SCA NEWS

SOCIETY OF CARDIOVASCULAR ANESTHESIOLOGISTS
Knowledge • Care • Investigation

Volume 49, Number 32
August 2025

SOCIETY OF CARDIOVASCULAR ANESTHESIOLOGISTS

PRESIDENT'S MESSAGE

Amanda Fox
MD, MPH
President, Society of Cardiovascular Anesthesiologists

Dear SCA Members,

I hope you are all having a wonderful summer.

Four years ago, in the February 2021 SCA Newsletter, then-President Dr. Stanton Shernan announced the formation of the Diversity, Equity, and Inclusion (DEI) Committee. Dr. Shernan affirmed that, "The SCA is committed to upholding the highest standards of inclusivity and diversity in pursuing our mission of being an unbiased and credible source of information, expertise, and leadership".[1]

In the October 2021 issue of the *Journal of Cardiothoracic and Vascular Anesthesia*, Dr. Adam J. Milam, Dr. Ashley P. Oliver, Dr. Stewart A. Smith, Dr. Tom Mario Davis, and Dr. Michael Essandoh published a Letter to the Editor entitled ***"When are We Going to Address the Lack of Diversity in Cardiothoracic Anesthesiology?"*** The letter powerfully articulated the lack of representation in adult cardiothoracic anesthesiology (ACTA) fellowships, the benefits of a diverse medical workforce, and potential solutions to tackle the underrepresentation within our subspecialty.

Four years later, the DEI committee is thriving with many successes that have enhanced our society:

1. Creation of a pathway program to improve diversity among trainees—the first class of scholars are soon to be ACTA fellows.
2. Inviting and hosting a keynote speaker to discuss health equity within cardiovascular care.
3. Establishment of a podcast series focused on the issues important to the committee.
4. Creation of a community of cardiac anesthesiologists with similar interests, partnering with the Women in Cardiothoracic Anesthesia (WICTA).
5. The development and deployment of a SCA demographic survey to identify opportunities for improvement, ensuring our society represents the demographic characteristics of practicing cardiothoracic anesthesiologists.
6. Development of meeting sessions focused on the issues important to the DEI committee.

HEALTH
EQUITY AND PROFESSIONAL ADVANCEMENT COMMITTEE

PRESIDENT'S MESSAGE *continued*

The current environment warrants reflection on the past and a continued path forward. To ensure the committee can continue its vital work effectively and without external distraction, the DEI Committee will become the **Health Equity and Professional Advancement Committee.** This decision was made with the full endorsement and support of the SCA Board.

The committee's core mission remains steadfast. As Dr. Shernan so aptly put it in his 2021 newsletter, our goal is to uphold "the highest standards of inclusivity and diversity in pursuing our mission of being an unbiased and credible source of information, expertise, and leadership."

The SCA Board of Directors and I continue to offer our fullest support to the dedicated members of the Health Equity and Professional Advancement Committee. I'd like to thank the members of the committee for their leadership and guidance in defining the vision and fueling the successes that have been achieved over the last four years. There is still much to accomplish, and I look forward to the continued implementation of sustainable changes that will improve our specialty and the care we provide for years to come.

Please feel free to contact me, or members of the Executive Committee or Board of Directors, about any ideas or concerns as we continue to grow and move forward as a society.

With gratitude,

Amanda Fox, MD
SCA President, 2025-2027

HEALTH EQUITY AND PROFESSIONAL ADVANCEMENT COMMITTEE

[1] https://scahq.org/wp-content/uploads/2024/01/SCA21-Newsletter-February-2021.pdf
[2] https://www.jcvaonline.com/article/S1053-0770(21)00080-X/fulltext

SCA 2025 Annual Meeting OnDemand
at your convenience — anytime, anywhere.

Purchase HERE!

Get trusted Society of Cardiovascular Anesthesiologists meeting content in an easy-to-navigate platform designed to save you time. SCA 2025 Annual Meeting OnDemand is packed with hours of value, access to top presentations from the event, and the **opportunity to earn 59 CME.**

Gain access to clinical practice tips, advancements in Cardiovascular anesthesiology, case-based reviews, and over 36 Sessions covering topics including:

- **Recent advancements in cardiac surgery and anesthesia**
- **Patient-centered care and clinical outcomes**
- **Tools to strengthen multidisciplinary collaboration**

Journal of Anesthesia & Analgesia — How to View Free Access Articles

Below are links to the three SCA sections of the A&A Journal. Each month, these links automatically update with new publications. "Free Access" articles will have a "Free" tag just below the article details.

After one year, all A&A articles become complimentary.

[Cardiovascular and Thoracic Anesthesiology]

[Cardiovascular Pathophysiology and Outcomes]

[Hemostasis and Thrombosis]

A&A ANESTHESIA & ANALGESIA

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Take advantage of all that SCA University has to offer

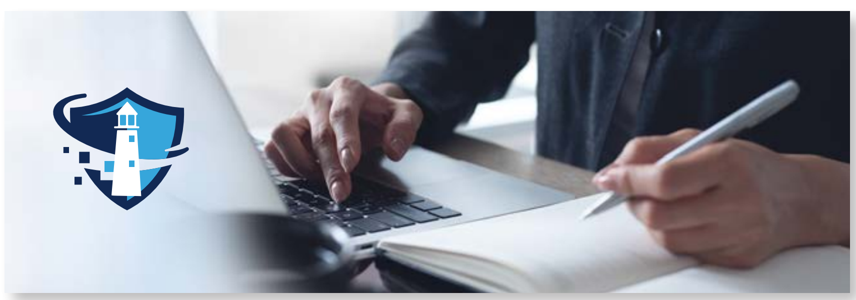
SCA University is a powerful new learning management system available exclusively to SCA members. This powerful platform allows you to access hours of learning tailored to your needs, accessible whenever, wherever is most convenient for you. Earn CME Anywhere! Earn CME credit for the courses you take with online quizzes and receive your certificate via email instantly!

Check Out This Great Member Benefit!

Included is ARC: A Review Course for the ABA's Adult Cardiac Anesthesia Board Examination

SCA's ARC: A Review Course focuses on the Adult Cardiac Anesthesia Board Examination that will be administered by the American Board of Anesthesiology in December!

Our review course embraces the intersection of technology and education and hosts a series of 48 interactive modules that will walk you through the content outline of the ACA exam.



Exclusive to SCA Members

To access, visit https://scauniversity.pathlms.com.

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2026 Call for Nominations
OPENING Soon!

The opportunity is NOW if you want to play an integral role in shaping the future of the Cardiovascular Anesthesiology profession. Eligible nominees must be an SCA "Active" Member in good standing.

The SCA seeks nominations for the following positions:

DIRECTOR-AT-LARGE (2 openings)

- **Term:** 3-year term commencing in April 2026.
- **Overview:** The Director-at-Large will bring expertise in cardiovascular anesthesiology, governance, and finance to the Board.
- **The ideal candidate will have prior SCA involvement experience**.
- Must attend up to 4 Board meetings per year.

EARLY CAREER BOARD OF DIRECTOR (1 opening)

- **Term:** 2-year term commencing in April 2026.
- *Nominee must be within ten years of completing Fellowship training.*
- **Overview:** The Early Career Board Members will be voting members of the SCA Board of Directors.
- **The ideal candidate will have had some previous involvement with SCA.**
- Must attend up to 4 Board meetings per year.

All nominees for any of the positions listed above must submit the following:

- A self-nomination letter or a letter of nomination from a Society member (for self-nominees, this letter cannot be combined with the statement of intent)
- Two letters from Society members seconding the nomination.
- A statement of intent from the nominee
- The nominee's curriculum vitae
- Biography – **150 words or less** (Those more than 150 words will be returned for revisions)
- A high-resolution, color business photo of the nominee

If you are self-nominating or submitting your application:
You will be required to complete the online application. Your SCA username and password is required.

Get Involved with SCA Leadership Today!

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PARTICIPANT USER FILE RESEARCH PROGRAM

LETTER OF INTENT SUBMISSION

The Call for Participant User File (PUF) Research Grant Letter of Intent (LOI) is NOW open. Each selected applicant will be awarded up to $15,000 to apply for and complete an STS Participant User File (PUF) application.

PUF applications being accepted for research projects based on data from the Adult Cardiac Surgery Database, General Thoracic Surgery Database, Congenital Heart Surgery Database, and the INTERMACS Database.

Please Note: *SCA will not consider applications from primary investigators (PI's) currently receiving SCA research funding. However, they may serve as a co-investigator on a PUF application.*

All STS Database related documents are available after a free registration through the STS website: www.sts.org.

FIRST STEP

LETTER OF INTENT REQUIRED DOCUMENTS ***(All documents are required to be uploaded as a PDF):***

- The Letter of Intent (LOI) should not be more than two pages.
- The LOI should detail the proposed title of the project and a statement that the PI/applicants checked and verified that their proposed work is not similar to a previously completed or presently active STS approved research proposal.
    - List of active STS research proposals from all programs
    - List of recently published STS research studies based on STS National Database data
- The LOI should describe the roles of the key personnel including PI, co-investigators, cardiac surgeon who are also an active STS member, and a PhD level biostatistician. Their backgrounds/connection to the topic area, the key personnel, and the unique skills or resources they and their institutions bring to the project.
- Details of the proposed study, including background, specific aims, the study design, and target patient population or disease process, along with a description of any translational/ mechanistic components.
- Biosketch in the new NIH formatting for the PI.

AWARD DETAILS

Total award amount: $60,000 for a total up to 4 grants awarded at $15,000 each.

- Award duration: One time award.
- **Letter of Intent (required) deadline: September 25, 2025**
- Notification of invitation for full application: November 5, 2025.
- Application deadline for invited applicants: December 5, 2025.
- Award recipients announced: January 2026.
- **Please visit the SCA website for full application requirements.**

CONGRATS

Participant User File (PUF) Award Winners!

The winners were awarded for research projects based on data from the Adult Cardiac Surgery Database, General Thoracic Surgery Database, Congenital Heart Surgery Database, and the INTERMACS Database.

2024 – 2025 Winners:	2023 – 2024 Winners:	2022 – 2023 Winners:
Andra Duncan, MD, MS, Cleveland Clinic **Fredrick Wilhelm Lombard, MBChB, FANZCA**, Vanderbilt University Medical Center **Tiffany Williams, MD,** UCLA **Jessica Zvara, MD,** University of Virginia School of Medicine	**Jiapeng Huang, MD, PhD,** University of Louisville **Harikesh Subramanian**, **MBBS, MS,** University of Pittsburgh **Isaac Y. Wu, MD,** University of Rochester	**Anne Cherry, MD,** Duke University Medical Center **Amanda Kleiman, MD,** University of Virginia **Emily MacKay, DO, MSHP,** University of Pennsylvania **Jacob Raphael, MD, FAHA,** Thomas Jefferson University

2026 SCA Annual Society Awards

Now Open!

The SCA encourages its members to honor those who have made a significant impact within the Society and the sub-specialty of cardiovascular anesthesiology by recommending them for one of its annual awards.

> The call will be open July 15 – September 15, 2025.

The Distinguished Service Award

- Honors an individual who has made a meaningful contribution to the ***field of cardiovascular anesthesiology*** through research, education, or service that has produced a significant impact in the field.
- This individual does not have to be an anesthesiologist but must be a member of the SCA.

To make a recommendation for this award, CLICK HERE

The Presidential Outstanding Service Award

- Honors an individual who has made outstanding, long-term contributions to the ***Society of Cardiovascular Anesthesiologists (SCA).***
- This individual must be an anesthesiologist and a member of the SCA.

To make a recommendation for this award, CLICK HERE

The John Hinckley Outstanding Service Award

- Honors an individual who has contributed to or advanced the ***field of cardiovascular anesthesiology*** through education, research, or innovative clinical work.
- This individual must be a ***non-physician.*** Membership in the SCA is not required. – Examples of possible recipients include perfusionists, blood bank personnel, etc.

To make a recommendation for this award, CLICK HERE

A listing of past Society awardees may be found on the SCA website: CLICK HERE

Call for Volunteers Coming this Fall!

April 2026 – April 2028 Term Selection

Support your Society's strategic goals and initiatives by serving one of its 30-plus committees and sub-committees! The Call for Volunteers will be open this October to fulfill the 2026-2028 term. Watch your in-box and the October Newsletter for details.

Click **HERE** to learn more about SCA committees!

For questions related to the Call for Volunteers, please email **committees@scahq.org.**

SAVE THE DATE

For symposium details, please visit https://3scts2025.com

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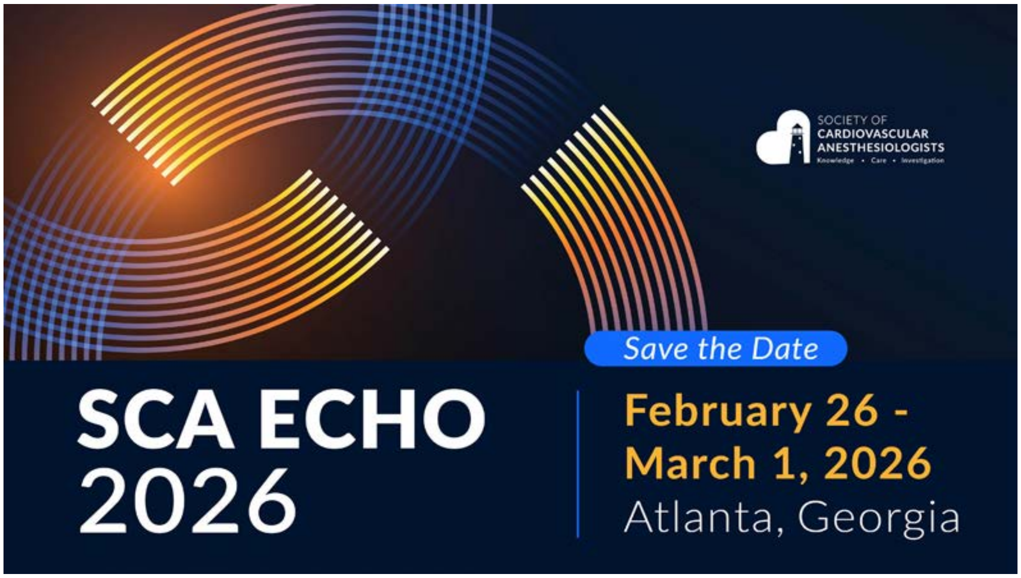
SAVE THE DATES 2026



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2026 Kaplan Leadership Development Award Accepting Applications Beginning September 12th

Applications for the 2026 Kaplan Leadership Development Award will be accepted September 12, 2025 - January 18, 2026. The award is designed to assist cardiothoracic and vascular anesthesiologists in their career by granting funding to further their leadership development through coursework and leadership-specific studies.

The Kaplan Leadership Award will be adjusted accordingly to offer an aggregate of $5,000 to either one recipient or divided among two.

- **$5,000/$2,500 from the SCA Endowment, with a $5,000/$2,500 match from the applicant's institution to fund a leadership education strategy.**

Click here to submit an application beginning September 12!

Year	Awardee	Leadership Development Opportunity
2025	Nadia Hensley, MD	Executive Leadership in Healthcare Certificate of Specialization at Harvard T.H. Chan School of Public Health
2025	Regina Linganna, MD	Master's in Medical Education
2024	Sarah Cotter, MD	Developing an Evidence-Based Perioperative Curriculum for Cardiac Residents
2024	Ashley P. Oliver, MD	Stanford Physicians Leadership Training Certificate
2023	Sergey Karamnov, MD	Brigham Leadership Program
2022	Sheela Pai Cole, MD, FASE, FASA	Stanford LEAD Program
2022	Stephanie Ibekwe, MD, MPH, MS	University of Texas at Dallas Executive MBA – Healthcare Organizational Leadership
2021	Karsten Bartels, MD	Harvard Leadership Development Course for Physicians in Academic Health Centers
2020	Lisa Rong, MD	Executive Leadership Coaching Program for Research Leaders
2019	Ruma Bose, MD	Structural Heart Disease Curriculum for Cardiothoracic Anesthesia Fellowship
2019	Danny Muehlschlegel, MD, MMSc	MIT Sloan Executive MBA
2018	Anne Cherry, MD	Development for Leadership of Anesthesiology Fellowship Research Program
2018	Michael Grant, MD	Design and Implementation of an Enhanced Recovery After Cardiac Surgery (ERACS) Program
2017	Rebecca M.Gerlach, MD, FRCPC	Development of Preoperative Anemia Treatment Program for Cardiac Surgery Patients
2016	James D. O'Leary, MBBCh MD	Advanced Health Leadership Program: Rotman School of Management, University of Toronto
2015	Andrew L Wilkey, MD	Improving Blood Product Utilization in the Cardiac Operating Theater: Thromboelastometry-Guided, Evidence Based Best Practice Guideline for Coagulation Management in Cardiac Surgery
2014	Tjorvi Perry, MD	Improving Operational Efficiency and Clinical Utilization in the Cardiac Surgical and Procedure Areas: Mapping Intervals of Care During a Patients' Care Cycle!
2014	Amanda Rhee, MD	The Harvard School of Public Health's Leadership Development for Physicians in Academic Health Centers Course
2014	Bryan Maxwell, MD, MPH	Development of a Perioperative Consult Service for Adult Congenital Heart Disease at the Johns Hopkins Medical Institutions and Across the Mid-Atlantic Region
2013	Kelly Ural, MD	Development of an Echocardiography Elective Rotation for the Ochsner residency program and Cardiothoracic Anesthesiology Fellowship Program Director Track
2012	Sasha K. Shillcutt, MD, FASE	The Development of a Multi-Specialty Perioperative Echocardiography Service at the University of Nebraska Medical Center
2012	Dalia A. Banks, MD	Leadership Coaching Workshop

Mary E. Arthur
MD, MPH, FASE, FASA

Joshua J. Sebranek
MD, MBA, FASA

Bridging the Gap: Leveraging Inclusive Recruitment for a More Diverse CT Anesthesiology Workforce

Authors
Mary E. Arthur, MD, MPH, FASE, FASA
Joshua J. Sebranek, MD, MBA, FASA

The Society of Cardiovascular Anesthesiologists (SCA) Health Equity and Professional Advancement Committee (HEPAC) seeks "to advance health equity and foster inclusive leadership and career development within perioperative cardiovascular medicine by promoting a deeper understanding of the unique experiences and perspectives of clinicians, patients, and communities." Among its objectives are broadening access and participation of all members to SCA membership, leadership, and training programs, advancing equitable representation among the ACTA workforce, and cultivating leadership throughout the organization. Aligned with these goals was the introduction of the SCA Underrepresented in Medicine (UIM) Junior Resident Scholar Program, which provides selected UIM CA1 residents with early exposure to cardiovascular anesthesiology by enabling them to attend the SCA Annual Meeting, present a poster, and interact with SCA members and leaders. The Scholars have distinguished themselves through notable achievements, including winning the Early Career Investigator award, successfully matching into competitive cardiothoracic anesthesia fellowships, and progressing into leadership roles as chief residents. A recent research letter in Anesthesia & Analgesia details practical strategies implemented over two residency recruitment cycles to enhance the recruitment of UIM individuals to the Department of Anesthesiology at Northwestern University Feinberg School of Medicine (Adeleke et al., 2023). We commend the authors for outlining specific and achievable steps that Adult Cardiothoracic Anesthesiology (ACTA) fellowship directors could adopt as part of a grassroots effort to enhance diversity in our subspecialty.

According to the 2021 U.S. Census, 18.9% of Americans identified as Hispanic and 13.6% as Black; however, recent ACTA fellowship cohorts are only 5.4% Hispanic and 3.9% Black (Sesi et al., 2024). Notably, only four Black fellows matriculated into ACGME-accredited ACTA programs in 2019 (Milam et al., 2021), underscoring the necessity for such initiatives. This underrepresentation has been linked to measurable differences in healthcare outcomes among specific population groups. These differences are not limited to race and ethnicity alone. They exist across other dimensions, including socioeconomic status, gender, sexual orientation, and disability status - all of which exert a financial burden on our society (Faloye et al., 2024). Diverse care teams are associated with better health outcomes, higher treatment adherence rates, and greater patient satisfaction. Additionally, Individuals from racial and ethnic minority populations disproportionately serve underserved populations (Adeleke et al., 2023), emphasizing the need to understand and reduce barriers to achieving a diverse healthcare workforce in cardiovascular anesthesiology.

A Society of Thoracic Surgeons (STS) survey found that 24% of respondents attributed the lack of diversity in the specialty to pipeline issues, 15% believed that diversity was a fad, and 12% reported that diversity required lowering standards. Additionally, 22% of respondents identified prejudice as a barrier to diversity in the specialty, 15% believed there were no barriers, and 8% cited a lack of role models as a root cause (Backhus et al., 2019). The wide range of responses—from attributing the lack of diversity to pipeline issues and prejudice to dismissing it as a fad or wrongfully linking it to lowered standards—highlights the urgent need to educate stakeholders about the evidence-based benefits of workforce diversity in cardiovascular anesthesia, such as improved patient outcomes, innovation, and equitable care delivery.

Simple, yet intentional interventions can create meaningful change. To increase the number of UIM residents in their program, Adeleke et al. took several steps. They made it easier for candidates to connect with UIM faculty during the interview process, encouraged UIM students to pursue away rotations at their program, communicated a message to all applicants regarding available resources and contacts, and offered hotel stipends to UIM applicants who were invited back for a second look after completing their interviews and finalizing the program's rank list. As a result, between 2020 and 2023, 12 out of 88 matched residents identified as UIM, which increased their UIM match rate from 5% to 26% (Adeleke et al., 2023).

Cardiothoracic anesthesiology presents unique challenges for learners, but it also offers a rewarding and impactful career path. While Adeleke et al. focused on resident recruitment, the SCA and HEPAC should also emphasize other critical areas. As a society without direct influence, the SCA and HEPAC could promote strengthening UIM pipelines across medical schools, residency programs, and ACTA fellowship programs through outreach and mentorship. The society should encourage ACTA training programs to foster inclusive environments, promptly address bias, identify diversity champions within the specialty who can establish and monitor diversity metrics, expand UIM access to SCA research mentorship, and motivate all SCA members to recognize the impacts of explicit and implicit bias while supporting the retention of UIM learners. (Sumler et al., 2022).

References

Adeleke, I., Smith, A., Hire, M., & Peralta, F. (2023). Systemic Efforts to Recruit Diversity in a Residency Program and the Impact on Representation Over 3 Years. Anesthesia & Analgesia, 803-804.

Backhus, L., Kpodonu, J., Romano, J., & al., e. (2019). An Exploration of Myths, Barriers, and Strategies for Improving Diversity Among STS Members. Annals of Thoracic Surgery, 108, 1617-1654.

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SPOTLIGHT

Awesome Woman Interview

Dr. Bola Faloye, FASE, FASA

Emory University
Atlanta, GA

Dr. Bola Faloye is a board-certified cardiac anesthesiologist with clinical experience since 2014 and specialized expertise in perioperative echocardiography and heart failure management. She is an active educator with national and international teaching experience, and a published author with work featured in several high-impact journals. Her research interests include health equity and cardiac surgery outcomes.

Dr. Faloye earned her medical degree from Emory University, completed her residency at Duke University, and pursued fellowship training in adult cardiothoracic anesthesiology at Emory. She is currently enrolled in Emory's Executive MBA program, with a focus on integrating clinical care and systems-based management to improve healthcare delivery.

1. What led you to become a Cardiovascular/Thoracic Anesthesiologist?
During my residency, I found the cardiac operating room to be the environment where I felt most professionally and intellectually fulfilled. The complexity of the disease processes, coupled with the dynamic physiological changes, offered a level of challenge and engagement that deeply resonated with me. It was also during this time that I developed a strong passion for echocardiography—there is truly nothing comparable to visualizing the heart from within and uncovering the underlying pathology in real time.

2. How did you hear about the SCA?
I learned about the SCA as an adult cardiothoracic anesthesiology fellow in 2013.

3. What roles have you held for the society?
I have served in multiple roles, including the SCA Mobile App Subcommittee, Nominating Committee, Vice Chair and Chair of the WICTA-SIG, and currently as Director-at-Large on the Board of Directors.

4. What is one of your greatest achievements as a Cardiovascular/Thoracic Anesthesiologist?
I'd have to say I don't pay much attention to accolades- I have a few- but who cares? I do what I do for the lives that I help make better.

5. Do you have any advice for fellows and residents?

a. Lean into training programs- take the opportunity to lay a solid foundation for the rest of your career.
b. Start the networking process during training, do not wait until you are done with training.
c. Be active with your national society- this is an avenue and forum for lifelong friendships and stimulating professional collaborations

6. Have you experienced any difficulties as a woman in the field?
I have had to learn how to walk the line between assertiveness and warmth. Finding that sweet spot is an art.

7. Do you have any advice for other women in the field?
Come to the table prepared to stand up and speak up. Do not be shy about going toe-to-toe.

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AWESOME WOMAN SPOTLIGHT

8. How do you balance work and personal life?
Boundaries – I carve out personal time in advance and do not let work interfere – that includes responding to emails, text messages, and phone calls.

9. What is something you enjoy doing outside of work?
Hiking! I love the solitude of the mountains and woods.

10. Would you change anything about the path you took to get to where you are now?
If I could change one aspect, I would have allowed myself to slow down and be more present in each stage of the journey. In hindsight, I often focused too intently on reaching the next milestone and, as a result, missed opportunities to fully appreciate and learn from the experiences along the way.

11. What was the best piece of advice you received?
Sit with your 66-year-old self and ask her what she would have done differently.

LEARNER NOTIFICATION

Society of Cardiovascular Anesthesiologists
Activity Title: Echo Corner (Myocardial Ischemia on Cardiopulmonary Bypass After Zone 0 TAVR Embolization)
Release Date: 8/1/2025
Expiration Date: 8/1/2027
Activity Type: Enduring Material

Acknowledgement of Financial Commercial Support
No commercial support was received for this educational activity.

Acknowledgement of In-Kind Support
No in-kind support was received for this educational activity.

ACCME ACCREDITED

Accreditation Statement
The Society of Cardiovascular Anesthesiologists is accredited by the Accreditation Council for Continuing Medical Education (ACCME) to provide continuing medical education for physicians.

The Society of Cardiovascular Anesthesiologists designates this enduring activity for a maximum of *.25 AMA PRA Category 1 Credits*™. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

Description:
The mission of the SCA Newsletter Sub-Committee is to inform the membership of the activities of SCA. The goal of the SCA Newsletter Sub-Committee is to produce and distribute the SCA official newsletter, the SCA Newsletter, six times per year. Each issue of the SCA Newsletter publishes education material including ECHO Corner. ECHO corner cases focus on clinical case presentation of diverse echocardiographic diagnosis encountered in clinical practice relevant to cardiothoracic anesthesiologists.

Educational Information

Physician Practice Gap:
Echo corner of the SCA newsletter is a written clinical case presentation with echocardiographic images and videos followed by multiple choice questions with explanations. The ECHO corner case review focuses on detailed and concise presentation of clinical findings accompanied by findings on transesophageal echocardiographic (TEE) exam to support the clinical diagnosis. The cases include a written portion with case description, TEE images, and TEE video clips. Three to five multiple choice question are presented to discuss the case. Each question provides an explanation of answer choices and includes a brief discussion of the topic present in each case.

- Cardiothoracic anesthesiologists may have limited expertise in TEE and fluoroscopic assessment and diagnosis of TAVI embolization sequela
- Cardiothoracic anesthesiologists can be inexperienced in preoperative decision making relating to anatomic TAVI suitability

Needs that Underlie the Gap
There is a need to provide education to clinicians on how to perform echocardiographic assessment of embolized TAVI (including assessment of ascending and descending thoracic aorta), and anatomic (and imaging) risk factors associated with TAVI embolization.

DESIGNED to Change/Outcome:
Note that in the field of intraoperative echocardiography in general improvements in patient outcomes are difficult to measure because most of the examinations are diagnostic and not therapeutic which are more determinative of outcomes.

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Educational Objectives

After completing this activity, the participant should be better able to:

- Assess risk factors for TAVR embolization
- Review perioperative TEE assessment and diagnosis of embolization
- Review clinical decision making about cardio-protection after TAVR embolization

Satisfactory Completion

Learners must complete an evaluation form to receive a certificate of completion. Partial credit of individual sessions is not available.

Contact Information

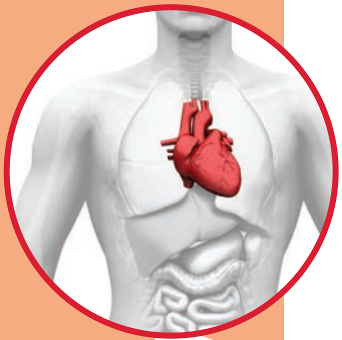
If you have questions regarding your CME certificate, please contact
Natalie Baus at nbaus@veritasamc.com.

Disclosure of Financial Relationships

As an accredited provider of the ACCME, SCA adheres to all **ACCME Standards for Integrity and Independence in Accredited Continuing Education.** The following individuals in control of content development for this activity have indicated that they do have financial relationships with ACCME defined ineligible companies within the past 24 months. All financial relationships have been mitigated. All have indicated that they have no financial relationships to disclose.

How to Get Your CME Certificate

1. Go to **https://scauniversity.pathlms.com/courses/109476**
2. Login and evaluate the meeting.
3. Print all pages of your certificate for your records.



ECHO CASE

Myocardial Ischemia on Cardiopulmonary Bypass After Zone 0 TAVR Embolization

Primary Author
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University of Pennsylvania
Philadelphia, PA

CASE PRESENTATION

The patient is an 86-year-old female with history of lung cancer s/p lobectomy, mixed pulmonary hypertension and severe aortic stenosis (aortic valve (AV) orifice area 0.97 cm2, dimensionless index 0.26, peak/mean gradients are 67/40 mmHg, AV annular area of 350 mm2) and class III NYHA heart failure. She presented for transfemoral TAVR procedure, with planned placement of self-expandable (SE) Evolut FX valve size 26. The valve was initially deployed in a standard fashion after 1 recapture. Post deployment angiogram shown below demonstrated a moderate paravalvular leak (PVL)

WATCH VIDEO

Question 1: What patient characteristics favor placement of a self-expandable TAVR valve compared to a balloon-expandable valve?

A) Low coronary ostial height
B) Potential need for future coronary angiography and intervention
C) Small aortic valve annulus
D) Horizontal aorta

Post deployment balloon dilation was attempted to resolve the PVL, however due to inability to capture during rapid pacing the balloon and the valve embolized in antegrade fashion toward the innominate artery (distal aspect of Zone 0). After several attempts to recapture, a smaller size (23 mm) balloon-expandable Sapien valve was deployed without difficulty in the aortic valve position. Transesophageal echocardiography (TEE) was performed for further evaluation.
Fluoroscopy and TEE images are shown below.

WATCH VIDEO WATCH VIDEO

Question 2: Risk factors for TAVR valve embolization include which of the following?

A) Balloon expandable valve
B) Self-expandable valve
C) Overestimation of the annular size
D) Presence of AV calcium

The following TEE images of aortic arch were obtained.

WATCH VIDEO

Question 3: What is depicted in the transesophageal image above?

A) Acute type A aortic dissection
B) Aortic valve annular rupture
C) Side lobe artifact
D) Reverberation artifact

Decision to proceed with open aortic dissection repair was made. Following initiation of cardiopulmonary bypass (CPB) via right axillary artery cannulation, the following midesophageal ascending aorta long axis view with color flow Doppler was obtained.

WATCH VIDEO

Question 4: Based on the image above, what is the primary concern that needs to be communicated with the surgeon immediately?

A) The patient is at risk of ascending aorta rupture
B) The patient is at risk of acute coronary ischemia
C) The patient is at risk for a cerebral vascular accident
D) The patient is at risk of Sapien TAVR valve injury

Question 5: Given this information, what is the best method to protect the heart and effectively deliver cardioplegia?

A) Anterograde cardioplegia
B) High dose systemic/intravenous potassium
C) Retrograde cardioplegia alone
D) Combination of retrograde and direct anterograde cardioplegia

ECHO CASE

ANSWERS

Question 1:

Answer: (C) Small aortic valve annulus

In a prospective trial of 716 patients, comparing balloon-expandable (BE) and self-expandable (SE) TAVR valves in patients with aortic valve annular area of 430 mm2 or less, the rate of post intervention valve dysfunction and patient prosthesis mismatch were significantly less with SE valves, with lower mean transaortic gradients and larger effective valve area at 12 months. However, SE valves have been historically associated with higher rates of paravalvular leak, risk of embolization, conduction abnormalities and pacemaker requirement. The SE valve cage structure as well makes it more challenging to engage the coronary ostia should the patient requires coronary angiography or left heart catheterization in the future. Other differences between BE and SE valves are indicated in the Table 1.

	Balloon expandable	Self-expanding
Pro	- Less PVL - Less risk of embolization - Less PPM need - Easier coronary angiography - Higher procedural success rate	- More effective orifice area for the same valve size, so more effective in a small annulus - Can recapture and reposition after partial deployment - Smaller delivery sheath - Less risk of annular rupture - No rapid pacing required
Con	- Less orifice area for the same valve size - Cannot recapture and reposition after - Larger or expandable delivery sheath - Higher risk of annular rupture - Requires rapid pacing	- More PVL - Higher risk of embolization - Higher PPM need - Less procedural success rate - More challenging coronary angiography

Table 1. Differences between SE and BE TAVR valves

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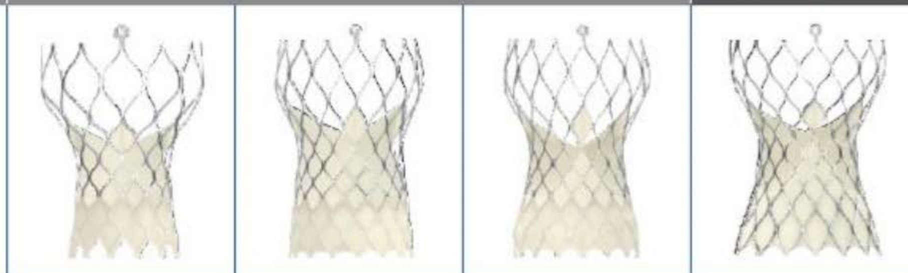
Question 2:

Answer: (B) Self-expandable valve

TAVR embolization is rare (incidence of 1.44%). Patient risk factors for valve migration include aortic regurgitation, bicuspid aortic valve, lack of calcification (need enough for anchoring), severe irregular calcification in the landing zone, irregular aortic geometry (horizontal aorta/ventriculo-aortic angulation), asymmetrical or ellipsoid aortic annulus, and low ejection fraction. Procedural and technical risk factors include, underestimation of the annular size, undersized prosthesis, incorrect positioning that is either too high or too low, insufficient rapid ventricular pacing, SE valves. SE TAVR valves should be positioned 4-6 mm or 3-5 mm relative to the aortic valve annulus for first generation and second-generation valves respectively (Figure 1).

Valve Size Selection	Evolut™ PRO Bioprosthesis			Evolut™ R Bioprosthesis
				
Size	23 mm	26 mm	29 mm	34 mm
Annulus Diameter (A)	17*/18-20 mm	20-23 mm	23-26 mm	26-30 mm
Annulus Perimeter†	53.4*/56.5-62.8 mm	62.8-72.3 mm	72.3-81.7 mm	81.7-94.2 mm
Sinus of Valsalva Diameter (Mean) (B)	≥25 mm	≥27 mm	≥29 mm	≥31 mm
Sinus of Valsalva Height (Mean) (C)	≥15 mm	≥15 mm	≥15 mm	≥16 mm

*Measurement for TAV-in-SAV only. | †Annulus Perimeter = Annulus Diameter x π

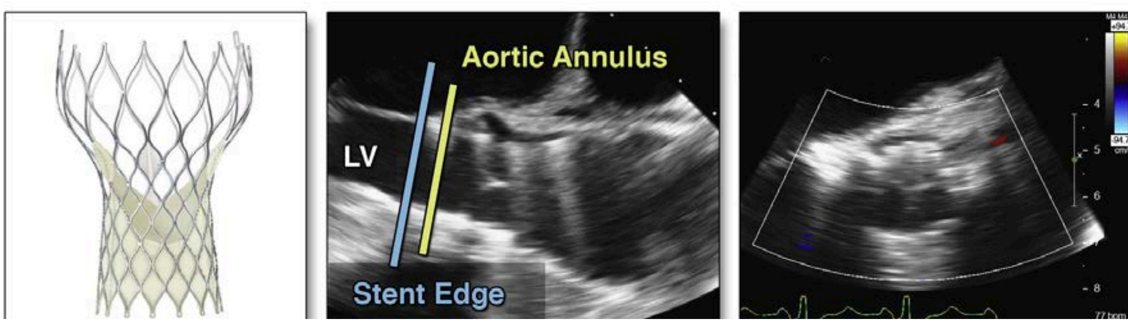


Figure 1. SE TAVR valve sizing and positioning

Question 3:

Answer:(A) Acute type A aortic dissection

This image shows iatrogenic type A aortic dissection (ATAAD) secondary to the embolized SE valve into the ascending aorta. Aortic dissection after TAVR is a very rare (0.1%) but highly fatal (50% mortality) complication with similar outcome to spontaneous type A dissection. Large registry studies indicate that patient factors (BAV, aortic aneurysms, atherosclerosis, highly calcified STJ and tortuous aorta), more than procedural or technical factors, play the highest risk of aortic dissection post TAVR. Both BE and SE valves have similar incidence of ATAAD, however SE valves have slightly higher incidence of delayed dissection post TAVR. While ATAAD is a surgical emergency, many patients undergoing TAVR are deemed a very high-risk surgical candidate in the first place. Accordingly, while surgical management is the most described approach, endovascular zone 0 TEVAR and even medical "anti-impulse" therapy have been described with varying outcomes. Patient's and patient's family wishes based on preoperative discussion plays a large role in the decision to proceed with surgical aortic valve and ascending aorta replacement.

Question 4:

Answer: (B) The patient is at risk of acute coronary ischemia

This patient has a competent Evolut valve in the ascending aorta that is in normal orientation (inflow/outflow). Upon initiation of CPB via right axillary artery cannulation, the valve slightly migrated towards the AV and blocked any retrograde flow from the CPB outflow into the aortic root, thus blocking flow into the coronary arteries leading to acute coronary ischemia. TEE was instrumental in anticipating and diagnosing this risk, as the patient had an underlying LBBB, making EKG changes less reliable and delayed; furthermore, with full support on CPB, hemodynamics remained entirely unaffected.

Question 5:

Answer: (D) Combination of retrograde and direct anterograde cardioplegia

A combination of retrograde cardioplegia followed by aortotomy and direct antegrade cardioplegia delivery would be the most effective way to arrest and protect the heart in this situation. Given the very close proximity of both deployed TAVR valves as shown in the Figure 2, it would be difficult to cross clamp the ascending aorta and pressurize the aortic root to deliver antegrade cardioplegia in a classic fashion. Given the lack of adequate coronary flow, systemic potassium might not be as effective in creating cardiac standstill. Retrograde cardioplegia alone is not sufficient to protect the heart and quite often lacks adequate protection to the right ventricle.

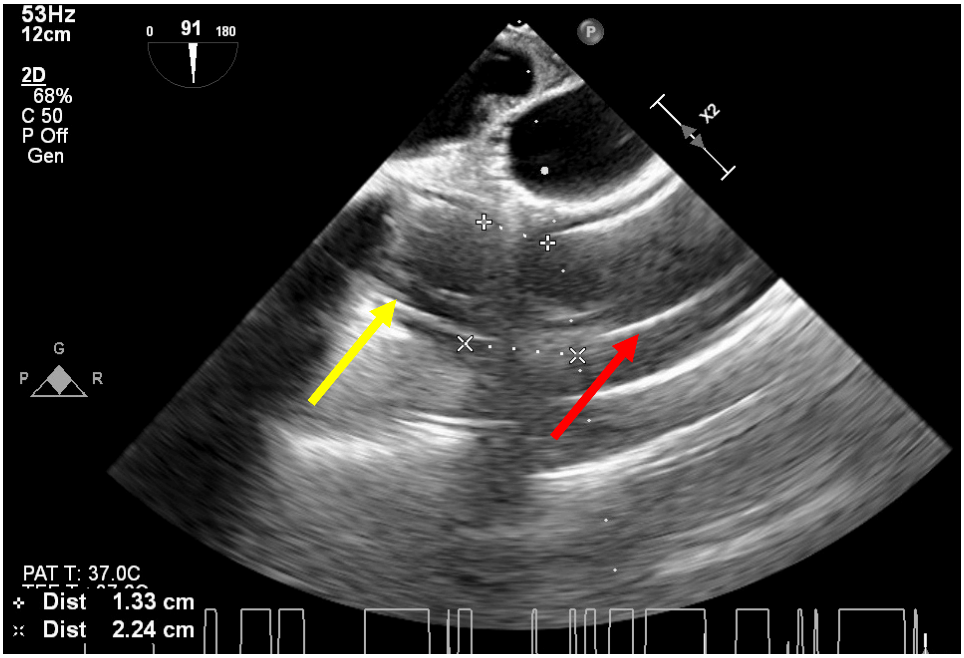


Figure 2. Long axis upper esophageal TEE view of ascending aorta showing SE valve (red arrow) and BE valve (yellow arrow) with calipers showing the distance between the valves.

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Preoperative Multivariable Model for Risk Stratification of Hypoxemia During One-Lung Ventilation

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Anesthesia & Analgesia 140(5):p 1029-1036, May 2025. | ***DOI:*** 10.1213/ANE.0000000000007306

Reviewer:

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Summary

Intraoperative hypoxemia is common during lung isolation in thoracic surgery and is strongly associated with postoperative cognitive dysfunction, atrial fibrillation, myocardial injury, renal injury, respiratory failure and pulmonary hypertension. Ventilation / perfusion (V/Q) lung scans can accurately predict intraoperative hypoxemia during one lung ventilation (OLV), but it is considered neither cost effective nor reasonable to order a V/Q scan indiscriminately prior to every thoracic surgery.

A multivariable model is proposed (PHYX-IT (Prediction of HYpoXemia In Thoracic score)), based on a stepwise logistic regression analysis sampling data from a single center retrospective cohort of 3228 consecutive patients. These patients underwent lung resections using OLV between January 1st 2017 and March 30th 2022. Readily available preoperative values within this model lend themselves to being widely used as a basis for a predictive model. Through preoperative risk stratification, it is hoped that informed and more rapid decisions may be made intraoperatively; It also raises the question as to whether there may still be value in additionally performing a V/Q scan.

Intraoperative hypoxemia, the dependent variable was defined as an episode of desaturation < 90% for ≥5 consecutive minutes. In this study, the incidence was 8.9% (95% CI: 8-10%). Weighted scores for the independent variables were assigned by multiplying their regression coefficients by 10, and then rounding off to the closest integer:

	Risk Score	OR (95% CI)
Preoperative SPO2 <92%	15	4.7 (2.3 - 9.6)
BMI >30kg/m2	8	2.3 (1.8-3)
CHF	7	2.0 (1.3-3.0)
Hb <10g/dL	6	1.9 (1.2 - 3.1)
Age>60y	4	1.6 (1.1-2.2)
Male gender	4	1.5 (1.2 -1.9)
Diabetes	4	1.6 (1.1-2.1)
Hypertension	3	1.4 (1-1.9)
Right sided surgery	3	1.4 (1.1-1.9)

The AUC achieved a value of 0.71 (CI 0.68, 0.74), with the optimal score balancing sensitivity (68%) and specificity (63%) at ≥13.

Secondary outcomes that were associated with intraoperative hypoxemia in univariate models as the independent variable included:

- Length of hospital stay
- Overall postoperative pulmonary complications
- Respiratory insufficiency
- Pulmonary edema
- ARDS

There was no association with pneumonia and pleural effusion. Pulmonary edema became nonsignificant in the multivariate model.

It is unclear whether this would necessarily lead to an earlier detection and management of impending hypoxemia, with an appropriately vigilant physician anesthesiologist, physically present in the operating room, who is in constant communication with the surgeons and is situation aware. The parallels to using a Hypotension Prediction Index software come to mind.

It is also unclear whether collinearity in the selected variables can be disentangled. The authors quite rightly state that this should be further explored in prospective trials.

Strengths

The quality and veracity of the data within the EDH and MPOG databases is well established, although only local MPOG data was extracted.

This is the largest retrospective study conducted to date looking at this specific outcome.

An O2 saturation of <90% for >5 consecutive minutes corresponding to a partial pressure O2 of <60mm Hg, as the dependent variable makes comparisons with previous studies easy.

Limitations

Although using an accepted, already published dichotomous construct as the definition for an outcome is statistically sound, it is widely appreciated that using all of the available underlying data to create a linear dependent variable may yield a better fitting model. The authors clearly stated though that there were some previous studies which had selected desaturation as a continuous variable, but that they had deliberately chosen to go with a logistic regression.

Preoperative SPO2, Hb, Age and BMI similarly lend themselves to being interpreted as linear variables. One possible option for redefining the dependent variable may be "The incidence of at least one episode of a mean saturation of ≤ 90% for ≥ 5 consecutive minutes" - perhaps treated as a restricted cubic spline.

Counting the number and severity of desaturations as well as integrating their time dependent areas under (or rather above) the curve would be of interest. In patients where more than one desaturation for an individual during each surgery is recorded, or indeed with multi-institutional studies, a linear mixed model may be considered to compensate for both fixed and random effects.

The cases were conducted with either an inhalational agent or with TIVA. The placement of arterial lines, selection of recruiting maneuvers as well as ventilator management were left largely at the discretion of the anesthesia team. The study design in pursuing a risk stratification model based on preoperative conditions, inherently misses what drives the intraoperative causal mechanisms, specifically the physiological perturbations of surgery and the intraoperative anesthetic interventions. The authors did quite rightly state that it was not their objective to look at these variables, and that no adjustment was made for these.

A sample size estimate was not calculated beforehand. The STROBE checklist suggestion #10 states: "Explain how the study size was arrived at." This does not stipulate that a power calculation must be done beforehand, although the intention of the STROBE checklist seems to be that some formal consideration be made other than "our plan was to include as many patients as possible during a period.". If a subset or random sample were being tested, a power calculation would have been relevant for that. Although the authors claim that their sample size was small (perhaps by modern standards), the patient sample size is more than sufficient to begin to observe meaningful patterns of association. Perhaps if multi-institutional data from MPOG had been more easily accessible (or pursued), the external applicability of these findings could have be explored.

Some missing values; Multiple imputation was used, presumably looking at the normality of distribution of the variances within variables as a sensitivity analysis (The term the authors used was "multivariate normal distribution"). Testing for interaction coefficients between the dependent variables in those cases with a large proportion of missing independent variables would have suggested whether missing values were missing "completely at random, missing at random, or missing not at random.".

Single center retrospective cohort. (The usual considerations).

89% of patients were white, and 58% were female.

One of the exclusion criteria was "missing intraoperative data of oxygen saturation." One would wonder whether this was because these were patients in a shock state, with diminished pulsatilty. Only 18 cases were excluded at the final stage of data cleaning due to missing pulse oximetry values. 625 cases were excluded where the surgery was <60 minutes. 196 cases had missing preoperative SPO2, 4 for gender and 100 for obesity.

FEV1 and FEV1/FVC have 1221 missing values, and yet the authors state that the p-values after multiple imputation were highly insignificant. This is noteworthy since in the discussion, they note that in comparative literature, (Slinger et al.[1],), FEV1 was found to be a significant risk factor, with a p-value of <0.01. This was a 1992 study where 50 out of 80 consecutive patients were studied retrospectively, and the remaining 30 prospectively. Despite the small sample size, a linear regression was used with saturation as a continuous variable. Lung and esophageal surgery cases were included. Isoflurane was used as the inhalational agent. It is historically interesting noting additionally that although pulse oximetry only became the standard of care in US operating rooms in 1987, a 1990 paper by Desiderio et al.[2] states: "The reliability of SpO2 measurements is not yet high enough to replace the need for corroboration by blood gas sampling in clinical situations, such as OLA, where hypoxemia is a considerable risk." This is still a valid consideration in situations with diminished pulsatilty and poor peripheral perfusion.

The regression coefficients of the independent variables were used as the basis for assigning weights. This does not necessarily reflect the strength of the effect and may inflate single institution effects.

The AUC is barely above 0.7, which seems unimpressive.

Only patients who were intubated with double lumen ET tubes (DLT) were selected, although bronchial blockers are still widely used.

In establishing a risk stratification model based on pre-existing conditions, questions arise as to what value this would bring to perioperative decision making. A recent parallel example would be various iterations of latent-class-analysis based models being proposed as an alternative to the ASA classification scale. Would knowing the likelihood of an outcome ahead of time affect scheduling or staff selection? Would one choose to exercise "enhanced vigilance" during a case, perhaps using lung recruitment strategies more frequently, and with lesser thresholds. Would one use cerebral oximetry, or try to optimize further measurements of right ventricular / PA coupling and renal perfusion? What choices would we have with inhalational agents in diminishing the hypoxic pulmonary vasoconstriction response? Would dexmedetomidine, nitric oxide, an inflammatory modulator or ECMO be reasonable choices? In this study, a propofol infusion was used 12.6% of the time, with no apparent differences in intraoperative hypoxemia during OLV.

A 2001 paper by Schwarzkopf et al.[3] showed no difference with NO, although there were 152 patients and no inhalational agent was used.

Conclusion

Preoperative conditions can serve within a model to pre-emptively stratify the risk of intraoperative hypoxia during OLV in thoracic surgery. These offer opportunities to further optimize patients in the perioperative condition.

Disentangling the effects of the independent variables based upon a single center retrospective study is challenging due the inevitable expected covariance across these preoperative variables. There exists evidence for a variety of multiplicative interactions.

Intraoperative factors such as communication and interaction across the various teams deserve attention.

Clinical Relevance to Practice

It is generally accepted that the degree of arterial O2 saturation is mainly dependent on the residual shunt within the nonventilated lung, the cardiac output, and on the degree of pulmonary vasoconstriction. A peripheral measurement of this using a pulse oximeter may not necessarily reflect simultaneous O2 delivery to critical organs.

During lung isolation maneuvers, particularly in patients with underlying lung disease, decreases in blood oxygen saturation are expected and tolerated well below what would normally be accepted in other surgeries. Intraoperative hypoxemia was shown to be associated with a variety of secondary outcomes, and is certainly associated with higher costs and mortality.

If patients at higher risk could be identified a priori, the question then opens up opportunities for assigning more resources, scheduling decisions, and in optimizing these patients ahead of surgery. The decision on whether to start with a video assisted approach and specific thresholds for converting to an open approach can be considered.

Preoperative pulse oximetry readings below 92% carried a risk score of 15. Acute (perhaps prophylactic) delivery of hyperoxia in the setting of chronic hypoxia is associated with oxidative stress, global inflammation, and affects the microcirculation within the coronary, cerebral and renal vascular beds.

Alternatives to transfusion with a Hb just below 10mg/dL - not simply prescribing parenteral Iron and EPO - may include considering the "Normobaric Oxygen Paradox" model that has been discussed as a preconditioning tool by Balestra et al.[4,5,6] Hypoxia within the renal vascular bed is well established as a driver for EPO production. Pulsed exposure to mild (30% O2) normobaric hyperoxia with a normobaric normoxia (21%) period presents an intriguing opportunity for rapidly raising the EPO / Hb preoperatively, in altering mitochondrial function, and in inducing the production hypoxia-inducible factors and heat-shock proteins. Ischemia – reperfusion related inflammatory responses can potentially be avoided, whilst still maximizing the benefits of preconditioning.

In terms of the inflammatory contribution of impaired glucose control, continuous glucose monitors have very recently become commonly used with minute-by-minute readings, not only for diabetics, but also with athletes and aspiring wellness strategists in general. This represents a rapidly developing opportunity for patients to properly optimize glucose tolerance in the preoperative period that has not existed until fairly recently.

The glucose level within the endothelial vascular bed (particularly in diabetics) is causally related to the degree of responsiveness of the pulmonary vascular vasoconstriction in response to acute hypoxia. Morphological changes in the capillary network and vascular bed are not merely limited to angiogenesis and vascular remodeling, but also to the tone and hypertrophy of pulmonary vascular smooth muscle. Hyperglycemia in animal models has in the setting of acute hypoxia been shown to increase vascular endothelial permeability, the adhesion of leucocytes and macrophages to pulmonary capillaries, and in the release of reactive oxygen species (ROS) within mitochondria, and NADPH-oxidase activity.

Chronic hypoxia is associated with the exacerbation of inflammatory conditions such as diabetes, so both conditions have a have a multiplicative interaction. Hypoxia induced Glucose-6-phosphate dehydrogenase (Glc-6-PD) and NADPH activity in lungs have been linked in a positive linear relationship with HPV, through influencing muscle contraction via activating Ca2+channels (Gupte et. al.7). In a lab study simulating NIDDM in rats (Khromov et al.8), simulating both a high fat diet and a diabetic model, RV pressure was increased. HPV was absent in the high fat model, but inverted in response with the NIDDM model.

Further human studies are needed to disentangle the effects of acute on chronic hypoxia in the setting glucose intolerance. Diabetes not only independently affects lung function, but is also associated with obesity. None of these interactions are ameliorated with advancing age. This manuscript strongly advocates for optimizing preoperative cardiopulmonary function, the oxygen carrying capacity of the blood, and possibly body weight if time allows.

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Comparison of ROTEM Delta and ROTEM Sigma Transfusion Algorithm Performance in Thoracic Aortic Surgery: A Single-Centre Prospective Observational Cohort Study

Published in British Journal of Anaesthesia, 134 (2):317-327 (2025) by Haeren M, et al

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Study Objective
This single-center prospective observational cohort study aimed to evaluate whether values obtained from the ROTEM Sigma device are interchangeable with and compatible with existing ROTEM Delta–guided transfusion algorithms in the setting of thoracic aortic surgery.

Key Findings/Results
A total of 111 patients were enrolled, with paired ROTEM samples collected at baseline, post-heparinization, and post-protamine administration, resulting in 300 total samples analyzed.

Comparison between ROTEM Delta and Sigma revealed 43 instances of conflicting transfusion recommendations:
- **29 instances** involved differing recommendations for plasma or prothrombin complex concentrate administration, which was statistically significant.
- In **25 of these,** Delta advised product administration, whereas Sigma did not.
- In **4 cases,** Sigma advised administration, whereas Delta did not.

Other non-statistically significant but noted differences included:
- **10 instances** regarding fibrinogen administration.
- **4 instances** regarding platelet administration.
- **0 instances** regarding additional protamine administration.

Additionally, statistically significant differences were observed in:
- **A10 FIBTEM** at baseline
- **A10 EXTEM** during heparinization and post-protamine.

However, these differences were deemed to be not clinically significant as they did not result in changes in clinical decision making. Notably, the ROTEM Sigma consistently produced lower A10 FIBTEM values at baseline compared to the ROTEM Delta.

Strengths
- One-to-one matching and comparison of ROTEM Delta to Sigma
- Adequate sample size to evaluate both clinical and statistical significance

Limitations
- Single-center study and transfusion algorithm focused on a narrow procedural population
- Findings may not be generalizable to other surgical settings or institutions with differing transfusion thresholds or protocols

Discussion
Viscoelastic testing has become a central component of modern transfusion algorithms, aiming to optimize blood product utilization and reduce transfusion-related complications. The ROTEM Delta system developed by Werfen, widely adopted in Europe, requires manual pipetting, requiring personnel training and introduces the potential for user error. In contrast, the newer ROTEM Sigma uses pre-packaged cartridges with lyophilized reagents, offering fully automated operation that enhancing ease of use and suitability as a point-of-care device.

Despite these advantages, the devices differ slightly in assay design and reference ranges. Notably, the Delta's FIBTEM assay uses a single platelet inhibitor (Cytochalasin D), while the Sigma employs dual inhibitors (Cytochalasin D and Tirofiban), which may account for the lower A10 FIBTEM values observed with Sigma.

While this study was conducted in the Netherlands, it is important to recognize that in the United States, the ROTEM Sigma is currently FDA-approved only for assessment of perioperative hemorrhage and/or thrombosis during cardiovascular and liver transplant surgeries, while the ROTEM Delta is approved for more broad coagulation evaluation.

Interpretation
ROTEM Sigma values can generally be used within ROTEM Delta–based transfusion algorithms for thoracic aortic surgery. However, clinicians should be aware that the Sigma may underestimate the need for plasma or PCC administration due to differences in clotting time (CT EXTEM) readings. Therefore, interpretation should consider device-specific reference ranges and the potential for under-treatment in some cases.

Acute Kidney Disease and Postoperative Glycemia Variability in Patients Undergoing Cardiac Surgery:
A Multicenter Cohort Analysis of 8,090 Patients

Reviewer:
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Summary

This is a retrospective analysis of 8,090 adult patients who underwent cardiac surgery utilizing cardiopulmonary bypass (CPB), and had a postoperative stay greater than seven days, in three academic medical centers in China, between the years of 2015 and 2023. The research hypothesis was that glycemic variability (GV) in the seven-day post-operative period, which the researchers defined using five variables – Standard Deviation (SD), Coefficient of Variation (COV), (COV=SD/mean glucose measurement), Mean Amplitude of Glycemic Excursion (MAGE), (mean of absolute glucose differences between each value and mean that are greater than one SD), Average Daily Risk Range (ADRR) (ADRR is poorly defined in the article, but is generally a variability metric obtained from glucose levels that are transformed to give equal weights to peaks and troughs), and Time Out of Target Range (TOR),(Percent of time spent out of the target range, 70-180 mg/dl) would correlate with acute kidney disease (AKD) in this patient population. AKD was defined as acute kidney injury (AKI) stage I or greater according to KDIGO criteria, categorized into "Delayed AKD" (cases emerging between days 8 and 90 post-op), and "Persistent AKD" (those persisting after 7 days post-op). The authors report that GV was correlated in a nonlinear way with persistent AKD, but not with delayed AKD, and that the TOR metric had the greatest effect size.

Strengths

1. **Large Study Population:** Over 8,000 Patients
2. **Multi-Institutional:** Three Academic Medical Centers
3. **Meticulous Data Collection:** Patient characteristics, inclusion/exclusion criteria are clearly delineated, sub-groups are clearly defined.
4. **Extensive Statistical Analysis:** Various appropriate models were utilized.

Limitations

1. **Format:** Retrospective Design
2. **Group Selection:** The study group is limited to those with a post-op stay of seven days or greater that may preselect a more critically ill population. Some other possible differences are the low mean age, 61, and the low average BMI, 23.9kg/m2.
3. **Data Collection:** No data collected on intraoperative glucose values or glycemic management.
4. **Pre-op Variables:** No information is provided on pre-op HbA1c, and whether pre-op glucose control impacted risk in the post-op period.
5. **Selection of Parameters:** ADRR and TOR are typically used as long-term measurements in ambulatory patients using continuous glucose monitoring (CGM)

Conclusion

The authors conclude that the risk of persistent AKD was 20-35% higher in patients with GV, with the greatest risk occurring in those with elevated TOR (Standardized Hazard Ratio 1.35 [95% CI 1.23-1.48], p<0.001).

Clinical Implications

Given that TOR had the greatest impact on the occurrence of AKD, it is difficult to know whether it was GV or simply hyperglycemia that was the culprit. In practical terms, frequent glucose monitoring and prompt correction of hyper/hypoglycemia continues to be prudent.

Mitochondrial Oxygenation Monitoring and Acute Kidney Injury Risk in Cardiac Surgery: A Prospective Cohort Study

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Summary
This is a retrospective analysis of 8,090 adult patients who underwent cardiac surgery utilizing cardiopulmonary bypass (CPB), and had a postoperative stay greater than seven days, in three academic medical centers in China, between the years of 2015 and 2023. The research hypothesis was that glycemic variability (GV) in the seven-day post-operative period, which the researchers defined using five variables – Standard Deviation (SD), Coefficient of Variation (COV), (COV=SD/mean glucose measurement), Mean Amplitude of Glycemic Excursion (MAGE), (mean of absolute glucose differences between each value and mean that are greater than one SD), Average Daily Risk Range (ADRR) (ADRR is poorly defined in the article, but is generally a variability metric obtained from glucose levels that are transformed to give equal weights to peaks and troughs), and Time Out of Target Range (TOR),(Percent of time spent out of the target range, 70-180 mg/dl) would correlate with acute kidney disease (AKD) in this patient population. AKD was defined as acute kidney injury (AKI) stage I or greater according to KDIGO criteria, categorized into "Delayed AKD" (cases emerging between days 8 and 90 post-op), and "Persistent AKD" (those persisting after 7 days post-op). The authors report that GV was correlated in a nonlinear way with persistent AKD, but not with delayed AKD, and that the TOR metric had the greatest effect size.

Objective
The primary objective of this single-centre prospective observational study, conducted among coronary artery bypass grafting (CABG) patients at elevated risk of cardiac surgery-associated acute kidney injury (CSA-AKI), was to assess the duration of mitochondrial oxygen tension (mitoPO_2) falling below 20 mm Hg during surgery and up to 48 hours postoperatively in patients who developed CSA-AKI. Secondary objectives included assessing the association between mitoPO_2 <20 mmHg (during and up to 48h post-surgery) and delirium, ICU stay, and hospital length of stay. Additional secondary analyses were performed using higher thresholds (<25, <30, <35, and <40 mmHg) to further explore their predictive value for CSA-AKI.

Key Findings
Sample: 75 adult patients at elevated risk of CSA-AKI, undergoing CABG with cardiopulmonary bypass (CPB) with or without valve surgery.

Primary Outcome
To determine whether the CSA-AKI group experienced a longer duration with mitoPO_2 < 20 mm Hg during surgery compared to the non-CSA-AKI group. The study compared the time each group spent below this threshold.

Main Result
CSA-AKI occurred in 57% of patients (43/75), identified mainly via elevated creatinine levels and reduced urine output. Patients with CSA-AKI had significantly higher levels of TIMP-2, IGFBP-7. They also spent more time with mitoPO_2 <20 mmHg (19% vs. 5% in non-AKI group). This trend persisted across all thresholds (<25, <30, <35, <40 mmHg). The duration of intraoperative mitoPO2 <25 mmHg showed the strongest association with CSA-AKI (Odds Ratio: 1.007 per minute; P = 0.021). Each minute with mitoPO_2 below 25 mmHg was associated with a 0.7% increased risk of developing CSA-AKI (P = 0.021).

Strengths
Novel Monitoring Technology: Utilization of the Cellular Oxygen METabolism (COMET®) monitor for real-time measurement of mitochondrial oxygen tension, reflecting local intracellular oxygen

balance. $MitoPO_2$ was measured on the skin of the upper arm. The COMET® device uses the Protoporphyrin IX Triplet Lifetime Technique (PpIX-TLST), which is based on oxygen-dependent quenching of delayed fluorescence from PpIX.

Granular Data Capture: $MitoPO_2$ measurements were taken every minute intraoperatively and every five minutes postoperatively.

Robust Study Design: A prospective observational cohort study with standardized inclusion criteria, based on an adjusted AKICS score (including combined surgery, NYHA classification >2, preoperative creatinine >106.1 μmol/L, age >65 years, and preoperative capillary glucose >7.8 mmol/L).

Complementary Biomarker Validation: Urinary biomarkers TIMP-2 and IGFBP-7 were measured within 24 hours of ICU admission. Their combined product, $[TIMP\text{-}2]_2$ [IGFBP-7] $(ng/ml)^2/1000$, has demonstrated utility in CSA-AKI risk stratification, with values ≥2.0 indicating a high risk.

Limitations

Challenges with CSA-AKI Classification: Variability in AKI definitions across studies (e.g., RIFLE, AKIN, KDIGO) and reliance on markers like serum creatinine and urine output may affect consistency in AKI diagnosis. Although KDIGO criteria were strictly applied, inherent limitations remain.

Technical and Logistical Barriers to $MitoPO_2$ Monitoring: Continuous $mitoPO_2$ monitoring over 48 hours was planned but proved unfeasible due to frequent probe dislodgment from patient movement, leading to discontinuation of postoperative data collection. Additionally, technical issues with the COMET® device resulted in the exclusion of five patients.

Single-Center Study: Limits generalizability.

Small Sample Size: Only 75 patients analyzed, reducing power for secondary outcomes (e.g., delirium).

Interpretation

This study demonstrates that sustained low mitoPO2 (<25 mmHg) during cardiac surgery is associated with higher risk of CSA-AKI. MitoPO2 monitoring could add value to intraoperative risk stratification and guide real-time interventions, such as hemodynamic or transfusion management, beyond traditional parameters like MAP or SpO2.

Clinical Implications

MitoPO2 could serve as a downstream, dynamic marker for tissue-level oxygen adequacy during surgery. Real-time monitoring may identify patients at high risk for CSA-AKI earlier than conventional indicators. Integrating mitoPO2 into intraoperative care protocols may enhance goal-directed perfusion and microcirculatory support.

Conclusion

This study supports the feasibility and potential utility of mitoPO2 monitoring in cardiac surgery. A threshold of <25 mmHg for mitoPO2 was significantly associated with increased CSA-AKI risk. These findings warrant further validation and suggest mitoPO2 could be developed into a trigger for intraoperative intervention to reduce CSA-AKI incidence.

ECHO REVIEW

Prognostic Value of Right Ventricular–Pulmonary Artery Coupling to a Clinical Risk Score in Tricuspid Regurgitation: The TRIO-RV Score

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Background

Tricuspid regurgitation (TR) has historically been underrecognized despite its growing link to adverse outcomes.[1,2] Traditionally considered secondary to left-sided heart disease, TR is now acknowledged as a primary contributor to morbidity and mortality. The TRIO (Tricuspid Regurgitation Impact on Outcomes) score, incorporating variables such as age, renal function, hemoglobin, natriuretic peptide levels, and right atrial pressure, provides clinical risk stratification but lacks specific echocardiographic markers of right ventricular (RV) function.[3,4]

Recent studies emphasize the importance of RV–pulmonary artery (PA) coupling—a physiologic metric reflecting the relationship between RV contractility and afterload.[5] This relationship can be noninvasively assessed using RV free wall strain (RVFWS) indexed to RV systolic pressure (RVSP), forming the RVFWS/RVSP ratio.[6] This study investigated whether integrating RV–PA coupling into the TRIO score could enhance mortality prediction in patients with at least moderate TR.[7]

Methods

This retrospective, single-center study enrolled 417 adults with at least moderate TR diagnosed at the Mayo Clinic between January and June 2019. Echocardiographic data included RVFWS and estimated RVSP, from which the RVFWS/RVSP ratio was calculated as a surrogate of RV–PA coupling. TRIO scores and comprehensive clinical data were collected, and all-cause mortality was tracked over a median of 3.96 years.[8]

The primary outcome was mortality, analyzed via Cox proportional hazards regression. Cox regression was employed to identify independent predictors of adverse outcomes in patients with tricuspid regurgitation by accounting for time-to-event data and adjusting for multiple covariates. The incremental value of RV–PA coupling was assessed by incorporating RVFWS and RVFWS/RVSP into the TRIO model, producing the new TRIO-RV score. Model performance was evaluated through C-statistics, chi-square tests, calibration, and reclassification analysis.[7]

Results

The mean age was 73 ± 13 years, and 47% of patients were female. TRIO risk classification yielded 51% low-risk, 39% intermediate-risk, and 10% high-risk. During follow-up, 157 patients (38%) died.[8]

Both RVFWS and RVSP individually correlated with mortality, but their combined use as RVFWS/RVSP demonstrated stronger predictive power. In adjusted Cox regression models, RVFWS <18.6% (adjusted hazard ratio [aHR] 3.08; 95% CI 2.01–4.72; P < .001) and RVFWS/RVSP <0.43 %/mm Hg (aHR 2.76; 95% CI 1.75–4.35; P < .001) remained independently associated with mortality even after adjusting for TRIO components.[7]

Adding RVFWS/RVSP to the TRIO score significantly improved model performance. The chi-square statistic increased from 38.3 (TRIO alone) to 72.2 (TRIO + RVFWS <18.6%) and 82.3 (TRIO + RVFWS/RVSP <0.43). The C-statistic improved from 0.65 to 0.70 with the TRIO-RV model. Notably, 151 patients (40%) initially classified as low or intermediate risk were reclassified into a higher-risk group with the addition of RVFWS/RVSP, indicating enhanced prognostic stratification. Kaplan-Meier analysis confirmed poorer survival in patients with lower RVFWS/RVSP values.[7]

Discussion

This study reinforces the growing recognition of RV–PA coupling as a critical determinant of outcomes in TR. Traditional risk scores like TRIO focus on systemic indicators but overlook RV adaptive capacity in response to pressure overload. The RVFWS/RVSP ratio offers a noninvasive, physiologically meaningful way to quantify this adaptation, integrating both myocardial contractility and afterload into a single parameter.[3,5]

By incorporating RV–PA coupling into the TRIO score, the TRIO-RV model enhances granularity—particularly in intermediate-risk patients where clinical decisions often face uncertainty. The reclassification of 40% of patients to higher risk supports its practical utility in better identifying candidates for closer monitoring or earlier intervention.[7]

The study is limited by its retrospective, single-center design and potential measurement variability in RVSP estimation via Doppler methods. Nevertheless, its robust statistical analysis and clinically relevant findings make a compelling case for further validation of the TRIO-RV score in broader populations.[7]

Conclusion

RV–PA coupling, as measured by RVFWS/RVSP, adds meaningful prognostic information to the TRIO score in patients with moderate or greater TR. The TRIO-RV score improves risk prediction and reclassification, particularly among those not clearly identified as high risk by traditional clinical parameters. This metric has the potential to refine right-sided heart failure assessment and guide management decisions in TR, warranting integration into future echocardiographic guidelines and risk algorithms.

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ECHO REVIEW

Sex-Specific Differences in Echocardiographic Parameters of Risk Stratification in Pulmonary Arterial Hypertension

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Objective

Determine if there are sex-specific differences between echocardiographic parameters of the right heart for risk stratification and survival estimation in patients with pulmonary artery hypertension (PAH). Parameters include right atrial area (RAR), right ventricular area (RVA) and tricuspid annular plane systolic excursion divided by systolic pulmonary artery pressure(TAPSE/sPAP).

Methods

This study uses a single center data set for a retrospective, cross-sectional analysis with survival follow-up. The above clinical parameters and thresholds of the European Society of Cardiology/ European Respiratory Society risk stratification parameters were evaluated. PAH was diagnosed using the hemodynamic definitions of the 2022 European PH guidelines.

Out of a total of 764 patients with PAH identified, 748 qualified for the study: 274 men and 474 women. Mean age of all the patients was 65 yrs old. Etiologies of PAH included 40.8% idiopathic, 27.1% associated, 2.3% hereditary and 29.4% other. Patients were classified into WHO functional classes: class III 56.3%, class IV 9.7%, class II 33.1% and class I 0.9%. Patients were followed for 3.2 years on average.

Results

In comparing the sexes, the men were found to be taller, heavier, higher BSAs with higher cardiac output and stroke volume while the women had a higher diffusion capacity of the lungs. Men had larger RVA in all WHO functional classes and larger RAR in functional classes II and III. BSA significantly but weakly correlated with RVA and RAA. TAPSE/sPAP significantly but weakly correlated with WHO functional class, weight, BMI, and BSA.

Discussion

This study found that European thresholds should be interpreted in the context of sex due to the difference in RAA between women and men based on WHO functional class and cardiac index risk groups. Prior studies have shown men have larger right hearts than females and thus TAPSE/sPAP an independent determining factor from both BSA and disease severity. This cohort also displayed this sex-specific difference making RAA and RVA suboptimal predictors of 1-year mortality when comparing between the two sexes but more accurate when comparing within the same sex. When comparing RAA between two men, a larger RAA has a lower mortality. On the other hand, no sex-specific differences were seen when comparing TAPSE/sPAP values making this a more accurate predictor.

Prior studies have established that women have PAH more commonly than men but tend to have better outcomes. These authors postulate that women may be able to compensate for a higher afterload leading to better RV function and survival despite more right heart enlargement. Alternatively, they suggest a hormonal influence via the "estrogen paradox". This theory states that estrogen is a risk factor for developing PAH but also has cardioprotective effects that leads to better outcomes. In contrast, testosterone leads to larger hearts, worse RV function and higher mortality.

Limitations of this study include data in isolation from a single center and retrospective analysis.

Conclusion

RAA is a viable factor when comparing sex-specific risk stratification adjusted for BSA. Sex correlates with right heart echocardiographic measurements independent of body size or WHO functional classifications. TAPSE/sPAP is an accurate non-sex specific prognosticator. Further research is required into clinical, social and economic factors influencing the outcomes of patients with PAH to rule out sex-specific differences.

Reevaluating Normal-Flow Low-Gradient Severe Aortic Stenosis

Clinical Phenotypes and Outcomes in Severe Aortic Stenosis Among Transcatheter Aortic Valve Replacement Patients

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Background and Rationale

Aortic stenosis (AS) is a common degenerative valvular disease in the elderly, often requiring transcatheter aortic valve replacement (TAVR) in symptomatic severe cases. AS has several hemodynamic subtypes, including high-gradient (HG), low-flow low-gradient (LFLG), and normal-flow low-gradient (NFLG). NFLG AS, despite meeting criteria for severe AS by valve area, remains controversial due to its preserved flow and low gradient—raising the question of whether it truly represents severe disease or merely a moderate form misclassified due to measurement limitations.

This study aims to reassess the characteristics and outcomes of patients with these subtypes and evaluate the potential overclassification of NFLG AS as "severe" in clinical practice.

Study Design and Methods

- **Design:** Retrospective cohort study
- **Population:** 930 patients undergoing TAVR for symptomatic severe AS at Mayo Clinic sites (2012–2017)
- **Classification:** Patients were grouped as:
  - o HG (n=563, 60.5%)
  - o LFLG (n=94, 10.1%)
  - o NFLG (n=273, 29.4%) initially, of whom 41 were reclassified as LFLG based on corrected LVOT stroke volume index (LVSVI <35 mL/m^2)
- **Outcomes:** One-year and five-year all-cause mortality; echocardiographic and CT-based phenotyping, including aortic valve calcium score (AVCS)

Key Findings

1. **Reclassification of NFLG AS:**
   - o 41 NFLG patients were found to be misclassified due to overestimated LVOT VTI (caused by Doppler misalignment).
   - o After correction, LFLG prevalence increased to 14.5%.
   - o Reclassified patients had higher AVCS and more atrial fibrillation (AF), consistent with the LFLG phenotype.
2. **Phenotypic Differences:**
   - o **LFLG AS** had the highest prevalence of AF (60%) and tricuspid regurgitation (TR).
   - o **NFLG AS** had the largest aortic valve area (AVA) and lowest AVCS, suggesting less severe stenosis.
   - o **HG AS** had the highest AVCS and mean pressure gradient.
3. **Mortality Outcomes:**
   - o **1-year mortality:** LFLG (17.4%) > HG (13.9%) > NFLG (10.9%); not statistically significant (p=0.20)
   - o **5-year mortality:** LFLG (54.9%) > HG (47.8%) ≈ NFLG (47.1%); also not statistically significant
   - o **Multivariate Cox models:** No significant mortality differences across groups after adjustment

Strengths

- Large multicenter TAVR cohort with 5-year follow-up
- Detailed imaging analysis using echocardiography and CT
- Identification of key measurement errors affecting AS classification
- Reassessment of LVOT VTI and subgroup reclassification provides valuable real-world insights

Limitations

- Retrospective design with no control group of conservatively managed NFLG patients
- Measurement variability in echocardiography
- Limited power for mortality comparison between subgroups
- Potential referral bias as only TAVR-treated patients were included

Clinical Implications

- **NFLG AS** may not represent true severe AS in many cases; lower AVCS and larger AVA suggest a milder form.
- **Multimodality imaging is crucial** to avoid misclassification and guide appropriate therapy.
- **LFLG AS remains a high-risk phenotype,** associated with more comorbidities and higher mortality, though statistical significance was not achieved.
- Treatment strategies for NFLG AS should be individualized, emphasizing **symptoms and calcification burden** rather than AVA or MPG alone.

Conclusion

This study challenges the assumption that all cases of NFLG AS with AVA ≤1 cm^2 warrant intervention. Many patients may be overdiagnosed due to Doppler or geometric errors. The findings underscore the importance of accurate stroke volume and gradient assessment using multimodality imaging. Future randomized trials are necessary to determine whether early intervention in NFLG AS improves outcomes compared to conservative management.

PRO CON

Andrew Maslow, MD

INTRODUCTION TO PRO CON DISCUSSION

Operating Room Extubation (ORE)

In this Pro-Con the authors discuss the extubating cardiac surgical patients in the operating room. Enhanced recovery after surgery (ERAS) had its beginnings in 1997 and 1999 with the work of Kehlet et al who introduced the concepts that, among other things, included early extubation, mobilization and multimodal pain control.[1,2,3] Over the years this has been associated with improved outcomes and shorter hospital stays.[2,3]

In 2017 the Enhanced Recovery After Cardiac Surgery began with the written guidelines and the establishment of the ERACS society.[4,5] The written guidelines is based on 197 studies selected from 4052 found in the literature. From the 197 included in the meta-analysis The following components are included in ERACS.[4]

1. Prehabilitation when possible and when needed
2. Perioperative glycemic control
3. Infection prevention
4. Minimize bleeding
5. Strategies to ensure extubation within 6 hours of surgery (Class IIa; B-NR)
6. Perioperative multimodal opioid sparing pain management plan (Class I; B-NR)
7. Early mobilization
8. Monitoring for postoperative delirium
9. Early return of bowel function

Although the ERACS society started in 2017 and the guidelines were written in 2019, the concepts and practice started more than 20 years earlier and was associated with reductions in morbidity and mortality, reduced ICU and hospital stays.[4,6] The concept of 'Fast Track' care was described in the late 1980s and 1990s. In 1990. Krohn et al reported a perioperative management protocol that focused on a number of practices and body functions designed to prevent complications while providing 'adequate analgesia', 'extubation as early as possible', and early mobilization.[7] The median hospital discharge was 4 days for 235 cardiac surgical patients scheduled for coronary artery bypass grafting, mitral valve replacement, or aortic valve replacement.[7]

In 1993 Chong et al eliminated the costs of a conventional intensive care unit and two groups of patients; 1) those admitted to a cardiac surgical recovery area and 2) those admitted to a traditional intensive care unit.[8] While both groups received a balanced anesthetic technique including fentanyl (10-15 ug/kg) followed by nitrous oxide and halothane, group one was managed with a propofol infusion during cardiopulmonary bypass compared to Fentanyl and Midazolam.[8] Muscle relaxant was reversed in group 1 patients followed by an infusion of morphine 1-4 mg/hr.[8] The median time for mechanical ventilation for group 1 was 1 hour (0-12 hours; mean 2 hours) with 15 (7.6%) extubated in the operating room, 42 (21.3%) within 30 minutes of arrival, and 105 (53%) within 2 hours.[8] Group 2 patients were extubated between 0 and 22 hours with a median time of 7 hours. Hospital stay was similar for both groups.[8]

In 2003 Aybek et al eliminated the endotracheal tube and mechanical ventilation completely using high thoracic epidural anesthesia in 35 patients who underwent awake, open sternotomy, coronary artery bypass grafting. Thirty two remained awake while three required intubation (Pneumothorax x 2; Incomplete analgesia x 1).[9] This group spent an average of 6 hours in the recovery room.[9] Whether or not awake cardiac surgery is an important step in ERACS is not clear, but the idea alone is of interest.[9,10,11]

Coincident with ERACS are changes in anesthetic technique with an emphasis on pain control. Pain control has traditionally been an opioid based regimen;[12-17] however, more recent publications and opinion describe a reduction of opioid administration or even an opioid sparing multimodal technique to provide analgesia while minimizing sedation and respiratory depression.[16-20] The selection and dosing range of opioids has changed dramatically from smaller doses of Meperidine in the 1950 and 1960s to high dose Morphine (0.5 to 3.0 mg/kg) or Fentanyl (50-100 ug/kg) in the 1960s and back to smaller doses or even the elimination of opioid.[12-15;18-22] Limitations and complications of a heavy reliance on narcotics include an incomplete blunting of the stress response, chest wall rigidity, nausea/vomiting, respiratory failure, hyperalgesia (more likely with more potent opioids) and a high incidence of awareness.[18-21;23,24] More modern care includes a balanced anesthetic technique, smaller opioid dosing regimens and a multi-modal analgesia protocol including any combination of the following.[5,16-21;25,26]

1. Ketamine infusion
2. Dexmedetomidine infusion
3. Lidocaine infusion
4. Acetaminophen
5. NSAIDs
6. Gabapentanoids
7. Regional analgesia (intrathecal, epidural, fascial plane blocks)

While the concept of multi-modal analgesia and opioid sparing are embraced, the fact remains is that 'Fast Tracking' and early or immediate extubation was possible with an opioid based regimen.[8,18-21] While clinicians are embracing an opioid sparing technique and seek to eliminate long-acting sedating medications Methadone, an opioid introduced in the 1930s, and used to combat heroin dependence since the 1960s, is introduced into modern day cardiac anesthesia practice despite its long-acting analgesia with a half-life up to 72 hours.[18,27] Reported benefits included less nausea and vomiting, NMDA antagonism and prevention of hyperalgesia.[18,27] The dosing of Methadone is equivalent to morphine and 0.3 mg/kg is $_2$ 12ug/kg of Fentanyl.

ERACS and Fast Tracking are not new concepts. While newer techniques have been introduced over the past 30-40 years there are some basic principles that are common. One is that 'Fast Track' is a mindset that requires the collaboration of a multi-disciplinary team, of which the anesthesiologist, the surgeon, and intensive care team are at the heart of it. It is not dependent on one technique or another. The embracement of a multimodal analgesia regimen is well supported to maximize the benefits of each component while minimizing their adverse effects.[18-21] Second, is that the success of 'Fast Tack' rests in patient selection. Extubation requires hemodynamic stability, hemostasis, 'adequate' analgesia, minimal sedation, and good pulmonary function.[17,28] The following Pro-Con debates the timing of extubation and its impact on outcome.

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Routine Operating Room Extubation Following Cardiac Surgery Involving Cardiopulmonary Bypass

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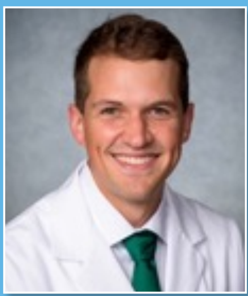

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Introdudction

Fast-track protocols in cardiac surgery emerged several decades ago in an effort to improve postoperative outcomes and optimize resource utilization. The central tenets of this approach include balanced opioid-sparing anesthetic techniques, as well as early extubation within 6 hours of intensive care unit (ICU) arrival. With advancements in surgical and anesthetic techniques over the years, early extubation was established as a quality marker by the Society of Thoracic Surgeons (STS) and was adopted by cardiac surgery programs nationwide. The overall signal from available evidence, graded as moderate strength by the STS and Enhanced Recovery After Surgery (ERAS) Society, supports the efficacy of fast-track extubation (FTE) in achieving the goal of shortening ICU and hospital length of stay (LOS) without adversely affecting patient morbidity or mortality.[1] As a natural evolution of this framework, there has been increasing interest in pushing the boundaries of extubation to even earlier after surgery, culminating in patients being extubated in the operating room. Early reports demonstrated the feasibility of operating room extubation following off-pump cardiac surgery,[2, 3] and the practice has since expanded to include cases involving cardiopulmonary bypass (CPB). ORE attempts to maximize the benefits of FTE under the premise that if early extubation is beneficial, then immediate extubation could be even better. However, in the pursuit of even earlier extubation, it is worth asking whether chasing "better" risks compromising patient safety.

Literature on ORE: Cautious Interpretation

A handful of retrospective analyses have compared ORE to FTE following CPB at the institutional level. While benefits have been inconsistently reported, the overall signal is that ORE is associated with equivalent to modestly reduced ICU and hospital LOS without concomitant increases in complication rates when performed in highly selected patients. To highlight a few examples, Chamchad et al. (2010) examined patients undergoing elective on- and off-pump cardiac surgeries at three community hospitals[4]. ORE in this cohort was associated with a shorter median ICU LOS by 19 hours and a shorter mean hospital LOS by nearly one day.[4] However, the FTE group included patients extubated up to 24 hours after ICU arrival, skewing outcomes by capturing those well beyond the typical 6-hour fast-track target.[4] In a small, single-center propensity-matched cohort of non-emergent cardiac surgery patients, Badhwar et al. (2014) found that ORE was associated with a 3-hour reduction in ICU time and a 1-day shorter median time to discharge compared to FTE within 6 hours, without differences in reintubation, reoperation, or mortality rates[5]. Results have been conflicting in patients undergoing isolated on-pump CABG. Whereas Montes et al. (2000) reported an 8% reintubation rate and no reduction in ICU or hospital LOS with ORE[6]. A more recent single-center analysis found that patients extubated in the OR spent 6 fewer hours in the ICU and a median of 2 fewer days in the hospital without increased rates of reintubation, reoperation, or mortality.[7] Jaquet et al. (2023) evaluated ORE in patients undergoing isolated valve surgery via a Mini thoracotomy approach and concluded no advantage over FTE in ICU or hospital LOS[8]. Collectively, these studies demonstrate the feasibility of ORE and suggest a possible association with reduced resource utilization, but their findings should be interpreted with caution in the setting of significant methodological limitations. Most importantly, patients who underwent ORE in these studies – and, more broadly, across much of the current literature comparing ORE to FTE – tended to be younger, healthier, and undergoing lower-risk surgeries. While propensity matching has been commonly used to create more balanced groups, the truth is that no amount of statistical adjustment can fully account for the unknown confounders that arise from the multidisciplinary

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decision to extubate these patients. As none of these studies were intention-to-treat analyses, patients originally destined for ORE would be deferred to ICU extubation if unanticipated intraoperative events or unfavorable changes in patient condition occurred. Consequently, these sicker patients would be analyzed under the FTE designation. Simply stated, with the currently available (and largely observational) evidence, ORE might be more of a marker for healthier patients than a causative factor driving improved outcomes.

ORE Associated With Increased Complications

In the past couple years, several large retrospective database analyses have been performed comparing ORE to FTE with conflicting results. In an analysis of a national STS database, Teman et al. (2024) found that ORE was associated with lower risk-adjusted odds of postoperative mortality, reintubation or reoperation for bleeding, and prolonged hospital stay of >14 days.[9] On unadjusted analyses, ICU and postoperative LOS were shorter by 0.3 and 0.8 days, respectively, but propensity-matched comparisons were not made. These results contradicted a study by Hawkins et al. (2024), which found higher rates of reintubation (4.3% vs. 1.8%) and reoperation for bleeding (2.5% vs. 0.9%) in ORE patients after CPB, with no differences in terms of major morbidity and mortality or ICU LOS.[10] Most recently, Etchill et al. (2024) compared extubation strategies in a propensity-matched cohort of patients undergoing CPB.[11] While no differences were noted in ICU or hospital LOS, they found that ORE was associated with higher rates of reintubation (5.2% vs. 2.9%), reoperation for bleeding (1.5% vs. 0.7%), and postoperative pulmonary complications, including pleural effusions requiring drainage and pneumonia. ORE also independently predicted mortality on multivariable regression, particularly among centers that had limited experience with the technique.[11] Considering the aforementioned selection bias favoring ORE inherent to retrospective studies, the increased risks of complications found by Hawkins et al. and Etchill et al. are especially alarming and raise concern that the intervention could be causing harm. At the very least, these findings strongly caution against the routine application of ORE to less carefully selected patients.

ORE: Physiologic Challenge to Patient

The dangers of routinely performing ORE after CPB lie in its potential to increase cardiac and respiratory workload in hemodynamically tenuous patients during the OR-to-ICU transition, a particularly vulnerable point in the continuum of perioperative care. CPB increases the risk of postoperative pulmonary complications through several well-described mechanisms, including ischemia-reperfusion injury, systemic inflammation, atelectasis, and pulmonary edema.[12] Not surprisingly, longer duration of CPB has been associated with a lower likelihood of successful ORE.[13] Routinely transporting these patients with suboptimal pulmonary mechanics to the ICU after extubation is a risky endeavor, predisposing to undetected episodes of airway obstruction in a setting with limited monitoring and airway equipment.[14] Notably, patients undergoing ORE following CPB have been shown to have lower peripheral O2 saturations, higher PaCO2, and greater base deficits on admission to the ICU compared with patients who arrived intubated and mechanically ventilated.[15] Pain management with opioid titration can be particularly challenging in this setting. On the one hand, opioid-induced respiratory depression in patients without a secure airway can cause hypoventilation, hypoxemia and hypercarbia, and potentially contributing to right heart dysfunction. On the other hand, inadequate pain control from underdosing can contribute to hypertension, in turn stressing suture lines and potentially increasing the risk of surgical bleeding.[16, 17] Increased catecholamine release secondary to pain or emergence delirium also has the potential to worsen myocardial ischemia, which is especially undesirable in the setting of predictable myocardial dysfunction commonly seen following CPB.[18] Maintenance of mechanical ventilation in this setting allows for simultaneous optimization of gas exchange and safe titration of opioids. Furthermore, the accompanying increased intrathoracic pressure might play a small role in facilitating mediastinal hemostasis.[19] From a pragmatic standpoint, the practice of ORE introduces workflow challenges that threaten patient safety. Patients who are emerging from anesthesia are more difficult to settle, potentially distracting nursing staff and ICU providers from hearing important details during verbal handoff.[14] Admitting and recovering an extubated patient requires additional support and communication, as well as the immediate availability of noninvasive ventilation devices and providers capable of airway rescue should a patient develop respiratory compromise.[20] Keeping patients intubated during this

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eventful transition permits a window of focused observation in the immediate postoperative phase when complications such as cardiac instability and unrecognized surgical bleeding are most likely to manifest.[17, 21]

Extubation Times: Selection Bias

In the only randomized trial to date comparing ORE to FTE in adults following CPB, Totonchi et al. found that ORE was associated with a 14-hour reduction in ICU LOS without increased risk of major complications.[15] However, these results must be interpreted within the context of a specific intraoperative protocol unique to the ORE group. These patients received significantly less cumulative doses of sedatives and narcotics, underwent bispectral index monitoring, early neuromuscular blockade reversal, and lung recruitment maneuvers, making it nearly impossible to isolate the independent effect of extubation timing from the anesthetic technique. Moreover, exclusion criteria included age greater than 65 years, obesity, left ventricular ejection fraction less than 35%, and COPD, again introducing selection bias in favor of ORE by excluding sicker patients who would be less likely to tolerate such an early extubation. Rather than demonstrating that ORE is independently beneficial, this trial more accurately illustrates that implementation of ORE is typically embedded within broader institutional strategies. Proponents of routinely performing ORE acknowledge that the success of this technique is dependent upon programmatic cultural shift and investment in standardized, multidisciplinary pathways that coordinate anesthesia, surgery, and ICU care.[9, 22] In this context, ORE serves less as a causative factor of improved outcomes and more as a surrogate marker for comprehensive goal-directed perioperative initiatives that optimize patients for subsequent recovery.[20] In other words, much of the positive results seen in select patients might be less attributable to the timing of extubation itself and more to the presence of well executed, team-based enhanced recovery protocols that begin well before the end of surgery. Without this structure in place, ORE becomes more vulnerable to failure and complications. This concept is reinforced by findings from Etchill et al. (2024), who demonstrated that the safety of ORE correlates with institutional experience. Mortality rates were higher in patients extubated in the OR at centers that used the technique infrequently (<10% of cases), but not at centers where it was routinely performed (>40% of cases).[11] Such a "learning curve" highlights the risks of premature or indiscriminate adoption of ORE and underscores its reliance on infrastructure, protocolized care, and team experience. This insight points toward a more balanced and safer alternative: applying the same institutional commitment and multidisciplinary coordination used to support ORE toward optimizing ICU-based extubation strategies. In doing so, programs could likely still achieve similar benefits, including shorter ICU stays and improved patient throughput, without exposing patients to unnecessary risks.

More In Depth Evaluation Workflow and Economics Needed

Even with appropriate institutional support, however, an important question remains: are the proposed economic benefits of ORE compelling enough to justify the extensive efforts required to implement it safely and consistently? ORE is assumed to promote cost savings primarily by obviating the need for mechanical ventilation in the ICU, thereby lessening resource utilization and facilitating a more rapid progression toward ICU discharge. However, a more comprehensive analysis must weigh these ICU savings against the increased OR time required to emerge and extubate these patients. Available evidence suggests that ORE shortens ICU LOS by around 3-6 hours,[23] but also adds at least 5-20 minutes to the window between surgery completion and OR exit.[7, 13, 24] Given that OR time is the single most expensive component of patient care and measured in minutes, any extra time spent here can disproportionately offset downstream savings accrued from shorter ICU stays. Moreover, prolonged OR occupancy can introduce systemic costs via the potential for downstream surgical case delays or cancellations, and by extending OR staff hours. Though more challenging to quantify on a per-patient basis, these indirect effects compound the financial and logistical burden. A full economic evaluation of ORE must also account for the potential increased risks of reintubation and reoperation for postoperative bleeding,[10, 11, 23] which would incur additional costs and resource utilization. In their analysis, Hawkins et al. (2024) reported an underwhelming absolute reduction in total hospitalization cost of approximately $1,964 with ORE, an amount they concluded was likely insufficient to justify the associated increase in clinical risk.[10] Finally, the extent to which shorter ICU stays translate into actual savings is dependent on infrastructure and capacity. Many factors

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unrelated to a patient's medical readiness, such as time of day, bed availability, and nursing staffing constraints, can delay ICU or hospital discharge. In institutions lacking the necessary infrastructure to leverage earlier extubation into faster turnover, the theoretical cost savings of ORE might be further diminished.

Conclusion

It has been suggested that routine ORE be pursued "because it's possible"[25] – a sentiment more at home in mountaineering than in medicine, where the ability to act should be matched by a compelling rationale for doing so. While ORE following CPB can be performed safely in carefully selected patients at experienced centers with robust multidisciplinary support, the question is whether it should be adopted routinely. The current evidence comparing ORE to extubation within 6 hours is simply not compelling enough to suggest that it should. The most recent ERAS guidelines advise limiting ORE to highly selected patients undergoing low-risk cardiac surgery.[1] This recommendation was based on low-quality evidence and preceded the publication of two large multicenter database studies that have since raised further safety concerns about the broader application of OR.[10, 11] Attempting to generalize ORE beyond its narrow margin of safety risks eroding its small advantages and, more importantly, endangering patients. By contrast, FTE strikes a more prudent balance between efficiency and safety. Since the vast majority of postoperative cardiac surgery patients are admitted to the ICU for one night anyway, FTE allows for a timely yet controlled reassessment of extubation readiness, supporting recovery without unnecessarily exposing patients to the added risks of extubation in the OR. Rather than pursuing ORE as a blanket strategy, institutions would be better served by directing their efforts toward strengthening ICU-based extubation protocols, thereby preserving patient safety while still advancing the goals of enhanced recovery.

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In OR Extubation After Cardiopulmonary Bypass Surgery: Key Considerations and Evidence

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Introduction

Enhanced Recovery After Surgery (ERAS) pathways aim to optimize perioperative care, minimize complications, and expedite recovery. In cardiac surgery, ERAS principles have evolved from early fast-track extubation protocols to comprehensive programs integrating multidisciplinary strategies. Operating room extubation (ORE), defined as tracheal extubation in the operating room (OR) immediately post-surgery, is a pivotal component of ERAS in cardiopulmonary bypass (CPB) surgery. Historically, prolonged mechanical ventilation was standard due to concerns about hemodynamic instability and respiratory compromise. However, advancements in surgical techniques, anesthesia management, and postoperative care now support ORE as a safe and effective strategy in appropriately selected patients. This paper synthesizes evidence, outlines protocols, and addresses controversies to advocate for ORE in suitable candidates.

Definition: Early Extubation

Extubation time and ICU length of stay are often related to the complexity of the procedure and the patient's medical condition. Early postoperative extubation is defined as extubation within 6 hours after surgery, and it is a Class IIa recommendation (moderate evidence) according to a Joint Consensus Statement by the Enhanced Recovery After Surgery (ERAS) Cardiac Society, ERAS International Society, and The Society of Thoracic Surgeons (STS) for routine low-risk and specific high-risk (i.e., aortic root, ascending aortic repairs) elective cardiac operations.1Its subset- intraoperative and immediate postoperative extubation -is defined as extubation within 1 hour after surgery. The goal for early extubation is to optimize—not avoid or streamline—ICU resources. Implementation of both early and immediate postoperative extubation is feasible and safe. Studies have reported similar reintubation and overall complication rates compared with standard extubation protocols.[2]

The 6-hour benchmark for early extubation after cardiac surgery likely emerged from expert consensus and trends in early studies rather than solid physiologic evidence. Early fast-track studies demonstrated safe extubation within a range of 3 to 9 hours, with 6 hours becoming a middle ground that balanced safety and efficiency. Over time, as more research adopted this cutoff—and with the STS endorsing it as a quality metric—it became a standard, even though it's not rooted in a specific physiologic rationale.

Perceived Benefits of Early/Fast-Track Extubation

The risk-benefit balance of early or fast-track extubation (FTE) after cardiac surgery depends heavily on patient selection, surgical complexity, and institutional expertise. Current evidence suggests that when applied to appropriately selected patients, the benefits of FTE outweigh the risks; however, improper patient selection or a lack of protocol standardization increases the likelihood of adverse outcomes. Below is a synthesis of findings from the provided studies:

Reduced ICU and Hospital Stay:

Multiple studies consistently report shorter ICU and hospital stays with FTE or on-table extubation (ORE).[1,3-8] Cost savings from reduced resource utilization are significant, especially in low-resource settings (Docs 3).[3,5]

Lower Complication Rates:

FTE/ORE is associated with reduced rates of ventilator-associated pneumonia, delirium, and

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opioid-related side effects.[7,9] As for studies on pediatric surgery, lower maternal anxiety and a faster return to feeding.[3,5]

Improved Hemodynamics:
Spontaneous ventilation post-ORE improves pulmonary blood flow in patients with congenital heart disease or single-ventricle physiology.[6,8]

In OR Extubation: The history and development
Ultra-fast track anesthesia—used synonymously with operating room extubation (ORE) in the operating room—refers to intraoperative or immediate postoperative extubation. This approach has gained momentum in cardiac anesthesia recently. The first reports of ORE date back to the 1980s in pediatric cardiac surgery.[10,11] It was observed that certain neonates and infants undergoing low-complexity procedures, such as atrial septal defect closures, could safely tolerate immediate extubation if they were hemodynamically stable. This practice was often driven by physiological considerations rather than logistical ones. In patients with single-ventricle physiology (e.g., post-Fontan procedures), spontaneous ventilation improves pulmonary blood flow. These early experiences laid the groundwork for rethinking the conventional reliance on prolonged postoperative mechanical ventilation. The 2000s saw critical advancements that enabled ORE to transition from anecdotal reports to a feasible strategy. By the 2010s, ORE had gained traction in the field of adult cardiac surgery.[7,10,11]

4.1 ORE Safety and Clinical Outcomes
Volume-Outcome Relationship: Centers performing more than 40% of ORE cases demonstrate comparable mortality and morbidity rates to those of early extubation (within 6 hours), suggesting that institutional experience is a critical factor.[12,13] In contrast, low-volume centers may report marginally higher complications (e.g., reoperation for bleeding, pneumonia), which is likely due to selection bias or suboptimal protocols.[1]

Morbidity and mortality: ORE does not increase mortality or major complications when applied to suitable patients. Avoidance of prolonged ventilation decreases ICU-acquired infections, fluid overload, and ventilator-induced lung injury.[2,3,14,15]

Pediatric Populations: ORE has been safely implemented in 85% of pediatric cases, including neonates and complex congenital repairs, with reintubation rates of 5% and no mortality linked to extubation timing. A multicenter survey involving 42 European centers revealed that 76% of congenital cardiac anesthesiologists practice ORE, primarily for low-complexity cases (Risk Adjustment for Congenital Heart Surgery categories 1–2). Procedures such as atrial septal defect (ASD) and ventricular septal defect (VSD) closures are common candidates.[16-19] Reintubation rates were 5–7.9%, comparable to delayed extubation, with no mortality attributed to ORE timing.[10]

Adult Populations: In minimally invasive valve surgery, ORE reduced ICU stays by 50% (median 7.76 vs 13 hours) without increasing reintubation rates (1.7% vs 7.9%).[8,9] For coronary artery bypass grafting (CABG), ORE was associated with a 1.24-day reduction in hospital stay ($p<0.001$) and lower postoperative glycemic peaks. A registry-based study recently published by Teman and colleagues found that ORE was safe and associated with superior outcomes in coronary artery bypass grafting and valve surgery.[20]

Decrease time for extubation: Transferring patients to the ICU introduces delays due to handoffs, time for new teams to assess physiology, and reliance on admission protocols (e.g., waiting for lab results and the night float team). These steps prolong ventilation time. ORE bypasses ICU hand-offs and allows immediate decision-making by the surgical/anesthesia team familiar with the patient's intraoperative course.[5,21] In addition, in busy ICUs, clinicians prioritize unstable patients, often delaying "simple" tasks like sedation weans or extubation assessments. ORE occurs before sedation is fully weaned, leveraging residual anesthesia for a smooth transition to spontaneous breathing.[7,9,21,22]

Ventilator-Associated Pneumonia (VAP): ORE decreases ventilator exposure, reducing VAP incidence. ERAS protocols incorporating ORE lowered nosocomial infections from 40% to 24%.

Fluid Overload and Delirium: Opioid-sparing regimens and early mobilization in ERAS pathways reduced delirium (6.9% vs. 13.4%) and nausea/vomiting (14.9% vs. 32.8%).12 ORE avoids even brief periods of postoperative mechanical ventilation, which can worsen lung injury caused by cardiopulmonary bypass, blood transfusions, and ischemia-reperfusion. While protective ventilation (low tidal volumes, PEEP) is standard, studies show that just 6 hours of ventilation increases risks such as pneumonia and inflammation.[1,21] ORE eliminates these risks by restoring natural breathing immediately, improving oxygenation and reducing ICU delays that prolong sedation and delirium.[7] By bypassing ICU workflows entirely, ORE preserves lung function better than fast-track protocols, even in low-risk patients.[9]

Improve hemodynamics: Operating room extubation avoids the adverse effects of positive pressure ventilation (PPV) on right ventricular (RV) function. PPV, particularly with PEEP, elevates transpulmonary pressure, which can compress pulmonary microvasculature, increase pulmonary vascular resistance (PVR), and raise RV afterload—a critical concern in patients with preexisting RV dysfunction or pulmonary hypertension.[1,21] By bypassing PPV entirely, ORE preserves RV preload and reduces strain, as demonstrated in studies where ORE patients exhibited lower rates of postoperative RV dysfunction and shorter ICU stays compared to those undergoing delayed extubation.[9] For example, minimally invasive cardiac surgery patients extubated in the operating room had improved hemodynamic stability and reduced need for inotropes, likely due to mitigated RV afterload. These benefits align with ERAS protocols, which recommend early extubation to optimize cardiopulmonary recovery.[7]

Alleviating Perioperative Anxiety: A significant concern for many patients during preoperative anesthesia consultations is not the inherent risks of surgery but the fear of experiencing awareness during tracheal intubation, particularly during periods of minimal or no sedation. While none of the provided studies explicitly address this anxiety, evidence highlights that ORE protocols can mitigate perioperative stress and enhance patient-centered outcomes. For instance, ERAS protocols emphasize reducing sedation exposure and promoting early mobilization, which aligns with patient preferences for minimal sedation and rapid recovery.[7,9] Additionally, studies report high patient satisfaction with early extubation, attributing it to reduced opioid use, faster return to normal activities, and avoidance of prolonged mechanical ventilation.[7,23]

4.2 Identifying suitable candidates for ORE

All patients selected for ORE should undergo an individualized, high-quality, and resource-aware selection process, considering patient comorbidities, the type of surgery, and the patient's clinical status immediately postoperatively. Many institutions that practice early extubation as part of the enhanced recovery after surgery (ERAS) protocol have developed their own protocols that work best in their specific setting. The decision whether to perform ORE should always be based on weighing in risk versus benefit for each patient, taking into account the preoperative, intraoperative, and immediate postoperative factors.[14] Traditionally patients who are hemodynamically stable after cardiopulmonary bypass, with good surgical hemostasis normothermia (core temperature ≥36°C), and lactate <4 mmol/L are considered good candidates for ORE.[4,14,26] While selecting patients, specific preoperative metrics such as Left ventricular ejection fraction (LVEF) >30%, forced expiratory volume in 1 second (FEV1) >70% predicted, and absence of severe pulmonary hypertension are considered favorable for early extubation.[8] Similarly early extubation is commonly preferred in elective surgeries since certain studies have shown a higher reintubation rate following emergent or non-elective surgeries. Among adults, low-risk cardiac surgeries such as CABG, isolated aortic/mitral valve repair/replacement, or minimally invasive surgeries (e.g., thoracoscopic approaches) are deemed suitable.[1,8] For the pediatric population, procedures such as ASD/VSD closures, Glenn procedures, and Fontan completions, which involve changes in physiological processes, are known to benefit from early extubation.[10,24]

4.3 ORE Contraindications

While many patients benefit from early extubation, in some subsets of patients, early extubation is contraindicated. Open sternum, significant residual defects, severe pulmonary hypertension or need for inhaled pulmonary vasodilating agents, hemodynamic instability requiring high-dose inotropes.[3,13]

- Preoperative mechanical ventilation, coagulopathy or ongoing bleeding (>200 mL/h in the first postoperative hour).4 Preoperative mechanical ventilation or severe coagulopathy (INR >1.5).[7]

- Need for advanced circulatory support other than intra-aortic balloon pump (IABP).
- Heart or lung transplant.
- Patients with significant lactic acidosis (lactate >4 mmol/L postadmission or >6 mmol/L with bicarbonate <18 mmol/L).

Relative Contraindications

- Patient factors: older age, chronic obstructive pulmonary disease, severe obstructive sleep apnea (OSA), New York Heart Association functional class IV, preoperative renal failure, lower arterial oxygen tension.[7]

Procedure-related factors: Complex surgeries (e.g., Norwood procedure, aortic arch repairs).[10] Redo surgery, surgical procedures involving the thoracic aorta, intraoperative transfusion of blood products of>10 units, and cardiopulmonary bypass time of>120 minutes, hypothermia.

4.4 ORE Anesthetic and Surgical Protocols

Intraoperative Management

Appropriate intraoperative anesthesia protocols: Limit fentanyl to ≤5 μg/kg combined with neuraxial blocks (e.g., caudal morphine/dexmedetomidine) to reduce sedation delays.[3,25,26] Effective postoperative analgesia is a cornerstone for planning extubation in the OR.[13] Postoperative analgesia in is described by ORE centers as mainly being achieved with multimodal analgesia techniques in the majority of centers practicing ORE including regional anesthesia. Incorporation of multimodal analgesia, including various regional blocks. Studies show that dexmedetomidine with continuous infusion (0.2–0.7 μg/kg/h) reduces opioid requirements and delirium risk.[11] Paravertebral/erector spinae blocks using Ropivacaine 0.5% (20 mL) reduce postoperative pain scores by 50%.Among the various regional anesthesia techniques, local infiltration analgesia is the most commonly performed. Although several authors have described the successful use of neuraxial techniques, including thoracic epidural and caudal anesthesia, in pediatric cardiac surgery with high ORE rates. 27,28 The safety and benefits of these techniques still remain to be established.[29,30] There is study shows that intrathecal morphine using a single bolus (4 μg/kg) provides 12–24 hours of analgesia.[11]

Balanced Anesthesia: Inhalational agents (sevoflurane/isoflurane) with intravenous adjuvants (e.g., dexmedetomidine) are recommended.[24,31] The choice of postoperative sedation agent by OR anesthesiologist has a significant effect on extubation and mechanical ventilation times—dexmedetomidine vs propofol.

Ventilation Strategies: Low Tidal Volume (6–8 mL/kg) ventilation reduces barotrauma and ventilator-induced lung injury.[8] Applying PEEP (5–8 cm H2O) prevents atelectasis without compromising venous return.[13]

CPB Optimization: Miniaturize circuits by reducing the prime volume (≤500 mL) and use modified ultrafiltration to remove inflammatory cytokines and excess fluid, thereby improving hemodynamics.[10] Target a hematocrit of≥25% during bypass.[13,32]

Antiemetics: Effective antiemetic protocols are critical for ORE success, as postoperative nausea and vomiting (PONV) can compromise airway safety and delay recovery. Reports of PONV show frequencies varying between 20% and 70% after cardiac surgery, which is indicative of the multitude of risk factors.[33] Multimodal strategies—combining dexamethasone (4–8 mg IV pre-incision) and 5-HT3 antagonists (e.g., ondansetron 4 mg IV)—reduce PONV risk by targeting multiple pathways.7[9,11] For high-risk patients (e.g., opioid exposure, history of PONV), adding NK1 antagonists (e.g., aprepitant) or low-dose propofol infusions further enhances protection.[21] These protocols align with ERAS principles, which prioritize opioid-sparing analgesia (e.g., regional blocks, acetaminophen) to minimize emetogenic triggers.[7] Studies show that optimized antiemetic regimens in ORE patients correlate with lower reintubation rates (0.8% vs. 2.1% in controls) and faster postoperative mobilization.[9,21] Prophylaxis should be tailored to individual risk factors to ensure smooth emergence and extubation.

Aspiration prevention strategies (head end elevation to 30 degrees): Elevating the head of the bed to 30–45 degrees during emergence and extubation reduces aspiration risk by leveraging gravity to minimize gastroesophageal reflux, particularly in patients with delayed gastric

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emptying (e.g., opioid use, prolonged fasting). This positioning is supported by ERAS guidelines and studies showing that a 30-degree elevation improves respiratory mechanics while maintaining hemodynamic stability.[7,9] In cardiac surgery patients, combining head elevation with rapid-acting neuromuscular reversal agents (e.g., sugammadex) and minimizing excessive positive-pressure ventilation further reduces the risk of regurgitation.[21] For high-risk cases (e.g., obesity, hiatal hernia), adding pre-extubation suctioning and continuous esophageal pH monitoring (where available) enhances safety. Institutions implementing these strategies report lower aspiration-related complications (0.5% vs. 1.8% in non-protocolized cohorts) during ORE.[9,21]

The other issues that can potentially deter anesthesiologists from ORE are impairment of pulmonary function and hypothermia. Impairment of pulmonary function was minimized by removing excess fluid with the aid of conventional and modified ultrafiltration. Hypothermia was avoided by wrapping the patients in a warm blanket, using a cotton pad, and blowing warm air under the drapes.[3]

Postoperative Readiness Criteria:
Hemodynamic Stability: Inotrope score ≤5 (e.g., dobutamine ≤7.5 μg/kg/min).34 Mean arterial pressure (MAP) >65 mmHg without vasopressors (e.g., norepinephrine <0.1 μg/kg/min).[9] Cardiac index ≥2.2 L/min/m^2.[7]

Respiratory Criteria: Spontaneous tidal volume ≥8 mL/kg, PaO_2 >80 mmHg (FiO_2 0.5), and $PaCO_2$ <55 mmHg.[3] Absence of paradoxical breathing or accessory muscle use.4 Spontaneous tidal volume ≥8 mL/kg, PaO2 >80 mmHg (FiO2 0.5), and PaCO2 <55 mmHg.[14] Absence of paradoxical breathing or accessory muscle use.

4.5 ORE Institutional Implementation
Multidisciplinary Collaboration: Consensus among surgeons, anesthesiologists, and intensivists is crucial for standardizing patient selection and managing expectations.[2,3]

Training and Protocols: High-volume centers report success by integrating ORE into fast-track pathways, emphasizing team coordination and contingency planning.[1,3] The evidence shows that OR extubation can be safely employed after cardiac surgery among centers that make programmatic decisions to do so. It is recommended to investigate mechanisms to improve ORE safety at low-volume centres.[12] Implement ERAS Integration protocols, including preoperative Carbohydrate loading (up to 2 hours pre-op) and smoking cessation, postoperative: Early enteral nutrition (within 6 hours) and mobilization (within 12 hours).[11] Checklists, such as standardizing ORE eligibility (e.g., bleeding, hemodynamics) and extubation criteria.[11] Team Training includes simulation drills for extubation failure scenarios (e.g., laryngospasm, hypoxia).

Efficiency Concerns: While 36% of providers cite turnover time as a barrier, structured workflows (e.g., parallel processing) mitigate delays.[13,24]

4.6 ORE Cost-benefit Balance
Historically, the reason for ORE in the developing world has been the lack of resources. Furthermore, the safety of this strategy in developing countries has been consistently shown, for example, in charity missions. Thereafter, ORE began appealing to the developed world as a strategy for reducing costs and improving resource utilization. The cost-benefit balance between faster operating room (OR) turnover (enabling multiple surgeries) and shorter hospital stays depends on institutional priorities, resource availability, and patient complexity.[3,35,36]

Shorter hospital stays save more money than trying to do more surgeries by rushing the operating room. Patients leaving the hospital faster free up beds, especially in crowded hospitals. Example: In India, ORE (waking patients right after surgery) cut ICU stays by half, saving money and beds.[3,5,32,37]

Speeding up OR time lets hospitals do more surgeries daily, but only if they have enough beds and staff. Example: Large hospitals with effective systems can do both—speed up operations and send patients home sooner.7[9,32,37] The extra operating room time is another reason many reject ORE, as it increases costs and slows turnover intervals. However, with growing experience and confidence, this time can be significantly reduced, minimizing its impact on costs and turnover time. The authors spend 5 to 10 minutes extra in the operating room, whereas an interval as short as 2 minutes has been reported by Shinkawa et al.[38]

For most hospitals, focus on shorter stays. Saving $ 3,000–$ 5,000 per patient by reducing ICU time is more beneficial than earning a little extra from performing more surgeries.[10] Simple surgeries (e.g., heart valve fixes) work best for fast OR turnover. Complicated surgeries risk delays and cost more if things go wrong.[5,21]

4.7 ORE Evidence Addressing Controversies

Reoperation for Bleeding: There is no causal link to ORE; it is likely a result of surgical technique rather than extubation timing.[1,22]

Pneumonia: Incidence differences (3% vs 2%) are clinically insignificant and confounded by baseline factors (e.g., COPD).[10]

Resource Constraints: ORE reduces ICU stays by 50% (from 2.6 to 5.4 days) in developing countries, thereby easing ventilator and staffing shortages.[3]

4.8 ORE Future Directions

Research Needs: Randomized trials comparing ORE vs. early extubation in matched cohorts to clarify morbidity risks.[2,22,24]

Protocol Refinement: Standardized extubation criteria and risk stratification tools (e.g., biomarkers, echocardiographic parameters).Harmonize criteria across societies (e.g., ERAS Society, STS).[3]

Conclusion

ORE is a safe, resource-efficient strategy that aligns with ERAS principles. Success hinges on patient selection, opioid-sparing analgesia, and institutional commitment. Future research should refine risk stratification and promote protocol standardization to maximize benefits while minimizing risks.

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