Global Capnography to Improve Safety for All Patients: Time for Urgent Action

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GLOSSARY

AoA = Association of Anaesthetists; **ASA** = American Society of Anesthesiologists; **CFC** = Coalition for Capnography; **GCAP** = Global Capnography Project; **GO** = global oximetry; **HICs** = high-income countries; **ICU** = intensive care unit; **LMICs** = low- and middle-income countries; **NAP4** = 4th National Audit Project; **NYT** = New York Times; **PACU** = postanesthesia care unit; **PUMA** = Project for Universal Management of Airways; **RFP** = request for proposal; **SECO2** = sustained (defined as 7 breaths) exhaled CO_2; **WCA** = World Congress of Anaesthesiologists; **WFSA** = World Federation of Societies of Anaesthesiologists; **WHO** = World Health Organization

In this capnography-focused issue of *Anesthesia & Analgesia*, the trilogy of capnography papers[1–3] will be read differently depending on one's established mental framework, life experiences, work ecosystem, and access to resources. On June 23, 2023, a *New York Times* (NYT) article entitled in part "5 Deaths at Sea Gripped the World" documented the large-scale rescue attempt of the submersible, the Titan.[4] Although multiple countries and private entities sent rescue experts, ships, planes, and high-tech equipment including an underwater drone, 5 men unfortunately lost their lives. The complete title of the aforementioned NYT article read "5 Deaths at Sea Gripped the World. Hundreds of Others Got a Shrug." It highlighted 2 events separated by a few days: the loss of the submersible "Titan" and the sinking of the Adriana, a boat carrying as many as 750 people. The magnitude of the response to the Titan may help us to consider our situational awareness and global response to the current state of capnography access which the articles in this issue highlight.

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The development of the modern infrared capnograph technology is accredited to Karl Friedrich Luft (1937) and even today, the "Luft Cell" remains the basis for modern carbon dioxide monitoring. In the early 1980s, capnography became available for clinical use. The capnography safety profile, supported by clinical research, has been well documented solidifying it as an essential monitor. Capnography's clinical value and ubiquitous clinical use have been well recognized.[5,6] Unfortunately, we have also discovered that access to monitors is not universal and some anesthesia providers, especially those practicing in lower-resourced settings, are lacking many of the "essential" monitors routinely used in modern anesthesia practice in high-income countries (HICs).[7]

Decades ago national societies from high-resourced regions of the world established standards for monitoring during anesthesia which include the mandatory use of both pulse oximetry and capnography. Initial discussions about promoting pulse oximetry globally took place at the 2004 World Congress of Anaesthesiologists (WCA). During these meetings, capnography access gaps were also discussed but pulse oximetry was appropriately prioritized. This decision prompted the initial trials (2007 and 2009) by the Global Oximetry (GO) project[8] whose aims were subsequently championed by the Lifebox Foundation (www.lifebox.org).[9] Lifebox later successfully set about achieving global access to oximeters by donating or working with other nonprofit organizations to distribute >33,000 oximeters, with an educational package, to low- and middle-income countries (LMICs) worldwide. Today, universal availability of pulse oximetry is becoming a standard of care even in

low-income countries. Another powerful driver in the uptake and dissemination of pulse oximetry was the fact that, at the insistence of anesthesiologists, it featured as an essential component of the World Health Organization (WHO) Safe Surgery Checklist. This assignment allowed national or regional anesthesia advocates to encourage their governments to provide pulse oximetry in all operating rooms, as they established national standards of care for anesthesia.

The importance of universal availability and use of capnography to improve patient safety has followed a slower trajectory. The 4th National Audit Project (NAP4), published in 2011 by the Royal College of Anaesthetists and the Difficult Airway Society, was a seminal document.[10] It looked at major complications of airway management over a year (2008–2009) in 97% of hospitals in the United Kingdom. As NAP4 demonstrated, even in HICs tracheal intubation mishaps are the most frequent problems that lead to a high death rate. Lack of capnography in critical care units (where it was available for only 25% of patients) was associated with much higher mortality than in theaters where general anesthesia was conducted while using continuous capnography. The NAP4 investigators commented that it is likely that 74% of the ICU deaths could have been prevented if continuous capnography monitoring had been available to these patients. This led to a number of standard setting organizations (Association of Anaesthetists [AoA; www.anaesthetists.org] and European Board of Anaesthesiology/UEMS)[11] to state that capnography should be available in all operating theatres, PACU, ICU, and resuscitation areas. The resultant increase in availability and use of capnography in HIC has not been matched in LMICs. Although exact reasons are not known, a possible barrier could be similar to one encountered in the earlier lack of pulse oximetry monitoring: affordability of a robust, easy-to-use, device. Another barrier may be lack of LMIC government motivation to prioritize funding for anesthesiology monitoring. In 2018, the WHO-World Federation of Societies of Anaesthesiologists (WFSA) International Standards for a Safe Practice of Anesthesia were published. These guidelines stated that oximetry is highly recommended (essential), whereas capnography is only recommended.[12] They state that "continuous waveform capnography will be highly recommended when appropriately robust and suitably priced devices are available." Once capnography is granted the same "highly recommended" status, advocacy for the device within a country's Ministry of Health may be more successful.

In 2017, proof of the concept of introducing capnography into a low-resource setting (Malawi), where it was not widely available, was demonstrated by the Global Capnography Project (GCAP).[13] GCAP successfully introduced 40 capnography devices to 8 hospitals in southern Malawi and trained 32 anesthesia providers in their use. In the 6 months postimplementation, 77% of the providers reported recognizing complications including 44 esophageal intubations, and 90% of providers believed that capnography had saved lives. In addition, recent guidelines from the Project for Universal Management of Airways (PUMA; www.UniversalAirway.org) provide comprehensive recommendations for the prevention of unrecognized esophageal intubation.[14] This publication was in response to a number of coronial reports related to deaths from unrecognized esophageal intubation. The first recommendation in this guideline states that "Capnography and pulse oximetry should be available and used for all episodes of airway management." This guideline, for the first time, defines the minimum criteria required for tracheal intubation as being sustained (defined as 7 breaths) exhaled CO_2 ($SECO_2$). If the healthcare provider is unable to satisfy the above criteria for sustained exhaled CO_2, then the endotracheal tube should be removed and ventilation reestablished. The ritual of using clinical signs to confirm esophageal intubation has been discouraged. A recent important clinical and statistical paper by Hansel et al[15] confirms that clinical tests and signs lack the discriminatory power to exclude esophageal intubation and so should not be used. Misting of the endotracheal tube after attempting tracheal intubation has a false-positive rate of 0.69. The incidence of unrecognized esophageal intubation worldwide is difficult to assess. The PUMA guideline has been endorsed by all the major airway societies, and supported by national societies including the American Society of Anesthesiologists (ASA) and the AoA. Fortunately, these guidelines can now be used as leverage to encourage global capnography and pulse oximetry access for each person undergoing anesthesia care. These safety standards are important goals for the entire global surgical population, including the high-, middle-, and low-income countries.

The papers by Evans et al,[1] in this capnography-focused edition, employ a global lens to describe our current situation regarding access to capnography, a proposed solution, and an implementation plan to address the massive capnography gap. The article, "Capnography – An Essential Monitor Everywhere." A narrative review by Wollner et al[2] establishes the safety culture foundation for the use of capnography in HICs and the lack of access to this monitor in many lower-resourced regions of the world. The second article, "The Capnography Project" by Evans et al,[1] describes the development of the Smile Train—Lifebox Capnography group. This consortium (2021) launched a request for proposals (RFP) for a suitable capnograph device based on specifications developed by the World Federation of Anesthesiologists

Minimum Capnometer Specifications 2021—A Guide for Health Care Decision Makers.[16] The paper by Evans et al[1] describes the detailed process to source a robust, context-appropriate, combined capnography and oximetry unit by ZUG Medical Systems. In addition to sourcing an appropriate technical solution, the importance of an effective and appropriate educational package is highlighted. This educational package was developed by an experienced global team, trialed in a low-resource setting, and subsequently revised. The third article, "Getting Capnography to the Front lines," by McDougall et al,[3] focuses on the barriers, strategies, and proposed solutions to an implementation plan to scale distribution of these combined devices where they are needed most, the thousands of LMIC operating rooms. McDougall et al[3] suggested a coalition for capnography (CFC) consisting of partners who have acquired expertise from the GO project. These partners need to have expertise in procurement, education, and advocacy if global capnography access is to be a reality. This paper suggests the likely lead partners as Lifebox, WFSA, and Smile Train, alongside additional collaborating partners including governments, academic institutions, and industry.

Reviewing these articles and the global status of capnography, we are prompted to consider some pragmatic steps to meet this urgent need. The safety profile in HICs has been demonstrated and, based on our understanding of the multitude of factors that impact LMIC maternal mortality, we have no doubt that capnography would make a mother's anesthesia safer. Certainly, a clinically focused outcome study, inclusive of education outcomes, is needed but not at the expense of a delay in the life-saving device scale-up. We must first prioritize operating rooms, then critical care, PACU, patient transfer, and finally emergency departments. We must assure that our distribution plans equally focus on both urban and rural hospitals. We need to customize our education packages depending on which cadre is providing the anesthesia care, physicians or nonphysicians. Education in device maintenance should be customized for referral hospitals as compared to the more rural district hospitals that may have a less solid infrastructure. We propose that the entire team in an operating room setting be trained on the use of capnography at a basic level so that if an alarm sounds and help is called for, each person in the room will be able to offer support. We have trained the anesthesia provider to be the expert for oximetry and we can do the same for capnography.

As many "disposables" in LMICs become multiuse, we can advocate for the development of capnography tubing that is more robust. The end-tidal sampling line will likely not be single use in the more rural settings and, possibly, not in the urban public hospitals either. We propose considering a hub and spoke biomedical support model in each country with loaner units and replacement parts. Warranty would be managed by these biomedical centers and a normal lifespan for these devices determined after 2 years of data has been captured in LMICs. A pragmatic, phone-based monitoring and evaluation system should be in place for device durability, use, and patient safety outcome measures. These are additional steps we suggest when developing a strategic plan for scale-up.

On July 3, 2023, an NYT follow-up article, "Everyone Knew the Migrant Ship Was Doomed. No One Helped,"[4] stated that, in contrast with the rescue response to the Titan, the Adriana did not capture the attention of the world, there were no similar headlines, and thus, the response was very different.

As reported by the NYT, satellite imagery, court documents and interviews with survivors suggest that hundreds of deaths were preventable. Preventable deaths—this is what we do! We are a specialty that focuses on patient safety. We would want our satellite imagery and patient interviews to tell a different response story.

In contrast, our response can read "Anesthesiologists and anesthesia providers worldwide know that capnography saves lives: they acted!". This is the time for urgent action.

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