed data were summarized as means and SDs; otherwise, median and interquartile ranges were provided. After recruitment completion, the patients were split into 2 groups: (1) patients without a history of AF; and (2) patients with a history of at least 1 verified AF episode before admission. Each group was further divided depending on the heart rhythm on baseline ECG (baseline ECG showing AF versus baseline ECG not showing AF). In patients with negative baseline ECG, the AF detection rate was compared for the different diagnostic strategies using the χ² test. The level of significance was set a priori at P=0.05.

Results

Characteristics of Patients

Three hundred forty-six consecutive patients (median age, 72 years; 53% men) with acute ischemic stroke were prospectively included. The demographic characteristics and risk factors are summarized in the Table. Stroke affected the anterior circulation in 63%, whereas 16 patients had acute cerebral infarction in >1 vascular territory. Intravenous thrombolysis was initiated in 24% of patients. A diagnosis of structural heart disease was present in 134 cases (39%).

Figure 1. Telemetric data were saved and separately evaluated in 24-hour intervals following a 6-step structured algorithm for the detection of atrial fibrillation (SEA-AF).
Conditions of Cardiac Monitoring

The median effective telemetric monitoring time was 75.5 hours (interquartile range, 64–86 hours). This excluded times during which the patient was not connected to the system, for example, during examinations, radiological scans, or physical therapy. A median of 4 serial ECGs (interquartile range, 3–4) in addition to the baseline ECG were conducted per patient in 24-hour intervals. Overall 119 patients (34.4%) with AF were identified (known history of AF or AF detected during stroke unit monitoring). In patients with negative baseline ECG, the first AF episode was detected at a median of 22 hours after the initiation of monitoring (interquartile range, 12–44 hours). The quantification of time to perform the SEA-AF in a 24-hour registration revealed a median effort of 8 minutes (range, 6–23 minutes).

Newly Diagnosed AF

Among the 271 cases without a history of AF (Figure 3), a first diagnosis was established in 44 patients (16%). In 26, AF was present on baseline ECG on admission. Continuous telemetric monitoring including SEA-AF identified 18 additional cases (Figure 3), whereas serial ECG assessments and

Figure 2. Example for the application of structured algorithm for the detection of atrial fibrillation (SEA-AF) in a patient with an episode of paroxysmal atrial fibrillation (pAF) over 14 hours. A. After generation of a 24-hour heart rate profile, paroxysmal drops and boosts in heart rate, changes in the amplitude of heart rate variation as well as tachycardia >120 beats/min and bradycardia <40 beats/min were identified. In this patient, evaluation of a paroxysmal heart rate boost (*) revealed the onset of pAF. B. The 2-lead electrocardiographic strip during the switch from sinus rhythm to AF corresponding to the time-point (*) identified in A is shown.
standard monitoring without SEA-AF were positive in 8 and 7 of these cases, respectively. No cases of AF found in serial ECGs or regular monitoring were missed by SEA-AF. The superiority of SEA-AF over both other methods was statistically significant ($P < 0.001$).

### Discussion

An unacquainted percentage of patients with acute ischemic stroke and normal ECG on admission have silent paroxysmal AF. In this study, continuous telemetry in combination with a

### Table. Baseline Characteristics and Demographic Data

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Patients</td>
<td>346</td>
</tr>
<tr>
<td>Women/men</td>
<td>164/182</td>
</tr>
<tr>
<td>Age, y (IQR)</td>
<td>72 (62–81)</td>
</tr>
<tr>
<td>Vascular risk factors</td>
<td></td>
</tr>
<tr>
<td>Arterial hypertension</td>
<td>292 (84%)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>144 (42%)</td>
</tr>
<tr>
<td>Smoking</td>
<td>82 (24%)</td>
</tr>
<tr>
<td>Hyperlipidemia</td>
<td>170 (49%)</td>
</tr>
<tr>
<td>Carotid intima-media thickness ≥1.0 mm</td>
<td>216 (62%)</td>
</tr>
<tr>
<td>Systolic blood pressure on admission, mm Hg</td>
<td>162±27</td>
</tr>
<tr>
<td>Diastolic blood pressure on admission, mm Hg</td>
<td>91±17</td>
</tr>
<tr>
<td>Prestroke mRS (IQR)</td>
<td>0 (0–1)</td>
</tr>
<tr>
<td>Medication on admission</td>
<td></td>
</tr>
<tr>
<td>Beta-blockers</td>
<td>95 (27%)</td>
</tr>
<tr>
<td>Anihypertensives</td>
<td>129 (37%)</td>
</tr>
<tr>
<td>Antiplatelet therapy</td>
<td>121 (35%)</td>
</tr>
<tr>
<td>Vitamin K antagonist</td>
<td>30 (9%)</td>
</tr>
<tr>
<td>Structural heart disease</td>
<td>134 (39%)</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>72 (21%)</td>
</tr>
<tr>
<td>Hypertensive heart disease</td>
<td>42 (12%)</td>
</tr>
<tr>
<td>Valvular heart disease</td>
<td>10 (3%)</td>
</tr>
<tr>
<td>Other</td>
<td>10 (3%)</td>
</tr>
<tr>
<td>Heart rhythm on baseline ECG</td>
<td></td>
</tr>
<tr>
<td>Sinus rhythm</td>
<td>272 (79%)</td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>59 (17%)</td>
</tr>
<tr>
<td>Atrial flutter</td>
<td>5 (1%)</td>
</tr>
<tr>
<td>Pacemaker</td>
<td>10 (3%)</td>
</tr>
<tr>
<td>Vascular territory</td>
<td></td>
</tr>
<tr>
<td>MCA</td>
<td>211 (61%)</td>
</tr>
<tr>
<td>ACA</td>
<td>7 (2%)</td>
</tr>
<tr>
<td>PCA</td>
<td>28 (8%)</td>
</tr>
<tr>
<td>Infratentorial</td>
<td>84 (24%)</td>
</tr>
<tr>
<td>More than 1 territory</td>
<td>16 (5%)</td>
</tr>
<tr>
<td>NIHSS on admission (IQR)</td>
<td>4 (2–9)</td>
</tr>
<tr>
<td>NIHSS at discharge (IQR)</td>
<td>2 (1–7)</td>
</tr>
<tr>
<td>Thrombolysis performed</td>
<td>82 (24%)</td>
</tr>
<tr>
<td>In-hospital mortality</td>
<td>13 (3.8%)</td>
</tr>
</tbody>
</table>

IQR indicates interquartile range; mRS, modified Rankin Scale; ECG, electrocardiogram; MCA, middle cerebral artery; ACA, anterior cerebral artery; PCA, posterior cerebral artery; NIHSS, National Institutes of Health Stroke Scale.

Therapeutic Consequences of AF Detection

Detection of new AF during continuous monitoring at the stroke unit had direct therapeutic consequences for all 18 patients. In 10 cases (55%), a switch from antiplatelet therapy to oral anticoagulation was initiated during the current in-hospital stay. In the 8 remaining patients, oral anticoagulation was initiated with a latency ranging from 2 to 8 weeks after the event by the rehabilitation center or the patient’s general practitioner.

Performance of Diagnostic Methods in Patients With a History of AF

Seventy-five patients had a history of documented and verified AF (paroxysmal or permanent; Figure 4). The overall AF detection rate in this cohort was 68%. Baseline ECG detected AF in 38 of 75 patients (51%). Of the remaining 37 patients with a negative initial ECG, only 13 (35%) displayed AF episodes during monitoring. Again, SEA-AF was more sensitive to detect these episodes ($P < 0.001$) compared with serial ECG assessments, which missed 4 of 13 cases.

### Figure 3

Two hundred seventy-one of 346 patients had no history of atrial fibrillation (AF). In individuals with a negative baseline electrocardiogram, telemetry with the structured algorithm for the detection of atrial fibrillation (SEA-AF) was the most effective strategy to detect new AF during treatment at the stroke unit.

### Figure 4

The performance of diagnostic approaches was assessed in patients with a documented history of atrial fibrillation (AF; **n = 75**). Comprehensively, in 68% of cases at least 1 paroxysmal AF episode was found during treatment at the stroke unit. In patients with a negative baseline electrocardiogram (ECG; **n = 37**), the sensitivity of structured algorithm for the detection of atrial fibrillation (SEA-AF) was significantly superior to serial ECGs ($P < 0.001$), but two thirds escaped detection over a median monitoring time of 75.5 hours.
structured and comprehensive analysis of the registration demonstrated a significantly higher detection rate than daily ECG assessments. Telemetry without structured reading was less effective. However, all methods are limited by the fact that approximately two thirds of patients with previously documented AF but negative baseline ECG did not display AF episodes during a median monitoring time of 75.5 hours.

Serial ECG Assessments Versus Continuous Monitoring
It is well established that patients with ischemic stroke have a better outcome with treatment on a monitored stroke unit compared with a nonmonitored ward and that a survival benefit may result from the early detection of malignant arrhythmia after stroke. Therefore, many centers are presently equipped with telemetric monitoring and patients are connected to the system for at least the first 24 hours. Besides its main original goal to detect life-threatening arrhythmia, it was suggested that cardiac telemetry facilitates the diagnosis of paroxysmal AF, too. However, the superiority of continuous monitoring for AF detection over serial ECG assessments was questioned by a study on 150 consecutive patients admitted to a Canadian stroke unit. On average, 2.4 ECGs were conducted during inpatient evaluation. Notably, there was no significant difference in the rate of AF detection with ECG compared with 24-hour Holter monitoring, and the latter identified only 50% of patients with positive ECG. It was suggested that serial ECGs should precede continuous monitoring or supplant it in centers where telemetry or Holter monitoring are not readily available. In the present study, a median of 4 ECGs were conducted in 24-hour intervals and showed equal sensitivity to standard telemetric monitoring. These results are conform to the data of Douen et al. However, both methods, serial ECGs and standard telemetry, were by far less effective than the introduction of a structured evaluation algorithm for telemetric data.

Improving Telemetric Monitoring Using SEA-AF
Conventional systems for telemetry do not automatically distinguish different forms of supraventricular arrhythmia and most conditions need to be identified personally during observation of the ECG traces. Thereby a number of limitations, including unattended time periods and insufficient experience on arrhythmia discrimination among the stroke unit personnel, may lead to poor sensitivity. In the present study, the telemetry data were saved and separately reviewed using a structured algorithm (Figure 1). This additional daily analysis increased the number of early identified new AF by a factor of 2.6 compared with conventional telemetry. Although a structured review of telemetric data is the standard of care in rhythmologic care units and many chest pain units, similar algorithms have infrequently been established on stroke units. Our results show that the additional standardized evaluation significantly increases the efficacy of telemetry and should constantly supplement routine stroke unit monitoring for the detection of paroxysmal AF.

Low Sensitivity of Either Method During the Acute Phase of Stroke
In many previous studies on AF detection after stroke, patients with a history of AF were excluded. Therefore, valid data on the sensitivity of monitoring are sparse. In the current investigation, continuous inpatient monitoring for a median of 75.5 hours did not reveal any episodes of AF in two thirds of patients with previously documented AF but negative baseline ECG. We cannot fully exclude that some of these patients had secondary AF in the past, which was terminated by treatment of the underlying disease. However, this population consisted of a high-risk group for AF with a median prestroke CHADS-2 score of 3 (interquartile range, 2.5–4; no patient with CHADS-2 score of 0). The low detection rate in this group clearly demonstrates the need for complimentary diagnostic strategies. One obvious but rather costly and in some instances invasive method is provided with long-term monitoring devices. Pilot studies have been undertaken and larger trials are underway. An intriguing but undervalued alternative is given by the natural time course of AF: >95% of patients with nonvalvular AF show a progression from short, rare paroxysmal AF episodes at onset to sustained and permanent forms at later stages. The majority of these patients will be identified if early monitoring at the stroke unit is followed by periodical cardiac rhythm evaluations with increased sensitivity at later time points.

Limitations
The main limitation of our study is the single-center design with limited patient numbers. In addition, comparison to 24-hours Holter ECG was not included in our study protocol. Previous investigations, however, indicate that 24-hour Holter ECG has low impact for AF detection during the acute phase of ischemic stroke and that it is clearly inferior to routine stroke unit monitoring. Although Holter recordings have been conducted in clinical routine in a subset of our study cohort, the data did not allow a systematic head-to-head comparison of 24-hour Holter ECG and SEA-AF. Because all steps of SEA-AF were performed and analyzed together, we cannot provide data on performance and value of single steps within the algorithm. With the lack of an established “gold standard” to detect AF after stroke, evaluation of the definite efficacy of our monitoring algorithm remains difficult. However, the overall AF prevalence of 34.4% in this cohort reaches the upper limit of previously reported rates in comparable cohorts.

Conclusions
Stroke unit telemetric monitoring including a structured evaluation algorithm is significantly more effective than daily ECG assessments or conventional telemetry for the detection of paroxysmal AF. Two thirds of patients with previously confirmed paroxysmal AF and normal heart rhythm on admission do not show AF during a median inpatient monitoring for 75.5 hours. Complimentary strategies such as long-term monitoring or thorough ambulatory follow-up examinations of cardiac rhythm must follow stroke unit monitoring in patients with cerebral ischemia of undetermined etiology.
Disclosures

None.

References

27. Kallmünzer et al. Improved Detection of AF After Stroke 999
A Structured Reading Algorithm Improves Telemetric Detection of Atrial Fibrillation After Acute Ischemic Stroke

Bernd Kallmünzer, Lorenz Breuer, Christiane Hering, Dorette Raaz-Schrauder, Rainer Kollmar, Hagen B. Huttner, Stefan Schwab and Martin Köhrmann

*Stroke*. 2012;43:994-999; originally published online February 2, 2012; doi: 10.1161/STROKEAHA.111.642199

*Stroke* is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2012 American Heart Association, Inc. All rights reserved.
Print ISSN: 0039-2499. Online ISSN: 1524-4628

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://stroke.ahajournals.org/content/43/4/994

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in *Stroke* can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to *Stroke* is online at:
http://stroke.ahajournals.org/subscriptions/