

# Assessment of Postoperative Bleeding and Blood Component Therapy

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# Scope

- Assessment of bleeding postoperatively
- Enumerate the causes and mechanisms of bleeding post cardiac surgery
- Explain and manage the coagulopathic causes of bleeding in the post op period
- Blood component therapy in the bleeding postop patient

# Definition of what constitutes severe post operative bleeding

- Highly varied
- Different markers used as endpoints to define severe postop bleeding:
  - volume of blood lost and rate of blood loss
  - no of blood units transfused
  - need for surgical re-exploration

# Universal Definition of Perioperative Bleeding in Cardiac Surgery

**TABLE 1. Bleeding categories according to the UDPB in adult cardiac surgery (if different categories indicate mixed definitions of bleeding, the worst definition applies)**

Bleeding definition	Sternal closure delayed	Postoperative chest tube						Reexploration/ tamponade	
		blood loss within 12 hours (mL)	PRBC (units)	FFP (units)	PLT (units)	Cryoprecipitate	PCCs rFVIIa		
Class 0 (insignificant)	No	<600	0*	0	0	No	No	No	No
Class 1 (mild)	No	601-800	1	0	0	No	No	No	No
Class 2 (moderate)	No	801-1000	2-4	2-4	Yes	Yes	Yes	No	No
Class 3 (severe)	Yes	1001-2000	5-10	5-10	N/A	N/A	N/A	No	Yes
Class 4 (massive)	N/A	>2000	>10	>10	N/A	N/A	N/A	Yes	N/A

*UDPB*, Universal definition for perioperative bleeding; *PRBC*, packed red blood cells; *FFP*, fresh frozen plasma; *PLT*, platelet concentrates; *PCCs*, prothrombin complex concentrates; *rFVIIa*, recombinant activated factor VII; *N/A*, not applicable. \*Correction of preoperative anemia or hemodilution only; the number of PRBCs used should only be considered in the UDPB when accompanied by other signs of perioperative bleeding.

# Active Bleeding Or Excessive Blood Loss

- Bleeding exceeding 1.5 ml/kg/h for 6 consecutive hours within the first 24 hours
- Likewise patients who were reoperated for bleeding within the first 12 hours were also considered as active bleeding

Colson PH, etal. (2016) Active Bleeding after cardiac surgery: a prospective multicenter study. PLoS ONE 11(9)

- Intraop or postop (during first 24 hours) blood loss exceeding 250ml/hr or 50ml/ 10mins

Weber et al. Anesth. 2012;117(3): 531-547

- Abnormal or diffuse bleeding that cannot be controlled by compression and electrocoagulation, necessitates  $\geq 2$  to 3 units RBC transfusion or  $\geq 400$  or 600 ml of cell salvaged blood depending on pts weight and a postoperative drain output of  $\geq 1.5$ ml/kg/h for at least 3 hours or a need for surgical reexploration for hemostasis during the first 48 hours.

PLASMACARD study. Transfusion 2014.;54:1114-1124

# Consequences of Massive Postop Bleeding

- Estimates of occurrence of severe or massive hemorrhage varies from 2-10%
- Co-existence of massive bleeding, RBC transfusions and preoperative anemia correlates with significantly higher mortality (“deadly triad” of cardiac surgery)
- Re-exploration rate of 6% for elective surgery (4.5% for CABG, 5.5% for single valve sx, 9.6% for combined sx, 7.9% for the rest of the cohort) and 15% for emergency surgery
- Re-exploration is significantly associated with increased mortality, and more perioperative stroke, renal dysfunction, prolonged mechanical ventilation and increased need for mechanical circulatory support.

Table 1: Factors contributing to the bleeding prediction models, found in the literature.

Variable	Any RBC Transfusion model <sup>33</sup>	BRiSc <sup>1</sup>	TRACK <sup>46</sup>	TRUST <sup>47</sup>	TRS-CABG <sup>49</sup>
Age	+	+	+	+	+
Gender	+	-	+	+	+
Weight, height, BMI	+	+	+	+	+
Preoperative Hb	+	-	+	+	+
Previous cardiac surgery	+	-	-	+	+
Type of operation	+	+	+	+	-
Status of operation	-	+	-	+	+
Serum Creatinine	+	-	-	+	+
LV EF%	+	-	-	-	+
Shock state	+	-	-	-	+
Previous stroke	+	-	-		
Diabetes mellitus	+	-	-	-	+
Previous MI	+	-	-	-	-
Use of CPB	+	-	-	-	-
Peripheral vascular disease	-	-	-	-	+
Preoperative albumin	-	-	-	-	+

RBC: Red Blood Cells, BRiSc: Papworth Bleeding Risk Score, TRUST: Transfusion Risk Understanding Scoring Tool, BMI: Body Mass Index, Hb: Hemoglobin, LV EF: Left Ventricle Ejection Fraction, MI: Myocardial Infarction, CPB: Cardio Pulmonary Bypass.

**Table 2:** Factors contributing to the massive perioperative bleeding prediction models, found in the literature.

Variable	Karkouti et al <sup>25</sup>	LVBT <sup>33</sup>	Williams et al <sup>19</sup>	BRS <sup>55</sup>
Age	+	+	-	+
Somatometric data	+	+	-	+
Preoperative shock	+	+	-	+
Preoperative platelet count	+		-	+
Preoperative Hb	+	+	+	-
Type of surgery	+	+	-	-
Status of operation	+	+	+	+
Surgeon	+		-	-
Previous cardiac surgery	+	+	-	+
DHCA duration	+	-	-	-
Duration of CPB	+	+	+	
Lowest Hct in CPB	+	-	-	-
Gender	-	+	-	+
Renal function	-	+	-	+
Previous neurological accident	-	+	-	-
Diabetes mellitus	-	+	-	+
LV ejection fraction	-	+	-	-
Preoperative MI	-	+	-	+

LVBT: Large Volume Blood Transfusion score, BRS: Bedside Risk Score, Hb: Hemoglobin, DHCA: Deep Hypothermic Circulatory Arrest, CPB: Cardio Pulmonary Bypass, LV: Left Ventricle, MI: Myocardial Index.

# Criteria for Surgical Reexploration

- Bleeding in the 1<sup>st</sup> 2 hours of >300 ml/hr or >200ml/hr for 4 hours consecutively

Choi et al. Rev Bras Anesthesiol.2017;67 (5):508-515

- Drainage of >500 ml in te 1<sup>st</sup> hour, total drainage of 800 ml in the 1<sup>st</sup> 2 hrs, 900ml in the first 3 hrs, >1000ml in the 1<sup>st</sup> 4 hours or 1200 ml in the 1<sup>st</sup> 5 hrs
- Sudden massive bleeding or cardiac tamponade

Kristensen et al. Interactive CV and Thoracic Surgery 14(2012):709-713

- Bleeding that exceeds 10ml/kg in the 1st postop hour or an average of  $\geq$  5ml/kg in the 1<sup>st</sup> 3 hrs.

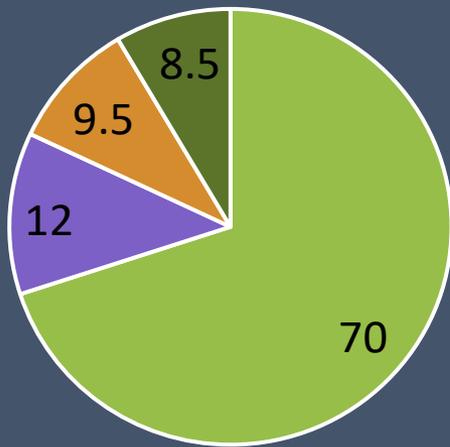
Woodman et al. Blood. 1990;76(9):1680-1697

# Causes of Bleeding Found on Reoperation

Vivacqua et al.

18,891 pts, 566 (3%) reop

Mortality 8.5% vs. 1.5% no reop

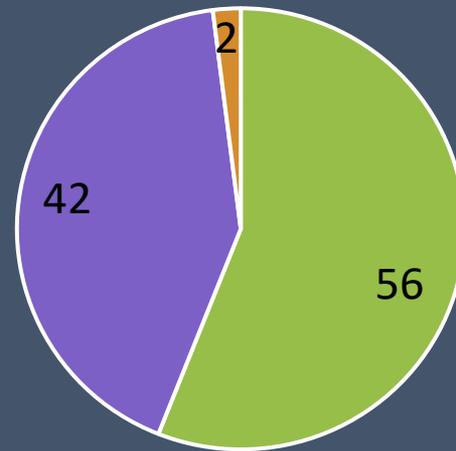


- Surgical Bleeding
- Coagulopathy
- Both
- Others (Tamponade, Clot)

Kristensen et al.

1452 pts , 101 pts( 7%) reop

Mortality 19% for surgical bleeding,  
10.5% for coagulopathic



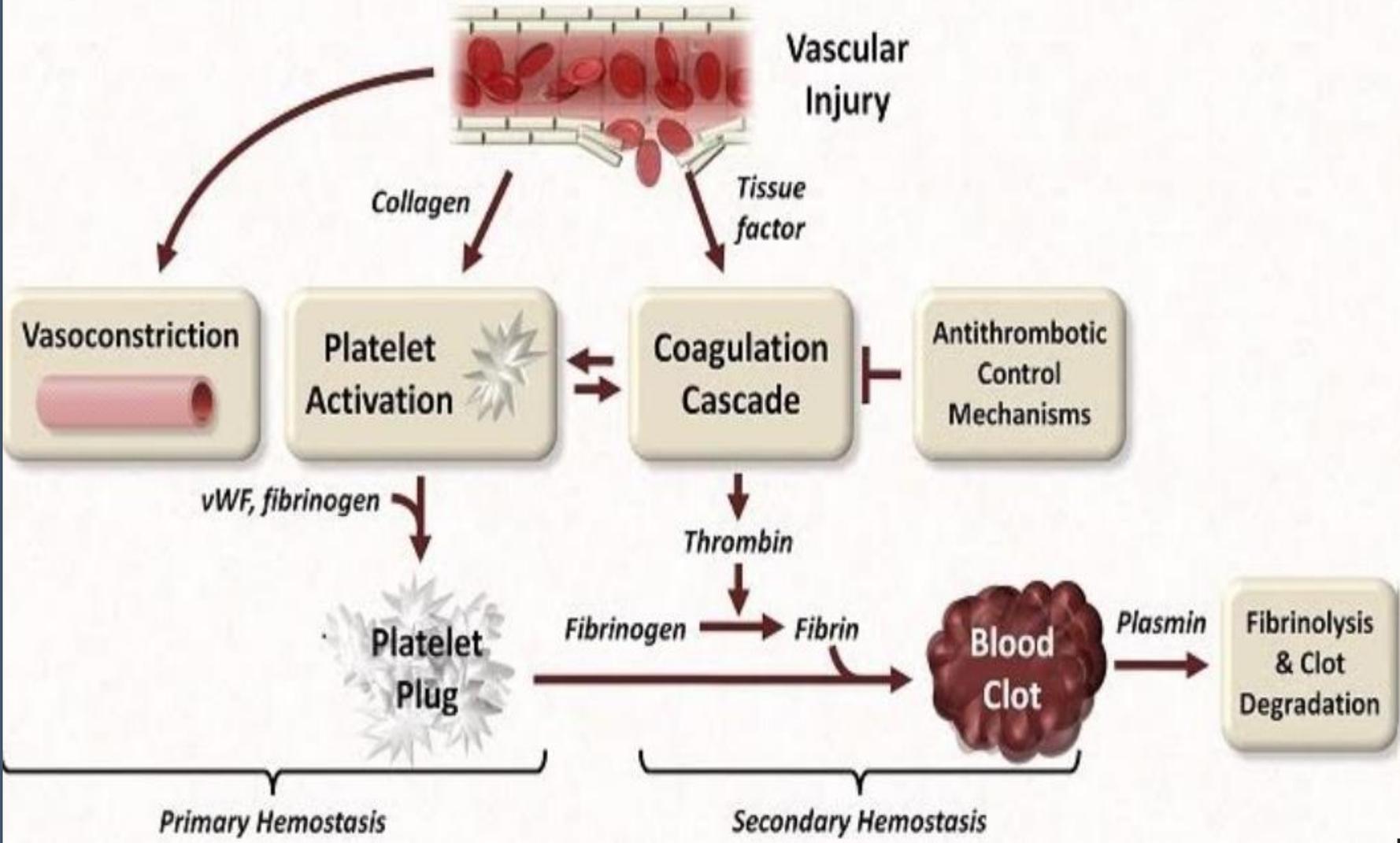
- Surgical Bleeding
- Coagulopathy
- Unknown

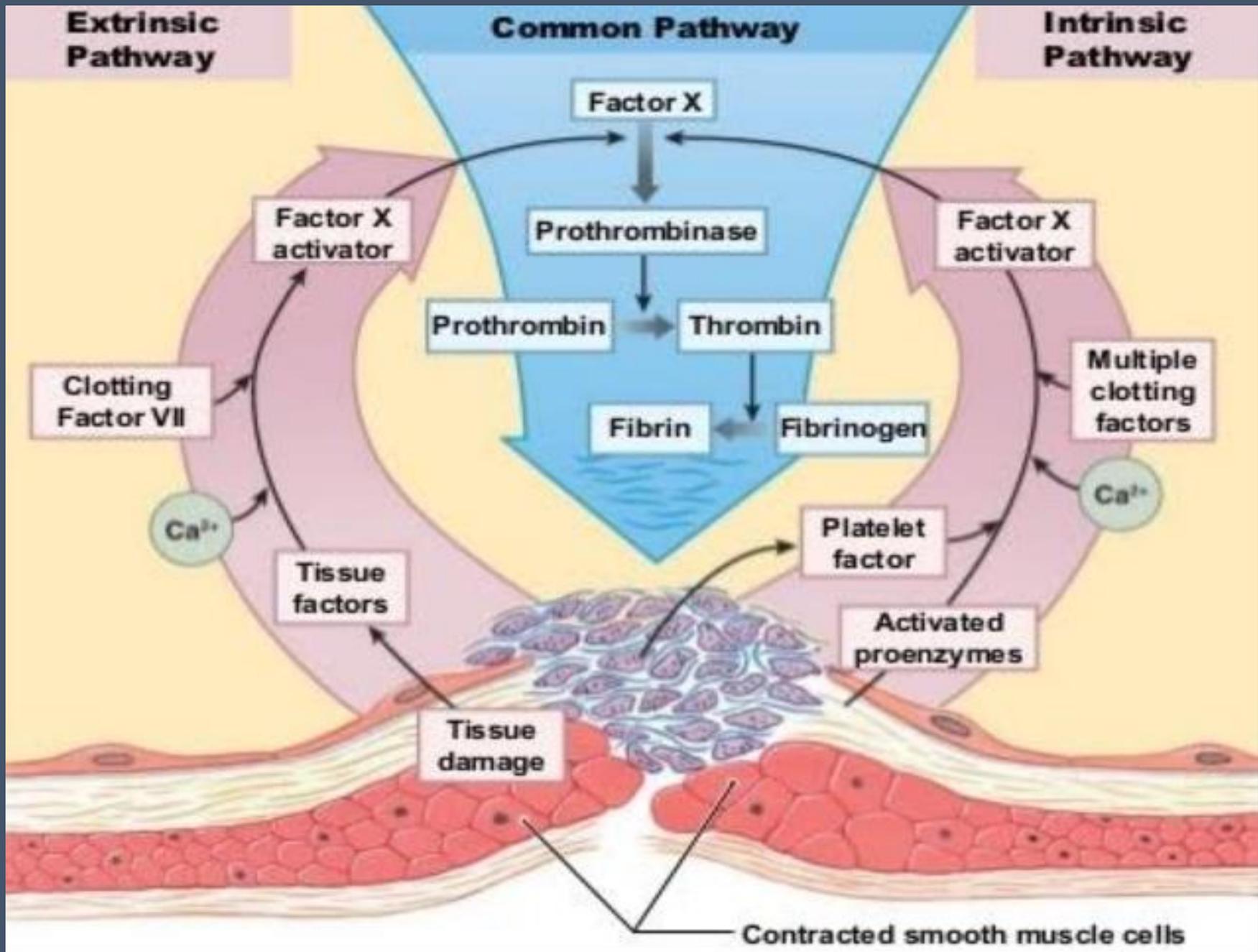
# Cardiac Surgery and the Hemostatic System

# Causes of Hemostatic System Disturbance in Cardiac Surgery

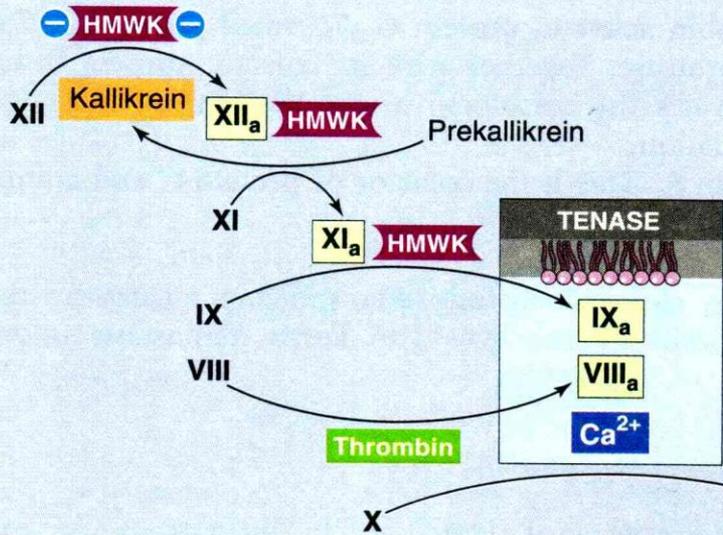
- Effects of drugs : Antiplatelet agents  
Warfarin, DOACs  
UFH, LMWH
- Effect of cardiopulmonary bypass on the hemostatic system

# Major Components of Hemostasis

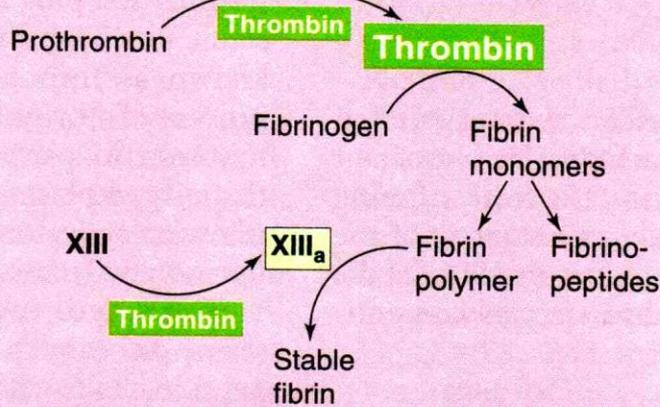
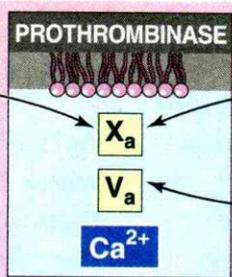
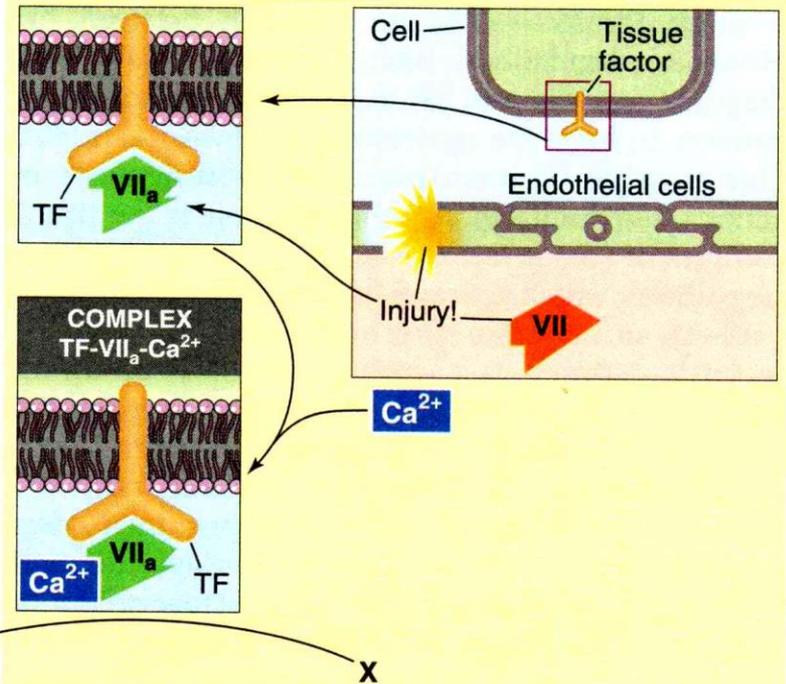




# INTRINSIC PATHWAY

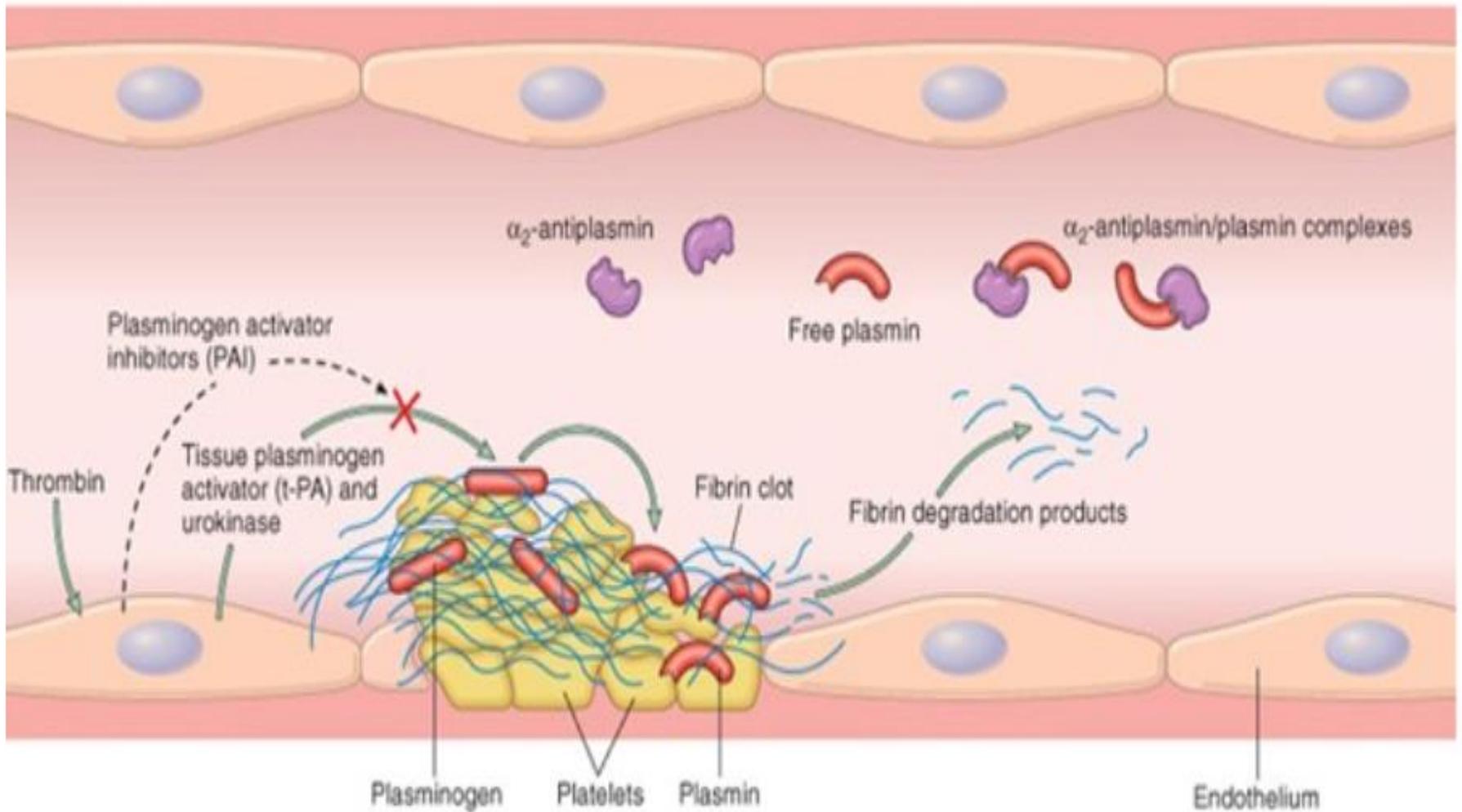


# EXTRINSIC PATHWAY



# COMMON PATHWAY

# Fibrinolytic System



# Mechanisms of Bleeding in Cardiac Surgery

## I. Residual heparin effect

- Exact dose of protamine for heparin reversal may actually be difficult to determine

protamine:heparin ratio: 1-1.3:1 but

1mg protamine/100units heparin is more commonly used

Thrombin and AT levels may already be low

Heparin maybe bound by endothelial cells, proteins, circulating cells and platelets

Incomplete heparin antagonization can occur as well as heparin rebound

# Mechanisms of Bleeding in Cardiac Surgery

## I. Residual heparin effect

- Residual heparinization is common after surgery and should be always considered in the presence of excessive microvascular bleeding following CPB cardiac surgery
- Test: ACT ( within 10% of the initial time)  
plasma heparin concentration  
APTT

# Mechanisms of Bleeding in Cardiac Surgery

## II. Reduced Thrombin Generation

- Dilution and consumption
- Main contributors: length of CPB time  
extent of hemodilution
- Other contributors to low coagulation factor activity:
  - poor liver synthesis of Vit.K dependent factors
  - preop use of warfarin/ DOACs
  - congenital factor deficiency

# Mechanisms of Bleeding in Cardiac Surgery

## II. Reduced Thrombin Generation

- Tests: PT, PTT

  - Thromboelastogram(TEG)

  - Thromboelastometry (ROTEM)

- Management:

  - FFP transfusion- 10-15 ml/k

  - PCC, rFVIIa

# Mechanisms of Bleeding in Cardiac Surgery

## III. Fibrin(ogen)-dependent poor clot firmness

- Fibrinogen and FXIII levels are consistently decreased after CPB and significantly associated with postop bleeding
- Cause: consumption
  - dilution due to long pump run, complex sx, aortic sx, congenital heart sx
- Diagnostic tests: TEG and ROTEM
  - fibrinogen assay

# Mechanisms of Bleeding in Cardiac Surgery

## III. Fibrin(ogen)-dependent poor clot firmness

- Management: Fibrinogen supplementation when levels fall below 1.0-2.0g/L

3 ways:

1. FFP transfusion. FFP contains about 2.0g/L fibrinogen  
need to transfuse 30ml/kg FFP
2. Cryoprecipitates contains about 12g/L fibrinogen  
Hemostatic dose: 5-10 units
3. Fibrinogen concentrate

# Mechanisms of Bleeding in Cardiac Surgery

## IV. Platelet-Dependent poor clot firmness from Thrombocytopenia

- PC falls 30-50% lower than preop levels
- NOT a big factor for bleeding
- Causes : dilutional

activation and increased consumption due to plt exposure to foreign surfaces of the CPB circuit and oxygenator

elevated shear stress at different levels of the CPB leads to plt activation and consumption

Management: Platelet transfusion

# Mechanisms of Bleeding in Cardiac Surgery

## V. Platelet-Dependent poor clot firmness from Platelet Dysfunction

- Greater significance and considered by many to be main cause of bleeding associated with CPB
- Possible mechanisms of platelet dysfunction:
  - CPB circuit blunts plt function by inducing a “transient refractory state”
  - platelet membrane trauma with loss of surface receptors
  - heparin induced plt dysfunction
  - hypothermia
  - preop use of antiplatelet agents

# Mechanisms of Bleeding in Cardiac Surgery

## V. Platelet-Dependent poor clot firmness from Platelet Dysfunction

- Bleeding maybe from the interaction of CPB-related platelet dysfunction, drug-related platelet dysfunction and thrombocytopenia
- Test: Platelet function tests (platelet aggregonometry), Bleeding time
- Management: Platelet transfusion

Desmopressin: dose 0.3ug/kg

# Mechanisms of Bleeding in Cardiac Surgery

## VI. Hyperfibrinolysis

- Extensive thrombin generation triggers massive fibrinolysis
- Difficult to demonstrate a clear association between fibrinolysis and excessive bleeding following CPB but several studies have shown that the use of antifibrinolytic agents during CPB decrease the activation of the fibrinolytic system with less postoperative blood loss and transfusions
- Plasmin and t-PA also impair platelet function
- Management is prophylactic:
  - Tranexamic acid low dose(25-30mg/kg) to high dose (60-250mg/kg)
  - EACA, aprotinin

# Mechanisms of Bleeding in Cardiac Surgery

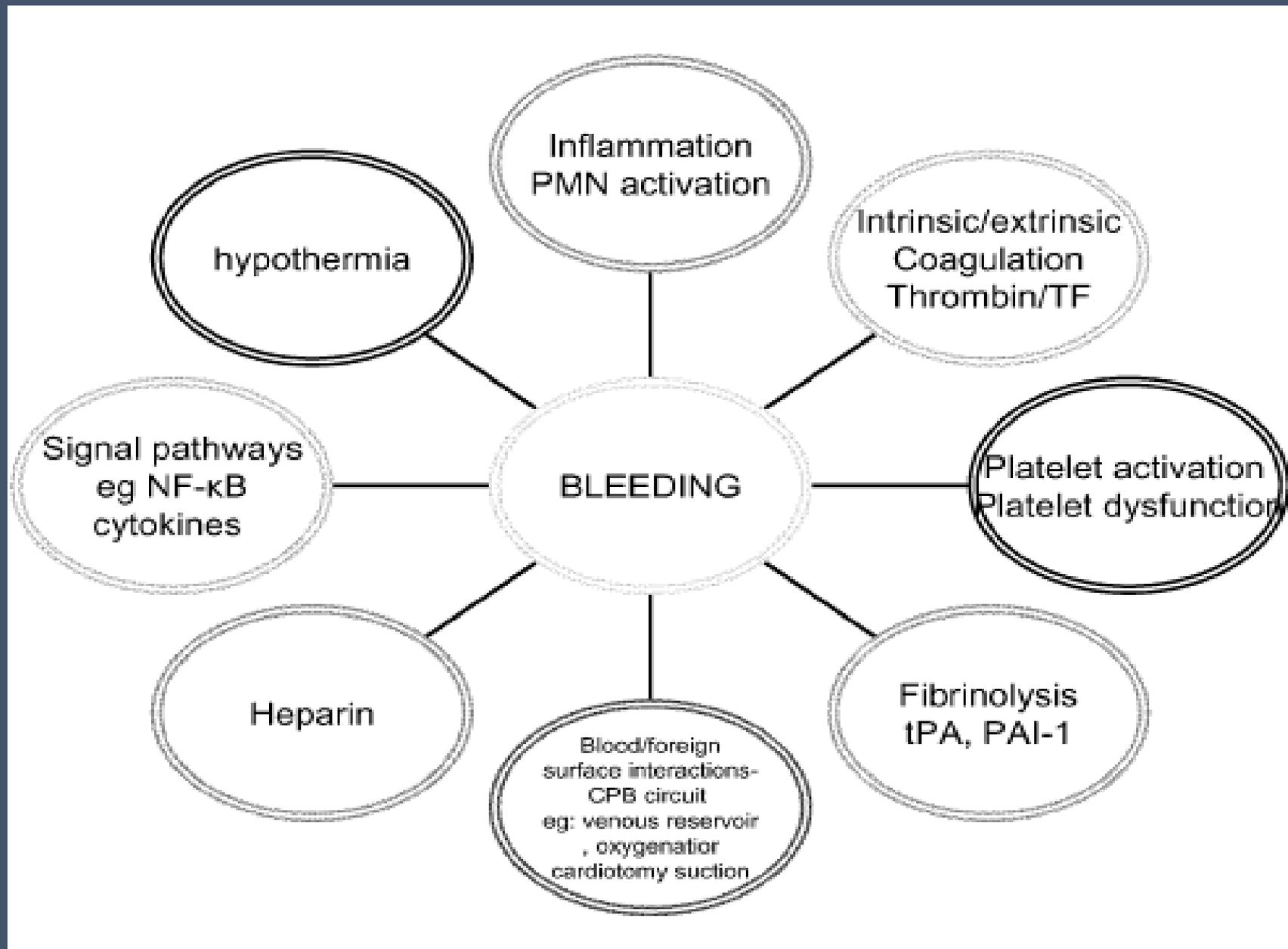
## VII. Other Contributory factors:

Hypothermia

Acidosis

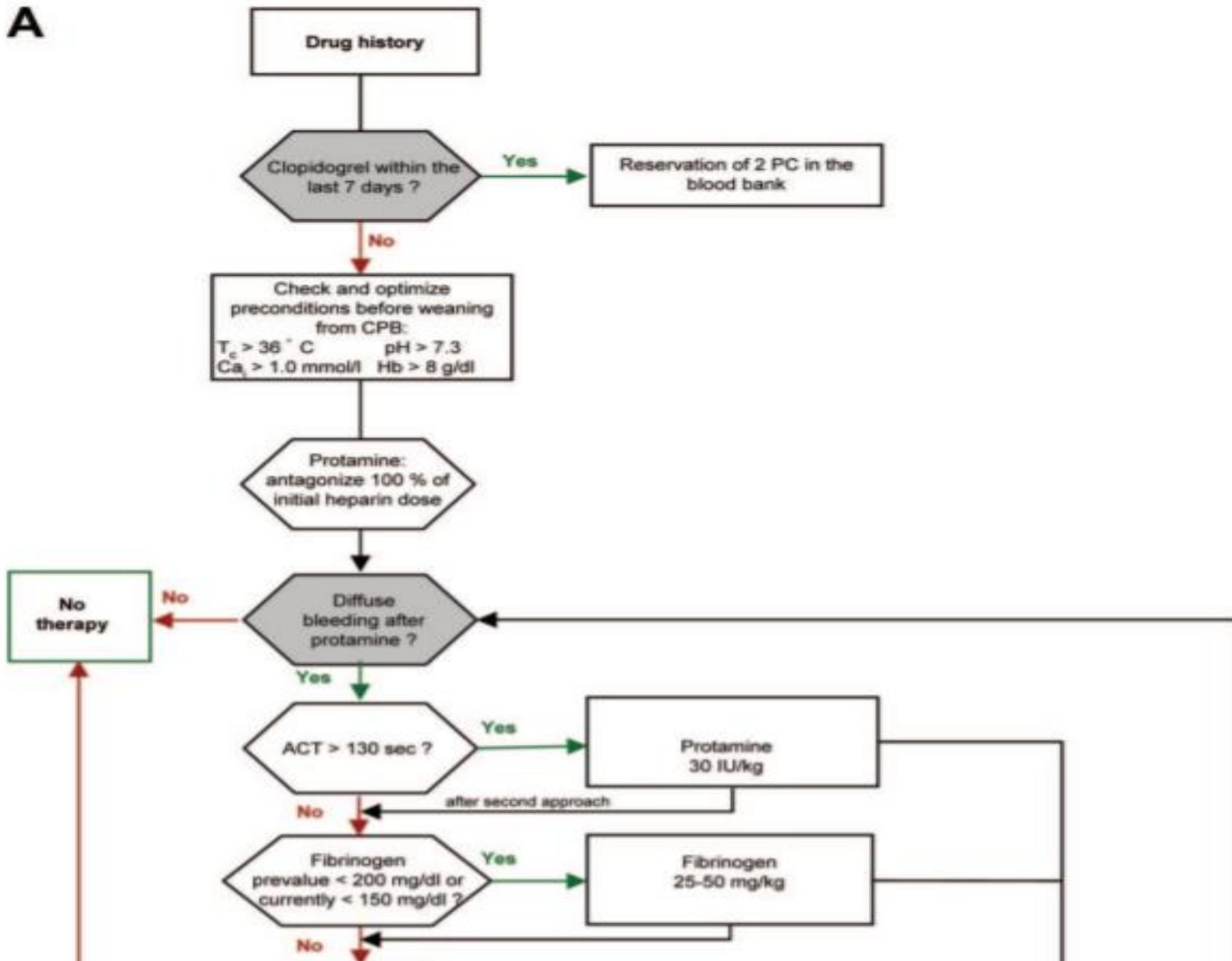
Inflammation and activation of PMNs: induces release of TF

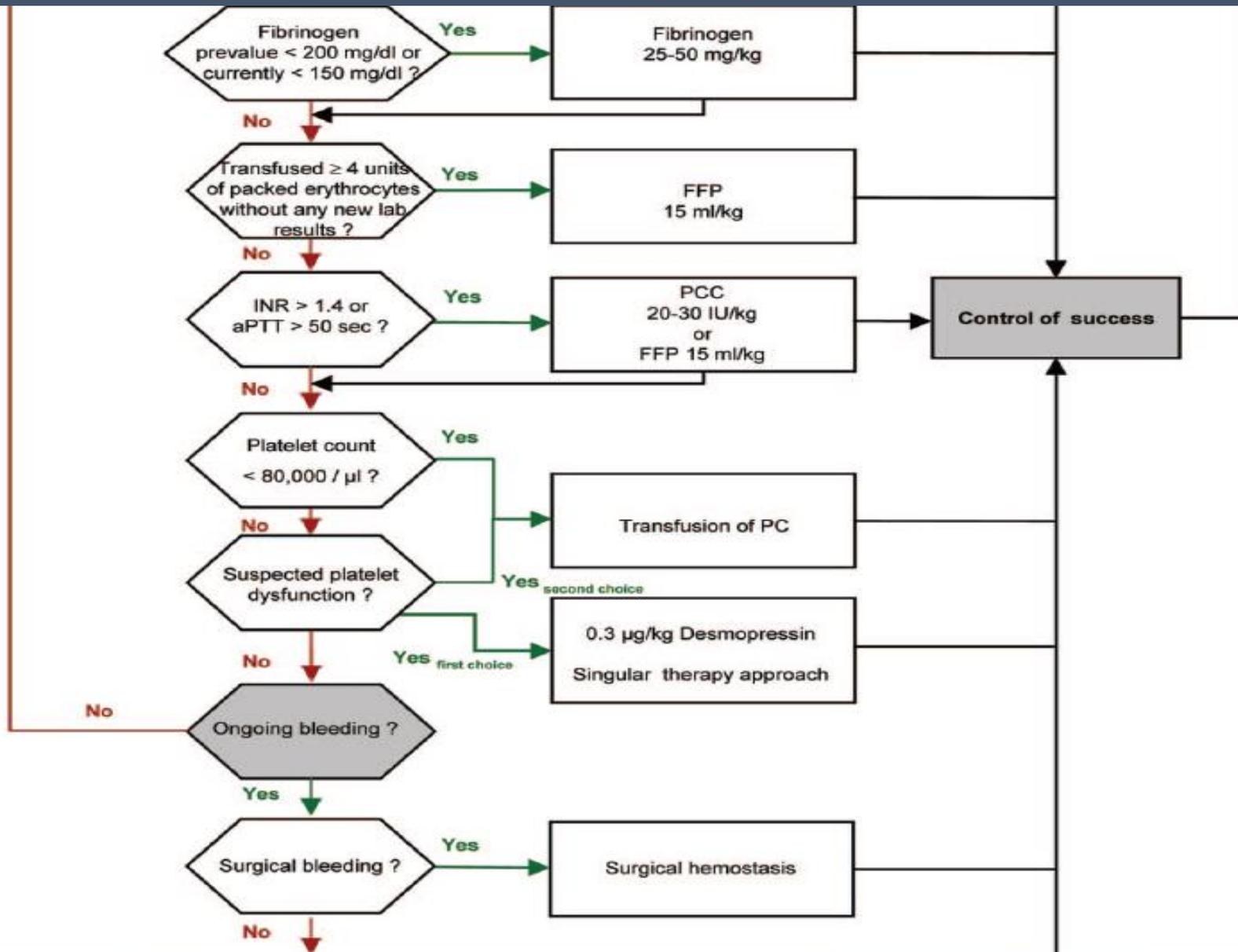
Enhanced NF- $\kappa$ B signaling pathways causing increased production of inflammatory cytokines enhancing TF production

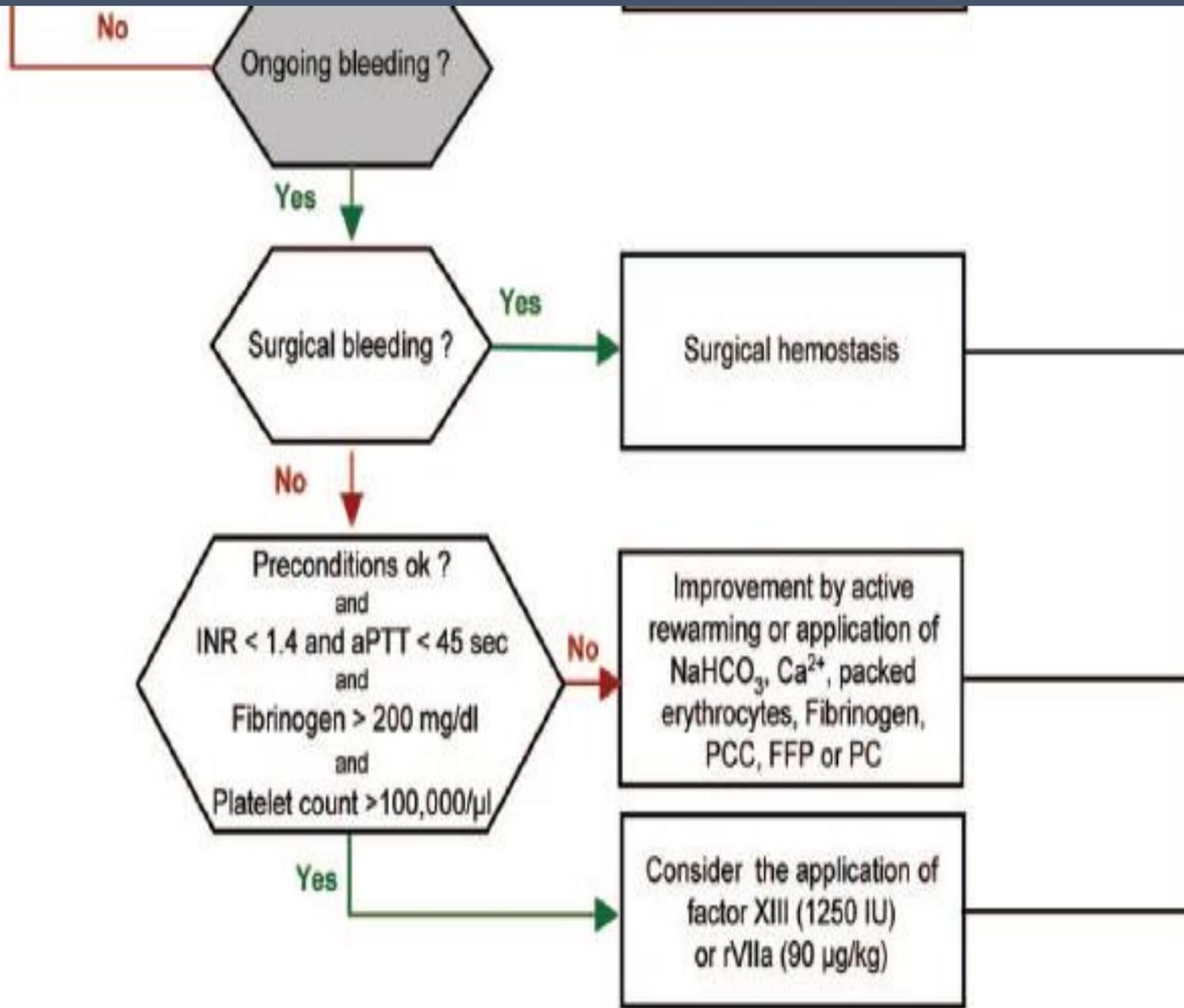


# Conventional Hemostatic Therapy Algorithm

Weber CF, et al. Point-of-Care Testing, A prospective ,  
Randomized Clinical Trial of Efficacy in Coagulopathic Cardiac  
Surgery Patients. Anesth 2012;117: 531-547

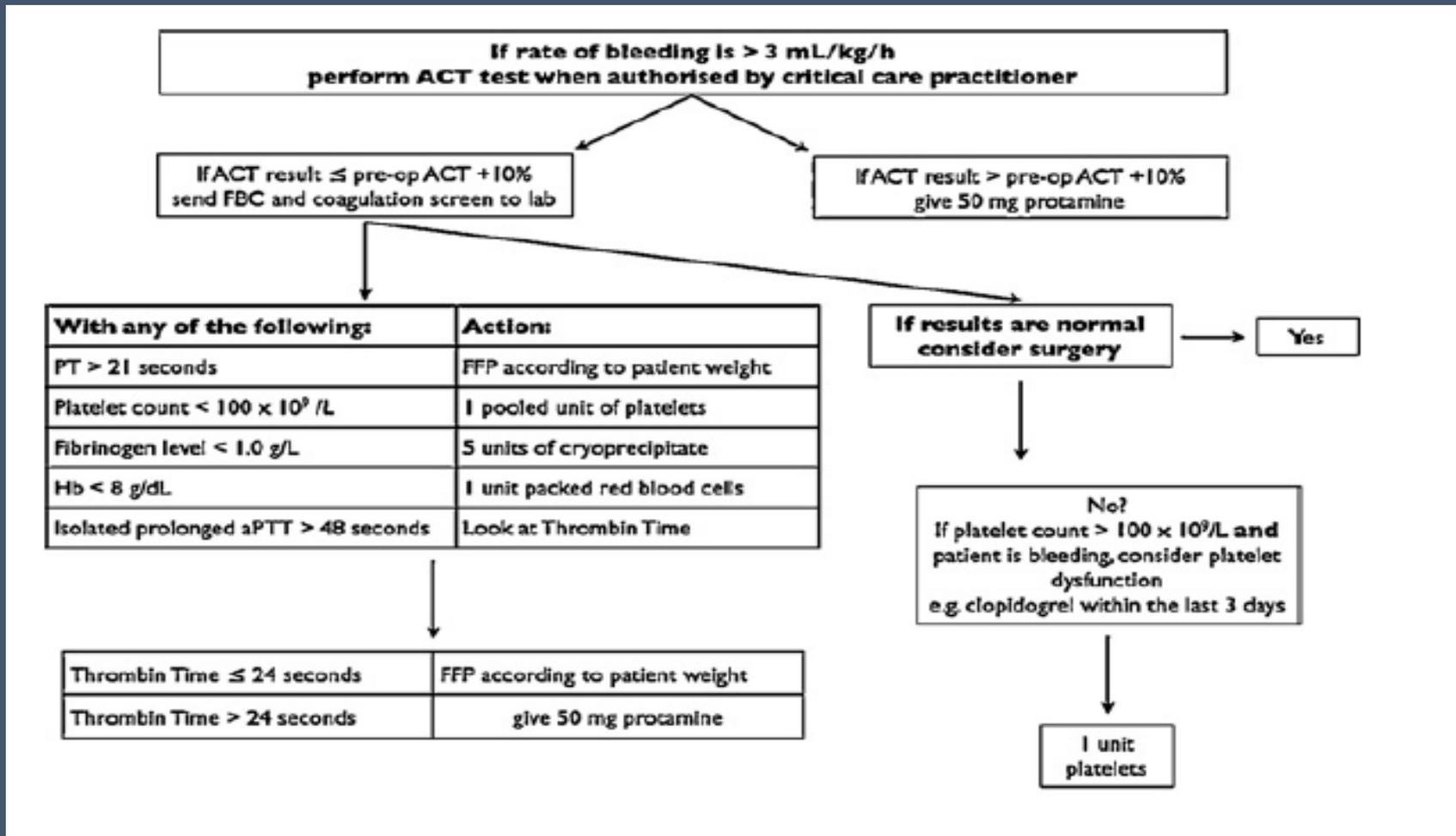
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# Papworth Hospital Perioperative Transfusion Algorithm

- Vuylsteke et al. Euro J CardioThor Surg 39(2011)924-931



# In Conclusion,

- Excessive bleeding in cardiac surgery is a dynamic, complex clinical entity.
- Main causes are surgical and disturbances of the hemostatic system from the use of the CPB and exposure to drugs.
- It is often difficult to delineate the factors causing coagulopathic bleeding as they cannot be often defined by the routine tests available and thus empiric transfusion management is often employed.
- In our setting, tests that can better assess the defects of hemostasis (viscoelastic tests and platelet function tests) should be made available to better manage the bleeding patient.

Thank You

# Mechanisms of Bleeding in Cardiac Surgeries

- Residual Heparin effect
- Dilutional coagulopathy

# Effect of Drugs

- Anti platelet agents
- Anticoagulants

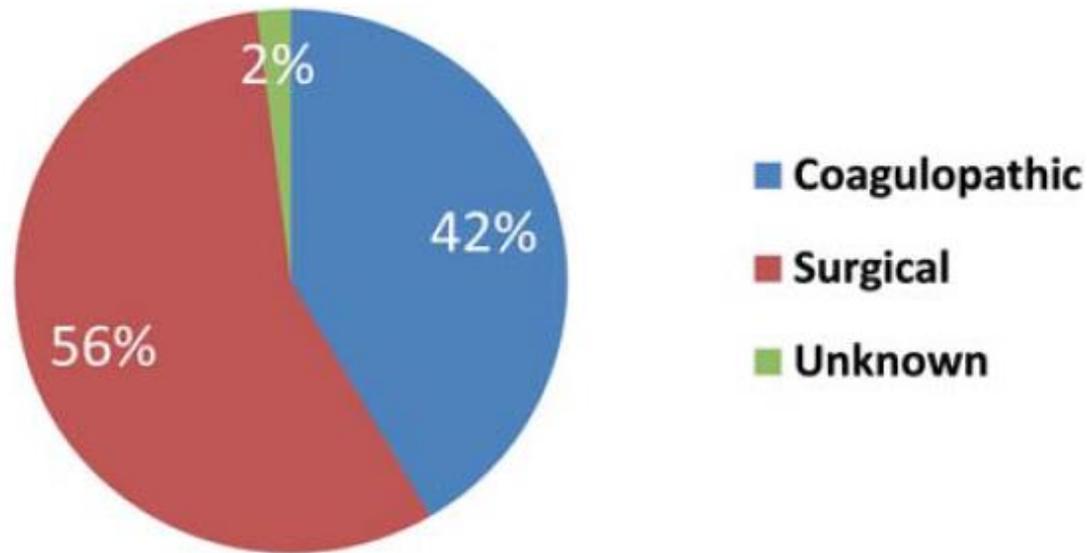
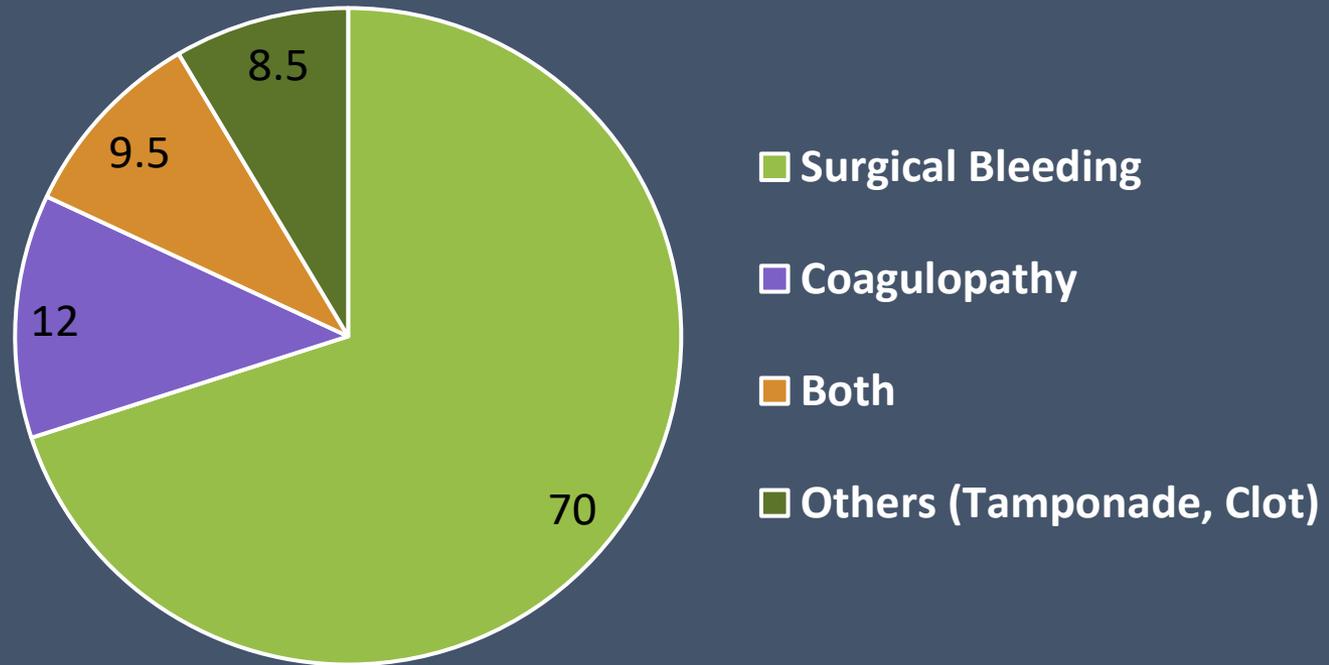


Figure 2: Types of bleeding found at reoperation. Forty-two patients had a coagulopathic bleeding, 57 patients had a surgical bleeding and 2 patients had an unknown type of bleeding as it was not described further in the operation description.

# Cause of Bleeding



## 1. Patient-related factors

- Advanced age
- Preop renal insufficiency
- Low BMI
- Low EF
- Preop use of warfarin or ASA
- Peripheral vascular disease

## 2. Surgery-related factors

- urgent surgery
- complex/special type surgeries
- Redo surgery
- prolonged bypass time
- multiple coronary anastomoses
- large volumes of intraoperative salvaged cells transfused

## 2. Surgical causes: urgent surgery

multiple coronary anastomoses

prolonged cardiopulmonary bypass time

special types of surgery

redo surgeries

Low intraoperative core temp

Large volumes of intraoperative salvaged cells transfused

# Risk Factors for Post-Op Bleeding

2. Surgical causes: urgent surgery

multiple coronary anastomoses

prolonged cardiopulmonary bypass time

special types of surgery

redo surgeries

Low intraoperative core temp

Large volumes of intraoperative salvaged cells transfused

3. Impaired hemostasis (coagulopathy)

Table 1. The Papworth Bleeding Risk Stratification Score table.

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Risk factor	Value = 0	Value = 1
Surgery priority	Elective	Urgent or emergency
Surgery type	CABG or single valve	All other surgery types
Aortic valve disease	None	Stenosis, regurgitation, both
BMI	BMI greater/equal to 25	BMI less than 25
Age	Younger than 75	75 years or older

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CABG: coronary artery bypass graft surgery; BMI: body mass index.

# Effects of CABG on the Hemostatic System

- Increased Thrombin production
- Hyperfibrinolysis
- Increased platelet activity and consumption
- Dilutional coagulopathy
- Effect of hypothermia and acidosis

# Mechanisms of Bleeding in Cardiac Surgeries

- Residual Heparin effect
- Dilutional coagulopathy

# Natural Anticoagulants

