

Changes in Transfusion Therapy and Reexploration Rate After Institution of a Blood Management Program in Cardiac Surgical Patients

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A retrospective study was performed to determine the impact of a coagulation and transfusion management program on blood utilization in 1,079 sequential patients for myocardial revascularization and open ventricle or combined procedures. Four hundred and eighty-eight patients (group 1) before, and 591 patients (group 2) after institution of thromboelastography (TEG)-guided coagulation were studied and compared for transfusion requirements, donor exposure, and the incidence of reoperation for hemorrhage. Group 2 patients had a significantly lower incidence of overall transfusion (78.5% v 86.3%) during hospitalization and in total transfusion in the operating room (57.9% v 66.4%). The

BLOOD PRODUCT utilization for cardiac surgery shows considerable variability between institutions.^{1,2} A number of studies have attempted to determine an appropriate threshold for transfusion;³⁻⁵ however, there are no data to suggest that an optimum hematocrit exists post-cardiopulmonary bypass (CPB), and therefore, triggers for transfusion are variable. The indications for red cell transfusion are multiple and tend to be individualized for anticipated or evolving patient pathophysiologic need. Such a lack of consensus predisposes transfusion behavior to variations based on practitioner goals and bias.

The utilization of coagulation cofactors also shows a significant degree of variability in clinical practice. The transfusion of fresh frozen plasma for routine coronary artery bypass graft (CABG) cases has been shown to be as little as 3% of patients to as many as 97% of patients in 18 major cardiac centers.¹ Similar variability in practice for platelet transfusions also exists. The quantity of chest tube bleeding does not decrease with the prophylactic or uncontrolled use of such products.⁶

The assessment of coagulation abnormalities post-CPB has historically been performed by the coagulation profile (CP) (prothrombin time, activated partial thromboplastin time; fibrinogen concentration; and platelet count) and the activated coagulation time (ACT). The CP is incapable of assessing platelet activity abnormalities. Platelet defects and fibrinolysis constitute the majority of post-CPB coagulopathies. The wide variability in transfusion practice may represent the inability to adequately rapidly assess perioperative CPB coagulopathies with routine CP monitoring.

Viscoelastic tests of coagulation such as thromboelastography (TEG) have emerged as alternatives to the routine CP for monitoring and assessment of coagulation abnormalities in liver transplantation and cardiac surgery. TEG has been shown to have the best sensitivity and specificity of the available coagulation tests for abnormal hemorrhage.⁷ TEG

incidence of each transfusion subtype was also significantly lower in group 2 patients. Actual total median donor exposure was 8 in group 1 patients and 6 exposures in group 2 patients. Mediastinal reexploration for hemorrhage was 5.7% before institution of TEG-based coagulation monitoring and 1.5% in TEG-monitored patients. Use of TEG monitoring before reexploration has decreased the cost and potential risk for patients undergoing CABG surgery.

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has also been used to guide factor replacement and has been shown to decrease blood product utilization in liver transplantation.⁸ No prior large series has been presented examining the effect of using TEG coagulation testing on transfusion practice for CPB.

This study has been performed to investigate the impact of a recently established unique program of TEG coagulation monitoring in CPB patients on blood utilization.

METHODS

After Institutional Review Board approval, a retrospective chart analysis study was undertaken of all patients undergoing CPB in the 7 months before the institution of TEG-guided coagulation laboratory testing. Seven months was chosen as the appropriate time interval because of earlier personnel changes. In December 1990, a new program was instituted to assess coagulopathies based on TEG guidance. TEG, a viscoelastic test of whole blood coagulation, measures the interaction of platelets and the plasma cascade from the time of initiation (the intrinsic cascade) through clot acceleration and growth, platelet and clot retraction, to eventual lysis. A unique approach to performing and reporting the TEG test was devised to ensure timely reporting of clot dynamics.

Blood samples for the study were drawn from an indwelling arterial cannula after a 10-mL flush withdrawal had been made. A 5-mL blood sample was placed in a citrated vacutainer and delivered to the central coagulation laboratory by a dedicated pneumatic tube system or by direct transport. Patient samples were immediately pipetted and run on one of six TEG machines. The laboratory procedure followed for citrated blood was to place 100 μ L of 0.645 g/dL of calcium chloride in saline into a prewarmed (37°C) TEG cuvette. Then 250 μ L of whole citrated blood were added to the calcium chloride solution in the cuvette. Mixing was accomplished by raising and lowering the TEG piston into the cuvette several times. The calcium chloride was placed in the cup first to prevent any surface activation of the blood sample without recording, which might occur if performed in reverse order. The TEG tracing began at the time of whole blood pipetting, and a few drops of mineral oil were placed on the sample surface to seal out air and prevent drying. The TEG was run in accordance with the manufacturer's instructions (Haemoscope, Inc., Park Ridge, IL) for 60 minutes.

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The TEG tracing was continuously displayed in the cardiac operating room as the coagulation test was progressing. This was performed using a closed circuit television system for transmission of the developing TEG trace to the cardiac operating rooms in real time.⁹ Video cameras were suspended directly above each TEG paper output and were projected onto a black and white television screen directly above and behind the cardiac anesthesia team (Fig 1). Charge coupled cameras were used to prevent image burn-in, which may occur with television cameras constantly focused on the same image. Ruled paper made estimation of R (reaction time), K (coagulation time), and MA (maximum amplitude) values of the TEG relatively easy from the television image. The anesthesia and surgical teams could discern coagulopathies during the testing phase rather than awaiting a final result from the laboratory. After a minimum 1-hour running time, the TEG tracings were removed from the machine, measured by a laboratory technician, and a hard copy was transmitted to the operating room by facsimile (FAX) where surgery was taking place. All cardiac and hepatic transplantation suites are equipped with the complete video technology to process TEG data. Other access sites are available in the institution's intensive care units (ICUs). The six TEG machines have the capability of handling samples from two liver transplants and up to three cardiac surgery cases at once. Images are sent to the appropriate clinical site by a signal switching system. Examples of this system are shown in Fig 2. Coagulation profile data can be ordered in the usual manner from the central coagulation laboratory, and the data may be sent by FAX to the operating room as well, if requested.

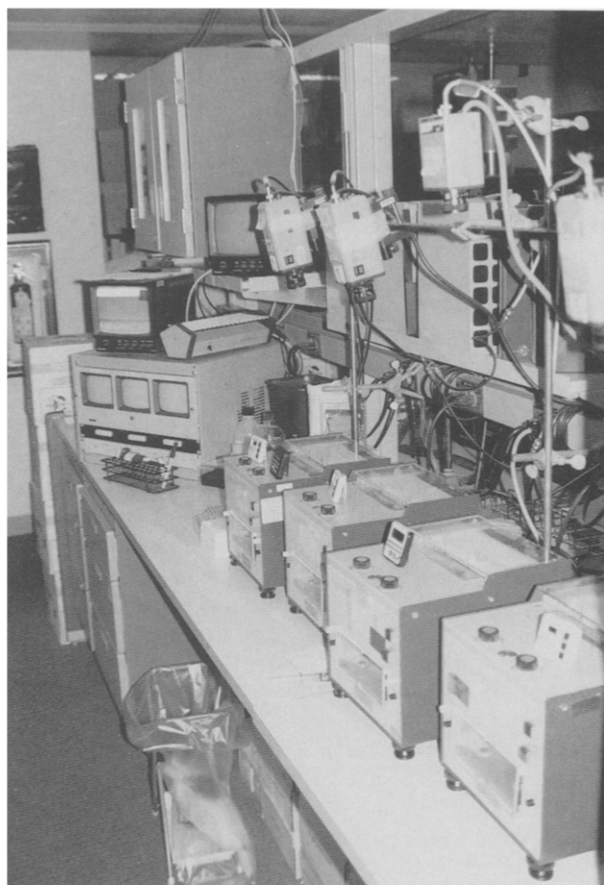


Fig 2 Video, TEG, and signal switching system (Reprinted with permission¹⁸)

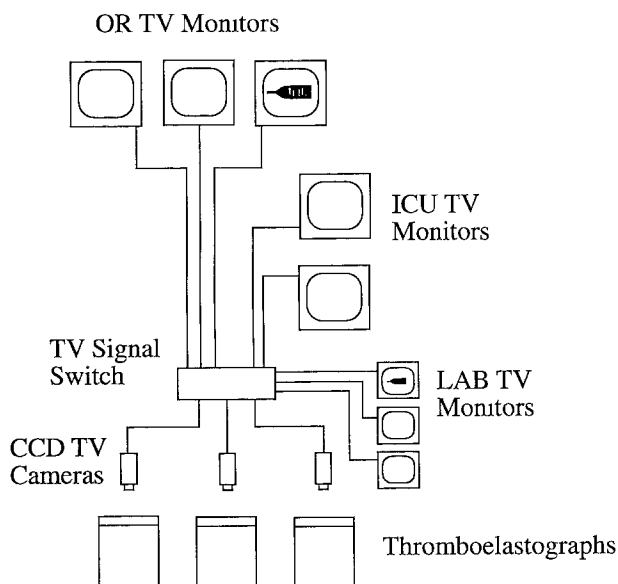


Fig 1 Diagram of thromboelastograph closed-circuit television system for real-time transmission of tracings to operating rooms (OR) and intensive care units (ICU) from the central laboratory. Charge-coupled device (CCD) cameras transmit the image of thromboelastograph tracing to television signal switch, which is used to direct the signal to the appropriate ordering location (Reprinted with permission⁹)

All patients undergoing cardiac surgery after December 1, 1990, underwent TEG testing. Baseline samples were collected after anesthetic induction before heparinization and sent to the coagulation laboratory. After weaning from CPB and final protamine administration, another TEG was performed. This sample time was most often 10 to 20 minutes after the last protamine dose.

TEG data were interpreted by the clinicians providing care for the CPB patient using a standard schematic key. Other coagulation profile data were used if deemed appropriate for the clinical situation. Before December 1, 1990, laboratory guidance of transfusion therapy was with the CP.

No rigid protocol for transfusion practice was proposed or enforced. However, multiple combined surgery/anesthesia staff meetings were held addressing transfusion issues. Attending staff discussion and education centered on the risks, appropriateness, and decision-making tree for transfusion therapy. Again, no rigid protocols were developed, but it was agreed that viscoelastic testing would be used as the mainstay of transfusion therapeutic decision making in group 2 patients. Patients in the ICU were treated for coagulopathies based on TEG findings and were returned to the operating room if hemodynamically unstable or if hemorrhage continued in the face of a normalized TEG.

Efforts were made to normalize the TEG with appropriate therapy before returning to the operating rooms.

The surgical staff and anesthesia staff remained fairly stable between the periods studied with turnover of one surgeon (1 of 5) and 2 of 8 anesthesiologists. Operative technique, bypass equipment (membrane oxygenation, centrifugal pump), and heparinization goals with porcine heparin (ACT 450 seconds or greater) were unchanged during the periods reviewed. Some differences in the technique for achieving full heparinization and the method for administering protamine did change. All ACTs postbypass were targeted to be the same or below baseline values before TEG tests were drawn or other coagulation testing and therapy were instituted.

Data obtained from the retrospective chart review included demographics (total number and type of case, age, sex). Data from the two time cohorts were compared for the total donor exposure and total number of red cell, plasma, and platelet transfusions. Patients requiring mediastinal reexploration for hemorrhage were also noted.

As the blood product utilization variables were decidedly not normally distributed, they are presented as median (interquartile range [IQ]). Comparisons between the two time groups were made by Mann-Whitney tests. Binary coded data were compared by chi-squared analysis. A two-tailed critical significance level of $p = 0.05$ was employed throughout. No adjustment for multiple comparisons was made; p values are nominal. Statistical manipulations were performed using SAS (vms version 6.06 ref: SAS User Guide: Statistics 1985, SAS Institute, NC).

RESULTS

Four hundred eighty-eight charts were analyzed of patients in the seven months before institution of the TEG-guided coagulation testing (group 1). Five hundred ninety-one patients were included in the group examined afterward (group 2). The demographics for age, sex ratio, or type of surgery (either CABG, complex, or open ventricle) showed no change in practice parameters from one historical period to another (Table 1).

The overall incidence of patients receiving any transfusion at any time during hospitalization decreased significantly from group 1 (86.3%) to group 2 (78.5%) and is noted in Table 2. The incidence of receiving any blood

Table 1 Demographic Data for Patients Before and After New Program

	Group 1	Group 2
<i>N</i>	488	591
Male	335	420
(%)	(72.83)	(72.16)
Female	125	162
(%)	(27.17)	(27.84)
CABG	355	443
(%)	(72.75)	(74.96)
Open ventricle or complex procedure	133	148
(%)	(27.25)	(25.04)
Age	61.90 ± 13.23	62.08 ± 12.78

Table 2 Overall Percent of Patients Receiving Transfusion

	Group 1 (<i>N</i> = 488)	Group 2 (<i>N</i> = 591)	<i>p</i>
Patient receiving no transfusion (%)	13.7	21.5	0.001
Patient receiving no transfusion in OR (%)	38.8	42.1	0.005
Red cell transfusion (%)	83.2	73.9	0.0001
Platelet transfusion (%)	59.2	48.2	0.0001
Plasma transfusion (%)	36.1	26.4	0.001
Cryoprecipitate (%)	9.1	6.4	0.091
Massive transfusion (%)	10.2	9.5	NS

NS, not significant

product in only the operating room was considerably lower in both groups and significantly different: group 1 (66.4%) and group 2 (57.9%). Overall utilization of each transfusion subtype showed significant changes from one group to another with the exception of cryoprecipitate transfusion (Table 2). The incidence of massive transfusion, defined as greater than 10 units of red cells or 20 total donor exposures, was similar over the two time periods. When transfusion practice for either CABG or open ventricle/complex procedures was compared for each surgery type, there was no difference in overall incidence of transfusion or in transfusion subtype for valve or combined procedures. The incidence of transfusion for CABG patients was similar to the overall transfusion for all procedures (Table 3).

A comparison of actual transfusion and donor exposure is shown in Table 4. The median total transfusion donor exposure was 8 in group 1 and 6 in group 2. The median transfusion exposure for blood subtype is also shown in Table 4. Red cell, platelet, and plasma transfusion exposures were significantly lower in group 2.

The incidence of mediastinal reexploration for hemorrhage is displayed in Table 5. In patients before the use of TEG monitoring, 28 of 488 (5.7%) patients were reexplored

Table 3. Transfusion Practice Per Surgical Case Type

	Group 1 (<i>N</i> = 488)	Group 2 (<i>N</i> = 591)	<i>p</i>
CABG (%)			
Total	87.6	77.7	0.01
RBC	84.5	73.1	0.01
Plt	57.2	42.7	0.01
FFP	31.6	19.6	0.01
Cryo	4.5	3.3	0.392
Open ventricle or complex (%)			
Total	82.7	81.1	NS
RBC	79.7	76.4	NS
Plt	64.7	64.9	NS
FFP	48.1	46.6	NS
Cryo	11.28	18.9	NS

NOTE: Overall decreases in blood utilization were made because of changes in the needs for transfusion in CABG patients. Open ventricle procedures did not change during this time period.

Abbreviations: CABG, coronary artery bypass graft; RBC, red blood cell count; Plt, platelet; FFP, fresh frozen plasma; cryo, cryoprecipitate; NS, not significant.

Table 4 Transfusion Donor Exposure

	Group 1 (N = 488)	Group 2 (N = 591)	p
Total exposure median (IQ)	8 (15)	6 (11)	0001
Total RBC median (IQ)	4 (4)	2 (5)	0001
Total platelets median (IQ)	4 (8)	0 (6)	0001
Total plasma	0 (3)	0 (2)	001

Abbreviations IQ, interquartile range 25 to 75 percentile, RBC, red blood cell count

versus 9 of 591 patients (1.5%) in the TEG-monitored patients.

DISCUSSION

There is no doubt from the data presented that the overall use of blood products declined between the two 7-month periods analyzed. These figures do not represent unusually low transfusion rates. As compared with data from Goodnough et al, the transfusion rates at this center appear to be about average.¹ If this technology change had been instituted at an institution with lower transfusion rates (ie, 40% to 50%), perhaps the findings would be less striking. However, this data for decreased blood utilization are of the same order of magnitude as changes observed with other monitoring systems being instituted.¹⁰ Therefore, clearly some monitoring is better than none at all, and much future work needs to be conducted to refine monitoring and transfusion behavior. However, therefore, comparison between individual centers is at times quite difficult. Many factors affect these differences including case mix, heparinization protocols, use and degree of systemic cooling, operative times, time of day, ICU practices, and level of personnel involved. Therefore, when changes are implemented within one institution and clinical behavior translates into a decreased use of blood products, that is particularly important. One important difference between the two groups is the actual donor transfusion exposure. The overall donor exposure in group 2 was significantly lower than in group 1 patients. This results in a lower risk of transfusion side effects and disease transmission

The reduction in use of red blood cell products from group 1 to group 2 represents a change in transfusion philosophy. Both anesthesiologists and surgeons held a number of meetings to discuss a trigger for transfusion (hematocrit 20% or below). This one decision alone probably accounts for the greatest reason for the decrease in use of red cells. Indicators of morbidity and mortality did not change during the periods studied. The incidence of major

Table 5 Mediastinal Reexploration Rates

	Group 1 (N = 488)	Group 2 (N = 591)	p
Mediastinal reexploration (N)	28	9	0 0001
Total %	5.7	1.5	
CABG (N)	16/355	6/443	0 007
(%)	4.5	1.4	
Complex (N)	12/133	3/148	0 009
(%)	9.0	2.0	

transfusion was not different between groups, so there is no suggestion that total red cell mass was different from one group to another. Perhaps the use of red cells could be further reduced by extension of this same program. Cordts et al have shown that erythrocyte volume may vary considerably among elderly patients undergoing major vascular surgery despite similar hematocrits.⁵ This may also have a significant impact on the transfusion threshold.

The use of coagulation products was reduced as well. Only the utilization of cryoprecipitate was not statistically changed. Its use before the study period was already infrequent, and a change was not likely to be evident. The treatment of coagulopathies was changed by instituting the use of a whole blood coagulation test, the TEG. That test was routinely run prebypass and postbypass on all patients in the second group. The use and interpretation of the test was left up to the individual clinicians. A wide range of expertise existed within the group of personnel rendering care with regards to TEG interpretation as well as coagulation management in general. The fact that significant decreases in use of coagulation products were effected by the institution of this test is more impressive when it is realized that this was a retrospective analysis of clinical behavior. Perhaps the savings of coagulation blood products would have been greater if a carefully controlled study was performed with cohort matched groups and a well-established, rigid protocol for coagulation replacement. Such a study has been proposed in the past by this group of researchers. The logistics of policing such a protocol in a major teaching hospital have precluded that desirable study from being performed. In light of not being able to perform such a "more scientifically pleasing" study, the authors believe that clinical care can be changed to be of even more importance.

A great deal of literature exists regarding the use of pharmacologic agents to decrease chest tube output and blood product utilization. Some positive findings have produced excitement and at times near-universal application of a therapy. D-8-arginine-vasopressin (DDAVP) has enjoyed both an initial enthusiasm and then a period of disappointment as subsequent studies failed to support initial decreases in bleeding. Recent research using the TEG as a discriminator of abnormal platelet activity has once again shown some use for the drug.¹¹ The antifibrinolytic agents, epsilon aminocaproic acid and tranexamic acid, both can be used prophylactically and reductions in the chest tube output in some patient groups have been noted.^{12,13} Decreases in total transfusion requirements have been less than astounding. Aprotinin has been widely tested in Europe, and in patients undergoing reoperations major transfusion savings have occurred.^{14,15} At best these agents appear to effect a moderate reduction in blood loss or transfusion in overall patient groups. The data indicate that a modest reduction in transfusion can be caused by behavior changes and by enhanced coagulation monitoring. The application of any drug therapy to all patients may be either not effective, as demonstrated by the most recent DDAVP study, or even possibly detrimental. A combination of more effective monitoring and drug therapy may

combine the best reduction in transfusion needs. It is clear that a great deal more knowledge about coagulation and bypass is necessary.

The most impressive finding of this retrospective analysis is the reduction in reoperation for abnormal hemorrhage. Once again the reader should be reminded that this data represent an examination of clinical practice. The only protocol adhered to was that if a patient was bleeding in the operating room at the time of chest closure and the TEG was normal, surgical bleeding was suspected and corrected. In addition, if a patient was hemorrhaging in the ICU, attempts would be made to normalize the TEG before returning the patient to the operating room. The reoperation rate reported from other centers averages around 8%. Therefore, the data reflect a low reoperation rate. The decrease in the reoperation rate for complex and open procedures may be of particular note. These procedures have the greatest tendency for surgical bleeding due to the presence of multiple suture lines in crucial structures such as the aorta. Essell et al have shown that the TEG is capable of discerning a surgical bleed with greater than 90% confidence (negative predictive value 92.3%).⁷ The data support this finding in clinical practice because the TEG was used as a method to discern surgical from coagulopathic bleeding. It is interesting that the percentages of patients receiving each blood product did not change in the complex patient group, but reexploration rates dropped. This probably bespeaks the fact that transfusion behavior may be most difficult to change in a group of patients with perceived elevated risk. The reoperation rate was achieved with concomitant significant decreases in the use of coagulation blood products. Previous studies have shown that prophylactic, undirected use of platelet transfusions does not change chest tube output.⁶ The use of whole

blood clot monitoring provides a very accurate indicator of coagulopathy versus surgical bleeding.^{16,17} That one bit of information can be extremely useful in a patient's care and could translate into differences in morbidity and mortality. Patients returning to the operating room for postoperative hemorrhage or tamponade have inherent problems. The cost savings should be considered as well. Operating room time and anesthesia costs for emergency surgery are particularly expensive. It has been demonstrated that in clinical practice a relatively inexpensive monitor, the TEG (cost is approximately \$10,000), can decrease the reoperation rate. A single TEG run charge is less than 50% that of a coagulation profile. If an emergency mediastinal reexploration costs a minimum of \$2,000, then the cost savings demonstrated by the data would have been greater than \$50,000 in 6 to 7 months. Those numbers are derived from the fact that had the expected reoperation rate of 5.7% continued in the 6 months after institution of the new plan, then 33 patients would have required reexploration. As it was, only 9 patients required such an operation. The estimation for cost of the reexploration is probably low and therefore savings could be even greater. In the day of capitation payments for diagnostic or procedural categories, the need to reexplore patients for bleeding becomes not only a problem of patient morbidity and mortality but one of economic gain or loss. Those centers with the lowest reoperation rates will clearly have an additional economic and competitive edge.

In summary, this retrospective analysis of clinical care change comparing 6-month time intervals is not perfect. But unlike a much preferred cohort matched and randomized prospective study, it does show that some cooperative behavioral and monitoring changes can translate into very real gains in patient care and outcome.

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