ERAS Cardiac Society turnkey order set for patient blood management: Proceedings from the AATS ERAS Conclave 2023

Rawn Salenger, MD,a Sameer Hirji, MD, MPH,b Amanda Rea, DNP,c Busra Cangut, MD,d Vicki Morton-Bailey, DNP,e Alexander J. Gregory, MD,f Rakesh C. Arora, MD, PhD,g Michael C. Grant, MD, MSE,h Jacob Raphael, MD,i and Daniel T. Engelman, MD,j on behalf of the ERAS Cardiac Working Group*

ABSTRACT

Objectives: There are multiple published guidelines on comprehensive patient blood management (PBM), centered on the 3 pillars of PBM: managing preoperative anemia, minimizing blood loss, and tolerating intraoperative/postoperative anemia. We sought to create an order set to facilitate widespread implementation of evidence-based PBM for cardiac surgery patients.

Methods: Subject matter experts were consulted to translate existing guidelines and literature into a sample turnkey order set (TKO) for PBM. Orders derived from consistent class I, class IIA, or equivalent recommendations across referenced guidelines and consensus manuscripts appear in the TKO in bold type. Selected orders that were inconsistently class I or IIA, class IIB, or supported by published evidence are presented in italic type.

Results: Preoperatively, there are strong recommendations to screen and treat preoperative anemia with iron replacement and erythropoietin and to discontinue dual antiplatelet therapy if the patient can safely wait for surgery. Intraoperative orders outline the routine use of an antifibrinolytic agent, cell saver, point of care viscoelastic testing, and use of a standard transfusion algorithm. The order set also reflects strong recommendations intraoperatively and postoperatively for agreed-upon hemoglobin thresholds to consider transfusion of packed red blood cells. A hemoglobin threshold should be adopted according to local team consensus and should trigger a discussion regarding transfusion.

Conclusions: The benefit of a multidisciplinary PBM care pathway in cardiac surgery has been well established, yet implementation remains variable. Using recommendations from existing guidelines, we have created a TKO to facilitate the implementation of PBM. (J Thorac Cardiovasc Surg 2023; -:1-8)
Patient blood management (PBM) is an essential quality component in contemporary cardiac surgery perioperative care. PBM is characterized by 3 main pillars: managing preoperative anemia, minimizing blood loss, and tolerance to intraoperative/postoperative anemia (Figure 1). Management of preoperative anemia requires mechanisms for early anemia detection and the use of pharmaceutical adjuncts, including supplemental iron and erythropoiesis-stimulating agents (ESAs) in selected patients. Minimization of intraoperative blood loss involves meticulous surgery, communication with the intraoperative team, collaborative measures to avoid hemodilution, and the use of cell salvage devices. Tolerance of intraoperative and postoperative anemia, the third pillar, necessitates optimization of oxygen delivery to maintain well-compensated physiology and avoid end-organ malperfusion in the setting of anemia.

Beyond the 3 pillars, PBM also may use established standardized algorithms to guide the appropriate use of blood products in hospitalized patients. Multiple societies have published evidence-based guidelines for PBM. From a provider standpoint, however, meaningful standardized adoption and implementation of comprehensive PBM from among the various available guidelines can be challenging. The intention of this endeavor, therefore, was to undertake an analysis of published guidelines and develop a practical PBM order set that can be widely implemented. We sought to synthesize a feasible, evidence-based order set that encompasses strong recommendations from all the major guidelines. Our goal was to provide clinicians with a valuable tool to aid the bedside implementation of the essential recommendations regarding PBM. Each order included in Table 2 is either a consistent class I or IIA recommendation across guidelines or supported by published peer-reviewed evidence. Each of these orders should be considered based on local institutional priorities, resources, practices, and expertise. This turnkey order set was created by the Enhanced Recovery After Surgery (ERAS) Cardiac Society to aid in the implementation of high-quality PBM and was presented at the American Association of Thoracic Surgeons Annual Meeting ERAS Conclave in April 2023.

**Abbreviations and Acronyms**

DAPT = dual antiplatelet therapy
DDVAP = 1-deamino-8D-arginine vasopressin
ERAS = Enhancing Recovery After Surgery
ESA = erythropoiesis-stimulating agent
PBM = patient blood management
PRBC = packed red blood cells
TKO = turnkey order set

**See Commentary on page XXX.**
American Association of Thoracic Surgeons (AATS) Annual Meeting ERAS Conclave in April 2023.

**METHODS**

Key subject matter experts were consulted to review and translate existing guidelines and peer-reviewed literature into a sample TKO set for PBM. Table 1 provides an overview of existing class I and IIA (or equivalent) recommendations from relevant guidelines and consensus statements. Table 2 translates the recommendations into a TKO. Orders derived from consistent class I, class IIA, or equivalent recommendations across referenced guidelines and consensus reports appear in the TKO in bold type. Selected orders that were inconsistently class I or IIA, class IIB, or supported by evidence published in peer-reviewed journals, are included in italic type. Notably, the intent was not to recapitulate the evidence base justifying existing recommendations, because this task was performed as part of the original guidelines and consensus statements efforts. Decisions regarding order inclusion were made based on estimated benefit, risk, cost, implementation complexity, and generalizability. Each of these orders should be considered based on local institutional priorities, resources, practices, and expertise.

**Published Guidelines**

A large volume of evidence has been published on blood utilization from multiple disciplines, which has formed the basis of several major published guidelines (Table 1).

To facilitate creation of a TKO set, higher-level recommendations from 3 sets of guidelines and 1 consensus statement were compared, which included (1) Society of Thoracic Surgeons (STS)/Society of Cardiovascular Anesthesiologists (SCA)/American Society of Extracorporeal Technology (AmSECT)/Society for the Advancement of Blood Management (SABM),4 (2) European Association for Cardio-Thoracic Surgery (EACTS)/European Association of Cardiothoracic Anaesthesiology (EACTA),5 (3) American Society of Anesthesiologists,6 and (4) The Eighth Perioperative Quality Initiative (POQI-8) in collaboration with the ERAS Cardiac Society.7

**Preoperative.** The first 3 of the aforementioned documents are comprehensive guidelines, whereas the POQI-8 ERAS Cardiac Society publication is a consensus statement focused on preoperative anemia. We compare the consensus statement to the 3 comprehensive guidelines solely in the focused area of preoperative anemia. The STS/SCA/AmSECT/SABM guidelines and POQI-8/ERAS Cardiac Society statement recommend screening and workup for preoperative anemia. Each recommends the treatment of iron deficiency anemia with iron replacement therapy, using intravenous (IV) iron if possible. The POQI-8/ERAS Cardiac Society further recommends treatment of iron-deficient, nonanemic patients with iron replacement, who are at higher risk of perioperative anemia and blood transfusion (Table E1e1-e4). All the publications recommend treatment with ESAs for most anemic patients, although the specific language varies.4-7

Regarding other preoperative elements, each of the guidelines reviewed recommend the creation of a multidisciplinary PBM program, and 2 of the guidelines explicitly call for the use of a standard transfusion algorithm throughout all 3 phases of care.4-6 Platelet aggregation studies are recommended to help determine the timing of surgery in urgent patients presenting on dual antiplatelet therapy (DAPT) by 2 of the guidelines.4,6 When this testing is unavailable prior to nonemergent or elective surgery, each guideline recommends a specific waiting period after stopping DAPT before proceeding to the operating room.4-7 Other preoperative recommendations include discontinuation of warfarin, direct oral anticoagulants,4-6 and aspirin in select patients without coronary artery disease.4-5 Guidance is also provided regarding bridging select patients needing anticoagulation or uninterrupted DAPT therapy.4,6

**Intraoperative.** The primary focus of intraoperative recommendations is on limiting blood loss. The guidelines strongly recommend cell salvage, administration of an antifibrinolytic agent, and point of care viscoelastic testing to diagnose and treat coagulopathy.4,6 Minimizing intraoperative hemodilution is recommended, with retrograde autologous priming the method of choice to achieve this goal.4,5 Acute normovolemic

![FIGURE 1. Enhancing Recovery After Surgery (ERAS) Cardiac Society turnkey order set for patient blood management.](https://example.com/fig1.png)
TABLE 1. Comparison of class I/IIa or equivalent recommendations for cardiac surgery patient blood management

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>STS/SCA/AmSECT/SABM guidelines</th>
<th>EACTS/EACTA guidelines</th>
<th>ASA guidelines</th>
<th>POQI-8/ERAS-C consensus statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multidisciplinary PBM program</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Standard transfusion protocol</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative anemia screening/identification</td>
<td>★</td>
<td></td>
<td>✔</td>
<td>★</td>
</tr>
<tr>
<td>For hemoglobin &lt;12 g/dL, administer erythropoietin for appropriate patients who have preoperative anemia (i), refuse blood transfusion (ii), or are deemed at high risk for postoperative anemia</td>
<td>★</td>
<td>(non-Fe-deficient)</td>
<td>✔</td>
<td>★ (select)</td>
</tr>
<tr>
<td>Iron therapy for iron deficiency anemia</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discontinue low-intensity antiplatelet medications (eg, aspirin) 1 wk prior to surgery in elective patients without coronary artery disease</td>
<td>★</td>
<td></td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>In the absence of PLAGS, stop ticagrelor 3 d, clopidogrel 5 d, and prasugrel 7 d prior to surgery</td>
<td>★</td>
<td></td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>For nonemergent patients, DOACs should be discontinued 3-5 d prior to surgery</td>
<td>★</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>For urgent cases, perform platelet aggregation studies to determine timing of surgery for patients on DAPT</td>
<td>★</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>For emergent surgery in patients on novel anticoagulant, administer specific antidote, or, if unavailable, prothrombin complex concentrate</td>
<td>★</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>If on oral anticoagulation or high-risk for thromboembolic event, bridge patient with unfractionated heparin</td>
<td>★</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cell salvage</td>
<td>★</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antithrombin III for heparin resistance</td>
<td>★</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Administer DDAVP for patients with serious bleeding and platelet dysfunction post-CPB, are uremic, or have Von Willebrand disease</td>
<td>★</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limitation of hemodilution</td>
<td>★</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Administer tranexamic acid</td>
<td>★</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retrograde/antegrade autologous prime</td>
<td>★</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Continued)
hemodilution is also recommended in 2 of the guidelines as a method to reduce coagulopathic bleeding after cardiopulmonary bypass (CPB).4,6 Although there is not complete agreement between the different sets of guidelines, there is considerable consensus regarding cell salvage, antifibrinolitics, limiting hemodilution, and the contribution of careful surgical technique for limiting intraoperative blood loss.

**Postoperative.** In the postoperative phase of care, the most important guideline recommendations include following a standard transfusion protocol informed by a multidisciplinary PBM program.4,6 A successful standardized approach requires involving multiple stakeholders including surgeons, anesthesiologists, critical care intensivists, hematologists, blood banks, advanced practice providers, and nurses in the creation of a transfusion algorithm. The algorithm should address the lowest hemoglobin threshold and physiologic signs for considering the transfusion of packed red blood cells, as well as indications for other blood components, recombinant and synthetic factor concentrates, and pharmacologic agents such as 1-deamino-8-D-arginine vasopressin.

Tolerance of well-compensated anemia is a major component of reduced blood utilization perioperatively. Institutional efforts to establish consensus will reduce blood utilization as the team culture shifts toward blood conservation, thus limiting patients’ exposure to potentially harmful transfusions.5

**Putting the Guidelines Together: A TKO Set**

The TKO set (Table 2) provides an evidence-based framework to assist clinicians in bedside implementation of PBM. Preoperative, intraoperative, and postoperative recommendations have been translated into actionable orders.

The TKO set reflects strong recommendations intraoperatively and postoperatively for agreed-upon hemoglobin thresholds to consider transfusion of packed red blood cells.4,6 This important standard reflects the point at which the surgical team pivots to treating anemia from tolerating a physiologically compensated anemia. For a patient to tolerate anemic conditions, tissue oxygen delivery and mean arterial pressure must be optimized.10 Although the lowest safe hemoglobin trigger has not yet been identified, established “restrictive” transfusion triggers11 may be too liberal, as indicated by numerous reports of excellent outcomes in matched cohorts of severely anemic Jehovah’s Witness patients.12 When a patient reaches the threshold hemoglobin level, a transfusion is not automatically triggered; instead, there should be a determination regarding physiologic signs of malperfusion indicating the need for additional oxygen-carrying capacity, such as elevated base deficit or lactate level.13 This proposed order set establishes low hemoglobin thresholds by traditional standards, which should be adapted according to local team consensus.

Certain orders and recommendations were considered fundamental to high-quality PBM. These essential recommendations are depicted in Figure 2 as assessment, therapy, and clinical communication, organized by phase of care. In an additional effort to facilitate implementation, we have broken down the TKO set into components according to phase of care (Table E2).

**Future Study**

Despite the large amount of published research related to PBM, there remain numerous opportunities to improve our evidence base. Preoperatively, more research on the ideal agents and duration of treatment for anemia is needed. Regarding ESAs in particular, there is considerable evidence demonstrating safety and effectiveness in nearly all anemic patients. However, a practice gap exists owing to cost barriers and historical concerns about safety. Investigation of ways to break down implementation barriers would be valuable. Conversely, results from studies examining iron replacement only, such as the Intravenous Iron for Treatment of Anemia Before Cardiac Surgery (ITACS) Trial (NCT 02632760), may clarify the role of iron therapy alone for preoperative anemia. Outcomes of this trial could influence future recommendations. More studies defining optimal intraoperative techniques would be of value to clinicians, clarifying the relative roles of retrograde autologous priming, modified ultrafiltration, and mini-CPB circuits. The utility of acute normovolemic hemodilution also needs to be better defined. A safe hemoglobin nadir on pump needs to be defined under variable conditions. The field may benefit from randomized trials comparing outcomes with lower threshold hemoglobin values than historically studied. Future studies identifying which specific groups of patients can benefit from the use of recombinant therapies, such as recombinant factor VII, also would be beneficial. Finally, although the evidence has demonstrated the benefit of PBM in reducing blood utilization,6,13 we need to demonstrate its impact on other patient outcomes, including postoperative complications, failure to rescue, and mortality.

**Limitations**

There are several notable omissions in our order set. We have omitted reference to some of the more nuanced issues surrounding transfusion therapy, including indications for recombinant factors and prothrombin complex concentrate versus fresh frozen plasma. These are important clinical issues, but they are not well delineated throughout major published guidelines and thus are considered beyond our scope. Intraoperatively, acute normovolemic hemodilution, modified ultrafiltration, and miniaturized CPB circuits have been used for their blood-sparing effect and have evidence to support their use. In our estimation, optimal retrograde and antegrade autologous priming may obviate the need for modified ultrafiltration or mini-CPB circuits and is technically simpler to deploy. Nonetheless, this TKO set is not intended to be a comprehensive guideline for every possible blood-sparing technique. Rather, our aim is to provide programs with a sample of essential guideline-recommended techniques to achieve significant blood conservation and high-quality PBM. The provided order
### TABLE 2. PBM turnkey order set

#### Preoperative

- For nonemergent cases in the absence of platelet function studies, discontinue ticagrelor at 3 d, clopidogrel at 5 d, and prasugrel at 7 d before surgery
- For elective cases without coronary artery disease, discontinue aspirin for 7 d preoperatively
- Clinical communication: minimize phlebotomy
- Hemoglobin
- Platelet count
- PT/INR
- PTT
- Send platelet aggregation studies for patients receiving DAPT
- For patients requiring DAPT bridging: Cangrelor 30 mg/kg IV bolus followed by 4 µg/kg/min IV infusion; discontinue 1 h before OR
- For nonemergent patients on a DOAC, discontinue apixaban at 3 d, rivaroxaban at 4 d, and dabigatran at 4 d before surgery
- For emergent patients on a DOAC, choose an appropriate antidote:
  - Andexanet alfa (for apixaban, rivaroxaban)
    - 400 mg IV bolus, then 4 mg/min IV × 2 h (≥8 h since last DOAC)
    - 800 mg IV bolus, then 8 mg/min IV × 2 h (<8 h since last DOAC)
  - Idarucizumab 5 g IV × 1 (for dabigatran)
  - Kcentra/Beriplex 0.12 mL/kg/min IV; titrate to goal INR (or alternative prothrombin complex concentrate)
- For nonemergent patients on warfarin, discontinue 5 d prior to surgery
- For patients on warfarin who cannot wait 5 d, administer FFP according to parameters below
- In patients with atrial fibrillation and high risk for thromboembolic event, bridge with IV heparin, with weight-based titration to therapeutic range (see heparin order sheet)
- Preoperative anemia: Hgb <13 g/dL:
  - Laboratory tests:
    - Total iron binding capacity panel
    - Ferritin
    - Fecal occult blood screening
  - Medications
    - Ferric gluconate 250 mg IV once daily for up to 7 d (see Table E1 for alternate Fe formulations)
    - Erythropoetin alfa-epo 40,000 IU IV × 1
    - Folic acid tablet 5 mg orally once daily until surgery (up to 4 wk)
    - Vitamin B-12 1000 µg orally once daily until surgery (up to 4 wk)

#### Intraoperative

- Administer tranexamic acid: bolus 10 mg/kg IV × 1, then continuous IV drip based on serum creatinine:
  - <1.6 = 2 mg/kg/h
  - 1.6-3.2 = 1.5 mg/kg/h
  - 3.3-6.6 = 1 mg/kg/h
- Clinical communication: Limit pre-CPB IV fluid to 250 mL
- Clinical communication: Use cell salvage
- Clinical communication: Arterial and venous autologous prime
- Clinical communication: Centrifuge pump-salvaged blood
- Clinical communication: Use point of care viscoelastic testing to diagnose and then treat coagulopathy according to a standard transfusion algorithm
- Clinical communication: Utilize a hemoglobin threshold to consider PRBC transfusion (6.0 g/dL)
- For heparin resistance: Administer antithrombin III 500 U IV, repeat once as needed to achieve desired ACT

#### Postoperative

- Utilize a standard transfusion algorithm
- Notify provider if Hgb <7.5 g/dL (consider transfusion in nonbleeding patients only for signs of end-organ malperfusion, such as elevated lactate and significant base deficit)
- Notify provider for chest tube drainage of 200 mL/h for >1 h
- If actively bleeding:
  - Perform point of care VET and transfuse according to standard algorithm
  - PT/INR, PTT
  - Fibrinogen

(Continued)
set may be adopted or modified according to local clinical needs, constraints, and institutional policies.

CONCLUSIONS

The benefit of a multidisciplinary PBM care pathway in cardiac surgery has been well established in the literature and is reflected in the numerous guidelines published by our major societies. However, despite the importance of PBM, implementation remains variable across institutions. Using recommendations from existing guidelines, we have created a straightforward turnkey order set to facilitate the implementation of PBM into cardiac surgery practice.

Conflict of Interest Statement

D.T.E. reports serving on a device safety monitoring board for Edwards Lifesciences Medical and on advisory boards for Astellas Pharma, Alexion, Terumo, Medela, and Renibus Therapeutics. R.C.A. reports honoraria from

TABLE 2. Continued

- Platelet count
- Platelet aggregation study
- Hemoglobin

Treatment:
- For INR >1.7, transfuse 2 U of FFP
- For fibrinogen <150 mg/dL, transfuse 10 U of cryoprecipitate or administer Fib Ryga 4 g IV over 10 min (or alternative fibrinogen concentrate)
- For functional platelets <50 10^3/ulu, transfuse 2 U of platelets
- PRBC transfusion as needed
- Kcentra/Beriplex 0.12 mL/kg/min IV titrate if on a DOAC preoperatively and PTT is elevated (or alternative prothrombin complex concentrate)
- DDAPV 0.3 g/kg IV × 1 for patients with post-CPB platelet dysfunction, uremia, or Von Willebrand disease; repeat once as needed
- Hgb <8 g/dL
  - Ferric gluconate 250 mg IV once daily for 3 d
  - Ferrous sulfate 324 mg orally daily for 30 d

Bold orders indicate consistent class I, IIA, or equivalent recommendations across referenced guidelines; italicized orders indicate inconsistently class I or IIA, class IIB, or supported by published evidence. PT, Prothrombin time; INR, international normalized ratio; PTT, partial thromboplastin time; DAPT, dual antiplatelet therapy; IV, intravenous; OR, operating room; DOAC, direct oral anticoagulant; FFP, fresh frozen plasma; Hgb, hemoglobin; CPB, cardiopulmonary bypass; PRBC, packed red blood cells; ACT, activated clotting time; VET, viscoelastic testing; DDAPV, 1-deamino-8-D-arginine vasopressin. Reprinted with permission from the ERAS Cardiac Society.

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We would like to acknowledge the valuable assistance and expertise provided by Sherri Ozawa, MSN, RN, Immediate Past President of the Society for the Advancement of Patient Blood Management.

References


Key Words: patient blood management, enhanced recovery after surgery, critical care, perioperative care, transfusion
E-References


### TABLE E1. Alternative iron formulations

<table>
<thead>
<tr>
<th>Route</th>
<th>Dose</th>
<th>Cost</th>
<th>Benefits</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Oral</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ferrous sulfate</td>
<td>325 mg, 3 times/day</td>
<td>$0.70/tablet</td>
<td>• Low costs&lt;br&gt;• Easy to apply&lt;br&gt;• Less serious side effects</td>
<td>• Low bioavailability&lt;br&gt;• High rate of nonresponse&lt;br&gt;• GI side effects&lt;br&gt;• Low compliance</td>
</tr>
<tr>
<td>Ferrous gluconate</td>
<td>325 mg, 3 times/day</td>
<td>$0.90/tablet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ferrous fumarate</td>
<td>324 mg, 3 times/day</td>
<td>$1.40/tablet</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>IV</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ferric carboxymaltose</td>
<td>750 mg, 1.3 dose</td>
<td>$885.80 (15-mL vial)</td>
<td>• Faster replacement&lt;br&gt;• Fewer GI side effects&lt;br&gt;• Better control of compliance&lt;br&gt;• Can administer larger doses at one time</td>
<td>• Rare but possible life-threatening anaphylactic reactions&lt;br&gt;• Higher cost&lt;br&gt;• Hypophosphatemia</td>
</tr>
<tr>
<td>Ferric derisomaltose</td>
<td>1000 mg, 1 dose</td>
<td>$2464.20 (10 mL vial)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ferumoxylot</td>
<td>510 mg, 2 doses</td>
<td>$327.70 (17-mL vial)</td>
<td></td>
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</tr>
<tr>
<td>Iron sucrose</td>
<td>200 mg, 5 doses</td>
<td>$16.90 (2.5-mL vial)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LMW iron dextran</td>
<td>1000 mg, 1 dose</td>
<td>$28.70 (2-mL vial)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ferric gluconate</td>
<td>125 mg, 8 doses</td>
<td>$7.20 (5-mL vial)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

GI, Gastrointestinal; IV, intravenous; LMW, low molecular weight. Reprinted with permission from the ERAS Cardiac Society.
TABLE E2. Components of the cardiac surgery patient blood management turnkey order set by phase of care

**Preoperative**

- For nonemergent cases in the absence of platelet function studies, discontinue ticagrelor at 3 d, clopidogrel at 5 d, and prasugrel at 7 d before surgery.

- For elective cases without coronary artery disease, discontinue aspirin for 7 d preoperatively.

- Laboratory tests:
  - Hemoglobin
  - Platelet count
  - PT/INR
  - PTT
  - Send platelet aggregation studies or VET for patients receiving DAPT

- For patients requiring DAPT bridging:
  - Cangrelor 30 μg/kg IV bolus followed by 4 μg/kg/min IV infusion

**Discontinue 1 h before OR**

- For nonemergent patients on a DOAC, discontinue apixaban at 3 d, rivaroxaban at 5 d, and dabigatran at 5 d before surgery.

- For emergent patients on a DOAC, choose the appropriate antidote:
  - Andexanet alfa (for apixaban, rivaroxaban): 400 mg IV bolus, then 4 mg/min IV for 2 h (>8 h since last DOAC) or 800 mg IV bolus, then 8 mg/min IV for 2 h (<8 h since last DOAC)
  - Idarucizumab: 5 g IV × 1 (for dabigatran)
  - Kcentra/Beriplex: 0.12 mL/kg/min IV; titrate to goal INR (or alternative prothrombin complex concentrate)

- For nonemergent patients on warfarin, discontinue 5 d prior to surgery:
  - If atrial fibrillation and high risk for thromboembolic event, bridge with IV heparin, with weight-based titration to therapeutic range (see heparin order sheet)

**Preoperative anemia: Hgb <13 g/dL**

- Labs:
  - Total iron binding capacity panel
  - Ferritin
  - Fecal occult blood screening

- Medications:
  - Ferric gluconate 250 mg IV once daily for up to 7 d (see Table E1 for alternate Fe formulations)
  - Erythropoietin alfa-epo 40,000 IU IV × 1
  - Folic acid tablet 5 mg orally once daily until surgery (up to 4 wk)
  - Vitamin B-12 1000 μg orally once daily until surgery (up to 4 wk)

**Intraoperative**

- Administer tranexamic acid: bolus 10 mg/kg IV × 1, then continuous IV drip based on serum creatinine:
  - <1.6 = 2 mg/kg/h
  - 1.6-3.2 = 1.5 mg/kg/h
  - 3.3-6.6 = 1 mg/kg/h
  - For heparin resistance: administer antithrombin III 300 U IV, repeat once as needed to reach desired ACT

**Postoperative–ICU**

- Utilize a standard transfusion algorithm

- Notify provider if Hgb <7.5 g/dL (consider transfusion in nonbleeding patients only for signs of end-organ malperfusion, such as elevated lactate or significant base deficit)

- Notify provider for chest tube drainage of 200 mL/h for >1 h

  If actively bleeding:
  - Laboratory tests
    - Perform point-of-care VET and transfuse according to standard algorithm
  - or
    - PT/INR, PTT
    - Fibrinogen
    - Platelet count
    - Platelet aggregation study
    - Hemoglobin
  - Treatment:
    - For INR >1.7, transfuse 2 U of FFP
    - For fibrinogen <150 mg/dL, transfuse 10 U of cryoprecipitate or administer Fibryga 4 g IV over 10 min (or alternative fibrinogen concentrate)

(Continued)
TABLE E2. Continued

| ○ For functional platelets < 50 × 10^3/μL, transfuse 2 U of platelets |
| ○ PRBC transfusion as needed |
| ○ Kcentra/Beriplex 0.12 mL/kg/min IV titrate if on a DOAC preoperatively and PTT elevated (or alternative prothrombin complex concentrate) |
| ○ DDAVP 0.3 μg/kg IV × 1 for patients with post-CPB platelet dysfunction, uremia, or Von Willebrand disease, repeat once as needed |

Postoperative–Telemetry

- Hgb < 8 g/dL
- Ferric gluconate 250 mg IV once daily for 3 d
- Ferrous sulfate 324 mg orally daily for 30 d

PT, Prothrombin time; INR, international normalized ratio; PTT, partial thromboplastin time; DAPT, dual antiplatelet therapy; IV, intravenous; OR, XXX; DOAC, direct oral anticoagulant; FFP, fresh frozen plasma; Hgb, hemoglobin; ACT, activated clotting time; ICU, intensive care unit; VET, viscoelastic testing; PRBC, packed red blood cells; DDAVP, 1-deamino-8-D-arginine vasopressin; CPB, cardiopulmonary bypass.