SOCIETY OF CARDIOVASCULAR ANESTHESIOLOGISTS
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SCA NEWS

President's Message

AUGUST 2021

Ensuring Optimal Member Engagement is One of the Most Important Functions of a Professional Society

Andrew Shaw
MB, FCCM, FFICM, FRCA
President, Society of Cardiovascular Anesthesiologists

Over the years, the SCA, with the help of its Member Engagement Committee (MEC) and affiliated committees, has monitored its members' educational and professional needs and has implemented a variety of engagement strategies that have increased our effectiveness as a society. In this message, I provide a brief overview of the structure of our MEC, a history of initiatives from the past several years, and an update on upcoming member engagement improvements.

MEMBER ENGAGEMENT COMMITTEE AND ITS SUBCOMMITTEES

The MEC consists of cardiac anesthesiologists who are in active practice in academic and private settings. These volunteers are at the forefront of our profession and advise the Board of Directors and Veritas Association Management (SCA management company), on trends in practice patterns, digital communication needs, the educational requirements of our members, and their expectations of the SCA.

Four sub-committees related to the MEC assist with specific aspects of member engagement:

- The Newsletter Subcommittee
- The Economics and Governmental Affairs Subcommittee
- The SCA Mobile App Subcommittee
- The SCA Social Media Subcommittee

The first two hardly require an introduction. For many years, the **SCA Newsletter** has been a much-liked tool for information dissemination between the SCA and its members. It publishes the President's message and discusses a variety of topics, including reviews of recent articles in our field and a pro-con section.

continued...

President's Message

Our mobile app is a dynamic product... offering exceptional educational content

The Economics and Governmental Affairs Subcommittee is responsible for the biannual salary survey and updates on economic developments such as capitated payment models, new billing codes relevant to cardiac anesthesia, and session proposals for the annual meetings involving the economics of cardiac anesthesia.

Our Mobile App and Social Media Subcommittees launched in 2021. For many years, SCA members had expressed a desire to utilize mobile devices and social media to spread the message of the SCA and provide targeted online education for both practicing anesthesiologists and trainees (cardiac anesthesia fellows, residents).

It quickly became apparent that mobile apps and social media require specific skills and focus for optimal utilization and design, which spurred the formation of these subcommittees. The volunteers who comprise these groups are passionate individuals who are excellent anesthesiologists and who, through prior experiences, have know-how in those areas. They work tirelessly to help our management company, Veritas, to promulgate content through these channels.

In addition, they interact with other committees and Special Interest Groups, such as the Online Education Subcommittee, the Quality, Safety, and Leadership Committee, and the Women in Cardiothoracic Anesthesia (WICTA) SIG, to produce content suitable for the mobile app and distinct from traditional recorded lectures from the SCA Annual Meeting and Echo Week.

If you haven't already done so, I encourage you to download our mobile app from the **Apple app store** or **Google Play**. Please realize that the app is a dynamic product expected to grow significantly in the coming years regarding the types and amount of educational content offered and design and technology.

Similarly, if you haven't yet added the SCA to your social media contacts, you can do so on **Facebook, Twitter, and Instagram** (click on the links). Both the App and Social Media Subcommittees are open for suggestions, requests, and commentary. The SCA encourages members to interact with the volunteers on the committees and to participate as committee members themselves in the future.

MAJOR RECENT INITIATIVES

Since 2010, the SCA, the MEC, its subcommittees, and ad hoc workgroups convened have participated in two major SCA website re-designs, the creation of the mobile app, the launch of the SCA social media channels, and enhanced interactions with the remaining SCA committees.

The newest version of our website was launched in 2015/2016 and introduced responsive design. It realigns for use on mobile devices and a unified look-and-feel

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across SCA communications. With the transition to our current management company, Veritas Association Management, the SCA further strengthened its technological preparedness by adopting MemberClicks, our current user management system, and a host of other media technologies.

The SCA salary survey expanded in the scope of data gathered and its geographical reach. Numerous educational items have been added to our mobile app since its launch in 2020, which now includes, to mention but a few: 5 targeted fellow mini lectures by leaders in their respective field (aortic valve repair, coagulopathy after bypass, etc.), four videos on regional anesthesia for cardiac surgery, and six educational videos on advanced topics such as professional development, troubleshooting ECMO disasters, and others.

The former nine items represent education accessible for free via the app, whereas the latter 6 require login via the SCA website. Thus, the SCA provides global and targeted education via a mobile app for the first time, some of which are accessible for free to non-members.

UPCOMING MEMBER ENGAGEMENT INITIATIVES

The SCA will continue to design and hold the extraordinary live meetings for which we are known, **Annual Meeting & Workshops, Echo Week, Thoracic Anesthesia Symposium (TAS), and Perioperative Ultrasound Course Hands-On Workshop.**

We will continue to grow our online content and distribute it via our website and mobile app. We will streamline our use of social media to better communicate with our members. In response to requests by many of our constituents, we are about to introduce an online community and discussion forum for members in partnership with DocMatter.

The SCA DocMatter forum will be accessible via the website and mobile app. It will provide opportunities for person-to-person or group exchange of professional and scientific information in the fields of cardiac, thoracic, and vascular anesthesia. The SCA DocMatter online community will provide unique professional profiles for our members that are automatically generated, then verified by staff and the members themselves, which will enhance collaboration and our ability to promote our specific areas of expertise and professional interests.

Finally, we continue to explore options for providing CME credits as part of our online educational offerings. After engaging with online content of appropriate duration, e.g., via our Newsletter literature reviews, and upon responding to any post-educational surveys or tests and providing the proper activity evaluation, our goal is to be able to award CME credits commensurate with the duration of such activities.

Regards,

Andrew Shaw

MARK YOUR CALENDARS

PoCUS is Back!

We are thrilled to announce the return of the hands-on portion of the Perioperative Ultrasound Course at the SCA's Echo Week in 2022. Before this live workshop, participants in this course will have access to online modules via the iTeachU app covering basic echocardiography and point-of-care ultrasound of the lungs, abdomen, blood vessels, and nerves. Participants who complete both the online iTeachU modules and the hands-on workshop at Echo Week can later submit a case log of studies to receive a program completion certificate.

The course faculty for the workshop is comprised of anesthesiologists all of whom share an enthusiasm for teaching echocardiography and point-of-care ultrasound. To guarantee all participants have sufficient time for hands-on learning, the instructor to student ratio is maintained at 1:4 and each station length is 30 minutes.

Rotate through stations and practice imaging on live models

Participants will rotate through the following stations and practice imaging on live models:

- Vascular Access: Arterial & Venous Anatomy
- Gastric Ultrasound
- Abdominal Ultrasound
- Lung Ultrasound
- Lower Extremity Venous Ultrasound
- TTE: Parasternal Views
- TTE: Subcostal Views
- TTE: Apical Views
- TTE: Cardiac Exam Sequence
- Rescue PoCUS

This is a fantastic opportunity for any anesthesiologist who is eager to implement basic echocardiography and point-of-care ultrasound into their practice. The workshop focuses on the practical application of point-of-care ultrasound and can be useful to anesthesiologists in private practice or in the academic setting. Each station provides an opportunity to practice scanning and to receive feedback on how to improve one's technique. Also, the workshop includes a high yield presentation highlighting commonly encountered abnormal findings that can be identified with basic echocardiography and point-of-care ultrasound.

As the program chairs for the Perioperative Ultrasound Course, we look forward to providing you a constructive opportunity to continue building and improving your ultrasound skills so that you can utilize this important clinical tool as you care for your patients.

We hope to see you in Atlanta.

Loews Hotel
1065 Peachtree Street NE
Atlanta, GA 30309

Registration opening soon!

SCA website will be updated as more information becomes available

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DON'T
MISS OUT

ECHO WEEK

FEBRUARY 18-20
ATLANTA, GEORGIA

Make Plans to Attend 2022 Echo Week!

We are thrilled to announce the return of the flagship perioperative echocardiography conference of the Society of Cardiovascular Anesthesiologists (SCA), in an in-person abbreviated format as the SCA ECHO WEEK, February 18- 20, 2022 in Atlanta, GA.

This three-day conference will feature multidisciplinary panels on the role of echocardiography in surgical decision making in valvular disease and mechanical circulatory support, clinical dilemmas uniquely encountered in the operating room that may alter the surgical plan, and structural heart disease transcatheter procedures. These events will be recorded for durable content accessible to registrants after the live meeting.

We are planning on several in-person only, deep-dive sessions on acquisition and postprocessing using advanced echocardiographic techniques (3D echocardiography and strain), congenital disease using 3D heart models, and heart dissections geared towards a better understanding of echo-anatomic correlation in transcatheter procedures and surgical interventions. Finally, we will highlight emerging cutting-edge technologies, which will bring the operating room and the catheterization laboratory into the future.

Registrants to this event will also have access to our on-demand Echo Core Series, several lectures focused on reviewing fundamental echocardiographic concepts in physics, valvular disease, ventricular function evaluation, mechanical circulatory support, and transcatheter procedures.

Beyond the amazing educational content, we hope that our conference will once again bring together lifelong learners, and we are looking forward to making new friends and reconnecting with old friends.

We hope to see you in Atlanta.

Loews Hotel
1065 Peachtree Street NE
Atlanta, GA 30309

Registration opening soon!

SCA website will be updated as more information becomes available.

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Join SCA in Palm Springs, CA for the 2022 Annual Meeting

The Scientific Program Committee is so excited to gather in person at the SCA 44th Annual Meeting and Workshops in beautiful Palm Springs, California. After a challenging year in medicine, we look forward to coming together and networking with you.

The SCA Annual Meeting and Workshops will update you on the latest cardiothoracic anesthesia information through fantastic plenary sessions, controversial panel discussions, pro-con debates, hands-on workshops, mentoring sessions, and problem-based learning sessions.

Come and learn from abstract presentations, the always popular Super Echo Panel and legendary Echo Jeopardy, and a special session from the experts on the new Cardiothoracic Anesthesiology Certification exam.

Plan to hear on hot topics such as updates in coagulation, what's new in mechanical support, and professional development topics such as leadership and mentorship.

While we were glad to 'see' so many of you virtually in 2021, we are thrilled to welcome you to Palm Springs in 2022!

Start making your plans today to join us for the 2022 Annual Meeting!

Renaissance Palm Springs Hotel
888 Tahquitz Canyon Way
Palm Springs, CA 92262

Hyatt Palm Springs
285 North Palm Canyon Drive
Palm Springs, CA 92262

Hilton Palm Springs Resort
400 E. Tahquitz Canyon Way
Palm Springs, CA 92262

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SCA 2022

Submit your Scientific Abstract or Complex Case

Submit an Abstract for the Annual Meeting!

Get ready to submit your scientific abstract or complex case to be considered for presentation at the 2022 Annual Meeting & Workshops!

Submissions will be accepted for the following calls:

- Scientific Program
- Fellow and Resident Complex Cases
- Super Echo

Call Opens: **November 1, 2021** ***Call Closes:*** **December 10, 2021**

SCA website will be updated as more information becomes available.

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SAVE THE DATE FOR 2022 TAS

THORACIC ANESTHESIA SYMPOSIUM

Join us for a day of lectures, workshops, and mentoring

TAS in 2022!

The TAS Planning Committee is looking forward to seeing you in sunny Palm Springs, CA, for the 10th Anniversary Thoracic Anesthesia Symposium.

May 2022 marks an important date in the history of the Thoracic Anesthesia Symposium, and we are thrilled to share this milestone with all of you. During the past two years, the COVID pandemic and its aftermaths have posed challenges both at work and at home, forcing us to adapt and create a new "normal." The virtual format has taken over our practice and lifestyle because we may have forgotten what traveling and in person activities look like.

May 13, 2022, will mark the start of a new "old routine"; we are planning to see each other in person for a time of learning and networking, seeing old friends and making new ones, and celebrating the 10th anniversary of TAS.

Please join us in sunny California for a day of lectures, workshops, and mentoring through both PBLDs and resident/fellow sessions. Join us for a town hall discussion on anything you may want to explore or share with our panel of experts or with your colleagues.

Be sure to support and encourage our fellows and residents at the abstract/poster stations and during the "best case" and "best research" sessions.

We hope to see you in person, full of energy and enthusiasm for a great in-person event. Come, participate, evaluate, and give us your candid feedback. We are excited to offer you updates, controversies, and new practices in the field of thoracic anesthesia. You are the foundation for the success of this day. Without you, we could not reach this 10th anniversary, but we will continue to grow and advance the field with you.

Thanks to your ongoing interest, participation, constructive feedback, and passion for thoracic anesthesia, the Thoracic Anesthesia Symposium has grown to be ten years old!

TAS Abstracts – Here's Your Chance to Present

You are invited to submit a scientific abstract or complex case for consideration for the 2022 Thoracic Anesthesia Symposium!

Call opens: November 1, 2021
Call Closes: December 10, 2021

SCA website will be updated as more information becomes available.

We are looking forward to meeting you all in California.

Renaissance Palm Springs Hotel
888 Tahquitz Canyon Way
Palm Springs, CA 92262

Hyatt Palm Springs
285 North Palm Canyon Drive
Palm Springs, CA 92262

Hilton Palm Springs Resort
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SCA NEWS

ASA/SCA Joint Congratulatory Letter on Approval of ABA's ACA Examination

The American Society of Anesthesiologists (ASA) and the Society of Cardiovascular Anesthesiologists (SCA) congratulate the American Board of Anesthesiology (ABA) on the recent approval of a subspecialty certificate in Adult Cardiac Anesthesiology (ACA) by the American Board of Medical Specialties (ABMS).

SCA has documented a decade-long rise in demand for specialized cardiac anesthesiology care in the U.S., due to a growing prevalence of disease (48 percent in adults 20 years of age and older), and the growth of technological advancements enabling care.

With this rise in demand for specialized adult cardiac anesthesiology care in the U.S., the ACA subspecialty certification is timely and relevant.

"This is indeed a great day for everyone involved in cardiac anesthesiology – either as a provider or as a patient," said SCA President, Andrew D. Shaw, MB, FCCM, FFICM, FRC.

According to the ABA, physicians with an ACA subspecialty certification will be acknowledged as experts in the imaging, diagnosis, physiology, pharmacology and management of care for adults whose cardiac disease requires leading-edge techniques, interventions and the latest treatment technology.

"Patients will be confident they are getting the very best, expert anesthesiology care at critical times", said ASA president, Beverly K. Philip, MD, FACA, FASA.

The ASA and SCA congratulate ABA and look forward to a continued partnership that will elevate the specialty of anesthesia.

OPENING SOON!

2022 Call for Nominations Opening Soon!

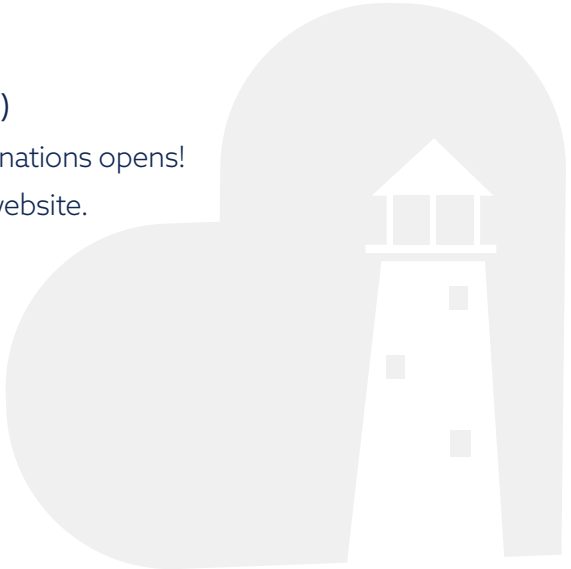
If you're considering running for an SCA leadership position, now is your chance to apply!

The SCA seeks nominations for the following positions:

- Director-at-Large (2 openings)
- Early Career Member (2 openings)
- CME Committee Member (1 opening)

Watch your email for when the Call for Nominations opens!

Information will also be posted on the SCA website.



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SCA NEWS

Seeking ABA question writers

Apply to Join ABA's Exam Writing Committee

Write Questions for the ABA's Adult Cardiac Anesthesiology Assessments

The American Board of Anesthesiology (ABA) is seeking question writers to develop items for its new Adult Cardiac Anesthesiology (ACA) Exam and Adult Cardiac Anesthesiology MOCA Minute. The ACA Exam is expected to launch in 2023, and the ACA MOCA Minute questions will be distributed the following year to diplomates certified in the subspecialty.

Writers will be responsible for preparing multiple-choice questions from assigned content areas and will be paired with experienced question editors who will provide guidance and feedback. To be eligible to apply, you must:

- Have valid, unexpired certification in anesthesiology
- Not participate in activities that may constitute a conflict of interest, such as exam review courses for which a fee is charged

Additionally, all applicants who are selected as question authors must be "Participating in MOCA" during their entire service term as an ABA volunteer.

What You'll Need to Apply

Submit an online application to provide two original assessment questions, demographic information and details on why you'd like to volunteer. If you are applying to write questions for both the ACA Exam and MOCA Minute, you'll submit one sample question for each area.

You must complete the application all at once, so please use this checklist of items you'll need and question development tips.

See the **Checklist & Question Tips**

Collect the Checklist Items & Apply by Aug. 31. Once you've collected the items on the checklist and created your questions, click on the link below to submit your application.

Submit Your Application

The ABA will notify applicants who have been selected as new question writers by Nov. 1. All new writers should attend an item-writing workshop on Jan. 27, 2022. A second workshop will be held June 15, 2022, for anyone who cannot participate in January.

If you have questions, please contact ABA Director of Assessment Development & Delivery, Anna Menzies at anna.menzies@theaba.org or (919) 745-2243.

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WICTA Professional Development Mentoring Program Webinars

The purpose of this program is to foster essential skills and competencies crucial to career development in early and mid-career women and underrepresented minorities in cardiothoracic anesthesiology.

This includes essential knowledge in clinical research, public speaking, leadership, networking, and mentorship.

At the end of this program, participants will be able to:

- Assess and recognize their personal opportunities for professional skill growth.
- Apply leadership fundamentals to their personal careers and advance their professional development.

To register for this FREE webinar, click here.

Register for FREE WICTA webinars!

Session: Grant Writing

DATE: SEPTEMBER 22, 2021
TIME: 4:00 PM PT, 6:00 PM CT, 7:00 PM ET

- *Explore commonalities shared by successful grants*
- *Explore how to search for grants*

Jochen (Danny) Muehlschlegel MD, MMSC, FAHA
Brigham and Women's Hospital, Harvard Medical School

Joint Statement on COVID-19 Vaccination of Health Care Personnel

A Message from ASA President Dr. Beverly K. Philip

ASA, in conjunction with the American Society of Regional Anesthesia and Pain Medicine, Anesthesia Patient Safety Foundation, Society of Academic Associations of Anesthesiology & Perioperative Medicine, Society for Ambulatory Anesthesia, Society of Cardiovascular Anesthesiologists, Society of Critical Care Anesthesiologists, Society for Education in Anesthesia, Society for Neuroscience in Anesthesiology and Critical Care, Society for Obstetric Anesthesia and Perinatology, and the Society for Pediatric Anesthesia, has issued the following statement strongly encouraging all health care personnel to get vaccinated against COVID-19:

Joint Statement on COVID-19 Vaccination of Health Care Personnel

The leadership of the American Society of Anesthesiologists and professional societies associated with the specialty offer our support and strong encouragement for COVID-19 vaccination of the nation's health care workers and all eligible Americans.

The health and safety of our members, our colleagues in health care, and the patients we serve is our highest priority. We believe widespread vaccination is the most effective path to reduce illness and death, and to ameliorate the impact of the pandemic.

COVID-19 vaccines have been shown to be safe and effective at significantly reducing the risk of becoming infected, spreading the infection to others, and becoming severely ill or dying from the disease. For health care personnel, COVID-19 vaccination is particularly essential because it significantly reduces the likelihood of unintentionally spreading COVID-19 to our patients, including those who may have weakened immune systems.

We believe anesthesiologists and anesthesiology professionals who work closely with patients in operating rooms and procedural areas, in hospitals and ambulatory settings, and in critical care units should be especially vested in closing the vaccination gap. We stand with all of our medical colleagues to strongly promote these efforts.

You can access the **Joint Statement on COVID-19 Vaccination of Health Care Personnel** and an accompanying **press release** on the ASA website.

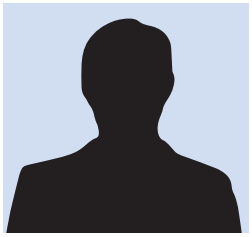
MEMBER CORNER

Update Your Member Profile

Please take a few minutes to update your profile. By updating member profile, it helps keeps the SCA Member Directory up to date.

Update Profile Here

If you have any questions or need any assistance updating your profile, please contact SCA Member Representative, Nikki Mackall at nikki@veritasamc.com.



Renew Your Membership Today!

You're a valued member of the SCA community.

Don't miss out! Continue receiving your SCA benefits uninterrupted by renewing today.

Renew Online – You can login to your membership account to pay your dues online with the option to enroll in auto renew.

If you have any questions about your membership or the renewal process, **please contact Nikki Mackall at 855.658.2828 or nikki@veritasamc.com.**

Subscribe to JCVA at discounted rates

JCVA Discounted Rates for Members

All SCA members are eligible to subscribe to the Journal of Cardiothoracic and Vascular Anesthesia (Red Journal) at discounted rates. JCVA is primarily aimed at anesthesiologists who deal with patients undergoing cardiac, thoracic, with contributions from cardiac, vascular, and thoracic surgeons; cardiologists; and other related specialists.

Interested in purchasing a subscription? **Click Here** for more details on the journal and to take advantage of the SCA member rates!

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THORACIC CORNER

Implementation and Outcomes of a Mobile Extracorporeal Membrane Oxygenation Program in the United States During the Coronavirus Disease 2019 Pandemic

Odish M, Yi C, Chicotka S, et al. Journal of Cardiothoracic and Vascular Anesthesia 00 (2021) 1-6.

Reviewers:

Ashley Virginia Fritz, DO[1]
Archer Kilbourne Martin, MD[1]
[1]Division of Cardiovascular and Thoracic Anesthesiology
Mayo Clinic College of Medicine, Jacksonville, Florida

Background

Extracorporeal membrane oxygenation (ECMO) was first used for long-term support for severe respiratory failure in a post-traumatic patient in 1972.[1] ECMO technology and the clinical indications have developed significantly, especially as use in adults increased during the 2009 H1N1 influenza pandemic.[2,3]

As the coronavirus disease 2019 (COVID-19) pandemic emerged in the United States in March of 2020, initial reports of ECMO support mortality were high.[4] Due to the potential overwhelming of medical resources in the United States secondary to COVID-19, the need to maximize resources and expand access to quality care became imperative. Odish et al. describes the implementation of a mobile ECMO team in April 2020 to care for patients with COVID-19 respiratory failure and limited access to care.

Methods

The authors describe a single center experience of implementing a mobile ECMO team from April 2020 to January 2021. The ECMO team consisted of three (3) primary members: a cardiothoracic (CT) surgeon, a perfusionist, and a third member which was either a CT surgery fellow, intensivist, or advanced practice provider. To enhance safety, the team performed high-fidelity training utilizing actual transport vehicles, equipment, and PPE to simulate patient transfers. Once consulted, the team was mobilized and prepared to depart for the patient's destination within 90 minutes.

The patients in this experience all received veno-venous ECMO with dual cannulation at the femoral and internal jugular vein sites utilizing a 25-29 french multistage cannula. In order to minimize the risk of guidewire kinking during cannulation, an Amplatz super-stiff wire was used. Cannulation and ECMO initiation took place at the intensive care unit (ICU) bedside with confirmation of placement confirmed by bedside chest x-ray. ECMO oxygenation, sweep gas flow, and ventilatory settings were then titrated to maintain oxygen saturation >94% and normal pH (7.35-7.45). Patient transfers occurred by fixed-wing air, helicopter, and ground ambulance to admitting hospital. The furthest transport occurred from a hospital 136 miles away from the receiving ECMO center. In order to provide a comprehensive evaluation to all mobile ECMO patients, patients underwent CT of the head, chest, abdomen, and pelvis within 24 hours of arrival to the author's institution.

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Results

The authors reported that during the ten months between April 2020 to January 2021 the mobile ECMO team was activated 22 times to 13 different facilities located in southern California. Of the patients who were accepted for mobile ECMO, 21 had a diagnosis of COVID-19 and 1 was diagnosed with vaping associated lung injury. 11 of the 21 patients (52.4%) with COVID-19 and the one patient with vaping lung injury survived to hospital discharge. The authors note that 4 of the patients were diagnosed with intracerebral hemorrhages after undergoing admission CT scan. Two of these patients expired within 48 hours. Survival to discharge of in-house ECMO cannulated patients with COVID-19 was 45.2%. The authors reported no significant patient complications or COVID-19 exposure to the mobile ECMO team.

Discussion

This paper highlights the process, outcomes, and utility of a mobile ECMO team to serve the respiratory failure patients during the COVID-19 pandemic. In a recent ELSO (Extracorporeal Life Support Organization) registry study of 213 hospitals in 36 countries, the mortality was reported as 39% in 968 COVID-19 patients.[4] The authors reported a mortality rate of 47.6%, with no significant patient complications or team exposures. Previous mobile ECMO teams had reported complications in up to 21% of cannulations, a contributing factor was kinking of the guidewire.[3] Odish et al. credited their results to the presence of experienced team members, familiar PPE, the use of stiff guide wire, and frequent high-fidelity team training. As the COVID-19 pandemic continues with the evolution of highly transmissible variants, it is crucial for methods to increase access to life saving care be developed. Further investigation is warranted into the development and utilization of mobile ECMO teams in expanding access to care in COVID-19 patients.

References

1. Makdisi G, Wang IW. Extra Corporeal Membrane Oxygenation (ECMO) review of a lifesaving technology. *J Thorac Dis* 2015;7:E166-76.
2. Martin AK, Jayaraman AL, Nabzdyk CG, et al. Extracorporeal Membrane Oxygenation in Lung Transplantation: Analysis of Techniques and Outcomes. *J Cardiothorac Vasc Anesth* 2021;35:644-61.
3. Odish MF, Yi C, Chicotka S, et al. Implementation and Outcomes of a Mobile Extracorporeal Membrane Oxygenation Program in the United States During the Coronavirus Disease 2019 Pandemic. *J Cardiothorac Vasc Anesth* 2021.
4. Barbaro RP, MacLaren G, Boonstra PS, et al. Extracorporeal membrane oxygenation support in COVID-19: an international cohort study of the Extracorporeal Life Support Organization registry. *Lancet* 2020;396:1071-8.

LITERATURE REVIEWS

Long-term Clinical and Echocardiographic Outcomes in Young and Middle-aged Adults Undergoing the Ross Procedure

Romeo J, Papageorgiou G, da Costa F, et al. JAMA Cardiol. 2021;6(5):539-548

Reviewer:
Jared Feinman, MD, FASE
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Background

Younger patients with aortic valve disease face limited options for surgical replacement. Bioprosthetic valves have a limited lifespan requiring re-operation at a later date, while mechanical valves commit an individual to lifelong anticoagulation. An alternative to these two options is the Ross procedure. The Ross procedure, also known as a pulmonary autograft, consists of replacing the diseased aortic valve with the patient's own pulmonic valve, which is itself then replaced using a cadaveric homograft. Despite evidence that the Ross procedure may be superior to traditional valve replacement, with no reduction in life expectancy when compared to an age- and sex-matched general population, it remains an underutilized operation, generally confined to a small number of experienced centers.[1,2]

The failure to widely adopt the Ross procedure is partially related to the technical complexity of the surgery when compared to a traditional aortic valve replacement, and also to concerns about early mortality and the need for late reintervention in some older studies.[3,4] As a result, the most recent ACC/AHA guidelines only recommend considering a Ross procedure in young patients who have a contraindication to anticoagulation, despite accumulating evidence that the Ross procedure offers a clear benefit in both young and middle-aged patients with aortic valve disease.[5,6]

This study presents the clinical and echocardiographic outcomes in Ross procedure patients between the ages of 18 and 65 from five high-volume centers in Brazil, Australia, Canada, Germany, and Belgium.

Methods

The authors examined all Ross procedures performed on patients ages 18 to 65 between January 1991 and December 2018 at the five aforementioned centers. Any patient who had emergent surgery, concomitant mitral valve surgery, or aortic dissection was excluded from the analysis, leaving 1431 patients who were included in the final analysis. Late all-cause mortality was defined as occurring >30 days after the Ross procedure, and reintervention was defined as reintervention on either the homograft or the autograft after the initial procedure. All echocardiographic data was obtained using a transthoracic exam with multiple views and graded as per standardized guidelines.

Results

The median age of operation of patients included in the study was 48.5 years, and 76.1% of patients with a known valve morphology had a bicuspid aortic valve.

Men also made up the majority of study patients (74.3%). Study participants were followed for an average of 9.2 years post-Ross procedure. Ten patients out of the 1431 included in the study suffered in-hospital mortality (0.7%), while autograft endocarditis occurred in 14 patients and homograft endocarditis in 11 patients. Overall survival following Ross procedure after 10 years was 95.1% (95%CI, 93.8%-96.5%), and after 15 years was 88.5% (95% CI, 85.9%-91.1%). Freedom from cardiac mortality was also quite high, at 98.6% (95%CI, 97.9%-99.4%) and 96.5% (95% CI, 95.0%-98.0%) at 10 and 15 years, respectively. An increased risk of late mortality was found in patients with a higher age at operation, peripheral vascular disease, chronic obstructive pulmonary disease, congenital heart disease, and congestive heart failure.

Freedom from any reintervention was 93.9% (95%CI, 92.4%-95.5%) and 90.8% (95%CI, 88.6%-93.1%) at 10 and 15 years, respectively, while freedom from autograft reintervention was slightly higher at 95.0% (95% CI, 93.6%-96.4%) and 92.0% (95% CI, 89.8%-94.2%). Severe preoperative aortic regurgitation was found to be a risk factor for the need for autograft reintervention, while a lower NYHA functional status, female sex, and the subcoronary implantation technique were found to be protective. Risk factors for homograft reintervention included both younger age of the homograft donor and a smaller homograft diameter.

Development of moderate or severe aortic regurgitation following the Ross procedure was uncommon, with a predictive prevalence of less than 1% after 20 years. Postoperative autograft gradients also remained low, with an average peak gradient of less than 20 mmHg at 20 years. The homograft gradients followed a regular pattern postoperatively, rising over the first decade after which the gradients would decline and plateau, with an average peak gradient of around 30 mmHg at 20 years.

Discussion

The results from this study show that the Ross procedure offers a safe alternative to traditional valve replacement surgery in both young and middle-aged patients, with a low risk of need for reintervention and stable valve performance profiles out to 20 years. Thus, it may offer advantages to the 25% of aortic valve replacement patients who are operated on before age 60, the majority of whom currently receive mechanical valves. While a previous analysis of the Society of Thoracic Surgeons Adult Cardiac Surgery database suggested a 3-fold increased operative mortality (2.7% vs 0.9%) compared with conventional mechanical AVR, much of this risk could be explained by higher mortality at inexperienced and low-volume centers, and subsequent studies examining high-volume Ross centers have found a similar operative mortality rate to mechanical AVR.[7,8] Indeed, a study by Skillington, et al. found superior survival at 20 years of Ross patients vs a matched mechanical valve replacement cohort (94% vs 84%).[9] The superiority of the Ross procedure when compared to mechanical AVR and its ability to maintain a life expectancy comparable to the general population was confirmed again in a 2014 Austrian study by Andreas, et al.[10]

Despite the fact that many in the past voiced concerns about the durability of the Ross procedure, the rate of reintervention on both the autograft and homograft were low in this study, and were comparable to those seen in other large, contemporary Ross series. Reintervention rates following the Ross procedure are superior to those of both bioprosthetic and homograft aortic

valve replacement, and similar to those seen in mechanical valve replacement. The most common reasons for autograft failure in Ross patients are dilation at the sinus, annulus, or sinotubular junction, but careful patient screening with preoperative echocardiography and computed tomography angiography as well as tight blood pressure control in the postoperative period can help limit the risk of autograft dilation. The increasing options for transcatheter pulmonic valve interventions will also help reduce the need for open redo surgery in the limited incidences of homograft failure.

The major limitation of this study is that it involved experienced surgeons in high-volume Ross procedure centers, so the results may not be widely applicable to less experienced centers. In addition, any differences in technique between the surgeons was not accounted for, and the Canadian population had limited follow-up when compared to the other centers. Finally, the careful preoperative selection process may have contributed a survival benefit beyond what would be expected from the freedom from anticoagulation and excellent valve hemodynamic profiles of the Ross procedure alone.

References

1. El-Hamamsy I, Eryigit Z, Stevens LM, et al. Long-term outcomes after autograft versus homograft aortic root replacement in adults with aortic valve disease: a randomised controlled trial. *Lancet*. 2010;376(9740):524-531.
2. David TE, David C,Woo A, Manlhiot C. The Ross procedure: outcomes at 20 years. *J Thorac Cardiovasc Surg*. 2014;147(1):85-93.
3. Stulak JM, Burkhart HM, Sundt TM III, et al. Spectrum and outcome of reoperations after the Ross procedure. Circulation. 2010;122(12):1153-1158.
4. Luciani GB, Favaro A, Casali G, Santini F, Mazzucco A. Reoperations for aortic aneurysm after the Ross procedure. *J Heart Valve Dis*. 2005; 14(6):766-772.
5. Etnel JRG, Grashuis P, Huygens SA, et al. The Ross procedure: a systematic review, meta-analysis, and microsimulation. *Circ Cardiovasc Qual Outcomes*. 2018;11(12):e004748.
6. Mazine A, El-Hamamsy I, Verma S, et al. Ross procedure in adults for cardiologists and cardiac surgeons: JACC state-of-the-art review. *J AmColl Cardiol*. 2018;72(22):2761-2777.
7. Reece TB,Welke KF, O'Brien S, Grau-Sepulveda MV, Grover FL, Gammie JS. Rethinking the ross procedure in adults. *Ann Thorac Surg*. 2014;97(1): 175-181.
8. Hughes GC, Zhao Y, Rankin JS, et al. Effects of institutional volumes on operative outcomes for aortic root replacement in North America. *J Thorac Cardiovasc Surg*. 2013;145(1):166-170.
9. Skillington PD, Mokhles MM, Takkenberg JJ, et al. The Ross procedure using autologous support of the pulmonary autograft: techniques and late results. *J Thorac Cardiovasc Surg*. 2015;149(2) (suppl):S46-S52.
10. Andreas M, Wiedemann D, Seebacher G, et al. The Ross procedure offers excellent survival compared with mechanical aortic valve replacement in a real-world setting. Eur *J Cardiothorac Surg*. 2014;46(3): 409-413.

Echocardiographic Predictors of Successful Extracorporeal Membrane Oxygenation Weaning After Refractory Cardiogenic Shock

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Background

Veno-Arterial Extracorporeal Membrane Oxygenation (VA-ECMO) is a temporary mechanical circulatory support device that can be used to rescue patients with severe cardiogenic shock. The decision about the timing of discontinuation of ECMO remains subjective due to the lack of clear guidelines and limited data on markers of successful weaning from ECMO. This present study by Kim et al investigated whether transthoracic echocardiographic (TTE) measures could be used to predict successful weaning from ECMO.[1]

Methods

This study was a multicenter prospective observational study of patients weaning off VA-ECMO placed due to cardiogenic shock. The decision to wean off VA- ECMO was made for patients with a mean arterial pressure (MAP) of > 60mmHG with no or low dose vasopressors and no evidence of compromise of pulmonary blood oxygenation while ECMO flow was 100%. VA-ECMO flow was weaned to 30-50% of initial flow for 15 minutes. TTE was performed at baseline ECMO flow (100%) and after 15 minutes of flow reduction between 30-50% (ECMO flow study). The following parameters were measured on TTE:

- Left ventricular ejection fraction (LVEF) using modified Simpson's disc
- Transmitral flow velocities using pulse wave Doppler (PWD); E velocity
- Tissue Doppler Imaging (TDI; S' e' a') of lateral mitral annulus
- Left ventricular outflow tract (LVOT) velocity time integral (VTI) using PWD
- Right ventricular fractional area change (RVFAC)
- Tricuspid annular plane systolic excursion (TAPSE)
- Tricuspid S' using TDI

The patients were divided into two groups: successful weaning group (no further mechanical support in the next 30 days) and failed weaning group (death on ECMO, bridge to heart transplant or ventricular assist device (VAD)). A separate data set from a prospective ECMO registry was used to validate the new echocardiographic criteria.

An additional analysis compared previously described echocardiographic predictors in the same patient population (Aissaoui 2011):

- Left ventricular ejection fraction (LVEF) >20-25%
- Aortic VTI > 10cm
- TDI; S' of lateral mitral annulus > 6 cm/s

Statistical significance was considered for $p < 0.0125$.

Results

A total of 92 patients were analyzed in this study, out of which 64 patients (Group A; 69.5%) were successfully weaned off ECMO, while of the remaining 28 (Group B), 5 received an LVAD, 19 received a heart transplant, and 4 died.

There was no difference in echocardiographic parameters between the two groups at baseline ECMO flow 100%. During the ECMO flow study significant differences between groups A and B were noted after weaning. In group A the LVEF, lateral e′ velocity, LVOT VTI, TV annular S′, and RV FAC increased upon ECMO weaning. In group B, upon ECMO weaning, the LVEF and RVFAC did not change. By contrast, for group B patients, the lateral e′ velocity and tricuspid S′ velocity declined significantly, while the mitral E/e′ increased.

Table 2 Hemodynamic and Doppler echocardiography characteristics

Variables	Successful weaning (n = 64)		Failed weaning (n = 28)	
	100% ECMO flow	30%–50% ECMO flow	100% ECMO flow	30%–50% ECMO flow
LV end-diastolic dimension, mm	51.5 ± 11.0	51.8 ± 10.1	54.1 ± 11.1	54.0 ± 11.0
LV end-systolic dimension, mm	42.0 ± 12.0	41.2 ± 11.6	44.1 ± 12.0	42.5 ± 13.1
LVEF, %	25.3 ± 15.8	32.3 ± 12.8*	26.3 ± 14.4	28.3 ± 14.4
Transmitral E velocity m/sec	0.56 ± 0.44	0.74 ± 0.44	0.76 ± 0.20	0.84 ± 0.20
Lateral e′ velocity, cm/sec	4.92 ± 2.37	6.06 ± 3.05*	6.19 ± 2.89	5.29 ± 2.84†
E/lateral e′	12.7 ± 12.4	12.5 ± 10.1	14.6 ± 7.6	19.2 ± 10.3*
LVOT VTI, cm	8.4 ± 4.6	10.8 ± 4.1*	7.9 ± 4.6	9.4 ± 4.6
TAPSE, mm	9.8 ± 5.9	11.5 ± 5.8	10.3 ± 4.8	9.6 ± 5.2
Tricuspid annular S′ velocity, m/sec	7.2 ± 3.6	8.9 ± 3.9*	7.0 ± 3.6	6.4 ± 2.7†
RV FAC	30.5 ± 11.5	35.3 ± 11.2*	30.9 ± 9.9	30.1 ± 10.9
RV systolic pressure, mm Hg	26.8 ± 15.7	31.1 ± 16.7	31.5 ± 15.4	30.9 ± 18.0

*$P < .0125$ when compared with parameters at ECMO flow 100%.
†$P < .0125$ when compared with successful weaning group.

ROC analysis and multivariate analysis showed that any increase in lateral e′, and > 10% increase in tricuspid S′ during the ECMO flow study test were independently associated with successful weaning from ECMO

When previously described predictors[2] were applied to the present patient group, only 16% of group A and 30% of group B would have been accurately predicted. Previous predictors would not have differentiated between groups A and B.

When both older[2] and newer[1] criteria were validated, the newer criteria were better predictors of outcome.

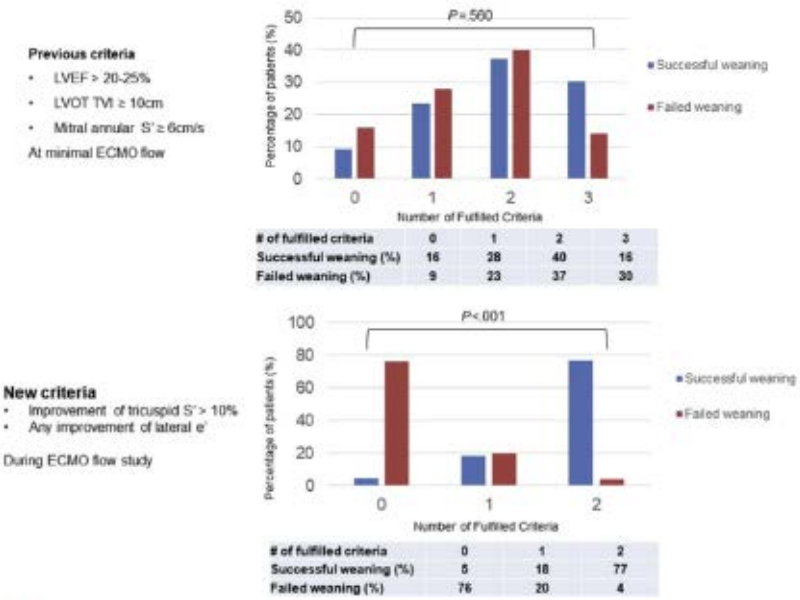

Figure 3 Percentage of patients fulfilling conventional weaning criteria vs suggested new criteria.

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Discussion

In the present study, during ECMO weaning (100% ECMO flow to 30-50% reduction in ECMO flow) any improvement in TDI of lateral mitral annular e' and/or >10% improvement in TDI tricuspid S' velocity was associated with successful weaning from VA-ECMO. When compared to prior weaning predictors, those of the present study were superior.[1,2]

A smaller study published in 2015, improved left heart functions/parameters (LVEF, Aortic VTI, TDI S' lateral mitral annulus) were associated with successful ECMO weaning.[2] Right heart functions were not assessed.[2] In 2015 Pappalardo et al studied 42 patients who weaned from VA ECMO, and compared 29 who survived and were discharged from the hospital to 13 who did not.[3] Right ventricular dysfunction was diagnosed by finding 2 out of the following; a) severe tricuspid regurgitation, b) RV end diastolic diameter > 35mm, c) tricuspid annular plane systolic excursion (TAPSE) < 1.5cm, d) TDI TV annulus S' < 10cm/s, and e) reduced RVEF.[3] The most significant predictor of hospital discharge was absence of right ventricular dysfunction.[3] Huang et al employed three dimensional (3D) RV analysis in comparing 28 successful to 18 unsuccessful patients weaned from ECMO.[4] From multivariate analysis, while RV strain (-14 vs - 7.6) and LVEF (35% vs 25%) were associated with weaning, an RVEF > 25% was the best predictor of weaning success and 30 day survival.[4]

Collectively, patients who were successfully weaned from ECMO, exhibited stable RV and LV volumes and increased contractility when compared to baseline/pre-wean values.[1,2,3,4,5]

Weaning protocols are typically initiated after 24-48 hours and when the baseline mean arterial blood pressure is > 60 mmHg while receiving no or low dose vasoactive medications (< 4ug/min of norepinephrine, and < 5 ug/kg/min dobutamine), and stable pulmonary oxygenation (PaO2/FiO2 > 100).[1,2,3,4,5] Although variations exist, a stepwise wean is in performed in 15 minute increments until flow is reduced to < 50% of baseline (100%) or a minimum flow of 1-1.5L/min. A drop of mean blood pressure < 60mmHg is considered unstable and flow returned to 100%.[1,2,4,5] Weaning protocols may vary as to how long intervals are, however, the same physiologic principle applies: reduced ECMO flow causes a volume challenge to the ventricles.[1,2,3,4]

The increased cardiac preload in successfully weaned ECMO resulted in increases of RVEF and LVEF, stable increases in right and left heart volumes and central venous pressure.[1,3,4] Previous predictors of favorable outcome include increases in LVEF, AoV or LVOT VTI.[2] In the present study while RV FAC, TAPSE, and LVEF were improved up successful weaning, tissue Doppler measures of RV systolic function (S') and LV diastolic function (lateral e') were the only independent predictors of successful ECMO wean.

In the present study, Kim et al, found significant predictive value of TDI over conventional echo data.[1] In a study of 33 patients requiring ECMO for cardiogenic shock, ECMO flow was incrementally decreased from 66 to 33 to <10% of baseline to assess load dependency of echocardiographic variables.6. Successful ECMO wean was associated with higher LVEF, aortic VTI, and TDI S'. Systolic strain was not significantly different a peak and minimal ECMO flow rates. VTI, LVEF, and LV strain rate were noted to be preload dependent, while tissue Doppler velocities were load independent.[6] TDI S', shown to be load independent, may be an early, pre-wean, predictor of cardiac reserve function.[6]

The role of RV dysfunction as an independent predictor of adverse outcome across multiple populations including severe left heart dysfunction has been increasingly appreciated.[7,8] Similar to the present study, higher baseline RV function and better LV diastolic function were found to be predictors of outcome and improved heart function after coronary bypass surgery in patients with preoperative severe depressed LVEF (< 25%).[8] Regardless of whether RV dysfunction is a primary problem or secondary to left heart failure, it is an independent predictor of outcome.[7,8] If secondary to severe LV failure, then RV performance may be a predictor of left heart cardiac reserve function.[1,7,8]

Left and right heart TDI analyses were found to be the best predictors of outcome in the present study.[1] In the Helical Ventricular Myocardial Band (HVMB) model, Torrent-Guasp presents a framework that combines structure with function based on myofibril architecture/direction, anatomy, and connectivity to explain the contractile pattern of the LV and RV and the interactive relationship between the two.[9] In this model, longitudinally directed myocardial fibers are shown to be the most significant contributor toward systolic contractility.[9] When you combine these findings, the load independent measures of longitudinal cardiac functions might offer an early predictor of ECMO weaning success.

The present study adds to a relatively small but growing body of literature that reports on predictors of successful outcome in patients managed with VA ECMO for cardiogenic shock. The tissue Doppler analyses of RV systolic and LV diastolic functions predict cardiac reserve function and the ability to tolerate the load increases associated with weaning and discontinuation of VA ECOM.

References

1. Kim D, Jang WJ, Park TK, Cho YH, Choi J-O, Jeon E-S, Yang JH: Echocardiographic Predictors of Successful Extracorporeal Membrane Oxygenation Weaning After Refractory Cardiogenic Shock. *J Am Soc Echocardiogr* 2021;34:414-422.
2. Aissaoui N, Luyt CE, Leprince P, et al. Predictors of successful extracorporeal membrane oxygenation (ECMO) weaning after assistance for refractory cardiogenic shock. *Intensive Care Med.* 2011;37(11):1738-1745.
3. Pappalardo F, Pieri M, Arnaez Corada B, et al. Timing and Strategy for Weaning From Venoarterial ECMO are Complex Issues. *J Cardiothorac Vasc Anesth.* 2015;29(4):906-911.
4. Huang KC, Lin LY, Chen YS, Lai CH, Hwang JJ, Lin LC. Three-Dimensional Echocardiography-Derived Right Ventricular Ejection Fraction Correlates with Success of Decannulation and Prognosis in Patients Stabilized by Venoarterial Extracorporeal Life Support. *J Am Soc Echocardiogr.* 2018;31(2):169-179.
5. Fried JA, Masoumi A, Brodie D: How I approach weaning from venoarterial ECMO. *Critical Care* 2020;24:307 https://doi.org/10.1186/s13054-020-03010-5
6. Aissaoui N, Guerot E, Combes A, Delouche A, Chastre J et al: Two-dimensional strain rate and Doppler tissue myocardial velocities: Analysis by echocardiography of hemodynamic and functional changes of the failed left ventricle during different degrees of extracorporeal life support. *J Am Soc Echocardiogr* 2012;25:632-640.

7. Rudski LG, Lai WW, Afilalo J, et al. Guidelines for the echocardiographic assessment of the right heart in adults: a report from the American Society of Echocardiography endorsed by the European Association of Echocardiography, a registered branch of the European Society of Cardiology, and the Canadian Society of Echocardiography. *J Am Soc Echocardiogr.* 2010;23(7):685-713; quiz 786-688.

8. Maslow AD, Regan MM, Panzica P, Heindel S, Machikian J, Comunale M: Precardiopulmonary bypass right ventricular function is associated with poor outcome after coronary artery bypass grafting in patients with severe left ventricular systolic dysfunction. 2002;95:1507-1518.

9. Torrent-Guasp F, Kocica MJ, Corno AF et al: Towards new understanding of the heart structure and function. *Eur J Cardiothorac Surg* 2005;27:191-20.

LITERATURE REVIEWS

Utilization and Outcomes of Transesophageal Echocardiography in 1.3 Million CABG Procedures

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Background

The use of intraoperative trans-esophageal echocardiography (TEE) is generally recommended in most open heart and thoracic aortic surgical procedures. Its use in coronary artery bypass graft (CABG) surgeries should be considered but is not a universal standard of care. While there are various reasons as to why TEE may not be performed during isolated CABG procedures, perhaps one of the most important reasons is that it remains unclear if TEE during CABG is associated with improved outcomes. As such this retrospective cohort study sought to determine the association of TEE with post-CABG mortality (primary outcome) and with unplanned valve surgery (secondary outcome).

Study Design

This study was a retrospective cohort study. To evaluate TEE in relation to operative mortality, the study included patients 18 years and older who underwent isolated CABG from 1/1/2011 – 6/30/2019, resulting in 1,255,860 patients from across 1,218 centers. Across TEE usage, patient characteristics (age, race, BMI, comorbidities) were evaluated and compared. Confounding variables (e.g. chronic lung disease, diabetes, heart failure) that influenced both the likelihood of intraoperative TEE use and patient outcomes were controlled for using statistical analyses, and a matched analysis was performed to account for these baseline differences. The matched analysis resulted in 560,639 CABG patients who underwent TEE matched to 560,639 CABG patients who did not. Furthermore, to determine if patient risk affected the relationship between TEE usage and outcome, patients were stratified into 3 risk groups – low risk (<4% operative mortality), moderate risk (4-8% operative mortality), or high risk (>8% operative mortality) – based on the Society of Thoracic Surgery predicted risk score.

To evaluate TEE in relation to unplanned valve operation, the study included patients 18 years and older who underwent CABG with possible unplanned valve procedure from 7/1/2014 – 9/30/2019, resulting in 831,528 patients from across 1,146 centers. Matched analysis resulted in 346,508 CABG patients with a possible unplanned valve procedure who underwent TEE matched to 346,508 patients who did not undergo TEE.

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The primary outcome was operative mortality, which included all deaths occurring during the hospitalization in which the surgery was performed, and all deaths occurring after discharge from hospital but before the end of the 30th postoperative day. Secondary outcomes included the association of TEE use with unplanned valve surgery, postoperative renal failure, prolonged mechanical ventilation >24hrs, prolonged ICU stay >2days, re-operation and hospital re-admission within 30 days. The researchers hypothesized that TEE use would be associated with improved clinical outcomes. A P-value < 0.05 was considered statistically significant.

Discussion

This study demonstrated that use of intraoperative TEE during isolated CABG procedures is associated with lower operative mortality, particularly in those patients with the highest predicted operative risk. The authors mention several potential mechanisms by which TEE could improve outcomes including guidance of post-operative therapy, and identification of regional wall motional abnormalities, aortic injury, or pericardial effusion post-bypass. The study also suggests that TEE can impact the operative plan as demonstrated by this study's conclusion that TEE is associated with increased odds of performing an unplanned valve procedure during a CABG.

Though this study noted a propensity for more medically complex patients (heart failure, cerebrovascular, pulmonary and vascular disease etc.) to receive intraoperative TEE compared to patients without these comorbidities, the authors performed a thorough statistical analysis and matching of patient characteristics. Furthermore, the large cohort sizes and variety in patient demographics and comorbidities allow this study's conclusions to be extrapolated to the general public. An additional outcome that this study could have evaluated include relation of intraoperative TEE use to postoperative neurologic outcomes, especially considering that the TEE cohort had higher odds of prolonged ICU stay and renal failure.

Related Reading

1. Eltzschig HK, Rosenberger P, Löffler M, Fox JA, Aranki SF, Shernan SK. Impact of Intraoperative Transesophageal Echocardiography on Surgical Decisions in 12,566 Patients Undergoing Cardiac Surgery. *The Annals of Thoracic Surgery*. 2008;85(3):845-852. doi:10.1016/jathoracsur.2007.11.015.

Left Atrial Appendage Occlusion During Cardiac Surgery to Prevent Stroke

Whitlock RP, Belley-Cote EP, Paparella D, et al.
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Atrial fibrillation is responsible for the most cases of ischemic strokes caused by thromboembolisms originate from the left atrial appendage.[1] It has been considered that the left atrial appendage occlusion should reduce the risk of stroke in patients with atrial fibrillation.[2] During cardiac surgical procedures, concomitant occlusion of the left atrial appendage has been performed to reduce the risk of ischemic stroke. This study was conducted to determine whether concomitant occlusion would prevent ischemic stroke or systemic embolism in patients who also receive anticoagulation.

Methods

This study is a multicenter, randomized trial. The study enrolled patients 18 years of age or older with atrial fibrillation scheduled to undergo cardiac surgery with cardiopulmonary and a score of at least 2 on the CHA2DS2-VASc scale which reflects the risk of stroke.

The study excluded off-pump surgery, mechanical-valve implantation, heart transplantation, surgery for complex congenital heart disease, or isolated implantation of a left ventricular assist device; those with a previous surgery that involved opening the pericardium; and those who had previously undergone implantation of a left atrial appendage closure device. The patients were randomized to two treatment groups based on a web based system: undergo or not undergo occlusion of the left atrial appendage at the time of cardiac surgery. The investigators were blinded with the choice of the procedure. A confidential email with the assigned procedure was sent only to the surgeons just before surgery. Any of the techniques were used for the occlusion: amputation and closure, stapler closure, double layer linear closure or closure with an approved surgical occlusion device. Percutaneous closure and purse-string closure was not permitted. Intraoperative transesophageal echocardiography was used to confirm successful closure. Patients were followed up at 30 days and then every 6 months with a validated stroke questionnaire7 to determine if a possible stroke had occurred.

The primary outcome was the occurrence of ischemic stroke (including transient ischemic attack) or systemic embolism. Secondary outcomes included any stroke or noncerebral systemic embolism; ischemic stroke, or death from any cause; the volume of chest-tube drainage in the first 24 hours, reexploration for bleeding within the first 48 hours; hospitalization for heart failure; myocardial infarction; and major bleeding.

Results

A total of 4811 participants from 105 centers were randomly assigned to undergo (2400 participants) or not undergo (2411 participants) left atrial appendage occlusion at the time of cardiac surgery. The mean duration of

follow-up was 3.8 years, and was completed by 97.9% of the participants. The mean CHA2DS2-VASc score was 4.2, and approximately half the participants were receiving oral anticoagulation at baseline. The mean cross-clamp time was 86 minutes in the occlusion group and 82 minutes in the no-occlusion group, and the mean cardiopulmonary bypass time was 119 minutes and 113 minutes, respectively. The 30-day mortality was 3.7% in the occlusion group and 4.0% in the no-occlusion group. At discharge, 83.4% of the participants in the occlusion group and 81.0% of those in the no-occlusion group were receiving oral anticoagulation. Ischemic stroke or systemic embolism occurred in 114 participants (4.8%) in the occlusion group and in 168 (7.0%) in the no-occlusion group CI 0.53 to 0.85; P = 0.001). During the first 30 days after surgery, a primary-outcome event occurred in 53 participants (2.2%) in the occlusion group and in 65 (2.7%) in the no-occlusion group. After 30 days, a primary-outcome event occurred in 61 participants (2.7%) in the occlusion group and in 103 (4.6%) in the no-occlusion group. Ischemic stroke occurred in 109 participants (4.6%) in the occlusion group and in 164 (6.9%) in the no-occlusion group (95% CI, 0.52 to 0.84).

Discussion

The study shows the risk of ischemic stroke or systemic thromboembolism was lower with concomitant left atrial appendage occlusion performed during cardiac surgery. The effects of surgical occlusion of the left atrial appendage has shown to be additive to those of oral anticoagulation.[3] These effects are due to the continuous and permanent protection against embolic stroke provided by the procedure. This study did not compare left atrial appendage occlusion with the anticoagulation, and occlusion at the time of surgery should not be considered as a replacement for anticoagulation. The study showed that patients with atrial fibrillation who had cardiac surgery and receive antithrombotic therapy, the risk of stroke or systemic embolism was lower with concomitant left atrial appendage occlusion performed during the surgery than without it.

References

1. Wolf PA, Abbott RD, Kannel WB. Atrial fibrillation as an independent risk factor for stroke: the Framingham Study. *Stroke* 1991; 22: 983-8.

2. Blackshear JL, Odell JA. Appendage obliteration to reduce stroke in cardiac surgical patients with atrial fibrillation. *Ann Thorac Surg* 1996; 61: 755-9.

3. Hart RG, Pearce LA, Aguilar MI. Metaanalysis: antithrombotic therapy to prevent stroke in patients who have nonvalvular atrial fibrillation. *Ann Intern Med* 2007; 146: 857-67.

PRO/CON DEBATE

Tidal Volume 8 ml/kg During One-Lung Ventilation Is Not Only Safe but It Is Preferred

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The management, practice, and implementation of positive pressure ventilation (PPV) has been the subject of discussion and debate for decades. Adequate gas exchange, achieved by adjusting respiratory rate (RR) and tidal volume (TV), is balanced with the risk of ventilator-induced lung injury (VILI) due to barotrauma, volutrauma, and atelectrauma.

In lab models, VILI occurs after 2 days of PPV using tidal volumes between 30 to 50 ml/kg and airway pressures between 40-50 cmH2O.[1,2] Histologically, there is endothelial dysfunction, protein-rich pulmonary edema, hemorrhage, and inflammation.[1,2,3,4,5] While it is evident that extremely high TV and airway pressures cause injury, it is equally clear that too little TV causes atelectasis, lung injury, and adverse outcome.[6,7]

Although VILI was first noted in the 1950s, interest soared after the publication of two landmark studies in 1998 and 2000 that reported mortality reduction for patients with ARDS when using 'Protective Lung Ventilation' (PLV) compared to 'Conventional Lung Ventilation' (CLV).[8,9] PLV included low or 'physiologic' tidal volume (TV; < 6 ml/kg; predicted or ideal body weight; PBW) and low airway pressure (mean airway pressure < 30 cmH2O, peak inspiratory pressure [PIP] < 30-40 cmH2O; plateau pressure [Ppl] < 30-35 cm H2O;), while CLV included 12 ml/kg.[8,9] Due to the occurrence of hypercarbia and atelectasis, low TV requires a higher respiratory rate, application of positive end-expiratory pressure (PEEP), and lung recruitment maneuvers (6,10). Although Amato et al reported a large mortality benefit of PLV at 28 days (38% vs 71%), 7 patients in the CLV group died within 24-36 hours of the study's onset, and there was no difference in survival at hospital discharge.[8] In the ARDSnet study, the mortality of PLV (31%) and CLV (39%) was similar to the PLV group reported by Amato et al. Notably, in the ARDSnet study, the airway plateau pressures in the CLV group were kept between 45 and 50 cmH2O, which are known harmful airway pressures.[9,11]

Other studies have shown no benefit of PLV on the outcome of ARDS.[3,7,12] Further, these studies have shown that inflammation is less and outcomes are better with higher TV and low plateau airway pressure (< 30cmH20).[3,7,12,13] A meta-analysis showed a parabolic effect of plateau airway pressures and tidal volume with lowest and highest TV and airway pressures associated with adverse outcome, while PLV per se was not associated with improved outcome.[7] Despite the enthusiastic adoption of PLV, overall mortality for patients with ARDS has not declined over the last 20 years and remains at 30-40%.[3,12]

Since pulmonary failure accounts for <15% of deaths in patients with ARDS, scientists speculate that barotrauma, volutrauma, and atelectrauma that causes

pulmonary inflammation, will also result in systemic biotrauma, systemic inflammation, non-pulmonary organ dysfunction, and mortality.[8,14] However, cytokine studies have not been consistent with regard to levels of inflammatory mediators during PPV, with pulmonary levels of Tumor Necrosis Factor-a (TNFa) ranging from 10 to 1000 pg/ml, and interleukin 6 (IL-6) ranging from less than 100 pg/ml to greater than 1500 pg/ml from different studies using the same experimental conditions, and sometimes the same researchers.[15,16,17,18,19]

Tidal volumes affect inflammation differently. Tremblay et al reported that ventilating rats with TV during TLV of 7 and 15 ml/kg was associated with minimal increases in cytokines compared with TV of 40 ml/kg.[15] Whitehead et al varied tidal volumes from 7 to 15 to 40 ml/kg with PEEP for two hours and reported lower inflammatory mediators in the 7 and 15 ml/kg TV groups. However, after intra-tracheal injection of lipopolysaccharide, a model for ARDS, pulmonary levels of TNFa and macrophages were lower for the highest TV ventilation (40 vs 7 ml/kg), suggesting a protective effect of higher TV ventilation in an ARDS model.[19]

Adoption of ICU PPV management for the OR environment lacks evidence and sound reasoning. The lung in the patient with ARDS is smaller, less compliant, and described as a heterogenous mixture of consolidated/atelectatic lung, bullous lung, and relatively normal lung. The relatively normal lung component in the ARDS lung is at risk for over-distention during positive pressure ventilation even with low TV ventilation. By comparison, the healthier, larger homogenous, and compliant lung allows a more uniform delivery and spread of the same tidal volume with less alveolar stress.

Even advocates of PLV recognize that low TV ventilation results in hypercarbia and atelectasis, both associated with adverse outcome, often necessitating higher RR, PEEP, and recruitment maneuvers.[6,14,20] While most patients tolerate mild hypercarbia, data demonstrate an association between hypercarbia and renal dysfunction,[14] and, more recently, diaphragmatic weakness.[20] To counter this problem, the respiratory rate is increased. The phasic closing and reopening causes alveolar stress, strain, and injury resulting in reduction in surfactant, inflammation, and bacterial growth, which may lead to systemic inflammation.[3,5,10,12,21,22,23,24,25,26] During low TV ventilation, the respiratory rate is most often increased to 15 to 20 breaths-per-minute, increasing alveolar opening and closing stress.[22] When piglets were ventilated with an extremely high TV of 38 ml/kg for 54 hours, lethal pulmonary edema occurred but only when the respiratory rate was increased > 15 breaths per minute.[23] Lower respiratory rates did not result in pulmonary edema.[23]

Perioperative atelectasis occurs in up to 75% of patients, causing alveolar collapse, depletion of surfactant, inflammation, bacterial growth, pneumonia, morbidity, and mortality.[3,4,5,10,21,29,30] Atelectasis is reversible with larger tidal volumes and/or by performing "periodic deep breaths capable of providing effective expansion of the lungs or 'hyperinflation'".[6] Animal data support the safety and benefits of higher TV during TLV equivalent to OLV of > 8 ml/kg. A gradual titration of TV from 6 to 22 ml/kg in an animal model was associated with less atelectasis, less alveolar damage, less interstitial edema, and less inflammation compared to either the control group (TV 6 ml/kg) or when the TV was abruptly increased from 6 to 22 ml/kg.[31] Broccard et al, using animals, compared 6 vs 18 ml/kg TV during TLV and reported significantly less hemorrhage, lung edema, and lung weight gain with a higher TV as long as mean airway pressure was low (13 vs 22 cmH2O).[32]

THORACIC

Patients undergoing thoracic and upper abdominal surgical procedures have a 40-50% decline in lung function. These dysfunctions are mainly due to atelectasis, alveolar collapse and subsequent reduction in alveolar gas exchange.[3,4,5,10,21,29,30] For patients requiring OLV, ARDS is reported in up to 2% of cases and usually occurs on the dependent or non-operated lung.[33] However, greater composite injury (e.g. pneumonia) occurs in the operated lung.[34] Since the enthusiastic adoption of PLV, clinicians have asked how to manage PPV during thoracic cases requiring OLV. While 'small tidal volume' has been suggested during OLV, it is clear that TV < 5 or even < 6 ml/kg (predicted body weight; PBW) isn't beneficial alone due to atelectasis/alveolar collapse, and resultant alveolar inflammation.[27,31]

'Small tidal volume' (< 5 ml/kg), or 'Protective one lung ventilation' (POLV) during OLV results in hypercarbia, atelectasis/alveolar collapse, inflammation, and morbidity.[31] Higher TV (> 8 ml/kg), or 'conventional OLV' (COLV), results in better ventilation, less dead space, and lower PaCO2.[35,36,37,38] Oxygenation, or PaO2/FiO2, is either better or similar using higher TV ventilation as compared to low TV.[35,36,37,38,39] Because there is less atelectasis with higher TV, pulmonary compliance is better.[35,39]

Slinger et al reported increases in auto-PEEP (and therefore total PEEP) when changing from TLV to OLV, in part related to reduced expiratory time i.e. increased respiratory rate which may not be interpreted accurately by anesthesia ventilators.[40,41] In addition, increased respiratory rate and lower tidal volume impaired exchange of respiratory gases.[41] While maintaining the same minute ventilation and varying the respiratory rate from 5 to 15/min, the higher tidal volume (1234 ml vs. 433 ml) resulted in more efficient CO2 excretion, while lower TV and higher respiratory rate resulted in auto PEEP, ventilatory dead space, and higher PaCO2.[53] Superior oxygenation and CO2 excretion were reported during Video Assisted Thoracic Surgery (VATS) with COLV (TV 10ml/kg; PEEP 0 cmH2O, RR 9/min) compared to POLV (TV 6 ml/kg; PEEP 5 cmH2O; respiratory rate 14/min).[36] Katz et al compared low (7 ml/kg) and high (14 ml/kg) tidal volumes with varying PEEP (0 vs. 10 cmH2O) during OLV.[39] Systemic oxygen levels and right-to-left pulmonary shunt was less during large TV and no PEEP ventilation.[39] Although peak airway pressures were higher, pulmonary compliance was better with the higher TV due to reduced atelectasis.[39]

Intraoperative alveolar/lung inflammation increases for both POLV and COLV, however, a connection between degrees of alveolar inflammation, mode of ventilation, and outcome has not been conclusively demonstrated.[36,37,42,43,44] Inflammatory markers, postoperative function and outcomes are similar in both groups.[36,37] Data shows same or less inflammation for COLV (10ml/kg x 9 breaths/min) compared to POLV (5 ml/kg TV x 15 breaths/minute) during surgery and also two hours after surgery.[37,44]

The impact of tidal volume ventilation during thoracic surgery and OLV was retrospectively analyzed in 1019 patients.[45] Patients were ventilated, during OLV, with TV ranging from 5 to > 8 ml/kg. Multivariate analysis reported the incidence of respiratory complications and non-respiratory morbidity and mortality was decreased 16% per 1 ml/kg increase in TV during OLV.[45] There was also a 3.4% increase risk of adverse outcome with each 1cm H2O increase in driving pressure (Ppl - PEEP). Overall, there was a biphasic effect regarding driving pressure i.e. low and high driving pressure was associated

with adverse pulmonary outcomes.[45] Rauseo et al titrated PEEP upward and reported best oxygenation at 6 cmH2O PEEP with TV between 6-8 ml/kg to yield a driving pressure of 20cmH2O during OLV.[46] The 'open-lung' approach including individualized PEEP and assessment of driving pressures yielded better oxygenation and higher pulmonary compliance.[47] In a double-blinded randomized study comparing 'traditional POLV' (TV 6 ml/kg, PEEP 5 cmH2O, and recruitment) was compared to management based on driving pressure (DPOLV), pulmonary complications were significantly less in the DPOLV group (5.5% vs 12.2%).[48] Current POLV strategies fail to protect the lung.

Consistent with prior data, a high TV with low Ppl, or driving pressure, yields the best outcome.[32,45,48] Preventing atelectasis and VILI requires a balance between adequate TV, respiratory rate, and airway pressure. When assessed by Electrical Impedance Tomography (EIT), Liu et al reported that optimal PEEP ranged from 9-13 cmH2O during OLV which resulted in maximum lung inflation.[49] Elsewhere, using EIT to assess TV and RR changes during OLV, dropping TV stepwise from 8 to 5 and increasing RR stepwise from 12 to 20 respectively caused significant reductions in aeration, oxygenation, and global compliance.[61] Based on blood gas analysis, EIT data, and outcome, TV < 5 ml/kg during OLV does not compare favorably to TV > 8 ml/kg.[50]

DATA AGAINST

While there is data reporting better results with low TV (5-6ml/kg) during OLV, these data were either not conclusive regarding outcome and/or did not control for other important variables.[51,52,53,54] The use of POLV during minimally invasive esophagectomies was associated with lower inflammatory mediators and extravascular lung water, though the authors did not conclude morbidity or mortality benefits.[51,53] In these studies, low TV patients are managed with PEEP and recruitment maneuvers while neither are employed during higher TV (> 8-10 ml/kg) patients.[51,52,54)] Perhaps these data only show benefits of PEEP and recruitment maneuvers during OLV and not low TV. Furthermore, there was no data on perioperative pain and sedation scores after surgery.[51,52,54] Clinical investigations that did not keep variables, such as recruitment and PEEP, constant, and/or did not report on postoperative pulmonary complications, pain, and sedation management cannot conclude that low TV reduces postoperative morbidity.[35,55,56]

CLINICAL CONSIDERATION

Those who argue whether barotrauma or volutrauma is more important ignore the relationship between lung and total respiratory system elastance (EL/ETOT), airway pressures (PIP, Ppl), and transpulmonary pressure.[57] For the person with a normal elastance, a Ppl of 30 cmH20 might yield a transpulmonary pressure of 24 cmH20 and a maximally inflated lung.[57] However, for an obese patient the elastance may be lower such that a Ppl of 30 cmH20 would yield a transpulmonary pressure of < 10 cmH20 and be associated with lung collapse and hypoxemia.[57] Before adjusting ventilator settings, it is best to first consider the individual total elastance (compliance) and that individual decisions regarding TV, RR, Ppl are necessary to prevent atelectasis and alveolar stress. Additional settings including PEEP, perhaps guided by driving pressures, and the application of recruitment maneuvers become critical components of respiratory care.[34,46,47,58]

CONCLUSIONS

High airway pressures (> 45 cmH2O) and extremely high TV (> 30-40ml/kg) are known to cause lung inflammation and injury, especially when applied for durations longer than 48 hours. Increasing RR also causes phasic alveolar stress. The arbitrarily determined low TV (< 5 or 6 ml/kg) with an increased RR during OLV is not supported by outcome data. Higher TV (> 8 ml/kg) while maintaining acceptable airway pressures provide the best protection from VILI while optimizing gas exchange and minimizing atelectasis. Ventilator settings should consider the total pulmonary elastance to help predict transpulmonary gradients to allow full lung inflation. Tidal volumes > 8 ml/kg during OLV while maintaining Ppl < 30 cmH2O, and/or driving pressures < 20-25 cmH2O, with PEEP and recruitment maneuvers should be considered protective. Regarding outcome, the intraoperative period is a part of the perioperative period and pulmonary therapies must continue during the postoperative period to prevent atelectasis.

References

1. Goldstein I, Bughalo MT, Marquette CH, Lenaour G, Lu Q, Rouby JJ: Mechanical ventilation-induced air-space enlargement during experimental pneumonia in piglets. *Am J Respir Crit Care Med* 2001;163:958-964.
2. Dreyfuss D, Saumon G: Ventilator-induced lung injury: Lesson from experimental studies. *Am J Respir Crit Care Med* 1998;157:294-323.
3. Wang T, Gross C, Desai AA, Zemskov E, Wu X, Garcia AN, Jacobson JR, Yuan J X-J, Garcia JGN, Black SM: Endothelial cell signaling and ventilator-induced lung injury:molecular mechanisms, genomic analyses, and therapeutic targets. *Am J Physiol Lung Cell Mol Physiol* 2017;312:L452-L476.
4. Duggan M, McCaul CL, McNamara PJ, Engelberts D, Ackerley C, Kavanagh BP: Atelectasis causes vascular leak and lethal right ventricular failure in uninjured rat lungs. *Am J Respir Crit Care Med* 2003;167:1633-1640.
5. Tojo K, Nagamine Y, Yazawa T, Mihara T, Baba Y, Ota S, Goto T, Kurahashi K: Atelectasis causes alveolar hypoxia-induced inflammation during uneven mechanical ventilation in rats. *Intensive Care Med Experimental* 2015;3:18. DOI 10.1186/s40635-015-0056-z.
6. Bendixen HH, Hedley-Whyte J, Laver MB: Impaired oxygenation in surgical patients during general anesthesia with controlled ventilation. A concept of atelectasis. *N Eng J Med* 1963:269:991-996.
7. Eichacker PQ, Gerstenberg EP, Banks SM, Cui X, Natanson: Meta-analysis of acute lung injury and acute respiratory distress syndrome trials testing low tidal volumes. *Am J Respir Crit Care Med* 2002;166:1510-1514.
8. Amato MBP, Barbas CSV, Medeiros DM, Magaldi RB, Schettino GP, Lorenzi-Filho G, Kairalla RA, Deheinzelin D, Munoz C, Oliveira R, Takagaki TY: Effect of a protective-ventilation strategy on mortality in the acute respiratory distress syndrome. *New England Journal of Medicine.* 1998;338:347-354.
9. Acute Respiratory Distress Syndrome Network: Ventilation with lower tidal volumes as compared with traditional tidal volumes for acute lung injury and the acute respiratory distress syndrome. *New England Journal of Medicine* 2000;342:1301-1308.
10. Marini JJ. Evolving concepts in the ventilatory management of acute respiratory distress syndrome. *Clin Chest Med* 1996;17:555-575.
11. Webb HH, Tierney DF: Experimental Pulmonary Edema due to Intermittent Positive Pressure Ventilation with High Inflation Pressures. Protection by Positive End-Expiratory Pressure. *American Review of respiratory disease.* 1974;110:556-565.
12. Villar J, Sulemanji D, Kacmarek RM: The acute respiratory distress syndrome: incidence and mortality, has it changed? *Current Opinion in Critical Care.* 2014;2:3-9

13. Petrucci N, Iacovelli W: Ventilation with smaller tidal volumes: a quantitative systematic review of randomized controlled trials. *Anesth Analg* 2004;99:193-200.
14. Stewart TE, Meade MO, Cook DJ, Granton JT, Hodder RV, Lapinsky SE, Mazer CD, McLean RF, Rogovein TS, Schouten BD, Todd TRJ, Slutsky AS for the Pressure- and Volume-Limited Ventilation Strategy Group: Evaluation of a ventilation strategy to prevent barotraumas in patients at high risk for acute respiratory distress syndrome. *N Eng J Med* 1998; 338:355-361.
15. Tremblay L, Valenza F, Ribeiro SP, Li J, Slutsky AS: Injurious ventilatory strategies increase cytokines and c-fos m-RNA expression in an isolated rat lung model. *J Clin Invest* 1997; 99:944-952.
16. Richard JD, Dreyfuss D, Saumon G: Production of inflammatory cytokines in ventilator-induced lung injury: A reappraisal. *Am J Respir Crit Care Med* 2001; 163:1176-1180.
17. von Bethmann AN, Brasch F, Nusing R, Vogt K, Volk HD, Muller K , Wendel A, Uhlig S: Hyperventilation induces release of cytokines from perfused mouse lung. *Am J Respir Crit Care Med* 1998; 157:263-272.
18. Uhlig U, Fehrenbach H, Lachmann RA, Goldmann T, Lachmann B, Vollmer E, Uhlig S: Phosphoinositide 3-OH kinase inhibition prevents ventilation-induced lung cell activation. *Am J Respir Crit Care Med* 2004; 169:201-208.
19. Whitehead TC, Zhang J, Mullen B, Slutsky AS: Effect of mechanical ventilation on cytokine response to intratracheal lipopolysaccharide. *Anesthesiology* 2004;101:1-3.
20. Michelet P, Carreira S, Demoule A, Amour J, Langeron O, Riou B, Coirault C: Effects of acute respiratory and metabolic acidosis on diaphragm muscle obtained from rats. *Anesthesiology* 2015;122:876-883.
21. Ferreyra G, Long Y, Ranieri VM: Respiratory complications after major surgery. *Curr Opin Crit Care* 2009;15:342-348.
22. Chen ZL, Song YL, Hu ZY, Zhang S, Chen YZ. An estimation of mechanical stress on alveolar walls during repetitive alveolar reopening and closure. *J Appl Physiol* 2015;119:190–201.
23. Mead J, Takishima T, Leith D. Stress distribution in lungs: a model of pulmonary elasticity. *J Appl Physiol* 1970;28:596-608.
24. Vaporidi K, Voloudakis G, Priniannakis G, Kondili E, Koutsopoulos A, Tsatsanis C, Georgopoulos D: Effects of respiratory rate on ventilator-induced lung injury at a constant PaCO2 in a mouse model of normal lung. *Crit Care Med* 2008;36:1277-83.
25. Retamal J, Borges JB, Bruhn A, Can X, Feinstein R, Hedenstierna G, Johansson S, Suarez-Sipmann F, Larsson A: High respiratory rate is associated with early reduction of lung edema clearance in an experimental model of ARDS. *Acta Anaesthesiol Scand* 2016;60:79-92.
26. Rich PB, Douillet CD, Hurd H, Boucher RC: Effect of ventilatory rate on airway cytokine levels and lung injury. *J of Surgical Research* 2003; 113:139-145.
27. Abdullah T, Senturk M: Positive end-expiratory pressure (PEEP), tidal volume and alveolar recruitment: Which one does matter in one-lung ventilation. *Current Anesthesiology Reports* 2019;9:452-458
28. Cressoni M, Gotti M, Chiurazzi C, Massari D, Algieri I et al. Mechanical Power and Development of Ventilator-induced Lung Injury. *Anesthesiology* 2016;124:1100-8
29. Miskovic A, Lumb AB: Postoperative pulmonary complications. *British J Anaesth* 2017;118:317-334.
30. Fernandez-Bustamante A, Sprung J, Kor DJ, Subramanian B, Ruiz RM, Lee J-W, Henderson WG, Moss A, Mehdiratta N, Colwell MM, Bartels K, Kolodzie K, Giquel J, Vidal Melo MF: Postoperative Pulmonary Complications, Early Mortality, and Hospital Stay Following Noncardiothoracic Surgery A Multicenter Study by the Perioperative Research Network Investigators. *JAMA Surg* 2017;152:157-166.

31. Felix NS, Samary CS, Cruz FF, Rocha NN, Fernandes MVS, Machado JA, Bose-Madureira RL, Capelozzi VL, Pelosi P, Silva PL, Marini JJ, Rocco PRM: Gradually increasing tidal volume may mitigate experimental lung injury in rats. *Anesthesiology* 2019;130:767-777.
32. Broccard AF, Hotchkiss JR, Suzuki S, Olson D, Marini JJ: Effects of mean airway pressure and tidal excursion on lung injury induced by mechanical ventilation in an isolated perfused rabbit lung model. *Crit Care Med* 1999;27:1533-1541.
33. Padley SP, Jordan SJ, Goldstraw P, Wells AU, Hansell DM. Asymmetric ARDS following pulmonary resection: CT findings initial observations. *Radiology.* 2002;223:468–73.
34. Halter JM, Steinberg HJ, DaSilva M, Gatto LA, Landas S, Nieman GF: Positive end-expiratory pressure after a recruitment maneuver prevents both alveolar collapse and recruitment/derecruitment. *Am J Resp Crit Care Med* 2003;167:1620-1626
35. Maslow AD, Stafford TS, Davignon KR, Ng T: A randomized comparison of different ventilator strategies during thoracotomy for pulmonary resection. *J Thorac Cardiovasc Surg* 2013;146:38–44.
36. Ahn HJ, Kim JA, Yang M, Shim WS, Park KJ, Lee JJ: Comparison between conventional and protective one-lung ventilation for ventilator-assisted thoracic surgery. *Anaesth Intensive Care* 2012; 40:780–788
37. Schilling T, Kozian A, Huth C, Bühling F, Kretzschmar M, Welte T, Hachenberg T: The pulmonary immune effects of mechanical ventilation in patients undergoing thoracic surgery. *Anesth Analg* 2005; 101:957–965
38. Vegh T, Juhasz M, Szatmari S, Enyedi A, Sessler DI, Szegedi LL, Fulesdi B: Effects of different tidal volumes for one-lung ventilation on oxygenation with open chest condition and surgical manipulation: a randomized cross-over trial. *Minerva Anestesiol* 2013;79:24-32.
39. Katz JA, Laverne RG, Fairley B, Thomas AN: Pulmonary oxygen exchange during endobronchial anesthesia: Effect of tidal volume and PEEP. *Anesthesiology* 1982;56:164-171.
40. Slinger PD, Hickey DR: The interaction between applied PEEP and auto-PEEP during one-lung ventilation. *J Cardiothorac Vasc Anesth* 1998; 12:133-136.
41. Szegedi LL, Barvais Y, Sokolow Y, Yernault JC, d'Hollander AA: Intrinsic positive end-expiratory pressure during one-lung ventilation of patients with pulmonary hyperinflation. Influence of low respiratory rate with unchanged minute volume. *Br J Anaesth* 2002;88:56-60.
42. Wrigge H, Uhlig U, Zinserling J, Behrends-Callsen E, Ottersbach G, Fischer M, Uhlig S, Putensen C: The effects of different ventilatory settings on pulmonary and systemic inflammatory responses during major surgery. *Anesth Analg* 2004; 98:775-781.
43. Baudoin SV: Lung injury after thoracotomy. *British J Anaesthesia* 2003;91:132-142.
44. Lin WQ, Lu XY, Cao LH, Wen LL, Bai XH, Zhong ZJ: Effects of the lung protective ventilatory strategy on proinflammatory cytokine release during one-lung ventilation. *Ai Zheng 2008*;27:870–873
45. Blank RS, Colquhoun DA, Durieux ME, Kozower BD, McMurry TL, Bender SP, Naik BI: Management of one-lung ventilation: Impact of tidal volume on complications after thoracic surgery. *Anesthesiology* 2016;124:1286-2995.
46. Rauseo M, Mirabella L, Grasso S, Cotoia A, Spadaro S, D'Antini, Valentino F, Tullo L, Loizzi D, Solitt F, Cinnella G: PEEP titration based on the open lung approach during one lung ventilation in thoracic surgery: a physiologic study. *BMC Anesthesiology* 2018;18:156 https://doi.org/10.1186/s12871-018-0624-3.
47. iPROVE Network investigators, Belda J, Fernando C, Garutti I: The effects of an open-lung approach during one-lung ventilation on postoperative pulmonary complications and driving pressure: A descriptive multicenter national study. *J Cardiothorac Vasc Anesth* 2018;32:2665-2672.

48. Park M, Hoo Ahn H, Kim JA, Yang M, Hey BY, Choi JW, Kim YR, Lee SH, Jeong HJ, Choi SJ, Song IS: Driving pressure during thoracic surgery. *Anesthesiology* 2019;130:385-393.
49. Liu K, Huang C, Xu M, We J, Frerichs I, Moeller K, Zhao Z: PEEP guided by electrical impedance tomography during one-lung ventilation in elderly patients undergoing thoracoscopic surgery. *Ann Transl Med* 2019;7:757. http://dx.doi.org/10.21037/atm.2019.11.95.
50. Wang W, Xu M-Y, Wu J-X, Zhao Z-Q: Influenc of tidal volume on ventilation distribution and oxygenation during one-lung ventilation. Kaohsiung *J of Med Sciences*. 2018:34:420-421.
51. Shen Y, Zhong M, Wu W, Wang H, Feng M, Tan L, Wang Q: The impact of tidal volume on pulmonary complications following minimally invasive esophagectomy: A randomized and controlled study. *J Thorac Cardiovasc Surg* 2013;146:1267-1274.
52. Michelet P, D'Journo XB, Roch A, Doddoli C, Marin V, Papazian L, et al. Protective ventilation influences systemic inflammation after esophagectomy: a randomized controlled study. *Anesthesiology*. 2006;105:911-919.
53. Qutub H, El-TahanMR,Mowafi HA, El Ghoneimy YF, RegalMA, Al Saflan AA. Effect of tidal volume on extravascular lung water content during one-lung ventilation for video-assisted thoracoscopic surgery: a randomised, controlled trial. *Eur J Anaesthesiol*. 2014;31:466–73.
54. Marret E, Cinotti R, Berard L, Piriou V, Jobard J, Barrucand B, Radu D, Jaber S, Bonnet F, PPV study group: Protective ventilation during anesthesia reduces major postoperative complications after lung cancer surgery: A double blind randomized controlled trial. *Eur J Anaesthesiol* 2018;35:727-735.
55. Karalapillai D, Weinberg L, Peyton P, et al: Effect of Intraoperative Low Tidal Volume vs Conventional Tidal Volume on Postoperative Pulmonary Complications in Patients Undergoing Major Surgery: A Randomized Clinical Trial. *JAMA*. 2020 Sep 1; 324(9):848-858.
56. Neto AS, Hemmes SNT, Barbas CSV, Beiderlinden M, Biehl M et al: Protective versus conventional ventilation for surgery. A systematic review and individual patient data meta-analysis. *Anesthesiology* 2015;123:66-78.
57. Tonetti T, Vasques F, Rapetti F, Maiolo G, Collino F, Romitti F, et al. Driving pressure and mechanical power: new targets for VILI prevention. *Ann Transl Med*. 2017;5(14):286. http://dx.doi.org/10.21037atm.2017.07.08.
58. Choi YS, Bae MK, Kim SH, Park J-E, Kim SY, Oh YJ: Effects of alveolar recruitment and positive end-expiratory pressure on oxygenation during one-lung ventilation in the supine position. *Yonsei Med* J 2015;56: 1421-1427.

PRO CON

PROS AND CONS OF PROTECTIVE LUNG VENTILATION STRATEGIES:

Mechanical Ventilation Using Tidal Volumes < 6 mL/kg in One-Lung Ventilation is Preferred

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INTRODUCTION

Lung-protective ventilation (LPV) strategies have been substantially tested and described for two-lung ventilation (TLV) but not as thoroughly for one-lung ventilation (OLV). The most quoted TLV study focused on acute respiratory distress syndrome (ARDS), demonstrating that lower tidal volumes (VT) decreased mortality from 40% to 31%.1 While a comparable comprehensive randomized controlled trial does not exist for OLV strategies, several smaller clinical trials and a multitude of animal models strongly suggest that smaller tidal volumes for OLV are indeed impactful. OLV has unique challenges, but it is clear that minimizing alveolar stress and strain are preeminent priorities.[2]

One-lung ventilation is necessary for surgical exposure in a variety of complex intrathoracic surgical procedures both on the lung itself and for other structures that lie in the thoracic cavity. This has been increasingly true as minimally invasive techniques have gained in popularity. Historic techniques of OLV had focused on maintaining close to normal minute ventilation with the application of large TV applied to the ventilated lung. We argue that these techniques are inherently injurious to the ventilated lung and that the continued application of large TV strategies have been shown to increase morbidity and potentially mortality. Increasing the FiO2 can help keep SPO2 > 95%,[3] but studies show additional changes are required to lower morbidity and mortality when compared to conventional, higher VT OLV practices. Changes include lowering VT and the application of PEEP.

PRO: In Favor of $V_T \leq 5$ mL/kg

While the best approach to one-lung ventilation continues to be studied, there is an impressive amount of research demonstrating how LPV in OLV should include low tidal volumes and higher PEEP than has been used in the past. With available clinical evidence, there is little doubt that lung protective strategies should now be the standard of care in the operating room.[4] There is increasing evidence that this concept is as applicable to OLV as TLV given thoracic surgery patients greater susceptibility to injurious processes and their greater risk of post –operative pulmonary complications compared to other types of surgery. In one study, minimally invasive esophagectomy patients undergoing OLV, the LPV group using 5 mL/kg predicted body weight (PBW) and 5 cm H2O of PEEP had significantly fewer pulmonary complications than the conventional group ventilated at 8 mL/kg.[5] In another study, the occurrence of lung dysfunction, defined as PaO2/FiO2 < 300 mm Hg, lung infiltration, or atelectasis, was significantly reduced from 22% to 4% when patients were ventilated with a lung protective strategy consisting of VT of 6 mL/kg and PEEP of 5 cm H2O.[3] A general trend is regardless of the pathology, health of the lung, or exact VT being examined, patients receiving the relatively lower VT have fewer post-operative respiratory complications, lower mortality rate, and shorter hospital stays.[6]

Clinical data from OLV studies in the operating room shows that even small differences in TV can make a difference on mortality, with lower rates of post-pneumonectomy acute lung injury (ALI)/ARDS seen in patients undergoing OLV with 7.7 [6.9 to 8.2] vs 8.2 [7.5 to 9.0] mL/kg PBW.[7] However, low VT by itself may not be as effective unless combined with PEEP.[8] Blank et al. examined this concept in OLV, studying 5, 6, 7, and 8 mL/kg mean tidal volumes in over 1000 patients undergoing OLV. Low VT did have a protective effect and were inversely proportional to respiratory complications, but only if PEEP was applied.[9]

Other key points supporting careful consideration of VT are as follows: Licker et al. report that during OLV in lung cancer surgery, their group with 5.3 mL/kg instead of 7.1 mL/kg had the rate of ALI reduced from 9.4% to 2.5% but, importantly, also a reduction in atelectasis from 8.8% to 5.0%.[10]

Inflammation may be a pathophysiological explanation why conventional ventilation strategies lead to poorer outcomes than lung protective ventilation strategies. For example, Michelet et al had a conventional group using 9 ml/kg during OLV without PEEP and a LPV group using 5 ml/kg during OLV with 5 cm H2O of PEEP. The LPV group had lower blood levels of IL-1β, IL-6, IL-8, and TNF-β at the end of OLV as well as 18 hours later11. Specifically, there is a mechanical to biologic transduction that occurs leading to local and systemic inflammatory responses.[2] Low VT reduces this inflammatory response. Schilling et al. compared 16 patients ventilated with 10 mL/kg to 16 patients ventilated with 5 mL/kg tidal volumes. They performed bronchoalveolar lavage (BAL) of each patient's ventilated lung and examined the degree of alveolar mediator release. Specifically, they determined that the concentrations of TNF-β (5.0 vs 8.4 µg/mL) and sICAM-1 (27.5 vs 52.7 µg/mL) were less in the 5 mL/kg VT group than the 10 mL/kg group, suggesting mechanical ventilation induces epithelial damage. TNF-β is produced by macrophages and sICAM-1 is a circulating form of ICAM-1 from endothelial cells. Both are seen in response to inflammation, and higher levels signify the more significant pro-inflammatory effect of higher VT in this study.[12] Despite lower VT, inflammation still occurs to some degree. It is proposed this is due to the persistent shear forces induced by cyclic opening and collapse of tissue which can lead to disruption in pulmonary epithelium which in turn can result in pulmonary edema.[13] This occurs less with low VT and adequate PEEP.[14] In summary, LPV strategies have been shown to cause lower levels of inflammation and should be recommended while research into pathophysiology continues.

In animal models, it has also been shown that high VT without PEEP causes injury in OLV. On study used isolated perfused rabbit lungs, finding that the non-LPV group comparatively had deterioration of pulmonary mechanics, induced pulmonary hypertension, gain in lung weight, and increased release of thromboxane B2.[15] Mechanically ventilated sheep undergoing pneumonectomy had less lung injury and resulting pulmonary edema in the 6 mL/kg with 2 cm H20 PEEP group than the 12 mL/kg with no PEEP group.[16] Though animal studies are not a substitute for human studies, they do add to the knowledge base strongly supporting LPV strategies in humans.

The anesthesiology community should continue to seek ways to improve OLV management and put current evidence into practice. Treatment of patients during OLV should be individualized, with providers keeping in mind the mainstay of tidal volumes <5 ml/kg when the patient can tolerate it.

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CON: In Favor of V_T > 5 mL/kg

Low VT < 5 mL/kg may not be necessary in all patients, may not adequately ventilate all patients, and can be potentially problematic or harmful in some. For example, some patients with emphysema may experience auto-PEEP, preventing the use of PEEP and requiring the use of higher respiratory rates with conventional tidal volumes to prevent hypoxia without the use of PEEP. In these patients, LPV strategies may not be possible. Because low VT strategies are proposed to require higher PEEP to be effective, this also can result in hypotension from decreased venous return, causing reduced cardiac output and decreased mean arterial pressures which is problematic for organ perfusion. Efforts should be made to keep plateau inspiratory pressures < 25 cm H2O and peak pressures < 35 H2O#Slinger. This is true for one or two lung ventilation, as mechanical ventilation affects these values for both lungs, and reducing PEEP while increasing VT above 5 mL/kg can assist in this, despite the risk of lung inflammation and damage.

CONCLUSION

Unfortunately, it is not as simple as using low VT and high PEEP. Other factors need to be considered in addition to these recommendations. This includes avoiding IV overhydration, as treatment of hypotension, increases the risk of post-pneumonectomy pulmonary edema.[17] Hypotension can be worsened by ACE inhibitors and nitrates, as well as epidurals sometimes used to control intraoperative pain.[18] Finally, regardless of the ventilatory technique, recruitment maneuvers may cause hypotension and hypoxemia.[19] Low VT LPV will be maximally effective only if factors such as these are taken into consideration.

The trend in the previous decade showed a steady but gradual increase in implementation of lower VT, higher PEEP, and a greater proportion of patients receiving LPV, though less so in high risk groups.[20] After considering the pros and cons of a one-lung ventilation strategy using ≤ 5 mL/kg versus > 5 mL/kg, the pros outweigh the cons when it comes to LPV. When a patient can tolerate this strategy, low VT of ≤ 5 mL/kg with PEEP of 5 – 10 cm H2O should be used in OLV.

References

1. Brower RG Acute Respiratory Distress Syndrome Network. "Ventilation with Lower Tidal Volumes as Compared With Traditional Tidal Volumes for Acute Lung Injury and the Acute Respiratory Distress Syndrome". *The New England Journal of Medicine*. 2000. 342(18):1301-1308.
2. Lohser J, Slinger P. Lung injury after one-lung ventilation: a review of the pathophysiologic mechanisms affecting the ventilated and the collapsed lung. *Anesthesia & Analgesia*. 2015;121(2):302–318.
3. Yang M, Ahn HJ, Kim K, et al. Does a protective ventilation strategy reduce the risk of pulmonary complications after lung cancer surgery?: A randomized controlled trial. *Chest*. 2011;139(3):530-537.
4. Futier E, Constantin JM, Paugam-Burtz C, et al; IMPROVE Study Group. A trial of intraoperative low-tidal-volume ventilation in abdominal surgery. *N Engl J Med*. 2013;369:428–437
5. Shen Y, Zhong M, Wu, W, Wang, H, Feng, M Tan, L Wang, Q The impact of tidal volume on pulmonary complications following minimally invasive esophagectomy: a randomized controlled study. *J Thorac Cardiovasc Surg* 2013;146(5) 1267-73.
6. Fernández-Pérez ER, Keegan MT, Brown DR, Hubmayr RD, Gajic O. Intraoperative tidal volume as a risk factor for respiratory failure after pneumonectomy. *Anesthesiology*. 2006;105(1):14-18.

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7. Jeon K, Yoon JW, Suh GY, Kim J, Kim K, Yang M, Kim H, Kwon OJ, Shim YM. Risk factors for post-pneumonectomy acute lung injury/acute respiratory distress syndrome in primary lung cancer patients. *Anaesth Intensive Care* 2009;37:14–9.
8. Levin MA, McCormick PJ, Lin HM, Hosseinian L, Fischer GW. Low intraoperative tidal volume ventilation with minimal PEEP is associated with increased mortality. *Br J Anaesth*. 2014;113(1):97-108.

9. Blank RS, Colquhoun DA, Durieux ME, et al. Management of one-lung ventilation: impact of tidal volume on complications after thoracic surgery. *Anesthesiology*. 2016;124(6):1286-1295.
10. Licker M, Diaper J, Villiger Y, et al. Impact of intraoperative lung-protective interventions in patients undergoing lung cancer surgery. *Crit Care*. 2009;13(2):R41.
11. Michelet P, D'Journo XB, Roch A, et al. Protective ventilation influences systemic inflammation after esophagectomy: a randomized controlled study. *Anesthesiology*. 2006;105:911–919.
12. Schilling T, Kozian A, Huth C, et al. The pulmonary immune effects of mechanical ventilation in patients undergoing thoracic surgery. *Anesth Analg*. *2005*;101(4):957-965, table of contents.
13. Dreyfuss D, Saumon G. Ventilator-induced lung injury: lessons from experimental studies. *Am J Respir Crit Care Med*. 1998;157(1):294-323.
14. Kozian A, Schilling T, Schütze H, Senturk M, Hachenberg T, Hedenstierna G. Ventilatory protective strategies during thoracic surgery: effects of alveolar recruitment maneuver and low-tidal volume ventilation on lung density distribution. *Anesthesiology*. 2011;114(5):1025-1035.
15. Gama de Abreu M, Heintz M, Heller A, Széchényi R, Albrecht DM, Koch T. One-lung ventilation with high tidal volumes and zero positive end-expiratory pressure is injurious in the isolated rabbit lung model. *Anesth Analg* 2003;96:220–8.
16. Kuzkov VV, Suborov EV, Kirov MY, Kuklin VN, Sobhkhez M,Johnsen S, Waerhaug K, Bjertnaes LJ. Extravascular lung water after pneumonectomy and one-lung ventilation in sheep. *Crit Care Med* 2007;35:1550–9.
17. Slinger P. Pro: low tidal volume is indicated during one-lung ventilation. *Anesth Analg*. 2006;103(2):268-270.
18. Gothard J. Lung injury after thoracic surgery and one-lung ventilation. *Curr Opin Anaesthesiol*. 2006;19(1):5-10.
19. Ashok V, Francis J. A practical approach to adult one-lung ventilation. *BJA Education*. 2018;18(3):69-74.
20. Colquhoun DA, Naik BI, Durieux ME, et al. Management of 1-lung ventilation-variation and trends in clinical practice: a report from the multicenter perioperative outcomes group. *Anesth Analg*. 2018;126(2): 495-502.