

A Technique To Give Clinical Relevance to Parameters from the Thrombelastograph

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Abstract

The thrombelastograph (TEG) is a photokymographic device to measure the dynamics of clot formation in vitro. The TEG graphic parameters offer clinical information regarding clotting factor function.

Graphic values from 88 open heart and liver transplantation patient TEGs were correlated to bleeding time, PT, aPTT, FIB, PLT, ACT, TT, ionized Ca^{++} and D-Dimer (DD) concentration. Linear and multiple regression demonstrated significant ($r > .40$ or $r < -.4$, $p < .10$) relationships between the following parameters.

TEG VARIABLE	CLOTTING STUDY VARIABLE
r	ACT, TT, BT
k	ACT, aPTT, TT, BT
r+k	ACT, aPTT, TT
α -angle	ACT, aPTT, TT, FIB, HCT
ma	PT, aPTT, TT, FIB, PLT, Ca^{++}
emx/k	aPTT, TT, FIB, PLT
me	PT, aPTT, TT, FIB, PLT, Ca^{++}
ma'	PT, aPTT, TT, FIB, PLT, DD, Ca^{++}
me'	PT, aPTT, FIB, PLT, Ca^{++}
%ama	DD

FIB=fibrinogen, PLT=platelet count, TT=thrombin time, aPTT=partial prothrombin time, PT=prothrombin time, BT=bleeding time, HCT=hematocrit, Ca^{++} =ionized calcium, DD=D-Dimers

A Basic algorithm was created to employ TEG parameters to predict the clotting function study parameter values. The TEG blood study is much less expensive than a clotting function screen, may be used to predict some of the routine clotting function study values, and whole blood coagulation information is available patient-side in 20 to thirty minutes.

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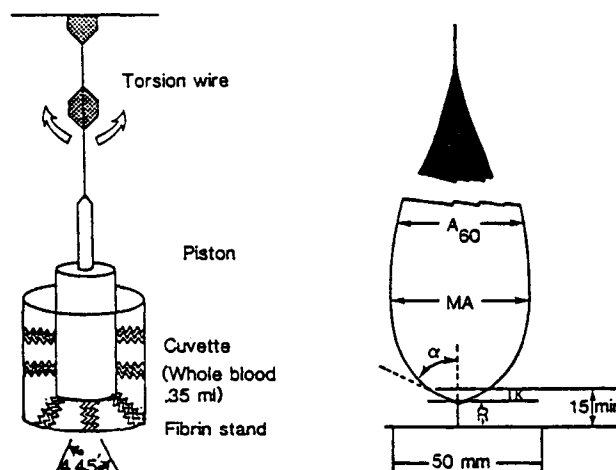
Introduction

The thrombelastograph technique and device^a were described by Hartert¹ in 1948. The thrombelastograph (TEG) is a photokymographic device that measures the dynamics of clot formation in vitro.^{1,4} The TEG graphic parameters offer clinical information regarding whole blood clotting factor function. Recently the TEG has been successfully employed bedside for liver transplantation^{5,9} and cardiac surgical patient monitoring.^{2,3,8} The TEG uses a .36 ml sample of whole blood, mprotamine-reversed heparinized blood or recalcified citrated blood to create a graphic representation of the blood sample's clot reaction time, rapidity of fibrin build-up, clot strength and destruction.

Figure One depicts a TEG apparatus, a TEG chart recording and the measurement of TEG parameters described in

FIGURE ONE

THROMBOELASTOGRAPH APPARATUS



PHOTOKYMOGRAPH

Table One.

Table One describes the TEG parameters and normal limits taken from the TEG chart recording generated with metal sampling wells and stabs.^{1,5}

TABLE ONE
THROMBOELASTOGRAPH PARAMETERS

PARAMETER	NORMAL VALUE	FUNCTION
r	7-15 min	reaction time, initial fibrin formation
k	3-6 min	coagulation time, rapidity of fibrin build-up
α -angle	45°-55°	speed of clot strengthening
ma	50-60 mm	maximum clot strength
ma' (A ₆₀)	ma-5 mm	measure of clot destruction
f	> 300 min	whole blood clot lysis time

Investigators have described relationships between TEG parameters and offered derived parameters from TEG measurements to further describe clot formation and destruction. Some of these derived parameters are listed in Table Two.

TABLE TWO

CALCULATIONS FROM TEG PARAMETERS		
PARAMETER	FORMULA	FUNCTION
me	$100 \cdot ma / (100 - ma)$	modulus of elasticity
r+k	r+k	kinetic coagulability
ITP (emx/k)	ma/k	Index of thrombodynamic potential
%dma	$(ma - ma') / ma \cdot 100$	percent change in ma-ma' due to fibrinolysis

Caprini, Zuckerman, Tuman, Spiess, McCarthy and Ivankovich^{3,5,8,11,13,14} have contributed the greatest volume of general and open heart surgery clinical data and information regarding the TEG in the last five years. Many clinical trials^{1-3,5-7,10-14,17} have yielded moderate correlation between TEG parameters and routine clinical laboratory coagulation profile studies typically performed during general, cardiac, and hepatic surgery. In this study we endeavored to reproduce previously reported results and generate our own institutional normal values for TEG parameters using plastic disposables.

Tuman et al.³ recently compared TEG and Sonoclot viscoelastic clot measures to activated clotting time (ACT), prothrombin time (PT), partial thromboplastin time (PTT), fibrinogen concentration (FIB) and platelet count (PLT). Tuman compared excessive bleeders to other post cardiopulmonary bypass (CPB) patients at high risk for bleeding. The routine clotting studies were normal, but there were abnormalities in the viscoelastic measurements that were 100% accurate in predicting bleeding. The viscoelastic abnormalities were reflected in the platelet-fibrin interaction and the authors found the Sonoclot and TEG more useful

than routine clotting studies in the management of coagulation defects after CPB.

Spiess with the same coworkers⁸ demonstrated that the TEG was a significantly better predictor (87% accurate) of post-operative bleeding and the need for reoperation than the ACT (30%) or the routine coagulation profile (51%). In their group of 33 patients, the TEG parameters showed only moderate correlation with routine coagulation parameters and primarily with PTT.⁸ ACT did not correlate significantly with any TEG parameter.

Spiess and Ivankovich⁵ offer an algorithm for TEG interpretation that centers around the TEG ma, ma', r, k, and α -angle. They report that the TEG r correlates with the ACT ($r = .5399$, $p = .01$) and the PTT ($r = .611$, $p = .01$). The authors go on to report that ACT, PT, PTT, FIB, fibrin split products and PLT did not significantly correlate with any other parameters. Their chapter 5 goes on to describe the predictable effects on TEG k, α -angle, and ma by varying calcium ion activity, fibrinolysis, Factors VII and VIII concentrations, and the use of desmopressin acetate (DDAVP) and cryoprecipitate.

Tuman et al.⁶ in a clinical case report and discussion illustrated the role of the TEG in documenting the return to normal clotting function with the administration of desmopressin acetate to a patient with Factor VIII (von Willibrand's factor) deficiency. The authors used the TEG parameters (r, k, α -angle and ma) to monitor Factor VIII activity and platelet function as the patient's need for desmopressin fluctuated. Obtaining patient-side assessment of patient clotting function within 30 min is attainable and clinically useful with the TEG.^{5,6}

Hypercoagulability is manifest on the TEG graph by decreased r and k values with increased α -angle and ma values.^{5,13,14} In the data set collected in this method, some patients presented with elevated FIB and PLT yielding low r, k and r+k values. It has been our observation that these hypercoagulable patients present clinical challenges in maintaining the patency of intravenous and arterial lines, as well as the saphenous vein grafts post CPB and CABG.

In 1987, Toman's group⁷ concluded by monitoring 87 general surgery patient TEG graphs, that during moderate to excessive bleeding fresh frozen plasma and platelet administration should be reserved for patients only with documented defects in coagulation defects associated with intraoperative blood loss.⁷

In 1985, Kang et al.⁹ studied the blood coagulation system in 66 liver transplant patients using TEG and analytic coagulation profile. Kang found a poor preoperative coagulation state, decrease in levels of coagulation factors, progressive fibrinolysis and whole blood clot lysis during the pre-anhepatic and anhepatic stages of transplantation. There was a measurable recovery of blood coagulability 30-60 minutes after reperfusion of the liver graft. Coagulability returned to baseline values two hours after reperfusion. Kang reported that the general correlation between the TEG variables and those of the coagulation profile was

a Sonoclot, Sienco Inc., Morrison CO

poor. However, TEG r correlated best with aPTT ($r = .49$) ma correlated with PLT ($r = .59$) and FIB ($r = .64$). TEG clot lysis time, f , correlated with euglobulin lysis time ($r = .54$). These correlations were all significant at $p < .05$.⁹

D-dimers (DD) are the expressed degradation product of fibrin during fibrinolysis and are easily measured clinically.¹⁹ The data set in this method contains ten simultaneous DD and TEG measurements. The TEG graph depicts active fibrinolysis, if present, through the rapid compared to normal decrease in ma as time proceeds. The ma' or the TEG f value, the time for the clot to disappear on the TEG measure clot dissolution, should correlate with DD or other measurements of fibrinolysis. If fibrinolysis is present and DD is elevated, then the TEG difference between ma and ma' should be greater than 5 mm and the TEG f decreased. In this method we compared routine clotting factor values including DD to the percent change in ma' from ma (% dma). Clinically, it is desirable to assess fibrinolysis expediently. If the % dma predicts fibrinolysis then the clinician will have the information needed in 60 minutes plus the TEG $r+k$ minutes, usually about 90 minutes total. In some clinical settings it may take 90 minutes to obtain the results to a central laboratory routine clinical coagulation profile.

Kongsgaard et al.⁴ in 1989 measured the activation of plasminogen with heparinization of CPB patients. Their patient data suggested that the combined effect of plasminogen activation normally accompanying heparin and CPB may offer additional protection of the coagulation system. The TEG will depict fibrinolysis ($ma-ma'$, f , and % dma) as well as heparin activity (r, k, α -angle) should CPB be complicated by plasmin activation or persistent heparin activity.

Platelet activity (aggregation) is monitored by TEG r, k, α -angle, and ma . The PLT data employed in this method came from patients considered to have normal functioning PLT before CPB.

With two TEG machines, TEG measurements may be taken hourly during major surgery to assess patient coagulability. TEG analysis, in our institution, costs less than 10% the charge for a routine coagulation profile. Central lab results are reported to the operating room in 55 +/- 30 minutes by our central laboratory. TEG results require 20 to 60 minutes to develop. If the TEG parameters can be successfully employed to predict the coagulation profile values and patient coagulability, TEG monitoring will save money and may save time in making patient management decisions.

The current study employs newly available plastic, disposable blood sample wells opposed to the metal reusable wells employed in most other studies. This manufac-

turer believes that the plastic wells may well yield more consistent and reproducible results. The current method may yield stronger clinical correlation than previous methods using metal TEG wells.

The purpose of this study is to present a method to give clinical relevance to the TEG parameters in terms of routine clotting study results. The manufacturer suggests that the TEG user establish their own institutional normal values for the TEG variable values. The use of multiple linear regression quantitates the role of the multiple TEG parameters to simultaneously predict routine clot profile variable results. With the assistance of a computer, this method allows the TEG user to predict the value of routine clotting profile parameters from the TEG results within the correlation and variability of the TEG-clot profile parameter statistical relationship.

Method

Four steps are required to document the clinical relevance of measured TEG parameters and to measure the coagulation screen predicting power of the TEG parameters. The TEG blood analysis equipment and process have been described accurately in numerous publications.^{1, 3, 5-13} The only deviation in this method from previously described methods was the use of disposable plastic blood wells. The manufacturer's instructions for use were followed. No attempt was made to supplement blood samples with citrate to enhance coagulation and known heparinized patient blood samples were not included in this database.

I. Data Collection

Baseline thrombelastographs were created for open heart and liver transplantation patients for whom approximate-in-time coagulation profile parameters were available. Many post protamine open heart patient data are included when coagulation screen results were available. Minimal disruption of the patient's coagulation status was assured between coagulation screen and TEG analyses. Every attempt was made to collect TEG parameters from blood of patients with no blood heparin level, or having taken drugs known to affect platelet function. TEG parameters were taken graphically from the TEG strip chart recordings following manufacturer's instructions.

II. Database

A spreadsheet^b was created that included the resulting TEG r, k, α -angle, ma , and ma' parameters. Coagulation screen parameters, ACT, PT, aPTT, fibrinogen concentration, platelet count, D-dimers, template bleeding time (BT), ionized calcium (CA^{++}) and hematocrit values were entered into the spread sheet when available. The spread sheet automatically calculated TEG $r+k$, emx/k , me , me' and % dma . The spread sheet values were passed to statistics^c and graphics^d software for analysis and plotting.

b Excel, Microsoft Corporation, Redmond, WA 98037-9717

c BMDP Statistical Software, Los Angeles, CA 90025

d Harvard Graphics, Software Publishing Co., Mountain View, CA 94039-7210

III. Analysis of Data

Linear regression and multiple linear regression was performed between coagulation screen factors and TEG parameters. Regression coefficients and linear graphic correlations are reported when significant at $p \leq .05$. The best subsets for TEG parameters to predict a coagulation screen parameter through multiple linear regression are reported with regression coefficients, statistics and the intercept. Example data set variable residuals were calculated and plotted from the multiple linear regression prediction equations to examine the accuracy of the predicting formulae.

IV. Prediction Algorithm

A BASIC language^e computer algorithm was created to take input of TEG parameters, perform extended TEG calculations, and predict coagulation screen parameter values when possible. The computer algorithm reports TEG parameters, TEG calculations and predicted coagulation parameters. The prediction statistics, based on the original data set statistics are included in the prediction algorithm output.

Results

Table 3 presents the descriptive statistics for the TEG and routine coagulation parameters. There were minimal simultaneous DD ($n=10$) and Ca^{++} ($n=17$) measurements. The statistical analysis software accounted for missing data and employed the appropriate degrees of freedom in calculating correlation coefficients and p values. The data set contains clinically abnormal profiles that include prolonged PT, aPTT and TT blood values. As well, potentially hypercoagulable patients with FIB > 550 mg/dL and PLT > 350 k/mm³. are included.

Tables 4 and 5 list the correlation coefficients for the TEG parameters versus the routine coagulation profile values. Significant correlations are noted.

Table 6 lists the multiple linear regression correlation coefficients and standard errors for predicting the routine coagulation profile parameters from the TEG parameter results. Table 6 refers to BASIC program line numbers found in Appendix One. Appendix One contains the algorithms employed to predict routine coagulation parameter values. TT, DD, BT, and HCT multiple linear regression predictions were not significant at $p < .05$. BMDP software forced the best fit multiple linear regression equations for TT, DD, BT, and HCT, though not significant. Multiple linear regression analysis for ACT, PT, aPTT, FIB, PLT and Ca^{++} against TEG parameters yielded significant prediction equations that use from one to eight of the TEG parameters.

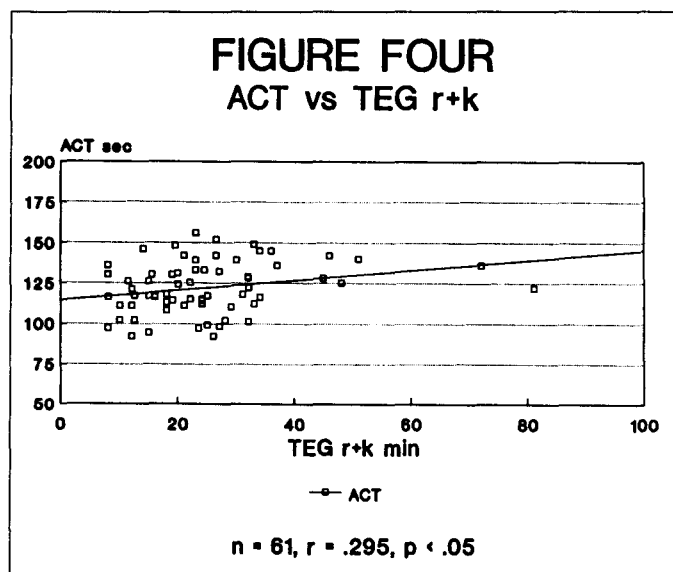
Figures Two and Three illustrate the correlation and prediction power of the TEG variables for FIB. FIB correlated significantly with ma, a-angle, ma', me, me' and emx/k. The FIB predicting equation is found in program line #446 (Appendix One) and has a standard error of 94.4 mg/dL. Figure Three plots the residual differences for the predicting equation for actual FIB values from this database.

Clinically, TEG variable results may be entered into the BASIC program to predict routine clotting study values within the experimental standard errors. Appendix Two contains an example printout for the BASIC algorithm in Appendix One. The print-out restates the TEG input variable values, prints the calculated TEG parameters and the predicted values for routine coagulation profile tests. Prediction statistics and a disclaimer are included to remind the clinician that the print-out is only a partial guideline for clinical management decisions.

Discussion

There are many more factors that affect the TEG clot dynamic measurement than just the routine coagulation profile parameters studied in this method. Platelet function as well as count will affect TEG ma, k and α -angle. Hormonal stress factors and hemodilution accompanying anesthesia may decrease coagulability.⁵ The TEG monitors the interaction of platelets and the proteins from the coagulation cascade, especially the intrinsic pathway and reports in vitro clot formation and dissolution.

The TEG is sensitive to low doses of heparin. Figure Four depicts the relationship between TEG r+k and ACT ($r = .295$, $p < .05$) in the data set presented here. The low but significant correlation may be due to variability in HCT, PLT function, and FIB in this data set of all non-heparinized patients that presented clinically in our practice. The ACT measures the time for fibrin to form but gives no qualitative data regarding the strength and fate of the clot as the TEG offers. In our data set TEG r, k, ma, a-angle and ma' correlated significantly with TT, although multiple regression failed to yield a significant predicting equation (p



^e BASIC, Microsoft Corporation, IBM Corp., Boca Rotan, FL 33432

= .1325).

The multiple linear regression technique employed here assesses the simultaneous correlation (prediction) of routine clot study values with TEG parameters. In regard to the prediction of FIB by multiple linear regression, the ma , ma' , me' , emx/k and me , in descending order, contributed greatest to the r^2 ($r^2 = .679$, $p < .0001$) for FIB prediction in this method. Zuckerman et al.¹¹ observed significant correlation between TEG parameters that reflect clot strength and FIB. In the same work, Zuckerman et al. employing weighted variables, could find no correlation in post-CPB patient data.

The present data set included diluted whole blood samples as well as normal hematocrit blood. Hematocrit only correlated negatively and weakly with TEG a -angle ($n = 43$, -0.365 , $p < .050$) in this data set. Increasing sample size may reveal significant correlation of HCT with TEG r , k , or emx/k .

Speiss and Ivankovich⁵ argue that the TEG has unfairly been criticized for not agreeing better with routine coagulation parameters. They point out that the TEG monitors whole blood clotting dynamics while routine coagulation tests including the ACT measure other aspects of coagulation and should not be expected to correlate.

Tuman et al.³ recently demonstrated that most bleeding abnormalities following CPB could be measured by the TEG a -angle and ma , or the fibrin-platelet interaction. Multiple qualitative platelet dysfunctions have been reported post CPB. The TEG will identify platelet function abnormalities despite normal platelet counts. In this data set, some of the prediction error for the platelet count from TEG ma ($r = .551$) and emx/k ($r = .292$) is probably due to varying platelet function despite adequate platelet count.

The TEG provides a qualitative, general assessment of whole blood coagulation status patient-side in the operating room within 20 to 30 minutes. The characteristics of the TEG allow specific goal-directed blood component therapy intervention minimizing patient exposure and expense.⁷

The lack of strong correlation and coagulation screen multivariant predicting capability of the TEG parameters may illustrate that the TEG is either sensitive to other variables involved in the clotting cascade or the sources of error in predicting coagulability in-vitro exceed accountability. The lack of high TEG-coagulation screen predictability in its data set is probably a function of both. Clot formation ability during and after CPB is dynamic and multivariant. The TEG generally behaves as expected clinically when compared to traditional coagulation tests. However, the TEG parameters are sensitive to other variables not routinely monitored in coagulation profiles.

The future uses for TEG monitoring in open heart patient care include: 1) prediction of post protamine coagulation disorders by using a heparinase or protamine treated on-CPB blood sample to reflect platelet and clotting studies, 2) predict the quantitative value of clotting factor administration, and 3) predict the efficacy of hemostatic

drugs (DDAVP, aminocaproic acid, etc.) as corrective measure to treat post pump coagulopathies.

The TEG carries in-vitro study of whole blood coagulation past the ACT, aPTT, PT and TT to further examine the intrinsic coagulation pathway; clot formation speed, strength and lysis. The TEG sensitivity to other factors (VII, VIII, platelet factor 3, anti-thrombin III, plasmin, etc.) interferes with high correlation to routine coagulation profile screening tests. The TEG does not measure fibrinogen concentration, it measures the speed, magnitude, and strength of the platelet-thrombin-fibrinogen reaction. The TEG results may be employed to qualitatively predict bleeding potential and to direct and monitor specific donor blood therapy during operation, patient-side, in a cost-effective manner.

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TABLE THREE

DESCRIPTIVE STATISTICS					
VARIABLE NAME	MEAN	SAMPLE SIZE	STANDARD DEVIATION	SMALLEST VALUE	LARGEST VALUE
r	14.2	87	6.3	5.0	45.0
k	9.0	88	5.8	2.0	27.0
ma	52.4	88	11.3	22.0	76.0
me	123.8	88	63.3	28.0	317.0
r+k	23.3	87	11.1	7.0	72.0
emx/k	23.4	88	23.7	1.0	117.0
α -angle	38.5	88	16.4	8.0	71.0
ma'	46.4	80	11.1	16.0	72.0
me'	95.4	80	46.1	19.0	257.0
%dma	-11.7	80	6.5	-41.0	-3.0
ACT	121.9	61	16.7	92	156
PT	14.1	76	2.2	11.5	20.1
aPTT	34.5	73	10.4	24.0	69.0
TT	33.4	33	12.3	16.3	73.4
FIB	263.0	75	155.0	50	812
PLT	201.0	64	103.2	49	585
DD	2.3	10	2.3	0.5	8.0
Ca ⁺⁺	2.06	17	1.01	1.1	2.4
BT	5.0	32	1.8	1.5	8.8
HCT	35.1	43	9.4	18	58

BIostatistics for the Health Sciences, John Wiley & Sons, New York, NY, 2nd Ed., 1976, p. 199

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TABLE FOUR

TEG PARAMETER CORRELATION WITH ROUTINE CLOT STUDY VARIABLES					
TEST	TEG	r	k	ma	α -angle
ACT		.291*	.255*	-.066	-.265*
PT		-.104	.183	-.437*	-.204
aPTT		.194	.373*	-.380*	-.393*
TT		.384*	.508*	-.470*	-.528*
FIB		.104	-.154	.661*	.263*
PLT		.022	-.145	.551*	.145
DD		.278	.550	-.594	-.484
Ca ⁺⁺		.180	.040	.531*	.257
BT		.347*	.217	-.066	-.309
HCT		.206	.284	-.070	-.365*

Correlation coefficients marked * where p <.05 from reference 18

TABLE FIVE

TEG CALCULATIONS CORRELATED TO ROUTINE CLOT STUDY VARIABLES					
TEST	TEG	me	r+k	emx/k	me'
ACT		-.023	.295*	-.229	-.017
PT		-.354*	.033	-.212	-.296*
aPTT		-.292*	.301*	-.336*	-.240*
TT		-.417*	.488*	-.372*	-.318
FIB		.631*	-.016	.331*	.589*
PLT		.519*	-.058	.292*	.455*
DD		-.501	.434	-.332	-.526
Ca ⁺⁺		.490*	.141	.202	.542*
BT		-.018	.314	-.103	-.092
HCT		-.078	.255	-.251	-.041

Correlation coefficients marked * where p <.05 from reference 18

monary bypass. J EXTRA-CORPOR TECHNOL 22 (3): 131-136, 1990

Questions and Comments

Rick Beecher, Dubuque, Iowa

- Q. Who analyzes the data, who dictates the response to the TEG and do you respond to the results before the patient leaves the operating room?
- A. We just started using the TEG as a diagnostic tool. I think we just had our first successful diagnosis on Thursday morning when we had a patient come back with heparin rebound. We decided that it was the heparin effect and that the platelets were working, but there was just residual heparin. You would have found our with a Hepcon® and you could have

TABLE SIX

COAGULATION PARAMETER	TEG PARAMETER	r VALUE	p VALUE
ACT (n=68)	r+k	.295	.021
Appendix One: Program line # 410 Multiple r = .02949, p = .021, Std Err = 16.1 sec			
PT (n=76)	ma	-.437	<.01
Appendix One: Program line # 420 Multiple r = .591, p < .0001, Std Err = 1.9 sec			
aPTT (n=73)	ma, α -angle	-.380	<.01
Appendix One: Program line # 430 Multiple r = .494, p = .0002, Std Err = 9.2 sec			
TT (n=33)	k, α -angle	.508	<.01
Appendix One: Program line # 440 Multiple r = .638, p = NS (.1325), Std Err = 11.2 sec			
FIB (n=75)	ma	.714	<.05
Appendix One: Program line # 446 Multiple r = .824, p < .0001, Std Err = 94.4 mg/dL			
PLT (n=64)	ma	.576	<.05
Appendix One: Program line # 452 Multiple r = .658, p = .0004, Std Err = 84.7 k/mm ³			

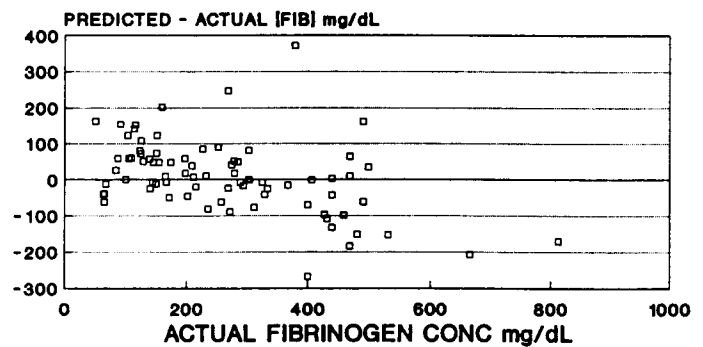
COAGULATION PARAMETER	TEG PARAMETER	r VALUE	p VALUE
DD (n=10)	t _{clma}	-.757	<.05
Appendix One: Program line # 456 Multiple r = .988, p = (NS) .0761, Std Err = .7 ug/mL			
Bleed Time (n=32)	r	.347	<.05
Appendix One: Program line # 464 Multiple r = .568, p = NS (.4722), Std Err = 1.8 min			
Hematocrit (n=43)	k, α -angle	.28, -.36	<.05
Appendix One: Program line # 466 Multiple r = .457, p = NS (.5891), Std Err = 9.6 %			
[Ca ⁺⁺] (n=17)	ma	.531	<.01
Appendix One: Program line # 470 Multiple r = .911, p = .0451, Std Err = .6 mmol/L			

demonstrated that heparin was still left on board but you wouldn't have known if the patient's platelets were working after you got rid of the heparin. We avoided giving the patient platelets and fibrinogen and blood products and just gave protamine, which fixed the problem. We have not gotten to the point where it is a diagnostic test. We are going to find that out in the next coming months here. Looks like we'll do the analysis and the anesthesiologist will execute the patient management with the surgeons watching closely.

Peter Swanney, Terra Haute, Ind.

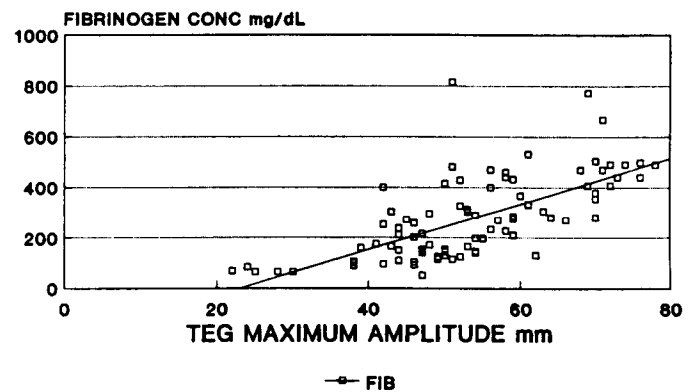
Q. Can you tell me if it has cut down on your blood component therapy yet? And how predictive do you think it will be in blood component usage?

FIGURE THREE
PREDICTED - ACTUAL FIB RESIDUALS



n = 75, Std Err = 94.4 mg/dL, p < .0001

FIGURE TWO
FIB vs TEG ma



n = 75, r = .661, p <.01

A. We don't have any hard data on whether it's cut back on our blood component usage. As I said, we are just to the point where we have confidence that we can predict what the patient's doing from the thrombelastograph. We will answer that question in the next year.

Kent Hoxmeier, Nebraska

Q. Were post-cardiopulmonary bypass patients included in your data base?

A. If there wasn't any heparin on board, and throughout the thrombelastographs had long R times and long K times which were indicative of heparin. This was all comers except blood samples we knew were heparinized.

Q. We have noticed in Spiess — you mentioned his article — that post-bypass patients have an altered coagulation cascade and also platelet activity from

the bypass itself. To include these with pre-bypass patients, you have a poor correlation post-bypass with normal TEG and routine coagulation tests.

- A. That's a good point. We threw everybody together in attempting to make an institutional norm. Other studies have looked at isolated patient groups and tried to maximize the potential for correlation. We threw everything together and got fairly good correlation. Platelet function is documented fairly well. The one disorder we see the most after bypass that interests us is fibrinolysis. There is a lot of fibrinolysis going on, and we hope to learn to recognize and treat it.

Bruce Bartel, San Diego, Calif.

- Q. Have you been able to establish a quality assurance program or some other method of reassuring that your results are reflecting what's going on in the patient?

- A. That's a timely question. No, and I think collecting this data is the first step. We know what normal limits are, and we know the extreme limits. There is no standard to put into the thrombelastograph nor has anyone done any studies looking at the reproducibility of the thrombograph by putting the same blood sample into two, or three, or four to see if you get the same r value time and time again. The ones that we have done multiple repetition on, we have been very pleased in its reproductibility. Those issues have not been answered and I think the only way to do it is to get a normal blood sample that we know can clot and put it in there and see if it works that morning, then believe everything that follows. The consistency and the standard deviations in our data lead us to believe that it is a predictable device.

- Q. Do you still find yourself looking more at the pictures that you do at the numbers?

- A. Yes.

Mike Cramer, Bend, Ore.

- Q. Spiess now is at the University of Washington. Anyone can talk to him about a protocol that he has developed using a TEG machine for cardiopulmonary bypass. How much does the machine cost, and do you need two of them and who did all the testing — your lab people?

- A. How much does the machine cost? I don't know exactly..\$9,000? The number of machines you need depends on how many rooms you have going at a time and how often you want to take thrombograph samples. We have four channels for our liver transplant program, and we are going to buy four more channels for the open heart program.

APPENDIX ONE: PROGRAM LISTING

```

80 CLS
85 REM ***** REVISED 2/7/91: JBR *****
90 REM *****
100 REM *** DECEMBER, 1990 ROUTINE TO PREDICT COAG SCREEN ***
110 REM *** FROM THROMBOELASTOGRAPH PARAMETERS ***
120 REM *** J RILEY, A STAMMERS, R SUTTON ***
130 REM *** ECT DEPT, CHRP, MUSC ***
140 REM *** VERSION 2.3 ***
150 REM *****
160 PRINT TAB(10)"SUBROUTINE TO PREDICT COAGULATION SCREEN FROM TEG PARAMETERS"
170 PRINT TAB(25)"VERSION 2.3, FEBRUARY 7, 1991"
180 PRINT TAB(14)"DEPARTMENT OF EXTRACORPOREAL CIRCULATION TECHNOLOGY"
190 PRINT TAB(19)"CHRP, MEDICAL UNIVERSITY OF SOUTH CAROLINA"
200 PRINT: PRINT
202 PRINT TAB(10)"ENTER PATIENT INFORMATION:"
204 INPUT "ENTER THE PATIENT'S MRN, THE DATE AND TIME";MRN$,DTE$,TME$
206 PRINT
210 PRINT TAB(10)"DATA ENTRY: PLEASE PROVIDE THE FOLLOWING TEG VALUES"
220 PRINT
230 INPUT "ENTER THE TEG VALUES FOR r, k, alpha angle, ma and ma'";R,K,AA,MA,MAP
240 PRINT
250 REM ***** EXPANDED TEG CALCULATED PARAMETERS *****
260 RK=R+K
270 ME=MA*100/(100-MA)
275 ME=INT(ME*10+.5)/10
280 MEP=MAP*100/(100-MAP)
282 MEP=INT(MEP*10+.5)/10
285 EMXK=ME/K
287 EMXK=INT(EMXK*10+.5)/10
290 DMA=MAP-MA
292 PDMA=(DMA/MA)*100
295 DMA=INT(DMA*10+.5)/10
297 PDMA=INT(PDMA*10+.5)/10
300 DME=MEP-ME
302 PDME=(DME/ME)*100
305 DME=INT(DME*10+.5)/10
307 PDME=INT(PDME*10+.5)/10
308 REM ***** PRINT OUT RESULTS OF TEG CALCULATIONS *****
309 PRINT: PRINT TAB(10)"TEG INFO FOR PATIENT: MRN = ";MRN$;" , DATE = ";DTE$;" , TIME =
    ";TME$
310 PRINT TAB(10)"EXPANDED THROMBOELASTOGRAPH PARAMETER VALUES"
320 PRINT
330 PRINT TAB(10)"r = ";R;" [3-7 min]";TAB(40)"k = ";K;" [3-7 min]"
340 PRINT TAB(10)"r+k = ";RK;" [6-14 min]";TAB(40) CHR$(224)" < o = ";AA;"
    [45-60o]
350 PRINT TAB(10)"ma = ";MA;" [40-60 mm]";TAB(40)"me = ";ME;" [70-200]
355 PRINT TAB(10)"emx/k = ";EMXK;" [10-40]"
360 PRINT TAB(10)"ma' = ";MAP;" [< ma-5 mm]";TAB(40)"me' = ";MEP;" [70-200]"
370 PRINT TAB(10)"ma - ma' = ";DMA;" [< -5 mm]";TAB(40)"%dma = ";PDMA;" [< -7. %]"
380 PRINT TAB(10)"me - me' = ";DME;" [< -25]";TAB(40)"%dme = ";PDME;" [< -5. %]"
385 PRINT

```

```

390 INPUT "ENTER '1' TO PREDICT COAGULATION SCREEN PARAMETER VALUES, OR '2' TO
    CONTINUE";PC
400 ON PC GOTO 405,890
405 PRINT
406 REM ***** PREDICT COAGULATION PARAMETERS FROM TEG PARAMETERS *****
410 ACT=111.079+.451366*RK
415 ACT=INT(ACT+.5)
420 PT=24.3583-.0939891*R-.40898*MA+.0200945*ME+.215382*MAP
425 PT=INT(PT*10+.5)/10
430 APTT=75.2956-.909863*MA+.0959465*ME+.424595*PDMA
435 APTT=INT(APTT*10+.5)/10
440 TT=53.2058-.836827*K-.0902775*MA-.907581*ME+.396064*RK+.170178*EMXK
    -.272057*AA-.226883*MAP+1.03641*MEP-.54992*PDMA
444 TT=INT(TT*10+.5)/10
446 FIB=-184.032-25.0898*R-25.3214*K+72.082*MA-3.08509*ME+30.3021*RK
    -.996002*EMXK+1.14494*AA-76.0951*MAP+6.72116*MEP+16.9516*PDMA
448 FIB=INT(FIB+.5)
452 PLT=26.1474+2.94881*R+4.80984*K+35.4792*MA-.658225*ME-3.90596*RK
    +.291478*EMXK-2.57857*AA-32.0486*MAP+.999055*MEP+9.82303*PDMA
454 PLT=INT(PLT+.5)
456 DDM=-20.8228-.482927*R+.686498*K+.867529*MA-.93136*ME+.218899*
    EMXK+.774768*MEP-.465769*PDMA
460 DDM=INT(DDM*10+.5)/10
462 BIM=4.47623-.122066*R-.353473*K-.217420*MA+.0507815*ME+.225415*
    RK-.0167421*EMXK-.0548625*AA+.288591*MAP-.0675522*MEP-.0482363*PDMA
464 BIM=INT(BIM*10+.5)/10
466 HCT=47.8848-5.3177*R-5.48005*K+2.07316*MA-.193624*ME+5.20479*RK
    +.0207745*EMXK-.41644*AA-2.18845*MAP+.322592*MEP+.562906*PDMA
468 HCT=INT(HCT+.5)
470 CAL=7.06008-.00691554*R+.147398*K+.581155*MA-.0879471*
    ME-.0283959*EMXK+.0705033*AA-1.1637*MAP+.299563*MEP+.117976*PDMA
475 CAL=INT(CAL*10+.5)/10
480 PRINT TAB(9)"COAGULATION PARAMETER PREDICTION FROM TEG PARAMETER VALUES"
485 PRINT
490 PRINT TAB(10)"ACT = ";ACT;"      [90-110 sec]"
500 PRINT TAB(10)"PT = ";PT;"      [12-14 sec]";TAB(40)"aPTT = ";APTT;"      [18-24 sec]"
510 PRINT TAB(10)"FIB = ";FIB;"      [175-250 mg/dL]";TAB(40)"PLT CT = ";PLT;"      [150-275
    k/mm^3]"
520 PRINT TAB(10)"TT = ";TT;"      [14-16 sec]"
530 PRINT TAB(10)"BLEED TIME = ";BIM;"      [3-6 min]";TAB(40)"d-Dimer = ";DDM;"      [< 1.
    ug/ml]"
540 PRINT TAB(10)"HCT = ";HCT;"      [18-45%]";TAB(40)"[Ca++] = ";CAL;"      [.4-1.8 mM/L]"
600 PRINT
630 PRINT TAB(15)"*****"
640 PRINT TAB(15)"**          CAUTION          **"
650 PRINT TAB(15)"** While every attempt for accuracy has been **"
660 PRINT TAB(15)"** made by the authors, these calculations and **"
670 PRINT TAB(15)"** PREDICTED parameters represent scientific **"
680 PRINT TAB(15)"** estimates based on statistical sampling. **"
690 PRINT TAB(15)"** Use this information as a guideline to **"
700 PRINT TAB(15)"** YOUR own best clinical judgement. **"
710 PRINT TAB(15)"*****"
720 PRINT: INPUT "TO SEE THE CURRENT PREDICTION STATISTICS TYPE '1', TO CONTINUE TYPE
    '2'";NO
740 ON NO GOTO 750,870
750 CLS
760 PRINT TAB(24)"CURRENT PREDICTION STATISTICS": PRINT

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770 PRINT "PARAMETER";TAB(15)"MULTIPLE r";TAB(30)"STD ERR";TAB(45)"p VALUE"
780 PRINT "ACT";TAB(15)".295";TAB(30)"16.1";TAB(45)".0210"
790 PRINT "PT";TAB(15)".591";TAB(30)"1.9";TAB(45)";"<.0001"
800 PRINT "aPTT";TAB(15)".494";TAB(30)"9.2";TAB(45)";".0002"
810 PRINT "FIB";TAB(15)".824";TAB(30)"94.4";TAB(45)";"<.0001"
820 PRINT "PLT CT";TAB(15)".658";TAB(30)"84.7";TAB(45)";".0004"
830 PRINT "TT";TAB(15)".638";TAB(30)"11.2";TAB(45)";"NS(.1325)"
840 PRINT "d-Dimer";TAB(15)".989";TAB(30)".7";TAB(45)";".0761"
850 PRINT "BLEED TIME";TAB(15)".568";TAB(30)"1.8";TAB(45)"NS(.472)"
855 PRINT "HCT";TAB(15)".457";TAB(30)"9.6";TAB(45)"NS(.589)"
857 PRINT "[CA++]";TAB(15)".912";TAB(30)".6";TAB(45)".0451"
860 PRINT: PRINT TAB(20)"COPYRIGHT, 1990: JBR, AHS, RGS; ECT, CHRP, MUSC"
870 PRINT: INPUT "DO YOU WANT A HARD-COPY OF THIS DATA SET? 1) YES, OR 2) NO?";YN
880 ON YN GOTO 1540,890
890 PRINT: INPUT "ENTER '1' TO PERFORM ANOTHER SET OF TEG PREDICTIONS OR '2' TO
END";NE
900 ON NE GOTO 80,910
910 END
1540 REM ***** LINE PRINTER ROUTINE *****
1545 LPRINT TAB(10)"SUBROUTINE TO PREDICT COAGULATION SCREEN FROM TEG PARAMETERS"
1550 LPRINT TAB(25)"VERSION 2.6, FEBRUARY 8, 1991"
1560 LPRINT TAB(14)"DEPARTMENT OF EXTRACORPOREAL CIRCULATION TECHNOLOGY"
1565 LPRINT TAB(19)"CHRP, MEDICAL UNIVERSITY OF SOUTH CAROLINA"
1567 LPRINT: LPRINT TAB(5)"TEG INFO FOR PATIENT: MRN = ";MRN$";, DATE = ";DTE$";, TIME
= ";TME$"
1570 LPRINT: LPRINT
1600 LPRINT TAB(15)"EXPANDED THROMBOELASTOGRAPH PARAMETER VALUES"
1610 LPRINT
1620 LPRINT TAB(10)"r = ";R;" [3-7 min]";TAB(40)"k = ";K;" [3-7 min]"
1630 LPRINT TAB(10)"r+k = ";RK;" [6-14 min]";TAB(40)"alpha < o = ";AA;" [45-60o]"
1640 LPRINT TAB(10)"ma = ";MA;" [40-60 mm]";TAB(40)"me = ";ME;" [70-200]"
1650 LPRINT TAB(10)"emx/k = ";EMXK;" [10-40]"
1660 LPRINT TAB(10)"ma' = ";MAP;" [< ma-5 mm]";TAB(40)"me' = ";MEP;" [70-200]"
1670 LPRINT TAB(10)"ma - ma' = ";DMA;" [< -5 mm]";TAB(40)"%dma = ";PDMA;" [< -7.
%]"
1680 LPRINT TAB(10)"me - me' = ";DME;" [< -25]";TAB(40)"%dme = "PDME;" [< -5. %]"
1690 LPRINT: LPRINT
1695 LPRINT TAB(5)"#####"
#####
1700 LPRINT TAB(5)"#";TAB(70)"#": LPRINT TAB(5)"#";TAB(9)"COAGULATION PARAMETER
PREDICTION FROM TEG PARAMETER VALUES";TAB(70)"#"
1710 LPRINT: LPRINT TAB(5)"#";TAB(10)"ACT = ";ACT;" [90-110 sec]";TAB(70)"#"
1720 LPRINT TAB(5)"#";TAB(10)"PT = ";PT;" [12-14 sec]";TAB(40)"aPTT = ";APTT;"
[18-24 sec]";TAB(70)"#"
1730 LPRINT TAB(5)"#";TAB(10)"FIB = ";FIB;" [175-250 mg/dL]";TAB(40)"PLT = ";PLT;"
[150-275 k/mm^3]";TAB(70)"#"
1740 LPRINT TAB(5)"#";TAB(10)"TT = ";TT;" [14-16 sec]";TAB(70)"#"
1750 LPRINT TAB(5)"#";TAB(10)"BLD TME = ";BIM;"[3-6 min]";TAB(40)"D-Dimer = ";DDM;"
[< 1. ug/mL]";TAB(70)"#"
1755 LPRINT TAB(5)"#";TAB(10)"HCT = ";HCT;" [18-45%]";TAB(40)"[Ca++] = ";CAL;"
[.4-1.8 mM/L]";TAB(70)"#"
1760 LPRINT TAB(5)"#";TAB(70)"#"
1765 LPRINT TAB(5)"#####"
1770 LPRINT TAB(5)"#";TAB(24)"CURRENT PREDICTION STATISTICS";TAB(70)"#": LPRINT
1775 LPRINT TAB(5)"#####"
1780 LPRINT TAB(5)"#";TAB(10)"PARAMETER";TAB(25)"MULTIPLE r";TAB(40)"STD
ERR";TAB(55)"p VALUE";TAB(68)"#"

```

```
1790 LPRINT TAB(5) "#";TAB(10) "ACT";TAB(25) ".294";TAB(40) "16.1";TAB(55) ".0210
";TAB(68) "#"
1800 LPRINT TAB(5) "#";TAB(10) "PT";TAB(25) ".591";TAB(40) "1.9";TAB(55) "<.0001
";TAB(68) "#"
1810 LPRINT TAB(5) "#";TAB(10) "aPTT";TAB(25) ".494";TAB(40) "9.2";TAB(55) ";
.0002";TAB(68) "#"
1820 LPRINT TAB(5) "#";TAB(10) "FIB";TAB(25) ".824";TAB(40) "94.4";TAB(55) ;
"<.0001";TAB(68) "#"
1830 LPRINT TAB(5) "#";TAB(10) "PLT CT";TAB(25) ".658";TAB(40) "84.7";TAB(55) ;".0004"
";TAB(68) "#"
1840 LPRINT TAB(5) "#";TAB(10) "TT";TAB(25) ".638";TAB(40) "11.2";TAB(55) ";NS
(.1325)";TAB(68) "#"
1850 LPRINT TAB(5) "#";TAB(10) "d-Dimer";TAB(25) ".989";TAB(40) ".7";TAB(55) ";NS
(.0761)";TAB(68) "#"
1860 LPRINT TAB(5) "#";TAB(10) "BLEED TIME";TAB(25) ".568";TAB(40) "1.8";TAB(55) "NS
(.472)";TAB(68) "#"
1865 LPRINT TAB(5) "#";TAB(10) "HCT";TAB(25) ".457";TAB(40) "9.6";TAB(55) "NS
(.589)";TAB(68) "#"
1867 LPRINT TAB(5) "#";TAB(10) "[CA++]";TAB(25) ".912";TAB(40) ".6";TAB(55) "
.0451";TAB(68) "#"
1868 LPRINT TAB(5) "#####"
1870 LPRINT: LPRINT TAB(20) "COPYRIGHT, 1990: JBR, AHS, RGS; ECT, CHRP, MUSC"
1890 LPRINT:
1895 PRINT TAB(10) "PRESS 'PAPER FEED' ON LINE PRINTER"
1900 LPRINT
1910 LPRINT TAB(15) "#####"
1920 LPRINT TAB(15) "***          CAUTION          ***"
1930 LPRINT TAB(15) "*** While every attempt for accuracy has been ***"
1940 LPRINT TAB(15) "*** made by the authors, these calculations and ***"
1950 LPRINT TAB(15) "*** PREDICTED parameters represent scientific ***"
1960 LPRINT TAB(15) "*** estimates based on statistical sampling. ***"
1970 LPRINT TAB(15) "*** Use this information as a guideline to ***"
1980 LPRINT TAB(15) "*** YOUR own best clinical judgement. ***"
1990 LPRINT TAB(15) "#####"
2000 LPRINT: LPRINT: LPRINT
2050 LPRINT CHR$(12)
2100 GOTO 890
```

SUBROUTINE TO PREDICT COAGULATION SCREEN FROM TEG PARAMETERS
 VERSION 2.6, FEBRUARY 8, 1991
 DEPARTMENT OF EXTRACORPOREAL CIRCULATION TECHNOLOGY
 CHRP, MEDICAL UNIVERSITY OF SOUTH CAROLINA

TEG INFO FOR PATIENT: MRN = 123-45-678, DATE = 2/11/91, TIME = 07:00

EXPANDED THROMBOELASTOGRAPH PARAMETER VALUES

r = 15	[3-7 min]	k = 8	[3-7 min]
r+k = 23	[6-14 min]	alpha < o = 54	[45-60o]
ma = 68	[40-60 mm]	me = 212.5	[70-200]
emx/k = 26.6	[10-40]		
ma' = 64	[< ma-5 mm]	me' = 177.8	[70-200]
ma - ma' = -4	[< -5 mm]	%dma = -5.9	[< -7. %]
me - me' = -34.7	[< -25]	%dme = -16.3	[< -5. %]

```
#####
#
# COAGULATION PARAMETER PREDICTION FROM TEG PARAMETER VALUES #
#
# ACT = 121 [90-110 sec] #
# PT = 13.2 [12-14 sec] aPTT = 31.3 [18-24 sec] #
# FIB = 440 [175-250 mg/dL] PLT = 229 [150-275 k/mm^3] #
# TT = 19.5 [14-16 sec] #
# BLD TME = 4.3 [3-6 min] D-Dimer = -15.2 [< 1. ug/ml] #
# HCT = 36 [18-45%] [Ca++] = 0 [.4-1.8 mM/L] #
#
#####
# CURRENT PREDICTION STATISTICS #
```

```
#####
# PARAMETER MULTIPLE r STD ERR p VALUE #
# ACT .294 16.1 .0210 #
# PT .591 1.9 <.0001 #
# aPTT .494 9.2 .0002 #
# FIB .824 94.4 <.0001 #
# PLT CT .658 84.7 .0004 #
# TT .638 11.2 NS(.1325) #
# d-Dimer .989 .7 NS(.0761) #
# BLEED TIME .568 1.8 NS(.472) #
# HCT .457 9.6 NS(.589) #
# [CA++] .912 .6 .0451 #
#####
```

COPYRIGHT, 1990: JBR, AHS, RGS; ECT, CHRP, MUSC

```
*****
** CAUTION **
** While every attempt for accuracy has been **
** made by the authors, these calculations and **
** PREDICTED parameters represent scientific **
** estimates based on statistical sampling. **
** Use this information as a guideline to **
** YOUR own best clinical judgement. **
*****
```