Emerging Use Of Rotational Thromboelastometry (ROTEM) in Trauma Resuscitation

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Goals of this session:

1. Identify the deadly triad in trauma, the goal of damage control resuscitation and how coagulopathy requires aggressive and specific therapy.

2. Recognize what ROTEM® is and how it is used.

3. Discuss the case based resuscitation; how the results were interpreted and problems addressed.

4. Discuss how goal directed resuscitation based on ROTEM® results will be the standard of trauma care in the future.
Disclosures

• I am a member of the Canadian Armed Forces, and my attendance is paid for by them.

• ROTEM® is a commercial company whose product is used by the CAF.

• I have no financial interest in the company nor products described in this presentation.
Case

- 22 yo male
- GSW to pelvic/leg region
- Arriving 75 minutes from injury
- TCCC level care – TK, pressure bandage, IV
- Reports that bleeding is not well controlled
- BP 80/40, HR 120, 90%, RR 15
What would you do?
Damage Control Resuscitation (DCR)

Damage control is now a commonly used medical term; however, the original meaning comes from naval forces. It refers to the actions taken to avoid the sinking of a damaged ship, by concentrating the efforts on those crucial to the ship’s survival before definitive repair when in port.

The initial concept was Damage Control Surgery (DCS) allowing surgeons to quickly intervene and control bleeding and other immediate life-threatening conditions.

Damage Control Resuscitation may be defined as a systematic approach to resuscitating critically injured trauma patients along the entire continuum of care;

This is accomplished through aggressive hemorrhage control (including DCS as required) and blood transfusion, which restores tissue oxygenation and not only avoids platelet and coagulation factor dilution, but also replaces lost hemostatic potential.
Damage Control Resuscitation (DCR)

Limit and attempt to prevent:

- Acidosis
- Hypothermia
- Coagulopathy

**Acute Coagulopathy of Trauma Shock (ACoTS)**
Gorlinger et al, Rotational Thromboelastometry, 2016
Things you should do....

Activate blood bank / massive transfusion protocol

Notify the surgical team

ATLS
- Airway
- Breathing
- Circulation
- Disability
- Expose/Environmental control
  (Everything Else)

Lab:
- Blood typing, INR/PTT, CBC, Lactate, blood gas, Chemistry...

22 yo male
GSW to pelvic/leg region
TK, pressure bandage, IV

- **Vitals:**
  - BP- 67/40,
  - HR 41,
  - Resp 6,
  - Sats 71%,
  - T 33

- **Initial Labs:**
  - INR >8,
  - Hbg 65,
  - Hct 0.197,
  - PLT 146
  - Venous pH 6.59
  - Ca 0.94

- **What is your strategy?**
Case – What can we do?

- Tranexamic Acid 1g + 1g
- Blood products: Protocol-Driven / RATIO-Driven Resuscitation
  - 1:1:1 Transfusion PRBC:FFP:PLT ......But:
    - FFP can only be thawed 4 bags every 20 minutes
    - No Platelets Available!!!
    - Fresh Whole Blood (perfect 1:1:1 product) ?
  - Fibrinogen/Cryoprecipitate?
- Optimization of OTHER FACTORS
  - Acidosis Management – Intubation, ventilation
  - Temperature Management – warmed blood, BAIR hugger
  - Maintenance of Calcium
  - Limit crystalloids to avoid hemodilution
In surgery, wounds are oozing, and abdomen is filling with fluids and blood products. The Patient is still bleeding... Is there a better way?
Rotational thromboelastometry-guided trauma resuscitation

Damian D. Keene, Giles R. Nordmann, and Tom Woolley

Purpose of review
Haemorrhage from major trauma is a significant cause of death worldwide. The UK Defence Medical Service (UK-DMS) has had significant experience in managing severely injured and shocked trauma casualties over the last decade. This has led to the integration of rotational thromboelastometry (ROTEM) into damage control resuscitation delivered at Camp Bastion Field Hospital in Afghanistan. This review aims to describe the rationale for its use and how its use has evolved by UK-DMS.

Recent findings
Although there is reasonable evidence showing its benefit in cardiac and liver surgery, evidence for its use in trauma is limited. More recent studies and meta-analyses have demonstrated a reduced rate of transfusion and blood loss, but no benefit on mortality. Despite this, there is a growing body of opinion supporting ROTEM use in trauma with European guidelines supporting its use where available. Recent UK-DMS experience has shown that it is a fast, reliable and robust means of identifying transfusion requirements.

Summary
ROTEM provides a means to rapidly assess coagulation in trauma casualties, allowing targeted use of blood products. It provides information on clot initiation strength and breakdown. However, its use in trauma has still to be fully evaluated.

Keywords
coagulopathy, rotational thromboelastometry, trauma
ROTEM in Trauma?

Theory = Conservation of Product, Rational Administration, “Functional” or “Qualitative” test vs. “Quantitative” Test

Practice = Point-of-care test,
Useful in Transplant/Cardiothoracic Surgery and bleeding obstetrics patients.

Can it be useful in trauma, and how will it change therapeutic approach?
WHAT IS ROTATIONAL THROMBOELASTOMETRY?

• Rotational thromboelastometry (ROTEM) is a near patient test measuring the **viscoelastic properties** of whole blood *IN REAL TIME*.

• It is based on the technique of thromboelastography (TEG) developed by Professor H. Hartert in 1946.

• In ROTEM, a rotating pin is inserted into a cuvette containing citrated whole blood. As clot begins to form, pin movement is inhibited.

• The degree of inhibition is displayed in real time on the ROTEM® screen, with preset parameters displayed as the test progresses.

Keene et al, Rotational thromboelastometry and trauma resuscitation, 2013
ROTEM® Delta
The ROTEM® monitor displays a dynamic graphical representation showing the clot formation in **real time**: 

- **NORMAL**
- **NO FIBRIN OR PLTS**
- **CLOT FACTOR MISSING**
- **HYPER-FIBRINOLYSIS**

[Diagram showing clot formation time vs max clot formation]
ROTEM®
Measured Parameters

- Alpha Angle = Kinetic measurement predicting speed and firmness of clot formation
- A10 – Amplitude (Clot Firmness) 10 minutes after clot initiation
ROTEM® – What are the Tests?

• EXTEM – Extrinsic Pathway
  • Assessment of factors VII, X, V, II, I, platelets, fibrinolysis

• INTEM – Intrinsic Pathway
  • Assessment of factors XII, XI, IX, VIII, X, V, II, I, platelets, fibrinolysis

• FIBTEM – Platelet inhibitor isolates fibrin component of clot
  • Fibrinogen levels and fibrin polymerisation can be assessed in a functional way

• APTEM – Aprotinin blocks hyperfibrinolysis
  • In an assay comparing APTEM to EXTEM, fulminant hyperfibrinolysis can be recognised within 10-20 minutes.
EXTEM

A. NORMAL

B. Reduced MCF
-(Low PLT or FIB)

C. Long CT
-Low Coag Factors

D. Reduced MCF and Long CT

E. Hyperfibrinolysis
-Intrinsic Fibrinolytic activity
-Breaking down of clots

FIBTEM

1. Measurement of the contribution of Fibrin to clot formation

2. Predictor of Need for RBC Transfusion
   A10 < 7

3. Predictor of Massive Transfusion
   A10 < 4 → 85% receive MT
   A10 < 12 → 0% received MT

Br J Anaesth 2011;107(3):378-87
Crit Care 2011;15(6):R265
Platelet Effectiveness

- Clot Firmness between 40-50 mm is required to form stable clot
- Platelets + FIBTEM = EXTEM
APTEM

Gorlinger et al, Rotational Thromboelastometry, 2016
The Protocol

Initial

1. Severe clot deficiency

2. Hyperfibrinolysis

3. Fibrin Deficit

4. Thrombin Generation Deficit

5. Platelet Deficiency
Case
ROTEM – Our Approach

• 1. Look for Severe Clot Deficiency – EXTEM A10 <30 mm

→ NEGATIVE – Move to STEP 2
ROTEM – Our Approach

2. Hyperfibrinolysis $\rightarrow$ ML >15% within 60 minutes

$\rightarrow$ TXA 15-20 mg/kg if not already given
$\rightarrow$ APTEM should NOT show hyperfibrinolysis
$\rightarrow$ Note, after first dose, divide into Fulminant, Early, and Clot-retraction based on time to lysis
  $\rightarrow$ <20 mins = Fulminant hyperfibrinolysis $\rightarrow$ 1-2 g TXA
  $\rightarrow$ 20-40 mins = Early Fibrinolysis $\rightarrow$ 1g TXA
  $\rightarrow$ >40 mins = Clot retraction, no treatment required

ROTEM – Our Approach

3. Fibrin Deficit $\rightarrow$ FIBTEM A10 <7mm

$\rightarrow$ Fibrinogen 6g to target FIBTEM A10 12mm
ROTEM – Our Approach

4. Thrombin Generation Deficit \(\Rightarrow\) EXTEM CT>80sec

\[\rightarrow\text{FFP 15-20 mL/kg}\]
ROTEM – Our Approach

5. Platelet Deficiency $\rightarrow$ EXTEM A10 $<$40mm (N FIBTEM + PLT $<$50)

In this case, FIBTEM needs to be corrected first – and the PLT count was 146 at that time.
What has been done so far?

**Arrival (A) -> A+30 – Resuscitation Bay**

Pt Given:
10 Units PRBCs  
4 units FFP  
1g TXA

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**A+30 -> A+2 hrs 30 mins – OR**

Pt Given:
6 units PRBCs  
12 units FFP  
1 unit FWB (@ A+1 hr)  
6 g Fibrinogen  
1 g TXA

---

TTL first results interpretation  
= A+40 while pt is in OR

Step 1 – No Action Required  
Step 2 → TXA 15-20 mg/kg  
Step 3 → Fibrinogen 6g  
Step 4 → FFP 15-20 mL/kg  
Step 5 → No Action Required
ROTEM – Repeat Testing - while in OR

• 1. Look for Severe Clot Deficiency – EXTEM A10 <30 mm

Algorithm:
- Give TXA*
- Give FFP
- Give Fibrinogen
- Consider Platelets

→ This step was persistently positive for 16 hrs post-injury
What has been done so far?

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**Arrival (A) -> A+30 – Resuscitation Bay**

Pt Given:
- 10 Units PRBCs
- 4 units FFP
- 1g TXA

TTL first ROTEM interpretation
= $A+40$ while pt is in OR

Step 1 – No Action Required
Step 2 → TXA 15-20 mg/kg
Step 3 → Fibrinogen 6g
Step 4 → FFP 15-20 mL/kg
Step 5 → No Action Required

---

**A+30 -> A+2 hrs 30 mins – OR**

Pt Given:
- 6 units PRBCs
- 12 units FFP
- 1 unit Fresh Whole Blood (@ $A+1$ hr)
- 6 g Fibrinogen
- 1 g TXA

**2nd ROTEM Results (about A+ 1 hr 30)**

Step 1 – 2g Fibrinogen

Plus continuation of DCR in OR
- 4 units PRBC
- 2nd unit Fresh Whole Blood
- 4 units FFP
1. Look for Severe Clot Deficiency – EXTEM A10 <30 mm
ROTEM – 16 Hours Post-Op

• 2. Look for Hyperfibrinolysis – ML >15% within 60 minutes
ROTEM – 12-24 Hours Post-Operative

• 3. Look for Fibrin deficit – FIBTEM A10 <7 mm → Treat to target >12mm

Initial FIBTEM → Treated 6g

12 hrs post-op –>7, but still not at target

Intra-op FIBTEM → Treated 2g

24 hours post-operative
ROTEM – 24 Hours Post-Operative

4. Look for Thrombin generation deficit - EXTEM CT >80 sec

Pre-op (Treated – FFP)

Intra-op – Treated, Step 1 algorithm

EXTEM N – 24 hrs postop
ROTEM – 24 hours Post-Op

5. Look for Platelet Deficit – EXTEM A10 <40 (and FIBTEM A10>12mm, known PLT count <50)

\[
\text{PLT} = 21, \quad \text{FIBTEM A10} = 13\text{mm}
\]

Algorithm = Transfuse to PLT >50
Case

**Arrival → A+ 30 mins – Resuscitation Bay**
10 Units PRBCs
4 units FFP
1g TXA

ROTEM 1
Needs TXA, Fibrinogen, FFP

**A+ 30 → A+ 2hr 30 mins – OR**
10 units PRBCs
12 units FFP
2 units FWB
6 + 2g Fibrinogen
1 g TXA

ROTEM 2
Needs Fibrinogen, FFP

**A+ 2 hrs 45 min ICU Admission**
5 units PRBCs
6 units FFP
2 units Platelets*
1 unit FWB
4g Fibrinogen
2g TXA

ROTEM 3 @ 3 hrs post arrival
Needs FFP
ROTEM 4 @ 5 hrs
Needs Fibrinogen, FFP
ROTEM 5 @ 8 hrs
Needs Fibrinogen, FFP
ROTEM 6 @ 10 hours
Needs Fibrinogen, FFP
ROTEM 7 @ 16 hours
Needs Fibrinogen
ROTEM 8 @ 24 hours
Needs Platelets
ROTEM 9 @ 30 hours
Needs Fibrinogen
ROTEM 10 @ 38 hrs
Needs Platelets
ROTEM 11 @ 48 hrs
PLT Count 52,
no further products given
Review of Protocol

Initial

1. Severe clot deficiency

2. Hyperfibrinolysis

3. Fibrin Deficit

4. Thrombin Generation Deficit

5. Platelet Deficiency

Lessons Learned:

**ROTEM testing can:**

- Provide early indications for the need of blood products,
- Detect shortages of key clotting component and factors,
- Can assess the qualitative state of clot formation in real time,
- Can show states of hyperfibrinolysis and,
- Can show deficits in thrombin generation and platelet function.

Is there studies to back up these conclusions?
BACKGROUND:
• Hypothesis was that incorporating ROTEM measurements into DCR methods at the US Role 3 hospital at Bagram Airfield, Afghanistan would change the standard transfusion ratios of 1:1:1:1 to a product mix tailored specifically for the combat causality.

• Measurement of hemostatic function with rotational thromboelastometry (ROTEM) may allow optimization of the type and quantity of blood products transfused.

METHODS:
• Over the course of six months, 134 trauma patients received a transfusion (pre-ROTEM), 85 received a transfusion and underwent ROTEM testing (post-ROTEM).

RESULTS:
• The post-ROTEM group received a significant increase in PLT and CRYO transfusions ratios, 4× and 2×, respectively.

CONCLUSION:
• The introduction of ROTEM significantly improved adherence to DCR practices.
• The transfusion differences suggest that aggressive DCR without thromboelastometry data may result in reduced hemostatic support and underestimate the need for PLT and CRYO.
• Thus, future controlled trials should include ROTEM-guided coagulation management in trauma resuscitation.
What we can do...

Activate blood bank / massive transfusion protocol (MTP)

Notify the surgical team

ATLS

• Airway
• Breathing
• Circulation
• Disability
• Expose/Environmental control (Everything Else)

Lab:

• Blood typing, INR/PTT, CBC, Lactate, blood gas, Chemistry,
and ROTEM testing

22 yo male
GSW to pelvic/leg region
TK, pressure bandage, IV

• Tranexamic Acid 1g + 1g

• Bring BP up to 90-100 Systolic:
  1:1:1:1 transfusion PRBC:FFP:PLT:Fibrin
  Or
  Fresh Whole Blood (FWB)

• Optimize:
  Temperature Management – Warmed IV products
  Acidosis Management – intubate/ventilate
  Maintenance of Calcium – 2-5 mg calcium chloride

• Receive results of ROTEM
  • -> transition to goal directed resuscitation
  • -> Inhibit Fibrinolysis with TXA
  • -> Provide Fibrinogen/Cryoprecipitate
  • -> Provide Fresh Frozen Plasma
  • -> Provide Platelets
Where is ROTEM® being used now?

Vancouver General Hospital
St Paul’s (Vancouver)
Royal Columbian Hospital
University of Alberta Hospital
Foothills Medical Center
University of Saskatchewan
St. Boniface Hospital (Winnipeg)
Sunnybrook Health Science Center

The Ottawa Hospital
Children’s Hospital of Eastern Ontario
Ottawa Heart Institute
Montreal General Hospital
Centre Hospitalier de l'Université de Montréal
Hopital du Sacre Couer (Montreal)
The Moncton Hospital
The future?

• Instruments are getting smaller, and closer to POC
  • ROTEM®: Delta -> Sigma
  • TEG: TEG® 6S

• Military:
  • DCR pushed closer to point of injury (FWB, Fibrinogen and TXA)
    • Qualitative assessment tool to measure effectiveness of DCR
  • More deployments in low resource or difficult to support
    • (Role 2/3 support to UN missions)
    • Humanitarian missions
  • Small medical team support
    • On ship (HMCS Protecteur/Provider)
    • Special operations

• Civilian:
  • Small center
  • Transport decisions
  • Disaster/resource depletion
ROTEM® Learning

www.rotem.de

German company site provided in English
Provides E-Learning
• Essentials,
• Operation,
• Interpretation with,
• Test and certification.

https://www.rotem.de/en/methodology/rotem-delta-and-sigma-analysis/
To conclude, we have:

1. Identified the deadly triad in trauma, the goal of damage control resuscitation and how coagulopathy requires aggressive and specific therapy.

   2. Recognized what ROTEM is and how it is used.

3. Discussed the case based resuscitation; how the results were interpreted and problems addressed.

   4. Discussed how goal directed resuscitation based on ROTEM results will be the standard of trauma care in the future
Discussion and Questions
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