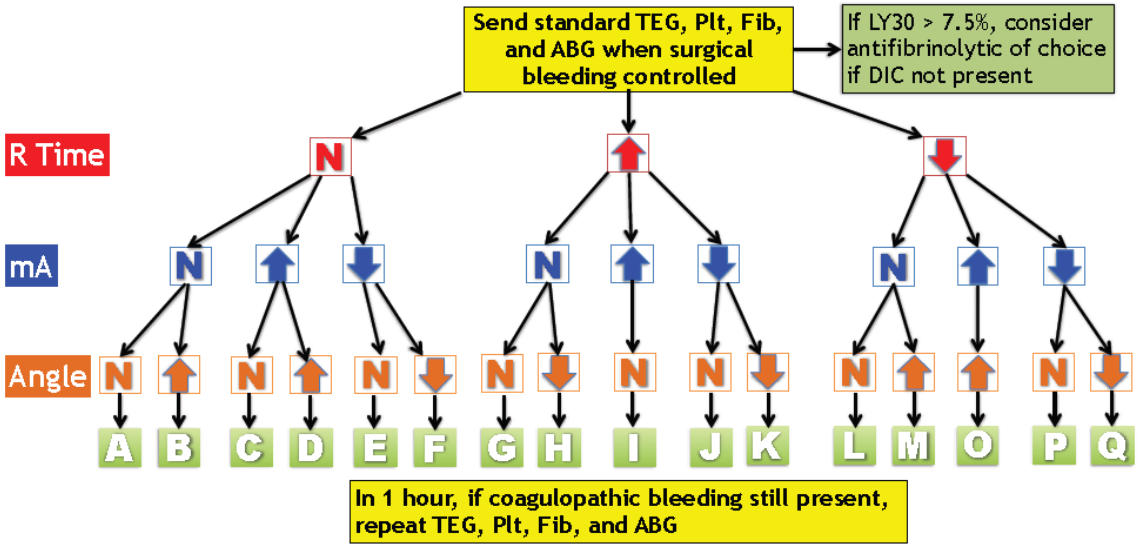
TEG Therapy Algorithm for Clotting Dysfunction for Trauma



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L, M, O – TEG is abnormal. Patient is hypercoagulable. **Do not transfuse clotting components**. If DIC, or HIT, **consult hematologist as needed**. If patient on CPB, on ECMO, or has VAD, **verify adequate heparinization.** Patient may need AT III if no response with escalating heparin doses.

P, Q – TEG is abnormal. Clotting start time is fast, however clot is weak. Likely von Willebrand factor deficiency. **Administer ddAVP and if continued bleeding occurs, transfuse platelets and cryo.**

Suggested guide for transfusion:

Platelet Count	Platelet Transfusion	Fibrinogen	Cryo Transfusion
<50,000	2 units of platelets	<100	2 units of cryo
<75,000	1 units of platelets	<150	1 unit of cryo

Raja, Huening, Bradford, Lamphere November 2013; Sillings edited 2014

The Thromboelastogram and its Applications

Overview: Blood products administration is an "intravenous tissue transplant", in that cells or acellular components are administered for the well being of the patient. Just as immunologic reactions or rejections are possible with solid organ transplant, the administration of blood products may also be dangerous in the same regard. It is prudent to carefully weigh risks and benefits of transfusion. In addition to hemodynamic monitoring information and traditional laboratory analyses (hemoglobin, platelet count, INR, ACT), the Thromboelastogram (TEG) provides an active, comprehensive view of clotting formation and lysis. Proper interpretation of this information is particularly useful in both bleeding and hypercoagulable diatheses.

Goal: This document will focus on the mechanics of obtaining the TEG and its interpretation with associated pitfalls. An algorithm will be provided to aid in understanding of thromboelastography. Sample collection information is also provided.

Mechanics of TEG: The biggest hurdle in interpreting the Thromboelastogram is to understand what it means and how the values were obtained. Let us share a couple of anecdotes with color-coding:

> **Story A**: Imagine placing a dime sized amount of craft glue onto your thumb, then touching it repeatedly with your index finger. Ultimately, the "tackiness" will increase and your fingers will stick together; the bond is pretty strong your fingers stay together, until the bond weakens and you are able to break it. This basic example you are demonstrates "how quickly the glue sets", "how strong the bond is when it sets", and "how long it takes for the bond to weaken to be able to break it".

Now let us rephrase the story and replace a few words.

> **Story B**: Imagine placing a specific amount of blood into a well and immersing a small pin; then repeatedly rotating the well and with pin immersed. Ultimately the "stickiness" will increase and the pin and well stick and rotate together because of clot formation. A short time after the bond weakens and the clot breaks down. You now have information of how quickly a clot forms, how strong the clot is, and how quickly it breaks down. If you were able to graph this information, suddenly you have an objective picture of clotting/bleeding. **This information when graphed over time is the Thromboelastogram.**

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Let us summarize:

Red is the amount of time it takes for things to get sticky, let's call this the **R time.** The R time is important because it tells you how long it takes for the **enzymatic portion of clotting to activate**.

Blue is the **maximum strength of the clot**. If we graphed this value, it would be the maximum value, and if we were measuring amplitude…well, why not just call this the maximum amplitude…or **mA value**.

Green is a measure of **how long it takes for a clot to break down**. If we want to measure how much of the clot has lysed at 30 minutes, we can call this the **LY30 time** (in figure noted as A30).

Highlighted are the locations of TEG parameters:

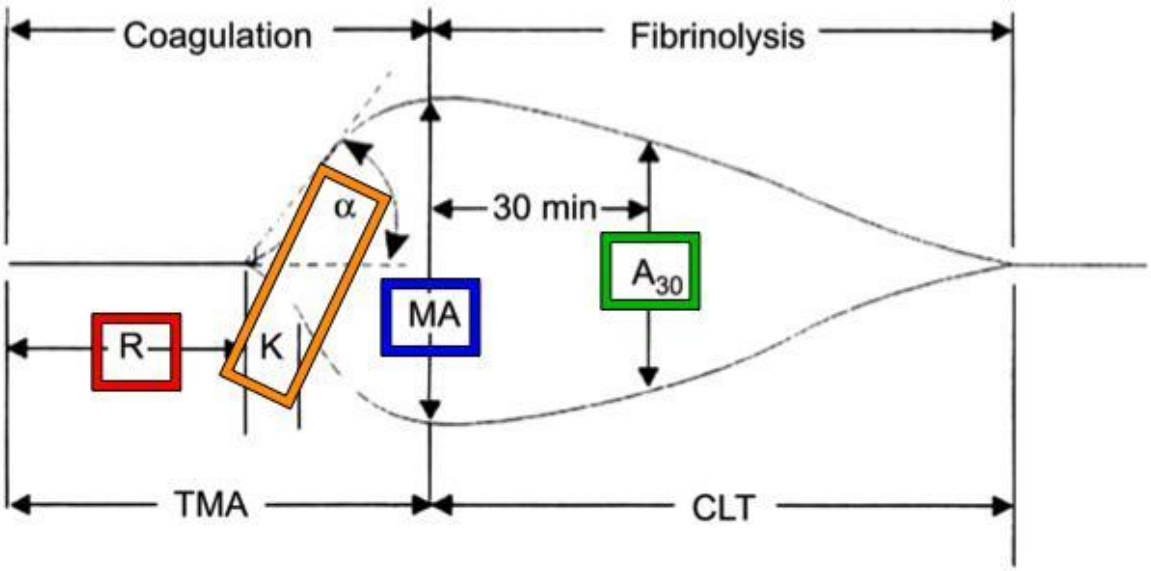
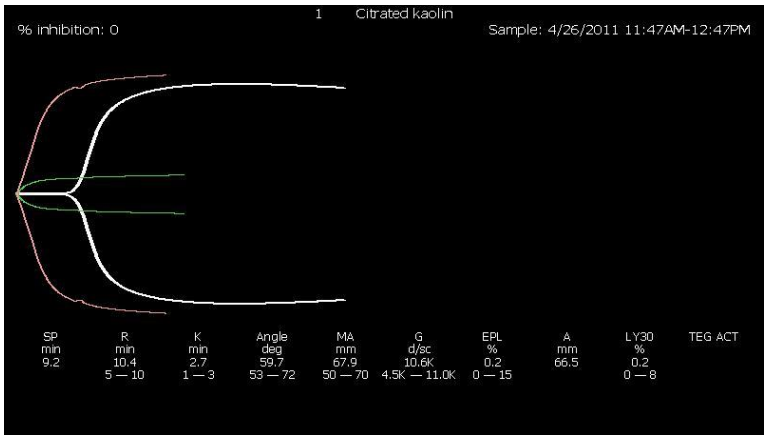


Figure (A) Edited. See Reference Section for Source.

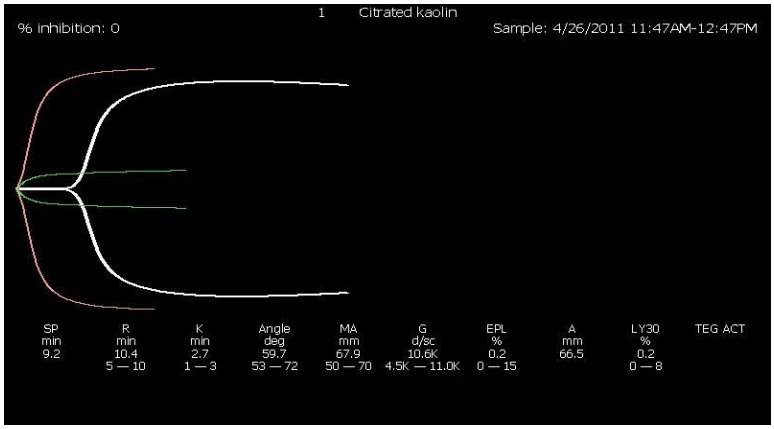
Simple enough? This representation is a very basic, yet useful way to understand the Thromboelastogram. There are a few more measurements that can be made: the Kinetics Time or **K time** (how long it takes for the Thromboelastogram to reach an amplitude of 20 mm) and the Angle or **alpha** (the angle of the slope from a line made between R and K). Both of these values relate to the level or functionality of fibrinogen. A **low angle or a prolonged k time suggests hypofibrinogenemia** may be an indication for cryoprecipitate or fresh frozen plasma with an equivalent amount of fibrinogen as one unit of cryoprecipitate (typically 2.5 FFP).

Platelet Mapping: Although thromboelastography has been around for over 40 years, the platelet mapping (PM) TEG was introduced closer to 10 years ago. The PM-TEG provides important clinical information that has the potential to affect perioperative blood product administration as well as feasibility of surgery on a patient who discontinued antiplatelet therapy. For example, certain patients may have Plavix (clopidogrel) resistance, and may be surgical candidates sooner than the traditional 5-day wait time. This can save the patient and hospital a considerable amount of money for an inpatient stay and allow the patient to have surgery sooner. A gene study for CYP2C19 expressed in liver metabolism could be obtained, however the test has to be outsourced, is expensive, takes 5 days. Even then, it may not yield functional or applicable information since it may not account for all gene variants. Furthermore, a gene test does not necessarily translate to gene function.

PM-TEG on the other hand specifically tests for platelet suppression as a result of drugs affecting Arachidonic Acid pathway (such as Aspirin), or ADP pathway (such as clopidogrel, ticlopidine etc.). **An mA-ADP greater than 50 is considered safe for surgery.** It should be noted that one must also take thrombocytopenia into account. Examples below of what a normal platelet mapping TEG looks like *(Tracing Courtesy Tobin Timmons, Haemonetics).*



PM-TEG ADP Assay (above)



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Equipment: There are two types of Thromboelastogram machines currently on the market. TEG (utilizes a rotating cup) is manufactured and supported by Haemonetics Corporation; which is what we will focus on since it is used at our institution. The other is ROTEM (has an immobile cup but an oscillating pin) which is discussed elsewhere.

Normal values at our institution are those from Haemonetics TEG. **It is worth noting that normal values are based on those obtained from the local/regional population for the hospital.** That is why specific normal values are not discussed. The TEG machine also requires frequent calibration (at least once a day).

Link to Haemonetics TEG animation: http://bcove.me/bh09gpoa

Haemonetics Thromboelastogram Machine (source: www.haemonetics.com)

Pitfalls: At this point you're feeling pretty good about understanding the TEG right? This brings us to a common pitfall...interpreting the values individually. The best way to interpret the Thromboelastogram is as a whole! Look at the entire picture and not isolated values. Another pitfall is not comparing the patient condition to the TEG results. Typically, the sample is heated to 37C to perform the test. However, if your patient is cold (34.5C) and your TEG values were normal in the absence of surgical bleeding, hypothermia may be a contributing cause to the coagulopathy! A final pitfall is poor sample collection or improper handling…which is particularly frustrating to the clinician. The Thromboelastogram is literally a picture of coagulation that develops over time…if results cannot be obtained in a timely fashion, a great deal of time is wasted which affects patient outcome. The only way to avoid this is to draw the blood sample for TEG at the proper time, obtain an adequate amount and send the sample in a timely fashion according to protocol.

Examples: One of the best ways to master interpretation of the TEG is to review the tracing for various clinical states.

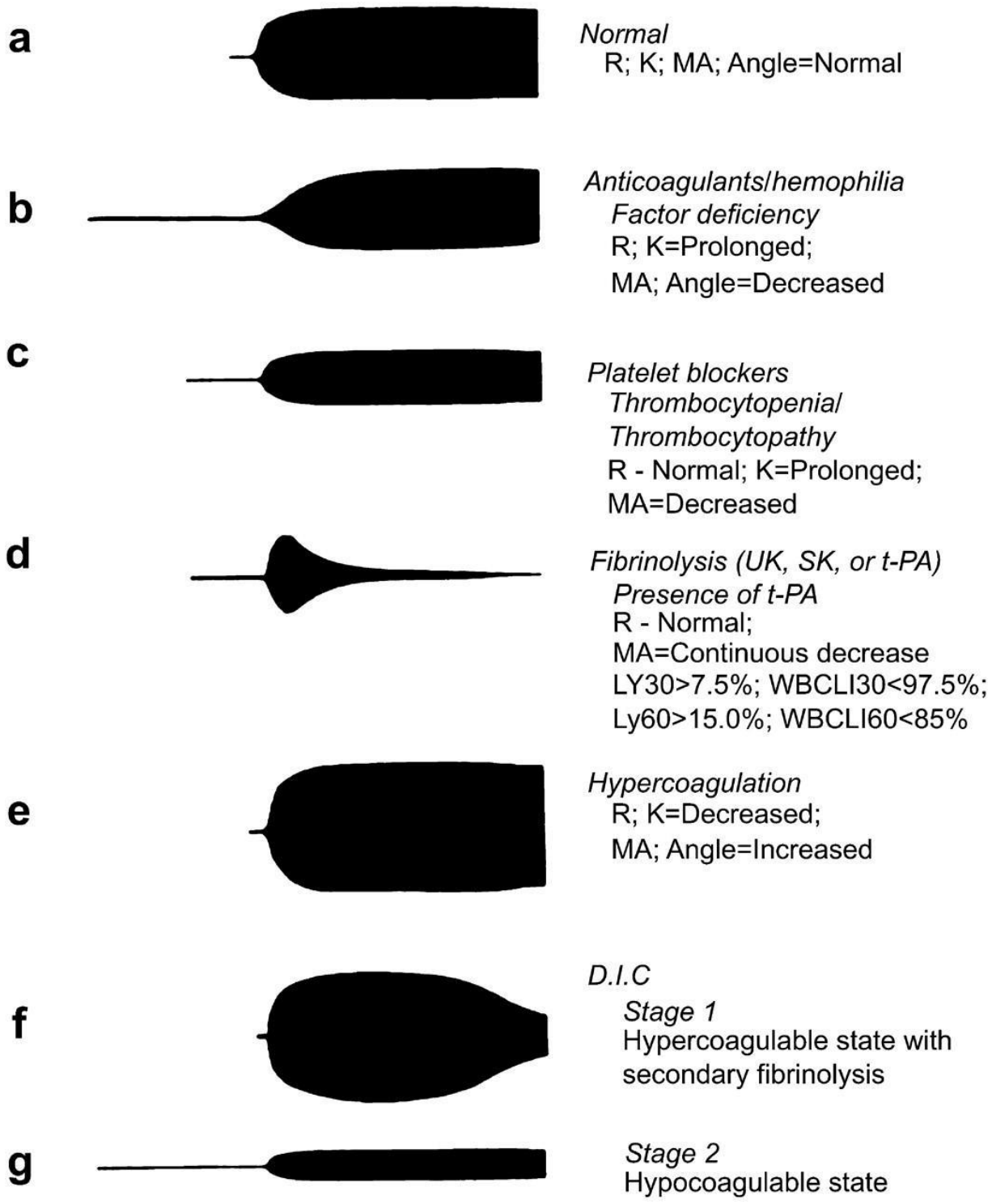

Figure (B) Unedited. See Reference Section for Source.

TEG Protocol for Trauma

1. Patient will come to the operating room *already on or to be started on the Massive Transfusion Protocol (MTP).*

2. Continue the MTP in the operating room until patient stabilizes, surgical bleeding controlled and MTP near cessation (with communication to the blood bank to stop MTP if applicable).

3. If surgeon believes all surgical bleeding is controlled *and there appears to be coagulopathic bleeding*, obtain a baseline **standard thromboelastogram, platelet count, fibrinogen count and ABG.**

4. Transfuse blood products per the TEG (Fresh Frozen Plasma, Cryoprecipitate and platelets) and ABG results (calcium, packed red blood cells).

5. All attempts and maintaining patient temperature above 36º Celsius, normocalcemia, hemodynamics, and pH will be done.

6. After approximately 60 minutes (to allow transfusion and correction of coagulopathy), if surgical bleeding is still controlled and the patient is bleeding from coagulopathy, repeat TEG, platelet count, fibrinogen count and ABG and transfuse accordingly. Repeat this process until patient bleeding is controlled. **Do not transfuse for abnormal lab results if coagulopathic bleeding is not present (i.e. don't treat the number, treat the patient).**

7. If postoperative bleeding increases or returns to abnormal levels, repeat TEG, platelet count, fibrinogen count, and ABG to determine if coagulopathy or deficiency has returned. If bleeding is severe, repeat steps 4-6 until correction of bleeding has been done and consider the possibility of returning to operating room for re-exploration of surgical bleeding.

Intra-Op Sample Draw Instructions/Protocol using standard cup

1) CRNA calls TEG lab tech directly from OR in anticipation of sample (x05268). Ordering physician is Attending Anesthesiologist for case. Circulating RN calls OR tech to room specifying: "a TEG sample needs to be sent".

2) Sample drawn after 12mL blood "waste" (returned intravenously) is drawn and sent in a blue top tube. **Also sent is a platelet count** (do not send full CBC unless otherwise indicated), **ABG,** and a **fibrinogen level** (do not send a DIC panel).

3) Sample is provided to OR Tech (PCT), with TEG lab slip, who then hand delivers sample directly to lab. Sample is accepted or rejected on the spot. Lab will call the OR directly if sample has been rejected, at which point another sample is immediately drawn and sent.

4) Approximately 10-15 minutes after the sample has been sent, circulating RN will pull up the Thromboelastogram in progress (username Trauma, password trauma). This tracing program window will not be closed until the patient leaves the room to the ICU.

Use ONE Citrate Tube (BD)

Sample Draw Instructions/Protocol (ICU Post-operative) using standard cup

1) If coagulopathic bleeding continues in ICU, and adequate time has been given to allow for recently transfused blood products to potentially correct coagulopathy, a standard TEG sample will be sent from the ICU, in addition to a **platelet count** (do not send full CBC unless otherwise indicated), **ABG,** and a **fibrinogen level** (do not send a DIC panel).

2) ICU RN or Charge RN will call TEG tech (x05268) in anticipation of sample.

3) Sample drawn after 12mL blood "waste" (returned intravenously) is drawn and sent in a blue top tube. This is hand delivered to lab.

4) Sample is accepted or rejected on the spot.

5) Real-time results will be viewable by the Trauma/ICU attending or midlevel by logging in to the TEG app in the user's Citrix dashboard (username: Trauma, password: trauma). Real-time results can be expected within the first 15 minutes.

Use ONE Citrate Tube (BD)

The next two pages can be printed separately for reference purposes as a guide.

Important notes:

Since great variation exists in thromboelastography, it is best to adopt an approach for understanding the parameters rather than rote memorization of the algorithm. The algorithm is a guide/tool to help you accomplish that goal.

When using the algorithm, circle the relative values (Normal, Increased, Decreased) starting from the top, working downward. Match the appropriate letter to the therapy.

If TEG is abnormal, first verify that the patient is not hypothermic, that blood pH is corrected, and serum calcium is at an appropriate level.

For patients with high velocity lesions, deep hypothermic circulatory arrest, moderate to severe renal dysfunction, ventricular assist devices, consider administering ddAVP and also ensuring that blood viscosity is adequate (typically a Hemoglobin of 10 gm/dL or higher).

If the patient is not bleeding, DO NOT transfuse for an abnormal TEG value unless clinically necessary. On the same note, appropriate blood component therapy earlier in patient course typically reduces overall transfusion.

The team taking care of the patient should exercise final clinical judgment and therapy. Author of this document assumes no responsibility, and no guarantees have been made. Refer to TEG manufacturer literature and relevant thromboelastography critically reviewed evidence based literature for most up-to-date information.

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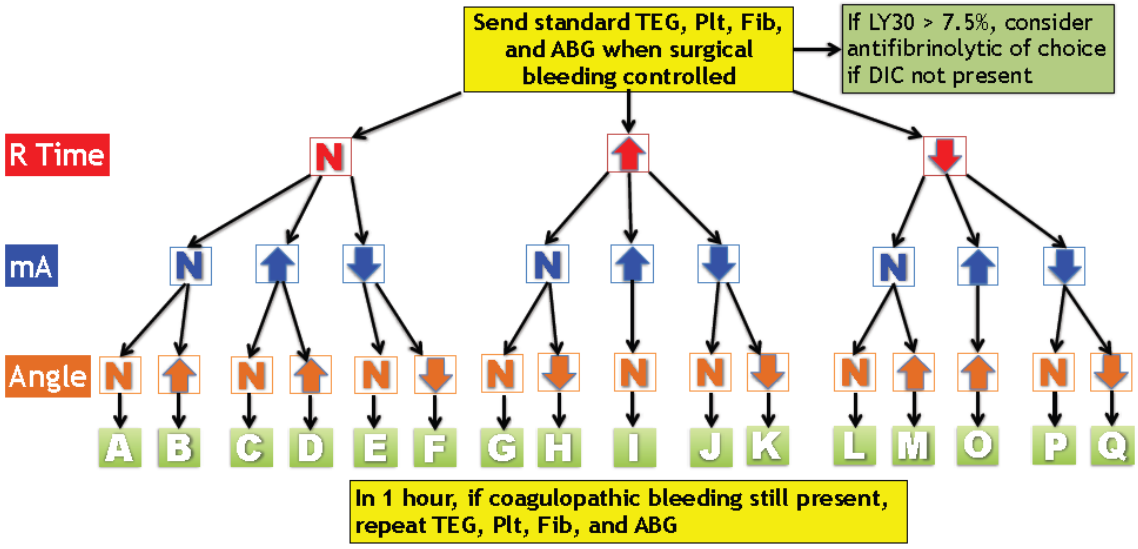

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G, H – TEG is abnormal. Clotting start time is delayed, but the clot is strong. **Transfuse 1-2 FFP and consider transfusion of cryo.**

I – TEG is abnormal. Clotting start time is delayed, but clot strength is supra normal. **Do not transfuse.** Verify correction of pH, temperature and hypocalcemia.

J – TEG is abnormal. Clotting start time is delayed and the clot is weak. **Transfuse 1-2 FFP and transfuse platelets.** If the patient has ESRD, **transfuse ddAVP**.

K – TEG is abnormal. Clotting start time is delayed and clot is weak. **Transfuse 1-2 FFP, platelets and cryo.**

L, M, O – TEG is abnormal. Patient is hypercoagulable. **Do not transfuse clotting components**. If DIC, or HIT, **consult hematologist as needed**. If patient on CPB, on ECMO, or has VAD, **verify adequate heparinization.** Patient may need AT III if no response with escalating heparin doses.

P, Q – TEG is abnormal. Clotting start time is fast, however clot is weak. Likely von Willebrand factor deficiency. **Administer ddAVP and if continued bleeding occurs, transfuse platelets and cryo.**

Suggested guide for transfusion:

Platelet Count	Platelet Transfusion	Fibrinogen	Cryo Transfusion
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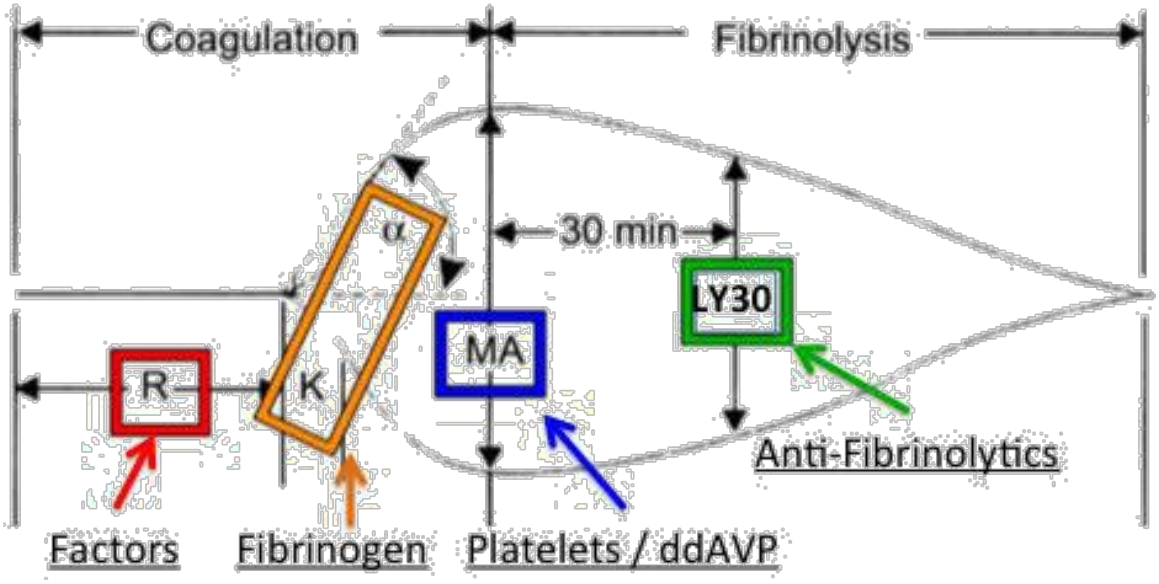
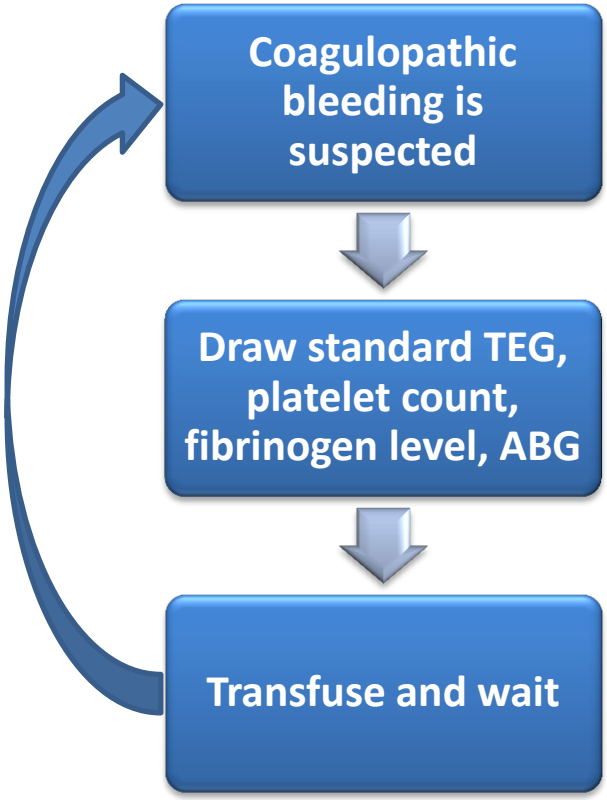
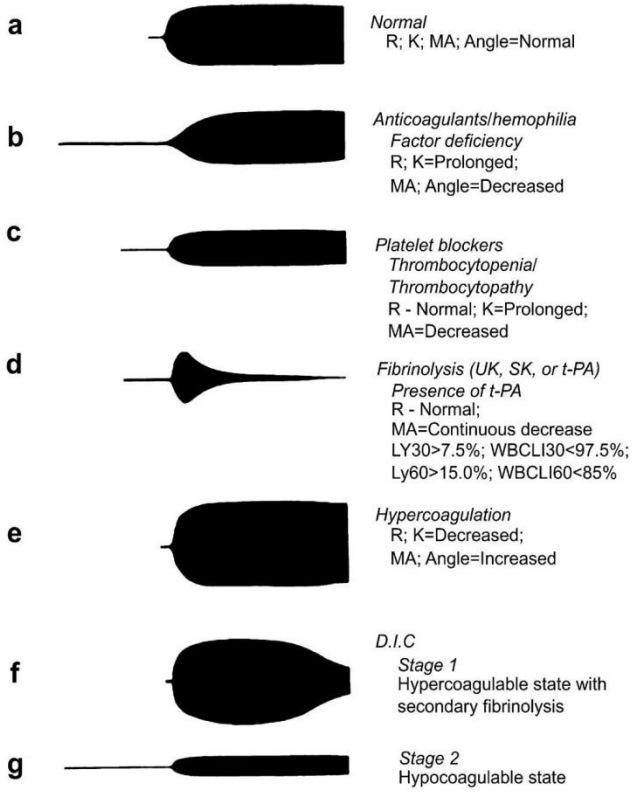


Parameter	Normal range –Standard TEG	Unit of measure
R (reaction time)	5-10	Minutes
K (Kinetic time)	1-3	Minutes
Angle	53-72	Degrees
MA (Maximum amplitude)	50-70	Millimeters
LY30 (Lysis time at 30 min)	0-8	percent





References:

Bolliger D, Seeberger MD, Tanaka KA. *Principles and practice of thromboelastography in clinical coagulation management and transfusion practice.* Transfus Med Rev. 2012 Jan;26(1):1-13.

Bowbrick VA, Mikhailidis DP, Stansby G. *The use of citrated whole blood in thromboelastography.* Anesth Analg 2000, 90:1086–88.

Chen L, Bracey AW, Radovancevic R, et al. *Clopidogrel and bleeding in patients undergoing elective coronary artery bypass grafting.* J Thorac Cardiovasc Surg 2004;128:425-31.

Collyer TC, Gray DJ, Sandhu R, Berridge J, Lyons G. *Assessment of platelet inhibition secondary to clopidogrel and aspirin therapy in preoperative acute surgical patients measured by Thrombelastography Platelet Mapping.* Br J Anaesth 2009;102:492-8.

Ganter MT, Hofer CK. *Coagulation monitoring: current techniques and clinical use of viscoelastic point-of-care coagulation devices*. Anesth Analg. 2008 May;106(5):1366 - 75.

Harr JN et. al. *Functional fibrinogen assay indicates that fibrinogen is critical in correcting abnormal clot strength following trauma.* Shock 2013, 39(1): 45–9.

Levrat A et. al. *Evaluation of rotation thrombelastography for the diagnosis of hyperfibrinolysis in trauma patients*. Br J Anaesth 2008, 100:792–7.

Kaur J, Jones N, and Mallett S. *Thrombelastography Platelet Mapping is a useful preoperative tool in surgical patients taking antiplatelet medication*. Br. J. Anaesth. (2009) 103 (2): 304-5.

Mahla E, Suarez TA, et.al. *Platelet function measurement-based strategy to reduce bleeding and waiting time in clopidogrel-treated patients undergoing coronary artery bypass graft surgery: the timing based on platelet function strategy to reduce clopidogrel-associated bleeding related to CABG (TARGET-CABG) study*. Circ Cardiovasc Interv. 2012;5:261-69.

Ronald A et al. *Can the use of TEG predict and decrease bleeding and blood product requirements in adult patients undergoing cardiac surgery?* Inter CV and Thor Surg 4 (2005) 456-63.

Shore-Lesserson L et. al. *Thromboelastography-guided transfusion algorithm reduces transfusions in complex cardiac surgery.* Anesth Analg. 1999 Feb;88(2):312-9.

Spiess BD et. al. *Thromboelastography as an indicator of post-cardiopulmonary bypass coagulopathies.* J Clin Monit. 1987 Jan;3(1):25-30.

Scarpelini S et.al. *Normal range values for thromboelastography in healthy adult volunteers.* Braz J Med Biol Res 2009, 42(12):1210–17.
Tuman KJ et al. *Evaluation of coagulation during cardiopulmonary bypass with a heparinase modified thromboelastographic assay*. J Cardiothoracic Vasc Anesth 1994; 8:144-9.

Weber CF, Klages M, Zacharowski K. *Perioperative coagulation management during cardiac surgery.* Curr Opin Anesthesiol 2013, 26:60–64.

Figures:

Figure (A) *The characteristic signature waveform output generated by the TEG analyzer (with permission from Elsevier Limited).* Kouerinis I A et al. Interact CardioVasc Thorac Surg 2008;7:560-56

Figure (B) *Unedited. Typical TEG waveforms for blood samples displaying various conditions (with permission from Elsevier Limited).* Kouerinis I A et al. Interact CardioVasc Thorac Surg 2008;7:560-563

Images*, as noted*, from Haemonetics and BD.

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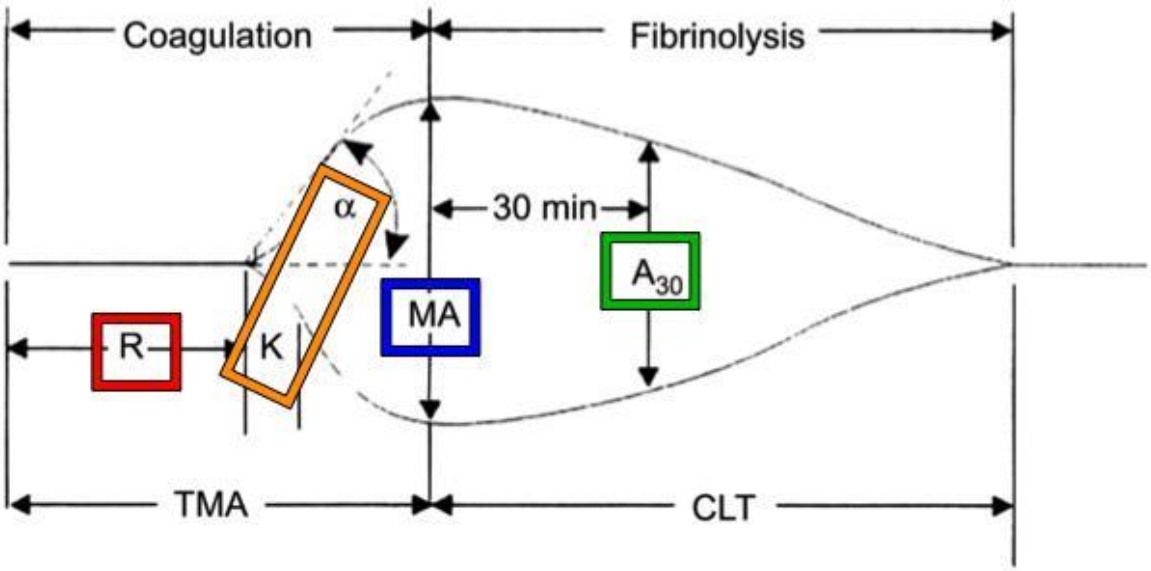

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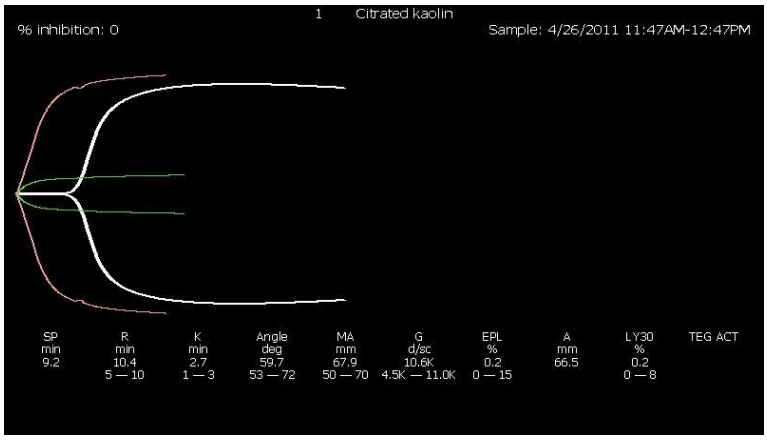

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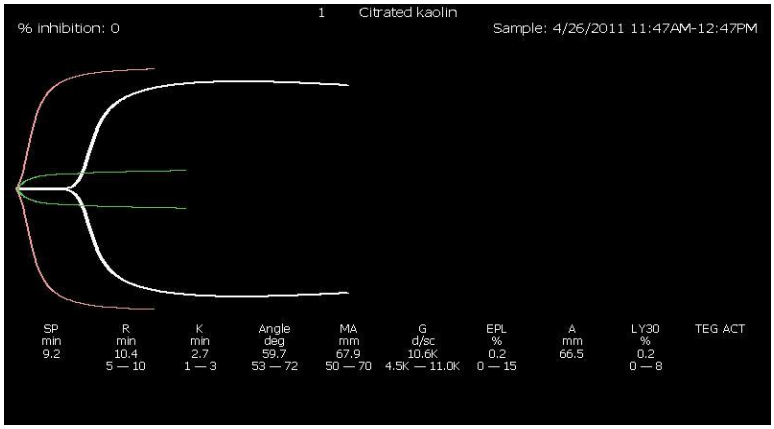

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Haemonetics Thromboelastogram Machine (source: www.haemonetics.com)

Pitfalls: At this point you're feeling pretty good about understanding the TEG right? This brings us to a common pitfall...interpreting the values individually. The best way to interpret the Thromboelastogram is as a whole! Look at the entire picture and not isolated values. Another pitfall is not comparing the patient condition to the TEG results. Typically, the sample is heated to 37C to perform the test. However, if your patient is cold (34.5C) and your TEG values were normal in the absence of surgical bleeding, hypothermia may be a contributing cause to the coagulopathy! A final pitfall is poor sample collection or improper handling…which is particularly frustrating to the clinician. The Thromboelastogram is literally a picture of coagulation that develops over time…if results cannot be obtained in a timely fashion, a great deal of time is wasted which affects patient outcome. The only way to avoid this is to draw the blood sample for TEG at the proper time, obtain an adequate amount and send the sample in a timely fashion according to protocol.

Examples: One of the best ways to master interpretation of the TEG is to review the tracing for various clinical states.

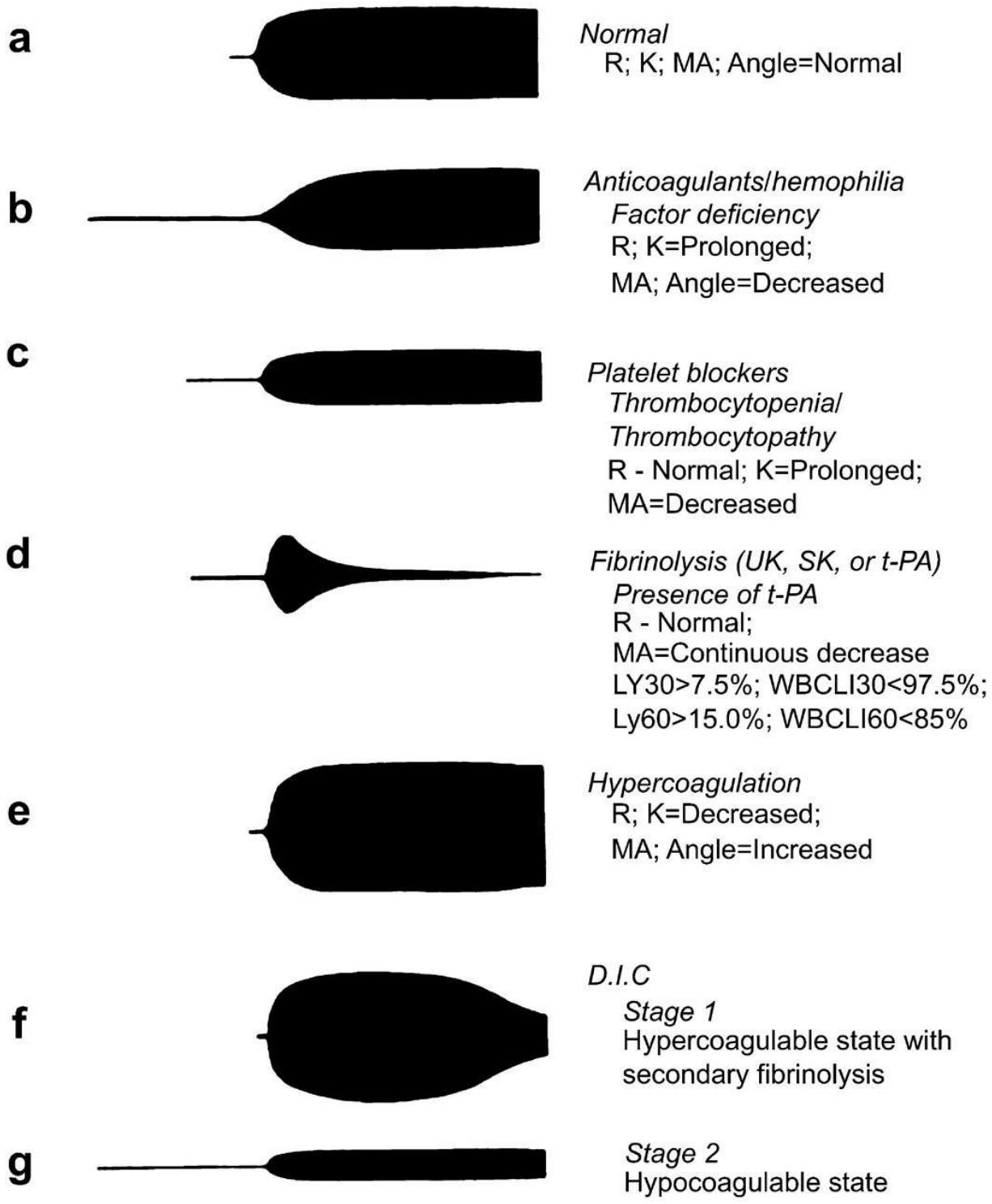


Figure (B) Unedited. See Reference Section for Source.

TEG Protocol for Trauma

1. Patient will come to the operating room *already on or to be started on the Massive Transfusion Protocol (MTP).*

2. Continue the MTP in the operating room until patient stabilizes, surgical bleeding controlled and MTP near cessation (with communication to the blood bank to stop MTP if applicable).

3. If surgeon believes all surgical bleeding is controlled *and there appears to be coagulopathic bleeding*, obtain a baseline **standard thromboelastogram, platelet count, fibrinogen count and ABG.**

4. Transfuse blood products per the TEG (Fresh Frozen Plasma, Cryoprecipitate and platelets) and ABG results (calcium, packed red blood cells).

5. All attempts and maintaining patient temperature above 36º Celsius, normocalcemia, hemodynamics, and pH will be done.

6. After approximately 60 minutes (to allow transfusion and correction of coagulopathy), if surgical bleeding is still controlled and the patient is bleeding from coagulopathy, repeat TEG, platelet count, fibrinogen count and ABG and transfuse accordingly. Repeat this process until patient bleeding is controlled. **Do not transfuse for abnormal lab results if coagulopathic bleeding is not present (i.e. don't treat the number, treat the patient).**

7. If postoperative bleeding increases or returns to abnormal levels, repeat TEG, platelet count, fibrinogen count, and ABG to determine if coagulopathy or deficiency has returned. If bleeding is severe, repeat steps 4-6 until correction of bleeding has been done and consider the possibility of returning to operating room for re-exploration of surgical bleeding.

Intra-Op Sample Draw Instructions/Protocol using standard cup

1) CRNA calls TEG lab tech directly from OR in anticipation of sample (x05268). Ordering physician is Attending Anesthesiologist for case. Circulating RN calls OR tech to room specifying: "a TEG sample needs to be sent".

2) Sample drawn after 12mL blood "waste" (returned intravenously) is drawn and sent in a blue top tube. **Also sent is a platelet count** (do not send full CBC unless otherwise indicated), **ABG,** and a **fibrinogen level** (do not send a DIC panel).

3) Sample is provided to OR Tech (PCT), with TEG lab slip, who then hand delivers sample directly to lab. Sample is accepted or rejected on the spot. Lab will call the OR directly if sample has been rejected, at which point another sample is immediately drawn and sent.

4) Approximately 10-15 minutes after the sample has been sent, circulating RN will pull up the Thromboelastogram in progress (username Trauma, password trauma). This tracing program window will not be closed until the patient leaves the room to the ICU.

Use ONE Citrate Tube (BD)

Sample Draw Instructions/Protocol (ICU Post-operative) using standard cup

1) If coagulopathic bleeding continues in ICU, and adequate time has been given to allow for recently transfused blood products to potentially correct coagulopathy, a standard TEG sample will be sent from the ICU, in addition to a **platelet count** (do not send full CBC unless otherwise indicated), **ABG,** and a **fibrinogen level** (do not send a DIC panel).

2) ICU RN or Charge RN will call TEG tech (x05268) in anticipation of sample.

3) Sample drawn after 12mL blood "waste" (returned intravenously) is drawn and sent in a blue top tube. This is hand delivered to lab.

4) Sample is accepted or rejected on the spot.

5) Real-time results will be viewable by the Trauma/ICU attending or midlevel by logging in to the TEG app in the user's Citrix dashboard (username: Trauma, password: trauma). Real-time results can be expected within the first 15 minutes.

Use ONE Citrate Tube (BD)

The next two pages can be printed separately for reference purposes as a guide.

Important notes:

Since great variation exists in thromboelastography, it is best to adopt an approach for understanding the parameters rather than rote memorization of the algorithm. The algorithm is a guide/tool to help you accomplish that goal.

When using the algorithm, circle the relative values (Normal, Increased, Decreased) starting from the top, working downward. Match the appropriate letter to the therapy.

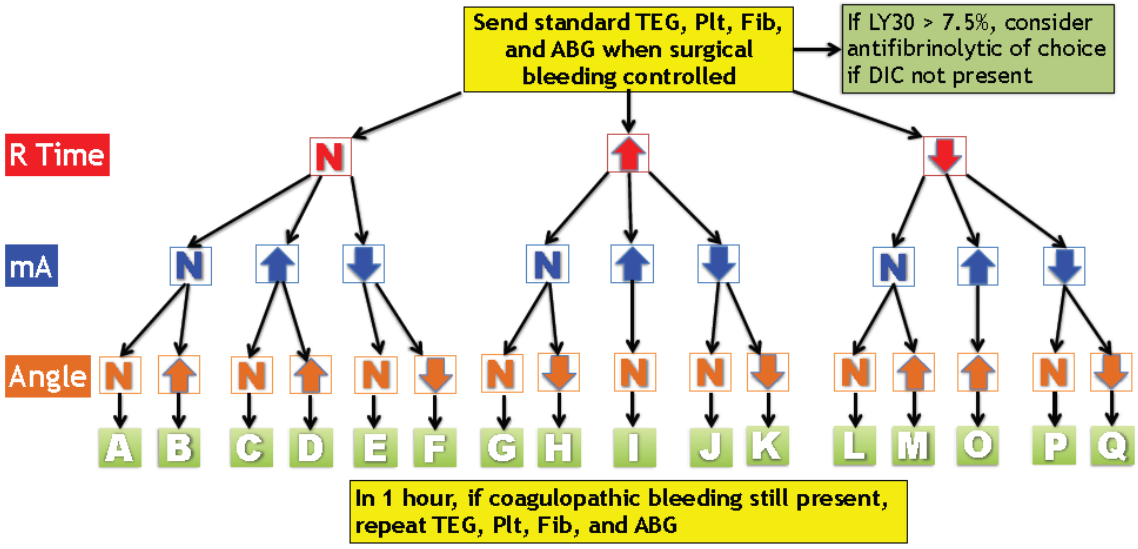
If TEG is abnormal, first verify that the patient is not hypothermic, that blood pH is corrected, and serum calcium is at an appropriate level.

For patients with high velocity lesions, deep hypothermic circulatory arrest, moderate to severe renal dysfunction, ventricular assist devices, consider administering ddAVP and also ensuring that blood viscosity is adequate (typically a Hemoglobin of 10 gm/dL or higher).

If the patient is not bleeding, DO NOT transfuse for an abnormal TEG value unless clinically necessary. On the same note, appropriate blood component therapy earlier in patient course typically reduces overall transfusion.

The team taking care of the patient should exercise final clinical judgment and therapy. Author of this document assumes no responsibility, and no guarantees have been made. Refer to TEG manufacturer literature and relevant thromboelastography critically reviewed evidence based literature for most up-to-date information.

TEG Therapy Algorithm for Clotting Dysfunction for Trauma



A, B – TEG is normal. **Do not transfuse clotting components**. Consider transfusion of PRBC if profound anemia and blood viscosity is low. Correct pH, temperature and Calcium if abnormal.

C, D – TEG is normal, with supra-normal clot strength. **Do not transfuse clotting components.** Consider transfusion of PRBC if profound anemia and blood viscosity is low. Correct pH, temperature and Calcium if abnormal.

E – TEG is abnormal. Clotting start time and clot formation rate are normal, but the clot is weak. The patient is either thrombocytopenic or the platelets are dysfunctional. **Transfuse platelets.** If the patient has ESRD, **transfuse ddAVP**.

F – TEG is abnormal. Clotting start time is normal, but the clot is weak and rate of clotting is slow. **Transfuse platelets and cryo.**

G, H – TEG is abnormal. Clotting start time is delayed, but the clot is strong. **Transfuse 1-2 FFP and consider transfusion of cryo.**

I – TEG is abnormal. Clotting start time is delayed, but clot strength is supra normal. **Do not transfuse.** Verify correction of pH, temperature and hypocalcemia.

J – TEG is abnormal. Clotting start time is delayed and the clot is weak. **Transfuse 1-2 FFP and transfuse platelets.** If the patient has ESRD, **transfuse ddAVP**.

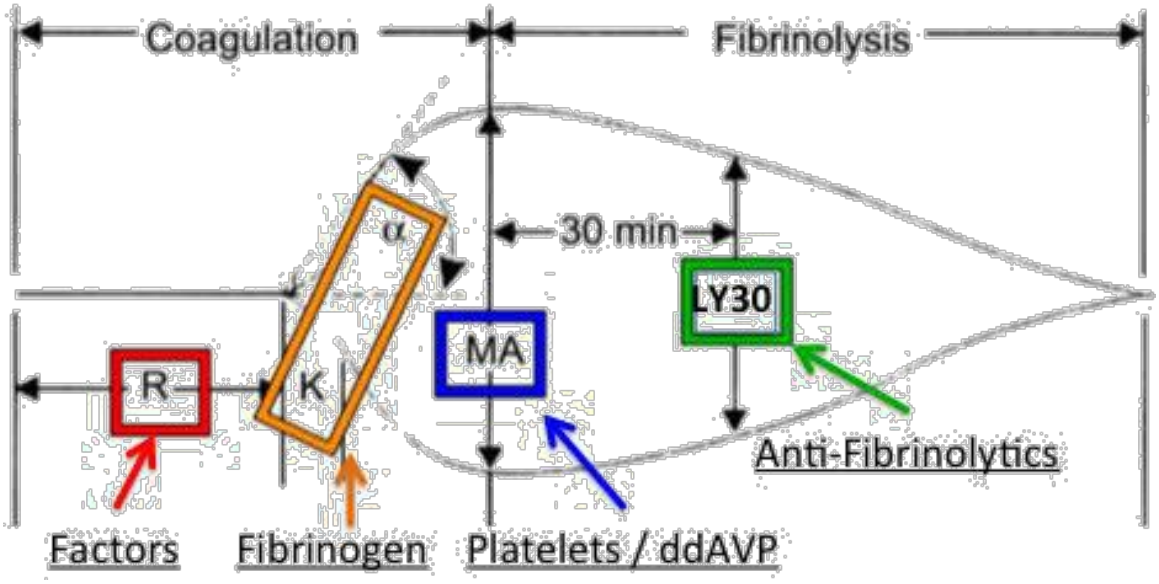
K – TEG is abnormal. Clotting start time is delayed and clot is weak. **Transfuse 1-2 FFP, platelets and cryo.**

L, M, O – TEG is abnormal. Patient is hypercoagulable. **Do not transfuse clotting components**. If DIC, or HIT, **consult hematologist as needed**. If patient on CPB, on ECMO, or has VAD, **verify adequate heparinization.** Patient may need AT III if no response with escalating heparin doses.

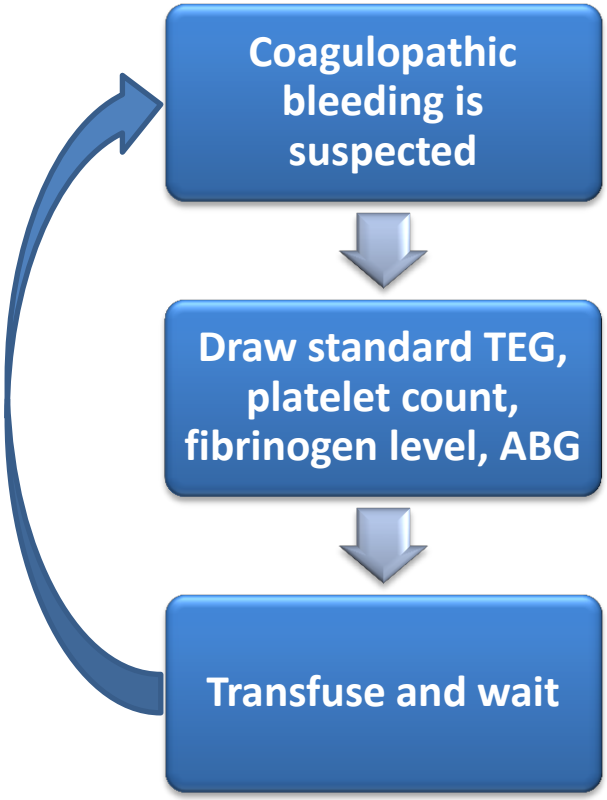
P, Q – TEG is abnormal. Clotting start time is fast, however clot is weak. Likely von Willebrand factor deficiency. **Administer ddAVP and if continued bleeding occurs, transfuse platelets and cryo.**

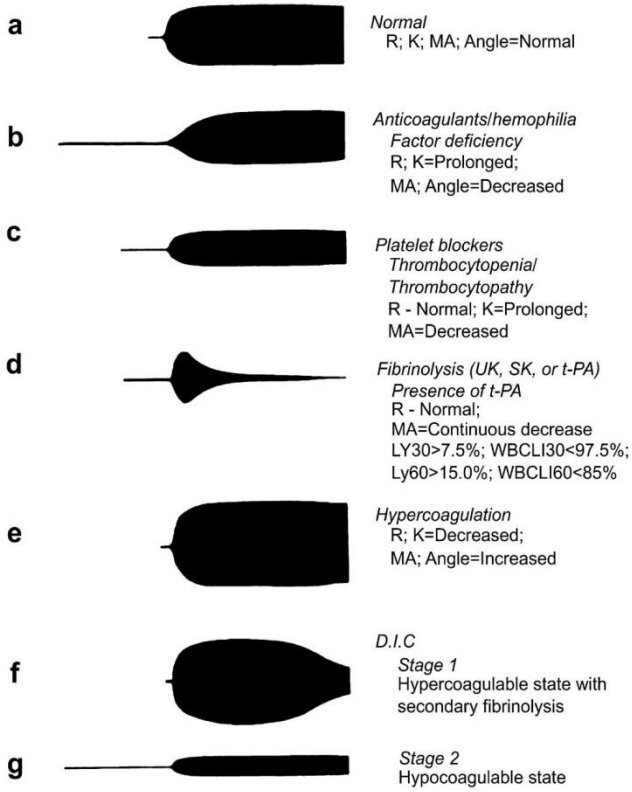
Suggested guide for transfusion:

Platelet Count	Platelet Transfusion	Fibrinogen	Cryo Transfusion
<50,000	2 units of platelets	<100	2 units of cryo
<75,000	1 units of platelets	<150	1 unit of cryo



Parameter	Normal range –Standard TEG	Unit of measure
R (reaction time)	5-10	Minutes
K (Kinetic time)	1-3	Minutes
Angle	53-72	Degrees
MA (Maximum amplitude)	50-70	Millimeters
LY30 (Lysis time at 30 min)	0-8	percent





References:

Bolliger D, Seeberger MD, Tanaka KA. *Principles and practice of thromboelastography in clinical coagulation management and transfusion practice.* Transfus Med Rev. 2012 Jan;26(1):1-13.

Bowbrick VA, Mikhailidis DP, Stansby G. *The use of citrated whole blood in thromboelastography.* Anesth Analg 2000, 90:1086–88.

Chen L, Bracey AW, Radovancevic R, et al. *Clopidogrel and bleeding in patients undergoing elective coronary artery bypass grafting.* J Thorac Cardiovasc Surg 2004;128:425-31.

Collyer TC, Gray DJ, Sandhu R, Berridge J, Lyons G. *Assessment of platelet inhibition secondary to clopidogrel and aspirin therapy in preoperative acute surgical patients measured by Thrombelastography Platelet Mapping.* Br J Anaesth 2009;102:492-8.

Ganter MT, Hofer CK. *Coagulation monitoring: current techniques and clinical use of viscoelastic point-of-care coagulation devices*. Anesth Analg. 2008 May;106(5):1366 - 75.

Harr JN et. al. *Functional fibrinogen assay indicates that fibrinogen is critical in correcting abnormal clot strength following trauma.* Shock 2013, 39(1): 45–9.

Levrat A et. al. *Evaluation of rotation thrombelastography for the diagnosis of hyperfibrinolysis in trauma patients*. Br J Anaesth 2008, 100:792–7.

Kaur J, Jones N, and Mallett S. *Thrombelastography Platelet Mapping is a useful preoperative tool in surgical patients taking antiplatelet medication*. Br. J. Anaesth. (2009) 103 (2): 304-5.

Mahla E, Suarez TA, et.al. *Platelet function measurement-based strategy to reduce bleeding and waiting time in clopidogrel-treated patients undergoing coronary artery bypass graft surgery: the timing based on platelet function strategy to reduce clopidogrel-associated bleeding related to CABG (TARGET-CABG) study*. Circ Cardiovasc Interv. 2012;5:261-69.

Ronald A et al. *Can the use of TEG predict and decrease bleeding and blood product requirements in adult patients undergoing cardiac surgery?* Inter CV and Thor Surg 4 (2005) 456-63.

Shore-Lesserson L et. al. *Thromboelastography-guided transfusion algorithm reduces transfusions in complex cardiac surgery.* Anesth Analg. 1999 Feb;88(2):312-9.

Spiess BD et. al. *Thromboelastography as an indicator of post-cardiopulmonary bypass coagulopathies.* J Clin Monit. 1987 Jan;3(1):25-30.

Scarpelini S et.al. *Normal range values for thromboelastography in healthy adult volunteers.* Braz J Med Biol Res 2009, 42(12):1210–17.
Tuman KJ et al. *Evaluation of coagulation during cardiopulmonary bypass with a heparinase modified thromboelastographic assay*. J Cardiothoracic Vasc Anesth 1994; 8:144-9.

Weber CF, Klages M, Zacharowski K. *Perioperative coagulation management during cardiac surgery.* Curr Opin Anesthesiol 2013, 26:60–64.

Figures:

Figure (A) *The characteristic signature waveform output generated by the TEG analyzer (with permission from Elsevier Limited).* Kouerinis I A et al. Interact CardioVasc Thorac Surg 2008;7:560-56

Figure (B) *Unedited. Typical TEG waveforms for blood samples displaying various conditions (with permission from Elsevier Limited).* Kouerinis I A et al. Interact CardioVasc Thorac Surg 2008;7:560-563

Images*, as noted*, from Haemonetics and BD.