Point-of-Care International Normalized Ratio Testing Accelerates Thrombolysis in Patients With Acute Ischemic Stroke Using Oral Anticoagulants

Timolaos Rizos, MD; Christian Herweh, MD; Ekkehart Jenetzky, MD; Christoph Lichy, MD, MSc; Peter Arthur Ringleb, MD; Werner Hacke, MD, PhD; Roland Veltkamp, MD

Background and Purpose—Thrombolysis in patients using oral anticoagulants (OAC) and in patients for whom information on OAC status is not available is frequently delayed because the standard coagulation analysis procedure in central laboratories (CL) is time-consuming. By using point-of-care (POC) coagumeters, international normalized ratio (INR) values can be measured immediately at the bedside. The accuracy and effectiveness of POC devices for emergency management in acute ischemic stroke has not been tested.

Methods—In phase 1, the reliability of emergency INR POC measurements in comparison to CL was determined. In phase 2, patients with ischemic stroke admitted within the time frame for systemic thrombolysis and who were either using OAC or for whom information on OAC status was not available were enrolled. Patients received thrombolysis if POC INR was ≤1.5. Precision and time gain was recorded for INR as measured by POC vs CL.

Results—In phase 1 (n=113), Bland-Altman analysis showed close agreement between POC and CL, and Pearson correlation was highly significant (r=0.98; P<0.01). In phase 2, 48 patients were included, of whom 70.8% were using OAC; 23 patients received thrombolysis. After subtracting the time needed for the diagnostic work-up, the net time gain was 28±12 minutes (mean±SD).

Conclusions—Measuring INR by POC in an emergency setting is sufficiently precise in OAC acute stroke patients and substantially reduces the time interval until INR values are available and therefore may hasten the initiation of thrombolysis. (Stroke. 2009;40:3547-3551.)

Key Words: acute ischemic stroke • emergency room • INR • oral anticoagulants • point of care • thrombolysis
self-monitoring purposes.\textsuperscript{11–14} The precision of POC measurements in the emergency setting of acute stroke, however, is largely unknown. Importantly, the time gain for stroke patients who are candidates for thrombolysis by using POC has not been investigated to date.

The main purpose of our study, therefore, was to assess the usefulness of a POC coagumeter for the emergency management of acute ischemic stroke. In the first phase of the study, we evaluated whether INR measurements by POC are sufficiently precise in the setting of a neurological emergency department. Thereafter, we measured the potential time gain for initiating thrombolysis provided by POC use as compared to CL INR measurements.

Materials and Methods

A 2-phase, prospective, observational monocenter study was conducted between November 2007 and March 2009 at the neurological emergency department of the University of Heidelberg.\textsuperscript{15} All study procedures were approved by the institutional ethics committee. All patients or their representatives gave informed consent.

Phase 1 of the study was performed to ascertain that INR measurement using a POC coagumeter device in an emergency setting was sufficiently precise. In a nonconsecutive manner, patients admitted to our emergency department who were known to be using or suspected of using OAC were enrolled in the study. Blood samples were drawn simultaneously in our emergency department to determine INR values using the bedside POC and by routine analytic technique in our CL. The time to obtaining INR results from POC and CL was noted. To test agreement between the POC and CL measurements, a Bland-Altman analysis was performed,\textsuperscript{15} for which the paired differences were plotted against the mean of the 2 data values. The limits of agreement represent the 95% reference range of comparable measurements and are defined as \pm 1.96 SD.\textsuperscript{15,16} Additionally, Pearson correlation coefficients between POC and CL were calculated.

The second phase of the study was primarily performed to assess the gain in time until INR values were available when measuring INR by using POC as compared to CL, which would then allow thrombolysis to be initiated earlier in OAC stroke patients. In a nonconsecutive manner, patients with acute ischemic stroke presenting in time for systemic thrombolytic therapy who were either currently using OAC or for whom the OAC status was not available (eg, severe aphasia, no documentation) were enrolled in the study. Blood samples were drawn simultaneously in our emergency department to determine INR values using the bedside POC and by routine analytic technique in our CL. The time to obtaining INR results from POC and CL was noted. To test agreement between the POC and CL measurements, a Bland-Altman analysis was performed,\textsuperscript{15} for which the paired differences were plotted against the mean of the 2 data values. The limits of agreement represent the 95\% reference range of comparable measurements and are defined as \pm 1.96 SD.\textsuperscript{15,16} Additionally, Pearson correlation coefficients between POC and CL were calculated.

In phase 1, 113 patients were enrolled (62 male). Mean age of this group was 76 (range, 28–95; SD, 11). Bland-Altman analysis revealed a mean deviation of paired differences of 0.02 (SD, 0.27), resulting in limits of agreement of –0.52 to +0.56 (Figure 1A). Precision of INR values depended on INR intervals. Absolute deviations and limits of agreement improved for INR values \(\leq\)2 (mean, 0.12; SD, 0.09; limits of agreement, –0.08 to +0.32), indicating an increasing agreement between POC and standard CL measurements in INR values \(\leq\)2. Pearson correlation showed a highly significant correlation between POC and CL INR values (\(r\)=0.98; \(P\)<0.01; Figure 1B).

Phase 2

In the second phase, 48 patients with ischemic stroke presenting within the time frame for systemic thrombolysis in our emergency department were included (male, 22). Mean age was 78 years (range, 34–96; SD, 10). At the time of presentation, 34 patients were using OAC, and 23 of the 48 patients received intravenous thrombolytic treatment.

Similar to phase 1, the precision of INR measurements according to POC as compared to CL was evaluated in these 48 patients (Figure 2). Bland-Altman analysis revealed a mean deviation of paired differences of 0.09 (SD, 0.17), resulting in limits of agreement of –0.23 to +0.41. In addition, Pearson correlation showed a highly significant correlation between POC and laboratory INR values (\(r\)=0.97; \(P\)<0.01).

Mean time until availability of CL INR in all phase 2 patients was 47 minutes (range, 31–95; SD, 14). After accounting for clinical and neuroradiological evaluation, the mean effective time gain when using POC compared to CL INR measurements was 28 minutes (range, 11–64; SD, 12). The time gain until possible start of thrombolysis when using POC in contrast to CL is presented in Figure 3, using intervals of 15 minutes.

Except for 3 patients, treatment was administered according to POC INR levels (in 2 patients POC revealed INR levels of 1.6 and in 1 POC revealed INR levels of 1.8, whereas CL results in these 3 patients showed INR levels \(\leq\)1.5). Analysis of the follow-up head CT performed 24 hours after stroke according to SITS-MOST criteria in patients who received thrombolysis (\(n\)=23) demonstrated small petechiae along the margins of the infarct (HI 1) in 3 patients and more confluent petechiae within the infarct area but without a space-occupying effect in 2 patients (HI 2). None of the patients

After 24 hours all patients receiving recombinant tissue plasminogen activator underwent routine follow-up CT. Post hoc, CT images were rated by a neuroradiologist who was blinded to whether patients were using OAC before treatment for the presence of intracerebral hemorrhage or hemorrhagic transformation according to SITS-MOST criteria.\textsuperscript{16} To evaluate correlations between the presence of intracerebral hemorrhage or hemorrhagic transformation and initial INR level, a Mann-Whitney U test was conducted. Level of significance was set at \(P\)<0.05. Data were analyzed using the Statistical Package for the Social Sciences (SPSS, Version 16; SPSS Corporation).

Results

Phase 1

In phase 1, 113 patients were enrolled (62 male). Mean age of this group was 76 (range, 28–95; SD, 11). Bland-Altman analysis revealed a mean deviation of paired differences of 0.02 (SD, 0.27), resulting in limits of agreement of –0.52 to +0.56 (Figure 1A). Precision of INR values depended on INR intervals. Absolute deviations and limits of agreement improved for INR values \(\leq\)2 (mean, 0.12; SD, 0.09; limits of agreement, –0.08 to +0.32), indicating an increasing agreement between POC and standard CL measurements in INR values \(\leq\)2. Pearson correlation showed a highly significant correlation between POC and CL INR values (\(r\)=0.98; \(P\)<0.01; Figure 1B).

Phase 2

In the second phase, 48 patients with ischemic stroke presenting within the time frame for systemic thrombolysis in our emergency department were included (male, 22). Mean age was 78 years (range, 34–96; SD, 10). At the time of presentation, 34 patients were using OAC, and 23 of the 48 patients received intravenous thrombolytic treatment.

Similar to phase 1, the precision of INR measurements according to POC as compared to CL was evaluated in these 48 patients (Figure 2). Bland-Altman analysis revealed a mean deviation of paired differences of 0.09 (SD, 0.17), resulting in limits of agreement of –0.23 to +0.41. In addition, Pearson correlation showed a highly significant correlation between POC and laboratory INR values (\(r\)=0.97; \(P\)<0.01).

Mean time until availability of CL INR in all phase 2 patients was 47 minutes (range, 31–95; SD, 14). After accounting for clinical and neuroradiological evaluation, the mean effective time gain when using POC compared to CL INR measurements was 28 minutes (range, 11–64; SD, 12). The time gain until possible start of thrombolysis when using POC in contrast to CL is presented in Figure 3, using intervals of 15 minutes.

Except for 3 patients, treatment was administered according to POC INR levels (in 2 patients POC revealed INR levels of 1.6 and in 1 POC revealed INR levels of 1.8, whereas CL results in these 3 patients showed INR levels \(\leq\)1.5). Analysis of the follow-up head CT performed 24 hours after stroke according to SITS-MOST criteria in patients who received thrombolysis (\(n\)=23) demonstrated small petechiae along the margins of the infarct (HI 1) in 3 patients and more confluent petechiae within the infarct area but without a space-occupying effect in 2 patients (HI 2). None of the patients
experienced a parenchymatous hemorrhage after thrombolysis. There was no significant correlation between INR level and development of petechiae \((U=79.0; P=0.35)\).

**Discussion**

The effectiveness of thrombolysis in acute stroke depends strongly on the interval between symptom onset and administration of the thrombolytic drug.\(^4\) Therefore, every effort should be taken to accelerate acute stroke management (“time is brain”).\(^{19}\) Initiation of thrombolysis is delayed in stroke patients using OAC because INR measurements in CL using standard analytic techniques are time-consuming. The major new findings of the present study are: (1) POC measurements of the INR are sufficiently precise for emergency management of thrombolysis who were either using OAC or for whom information about OAC status was not available \((n=48)\). Analysis revealed a mean deviation of paired differences of 0.17 \((\text{continuous line})\) with SD of 0.09, resulting in limits of agreement of \(-0.23\) to \(+0.41\) \((\text{broken lines})\). POC tended to slightly overestimate the INR in comparison to CL values. B, Scatterplot for phase 2 patients, indicating again close agreement between POC and CL results.

Figure 1. A, Bland-Altman bias plot for POC in comparison to CL results for patients in study phase 1 \((n=113)\). Analysis revealed a mean deviation of paired differences of 0.02 \((\text{continuous line})\) with SD of 0.27, yielding limits of agreement of \(-0.52\) to \(+0.56\) \((\text{broken lines})\). Absolute deviations and limits of agreement improved for INR values \(\leq 2\), indicating an increasing precision of the POC device for INR values \(\leq 2\). B, Scatterplot of bivariate INR POC and CL data of phase 1 patients, indicating high agreement between POC and CL results.

Figure 2. A, Bland-Altman bias plot for POC in comparison to CL results for patients with ischemic stroke admitted within the timeframe for systemic thrombolysis who were either using OAC or for whom information about OAC status was not available \((n=48)\). Analysis revealed a mean deviation of paired differences of 0.17 \((\text{continuous line})\) with SD of 0.09, resulting in limits of agreement of \(-0.23\) to \(+0.41\) \((\text{broken lines})\). POC tended to slightly overestimate the INR in comparison to CL values. B, Scatterplot for phase 2 patients, indicating again close agreement between POC and CL results.
of INR control did not differ between POC and standard monitoring methods.\textsuperscript{12,14} Hence, POC devices are considered to be a reliable and effective alternative for outpatient monitoring of long-term anticoagulation.\textsuperscript{11,13,20} In contrast, data regarding the use of INR POC devices in emergency departments are very limited. Green et al\textsuperscript{20} reported on INR measurements using a POC that provided reliable and rapid INR results in 150 patients, including 49 patients with acute ischemic stroke, but the stroke population was not precisely described in that study. The results from phases 1 and 2 of our study underscore the fact that the POC device used in our study is sufficiently precise for managing acute ischemic stroke. No patient was treated because of falsely low POC INR values in our study. However, the precision of POC INR devices may differ. The device that was used in the present study had already shown a strong correlation to standard laboratory methods in INR ranges, especially up to 2.0, in other studies.\textsuperscript{11,22,23} In addition, the mean differences in the cluster of results for INR up to 2.0 on the Bland-Altman plot for the device were much smaller than those of other analyzers tested in previous studies.\textsuperscript{22,23} Nevertheless, the reliability of each POC device should be evaluated locally before using it in emergency settings, including ischemic stroke. No patient was treated because of falsely low POC INR values in our study. However, the precision of POC INR devices may differ. The device that was used in the present study had already shown a strong correlation to standard laboratory methods in INR ranges, especially up to 2.0, in other studies.\textsuperscript{11,22,23} In addition, the mean differences in the cluster of results for INR up to 2.0 on the Bland-Altman plot for the device were much smaller than those of other analyzers tested in previous studies.\textsuperscript{22,23} Nevertheless, the reliability of each POC device should be evaluated locally before using it in emergency settings, including ischemic stroke. Although INR values measured by POC were generally highly consistent with CL results in the present study, our device measured INR values just above the locally set limit for excluding thrombolysis (\(>1.5\)) in 3 patients, whereas CL INR was \(\leq 1.5\). These 3 patients received thrombolytic treatment only after the CL INR values were obtained, whereas all others were treated based on POC results. Therefore, thrombolysis should not be excluded based on borderline POC INR measurements alone but should be reconsidered when the CL “gold standard” INR values are available.

The most relevant finding of our study is that the use of an INR POC drastically shortens the interval until INR values are available. Despite all efforts to accelerate availability of these values from the CL, including instantly informing the CL technician, CL INR measurements in patients with ischemic stroke presenting within the time frame for systemic thrombolysis were only available after a mean time of 47 minutes. Latency of CL INR availability in phase 1, in which the technician was not informed, and phase 2 did not differ significantly (data not shown), suggesting that the delay in receiving the CL results was mainly caused by the time needed to conduct the analysis and to transport the blood. To some extent, however, the time gain will vary among institutions, depending on local conditions. To our knowledge, the delay caused by awaiting CL INR values in emergency situations such as hyperacute ischemic stroke has barely been studied to date. In our investigation, the use of POC decreased the time required to obtain an INR value; therefore, thrombolytic therapy could be started earlier. Even when taking the time needed to perform the CT into account, the mean time gain was \(\approx 30\) minutes, and in individual cases \(>1\) hour. These findings are in accordance with results reported by Green et al,\textsuperscript{21} who found an even larger delay caused by CL INR measurements compared to POC. Besides rapidly identifying stroke patients who could receive thrombolysis despite the fact that they are currently using OAC as based on an INR \(\leq 1.5\), instant POC measurements of INR levels that prohibit systemic thrombolysis can help to guide the diagnostic
work-up and subsequent therapeutic procedures at an early stage. For example, in patients with severe strokes and INR >1.5, rapid vascular imaging and interventional therapeutic measures can be considered.

Beyond examining the usefulness of POC in the management of acute ischemic stroke, our study revealed some relevant aspects regarding OAC patients with acute ischemic stroke. First, 59% of acute stroke patients that were currently using OAC and presenting in time for thrombolysis had subtherapeutic INR levels (<2.0). This is in accordance with other studies that reported inadequate INR levels in 41% to 74.2% of acute stroke patients. Second, in terms of hemorrhagic complications of thrombolysis in OAC acute stroke patients, our follow-up imaging data suggest that intravenous thrombolysis is safe in these patients when INR is ≤1.5.

Although our study has limitations, including a small sample size, nonconsecutive patient enrollment, and having been performed at only 1 center, our findings are of intuitive clinical relevance for the growing number of patients that are either using OAC or for whom information on OAC use is unavailable. In these patients, INR measurements with a POC device are sufficiently precise and can substantially shorten the interval until INR values are available as compared to CL analysis and consequently hasten the initiation of thrombolysis.

Acknowledgments
The authors thank the nursing staff of the neurological emergency room for their help with the POC measurements.

Sources of Funding
Department of Neurology, University of Heidelberg.

Disclosure
R.V. is supported by an Else-Kröner Memorial Scholarship.

References
Point-of-Care International Normalized Ratio Testing Accelerates Thrombolysis in Patients With Acute Ischemic Stroke Using Oral Anticoagulants
Timolaos Rizos, Christian Herweh, Ekkehart Jenetzky, Christoph Lichy, Peter Arthur Ringleb, Werner Hacke and Roland Veltkamp

*Stroke.* 2009;40:3547-3551; originally published online August 20, 2009; doi: 10.1161/STROKEAHA.109.562769

*Stroke* is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2009 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/40/11/3547

**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/