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Coagulation Markers and Functional Outcome in Acute Ischemic Stroke: Impact of Intensive versus Standard Hyperglycemia Control

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ESSENTIALS:

- Hyperglycemia stimulates blood coagulation after acute ischemic stroke (AIS).
- Alterations in coagulation with glucose control may mediate functional outcome in AIS patients.
- We compared coagulation markers between intensive and standard insulin treatment groups.
- Changes in coagulation markers with hyperglycemia control are linked to improved outcome in AIS.

Abstract

Objective—Alterations in coagulation could mediate functional outcome in patients with hyperglycemia after acute ischemic stroke (AIS). We prospectively studied the effects of intensive versus standard glucose control on coagulation markers and their relationships to functional outcomes in patients with AIS.

Approach—The Insights on Selected Procoagulation Markers and Outcomes in Stroke Trial

(iSPOT) measured coagulation biomarkers, whole blood tissue factor procoagulant activity (TFPCA); plasma factors VII, VIIa, and VIII, thrombin-antithrombin (TAT) complex, D-dimer (DD), TF pathway inhibitor (TFPI), and plasminogen activator inhibitor-1 (PAI-1) antigen in

patients enrolled in the Stroke Hyperglycemia Insulin Network Effort (SHINE) trial of intensive versus standard glucose control on functional outcome at 3 months after AIS. Changes in biomarkers over time (from baseline ~12 hours after stroke onset) to 48 hours, and changes in biomarkers between treatment groups, functional outcomes, and their interaction were analyzed by two-way ANOVA.

Results—125 patients were included (57 in the intensive and 68 in the standard treatment group). The overall mean age was 66 years; 42% were female. Changes from baseline to 48 hours in coagulation markers were significantly different between treatment groups for TFPCA ($p=0.023$) and PAI-1 ($p=0.042$) and FVIIa ($p=0.039$). Increases in FVIIa and decreases in FVIII were associated with favorable functional outcomes ($p=0.042$ and 0.038 , respectively). In the intensive treatment group, reductions in TFPCA, FVIII and increases in FVIIa were greater in patients with favorable than unfavorable outcomes ($p=0.019$, 0.002 , 0.029 , respectively). In the standard treatment group, changes in FVII were different by functional outcome ($p=0.006$).

Conclusions—Intensive glucose control induced greater alterations in coagulation biomarkers than standard treatment and these were associated with a favorable functional outcome at 3 months after AIS.

Clinical Trial Registration- <http://www.clinicaltrials.gov>. Unique identifier: NCT01811550

Introduction

Hyperglycemia is a prothrombotic¹⁻³ and proinflammatory state^{2,4} and is associated with worse functional outcomes after acute ischemic stroke (AIS).^{5,6} These deleterious effects may be mediated by the activation of the tissue factor pathway of blood coagulation.^{3,7,8} Tissue factor (TF) is a membrane-bound protein and a cofactor in the proteolytic conversion of coagulation factor VII to its activated form (FVIIa) to initiate blood coagulation. The resulting TF–FVIIa complex activates factors IX and X leading to the conversion of prothrombin to thrombin.⁹ TF is highly expressed in atherosclerotic plaques and initiates thrombus formation when the vessel wall is injured or plaques are fissured.¹⁰ There is also a pool of circulating TF in blood associated with monocytes and other cells and microparticles; elevated levels of circulating TF are associated with a prothrombotic state.^{10,11}

Patients with hyperglycemia and Type 2 diabetes mellitus (T2DM) have marked alterations in blood coagulation⁷ and fibrinolytic mechanisms.¹² We and others have shown that patients with hyperglycemia during AIS have marked increases in circulating TF procoagulant activity (TFPCA) and plasma coagulation factors VII, VIIa and VIII;^{8,13} markers of thrombin generation (prothrombin fragment factor 1.2, and thrombin-antithrombin (TAT) complexes);^{8,13} and markers of fibrinolysis (D-dimer and plasminogen activator inhibitor, PAI-1).^{12,14} After AIS, elevated TF may contribute to enhanced coagulation by promoting thrombin generation, fibrin deposition, and thrombus formation.¹⁵ In addition, VIIa and TAT levels are related to stroke severity,^{16,17} and high FVIII and F1.2 levels are associated with recurrent stroke following transient cerebral ischemia.^{13,18} While hyperglycemia is known to have prothrombotic effects, the effects of hyperglycemia control on blood coagulation or fibrinolysis in AIS patients are unknown. The Insights on Selected Procoagulation Markers and Outcomes in Stroke Trial (iSPOT) (Clin Trials.gov NCT01811550) was designed to compare the effects of intensive versus standard treatment of hyperglycemia on selected markers of blood coagulation and fibrinolysis and their relationship to functional outcomes in AIS patients enrolled in the Stroke Hyperglycemia Insulin Network Effort (SHINE)¹⁹ trial (Clin Trials.gov NCT01369069)

Methods

Patient Population: iSPOT was prospectively designed as an ancillary study to the SHINE clinical trial. A full description of the SHINE trial methodology and rationale has been reported.^{19,20} The key SHINE inclusion criteria were ischemic stroke onset within 12 hours, baseline blood glucose >110 mg/dL with history of T2DM or baseline blood glucose \geq 150 mg/dL without history of T2DM, and baseline National Institute of Health Stroke Score (NIHSS) of 3-22. Patients in the intensive treatment group received continuous intravenous insulin infusion guided by an electronic decision support tool (target blood glucose 80–130 mg/dL).

Patients in the standard treatment group received only subcutaneous insulin (target blood glucose 80-179 mg/dL). The primary outcome in the SHINE trial was the modified Rankin Scale (mRS) at 90 days adjusted to baseline stroke severity. Favorable clinical outcome was defined as mRS of 0 for patients with baseline NIHSS 3-7 (mild stroke severity), mRS 0-1 for patients with baseline NIHSS 8-14 (moderate stroke severity), or mRS 0-2 for patients with baseline NIHSS 15-22 (severe stroke). Of 63 enrolling SHINE sites, 58 also

participated in iSPOT and 34 of these sites enrolled at least one patient in the study. In addition to the SHINE exclusions, the iSPOT exclusion criteria included: treatment with rtPA, anticoagulation therapy (other than standard deep vein thrombosis prophylaxis), or endovascular thrombectomy, known coagulopathy or hypercoagulable disorder, significant liver impairment assessed by evidence of jaundice or hepatic encephalopathy. Enrollment in iSPOT began October, 2012. Of 63 enrolling SHINE sites, 58 also participated in iSPOT and 34 of these sites enrolled at least one patient in the study.

Sample size calculations: The study was designed to test the effect of treatment on the change from baseline to 48-hour biomarker levels. Assuming the magnitude of a clinically relevant difference in FVIIa between treatment and control to be 25%,^{3,8} at an overall significance level of 5% (with a Bonferroni adjustment for 5 biomarkers leading to 1% for each biomarker), 80% power, and a standard deviation of 25 units, a total of 315 patients (148 in each treatment group plus 6% additional subjects for attrition) would be needed.

There was lower than expected accrual of patients in the iSPOT study. Accrual in iSPOT was contingent on identifying eligible patients among those enrolled in the SHINE trial. Over the course of iSPOT enrollment, many SHINE enrolled patients were ineligible for iSPOT primarily because they were treated with intravenous rtPA (63% of SHINE-enrolled patients) with or without endovascular thrombectomy (13%).¹⁹ However, the primary analysis of iSPOT data was not compromised with the lower sample size. Simulations were used to estimate the sample size required, under appropriate assumptions of uncertainty, to detect both interaction and main effects. Sample size calculations were repeated based on unblinded interim information when protocol modifications with respect to inclusion of t-PA were considered. The variability observed in biomarkers was less than estimated initially from prior studies; we estimated there was sufficient power to detect even a fairly conservative effect size with 96 subjects per SHINE treatment group for a total of 192 subjects. All post-hoc comparisons from the General Linear Models approach used to analyze the data were adjusted using Tukey. Sequential recruitment to iSPOT continued until the completion of SHINE enrollment. At the end of the study we accrued a total of 125 patients for the per protocol analysis, which is smaller than the 192 expected. However, the effect sizes for several biomarkers (see results section) were adequate enough to reach statistical significance.

Measurement of Biomarkers: Venous blood samples were collected into one-tenth volume of 3.2% sodium citrate at the time of SHINE randomization (baseline) and 46-54 hours later (48 hour sample). Whole blood and plasma aliquots were stored at -70 to -80°C. All assays were performed in a blinded manner with respect to treatment group assignment and to functional outcome. Tissue factor procoagulant activity (TFPCA) was measured in whole- blood cell lysates as previously described^{3,11} with a two-stage clotting assay using recombinant human FVIIa (Sekisui Diagnostics, LLC. Stamford, CT), human factor X (Haematologic Technologies Inc. Essex Junction, VT), and pooled normal human plasma (George King Bio- medical, Inc) containing phospholipid vesicles. This assay measures cell membrane-bound and microparticle-associated TF activity in lysed whole blood. HemosIL RecombiPlastin 2G (Instrumentation Laboratory, Bedford,MA) was used as a standard. Plasma factor VII and factor VIII activities were measured by standard clotting assays. Plasma factor VIIa activity was measured by a commercially available assay (STACLOT VIIa-rTF, Diagnostica Stago Inc. Parsipanny, NJ). Plasma thrombin-antithrombin complexes (Enzygnost TAT micro, Siemens Healthcare Diagnostics. Marburg, Germany), D-Dimer (IMUCLONE D-Dimer, Biomedica Diagnostics. Windsor, NS, Canada), TFPI, (IMUBIND total TFPI, Louisville APL Diagnostics, Inc. Texas city, TX) and PAI-1 antigen (Biomedica Diagnostics. Windsor, NS, Canada) were measured using ELISAs. Reference ranges for the biomarkers are provided in the Supplemental Materials.

Statistical analysis: The main dependent variable for analysis was the change in the biomarker levels from baseline to 48 hours when both time points were available. Data were analyzed using a single two-way ANOVA with the independent factors being 1) treatment group (intensive and standard), 2) functional outcome at 90-days (favorable and unfavorable), and 3) the interaction between treatment group and functional outcome. For each marker, interaction between treatment group and functional outcome was tested and linear contrasts were constructed to test the difference between functional outcomes for each treatment group. The assumptions were tested for the residuals and found adequate. Variables that were significantly different between treatment groups (see Table 1) were, along with other covariates that were considered clinically relevant, included in the model and the analyses described above were repeated. Covariates include

demographic variables such as age, race, and gender; medical history variables including hypertension, prior stroke, congestive heart failure, coronary artery disease, hyperlipidemia; baseline measurements such as HbA1c, NIHSS at randomization, and blood glucose level; and other potential factors such as total insulin dose given before 48 hour blood draw, use of VTE prophylaxis during 48 hours, and time of stroke onset to baseline blood draw. A backward selection approach was employed to identify useful covariates. Conclusions regarding group differences are based on an overall significance level of 0.05. Results of both unadjusted and adjusted analyses are provided.

Results

Between October 2012 and August 2018, 149 patients were enrolled (Figure 1), 24 patients were excluded from the analysis who received prohibited medications including systemic thrombolytic and anticoagulant therapy, were treated with mechanical thrombectomy, had a history of hypercoagulable condition, or were ultimately determined to have had a stroke mimic. Thus, 125 patients (57 in the intensive and 68 in the standard treatment group) were included in the analyses. The key baseline characteristics were compared between the intensive and standard treatment groups (Table 1). By design, the 48-hour blood glucose was significantly lower in the intensive as compared to the standard treatment group. There were more women in the standard as compared to the intensive treatment group (table 1). There were more patients with a history of hyperlipidemia in the intensive than in the standard treatment group.

Changes in biomarkers from baseline to 48 hours

Figure 2 shows biomarker levels at baseline and at ~ 48 hours separated by insulin treatment groups. In the standard treatment group levels of FVII and FVIIa were lower at 48 hours compared to baseline. In the intensive treatment group 48-hour TFPCA, FVII and PAI-1 levels were lower than at baseline. The 48 hr levels of other biomarkers were not different from baseline in the two treatment groups.

Changes in biomarker levels (TFPCA, FVIIa and PAI-1) by insulin treatment group

The main dependent variable for analysis for this study was the change in the biomarker levels from baseline to 48 hours. Changes from baseline to 48 hours in TFPCA, FVIIa and PAI-1 were significantly different between intensive and standard treatment groups (Figure 3). TFPCA fell by -32.10 ± 10.04 U/ml (mean \pm SEM) from 102.96 ± 13.05 U/ml at baseline (BL) to 70.86 ± 13.05 U/ml at 48 hours in the intensive treatment group compared with a small increase of 2.62 ± 11.21 U/ml from 68.49 ± 14.56 U/ml to 71.11 ± 14.56 U/ml in the standard treatment group (Difference (95% Confidence Interval (CI)): -34.72 (-64.58 , -4.87) U/ml, $p=0.023$). FVIIa increased by 7.30 ± 6.42 mU/ml from a 55.29 ± 7.54 mU/ml to 62.59 ± 7.54 mU/ml in the intensive treatment and fell -12.06 ± 6.66 mU/ml from 63.28 ± 7.83 to 51.23 ± 7.83 mU/ml with standard treatment (Difference (95% CI): 19.36 (1.01 , 37.70) mU/ml, $p=0.039$). PAI-1 levels decreased by -6.31 ± 3.39 ng/ml from 35.74 ± 5.15 ng/ml to 29.43 ± 5.15 ng/ml from BL to 48 hours with intensive treatment compared to a rise of 3.74 ± 3.51 ng/ml from 42.43 ± 5.34 ng/ml to 46.17 ± 5.34 ng/ml with standard treatment (Difference (95% CI): -10.06 (-19.73 , -0.39) ng/ml, $p=0.042$). Changes from baseline to 48 hours in the other biomarkers were not different between the standard and intensive treatment groups. Mean changes and mean BL and 48-hour biomarker levels in patients treated with intensive and standard insulin treatment are included as Supplemental Table 1a.

Changes in biomarker levels (FVIII and FVIIa) by functional outcome

Figure 4 shows that, with both intensive and standard insulin treatment groups combined, FVIII decreased -0.46 ± 0.28 U/ml from 3.19 ± 0.35 U/ml at BL to 2.73 ± 0.35 U/ml at 48 hours in patients with a favorable outcome but increased 0.17 ± 0.11 U/ml from 3.17 ± 0.14 U/ml at BL to 3.33 ± 0.14 U/ml at 48 hours with unfavorable outcome (Difference (95% CI): -0.63 (-1.23 , -0.03) U/ml, $p=0.038$). FVIIa increased 7.17 ± 8.60 mU/ml from 55.98 ± 10.10 mU/ml at BL to 63.14 ± 10.10 mU/ml at 48 hours in patients with favorable outcome but decreased -11.92 ± 3.43 mU/ml from 62.60 ± 4.03 mU/ml at BL to 50.68 ± 4.03 mU/ml at 48 hours in patients with unfavorable outcomes (Difference (95% CI): 19.09 (0.74 , 37.43) mU/ml, $p=0.042$). Changes in the other biomarkers were not significantly different by functional outcome. Mean changes and BL and 48-hour biomarker levels separated by functional outcome groups are included as Supplemental Table 1b.

Changes in biomarker levels by both treatment and functional outcome

Patients in the intensive treatment group with favorable outcome had a greater reduction in TFPCA (-55.98 ± 18.34 U/ml) than patients with unfavorable outcome (-8.22 ± 8.20 U/ml, $p=0.019$, Figure 5). Patients in the intensive treatment group with favorable outcome had reductions in FVIII levels (-0.97 ± 0.38 U/ml) as compared with increases (0.34 ± 0.17 U/ml) in patients with unfavorable outcome ($p=0.002$). FVIIa levels rose (21.55 ± 11.74 mU/ml) in patients in the intensive treatment group with favorable outcome but decreased in patients with unfavorable outcome (-6.95 ± 5.19 mU/ml, $p=0.029$). Patients in the standard treatment group with favorable outcome had a small increase in FVII (0.14 ± 0.11 U/ml) as compared with reduction (-0.19 ± 0.04 U/ml, $p=0.006$) with unfavorable outcome.

Analysis of covariates

In the adjusted models, changes from baseline to 48 hour level in FVIII was significantly different by history of hypertension, FVII by baseline blood glucose and history of hyperlipidemia, TFPI by baseline blood glucose, and PAI-1 by history of hypertension. After adjusting for potential confounding variables, FVIII was not significantly different between functional outcome groups (-0.61 ± 0.29 U/ml in favorable versus -0.10 ± 0.17 U/ml in patients with unfavorable outcome, $p=0.091$). However, as in the unadjusted analyses, there were significant differences in PAI-1 between intensive (-10.38 ± 3.79 ng/ml) and standard treatment groups (0.33 ± 3.77 ng/ml, $p=0.028$), in FVIII in the intensive treatment group with favorable (-1.13 ± 0.38 U/ml) as compared to unfavorable outcome (0.05 ± 0.22 U/ml, $p=0.0053$), and in FVII in patients in the standard treatment group with favorable (0.03 ± 0.14 U/ml) as compared to unfavorable outcome (-0.24 ± 0.11 U/ml, $p=0.015$).

Discussion

We found that intensive treatment of hyperglycemia induced greater alterations in markers of blood coagulation compared to standard treatment (Figure 3) and these were associated with a favorable functional outcome at 3 months (Figure 4 and 5). There were significantly greater reductions in TFPCA and PAI-1 and increases in FVIIa with intensive as compared with standard insulin treatment. Further, in the intensive treatment group,

favorable outcome was associated with greater reductions in TFPCA and FVIII and greater increases in FVIIa (Figure 5). Together, these results demonstrate that intensive insulin treatment reduces biomarkers reflecting the hyperglycemia-induced procoagulant state; and this effect is associated with improved functional outcome after AIS. In a prior study, circulating TFPCA was markedly elevated in AIS patients with hyperglycemia; and the levels correlated with stroke severity.⁸ We now show that reductions in TFPCA are associated with improved functional outcome after AIS. This is important because TF is known to enhance coagulation and thrombosis¹⁵ and elevated TFPCA has been associated with increased risk of arterial events.²¹

The increase in plasma FVIIa levels with intensive insulin treatment observed (Figure 3) likely reflects the decrease in TF, the principal ligand for FVIIa. A reduction in TF leads to a decrease in FVIIa binding and concomitant increase in plasma FVIIa. This inverse relationship has been reported in patients with hyperglycemia^{3,7} and in AIS patients.⁸ High plasma FVIIa is generally considered prothrombotic; however, in the present study, an increase in FVIIa was associated with improved outcome. Plasma FVIIa has been shown to reduce thrombin-mediated endothelial barrier disruption²² and to have cytoprotective and anti-inflammatory effects *in vivo*.²³ Pretreatment with FVIIa has been shown to downregulate pro-inflammatory cytokines in response to lipopolysaccharide (LPS) administration, decrease microvascular endothelial cell apoptosis, and may have a protective role following experimental brain contusion.²⁴ In the present study, hyperglycemia control could have, by decreasing TF activation, reduced thrombus generation and improved regional blood flow limiting infarct size. Higher FVIIa levels may also have provided protection against penumbral microvascular leakage²⁴ and hyperpermeability²³ ameliorating brain damage and edema. In the present study, elevations in FVIIa and reductions in FVIII, a cofactor that amplifies thrombin generation, were associated with improved 3-month functional outcome with intensive and standard glucose treatment groups combined (Figure 4). These findings suggest that potential strategies that selectively reduce TF or reduce FVIII including glycemetic control could improve outcome in AIS patients with hyperglycemia.

Intensive insulin treatment was associated with reductions in PAI-1, an inhibitor of fibrinolysis (Figure 3). However, changes in PAI-1 were not related to functional outcome

in this study (Figure 4,5). Insulin administration has been previously shown to reduce PAI-1 levels; and reductions in PAI-1 levels have been shown to enhance fibrin clot lysis²⁵ and augment blood flow in the stroke penumbral area.²⁶ However, these effects depend on the stroke subtype. The impact of PAI-1 expression is different in thrombotic as compared with atherosclerotic stroke etiologies.¹² Further analyses are needed to understand the relationship between changes in PAI-1 and functional outcome in our study.

Potential explanations for the observed changes in TF and other factors in the intensive treatment arm can be offered by the distinct effects of hyperglycemia and insulin.^{2,4} Hyperglycemia induces a procoagulant state and insulin has anti-thrombotic and anti-inflammatory effects². Hyperglycemia reduces local microvascular perfusion²⁷ compromising regional blood flow in the penumbral areas of an ischemic stroke.²⁸ Decreasing TF activation, intensive insulin treatment could restore regional blood flow limiting stroke size and reducing brain damage.²⁹ Insulin has anti-inflammatory effects and inhibits expression of transcription factors (nuclear factor kappa B (NF- κ B), epidermal growth factor receptor1 (EGR1), activator protein (AP)-1, toll-like receptor 4 (TLR4), and generation of reactive oxygen species (ROS).^{2,4} Monocytes and macrophages, a major source of tissue factor, have insulin receptors and insulin inhibits lipopolysaccharide (LPS)-induced increases in TF and TLR-4.³⁰ In our study, intensive insulin treatment could, by suppressing prothrombotic and pro-inflammatory mediators, decrease the disruption of the blood-brain barrier preventing cerebral edema, leakage of plasma proteins, and inflammatory cells²⁹ thereby attenuate the detrimental inflammatory cascade.

In iSPOT, we found that intensive insulin treatment is associated with changes in coagulation markers that are associated with improved functional outcome after stroke. However, the parent SHINE trial showed no beneficial effect of intensive versus standard insulin treatment on functional outcome.¹⁹ One possible explanation is that the SHINE trial included rt-PA and non-rt-PA treated patients whereas the iSPOT primary analyses only included non-rt-PA treated patients. Since over 63% of SHINE patients received rt-PA, it is possible that the positive effects of intensive glucose treatment on blood coagulation observed in non-rt-PA treated in the present study were obscured. The present findings are nonetheless relevant to AIS patients since, unlike the SHINE trial cohort, the majority of AIS patients are not treated with rt-PA.³¹⁻³² Further studies are needed to understand the relative effects of insulin treatment alone and thrombolytic therapy on functional outcome in AIS.

The present study was limited by the relatively small number of patients. While the effect sizes for several comparisons were substantial and reached statistical significance, we might have failed to achieve significance for some biomarker effects and some important differences may have been missed due to lack of power. We believe it is unlikely that an increased sample size would substantially alter the findings in this study. On review of the analyses, there were no comparisons in which the differences were “close” to significance, ie none with p values between 0.05 and 0.1 that we would feel could have achieved statistical significance if the study was more adequately powered. The study may also be limited by the inclusion of patients with and without diabetes and patients with different stroke subtypes and severities. In addition, there was a wide range of blood glucose values within treatment arms including a higher rate of hypoglycemia in the intensive arm in the SHINE trial.¹⁹ These factors may have impacted stroke outcome;³³⁻³⁶ further analyses are warranted to address their influence on the relationships between blood coagulation, hyperglycemia control and stroke outcomes.

In summary, the iSPOT trial showed that intensive insulin treatment of hyperglycemia during the first 48 hours of acute stroke induced alterations in blood coagulation that were associated with improved functional outcome. Leveraging the effects of glycemic control on the coagulation pathway for therapeutic purposes, however, will require further insight into these complex relationships.

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Disclosures

None

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Author

Table 1. Characteristics of the Patients

Characteristic	Intensive treatment (N=57)	Standard treatment (N=68)
Age (yr) - median (interquartile range)	69 (55-75)	67 (59.5-73)
Female sex- no. (%)*	18 (31.6)	34 (50)
Race - no. (%)		
Black	19 (33.3)	22 (32.4)
White	37 (64.9)	37 (54.4)
Other	1 (1.8)	9 (13.2)
Ethnicity - no. (%)		
Hispanic	8 (14)	10 (14.7)
Not Hispanic or Unknown	49 (86.0)	58 (85.3)
Baseline BG level (mg/dL) - median (interquartile range)	160 (115-246)	199 (155.5-237.5)
48Hr BG level (mg/dL) - median (interquartile range)*	107 (96-134)	190.5 (152.5-232)
Medical History - no. (%)		
Previous Ischemic stroke	11 (19.3)	11 (16.2)
Diabetes mellitus	49 (86.0)	55 (80.9)
Hyperlipidemia*	35 (61.4)	29 (42.6)
Hypertension	52 (91.2)	58 (85.3)
Eligibility POC blood glucose (mg/dL) - median (interquartile range)	201 (155-267.5)	220 (178.5-265.5)
NIHSS at Randomization- median (interquartile range)	7 (5-12)	7 (4.5-11)
Stroke onset to BL blood draw (Hour) - median (interquartile range)*	9.6 (7.7-12.3)	10.6 (8.8-12.3)

*denotes difference between treatment groups at 0.05 significance level

Figures 1-5 for manuscript, **Coagulation Markers and Functional Outcome in Acute Ischemic Stroke: Impact of Intensive versus Standard Hyperglycemia Control**

Figure 1. Enrollment diagram

Figure 2. Temporal changes in markers of blood coagulation after acute ischemic stroke by insulin treatment groups: intensive (red, hatched line) and standard (blue, solid line) treatment. Average levels of biomarkers measured at baseline (BL) and 48 hours (48 Hr) are shown. Comparisons were made between baseline and 48-hr levels for each marker within each treatment group, *p < 0.05, **p < 0.01.

Figure 3. Average changes from baseline to 48 Hr in levels of biomarkers measured in patients treated with intensive (shown in red) and standard treatment (blue) after AIS. Comparisons were made between intensive and standard treatment for each marker. *p < 0.05

Figure 4. Average changes from baseline to 48Hr in levels of biomarkers measured in patients with favorable (solid bar) and unfavorable SHINE outcome (hatched) at 3 months after AIS. Comparisons were made between favorable and unfavorable functional outcomes. All significance (* denoting 5% levels, P<0.05) hold for both adjusted and unadjusted analyses, except for FVIII where a # symbol is added to denote significance at 5% level only for unadjusted analysis.

Figure 5. Average changes from baseline to 48 Hr biomarkers levels in patients treated with intensive (left panel, shown in red) or standard treatment (right panels, blue) with favorable (solid bar) and unfavorable outcome (hatched) after AIS. Comparisons were made between favorable and unfavorable functional outcomes measured 3-months after AIS. All significance (*, ** denoting 5% and 1% levels, respectively) hold for both adjusted and unadjusted analyses, except for FVII where ** $p < .01$ for unadjusted and # denotes $p < .05$ for the adjusted analysis.

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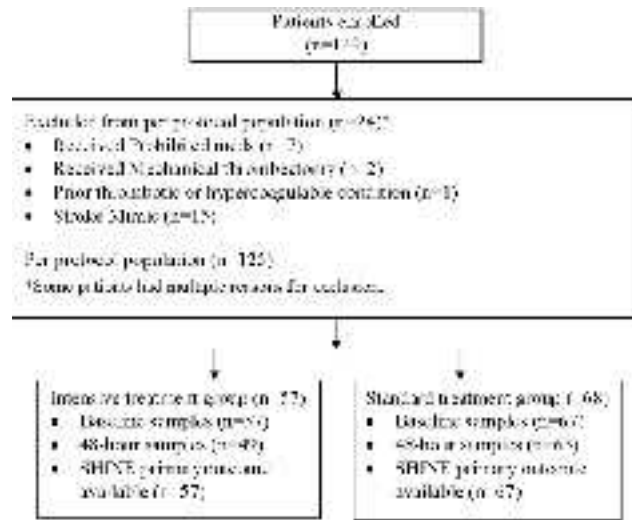
Table 1a. Pairwise comparisons of changes in biomarkers from baseline to 48hrs by insulin treatment groups.

	Treatment Group											p-value for difference of changes between 2 groups	
	Intensive Insulin Treatment					Standard Insulin Treatment							
	n	Estimated mean at BL	Estimated mean at 48hr	Estimated mean of changes	95% CI		n	Estimated mean at BL	Estimated mean at 48hr	Estimated Mean of changes	95% CI		
DDIMER (ng/ml)	49	1529	1424	-105	-786	577	62	1474	1389	-84	-791	623	0.9676
FVII (U/ml)	49	1.14	1.01	-0.13	-0.24	-0.02	62	1.20	1.18	-0.02	-0.14	0.09	0.1982
FVIII (U/ml)	49	3.14	2.83	-0.31	-0.73	0.10	62	3.22	3.23	0.02	-0.41	0.45	0.2711
FVIIa (mU/ml)	49	55.29	62.59	7.30	-5.42	20.03	62	63.28	51.23	-12.06	-25.27	1.16	0.0388
PAI1 (ng/ml)	48	35.74	29.43	-6.31	-13.03	0.40	62	42.43	46.17	3.74	-3.21	10.70	0.0416
TAT (µg/l)	48	12.79	10.90	-1.89	-10.23	6.45	62	9.42	9.75	0.33	-8.31	8.98	0.7139
TFPCA (U/ml)	48	102.96	70.86	-32.10	-52.03	-12.17	56	68.49	71.11	2.62	-19.61	24.85	0.0231
TFPI (ng/ml)	48	48.31	49.49	1.18	-11.33	13.68	62	52.92	50.54	-2.38	-15.34	10.58	0.6962

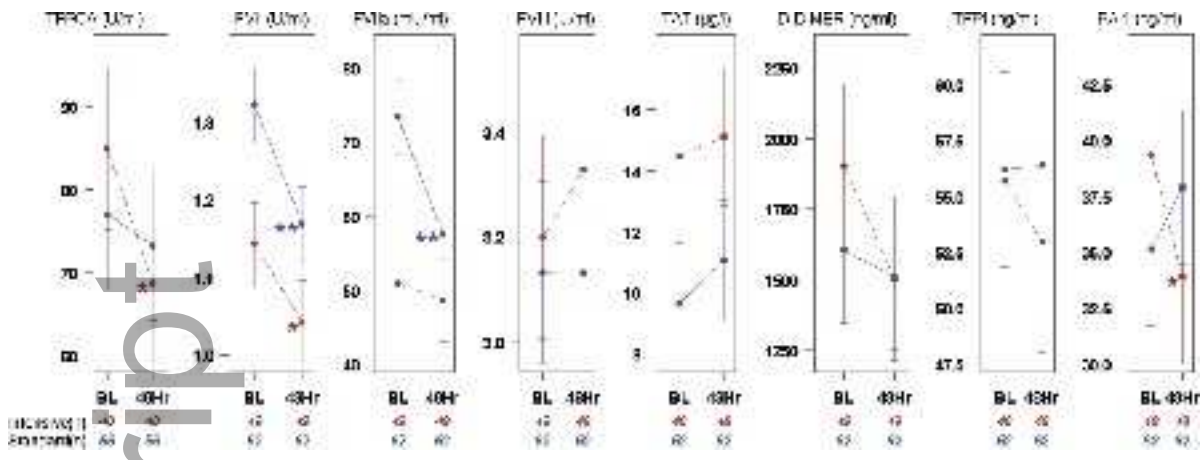
Table 1b. Pairwise comparisons of changes in biomarkers from baseline to 48hrs by functional outcome groups.

	Functional outcome												p-value for difference of changes between 2 groups
	Unfavorable Outcome						Favorable Outcome						
	n	Estimated mean at BL	Estimated mean at 48hr	Estimated Mean of changes	95% CI		n	Estimated mean at BL	Estimated mean at 48hr	Estimated Mean of changes	95% CI		n
DDIMER (ng/ml)	96	1862	1541	-320	-684	43.11	15	1140	1272	131	96	1862	0.3632
FVII (U/ml)	96	1.25	1.11	-0.14	-0.20	-0.08	15	1.10	1.08	-0.02	96	1.25	0.1383
FVIII (U/ml)	96	3.17	3.33	0.17	-0.05	0.39	15	3.19	2.73	-0.46	96	3.17	0.0383
FVIIa (mU/ml)	96	62.60	50.68	-11.92	-18.71	-5.13	15	55.98	63.14	7.17	96	62.60	0.0416
PAI1 (ng/ml)	95	37.06	35.80	-1.26	-4.86	2.34	15	41.10	39.79	-1.31	95	37.06	0.9920
TAT (µg/l)	95	12.51	14.32	1.81	-2.66	6.29	15	9.70	6.33	-3.37	95	12.51	0.3941
TFPCA (U/ml)	90	77.57	70.71	-6.87	-17.78	4.05	14	93.88	71.27	-22.61	90	77.57	0.2980
TFPI (ng/ml)	95	58.23	56.37	-1.85	-8.56	4.86	15	43.01	43.66	0.65	95	58.23	0.7831

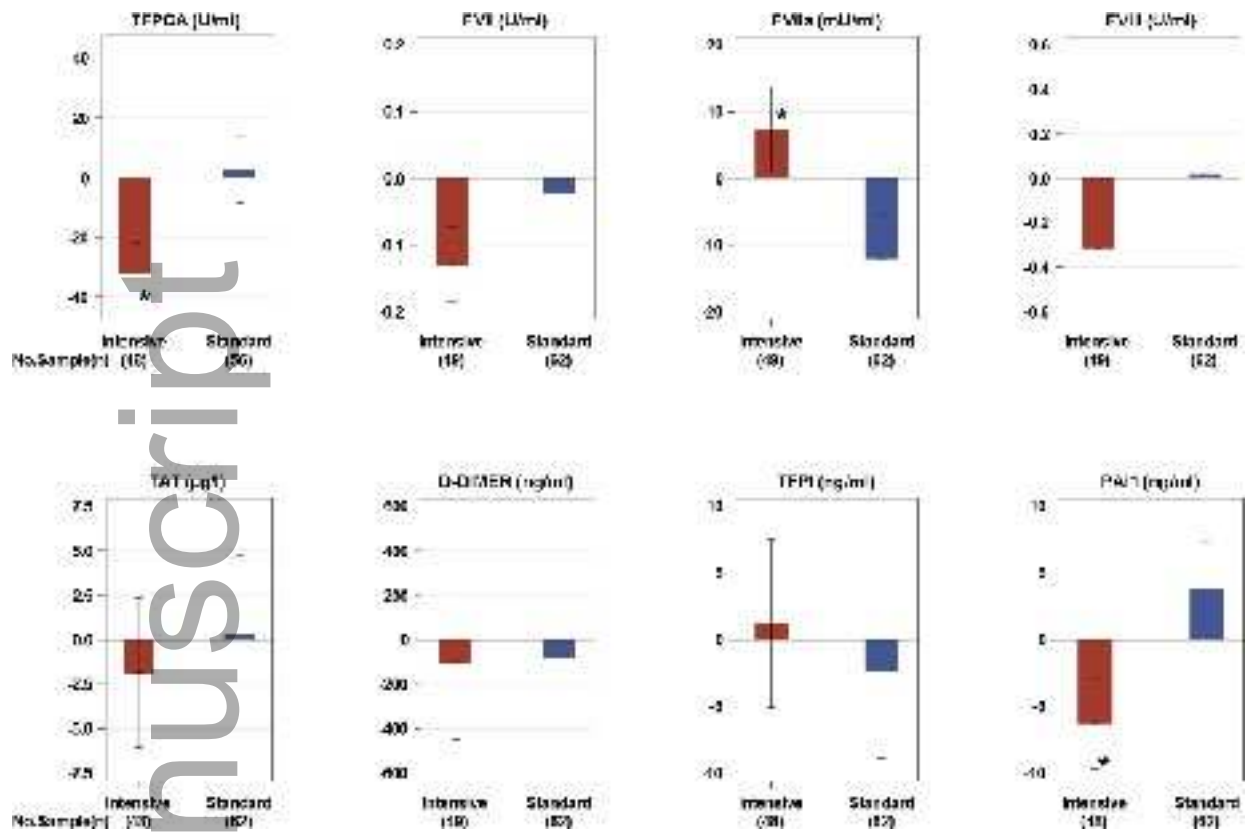
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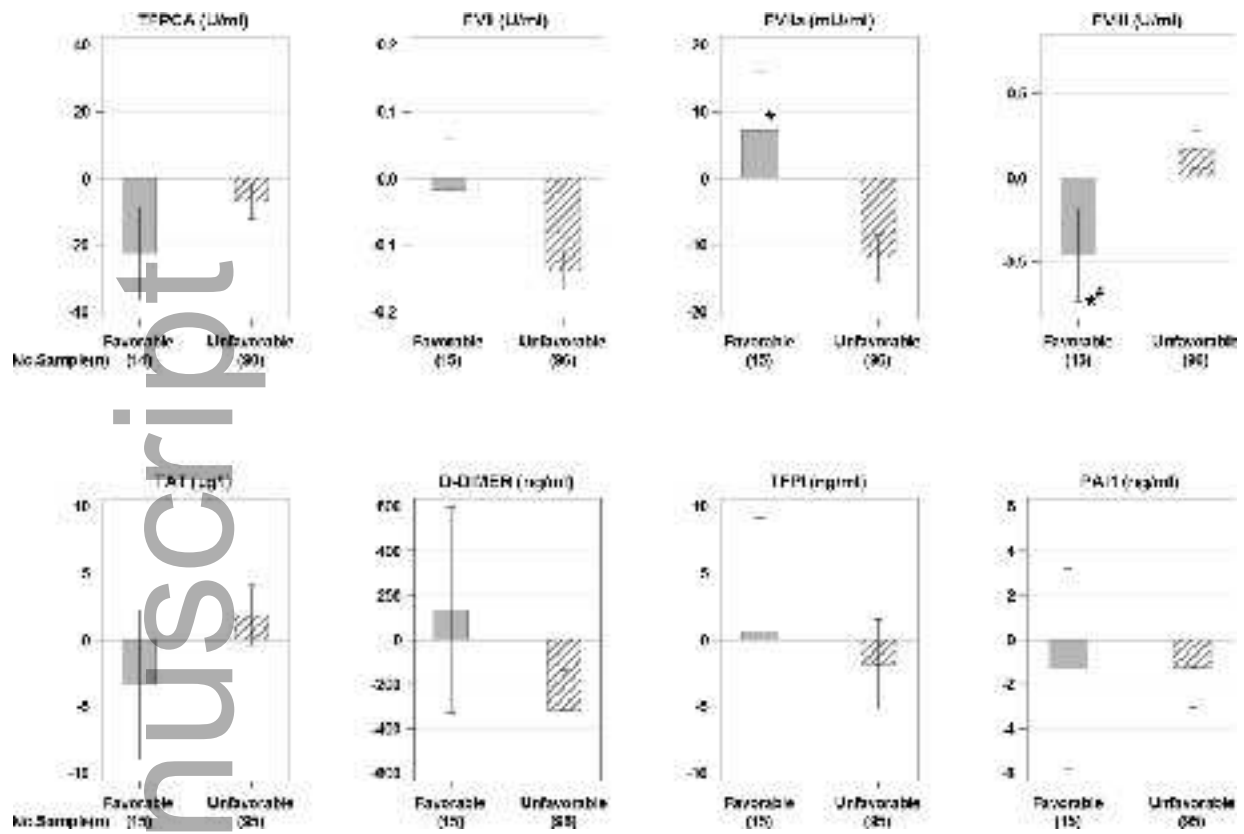
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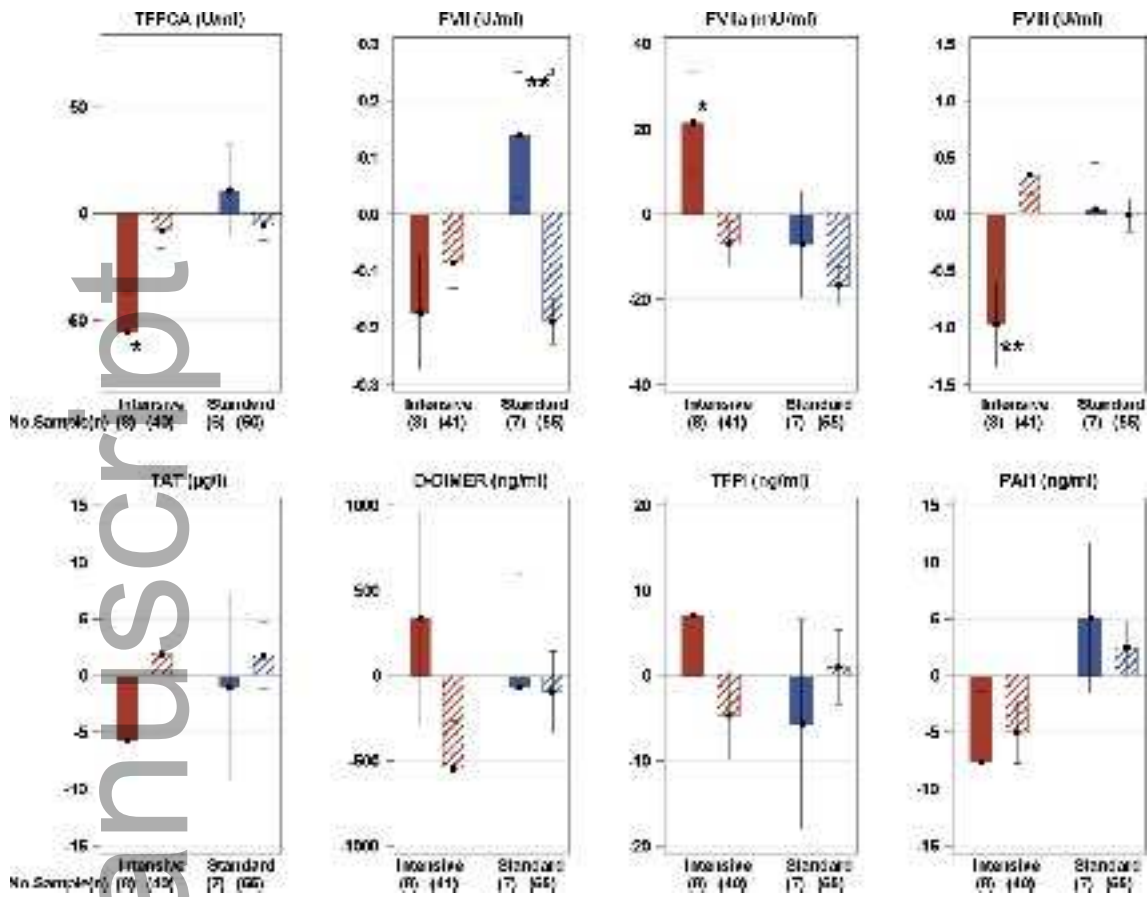
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