Editorial Commentary

The future of cardiac critical care: an anesthesia perspective

Kelly Tankard^, Kenneth Shelton

Department of Anesthesiology, Pain Medicine, and Critical Care, The Massachusetts General Hospital, Harvard Medical School, Boston, MA, USA
Correspondence to: Kelly Tankard, MD; Kenneth Shelton, MD. Department of Anesthesiology, Pain Medicine, and Critical Care, The Massachusetts General Hospital, Harvard Medical School, 55 Fruit Street, GRB 444, Boston, MA 02114, USA. Email: ktankard@partners.org; kshelton@mgh.harvard.edu.

Keywords: Cardiac; anesthesiology; critical care; extracorporeal membrane oxygenation (ECMO); telehealth

Submitted Sep 14, 2022. Accepted for publication May 19, 2023. Published online May 30, 2023.
doi: 10.21037/atm-22-4495
View this article at: https://dx.doi.org/10.21037/atm-22-4495

Introduction

The role of the anesthesiologist in critical care has evolved significantly over the last several decades. While previously the future role of the anesthesiologist in the intensive care unit (ICU) has been uncertain (1), the skills of anesthesiology intensivists have created new avenues for developments in the management of critically ill patients and shock (2). In cardiothoracic critical care, anesthesiologists have played an increasingly central role in the management of advanced heart failure, shock, and mechanical circulatory support such as extracorporeal membrane oxygenation (ECMO) alongside our cardiology and cardiac surgery colleagues (2,3). Despite a once uncertain trajectory, the future of cardiac critical care and the anesthesiologist's role within it is bright. In this article we will outline our vision of the future possibilities within anesthesia cardiac critical care based on historical context, present advancements, and future opportunities.

Current role: anesthesiology intensivist as shock consultant

The anesthesiology intensivist's role in the cardiothoracic critical care unit has become increasingly vital over the last several years. As outlined by Shelton *et al.* in 2020 (2), the anesthesiology intensivist currently serves at our institution as the primary consultant for escalating shock. At Massachusetts General Hospital, the cardiac intensivist is the shock consultant for the hospital who can be reached by a "shock pager" and via a mobile application (*Figures 1*,*2*). When a consult is requested, the cardiac intensivist works to quickly gather information, triage based on patient acuity, offer ideas for monitoring and management strategies, institute mechanical circulatory support when deemed necessary (including initiating the procedure of cannulation), and assess patients and/or guide cannulation using advanced skills in echocardiography (both transthoracic and transesophageal) (2,4-6). This has placed the cardiac anesthesiology intensivist at the forefront of assessing, triaging, and managing the hospital's sickest patients and serves to highlight the ability of our anesthesiology specialists to perform in this role that was once dominated only by medically-trained intensivists and cardiac surgeons.

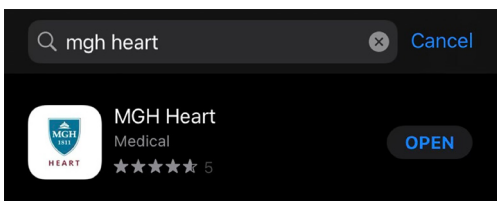

Figure 1 MGH Heart application. MGH, Massachusetts General Hospital.

Future prospects

The growing role of the anesthesiology-trained cardiac intensivist opens many doors for future possibilities in the

^ ORCID: 0000-0002-3691-1901.

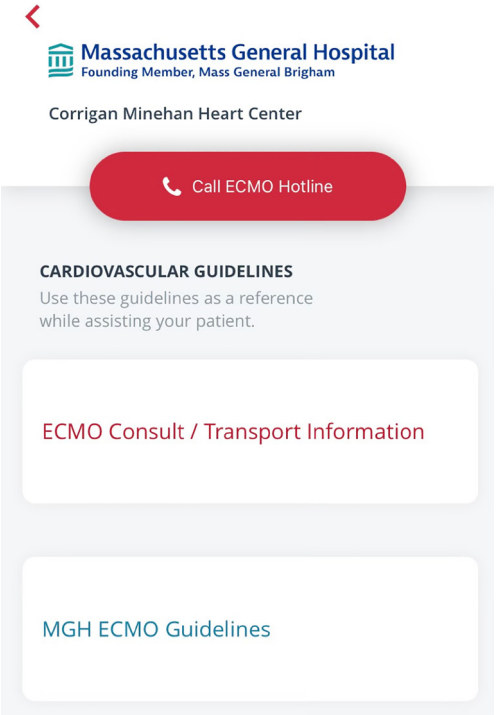

Figure 2 MGH Shock Consult application interface. ECMO, extracorporeal membrane oxygenation; MGH, Massachusetts General Hospital.

advancement of care of our patients. Future possibilities regarding the care of critically-ill cardiac patients include prospects in telehealth and technology to allow new opportunities for the shock consultant, expansion of the anesthesiologist role in ECMO, and investment in training our future cardiac anesthesia intensivists.

Telehealth and new opportunities for the shock consultant

Since the first implementation of telemedicine in intensive care dating back to 1982, telemedicine in critical care, often referred to as "eICU", has grown dramatically due to increasing demand for intensivist care and short supply of intensivist providers particularly in underserved areas (7,8). The goal of telemedicine and the eICU model is to improve access to care for patients who would otherwise not be able to access subspecialist care. Prior models of the eICU have shown improvement in patient outcomes likely due to the ability to staff with more specialist presence through this technology (7,9). The eICU model has promoted the idea of preemptive medicine by recognizing signs and symptoms of disease and instituting treatment before complications arise (7). The eICU has been shown specifically in cardiac patients to improve outcomes in the setting of acute myocardial infarction by recognizing the diagnosis earlier and getting patients to intervention faster (10). This model of the eICU, although published back in 2001, still provides an important framework to think about the use of technology, remote consultation, and preventive medicine both today and in the future for our cardiac critical care patients. Furthermore, the data that can be extracted via the technology of telemedicine provides opportunity for collaborative research efforts geared toward improvement in clinical care of patients (11).

Extrapolating the eICU model and combining this with the concept of the cardiac shock consultant could offer a new frontier for the role of the cardiac intensivist. The cardiac critical care intensivist could serve remotely as a shock consultant to neighboring hospitals that do not have such subspecialist care at their institution. In the same way that the shock consult is placed at Massachusetts General Hospital, through a mobile application (*Figures 1*,*2*), this could be used across institutions as well. The cardiac intensivist would play the same role as is in place at our hospital but via a remote telemedicine technology. The shock consultant would be tasked with gathering information, triaging based on patient acuity, offering ideas for monitoring and management strategies, and recognizing when mechanical circulatory support or other specialized intervention is necessary which would indicate that the patient may need to be transferred to another center capable of performing the indicated intervention.

The use of remote bedside echocardiography may also be possible with the use of telemedicine video systems and could offer another new frontier for data collection for the shock consultant to remotely receive video data regarding bedside echocardiography to aid in decision-making and patient triage.

The telehealth shock consultant could also offer second opinions to patients and families from neighboring hospitals when requested without a need to physically transfer a patient to a different facility. The remote shock consultant could offer insight and advice to patients, families, and providers caring for the patient after the patient's ICU stay to help clarify treatment plans, aid in providing historical context of the patient's ICU course, offer clinical advice, triage if a patient is developing recurrent shock that may necessitate ICU care, and work to prevent ICU readmission

after discharge. Perhaps there could even be a future in the use of a telehealth consult for direct-to-consumer healthcare or an ICU or shock consult from nursing homes, rehabilitation centers, or even directly from the patient to his/her home.

The concept of a telehealth shock consult could lead to less delay in important interventions such as initiation of mechanical circulatory support, interventional cardiology catheterization procedures, or cardiac surgery. In an era including and after COVID-19, the utilization of ICU beds and critical care resources at quaternary care facilities is extremely important, and having the ability to triage via telemedicine and use of the shock consultant across hospitals before transporting a patient to a new institution to be evaluated in person would allow for better use of resources and appropriate triage and transfer of patients only when necessary.

Role in mobile ECMO

In situations where a patient is too unstable to be safely transported to a care center which offers ECMO, the use of mobile ECMO is growing throughout the United States and has been performed in Europe for many years (12-14). Transporting a patient on ECMO was first reported in 1986 by Cornish *et al.* with use of ECMO for an infant patient (15). Since that time, international use of mobile ECMO has been studied both for shock and respiratory failure. ECMO has been shown to be feasibly initiated at a remote hospital with subsequent transportation to a quaternary center with appropriate ECMO support. Mobile ECMO even across country lines has been described, including hours of transport on ECMO without patient harm (13). At our own institution, Dalia *et al.* studied differences in survival or survival to discharge between patients cannulated for veno-arterial (VA) ECMO at our institution versus elsewhere and then transferred and found no differences (16). In 2019, Bonadonna and colleagues at Duke described a mobile ECMO triage system and mobile ECMO team consisting of cardiac surgery, perfusion, and nursing. Approximately half of accepted transfers to their facility were cannulated prior to transfer (17).

Previous descriptions of mobile ECMO teams at other centers often describe a team consisting of a cardiac surgeon, perfusionist, and nursing staff (18). While cardiac critical care anesthesiologists have not formerly been at the forefront of many mobile ECMO programs, the skill set of the intensivist, particularly one with an anesthesiology background, lends itself well to taking an active leadership role within mobile ECMO programs. In Poland, Gawda *et al.* described the creation of an ECMO center including mobile ECMO established and run entirely by intensivists. They advocate that this allows greater access for patients to ECMO without relying on surgeons or interventional cardiologists who may be otherwise preoccupied with their scheduled procedural obligations (19). Gutsche *et al.* advocated for the importance of the use of transthoracic or transesophageal echocardiography in the mobile ECMO process, another skill which cardiac anesthesia intensivists offer and add (20). Nwozuzu *et al.* showed that compared to European mobile ECMO teams in which 53% of included studies incorporated an anesthesiologist on the mobile ECMO team, of the 6 North American mobile ECMO teams included, 0% incorporated anesthesiologists from a period of 1986–2015 (21). In 2016, Gutsche *et al.* commented that the cardiac anesthesiology intensivist possesses all the important skills to lead a mobile ECMO team and advocated for a stronger role of the anesthesiologist in this arena. They commented on the ability of the cardiac anesthesia intensivist to cannulate and obtain vascular access, be proficient in echocardiography, and manage critical changes in respiratory status and hemodynamics (22). There is much that can go wrong during mobile ECMO runs including equipment malfunction, transportation issues, and patient clinical deterioration. Having an anesthesiology intensivist as part of a mobile ECMO team would add a great skillset through an understanding of cardiac and respiratory compromise and the nuances of mechanical circulatory support devices that allows them to be able to manage the device and hemodynamics during transport. Additionally, the cardiac critical care anesthesiology intensivist serving as shock consultant would play a vital role in this process and would lead the effort to identify which patients may benefit from mobile ECMO initiation. As Bonadonna *et al.* described, ECMO consultation from a remote hospital to a quaternary care center does not need to always result in cannulation and/or transfer, and intensivists can support remote hospitals by offering clinical advice and recommendations remotely even without ECMO initiation or transfer (17).

Cardiac anesthesia intensivists have a unique set of knowledge, procedural skills, and leadership attributes which make them clearly valuable as the leaders of not only a mobile ECMO team but a mobile shock team, and the future for this role is bright. Many institutions have already shown improvements in access to care across regions

and countries with mobile ECMO and extracorporeal cardiopulmonary resuscitation (23). Could there be even more opportunities for the cardiac anesthesia intensivist to help bring ECMO and shock consults not only to neighboring institutions and regions but also directly to patients' homes? With the growing infrastructure of telemedicine and direct-to-consumer healthcare with programs like Amazon Care (24), perhaps even ECMO can be direct-to-consumer one day. And most certainly the cardiac anesthesia intensivist skillset would be most apt to bring these new technologies and opportunities to the forefront.

The next generation: training for the future of the cardiac anesthesia intensivist role

As the role of the anesthesiology-trained cardiac intensivist evolves, the unique skills and training required to take on these new roles becomes more important than ever. As Hanson *et al.* previously described back in 2001, many residents in anesthesia do not spend a significant amount of time in the ICU during their training compared to European counterparts, and there has been and continues to be a shortage of anesthesiology-trained intensivists (1). While the United States may never adopt the European model of incorporating critical care training into core residency training, there certainly is an argument for improved education and recruitment of anesthesia residents into the field (25).

Particularly in the cardiac ICUs, anesthesiologists benefit from dual training in both cardiac anesthesia fellowship and critical care medicine fellowship. While cardiac anesthesia fellowship is not required to staff a cardiac ICU, the advanced skills in echocardiography and intraoperative care of cardiac surgical patients certainly offers an advantage to those with dual training (26). While presently completing a dual anesthesia fellowship in cardiac and critical care medicine requires sequential enrollment in one fellowship followed by the other, there certainly could be benefit in combining the fellowships into an integrated two-year program that allows fellows to train in both subspecialties across the two years. With sequential rather than combined fellowships, each fellow must choose a sequence of years. If doing cardiothoracic anesthesia fellowship first, the fellow spends one year becoming an expert in transesophageal echocardiography in the operating room and then taking a full year away from the operating room to become an expert in critical care medicine. If the fellow does the reverse order, the opposite is true. While there are no data to suggest one sequence is preferred to another and certainly no data to suggest combining the fellowships would improve training, one could theorize that having a combined fellowship where a trainee could become an expert in the care of cardiac patients and transesophageal echocardiography in the operating room and critical care medicine and management of cardiac patients in the ICUs simultaneously throughout both years could improve training. This could be of great benefit for the future role of the cardiac anesthesia intensivist as we describe-an anesthesiologist with expert skills in vascular access, echocardiography, management of shock, and leadership in the operating room, ICU, and community. Regardless of the path there, we are certain that investing in the education and training of the next generation of cardiac anesthesia intensivists is key to the future success of our field.

Conclusions

The anesthesiology-trained cardiac intensivist has a unique and refined set of skills which makes him or her clinically adept at caring for patients in shock. The role of the anesthesiology intensivist as the shock consultant has been in place at our institution for many years. We see the future of cardiac critical care expanding on this role to provide shock consults and offer the unique skillset of our providers to patients across our region via technology and mobile support, including ECMO, when necessary. We look to a future where we continue to invest in the training of the next generation of cardiac anesthesia intensivists and continue to build ourselves up as leaders in the field of cardiac critical care in order to best serve our patients and our communities.

Acknowledgments

The authors would like to acknowledge and thank the Massachusetts General Hospital Department of Anesthesiology, Pain Medicine, and Critical Care and the Massachusetts General Hospital Corrigan Minehan Heart Center for its support of clinical and research interests.
Funding: None.

Footnote

Provenance and Peer Review: This article was commissioned by the Guest Editors (Tobias Eckle and Benjamin Scott)

for the series "Highlights in Anesthesia and Critical Care Medicine" published in *Annals of Translational Medicine*. The article did not undergo external peer review.

Conflicts of Interest: Both authors have completed the ICMJE uniform disclosure form (available at https://atm.amegroups.com/article/view/10.21037/atm-22-4495/coif). The series "Highlights in Anesthesia and Critical Care Medicine" was commissioned by the editorial office without any funding or sponsorship. The authors have no other conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Cite this article as: Tankard K, Shelton K. The future of cardiac critical care: an anesthesia perspective. Ann Transl Med 2023;11(9):324. doi: 10.21037/atm-22-4495

