The major treatment strategy for acute ischemic stroke (AIS) is pharmacological reperfusion using intravenous tissue plasminogen activator (tPA). In some circumstances, multimodal computed tomography (CT) evaluation consisting of noncontrast CT, perfusion CT, and CT angiography is performed before tPA administration. Although this multimodal approach provides greater information compared with non-contrast CT alone, there is evidence that radiographic contrast agents may interfere with thrombolytic therapy. For example, the presence of contrast agents iopamidol and diatrizoate is associated with decreased fibrinolysis by tPA and urokinase. Additionally, iohexol and amidotizoate significantly delay the time to optimal reperfusion after tPA administration.

Thromboelastography (TEG) has been in use since the 1940s, but recent advances in computer technology have made this technique more practical. In TEG, dynamic mechanical forces occurring during clot formation and lysis are transduced into electric signals that can be monitored by computer. Thus, TEG provides an integrated, dynamic view of the whole coagulation process. TEG parameters correlate with elevated coagulability associated with ischemic stroke patients, enzymatic versus platelet contributions to thrombosis, and specific effects of tPA on thrombosis and thrombolysis. Additionally, a recent study demonstrated that TEG was sensitive enough to detect attenuation in rtPA-induced thrombolysis by experimental manipulations, such as acute exposure to cigarette smoke, producing longer, thinner fibrin fibers.

We performed a prospective study in acute stroke patients to examine the effect of iodinated contrast agents iohexol and iodixanol in clinically relevant doses on rtPA-induced thrombolysis as measured by TEG. The major treatment strategy for acute ischemic stroke (AIS) is pharmacological reperfusion using intravenous tissue plasminogen activator (tPA). In some circumstances, multimodal computed tomography (CT) evaluation consisting of noncontrast CT, perfusion CT, and CT angiography is performed before tPA administration. Although this multimodal approach provides greater information compared with non-contrast CT alone, there is evidence that radiographic contrast agents may interfere with thrombolytic therapy. For example, the presence of contrast agents iopamidol and diatrizoate is associated with decreased fibrinolysis by tPA and urokinase. Additionally, iohexol and amidotizoate significantly delay the time to optimal reperfusion after tPA administration.

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We performed a prospective study in acute stroke patients to examine the effect of iodinated contrast agents iohexol and iodixanol in clinically relevant doses on rtPA-induced thrombolysis as measured by TEG.

Iodinated Contrast Does Not Alter Clotting Dynamics in Acute Ischemic Stroke as Measured by Thromboelastography

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Background and Purpose—Iodinated contrast agents used for computed tomography angiography (CTA) may alter fibrin fiber characteristics and decrease fibrinolysis by tissue plasminogen activator (tPA). Thromboelastography (TEG) measures the dynamics of coagulation and correlates with thrombolysis in acute ischemic stroke patients. We hypothesized that receiving CTA before tPA will not impair thrombolysis as measured by TEG.

Methods—Acute ischemic stroke patients receiving 0.9 mg/kg tPA <4.5 hours of symptom onset were prospectively enrolled. For CTA, 350 mg/dL of iohexol or 320 mg/dL of ioxianol at a dose of 2.2 mL/kg was administered. TEG was measured before tPA and 10 minutes after tPA bolus. CTA timing was left to the discretion of the treating physician.

Results—Of 136 acute ischemic stroke patients who received tPA, 47 had CTA before tPA bolus, and 42 had either CTA after tPA and post–tPA TEG draw or no CTA (noncontrast group). Median change in clot lysis (LY30) after tPA was 95.3% in the contrast group versus 95.0% in the noncontrast group (P=0.74). Thus, tPA-induced thrombolysis did not differ between contrast and noncontrast groups. Additionally, there was no effect of contrast on any pre–tPA TEG value.

Conclusions—Our data do not support an effect of iodinated contrast agents on clot formation or tPA activity. (Stroke. 2014;45:462-466.)

Key Words: thromboelastography ■ thrombosis
measured by TEG. Specifically, we hypothesized that thrombolysis by tPA will not be reduced after CT angiography (CTA).

Methods
This study was approved by the Committee for the Protection of Human Subjects (CPHS) of the University of Texas Health Science Center at Houston.

Subjects
All stroke patients presenting to Memorial Hermann Hospital Emergency Department (MHHED) and meeting published criteria for receiving intravenous tPA <4.5 hours of symptom onset were screened. Subjects were ≤18 years of age.

Data Collection
All acute stroke patients have blood drawn on arrival at MHHED as standard care. Patients (or their legal guardian or next-of-kin) who agreed to participate were consented for TEG analysis to be performed on residual blood. Within 10 minutes post–intravenous tPA bolus, a second blood draw was obtained. This time was chosen because in previous studies there was a substantial effect of tPA on TEG at 10 minutes. If TEG were eventually shown to predict success of clot lysis or subsequent bleeding, 10 minutes might be soon enough to adjust the tPA dose. TEG values, time of TEG draw and tPA administration, and CTA times were recorded. Additionally, we recorded whether or not a patient received CT perfusion imaging. The timing of CT imaging was at the discretion of the treating physician.

Dosage of tPA and Iodinated Contrast
For patients with estimated glomerular filtration rate >60 mL/min, 350 mg/dL of iohexol (Omnipaque; GE Healthcare) at a dose of 2.2 mL/kg was administered using a Dual Head Power Injector at a rate of 3 mL/s. For patients with estimated glomerular filtration rate between 30 and 60 mL/min, 320 mg/dL of iodixanol (Visipaque; GE Healthcare) at a dose of 2.2 mL/kg was given. For those receiving CT perfusion in addition to CTA, an additional 30 mL of contrast was administered. For tPA, an intravenous bolus dose of 0.09 mg/kg over 1 to 2 minutes was followed by an infusion of 0.81 mg/kg over 1 hour.

Blood Sampling and Processing

TEG Analysis
Seven to 10 mL of whole blood was collected into a citrated tube on patient’s arrival before administration of tPA. Blood was held at room temperature and processed <2 hours of collection. Briefly, 1 mL of whole blood was placed into a kaolin vial and inverted 5 times for mixing. Then, 340 μL was pipetted (polyethylene) into the disposable cup in the machine well. Citrate was then reversed with 20 μL of 0.2 mol/L calcium chloride, gently mixed in the cup by pipette, and TEG run on a computerized coagulation analyzer (Model 5000; Haemonetics Corp, MA). Personnel who performed the tests were all trained on the procedure. The following TEG values were documented at the completion of the test: R (minutes), K (minutes); α angle (degrees), maximal amplitude (MA; mm), G (dynes/cm²), and LY30 (percentage).

Figure 1. Labeled thromboelastography elastogram.

Figure 2. Effect of iodinated contrast on thrombosis in the absence of tissue plasminogen activator.
Categorical variables were reported as frequency and percentages. The differences between groups were evaluated using $t$ test (or Wilcoxon rank-sum test) and $\chi^2$ test (or Fisher exact test) as appropriate. Quantile regression was performed to compare the median of TEG parameters between different groups. Additionally, multivariable quantile regression models were fitted to compare the median of TEG parameters between groups after controlling for the effect of confounders. The identification of confounders was based on both a priori and empirical considerations. First, variables shown previously to be correlated with TEG parameters (eg, age, smoking status, and antithrombotic medications) were included in the analysis. Second, in a univariable analysis using $P$ value <0.20, we identified factors that both differed between contrast and noncontrast groups and were associated with TEG parameters. The covariates were considered to be confounders if the regression coefficient of the independent variable, that is, presence of contrast, varied by >20% when the covariate was added to or deleted from the final model. All statistical analyses were performed using SAS version 9.3 (SAS Institute, Inc, Cary, NC), and a $P$ value <0.05 was considered significant.

Results

Our cohort consisted of 136 AIS patients receiving tPA. Patients with errors in TEG processing, missing data, or patients for which TEG blood draw times or CTA times could not be accurately ascertained were excluded (n=22), leaving 114 patients for analysis. The demographics of patients studied are listed in Table 1. There were no differences between groups, but a trend for differences in platelet count ($P=0.06$), small vessel occlusion ($P=0.06$), and diabetes mellitus ($P=0.09$) was observed.

For our analysis of the effect of CTA on baseline pre–tPA TEG, 37 patients had CTA before TEG versus 77 having CTA after tPA or no CTA (Figure 2). In our multivariable Quantile regression models, we compared the median of pre–tPA TEG parameters between CTA and no CTA groups, while controlling for several potential confounders as described in Table 2. No significant differences were found in any of the TEG parameters between the 2 groups (Table 2), indicating that the speed of clot formation was comparable between the 2 groups as was clot strength.

For the examination of the effect of CTA on tPA activity, 47 patients received a CTA before post–tPA TEG draw, whereas 42 patients did not (Figure 3). After controlling for several potential confounders in our final Quantile regression model, as explained in Table 3, no differences in median of post–tPA LY30 were found, indicating that the presence of contrast does not alter tPA-induced thrombolysis as measured by TEG. It is possible that contrast only has an effect at higher doses. Patients having both CT perfusion and CTA receive an additional 30 mL of contrast. In our cohort, 34 patients received both CT perfusion and CTA before tPA (high-dose contrast group), whereas 42 patients did not receive any contrast before tPA. We found no significant difference in post–tPA LY30 between the high-dose and noncontrast groups ($P=0.57$; data not shown).

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Table 1. Comparison of Demographics and Medical History

<table>
<thead>
<tr>
<th>Demographics</th>
<th>Contrast Group (N=37)</th>
<th>Noncontrast Group (N=77)</th>
<th>$P$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>67.2±15.3</td>
<td>63.5±14.7</td>
<td>0.23</td>
</tr>
<tr>
<td>Men</td>
<td>18 (48.7)</td>
<td>44 (57.1)</td>
<td>0.40</td>
</tr>
<tr>
<td>Hypertension</td>
<td>28 (75.7)</td>
<td>65 (84.4)</td>
<td>0.26</td>
</tr>
<tr>
<td>Hyperlipidemia</td>
<td>15 (40.5)</td>
<td>20 (26.0)</td>
<td>0.11</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>8 (21.6)</td>
<td>29 (37.7)</td>
<td>0.09</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>6 (16.2)</td>
<td>10 (13.0)</td>
<td>0.64</td>
</tr>
<tr>
<td>Smoking</td>
<td>7 (19.4)*</td>
<td>16 (21.6)†</td>
<td>0.79</td>
</tr>
<tr>
<td>Aspirin</td>
<td>13 (35.1)</td>
<td>24 (31.2)</td>
<td>0.67</td>
</tr>
<tr>
<td>Clopidogrel</td>
<td>7 (18.9)</td>
<td>12 (15.6)</td>
<td>0.66</td>
</tr>
<tr>
<td>Coumadin</td>
<td>1 (2.7)</td>
<td>3 (3.9)</td>
<td>1.0</td>
</tr>
<tr>
<td>Small vessel occlusion</td>
<td>1 (3.3)‡</td>
<td>13 (20.0)§</td>
<td>0.06</td>
</tr>
<tr>
<td>Platelet count, mEq/L</td>
<td>240.8±65.1</td>
<td>211.5±80.4</td>
<td>0.06</td>
</tr>
<tr>
<td>Glucose, mg/L</td>
<td>119.0 (104.0, 135.0)</td>
<td>120.0 (105.0, 151.0)</td>
<td>0.52</td>
</tr>
<tr>
<td>INR</td>
<td>1.0 (0.9, 1.1)</td>
<td>1.0 (1.0, 1.1)‖</td>
<td>0.21</td>
</tr>
<tr>
<td>Hemoglobin, mEq/L</td>
<td>14.4±5.5</td>
<td>13.9±1.9</td>
<td>0.60</td>
</tr>
<tr>
<td>Baseline NIHSS</td>
<td>7.0 (5.0, 13.0)</td>
<td>8.0 (4.0, 13.0)¶</td>
<td>0.67</td>
</tr>
</tbody>
</table>

Demographics are reported as mean±SD, frequency (percentage), and median (1st quartile, 3rd quartile); $P$ values are obtained by $t$ test (or Wilcoxon rank-sum test) for continuous variables and $\chi^2$ test (or Fisher exact test) for categorical variables. INR indicates international normalized ratio; and NIHSS, National Institutes of Health Stroke Scale.

* N=36.
† N=74.
‡ N=30.
§ N=65.
‖ N=75.
¶ N=75.
Our study is the first to examine the effect of the interaction between iodinated contrast and tPA in AIS patients on clotting dynamics and thrombolysis in real time as measured by TEG. In our multivariable Quantile regression model for pre–tPA TEG parameters, we controlled for potential confounders, namely, age, aspirin use, clopidogrel use, smoking status, baseline platelet count, and diabetes mellitus, and in our final multivariable Quantile regression model for post–LY30, we controlled for age, smoking status, aspirin use, and clopidogrel use. Our results support our hypothesis that the presence of contrast from CTA does not impair blood clotting or tPA-induced thrombolysis. Specifically, clot lysis occurring during 30 minutes after the clot achieved maximum strength (LY30) was not significantly different between contrast and noncontrast groups. In support of the current finding, a recent systematic review investigating the effects of contrast media in patients receiving CT angiography before cardiac catheterization, found prolonged mean lysis onset time with tPA as the thrombolytic agent. Our study examined lysis occurring over a 30-minute interval from blood drawn 10 minutes after tPA bolus. Therefore, we might have failed to capture an initial delay in thrombolysis resulting from contrast–tPA interaction starting immediately after the bolus or occurring earlier in the process of clot lysis. Despite these considerations, based on our data, it is unlikely that systemic thrombolysis by doses of tPA given to stroke patients is significantly affected by the amount of contrast administered as a result of obtaining a CTA.

A limitation of this study is that clot lysis was measured in a TEG sample obtained 10 minutes after the clot achieved maximum strength (LY30). It is possible that the greater efficacy of tPA in lysing the thrombolytic agent. Our study examined lysis occurring over a 30-minute interval from blood drawn 10 minutes after tPA bolus. Therefore, we might have failed to capture an initial delay in thrombolysis resulting from contrast–tPA interaction starting immediately after the bolus or occurring earlier in the process of clot lysis. Despite these considerations, based on our data, it is unlikely that systemic thrombolysis by doses of tPA given to stroke patients is significantly affected by the amount of contrast administered as a result of obtaining a CTA.

Another limitation of the present study is that coagulation measures from more established fibrinolytic tests, such as D-dimers and fibrinogen assays, were not collected. Although these assays differ from TEG in that they provide static, indirect measurements of in vivo thrombolysis, they would have been useful in confirming the lack of an effect of contrast on tPA-induced thrombolysis we observed using TEG. However, previous studies have confirmed the sensitivity of detection of fibrinolysis by TEG in numerous clinical settings where a significant advantage is earlier results from a point-of-care test. An additional limitation in this study is the sample size. Our small sample size may not be adequate to detect a small but genuine effect of contrast on tPA-induced thrombolysis. However, even if a small difference were to exist, it will be

| Table 2. Effect of Iodinated Contrast on Thrombosis in the Absence of Tissue Plasminogen Activator (tPA) |
|-------------------------------------------------|-------------------------------------------------|------------------------|
| Pre–tPA TEG Values                              | Contrast (n=37)                                 | Noncontrast (n=77) |
| R, min                                          | 3.9 (2.9, 5.8)                                  | 4.3 (3.8, 6.0)      | 0.12        |
| K, min                                          | 1.4 (1.2, 1.9)                                  | 1.7 (1.3, 2.2)      | 0.10        |
| Angle, °                                        | 68.1 (64.4, 71.5)                               | 66.5 (58.6, 70.2)   | 0.30        |
| Maximal amplitude, mm                          | 65.7 (63.6, 67.7)                               | 66.4 (62.3, 68.3)   | 0.63        |
| G, dynes/cm²                                    | 9.5 (8.8, 10.5)                                 | 9.7 (8.5, 11.4)     | 0.61        |

Thromboelastography (TEG) values are listed as median (1st quartile, 3rd quartile). Quantile regression was performed for all pre–tPA TEGs. P values were obtained to compare the median of pre–tPA TEG values between contrast and noncontrast groups by likelihood ratio test after adjusting for potential confounders: age, aspirin use, clopidogrel use, smoking status, baseline platelet count, and diabetes mellitus (only for maximal amplitude). *N=76.
unlikely that this effect would be clinically meaningful given the absence of an effect in the current study.

In summary, the current data do not support an impairment of tPA-induced clot lysis by iodinated contrast or an effect of contrast on thrombosis independent of an interaction with tPA. Furthermore, TEG may be a useful method for assessing the effect of tPA as evidenced by lytic activity seen in all samples post-tPA. Whether TEG is sufficiently sensitive to detect variables decreasing tPA-induced lysis remains a question and needs further study.

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Disclosures
None.

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