Controlling Hemorrhage and Clotting: What's on the Horizon?

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McCAIG INSTITUTE FOR BONE AND JOINT HEALTH

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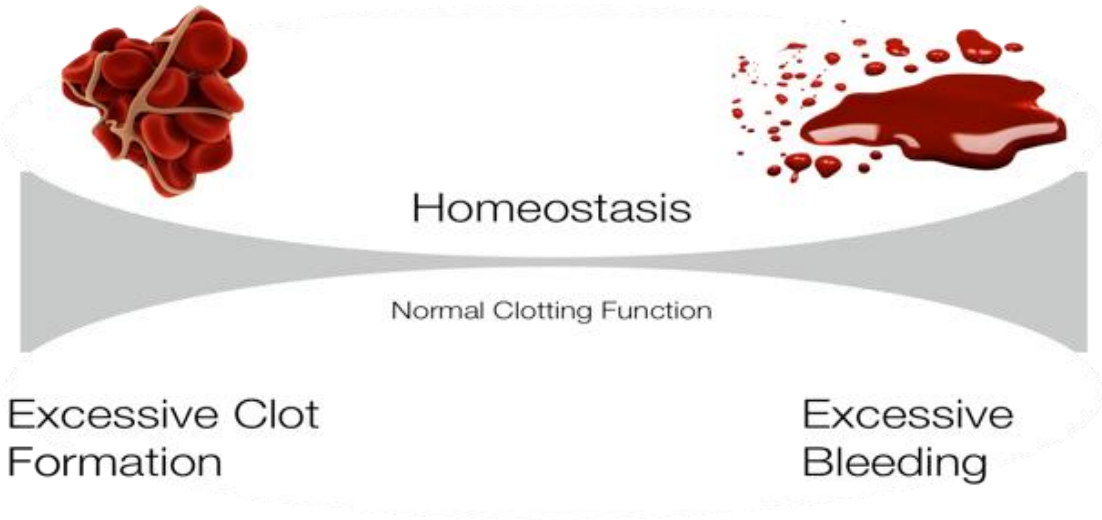
  - Canadian Journal of Surgery

Objectives

- **Trauma-induced Coagulopathy**
- **Noncompressible Truncal Hemorrhage**
  - REBOA
  - Intracavity self-expanding foam
  - Abdominal Aortic Junctional Tourniquet
- **Extremity Hemorrhage**
  - Tourniquet Use Revisited
- **Viscoelastic Assays**
  - Personalized Resuscitation
  - Personalized Thromboprophylaxis

Trauma-induced Coagulopathy

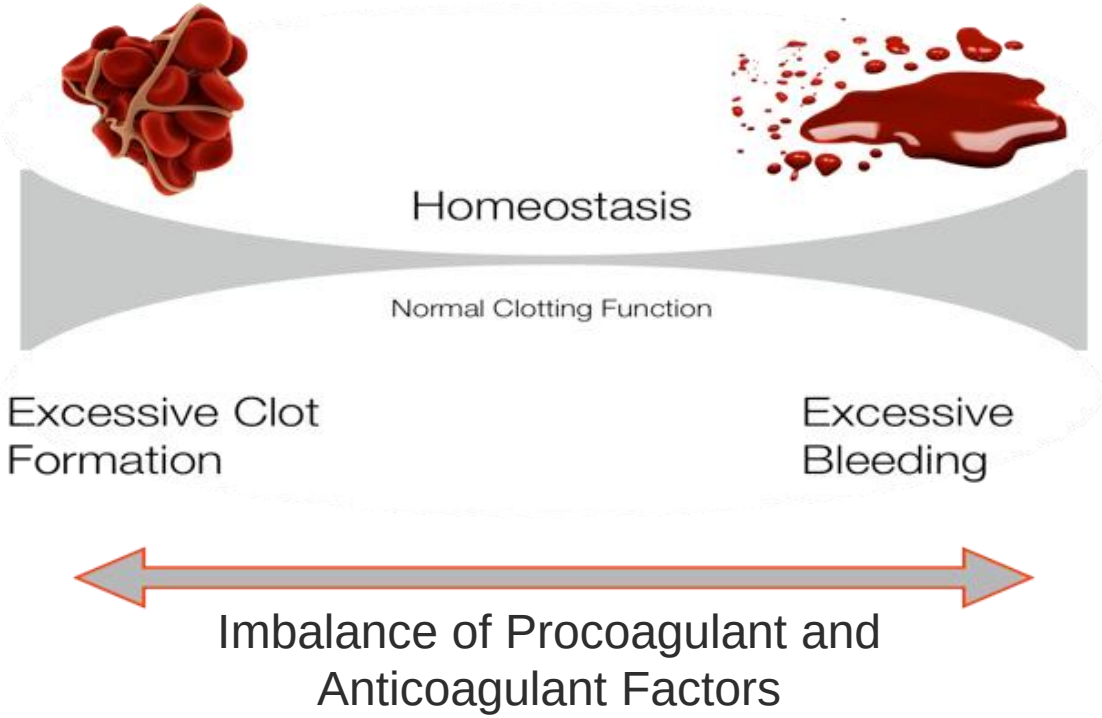
TIC is a spectrum of disrupted clotting function that ranges from excessive bleeding to excessive clotting



Trauma-induced Coagulopathy

Hemorrhage is the leading cause of potentially survivable death after trauma

Venous thromboembolism remains a leading cause of morbidity and mortality following trauma



Noncompressible Truncal Hemorrhage

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Early interventions that may improve survival:

- Resuscitative endovascular balloon occlusion of the aorta (REBOA)
- Injection of intracavitary self-expanding foam
- Abdominal Aortic Junctional Tourniquet (AAJT™)

REBOA

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Resuscitative Endovascular Balloon Occlusion of the Aorta

- A minimally invasive technique using a balloon catheter to temporarily occlude large vessels for hemorrhage control

- Potential indications:
  - Pre-hospital setting
  - Transfer to another hospital
  - Transfer to the OR
  - Postpartum hemorrhage
  - Adjunct to surgical procedures

REBOA

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REBOA

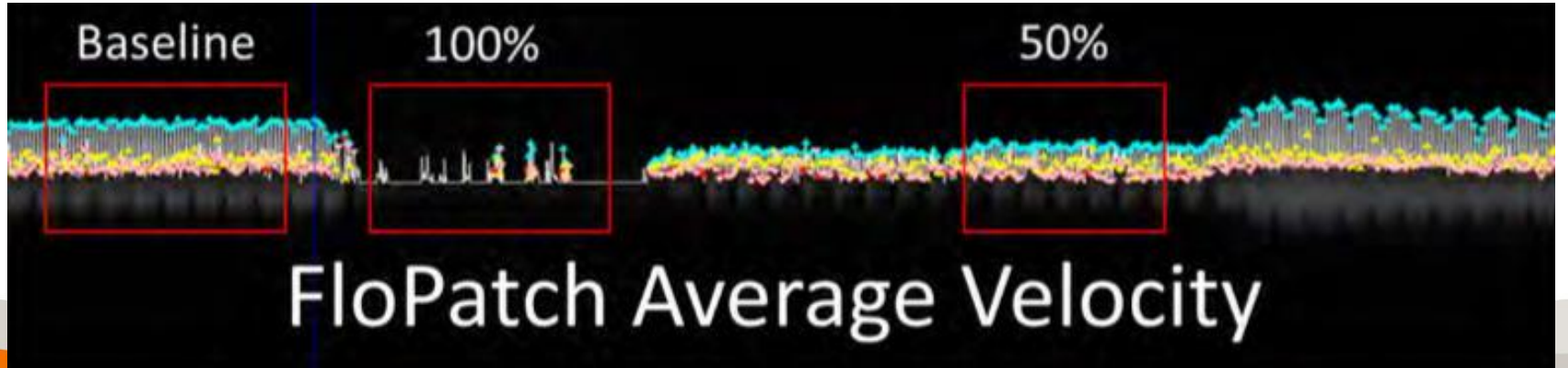
- Depending on the location, can be inflated for a maximum of 30 to 60 minutes

- REBOA is not recommended in patients with evidence of significant injury above the diaphragm
  - its use could elevate proximal blood pressure and increase hemorrhage

REBOA

- Partial REBOA (p-REBOA) is an emerging technique to maintain favourable hemodynamics with less distal ischemia than continuous occlusion

- FloPatch – wireless, wearable doppler ultrasound to monitor pressure



Abdominal Aortic Junctional Tourniquet

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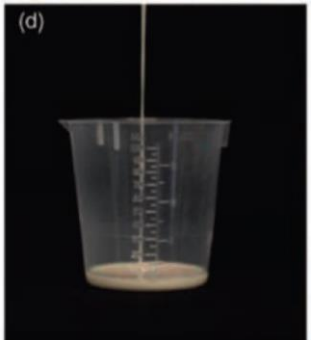
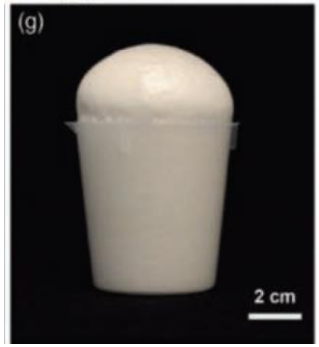
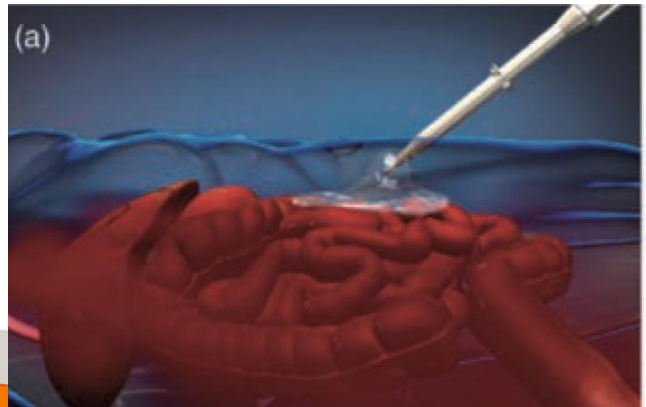
- Applied to the mid-abdomen of a patient
- A pneumatic bladder is then inflated, putting pressure on the aortic bifurcation, until distal pulses are no longer felt
- Requires minimal training
- Designed for field application
- Can be placed by nonmedical personnel

Self-expanding Intracavity Foams

- ResQFoam - 2 liquids percutaneously injected into the abdomen create an expanding foam, leading to a direct tamponade
- Laparotomy at receiving centre
- Recently FDA approved







Noncompressible Truncal Hemorrhage

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Methods for Early Control of Abdominal Hemorrhage

An Assessment of Potential Benefit

Paul M. Cantle, MD, MBT, FRCSC[1]; Matthew J. Hurley, BSc[2]; Michael D. Swartz, PhD[3]; John B. Holcomb, MD, FACS[4]*

- Single-centre retrospective study of 402 patients with laparotomy
- No statistically significant difference in the potential scope of applicability between REBOA and ResQFoam
- REBOA was potentially beneficial for hemorrhage control in 96% of patients, ResQFoam in 87%, and AAJT in 9%

Tourniquet Use for Extremity Hemorrhage

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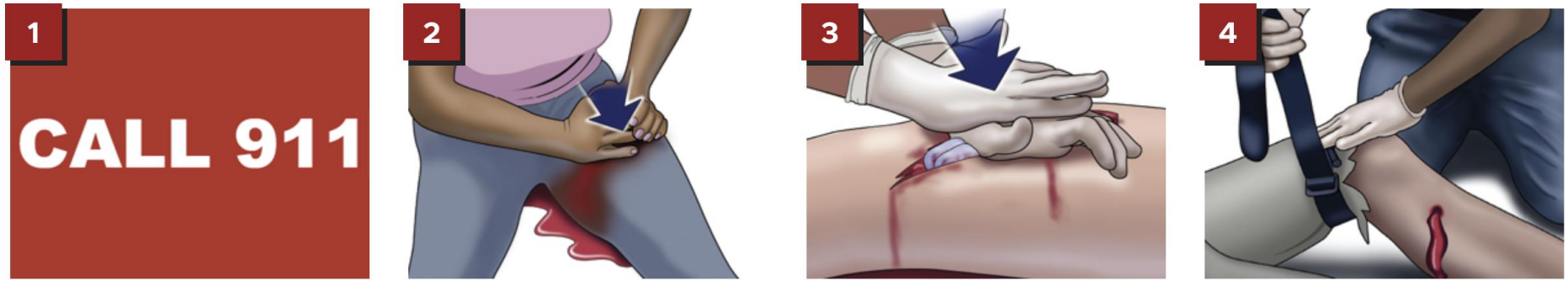
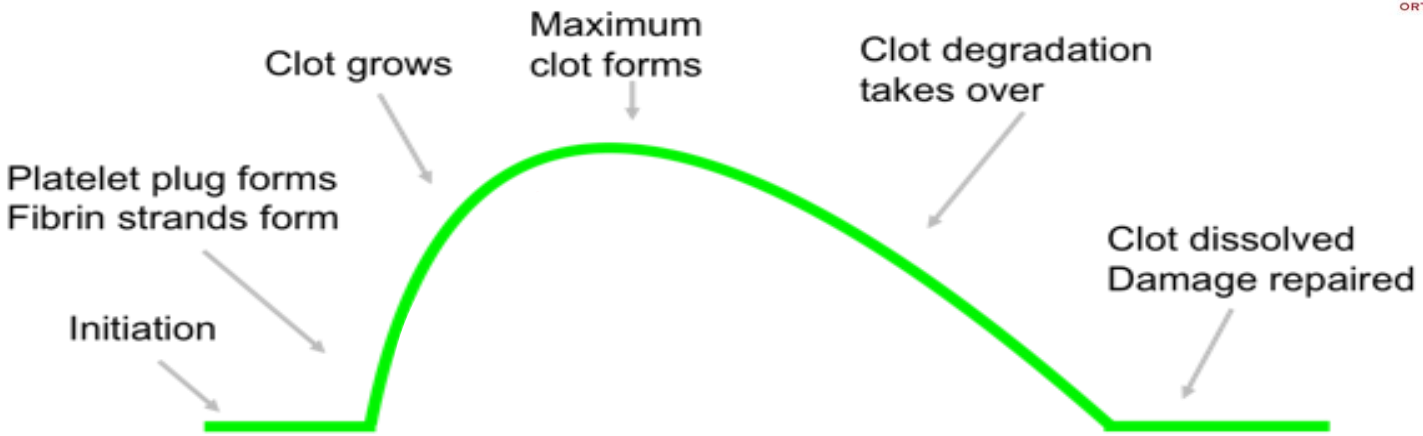
American College of Surgeons (ACS)
ACS Committee on Trauma (ACS COT)

STOP THE BLEED®



Call 911 | Apply Pressure with Hands | Pack Wound and Press | Apply Tourniquet

Limitations of Conventional Coagulation Tests



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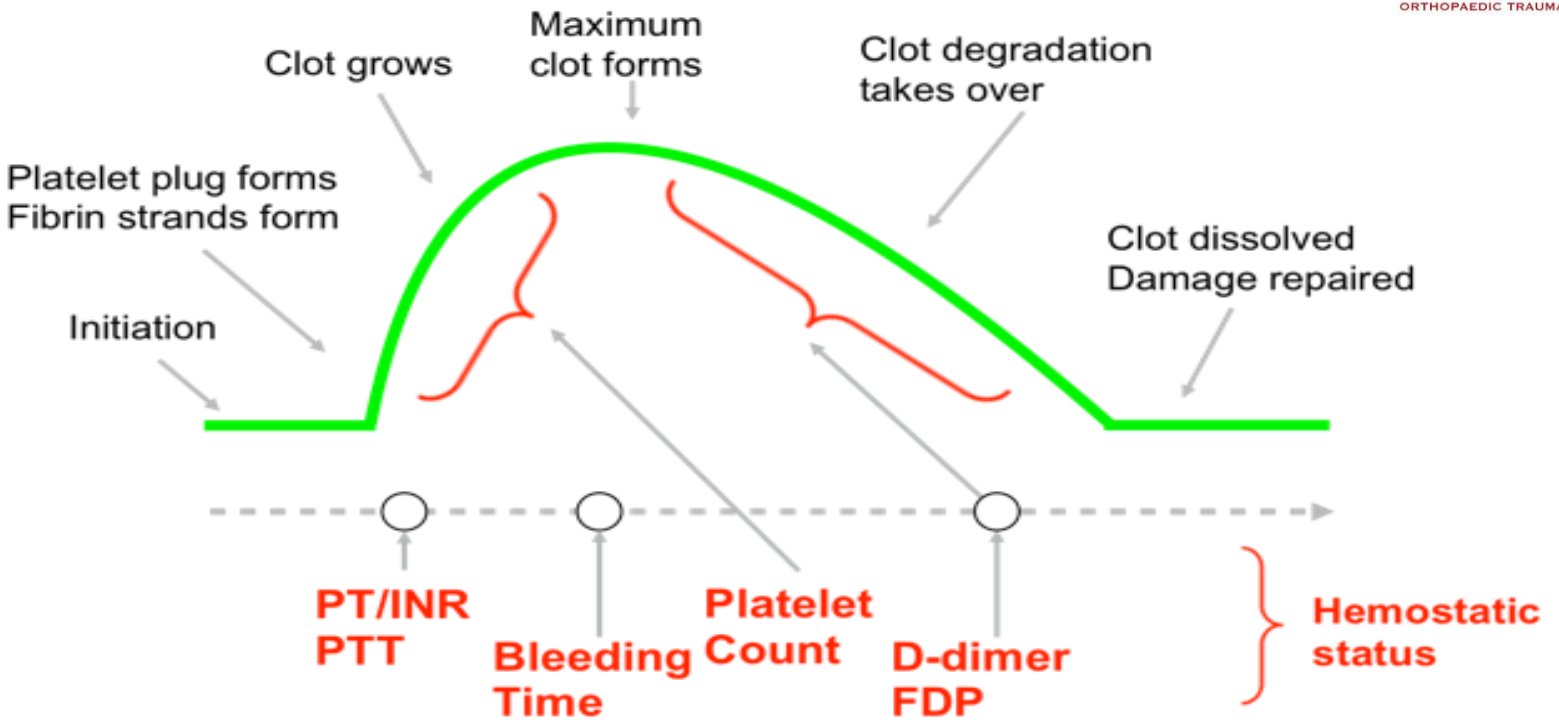


Traditional Hemostasis Tests → Do not define the overall process, just provide pieces of the process!

Viscoelastic Assays

TEG and ROTEM

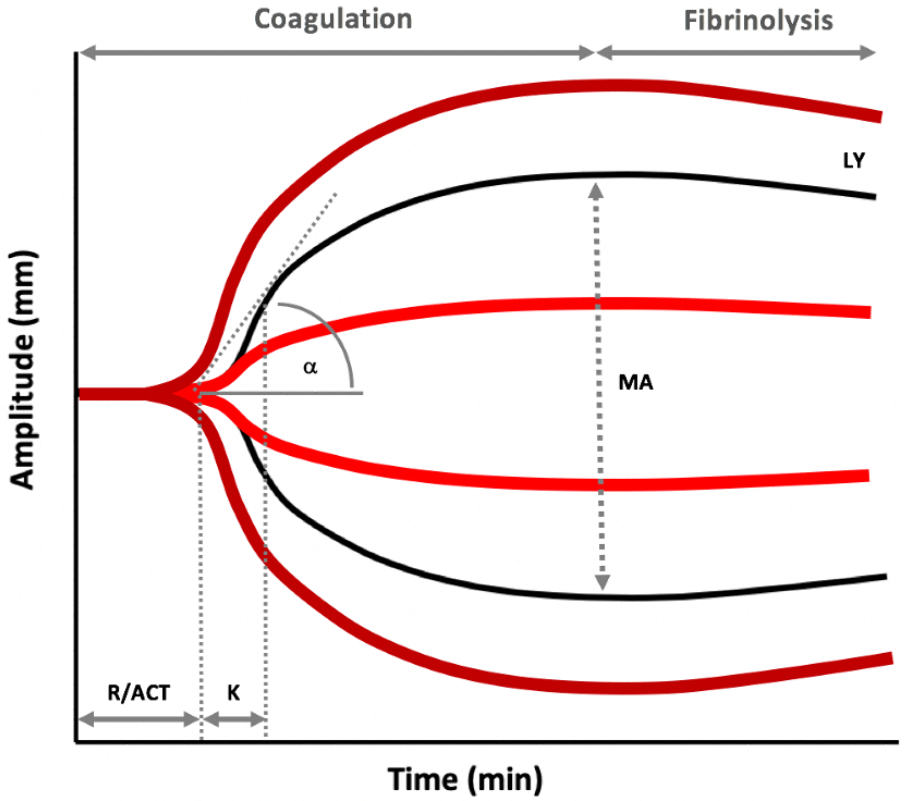
Thrombelastography (TEG) assesses whole blood (including platelets)

- Representation of what is happening *in vivo*
- Point-of-care tool

Thrombelastography

TEG Parameter	Coagulation Measure
Reaction time (R-time) **Activated clotting time (ACT)**	Clot Initiation
Kinetic time (K-time) **Alpha-angle**	Clot Propagation
Maximal amplitude (MA)	Maximal Clot Strength
Lysis30 (LY30)	Fibrinolysis

- TEG is a whole blood test capable of measuring hypo- and hypercoagulable states
- Insights into pathophysiology



Viscoelastic Assays

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Surgical Innovation

Thromboelastography-Guided Resuscitation of the Trauma Patient

Madhu Subramanian, MD; Lewis J. Kaplan, MD; Jeremy W. Cannon, MD, SM

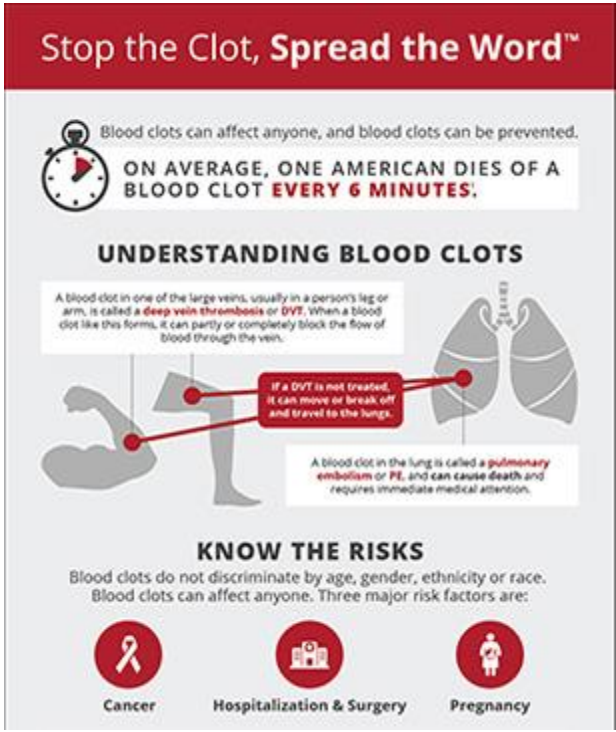
- Goal-directed resuscitation based on TEG has been shown to:
  - Use less plasma and platelet transfusions[1]
  - Improve survival compared to massive transfusion protocols guided by conventional coagulation assessment[2]
- Can be used to guide pathologies of fibrinolysis and guide treatment with tranexamic acid (i.e. >3% fibrinolysis for initiation)[3]

1. Holcomb et al Ann Surg 2012, 2. Gozalez et al Ann Surg 2016, 3. Chapman et al J Trauma Scute Care Surg 2013

Burden of Venous Thromboembolism (VTE)

- ***Life-threatening*** thromboses after injury continue to be devastating complications
  - Pulmonary embolism (PE) is a ***significant cause of preventable death***
  - Deep vein thrombosis (DVT) can cause significant dysfunction

- Major orthopaedic fracture is an independent risk factor for VTE
  - 7-fold increased risk for VTE, ***despite thromboprophylaxis***[4]



4. Gary, Schneider et al. *J Ortho Trauma 2018*

VTE and Viscoelastic Assay Research

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Thrombelastography (TEG) can measure increased VTE risk[4-6]

Can Thrombelastography Predict Venous Thromboembolic Events in Patients With Severe Extremity Trauma?

Joshua L. Gary, MD, Prism S. Schneider, MD, PhD,* Matthew Galpin, RC,* Zayde Radwan, MD,* John W. Munz, MD,* Timothy S. Achor, MD,* Mark L. Prasarn, MD,* and Bryan A. Cotton, MD†*

Elevated MA = independent predictor of *in-hospital* VTE

MA > 65 mm (OR = 3.7, 95% CI 1.9-7.0)

4. Gary, Schneider et al J Orthop Trauma. 2016 Jun; 30(6):294-8; 5. Brill et al J Trauma Acute Care Surg. 2017 Sep; 83(3):413-19; 6. Kashuk et al Surgery. 2009 Oct; 146(4):764-72

VTE and Viscoelastic Assay Research

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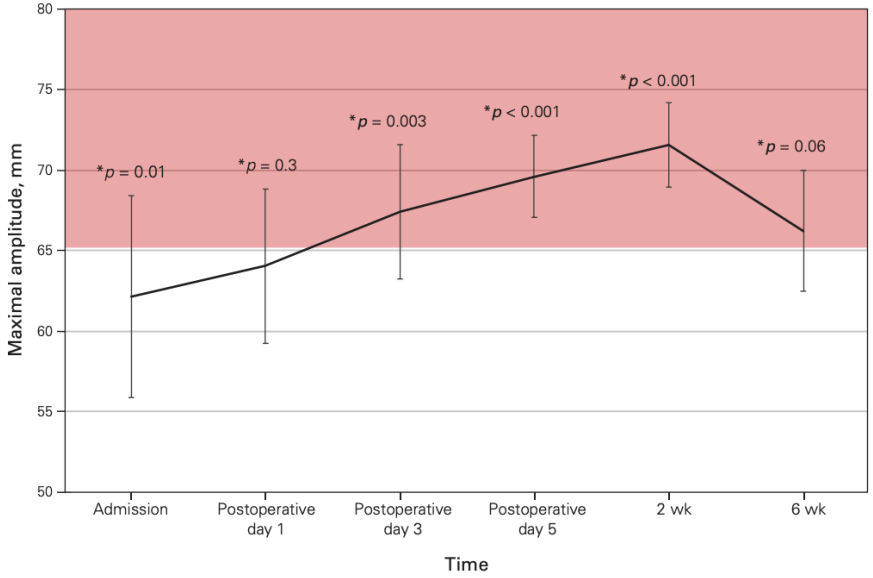
Patients with hip fractures have prolonged hypercoagulability

HEALTH and FAITH studies (n = 2,520)
45.3% of VTE occurred 6-weeks post-injury or later[8]

Daniel You, MD
Leslie Skeith, MD, MHPE
Robert Korley, MD
Paul Cantle, MD, MBT
Adrienne Lee, MD
Paul McBeth, MD, MASc
Braedon McDonald, MD, PhD
Richard Buckley, MD
Paul Duffy, MD
C. Ryan Martin, MD
Andrea Soo, PhD
Prism Schneider, MD, PhD

Identification of hypercoagulability with thrombelastography in patients with hip fracture receiving thromboprophylaxis

Can J Surg 1 Jun; 64(3):E324-29



7. You et al Can J Surg. 2021 Jun; 64(3):E324-29;
8. MacDonald et al *J Orthop Trauma* **34**, S70–S75 (2020).

VTE and Viscoelastic Assay Research

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Extremity Trauma Results in Severe Coagulopathy and Impaired Fibrinolysis Based on Serial TEG

Prism S. Schneider MD, PhD, FRCS; Elaheh Rahbar PhD; Ioannis N. Liras; Mark L. Prasarn MD; Joshua L. Gary MD; Bryan A. Cotton MD, MPH

- 340 Level 1 trauma activations with 5 day serial TEG
- ORTHO (N = 75) vs. CONTROLS (N = 265)
- ORTHO group demonstrated **6-fold increased risk of VTE**
- ORTHO group had **decreased fibrinolysis** which may explain the higher VTE rates

Thrombelastography Platelet Mapping (PLM)

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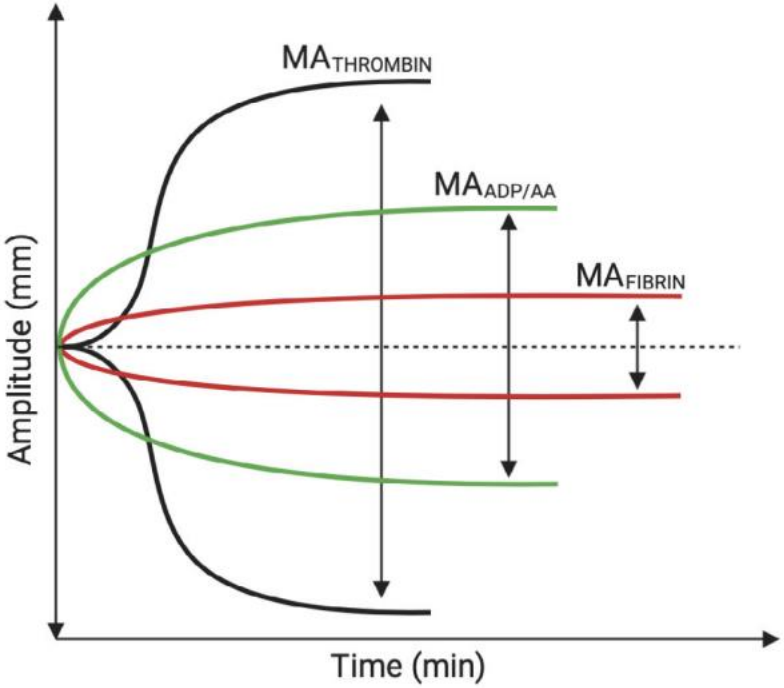
Analysis of Platelet Function

- Factor XIII (Activator F) generates a fibrin cross-linked clot
  - Contribution of fibrin
- Addition of adenosine diphosphate (ADP)
  - Contribution of ADP receptors
  - P2Y12 receptor antagonist
- Addition of arachidonic acid (AA)
  - Contribution of thromboxane A2 receptors
  - Thromboxane A2 synthesis inhibitors

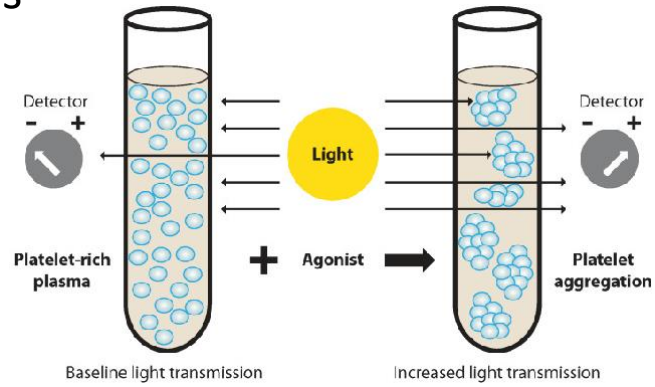


Thrombelastography Platelet Mapping (PLM)

Cardiac Sciences uses TEG-PM for:[9-11]

- Measurement of platelet inhibition
- Measurement of resistance to anti-platelets
- Patient-specific antiplatelet prescription based on Platelet Mapping

- Strong correlation between light transmission aggregometry and TEG-PLM values



9. Ghamraoui et al J Vascular Surg (2002); 10. Lochsen L et al. J Thrombosis (2007) 5, 3; 11 Dalal et al Indian Heart Journal (2016) 16: 624-632

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