

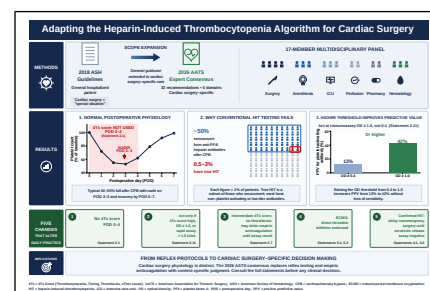
From general guidance to surgical reality: Adapting the heparin-induced thrombocytopenia algorithm for cardiac surgery



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Unfractionated heparin (UFH) exposure before cardiac surgery is ubiquitous. Patients who undergo urgent coronary surgery have almost invariably received intravenous UFH, and patients who undergo elective surgery receive it during preoperative angiography. Patients who undergo cardiac surgery also frequently develop early postoperative thrombocytopenia. This combination often yields a 4 Ts score (Thrombocytopenia, Timing, Thrombosis, oTher cause) of 4, an intermediate pretest probability for heparin-induced thrombocytopenia (HIT). Per the 2018 American Society of Hematology (ASH) guidelines,¹ standard practice at intermediate or high pretest probability is to discontinue heparin, begin a nonheparin anticoagulant (often a direct thrombin inhibitor), send a platelet factor 4 (PF4) immunoassay, and await results. Two problems arise after cardiac surgery. Most such patients do not have HIT. In addition, a direct thrombin inhibitor started shortly after surgery carries a risk of bleeding in a patient with fresh suture lines, frequently impaired renal clearance, and no available reversal agent.² Many patients meet bedside criteria for intermediate or high 4 Ts probability, even though the actual incidence of HIT is only 0.5% to 3%.³⁻⁶ This article contextualizes the American Association for Thoracic Surgery (AATS) HIT guidance⁷ for the cardiac surgical team.

After cardiac surgery, platelet counts typically decrease 40% to 50% from baseline, reaching a nadir on postoperative days 2 to 3 and generally recovering between days 5 and 7.³ Anti-PF4/heparin antibodies are present in roughly one half of patients after cardiopulmonary bypass (CPB), although most are IgM or low-titer IgG and do not activate platelets.^{3,E1} Thrombocytopenia alongside a low-positive



The 2026 AATS consensus adapts HIT diagnosis and management to cardiac surgery.

CENTRAL MESSAGE

The 2026 AATS Expert Consensus Document extends HIT guidance to cardiac surgery-specific management and cardiopulmonary bypass-related physiology.

PF4 immunoassay is therefore common and often not pathologic. Reflexively ordering a heparin antibody test on postoperative days 2 or 3 for any degree of thrombocytopenia is of limited value and carries the potential for harm through unnecessary anticoagulation after a weakly positive result or false reassurance from a negative test when a true biphasic pattern later appears. When true HIT does occur, the consequences are severe. In a propensity-matched analysis, operative mortality was 21.8% versus 5.3% and thromboembolism 29.1% versus 2.9%, with mortality reaching 34.4% when thrombosis was present and 16.7% when absent.⁸

The 2018 ASH guidelines¹ are rigorous and meticulously developed. The writing panel applied established evidence-appraisal methodology to the general hospitalized patient and treated cardiovascular surgery as a designated special situation, consistent with its charter, with input from experts in HIT and cardiac surgery, including the originator of the 4 Ts score, who flagged the limits of a general medical framework for post-CPB physiology 2 decades ago.⁹ The underlying observation is older still. HIT with

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Abbreviations and Acronyms

4 Ts score	= Thrombocytopenia, Timing, Thrombosis, oTher cause
AATS	= American Association for Thoracic Surgery
ASH	= American Society of Hematology
COR	= Class of Recommendation
CPB	= cardiopulmonary bypass
ECD	= Expert Consensus Document
ECMO	= extracorporeal membrane oxygenation
ELISA	= enzyme-linked immunosorbent assay
HIT	= heparin-induced thrombocytopenia
LOE	= Level of Evidence
NR	= nonrandomized
OD	= optical density
PF4	= platelet factor 4
UFH	= unfractionated heparin

thrombosis was reported after CPB in the early 1990s,^{E2} and anti-PF4/heparin seroconversion after CPB was well characterized by the end of that decade.^{E1} The 2026 AATS Expert Consensus Document (ECD) on HIT in cardiac surgery⁷ is best understood not as a correction of the ASH document but as a scope expansion: a complementary, cardiac surgery–specific framework built by a multidisciplinary panel that paired cardiac surgeons, anesthesiologists, intensivists, perfusionists, and pharmacists with hematology leadership, including the ASH 2018 lead author (Cuker) and the originator of the 4 Ts score (Warkentin).

WHY A CARDIAC SURGERY–SPECIFIC FRAMEWORK WAS NEEDED

The 4 Ts Score Does Not Work Well Early After CPB

The 4 Ts score awards points for platelet-count decline, the timing of that decline relative to heparin exposure, new thrombosis, and absence of alternative causes.^{E3} Three of these 4 domains behave abnormally after cardiac surgery. The platelet-count domain is driven by the aforementioned nonimmune mechanisms. Timing points accumulate almost automatically, because all patients receive intraoperative UFH for CPB, and most have preoperative exposure.¹⁰ CPB is itself a powerful “other cause” of thrombocytopenia, but the score, developed in medical inpatients, does not weight it accordingly. Modified scores for critically ill and cardiac surgical populations have not performed well enough to supplant the 4 Ts in guideline-based practice.^{11,12} As a result, most postoperative patients with thrombocytopenia have a 4 Ts score of 4 or greater, regardless of whether immune-mediated HIT is present.

Seroconversion is not a diagnosis. Given that roughly one half of patients seroconvert after CPB, the ELISA action

threshold is critical. At an optical density (OD) of 0.4, the value at which most commercial assays report a positive result, the positive predictive value for a platelet-activating antibody is approximately 13%. Increasing the action threshold to 1.0 more than tripled that value, to approximately 42%, without loss of sensitivity in the cohort of Chan and colleagues.¹³ True HIT prevalence between OD 0.4 and 1.0 is less than 2%.⁷ This threshold shift has not been prospectively validated in a dedicated cardiac surgical cohort. The supporting evidence is observational, appropriately reflected in the ECD’s Level of Evidence (LOE) B-nonrandomized (NR) designation, with prospective validation listed to follow. With that caveat, labeling all patients with OD between 0.4 and 1.0 as positive leads to unnecessary treatment and risk.

The Bleeding Cost of Empiric Anticoagulation in Postoperative Cardiac Surgery

ASH 2018 Recommendation 3.2 directs clinicians caring for patients with an intermediate 4 Ts score to order a PF4 immunoassay, discontinue heparin, and empirically start a nonheparin anticoagulant.^{1,14} After cardiac surgery, that bleeding cost is substantial. Pishko and colleagues¹⁵ studied 310 patients with suspected HIT treated with nonheparin anticoagulants, most often argatroban. Major bleeding occurred in 36% of patients with confirmed HIT, and in 44% of treated patients who did not have the disease. That cohort came from a tertiary center likely enriched for severity, and argatroban was dosed high by current standards. Contemporary weight-based dose-reduction protocols may lower these rates. The same data can also be read in the opposite direction. A bleeding rate of 36% to 44% may be an acceptable trade where missed HIT carries a mortality of approximately 22%. We therefore endorse individualized risk stratification at the bedside, not categorical withholding of empiric therapy. None of the available nonheparin agents (bivalirudin, argatroban, fondaparinux, danaparoid, and direct oral anticoagulants) has a practical reversal option in the immediate postoperative window.² Monitoring mitigates this risk without eliminating it. Bivalirudin, the direct thrombin inhibitor commonly selected in cardiac surgical practice, has predictable pharmacokinetics, and a dilute thrombin time reflects its plasma concentration more accurately than the activated partial thromboplastin time, permitting precise titration and reducing the risk of over- and underanticoagulation. Such assays, however, are not routinely available at every hospital, and their target values require further validation in controlled studies.²

Extracorporeal Membrane Oxygenation (ECMO) and Perioperative Scenarios Outside the ASH 2018 Scope

ASH 2018 contains no dedicated section on ECMO or temporary mechanical circulatory support. In postcardiotomy

ECMO, the 4 Ts score performs worse than after isolated CPB, with a positive predictive value of approximately 25% in a single cohort in which patients with and without HIT had similar 4 Ts distributions.¹⁶ The score is therefore of limited utility here. This single-center study has not been prospectively validated across heterogeneous ECMO platforms, a limitation reflected in the ECD's class III, LOE B-NR designation (Statement 5.1). Heparin-coated circuits, direct thrombin inhibitor dosing during ECMO, and microaxial pump purge solutions were all outside the ASH scope. A meta-analysis supporting bivalirudin over UFH for adult ECMO anticoagulation has since emerged.¹⁷ The 2018 ASH guidance on managing patients with previous HIT who require cardiac surgery was also largely nondefinitive, leaving choices between bivalirudin-only CPB and heparin with adjunctive antiplatelet therapy or plasma exchange to institutional judgment.^{18,19}

WHAT THE 2026 AATS ECD CHANGES

The AATS ECD contains 32 recommendations across 5 domains, developed by a 17-member multidisciplinary panel using the AATS/Society of Thoracic Surgeons COR and LOE framework, harmonized with the joint AATS/European Association for Cardio-Thoracic Surgery/European Society of Thoracic Surgeons/Society of Thoracic Surgeons methodology manual.^{7,E4} Table 1 compares the two. Five departures deserve direct attention because they have changed daily practice.

The 4 Ts Score Is Suspended in the First 4 Postoperative Days

ECD Statement 2.1 (Class of Recommendation [COR] III, LOE C-EO) directs that the 4 Ts score not guide HIT testing in the first 4 days after cardiac surgery. Statement 2.2 (COR I, LOE B-NR) narrows early-window immunoassay testing to patients with preoperative UFH exposure in the previous 5 to 10 days who develop new thrombosis. Together, they remove the largest driver of false-positive pretest scoring in this population. Real-world data support the reset: an observational cohort of 1722 patients who underwent cardiac surgery found 4 Ts specificity of 55% and overall accuracy of 69%.²⁰

Individualized Anticoagulation at Intermediate 4 Ts

ECD Statement 2.7 (COR IIa, LOE C-EO) states that in patients with an intermediate 4 Ts score, awaiting an immunoassay, and without thrombosis, it is reasonable to postpone a nonheparin anticoagulant until the result is available. Drawing on the panel's cardiac surgical and intensive care experience, the committee judged individualized anticoagulation more appropriate for this population than uniform empiric therapy.⁷ Implementation requires explicit bedside documentation of the risk-benefit judgment, including bleeding risk, current anticoagulation status, thrombosis

assessment, and anticipated immunoassay turnaround. Statement 2.7 is a physician-level judgment, not a blanket protocol for withholding anticoagulation, supported by shared decision-making with the patient or surrogate where possible.

Greater OD Threshold for Empiric Therapy

ECD Statement 2.11 (COR I, LOE B-NR) recommends initiating therapeutic-intensity nonheparin anticoagulation only when the 4 Ts score is high probability, ELISA OD is 1.0 or greater, or rapid immunoassay exceeds 1.0 U/mL. Increasing the threshold for empiric treatment from an OD of 0.4, the value at which most commercial assays report a positive result, to an OD of 1.0 substantially reduces the number of patients exposed to empiric treatment and its bleeding risk without sacrificing sensitivity in the supporting cohort, with the prospective-validation caveat noted above.

A Dedicated ECMO and Mechanical Circulatory Support Section. Section 5 contains 5 statements specific to postcardiotomy extracorporeal and temporary mechanical support, building on contemporaneous European guidance on CPB.^{E5} Statement 5.1 (COR III, LOE B-NR) directs that the 4 Ts not be used in postcardiotomy ECMO. Statement 5.3 (COR IIa, LOE B-NR) endorses direct thrombin inhibitor anticoagulation during postcardiotomy ECMO, with evidence it may reduce HIT development compared with heparin. Statement 5.5 (COR IIa, LOE B-NR) supports sodium bicarbonate over heparin-based purge solutions for microaxial flow pumps in patients with HIT concern. None were explicitly addressed in ASH 2018.

Structured Management of Previous or Active HIT Before Cardiac Surgery

ECD Statements 4.1 through 4.3 build the first operational framework for cardiac surgery in patients with a HIT history. Statement 4.1 (COR I, LOE C-EO) requires an immunoassay before nonemergency surgery in any patient with a HIT history. Statement 4.2 (COR I, LOE B-NR) recommends delaying nonemergency surgery in confirmed HIT until the functional assay is negative. Together, they establish a standardized preoperative pathway that has historically varied widely between institutions.

ECD Statement 4.4 (COR I, LOE C-limited data) addresses the patient with resolved HIT who remains immunoassay-positive before elective cardiac surgery, historically managed by gut instinct or bivalirudin-based CPB at greater cost, complexity, and bleeding risk. Statement 4.4 directs that intraoperative UFH is appropriate when the functional assay is negative, even if the immunoassay remains positive. The biology supports this: HIT antibodies are transient, and persistent low-titer or IgM positivity does not predict platelet activation when

TABLE 1. Side-by-side comparison of the 2018 ASH HIT guidelines and the 2026 AATS Expert Consensus Document across 7 domains of cardiac surgical practice

Clinical domain	2018 ASH guidelines Cuker et al ¹	2026 AATS expert consensus document Chatterjee et al ⁷
Pretest probability in the first 4 postoperative days	4 Ts score applied routinely to postoperative thrombocytopenia. No cardiac surgery-specific exclusion window.	Statement 2.1 (COR III, LOE C-EO): 4 Ts score should not be used to guide HIT testing in the first 4 postoperative days. Statement 2.2 (COR I, LOE B-NR): immunoassay without previous 4 Ts is appropriate if preoperative UFH within 5-10 days and new thrombosis.
ELISA optical density threshold for clinical action	OD ≥ 0.4 considered positive; triggers further workup and empiric therapy per Recommendation 3.2. No cardiac surgery-specific threshold.	Statement 2.11 (COR I, LOE B-NR): therapeutic-intensity nonheparin AC recommended only when 4 Ts is high probability, ELISA OD ≥ 1.0 , or rapid immunoassay > 1.0 U/mL. Acknowledges HIT prevalence at OD 0.4-1.0 in this population is below 2%; threshold not yet prospectively validated in a cardiac surgical cohort (research priority).
Empiric anticoagulation at intermediate 4 Ts	Recommendation 3.2: discontinue heparin, initiate nonheparin AC, send immunoassay (strong recommendation, moderate certainty). Uniform approach.	Statement 2.7 (COR IIa, LOE C-EO): reasonable to postpone nonheparin AC until immunoassay result available, if no thrombosis. <i>Implementation requires explicit bedside documentation of bleeding risk, thrombosis assessment, and anticipated immunoassay turnaround; this is a physician-level shared decision, not a blanket institutional protocol.</i>
Functional assay confirmation and laboratory availability	Confirmatory functional assay recommended but not operationalized for cardiac surgery turnaround requirements. No institutional availability standard.	Statement 2.9 (COR I, LOE B-NR): confirmatory testing with a functional assay is recommended for any positive immunoassay. Statement 2.4 (COR I, LOE C-EO): HIT immunoassay testing available 7 days a week with turnaround within 24 hours at any cardiac surgery center.
Postcardiotomy ECMO	Not addressed as a distinct domain. No recommendation on 4 Ts applicability, DTI vs heparin, or AC strategy in patients supported by ECMO.	Statement 5.1 (COR III, LOE B-NR): 4 Ts not to guide HIT testing in postcardiotomy ECMO. Statement 5.3 (COR IIa, LOE B-NR): DTI AC reasonable; may reduce HIT development. Statement 5.4 (COR I, LOE C-EO): discontinue all heparin and switch to DTI when HIT suspected on ECMO.
Microaxial mechanical circulatory support: purge solution	Not addressed.	Statement 5.5 (COR IIa, LOE B-NR): sodium bicarbonate-based purge solutions preferred over heparin-based in postcardiotomy microaxial flow pump patients with HIT concern.
VTE prophylaxis after cardiac surgery	LMWH vs UFH preference not framed as a HIT-prevention strategy in the cardiac surgical population.	Statement 1.2 (COR IIa, LOE B-NR): LMWH should be considered over UFH for VTE prophylaxis because of lower HIT risk (risk ratio 0.23 in Cochrane analysis).

ASH, American Society of Hematology; AATS, American Association for Thoracic Surgery; 4 Ts, 4 Ts score (thrombocytopenia, timing, thrombosis, other cause); COR, Class of Recommendation; LOE, Level of Evidence (AATS/STS framework); HIT, heparin-induced thrombocytopenia; B-NR, nonrandomized; UFH, unfractionated heparin; ELISA, enzyme-linked immunosorbent assay; OD, optical density; AC, anticoagulation; C-EO, expert opinion; DTI, direct thrombin inhibitor; ECMO, extracorporeal membrane oxygenation; LMWH, low-molecular-weight heparin; VTE, venous thromboembolism.

functional assays (serotonin release assay or heparin-induced platelet activation assay) are negative.¹⁸ This single recommendation resolves the most operationally difficult decision in the preoperative HIT workup and should materially reduce both bivalirudin-CPB volume and case cancellations. Statement 4.4 governs the intraoperative window only, and the postoperative period deserves equal

attention. The serologic data supporting re-exposure come from patients given heparin during surgery but not afterward, in whom anti-PF4/heparin antibodies reappeared at a median of 7 days and recurrent HIT was uncommon.¹⁸ That reassurance does not extend to postoperative heparin. Heparin should therefore be confined to CPB, with a nonheparin agent used for postoperative anticoagulation and

venous thromboembolism prophylaxis, consistent with ASH 2018 Recommendation 4.2 and its accompanying remark.^{1,E6} Because delayed-onset HIT can begin 5 to 10 days after a single intraoperative exposure, platelet counts warrant monitoring after surgery even when no postoperative heparin is given.¹ For the patient whose functional assay remains positive and whose operation cannot be deferred, high-dose intravenous immunoglobulin (1 g/kg daily for 2 days) has been used to blunt Fc γ RIIa-mediated platelet activation and permit standard intraoperative heparin dosing, although the evidence is limited to case reports and small series and the ECD grades this approach COR IIb, LOE C.¹⁹

PRACTICAL IMPLICATIONS

For cardiac surgeons, 2 changes follow: expect postoperative thrombocytopenia recovering by days 5 to 7 and reserve HIT evaluation for a biphasic platelet trend or new thrombosis, not an absolute count alone. For cardiothoracic anesthesiologists and intensivists, 2 priorities follow: support 24-hour, 7-day immunoassay availability (ECD Statement 2.4, COR I, LOE C-EO) and confirm every positive immunoassay with a functional assay before a patient is labeled HIT-positive.

Many community programs lack around-the-clock immunoassay turnaround, and some cannot send functional assays at all. ECD Statement 2.4 will require reflex send-out protocols or partnerships with regional reference laboratories, where functional assay confirmation under Statement 2.9 is available as a send-out test. Pathology directors should establish standing-order pathways and turnaround agreements before implementation, and leadership should treat the capability gap as a quality-improvement priority, not a barrier to adoption.

For perfusionists, the ECD clarifies circuit and purge selection for bivalirudin-based CPB and for microaxial mechanical circulatory support in patients with HIT concern. Heparin allergy labels should be removed once the functional assay is confirmed negative, through a formal, documented physician order recording the functional assay date, result, and clinical context, not an administrative protocol or nursing-driven update.

Finally, the ECD addresses only open cardiac surgery with CPB. The increasing volume of transcatheter structural procedures (transcatheter aortic valve implantation, MitraClip, WATCHMAN, and related interventions) involves procedural UFH exposure in a population with distinct platelet biology and antiplatelet co-therapy patterns, warranting attention in future ECD updates.

DOCUMENTATION AND THE EVOLVING STANDARD OF CARE

The framework question also carries medicolegal implications. Cardiac surgery sits in a high-risk tier for malpractice

claims.²¹ When a postoperative HIT case ends in stroke, limb loss, or death, the prevailing guideline is what attorneys and expert witnesses cite as the standard of care.^{E7} Published guidelines are more often invoked against the physician than in his or her defense, and adverse outcomes drive their use.^{22,E8,E9} Until now, the HIT guideline available for these patients was scoped to the general hospitalized patient rather than to post-CPB physiology and its bleeding-risk window.

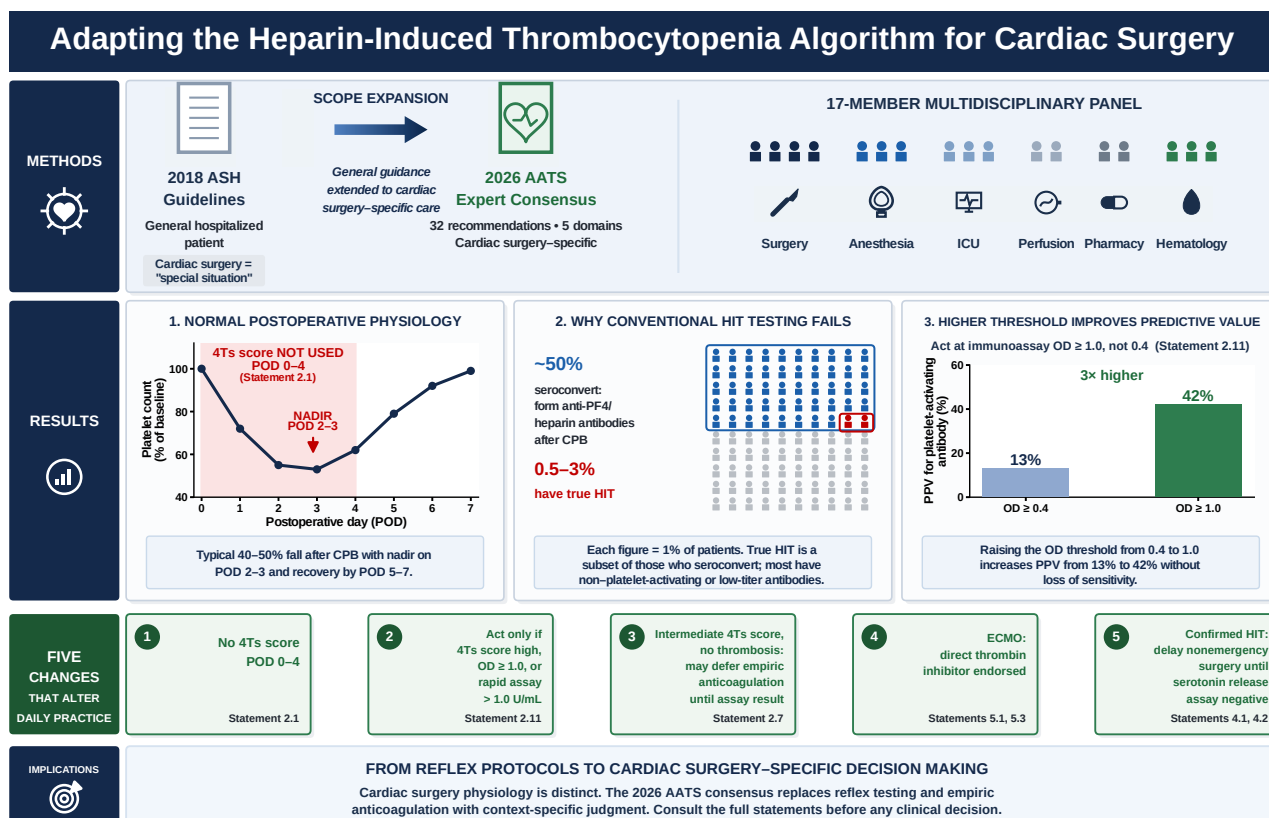
The 2026 AATS ECD does not retroactively absolve the cardiac surgical team. If anything, a specialty-specific consensus document raises the bar by removing the previous ambiguity about which framework applies. What it accomplishes is procedural. It offers a single consistent pathway for diagnosis, anticoagulation, and perioperative management in place of the institutional variability that has contributed to adverse outcomes. The multidisciplinary discussion, shared decision-making, and bedside risk-benefit documentation specified in Statement 2.7 serve the patient and the team alike.

In a contemporary analysis of cardiovascular closed claims, Kusumoto and colleagues²³ found nonclinical factors, including insufficient documentation and gaps in after-hours coverage, to be more common contributors than clinical ones. An ECD-aligned bedside note, documented contemporaneously at referral or at treatment initiation, is therefore worth the few minutes it takes.

At established reference laboratories, reported turnaround is approximately 5 days for the serotonin release assay and 1 day for heparin-induced platelet aggregation, reflecting the technical complexity and limited availability of these washed-platelet assays.^{E10} Closing the gap between local capacity and recommended turnaround is an institutional responsibility. Faster turnaround narrows the window of diagnostic uncertainty during which empiric anticoagulation must be initiated or deferred, where much of the risk in postoperative HIT resides.

CONCLUSION AND RESEARCH AGENDA

The 2018 ASH guideline is a rigorous hematology document scoped to the general hospitalized patient, with cardiovascular surgery designated a special situation. Applied across cardiac surgical practice, that scope produced a recurring mismatch with post-CPB physiology, with reflex testing, empiric anticoagulation, and persistent HIT labeling in a population for which it was not designed. The 2026 AATS ECD, authored by a multidisciplinary panel, complements rather than corrects the ASH framework, replacing reflexive decision-making with context-specific, multidisciplinary judgment consistent with the broader shift toward cardiac surgery-specific perioperative guidance.^{24,25} Figure 1 presents this comparison in summary form. It sets the scope of the 2 documents side by side, lists the five departures that have changed daily practice together with their ECD statement numbers and classes of recommendation, and translates



Conflict of Interest Statement

D.E. serves on the device safety monitoring board for Edwards Lifesciences Transcatheter Valves; on research trial executive steering committees for Alexion and Chugai; and on medical advisory boards for Medela, Arthrex, AtriCure, Pharmacosmos, and Roivios. A.C. has served as a consultant for Incyte and Pfizer; has received authorship royalties from UpToDate; and his institution has received research support on his behalf from Equilibra, Novartis, Pfizer, Sanofi, and Takeda. S.C. reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

Institutional review board approval was not required for this Expert Consensus commentary because it does not report original research involving human subjects or identifiable patient data. Because this article contains no individual patient data, informed written consent for publication was not applicable.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

During the preparation of this work the authors used Claude in to order to perform reference formatting and copy editing for grammar and clarity. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

References

- Cuker A, Arepally GM, Chong BH, et al. American Society of Hematology 2018 guidelines for management of venous thromboembolism: heparin-induced thrombocytopenia. *Blood Adv*. 2018;2(22):3360-3392.
- Koster A, Faraoni D, Levy JH. Argatroban and bivalirudin for perioperative anticoagulation in cardiac surgery. *Anesthesiology*. 2018;128(2):390-400.
- Selleng S, Malowsky B, Strobel U, et al. Early-onset and persisting thrombocytopenia in post-cardiac surgery patients is rarely due to heparin-induced thrombocytopenia, even when antibody tests are positive. *J Thromb Haemost*. 2010;8(1):30-36.
- Warkentin TE, Sheppard JI, Whitlock RP. Temporal presentations of heparin-induced thrombocytopenia following cardiac surgery: a single-center, retrospective cohort study. *J Thromb Haemost*. 2022;20(11):2601-2616.
- Pishko AM, Cuker A. Heparin-induced thrombocytopenia in cardiac surgery patients. *Semin Thromb Hemost*. 2017;43(7):691-698.
- Seigerman M, Cavallaro P, Itagaki S, Chung I, Chikwe J. Incidence and outcomes of heparin-induced thrombocytopenia in patients undergoing cardiac surgery in North America: an analysis of the nationwide inpatient sample. *J Cardiothorac Vasc Anesth*. 2014;28(1):98-102.
- Chatterjee S, Girardi NI, Crow J, et al. 2026 American Association for Thoracic Surgery Expert Consensus Document: diagnosis and management of heparin-induced thrombocytopenia in patients who undergo cardiac surgery. *J Thorac Cardiovasc Surg*. Published online May 4, 2026; <https://doi.org/10.1016/j.jtcvs.2026.03.619>
- Brown JA, Aranda-Michel E, Kilic A, et al. Outcomes with heparin-induced thrombocytopenia after cardiac surgery. *Ann Thorac Surg*. 2021;112(2):487-493.
- Warkentin TE, Greinacher A. Heparin-induced thrombocytopenia and cardiac surgery. *Ann Thorac Surg*. 2003;76(6):2121-2131.
- Crow JR, Nam L, Chasler JE, et al. Association of heparin dose, route, timing, and duration with heparin-induced thrombocytopenia. *Ann Thorac Surg*. 2021;112(1):32-37.
- Fiorenza MA, Frazee EN, Personett HA, Dierkhising RA, Schramm GE. Assessment of a modified 4T scoring system for heparin-induced thrombocytopenia in critically ill patients. *J Crit Care*. 2014;29(3):426-431.
- Lillo-Le Louët A, Boutouyrie P, Alhenc-Gelas M, et al. Diagnostic score for heparin-induced thrombocytopenia after cardiopulmonary bypass. *J Thromb Haemost*. 2004;2(11):1882-1888.
- Chan CM, Woods CJ, Warkentin TE, Sheppard JI, Shorr AF. The role for optical density in heparin-induced thrombocytopenia: a cohort study. *Chest*. 2015;148(1):55-61.
- Morgan RL, Ashoorion V, Cuker A, et al. Management of heparin-induced thrombocytopenia: systematic reviews and meta-analyses. *Blood Adv*. 2020;4(20):5184-5193.
- Pishko AM, Lefler DS, Gimotty P, et al. The risk of major bleeding in patients with suspected heparin-induced thrombocytopenia. *J Thromb Haemost*. 2019;17(11):1956-1965.
- Arachchillage DRJ, Laffan M, Khanna S, et al. Frequency of thrombocytopenia and heparin-induced thrombocytopenia in patients receiving extracorporeal membrane oxygenation compared with cardiopulmonary bypass and the limited sensitivity of pretest probability score. *Crit Care Med*. 2020;48(5):e371-e379.
- Wierszewska PM, Macielak SA, Nei SD, et al. Heparin versus bivalirudin for anticoagulation in adult extracorporeal membrane oxygenation: a systematic review and meta-analysis. *ASAIO J*. 2023;69(2):137-144.
- Warkentin TE, Sheppard JI. Serological investigation of patients with a previous history of heparin-induced thrombocytopenia who are reexposed to heparin. *Blood*. 2014;123(16):2485-2493.
- Warkentin TE, Geerts W, Sheppard JI, et al. High-dose intravenous immunoglobulin G and usual heparin anticoagulation for urgent cardiac surgery in a patient with severe autoimmune heparin-induced thrombocytopenia. *J Thromb Haemost*. 2025;23(1):321-324.
- Piednoir P, Allou N, Provenchère S, et al. Heparin-induced thrombocytopenia after cardiac surgery: an observational study of 1,722 patients. *J Cardiothorac Vasc Anesth*. 2012;26(4):585-590.
- Jena AB, Seabury S, Lakdawalla D, Chandra A. Malpractice risk according to physician specialty. *N Engl J Med*. 2011;365(7):629-636.
- Hyams AL, Brandenburg JA, Lipsitz SR, Shapiro DW, Brennan TA. Practice guidelines and malpractice litigation: a two-way street. *Ann Intern Med*. 1995;122(6):450-455.
- Kusumoto F, Dudzinski DM, Ross J, Jhamani S, Cassavar DK, Chazal RA. Analysis of closed claims in cardiovascular medicine: importance of nonclinical factors. *JACC Adv*. 2026;5(1):102467. <https://doi.org/10.1016/j.jaccadv.2025.102467>
- Engelman DT, Ben Ali W, Williams JB, et al. Guidelines for perioperative care in cardiac surgery: enhanced recovery after surgery society recommendations. *JAMA Surg*. 2019;154(8):755-766.
- Grant MC, Crisafi C, Alvarez A, et al. Perioperative care in cardiac surgery: a joint consensus statement by the Enhanced Recovery After Surgery (ERAS) Cardiac Society, ERAS International Society, and the Society of Thoracic Surgeons (STS). *Ann Thorac Surg*. 2024;117(4):669-689.

Key Words: heparin-induced thrombocytopenia, cardiac surgery, cardiopulmonary bypass, 4 Ts score, direct thrombin inhibitors, expert consensus, perioperative anticoagulation

E-References

- E1. Pouplard C, May MA, Iochmann S, et al. Antibodies to platelet factor 4-heparin after cardiopulmonary bypass in patients anticoagulated with unfractionated heparin or a low-molecular-weight heparin: clinical implications for heparin-induced thrombocytopenia. *Circulation*. 1999;99(19):2530-2536.
- E2. Singer RL, Mannion JD, Bauer TL, Armenti FR, Edie RN. Complications from heparin-induced thrombocytopenia in patients undergoing cardiopulmonary bypass. *Chest*. 1993;104(5):1436-1440.
- E3. Warkentin TE, Heddle NM. Laboratory diagnosis of immune heparin-induced thrombocytopenia. *Curr Hematol Rep*. 2003;2(2):148-157.
- E4. Milojevic M, Freemantle N, Hayanga JWA, et al. Harmonizing guidelines and other clinical practice documents: a joint comprehensive methodology manual by the American Association for Thoracic Surgery, European Association for Cardio-Thoracic Surgery, European Society of Thoracic Surgeons, and Society of Thoracic Surgeons. *J Thorac Cardiovasc Surg*. 2025;169(1):170-185.
- E5. Wahba A, Kunst G, De Somer F, et al. 2024 EACTS/EACTAIC/EBCP Guidelines on cardiopulmonary bypass in adult cardiac surgery. *Eur J Cardiothorac Surg*. 2025;67(2):ezae354.
- E6. Pishko AM, Cuker A. Heparin-induced thrombocytopenia and cardiovascular surgery. *Hematol Am Soc Hematol Educ Program*. 2021;2021(1):536-544.
- E7. Recupero PR. Clinical practice guidelines as learned treatises: understanding their use as evidence in the courtroom. *J Am Acad Psychiatry Law*. 2008;36(3):290-301.
- E8. Mello MM. Of swords and shields: the role of clinical practice guidelines in medical malpractice litigation. *Univ Pa Law Rev*. 2001;149(3):645-710.
- E9. Ruhl DS, Siegal G. Medical malpractice implications of clinical practice guidelines. *Otolaryngol Head Neck Surg*. 2017;157(2):175-177.
- E10. Barouqa M, Matta M, Reyes-Gil M. Performance evaluation of heparin-induced platelet aggregation vs serotonin release assay. *Am J Clin Pathol*. 2024;161(2):122-129.