Interactive CardioVascular and Thoracic Surgery

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Interact CardioVasc Thorac Surg 2005;4:456-463; originally published online Jul 11, 2005;
DOI: 10.1510/icvts.2005.115154

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doi:10.1510/icvts.2005.115154

INTERACTIVE
CARDIOVASCULAR AND
THORACIC SURGERY

Interactive CardioVascular and Thoracic Surgery 4 (2005) 456–463

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Best evidence topic - Cardiac general

Can the use of thromboelastography predict and decrease bleeding and blood and blood product requirements in adult patients undergoing cardiac surgery?

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Received 20 June 2005; accepted 22 June 2005

Summary

A best evidence topic in cardiac surgery was written according to a structured protocol. The question addressed was whether use of thromboelastography could predict and decrease bleeding and blood and blood product requirements in adult patients undergoing cardiac surgery. Altogether 170 papers were identified using the reported search strategy of which 14 represented the best evidence on the topic. The author, journal, date and country of publication, patient group studied, study type, relevant outcomes, results and study weaknesses were tabulated. We conclude that thromboelastography may be useful in predicting patients who are likely to bleed postoperatively but more importantly, it can guide transfusion therapy algorithms in the bleeding cardiac surgical patient resulting in significant decreases in blood and blood component transfusion requirements. However, the technique remains unvalidated in the eyes of many haematologists and further large studies involving them are required to fully validate its use and to define the 'ideal' treatment algorithm.
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Keywords: Evidence-based medicine; Thromboelastography; Blood products; Bleeding

1. Introduction

A best evidence topic was constructed according to a structured protocol. This protocol is fully described in the ICVTS [1].

2. Three part question

In [adult patients undergoing cardiac surgery], does [Thromboelastography] predict or decrease [bleeding and blood product requirements].

3. Clinical scenario

You start work in a new unit which routinely uses thromboelastography to manage coagulopathy and guide treatment with blood component therapy following surgery. As you have no experience of the technique you decide to review the literature to identify whether the technique is actually beneficial in decreasing exposure to allogeneic blood and blood component therapy.

4. Search strategy

Medline 1966 to June 2005 using the OVID interface and EMBASE 1980 to June 2005.

[CABG.mp OR exp Thoracic Surgery/OR Coronary art$ bypass.mp OR Cardiopulmonary bypass.mp OR exp Cardiovascular Surgical Procedures/OR exp Thoracic Surgical Procedures/OR exp Coronary Artery Bypass/] AND [thromboelastography.mp. OR exp Thrombelastography/OR TEG.mp] AND [bleeding.mp OR platelets.mp OR exp Blood Platelets/ OR blood transfusion.mp OR exp Blood Transfusion/OR fresh frozen plasma.mp OR exp Plasma/OR exp Blood Platelets/ OR exp Blood Component Transfusion/OR exp Platelet Transfusion/OR exp Blood Transfusion/OR blood component therapy.mp OR exp Erythrocyte Transfusion/].

5. Search outcome

A total of 170 papers were identified using the reported search of which 14 represented the best evidence on the subject. These studies are summarised below (Table 1).

6. Discussion

Thromboelastography (TEG) is a point-of-care whole blood coagulation monitor which provides information on specific aspects of coagulation including time to production of initial fibrin strands (R-time), time to develop clot (R-time, K-time), rate of fibrin build-up and cross linking (α-angle), maximum clot strength (maximum amplitude–bMA) and measures of fibrinolysis (decreasing amplitude post-MA).

Abnormal TEG data may predict patients who will bleed. Spiess [2] found that TEG correlated well with ACT and

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Table 1
Best evidence papers

Author	Patient group	Study type	Outcome	Key results	Study weaknesses
Spiess et al. (1987) J Clin Monitor, USA [2]	38 patients undergoing Cardiac Surgery (29 CABG, 9 valve replacements) Activated clotting times (ACT), Thromboelastography (TEG) and coagulation profiles performed pre-bypass, 45 min after institution of CPB and 30 min post-protamine Postoperative blood loss (1 ml/kg/h in first 8 h classed as abnormal)	Cohort study (level 2b)	Postop blood loss Correlation between TEG variables, ACT's and coagulation profiles, and comparison to postop blood loss to identify predictive capabilities of each test	Significant correlation between aPTT & TEG All TEG's abnormal during CPB (no evidence coagulation) 29/37 (78%) TEG's normal post-Protamine – no single coagulation test consistently abnormal No correlation between abnormal TEG's and single abnormal coagulation test (moderate correlation between A60 and aPTT – $r=-0.4708$, $P=0.01$) TEG 87% accurate as predictor of postoperative bleeding (ACT 30% and coagulation profiles 51% accurate, $P=0.004$)	Small study 1 patient returned to theatre with arterial bleeding from aortotomy site and normal TEG and excluded from further analysis
Ostrowski et al. (2004) J Extra Corporeal Technol Tech, USA [3]	35 adult patients undergoing cardiac surgery with CPB Excluded if history of haemostatic disorder or requiring deep hypothermic circulatory arrest Plateletworks platelet function analyser (platelet count + platelet aggregation in presence of agonist) vs. thromboelastography (TEG) Plateletwork assays – preincison, after removal of aortic cross-clamp, 1 h and 24 h postop using baseline, ADP and collagen reagent tubes TEG assays preop, post-protamine and 24 h postop	Cohort study (level 2b)	Plateletworks data TEG data Blood product use Chest tube (CT) drainage	No correlation between Plateletworks and blood product usage Significant change in α-angle from preop to post op TEG samples ($P<0.035$) No significant difference in k-time and MA at the time intervals No correlation between TEG data and CT drainage Correlation between preop TEG MA and blood product usage ($P=0.016$)	Wide range of procedures – CABG, Valve or combination procedures with range of CPB/cross-clamp times and lowest core temperatures
Ereth et al. (1997) Anesth Analg, USA [4]	200 adult patients undergoing cardiac surgery with CPB Comparison of platelet-activated clotting test (PACT HemoSTATUS) – vs. ACT and clotting studies (PT and APTT) vs. TEG to predict blood loss and platelet dysfunction associated with CPB Coagulation studies, platelet tests and TEG taken pre- and post-CPB; ACT samples taken post-heparin and on CPB; PACT performed pre-induction, after 40 min CPB and 20–40 min post-protamine	Cohort study (level 2b)	Mediastinal blood loss (MBL) at 4 and 24 h Abnormal blood loss level set at: [1] >100 ml/h in 1st [2] >200 ml/h in 1st 4 h Platelet activated clotting test (PACT) ACT Platelet count	Post-protamine PACT correlated with 4-h MBL ($r=-0.30$; $P=0.014$) TEG MA correlated with 4 h MBL ($r=-0.32$; $P=0.003$) PACT sensitivity and specificity comparable to conventional coagulation tests in prediciting blood loss TEG MA more predictive than both PACT and routine coagulation tests in predicting excessive blood loss post-CPB >100 ml/h blood loss in 4 h: – PACT 80% – sensitivity	Design of study to assess PACT HemoSTATUS test, not TEG Design of study specifically to correlate platelet function to bleeding Only small sub-group did not receive aprotinin

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Table 1 *(Continued)*

Author	Patient group	Study type	Outcome	Key results	Study weaknesses
	Sensitivity, specificity of tests analysed using receiver operating characteristics (ROC) analysis of system using excessive blood loss as abnormal state		PT; aPTT TEG – R-time; R+K-time; α-angle; MA; MA+30	80%; specificity 56%; – TEG-MA 48 mm – sensitivity 80%; specificity 75%; – Platelet count 110×10^9/l – sensitivity 64%; specificity 61%; – PT 14 s – sensitivity 68%; specificity 68%; – aPTT 40 s – sensitivity 50%; specificity 55%;	
Essell et al. (1993) J Cardiothorac & Vasc Anes, USA [5]	36 adult patients undergoing cardiopulmonary bypass Comparison of TEG to platelet function tests (bleeding time, platelet count, mean platelet volume) and standard coagulation tests (PT, aPTT, fibrinogen) Abnormal blood loss defined as loss of >1500 ml blood in first 24 h postop or need to transfuse platelets or FFP to control haemorrhage (platelet or FFP ordered on basis of lab tests or clinical decision)	Cohort study (level 2b)	Patients classed as 'bleeders' or 'non-bleeders' on basis of mediastinal tube (MT) or chest tube (CT) drainage Preop and postop bleeding time (BT) Preop and postop PT; aPTT: platelet count; MPV; Hb; Hct; fibrinogen; fibrinogen split products (FSP's); thrombin time TEG data – R-time; K-time; α-angle; MA; A60 (normal values derived from review of 'bleeders' and 'non-bleeders'	TEG – sensitivity 71.4%; specificity 89.3%; Bleeding time >9 min – sensitivity 71.4%; specificity 78.5%; Platelet count $<130\times10^9$ – sensitivity 100%; specificity 53.6%; PT >13.55 s – sensitivity 85.7%; specificity 10.7%; APTT>30.85 s – sensitivity 85.7%; specificity 21.4%; Fibrinogen <175 – sensitivity 85.7%; specificity 32.1%; Thrombin time <9.95 s – sensitivity 28.6%; specificity 78.6%; Hb <12 g/dl – sensitivity 85.7%; specificity 7.1%;	Small study 61% patients having CABG surgery. Remainder mix of valve, ASD repair, bundle ablations – wide range of procedures Assessing TEG as predictor of bleeding rather than to guide therapy Unclear whether 'bleeders' and 'non-bleeders' used to define TEG normal values were from study or other population Blood loss >1500 ml seems excessive compared with other studies 1/36 died 8 h postop ∴ 35/36 completed study
Cammerer et al. (2003) Anesth Analg, Germany [6]	255 consecutive patients Comparison of modified TEG (ROTEG) using activated blood samples ± Abciximab vs. platelet function analyser (PFA-100) using epinephrine and ADP coated cartridges post-induction of anaesthesia, during CPB after rewarming and post-protamine administration to predict postop blood loss Data for blood loss >750 ml in 6 h compared to group with blood loss <750 ml in 6 h	Cohort study (level 2b)	Absolute Blood loss Comparison of ROTEG and PFA-100 data for blood loss groups >750 ml and <750 ml in 6 h Comparison of ROTEG and PFA-100 data for blood loss groups more and less than 75th percentile in 6 h	Blood loss >750 ml vs. loss <750 ml – TEG data – no significant difference – PFA data – significant differences for preop ADP PFA vs. postop ADP PFA and epinephrine PFA ($P<0.05$) Blood loss >500 ml vs. loss <500 ml – significant differences between ROTEG MA's on CPB and post-CPB (± Abciximab); ROTEG post-CPB; α-angle (± Abciximab); and post-CPB PFA's with ADP and epinephrine ($P<0.05$) Post-protamine post-CPB samples best predictors for bleeding with univariate analysis – MA <57 mm – PPV 37%; NPV 77% – α-angle <71° – PPV 41%; NPV 82%	Bleeding threshold of 750 ml based on level from one other study and ∴ may be somewhat arbitrary Bleeding limit based on 75th percentile more useful Demonstrates low PPV and high NPV Low PPV means that coagulopathy identified by test may not necessarily cause bleeding – risk of over-treating if test result solely used to guide therapy

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Table 1 *(Continued)*

Author	Patient group	Study type	Outcome	Key results	Study weaknesses
	Data for blood loss above and below 75th percentile for 6 h blood-'enhanced blood loss' – also compared ROC curves used to identify/compare best predictors Significant variables with univariate analysis subjected to binary logistic regression analysis			– Abciximab MA <17 mm – PPV 41%; NPV 85% – Abciximab α-angle <26° – PPV 35%; NPV 84% – PFA ADP <118 s – PPV 34%; NPV 76% α-angle of TEG best predictor of postop bleeding on logistic regression analysis with PFA-ADP post-CPB an additional significant factor	
Ti et al. (2002) J Cardiothorac & Vasc Anes, Singapore [7]	40 patients undergoing elective multivessel CABG surgery TEG samples (plain and heparinase-modified) taken pre-induction and at 10 min and 60 min post-protamine administration Subdivided into 'bleeders' (blood loss >1000 ml over 24 h, or 250 ml over 2 consecutive hours) and 'non-bleeders'	Cohort study (level 2b)	Abnormal TEG values: – K-time >16 mm – α-angle <40° – MA<40 mm – LY60 >15%↓ in MA Absolute blood loss Requirement for FFP and/or platelet transfusion	Moderate correlation between TEG parameters, total blood loss & requirement for FFP &/or platelets 60 min TEG better than 10 min TEG (sensitivity 100% vs. 70%) Use of heparinase-modified-TEG ↑ specificity (83% vs.40% @10 min, 73% vs. 20% @ 60 min); and PPV (58% vs. 28% @ 10 min, 55% vs. 29% @ 60 min) 'Bleeder' vs. 'non-bleeder' lab tests – no significant difference	Definition of degrees of postop bleeding somewhat arbitrary and based on 'local institutional modifications of definitions by previous authors' though no references cited 6/40 (15%) 10-min and 10/40 (25%) 60-min TEG's produced unreadable 'straight-line' traces and were excluded from analysis Small numbers in study
Nuttall et al. (1997) J Cardiothorac & Vasc Anes, USA [8]	82 adult patients undergoing elective cardiac surgery Agreed subjective assessment by anaesthetist and surgeon into 'bleeders' and 'non-bleeders' 10 min post-protamine Quantitative assessment of bleeding post-CPB by collection of blood and irrigation fluid by suction from operative field Comparison of coagulation tests, bleeding times, platelet counts, TEG and sonoclot data as predictors of bleeding	Cohort study (level 2b)	Identification of 'bleeders' Thromboelastography – post-Protamine R & K times; α-angle; MA; MA+30(A30) Assessment of sensitivity, specificity, PPV and NPV achieved using Receiver Operator Characteristic (ROC) curves for bleeding	TEG data – R time – 18 vs. 16 mm (P=0.1475)) – sensitivity 47%; specificity 71%; – R+K time – 29 vs. 23 mm (P=0.0123) – sensitivity 53%; specificity 75%; – α-angle – 40 vs. 46° (P=0.0138) – sensitivity 63%; specificity 71%; – MA – 47 vs. 53 mm (P=0.0006) – sensitivity 60%; specificity 79%; – MA+30 – 45 vs. 49 mm (P=0.0614) – sensitivity 58%; specificity 67%; 30/82 (36.6%) classed as 'bleeders' 10 min post-protamine Median blood loss ('bleeders vs. 'non-bleeders'): – 775 vs. 200 ml intraoperative (P<0.001) – 949 vs. 547 ml first 24 h postop (P<0.001) Coagulation tests correlated best with intraoperative and postoperative blood loss (but predictive values	Diagnosis of bleeding subjective (although agreed between Surgeon & Anaesthetist) ROC analysis based on this subjective designation of 'bleeder' Lack of 'gold-standard' for diagnosis of bleeding might affect ROC analysis

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Table 1 *(Continued)*

Author	Patient group	Study type	Outcome	Key results	Study weaknesses
				outside normal ranges)	
Dorman et al. (1993) Anesth Analg, USA [9]	60 patients presenting for CABG surgery Comparison of preoperative tests to predict blood loss: – Coagulation screen (aPTT, PT, platelet count, fibrinogen level; bleeding time) vs. – ACT – TEG Blood/blood products given on basis of transfusion protocol	Cohort study (level 2b)	Absolute intraoperative blood loss Packed cell and blood product requirements Hb; Hct Coag screen results – PT; aPTT; fibrinogen; platelet count; forearm bleeding time ACT results TEG results – R time; R+K time; MA; MA+30; MA+60; α-angle	PT; platelet count; bleeding time identified as significant contributing variables when blood loss considered dependant variable ($r=0.75$; $P<0.05$) No significant relationship between any TEG variable and blood loss by step-wise linear regression analysis ($r<0.25$, $P>0.78$) Significant linear relationship between α-angle and MA ($r=-0.54$; $P<0.05$), α-angle and R-time ($r=-0.53$; $P<0.05$), and α-angle and R+K-time ($r=-0.7$; $P<0.05$) Significant correlation between α-angle and PT ($r=-0.58$; $P<0.05$). Poor correlation between other coagulation screen parameters and TEG variables	Looked at preoperative coagulation studies, ACT and TEG data only as predictors of intraoperative blood loss 2/60 TEG's repeated post-induction in view of unsatisfactory pre-induction traces
Avidan et al. (2004) Br J Anaesth, USA/UK [10]	102 patients undergoing elective CABG surgery with cardiopulmonary bypass 'Point of Care' (POC) – hepcon + Thromboelastography (TEG) + platelet function analyser (PFA-100) – vs. 'laboratory algorithm group' (LAG) management – rapidly available ACT, INR, APTT – to direct treatment algorithm POC & LAG transfusion trigger 8 g/dl Comparison to retrospective case-control group ($n=108$) – 'clinician directed therapy'	PRCT with retrospective cohort control group (level 2b)	24-h Blood loss Blood transfusion requirement Blood component requirement	Median blood loss between two study and case-control groups not significant Blood and component transfusion (Red cells, FFP and Platelets) in 'clinically directed' group > that in LAG or POCgroups ($P<0.025$) No significant difference between POC and LAG groups – ∴ POC no better than rapidly available coag tests Abnormal TEG MA associated with ↑ postop bleeding No results predicted ↑ postop bleeding	Study assessed effects of combined POC monitors, not just TEG Variations in antifibrinolytic therapy between groups (tested groups given tranexamic acid; Case control group mostly given tranexamic acid or aprotinin at clinician's direction) Study questions adequacy of its own POC algorithm Time delays obtaining conventional clotting studies compared to rapidly available POC and LAG data might skew outcomes No transfusion trigger in case-control group
Spiess et al. (1995) J Cardiothorac & Vasc Anes, USA [11]	1079 sequential patients for revascularisation and/or open ventricle procedures 2 groups – Group1 – 488 pre-introduction of TEG-based guidelines – Group 2 – 591 post-introduction of TEG-based guidelines Baseline and post-protamine	Cohort study (level 2b)	Number of patients transfused Number receiving platelet transfusion Number receiving FFP transfusion Number receiving cryoprecipitate	Overall outcomes – 13.7% pre-TEG vs. 21.5% post-TEG received no transfusion ($P=0.001$) – 38.8% pre-TEG vs. 42.1% post-TEG received no transfusion in operating room ($P=0.005$) – 83.2% pre-TEG vs. 73.9% post-TEG received red cell transfusion overall ($P=0.0001$) – 59.2% pre-TEG vs. 48.2% post-TEG received	Increased awareness of transfusion issues and philosophy and move towards less liberal transfusion and stricter transfusion triggers probably main contributor to decreased red cell transfusion during study. Introduction of TEG at same time may have been coincidental

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Table 1 *(Continued)*

Author	Patient group	Study type	Outcome	Key results	Study weaknesses
	TEG analysis performed		transfusion Incidence of massive transfusion Re-exploration rate	Platelets ($P=0.0001$) – 36.1% pre-TEG vs. 26.4% post-TEG received FFP ($P=0.001$) – 9.1% pre-TEG vs. 6.4% post-TEG received cryoprecipitate ($P=0.091$) – 10.2% pre-TEG vs. 9.5% post-TEG received massive transfusion (P=NS) – 5.7% pre-TEG vs. 1.5% TEG-monitored patients required re-exploration ($P=0.0001$)	Lack of rigid TEG protocol – use and interpretation of TEG data not standardised and left up to individual clinicians Other coagulation data also available to clinical team if deemed necessary Much of study may show advantages of cooperative behaviour in monitoring changes rather than true experimental differences between groups
Koster et al. (2001) J Extra Corporeal Technol Tech, USA [12]	30 adult patients undergoing surgery with cardiopulmonary bypass with prolonged ACT > 150 s after protamine reversal of heparin Treatment protocol based on analysis of data from multiple kaolin-activated TEG's: – Baseline – Heparinase – Heparinase/Abciximab – Heparinase/FFP-TEG ROTEG R-time <900 s and MA 40–50 mm regarded as normal	Case series (level 3b)	TEG (ROTEG) R-time and MA variables Pre-treatment ACT Post-treatment ACT	Therapy guided by ROTEG 2/30 (6.7%) given protamine 5/30 (16.7%) given desmopressin 19/30 (63.3%) given FFP 2/30 (6.7%) given platelets 2/30 (6.7%) given platelets + FFP Mean pre-treatment ACT 162.2 ± 7.8 s Mean post-treatment ACT 127 ± 8.3 s ($P<0.05$)	Small study No comparison to control group Mixed group of patients – CABG ± valve; multiple valves; aortic surgery; VAD implantation Mixed group of interventions Treatment algorithm more complicated than that used in other studies
Shore-Lesserson et al. (1999) Anesth Analg, USA [13]	107 adult patients undergoing cardiac surgery utilising cardiopulmonary bypass (105 completed study) Conventional vs. TEG protocol in presence of bleeding 53/105 TEG protocol – protamine, platelets, FFP, EACA, cryoprecipitate given according to TEG data (R-time, MA and LY30), platelet count and fibrinogen levels 52/105 Conventional protocol – protamine, platelets, FFP, and cryoprecipitate given according to ACT, platelet count, PT and fibrinogen levels	PRCT (level 1b)	Multiple time point analysis of: – Mediastinal tube drainage (MTD) – Blood component transfusion requirements – Lab coag tests (platelets, PT, aPTT, fibrinogen) – TEG variables (R-time, α-angle, MA and LY30)	34/52 (65.4%) Conventional group vs. 22/53 (41.5%) of TEG group transfused ($P=0.01$) 17/52 (33%) Conventional group vs. 7/53 (13%) TEG group received non-RBC transfusion ($P=0.02$) 16/52 (31%) Conventional group received FFP vs. 4/53 (7.5%) of TEG group ($P<0.002$) FFP volume significantly more in conventional than TEG group ($P<0.04$) 15/52 (29%) Conventional vs. 7/53 (13%) in TEG group received platelets ($P<0.05$) No significant difference in MTD between groups	Routine use of E-aminocaproic acid may modify TEG and make it more likely to trigger intervention Part of TEG protocol dependant on lab studies More options as part of TEG protocol Post-protamine lab tests used to guide 'Conventional protocol' vs. 'post-warm CPB heparinase modified samples' in TEG group. Ordering of component therapy based on this TEG sample but only actually given if patient bleeding ∴ facilitated very early intervention for bleeding post-CPB

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Table 1 *(Continued)*

Author	Patient group	Study type	Outcome	Key results	Study weaknesses
Royston et al. (2001) Br J Anaesth, UK [14]	Series 1 – 60 patients undergoing complex cardiac surgery given haemostatic treatment at clinician's discretion/lab tests in presence of bleeding vs. 'predicted' component requirements guided by heparinase modified celite activated TEG algorithm	Series 1 – retrospective cohort study (level 2b)	Mediastinal tube drainage (MTD) at 6 & 12 h post-op	Series 1 22/60 (37%) given blood components vs. 7/60 (12%) 'predicted' to require component therapy ($P<0.05$)	Patients who returned to theatre for bleeding discarded from study and replaced by additional patient
			Red cell usage		
			FFP usage	38 units FFP and 17 platelet pools given vs. 6 units FFP and 2 units pooled platelets in 'predicted' group ($P<0.05$)	TEG algorithm facilitated early intervention possibly before associated with excessive bleeding
			Platelet usage		
	Series 2 – 60 patients randomised to 'clinician directed/lab tests' or TEG-directed component therapy using algorithm driven by R-time, MA and LY30 data. Products ordered as soon as clinicians judged necessary or test results available	Series 2 – PRCT (level 1b)		Series 2 10/30 (33%) clinically managed patients received blood components vs. 5/30 (17%) TEG patients ($P<0.05$)	Could TEG give false positive result leading to unnecessary treatment?
				16 units FFP and 9 platelet pools in clinically managed group vs. 5 units FFP and 1 unit pooled platelets in TEG group ($P<0.05$)	Algorithm issues – study acknowledges that absolute values used in algorithm are derived from reference values in normal population and there is no evidence that they are optimal for study group
				MTD no significant differences between groups	

coagulation profiles and whilst no coagulation test was consistently abnormal the TEG was the most accurate predictor of bleeding.

Ereth [4] studied a 'Platelet-activated clotting test' (PACT HemoSTATUS), ACT and clotting studies, and TEG. Whilst PACT sensitivity and specificity was comparable to conventional coagulation tests in predicting blood loss, TEG was more predictive at both blood loss levels. Essell [5] found that whilst the bleeding time and platelet count had sensitivities similar to the TEG, TEG specificity was greater. In addition, they suggested that patients with an abnormal TEG were at increased risk of bleeding but that excessive bleeding in the face of a normal TEG implied surgical bleeding and FFP and platelets should not simply be used empirically. Ti [7] found moderate correlation between TEG parameters, total blood loss and requirements for FFP and/or platelets in their group of 'bleeders'.

In contrast, other studies did not find the TEG to be a useful predictor of blood loss. Nuttall [8] reported that TEG values had a low sensitivity and specificity in predicting 'bleeders'. Dorman [9] compared preoperative coagulation screens to ACTs and TEGs as predictors of blood loss but found no significant relationship between any TEG variable and losses.

A number of studies have used the TEG to guide transfusion management. Avidan [10] Compared TEG to a Laboratory based algorithm. They concluded that whilst blood and blood product usage was significantly more in the laboratory group, there was no statistically significant difference between the study groups. Spiess [11] analysed 1079 patients before and after the introduction of TEG as part of an overall transfusion management strategy. They identified significant changes in their practice with decreased usage of all blood and blood component therapies with the exception of cryoprecipitate. Their re-exploration rate also fell significantly. However, this study probably reflects the effects of education and co-operative behaviour in monitoring changes rather than a true experimental difference between groups.

Two randomised controlled trials have been performed. Shore-Lesserson [13] compared 'TEG-based' and 'conventional' protocols to manage postoperative bleeding. Whilst there was no significant difference in mediastinal tube drainage between the groups, blood and blood component therapy was significantly less in the 'TEG' than in the 'conventional group'. However, the 'TEG protocol' did have more options than the conventional protocol and was also partly dependent on laboratory tests. In addition, blood products were ordered on the basis of a TEG taken at rewarm on cardiopulmonary bypass and given in the presence of continued bleeding following protamine, whereas, the conventional group required post-protamine tests to dictate intervention. This inevitably meant earlier intervention in the TEG group. Royston [14] studied 60 patients who had undergone complex surgery comparing their actual blood/blood product use to a 'predicted usage' derived from a TEG-based algorithm. 'Predicted' blood/blood component transfusion was significantly less than 'actual' transfusion. They subsequently used this algorithm comparing it to conventional management in a further 60 patients. Again they demonstrated significantly less blood/blood component usage in the TEG-based group compared to the conventional 'clinician-directed' group with no excessive mediastinal bleeding. However, this study was designed to

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identify TEG-evidence of coagulation before physical evidence of microvascular bleeding and the authors acknowledge the fact that their protocol allowed much earlier intervention in the active than in the control limb.

A recent review by Samama [15] has raised concerns that thromboelastography remains an unvalidated technique which fails to achieve the stringent standard quality-control procedures essential in laboratory-based tests, citing absence of a formal standard operating procedure taking into account factors such as gender and pregnancy differences, stability of blood samples, and sampling site. There is also no standardised technique and multiple modifications exist including plain versus heparinase samples; celite, kaolin or tissue factor activation; abximimib (Reopro) modified; modified multi-channel; and ROTEG have been described. Several studies acknowledge that TEG facilitates earlier intervention than standard coagulation tests [10,13,14] thus making true comparisons difficult. Samama et al. conclude their review by suggesting that extended collaborative studies involving haematologists are required to further evaluate and validate thromboelastography [15].

7. Clinical bottom line

Thromboelastography can be used to predict bleeding in cardiac surgery, but it can also be used to guide transfusion therapy during postoperative bleeding using appropriate treatment algorithms where its use has been associated with significant decreases in blood and blood component transfusion. However, thromboelastography remains unvalidated compared to other laboratory-based routine coagulation studies and further large controlled studies involving haematology input are required to confirm that its use can be extrapolated to all types of cardiac surgery and also to define the 'ideal' treatment algorithm.

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Interact CardioVasc Thorac Surg 2005;4:456-463; originally published online Jul 11, 2005;
DOI: 10.1510/icvts.2005.115154

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