Patient Blood Management and Targeted Hemostatic Therapy

Blood conservation during CPB
and management of bleeding after CPB

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After CPB: What does this patient need?

72-year-old man

65 kg AVR + 2-vessel CABG

CPB duration	Washed blood returned	Current Hb
158 min	550 mL	8.1 g/dL

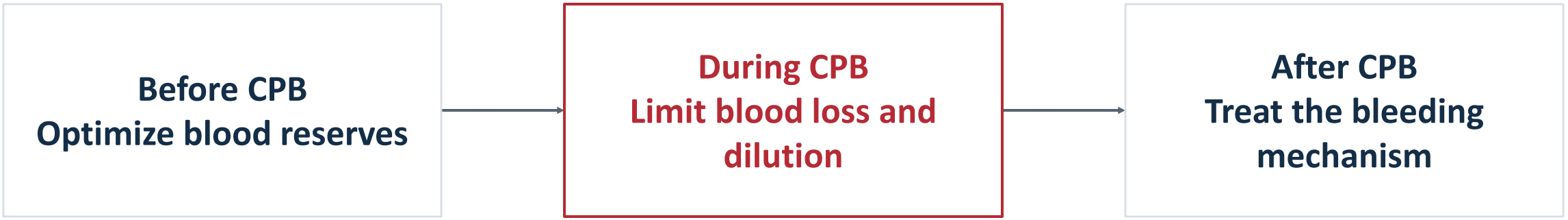
Persistent diffuse oozing after protamine

Which finding should guide the next treatment?

Fictional teaching case

EACTS/EACTAIC PBM 2024; EACTS/EACTAIC/EBCP CPB 2024

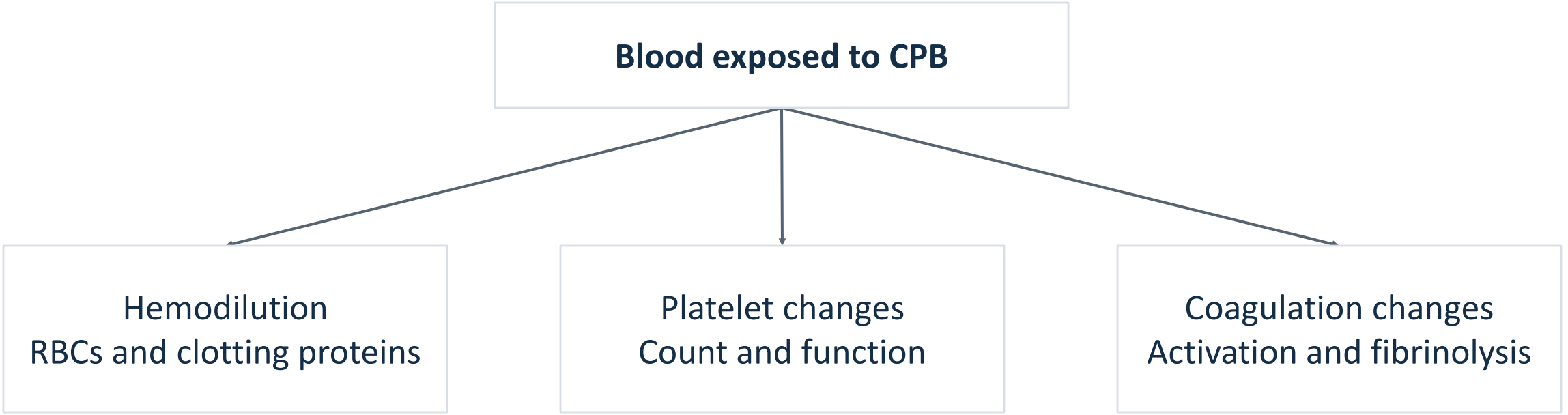
PBM starts before the pump



Plan → preserve → diagnose → reassess

Synthesis: STS/SCA/AmSECT/SABM 2021; EACTS/EACTAIC 2024; AHA Scientific Statement 2026

CPB creates more than one bleeding mechanism



Residual heparin and physiologic disturbances can add to the deficit

Conceptual synthesis: EACTS/EACTAIC PBM 2024; EACTS/EACTAIC/EBCP CPB 2024

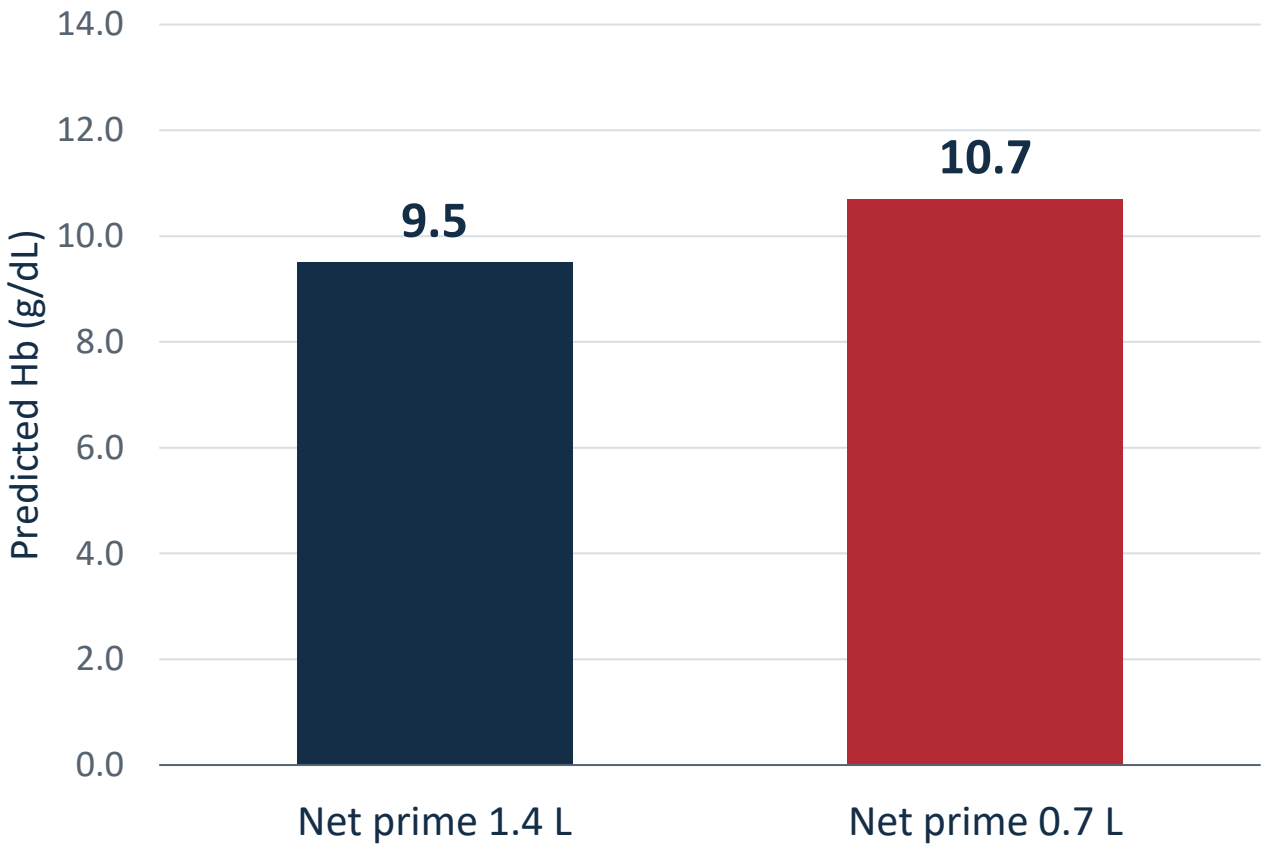
Before CPB: turn risk into a perfusion plan

Preoperative finding	Practical preparation
Anemia / iron deficiency	Flag optimization; anticipate dilution
Small blood volume	Select circuit and net-prime strategy
Antithrombotic exposure	Record agent, indication and last dose
Complex or prolonged procedure	Plan salvage, sampling and blood access

Use risk to prepare the workflow before bleeding begins

Practice synthesis: EACTS/EACTAIC PBM 2024; AHA Scientific Statement 2026

Hemodilution is a modifiable exposure



Same red-cell mass

65 kg, starting Hb 12.4 g/dL

Estimated blood volume 4.55 L

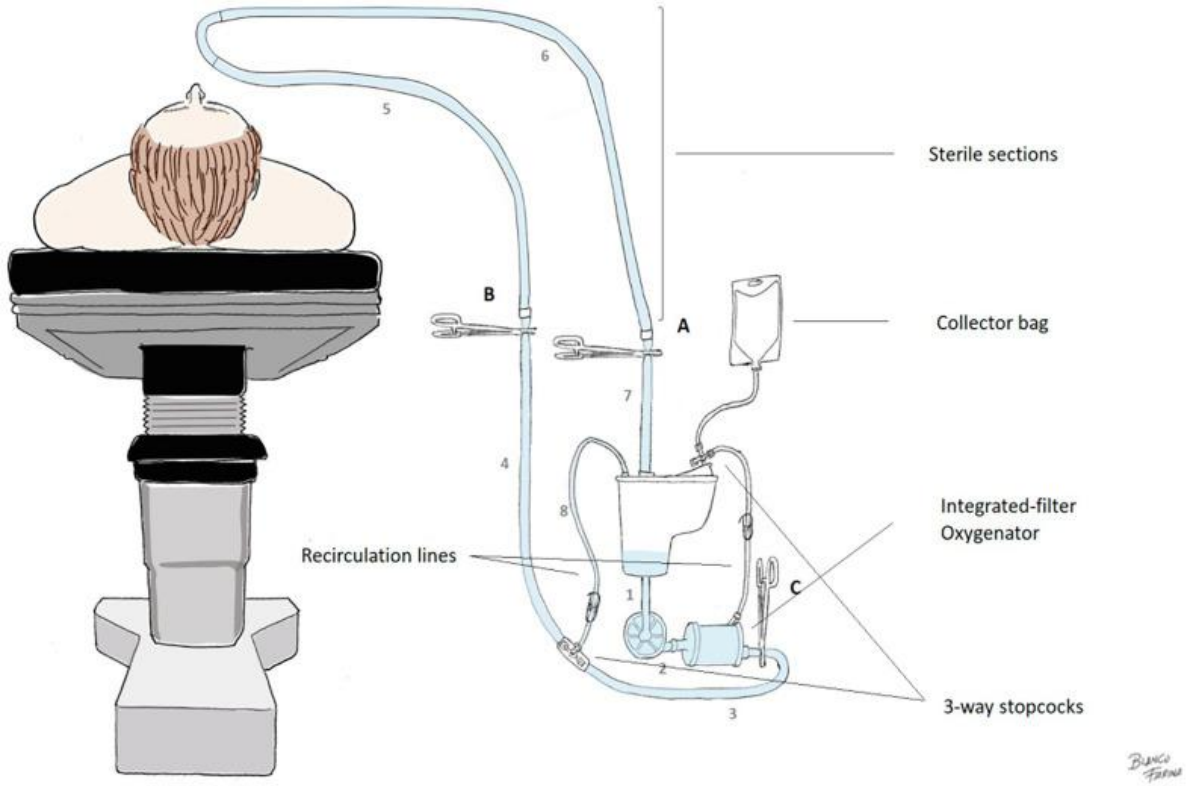
Only the added volume changes

Hb after dilution = initial Hb × blood volume / (blood volume + net prime)

Calculated illustration, not patient data. Blood volume assumed 70 mL/kg; values rounded.

Low prime and autologous priming

PUBLISHED HAR CIRCUIT



DESIGN / PATIENTS

Retrospective, propensity-adjusted study
225 HAR vs 210 historical controls
Elective CPB; logistic EuroSCORE ≥5

INTERVENTION

Minimized circuit + autologous repriming
Dilutional prime: 300 vs 1,350 mL

RESULT

Adjusted exposure to any transfusion:
6.9% vs 66.8%

Historical comparison:
the difference cannot be attributed to HAR alone.

Reduce avoidable dilution through a safe, standardized circuit plan.

Original Fig. 3: Blanco-Morillo et al. JECT 2023. doi:10.1051/ject/2023004. CC BY 4.0.

Blood conservation is a guideline-supported action

Recommendations	Class	Level
The use of low-molecular-weight starches in priming solutions is not recommended.	III	C
Minimizing priming volumes and using autologous priming (retrograde and antegrade) are recommended as part of a blood conservation strategy to reduce transfusions.	I	A
The routine use of mannitol in the priming solution is not recommended.	III	B
Maintenance of a normal pH (7.35–7.45) and avoidance of hyperchloraemic acidosis should be considered in order to reduce the risk of postoperative complications.	IIa	B
It is recommended that the addition of medications to the pump priming fluid be individualized to the patient and discussed by the clinical team.	I	C

Minimize dilution within a safe, patient-specific circuit plan.

Reformatted Recommendation Table 36: Wahba et al. 2024 CPB guideline. Eur J Cardiothorac Surg. 2025;67:ezae354. doi:10.1093/ejcts/ezae354.

Cell salvage returns red cells



RBC recovery ≠ full hemostatic recovery

Recover and wash shed blood

Return RBC-rich blood

Reassess coagulation separately

Image: Medtronic autoLog IQ, official product photograph. Clinical context: STS 2021; CPB guideline 2024.

Prevent fibrinolysis: the ATACAS TXA signal

MULTICENTER RANDOMIZED PLACEBO-CONTROLLED TRIAL

4,631 analyzed CABG patients ± other procedures; on-pump and off-pump

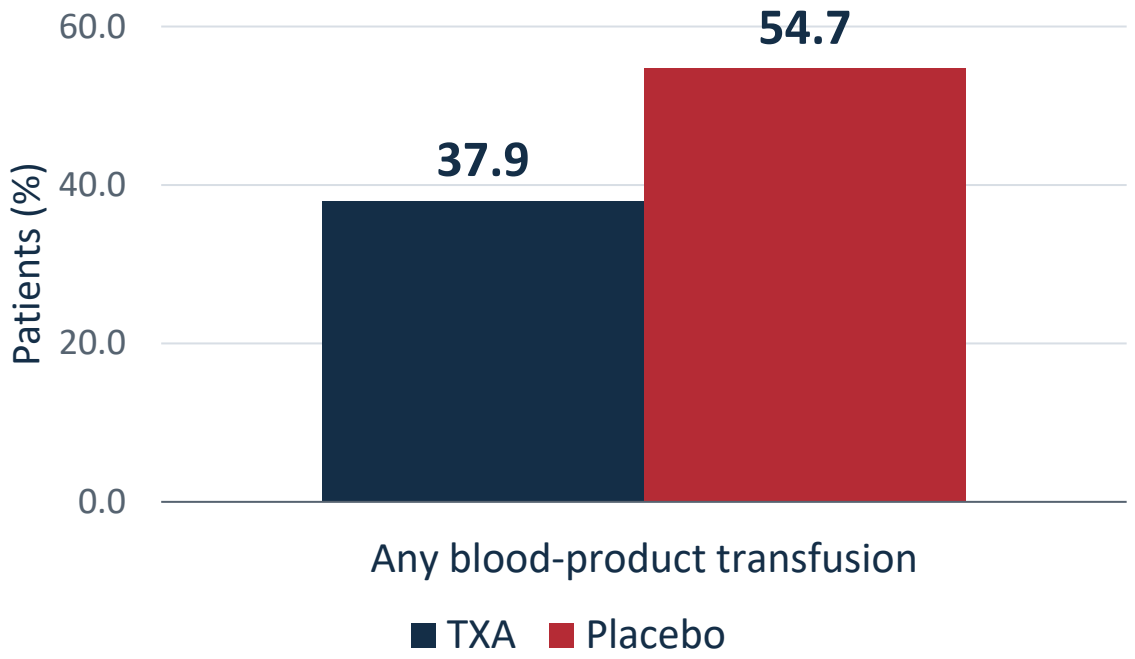
INTERVENTION / COMPARATOR

IV TXA after induction vs saline
Trial dose: 100 mg/kg, later 50 mg/kg

PRIMARY OUTCOME

30-day death / thrombotic composite
16.7% vs 18.1%; P = .22

Reoperation: 1.4% vs 2.8%
Seizures: 0.7% vs 0.1%



Prevent fibrinolysis; select the dose with renal function and seizure risk in mind.

Data redrawn: Myles et al. NEJM 2017;376:136–148. doi:10.1056/NEJMoa1606424.

RBC decisions combine Hb with oxygen delivery

Restrictive strategy

Hb threshold as a starting point

Ongoing bleeding and its trajectory

Hemoglobin trend after intervention

Clinical context

Pump flow and arterial O_2 content

Evidence of inadequate tissue oxygenation

Patient risk and physiologic reserve

DO_2 depends on blood flow and arterial oxygen content

EACTS/EACTAIC PBM 2024; EACTS/EACTAIC/EBCP CPB 2024; TRICS III, NEJM 2017

TRICS III: fewer transfusions, noninferior outcome

MULTICENTER RANDOMIZED NONINFERIORITY TRIAL

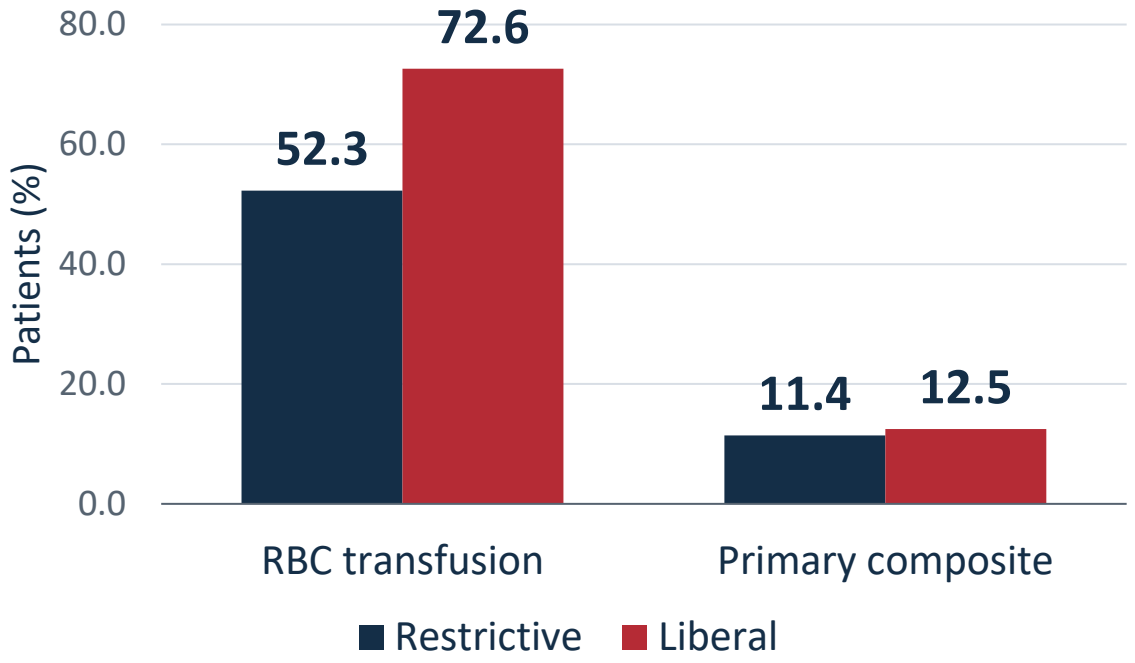
5,243 randomized adults undergoing CPB; EuroSCORE I ≥6

TRANSFUSION STRATEGIES

Restrictive: Hb <7.5 g/dL
Liberal: <9.5 in OR/ICU; <8.5 on ward
From induction to discharge / day 28

PRIMARY COMPOSITE

Death, MI, stroke or new dialysis
By discharge or day 28
11.4% vs 12.5%; noninferiority met



Use a restrictive strategy while assessing oxygen delivery and active bleeding.

Data redrawn: Mazer et al. NEJM 2017;377:2133–2144. doi:10.1056/NEJMoa1711818.

ACT protects the circuit; interpretation is contextual

01

Select the target for the assay and circuit

ACT >480 s is a conventional target in specified circuit settings

02

Measure regularly and after relevant changes

Follow the institutional monitoring and heparin-response protocol

03

Separate anticoagulation from post-CPB hemostasis

ACT alone cannot characterize every cause of bleeding

Wahba et al. 2024 EACTS/EACTAIC/EBCP CPB guideline. doi:10.1093/ejcts/ezae354.

Protamine is an individualized transition

Recommendations	Class	Level
A protamine-to-heparin ratio < 1.0 is recommended to avoid overdosing of protamine.	I	B
Individualized heparin–protamine management should be considered to reduce postoperative coagulation abnormalities and bleeding complications after cardiac surgery with CPB.	IIa	B
Cardiotomy suction should be discontinued with the start of the administration of protamine.	IIa	C

Ratio expressed conventionally as mg protamine per 100 IU heparin.

Avoid excess protamine; communicate the start of reversal.

Reformatted Recommendation Table 38: Wahba et al. 2024 CPB guideline. Eur J Cardiothorac Surg. 2025;67:ezae354. doi:10.1093/ejcts/ezae354.

Before component therapy, assess three domains

01

Source and bleeding severity

Inspect the surgical field; resuscitate major hemorrhage in parallel

02

Conditions for clot formation

Check temperature, pH, ionized calcium and perfusion

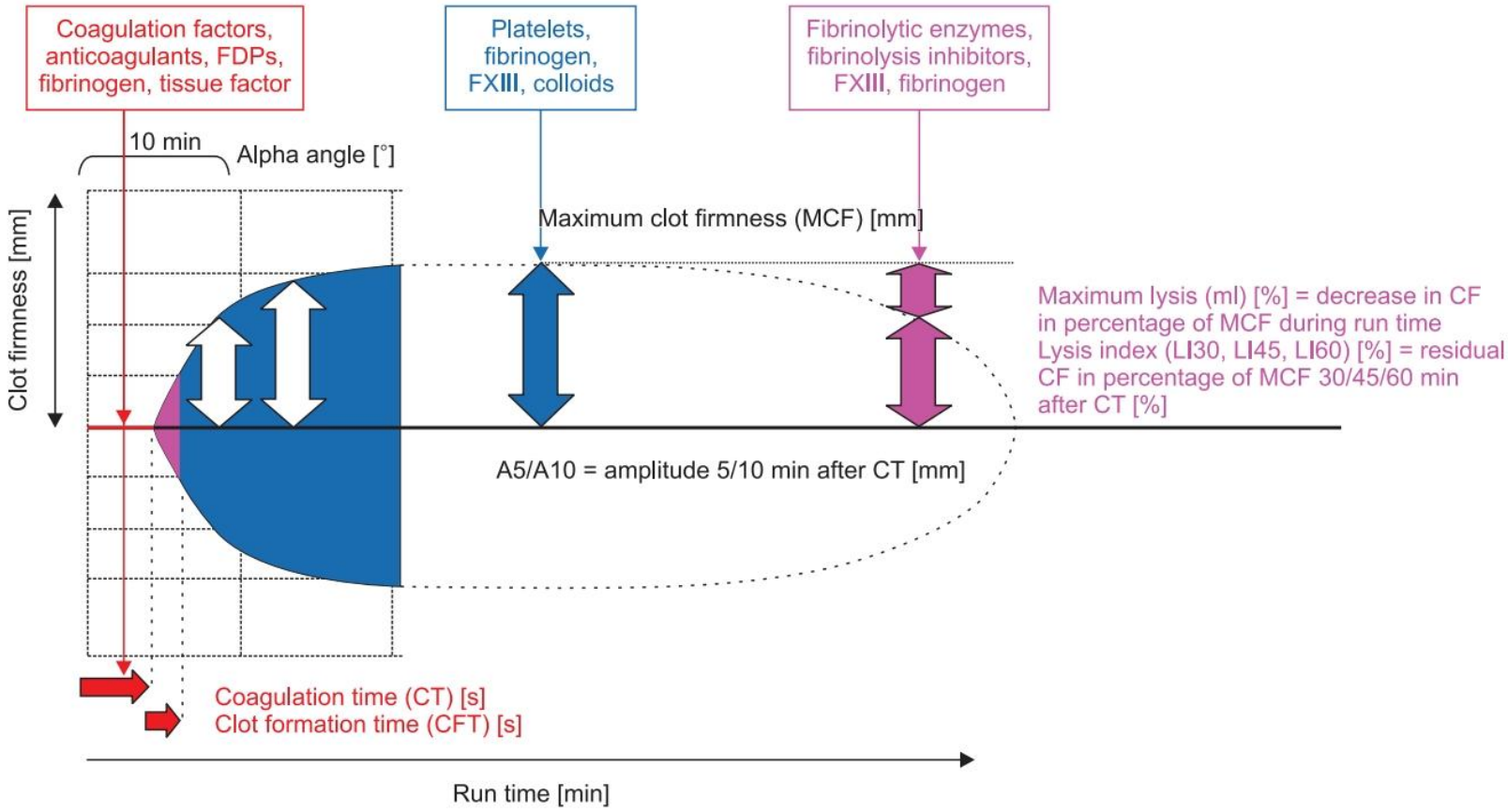
03

Anticoagulation and sample timing

Review heparin/protamine exposure and the time of the blood draw

Clinical synthesis: EACTS/EACTAIC PBM 2024; EACTS/EACTAIC/EBCP CPB 2024

Read a VET trace as a sequence



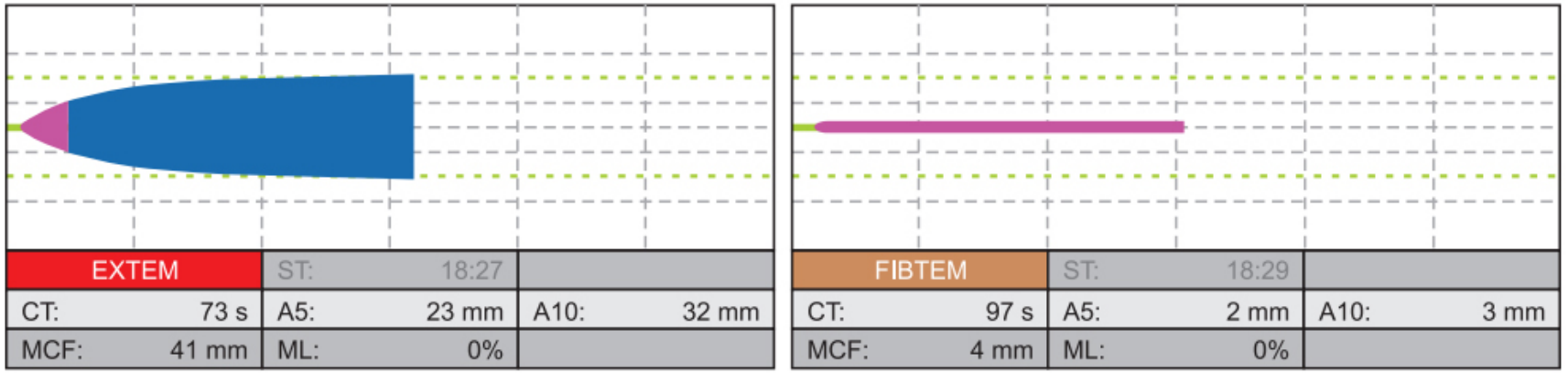
Initiation → early clot firmness → clot stability

Original Fig. 1: Görlinger et al. KJA 2019;72:297–322. doi:10.4097/kja.19169. CC BY-NC 4.0.

Low fibrin contribution identifies a treatment target

Original paired EXTEM / FIBTEM tracing

Fibrin polymerization disorder (e.g., low fibrinogen or low FXIII or colloid infusion):
$A5_{EX}$ < 35 mm
and
$A5_{FIB}$ < 9 mm



Low whole-clot firmness + low fibrin contribution

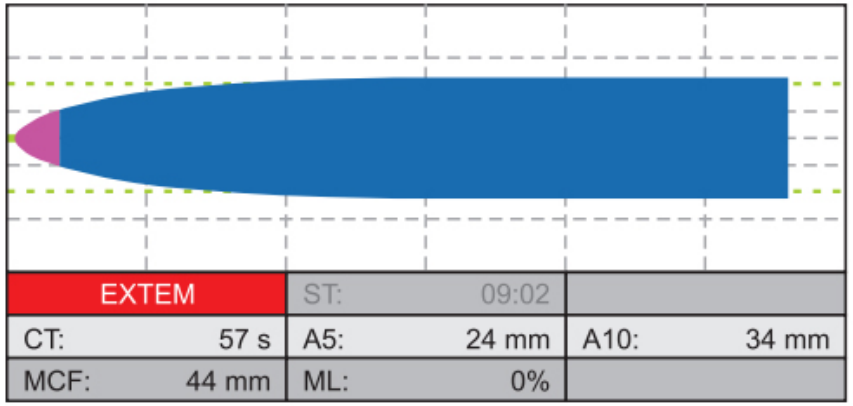
Confirm clinical bleeding and the fibrinogen deficit; use the local assay algorithm

Published teaching example: Görlinger et al. KJA 2019, Fig. 2 panel. doi:10.4097/kja.19169. CC BY-NC 4.0.

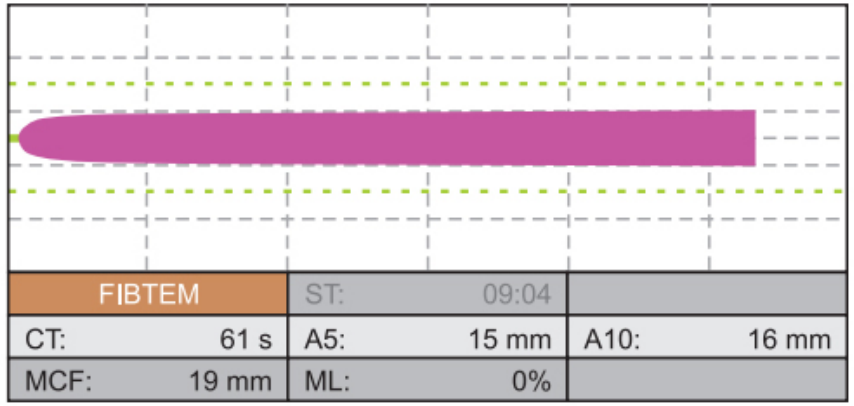
Preserved fibrin contribution changes the question

Original paired EXTEM / FIBTEM tracing

Thrombocytopenia or severe platelet dys-function (thrombin pathway or GPIIbIIIa-R):
$A5_{EX}$ < 35 mm
and
$A5_{FIB}$ ≥ 9 mm



EXTEM		ST:	09:02	
CT:	57 s	A5:	24 mm	A10: 34 mm
MCF:	44 mm	ML:	0%	



FIBTEM		ST:	09:04	
CT:	61 s	A5:	15 mm	A10: 16 mm
MCF:	19 mm	ML:	0%	

Consider the platelet count, function and drug history

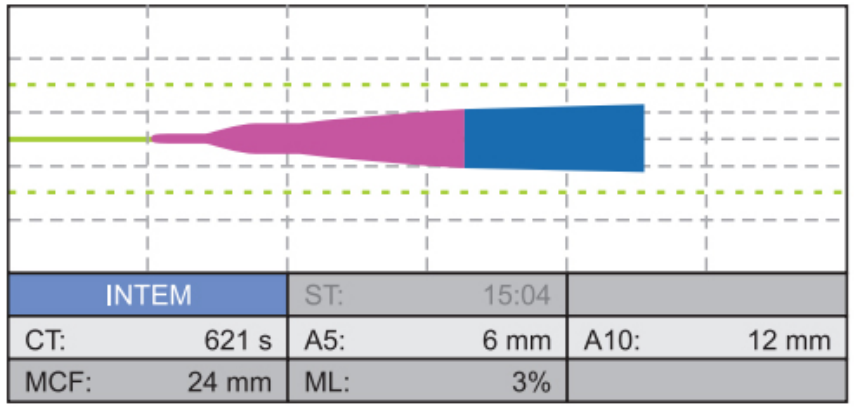
A standard VET result does not exclude every platelet defect

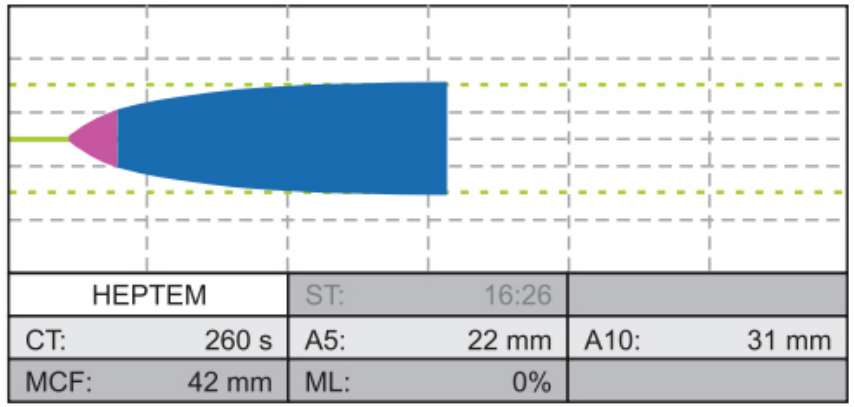
Published teaching example: Görlinger et al. KJA 2019, Fig. 2 panel. doi:10.4097/kja.19169. CC BY-NC 4.0.

Residual heparin: interpret the test and its limits

Published INTEM / HEPTEM teaching example — Görlinger 2019

Heparin, low dose (endogenous HLE, e.g., during OLT, sepsis or severe shock):
CT_{IN}/CT_{HEP}-ratio 1.1−2.5
(significant ≥ 1.25)





MOILANEN 2025 | PROSPECTIVE DIAGNOSTIC COHORT

51 analyzed cardiac-surgery patients: 45 CPB / 6 OPCAB

ACT and INTEM:HEPTEM vs anti-Xa, 10–15 min after protamine

Poor discrimination: INTEM:HEPTEM AUC 0.496

A near-normal ACT or negative comparison cannot reliably exclude heparin.

Trace: Görlinger et al. KJA 2019, Fig. 2. Diagnostic cohort: Moilanen et al. EJA 2025;42:398–406. doi:10.1097/EJA.0000000000002122.

A POC algorithm works as a clinical workflow

KARKOUTI 2016 | STEPPED-WEDGE CLUSTER RANDOMIZED TRIAL

7,402 CPB patients at 12 hospitals; randomized timing of algorithm adoption

INTERVENTION / COMPARATOR

ROTEM + PlateletWorks
+ treatment algorithm and training
vs usual care

PRIMARY OUTCOME

Any RBC transfusion
From surgery through day 7

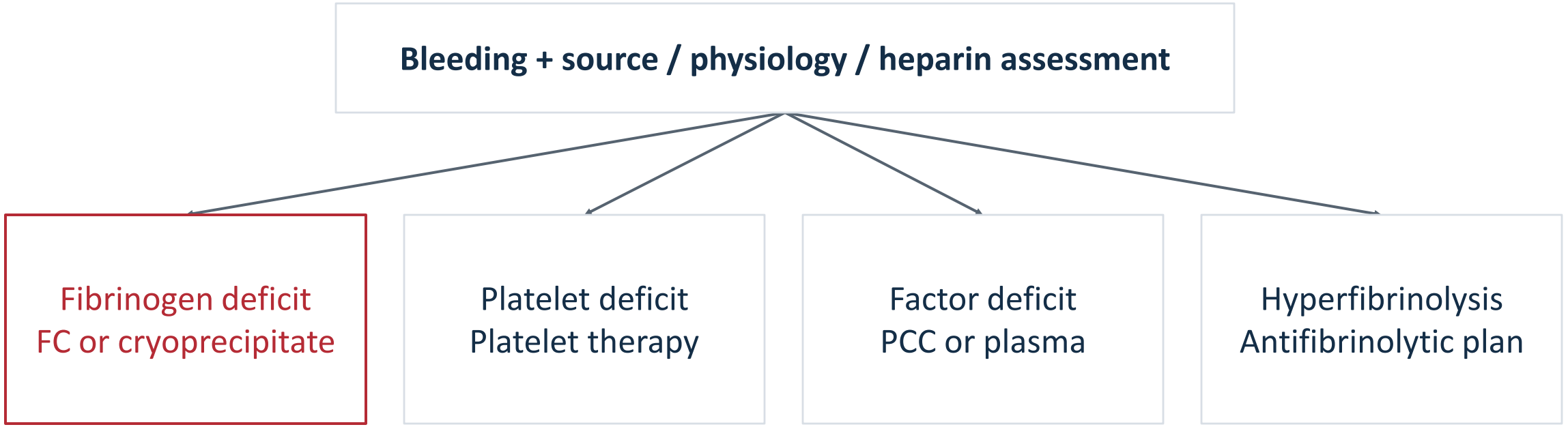
The intervention was a care pathway.

Outcome	Adjusted RR (95% CI)
RBC transfusion	0.91 (0.85–0.98)
Platelet transfusion	0.77 (0.68–0.87)
Major bleeding	0.83 (0.72–0.94)
Major complications	1.02 (0.81–1.28)

Connect sampling, interpretation, product selection and reassessment.

Data redrawn from Table 2 and Results: Karkouti et al. Circulation 2016;134:1152–1162. doi:10.1161/CIRCULATIONAHA.116.023956.

Match the intervention to the demonstrated defect



Treat the identified deficit → reassess bleeding and the test response

Editable conceptual algorithm synthesized from EACTS/EACTAIC PBM 2024; not a universal numeric trigger protocol.

Fibrinogen replacement: trigger, product, response

Decision	Evidence-informed approach
When to consider	Persistent microvascular bleeding + fibrinogen <1.5 g/L
Product options	Fibrinogen concentrate or cryoprecipitate
POC interpretation	Use the locally validated fibrin-based assay threshold
After replacement	Repeat clinical assessment and targeted testing

A5, A10 and Clauss fibrinogen are related measurements, with distinct thresholds

EACTS/EACTAIC PBM 2024; Callum et al. FIBRES, JAMA 2019. Clinical summary, not a product order set.

FIBRES: concentrate was noninferior

MULTICENTER NONINFERIORITY RCT

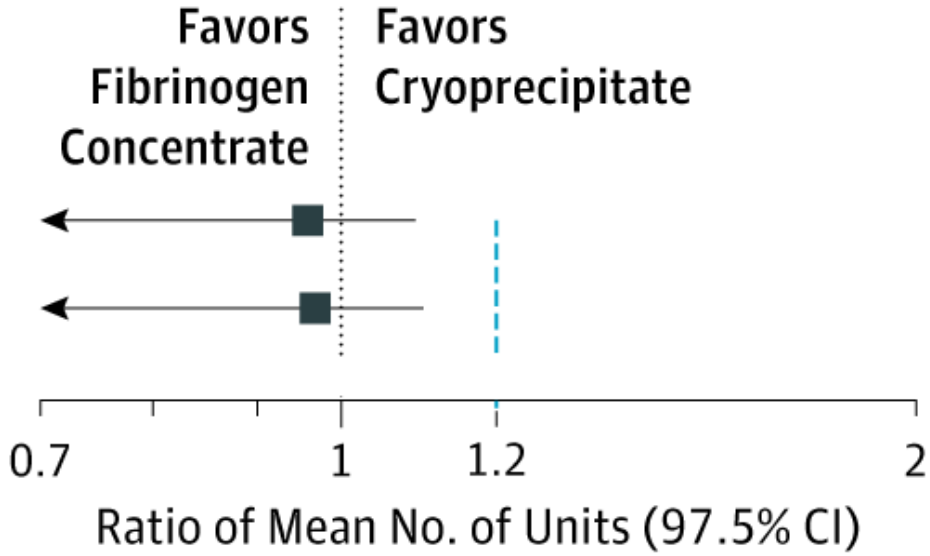
827 randomized / 735 analyzed
Post-CPB bleeding with low fibrinogen

INTERVENTION / PRIMARY OUTCOME

Concentrate 4 g vs cryoprecipitate 10 U
24-h RBC + platelet + plasma units

16.3 vs 17.0 units • Noninferiority met

Group/Subgroup	Ratio (97.5% CI)
Primary analysis set	0.96 (-∞ to 1.09)
Per-protocol analysis set	0.97 (-∞ to 1.10)



A replacement option when fibrinogen supplementation is indicated.

Original Fig. 2 excerpt: Callum et al. JAMA 2019;322:1966–1976. doi:10.1001/jama.2019.17312. ©AMA.

PCC and plasma address a different deficit

	4-factor PCC	Plasma
Primary content	Factors II, VII, IX, X	Broad plasma factor content
Delivery	Concentrated; low volume	Larger infusion volume
Role	Selected factor-deficit bleeding	Factor replacement when appropriate
What it does not solve	Fibrinogen or platelet deficit	A surgical bleeding source

Assess fibrinogen and heparin effects before escalating factor therapy

Clinical summary: EACTS/EACTAIC PBM 2024; FARES-II, JAMA 2025.

FARES-II: PCC improved effective hemostasis

MULTICENTER RANDOMIZED TRIAL

528 randomized / 420 analyzed
Post-CPB bleeding after heparin reversal

INTERVENTION / COMPARATOR

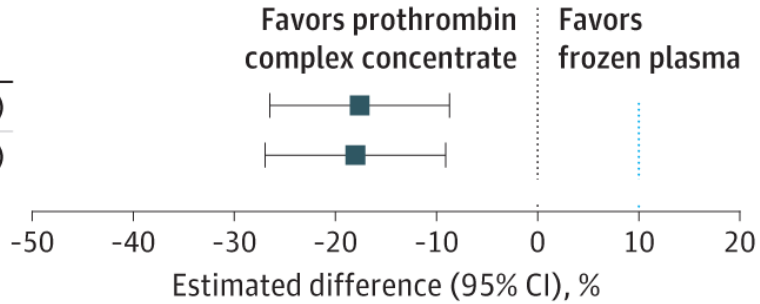
4F-PCC 1,500–2,000 IU
vs plasma 3–4 U (weight-based)

Effective hemostasis: 77.9% vs 60.4%

No additional hemostatic intervention from 60 min to 24 h after dose start; RBC excluded

ORIGINAL FIGURE: HEMOSTATIC RESPONSE FAILURE

Group or subgroup	No. hemostatic response failure/total (%) of patients: Prothrombin complex concentrate group	Frozen plasma group	Estimated difference (95% CI), %
Primary analysis set	47/213 (22.1)	82/207 (39.6)	-17.55 (-26.40 to -8.70)
Per-protocol analysis set	45/209 (21.5)	79/200 (39.5)	-17.97 (-26.91 to -9.03)



PCC is an option for selected factor-deficit bleeding after heparin reversal.

Original Fig. 2 excerpt: Karkouti et al. JAMA 2025;333:1781–1792. doi:10.1001/jama.2025.3501. ©AMA.

FARES-II: keep the safety result in context

FARES-II | SECONDARY SAFETY OUTCOMES THROUGH DAY 30

Same 420-patient cohort; open-label treatment; selected bleeding population

Patients with event	PCC (n = 213)	Plasma (n = 207)
Thromboembolic events	18 (8.5%)	15 (7.2%)
Acute kidney injury	22 (10.3%)	39 (18.8%)
Serious adverse events	77 (36.2%)	98 (47.3%)

Exploratory comparisons without multiplicity adjustment

Interpret the hemostatic benefit together with the individual thrombotic risk.

Data redrawn: Karkouti et al. FARES-II. JAMA 2025;333:1781–1792. doi:10.1001/jama.2025.3501. Exploratory secondary safety outcomes.

Back to our patient: physiology and reversal

Physiology	Observed values
Temperature / pH	36.4 °C / 7.36
Ionized calcium	1.16 mmol/L
MAP / cardiac index	70 mmHg / 2.6 L/min/m²
ACT / baseline ACT	132 s / 118 s

Concurrent assessment

Surgical field inspection

Heparin and protamine history

Sampling time and assay limita tions

A near-baseline ACT does not exclude residual heparin

Fictional teaching case

EACTS/EACTAIC PBM 2024; EACTS/EACTAIC/EBCP CPB 2024

Identify the dominant correctable defect

Measurement	After CPB
Hemoglobin	8.1 g/dL
Platelets	105 × 10^9/L
Clauss fibrinogen	1.1 g/L
EXTEM CT / A5	76 s / 28 mm
FIBTEM A5	4 mm

1.1 g/L

Low fibrinogen with ongoing diffuse bleeding

Low fibrin contribution provides a treatment target

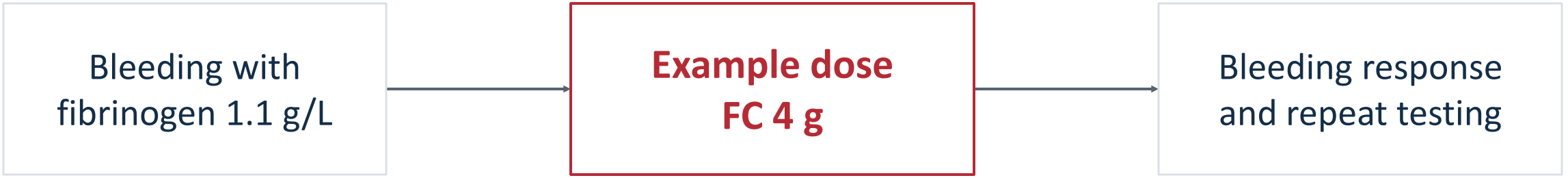
Interpret the whole-clot result together with the fibrin assay

Fictional teaching case

EACTS/EACTAIC PBM 2024; EACTS/EACTAIC/EBCP CPB 2024

Treat the measured deficit and reassess

Fibrinogen replacement



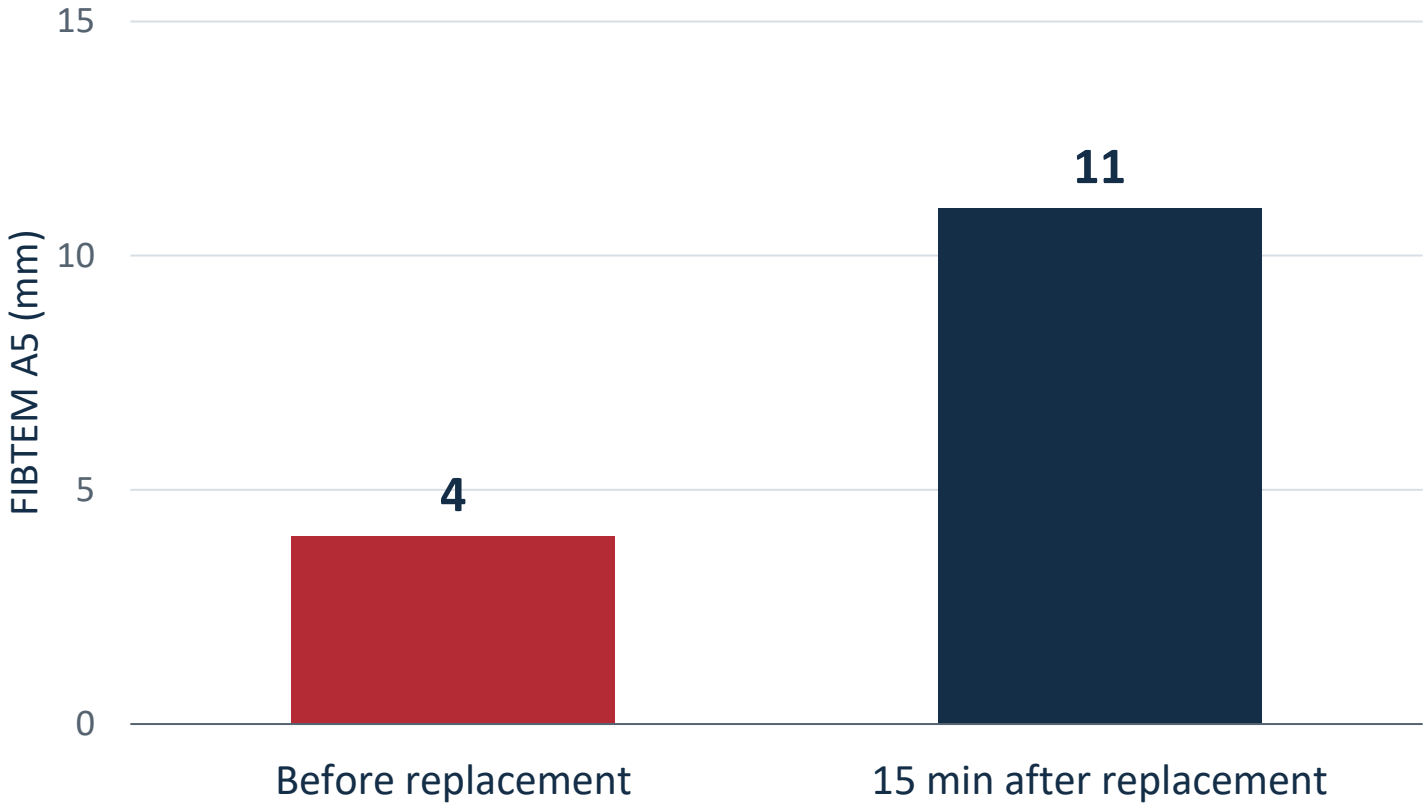
Cryoprecipitate is an alternative under the institutional protocol

The product and dose depend on the deficit and local preparation

Fictional teaching case

EACTS/EACTAIC PBM 2024; EACTS/EACTAIC/EBCP CPB 2024

The trace improves; the field still matters



1.1 to 2.1 g/L

Clauss fibrinogen

Diffuse oozing substantially decreases

Focal cannulation-site bleeding remains on repeat inspection

Fictional teaching case

EACTS/EACTAIC PBM 2024; EACTS/EACTAIC/EBCP CPB 2024

Complete the loop: source control and handoff



This patient required component replacement and surgical hemostasis

Recurrent bleeding prompts another assessment

Fictional teaching case

EACTS/EACTAIC PBM 2024; EACTS/EACTAIC/EBCP CPB 2024

Case B: evidence supports residual heparin

Paired assay	Clotting time
INTEM	380 s
HEPTEM	210 s

Anti-Xa 0.28 IU/mL

A separate confirmatory result supports heparin activity

Recurrent oozing 45 min after reversal

Review exposure and titrate reversal using the institutional method

Fictional teaching case

CPB guideline 2024; residual-heparin cohort, EJA 2025 (PMID39927521)

Case C: platelet contribution is the next target

Measurement	Observed value
Platelet count	42 × 10^9/L
Clauss fibrinogen	2.4 g/L
EXTEM A5 / CT	26 mm / 70 s
FIBTEM A5	13 mm

42 × 10^9/L

Significant thrombocytopenia with diffuse bleeding

Platelet replacement and reassessment

Preserved fibrin contribution changes the next treatment

Fictional teaching case

EACTS/EACTAIC PBM 2024; EACTS/EACTAIC/EBCP CPB 2024

The perfusion handoff is part of hemostatic therapy

Information	Include the timing and response
Heparin / protamine	Total, last dose, reversal method and completion time
Recovered blood	Washed or unprocessed; volume and return time
Current physiology / tests	Temperature, iCa, Hb, VET/labs and sampling time
Intervention / next check	Product, dose, bleeding response and reassessment plan

A number without its time and treatment context is incomplete

Practical handoff synthesized from CPB 2024 and PBM 2024 guidance; institutional workflow required.

Make testing actionable when bleeding evolves



Assign who samples, interprets, obtains treatment and confirms the response

Workflow synthesis: EACTS/EACTAIC PBM 2024; Karkouti et al. Circulation 2016.

Three messages to take back to the pump

01 Preserve blood before and during CPB

02 Link RBC transfusion to oxygen-delivery needs

03 Identify the defect, treat it, then reassess

The perfusionist connects blood conservation with targeted hemostasis

PBM guideline 2024; CPB guideline 2024; AHA Scientific Statement 2026.