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REVIEW PAPER

Journal of Clinical Monitoring and Computing 2015 end of year summary: anesthesia

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Abstract Clinical monitoring is an essential part of the profession of anesthesiology. It would therefore be impossible to review all articles published in the Journal of Clinical Monitoring and Computing that are relevant to anesthesia. Because other reviews will address monitoring of the respiratory and cardiovascular system, the current review will limit itself to topics uniquely related to anesthesia. The topics are organized according to the chronological order in which an anesthetic proceeds: secure the airway; ventilate and deliver anesthetic gases; monitor vital organ function and anesthetic depth; and ensure analgesia during/after emergence from anesthesia (locoregional anesthesia and pain control).

Keywords Anesthesia · Airway · Ventilation · Anesthesia machine · Ventilator · Anesthetic depth · Analgesia · Locoregional anesthesia · Neuromonitoring

1 Airway

Endobronchial intubation remains fairly common in anesthesia, potentially resulting in complications such as hypoxemia and lung injury as a result of overinflation of the ventilated lung. There are no simple and reliable methods to detect endobronchial intubation; although bronchoscopy does reliably confirm correct placement of the endotracheal tube, it is not always a realistic option. Efrati et al. [1] describe a modified endotracheal tube with 3 additional lumens for obtaining gas samples above the endotracheal tube cuff for CO_2 analysis (AnapnoGuard system). Such a system would allow the detection of a cuff leak or endobronchial intubation. When CO_2 is detected above the cuff, the cuff is automatically inflated to the maximum allowable pressure of 27 mm Hg. If this results in no CO_2 detection above the cuff, then the diagnosis of cuff leak is made, and the cuff pressure is gradually reduced to the minimum pressure required to prevent a cuff leak; however, if this results in continued CO_2 detection (with the CO_2 coming from the non-ventilated lung), then the diagnosis of endobronchial intubation is made, requiring correction of the tube position. It is unclear whether this system works well in the presence of copious, thick airway secretions. The accompanying commentary on this article, by Kalioubie and Nseir [2], review the currently available techniques to detect endobronchial intubation, noting that fiberoptic bronchoscopy is probably the most accurate technique in determining proper endotracheal tube placement, but is not very practical for universal use. The AnapnoGuard system has only been tested in goats, and needs further verification.

A study by Geng et al. [3] found that pneumoperitoneum and Trendelenburg positioning resulted in an increase in endotracheal tube cuff pressure. Since an increase in cuff pressure (>30 cm H_2O), is the main cause of postoperative sore throat through mucosal injury, the authors speculated that the incidence of sore throat was different in patients undergoing laparoscopic procedures versus those undergoing laparotomies, and that was exactly what the authors observed. This would suggest that all anesthesia providers

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should check and normalize the cuff pressure when patients are placed in the Trendelenburg position, although this still needs to be prospectively tested.

Smith et al. [4] examined whether some heart rate variability (HRV) indices could predict airway obstruction in ten patients receiving midazolam-fentanyl prior to induction of anesthesia. The hypothesis was that very short-term HRV could detect autonomic nervous system (ANS) changes caused by the sedatives and changes that precede critical respiratory events. The authors found that one HRV index, the so-called PolVar20, showed a burst of sympathetic activity preceding respiratory depression similar to sleep apnoea arousals that restore airway patency. Pending further evaluation, such information could e.g. become part of an early warning system.

2 Equipment

Anesthesiologists have to thoroughly understand the equipment they use, especially the anesthesia workstation. Vinay et al. [5] describe the reduction in F_IO_2 during the replacement of a CO_2 absorber canister with the Dräger Fabius GS and Primus (Dräger, Lübeck, Germany). Removing the CO_2 absorber results in a massive circuit leak, causing entrainment of air into the piston ventilator, subsequently diluting oxygen and anesthetic agent in the circuit. These anesthesia workstations have an optional CLIC system available, preventing loss of gas when the CO_2 absorber is removed and therefore preventing entrainment of air. However, not all workstations have such a CLIC system installed. In our opinion, stopping the ventilator by turning on the manual ventilation mode for the duration of the replacement of the CO_2 absorber (which should take <10 s) is an option when a CLIC system is not installed. Even then a small dilution effect will be seen, because the void space between the granules in the fresh CO_2 absorber is filled with air.

Anesthesia workstation manufacturers have reassured us that systems are in place that prevent the delivery of hypoxic gas mixtures. Unfortunately, anesthesia providers have mistaken this statement into believing that these systems prevent the formation of hypoxic inspired gas mixtures. "Delivered" refers to the gas that comes from the common gas outlet and enters the circle system, and the concentrations in inspired gas can be very different from delivered concentrations due to rebreathing of exhaled gas which occurs when fresh gas flow is lower than minute ventilation. The differences become more significant with lower fresh gas flow because there is more rebreathing. Even the most modern anesthesia work stations allow the use of only air as the fresh gas, and when fresh gas flow is lower than minute ventilation, this will always result in a hypoxic inspired gas mixture. De Cooman et al. [6] showed that the currently used hypoxic guard systems such as the S-ORC® (Dräger) (but also all others) do not prevent the development of a hypoxic inspired mixture with fresh gas flows that are considered not very low (0.7–3 L/min). Instead of relying on a hypoxic guard system with arbitrary thresholds, it would be much better to develop an automated system that controls fresh gas flow and composition based on measured inspired oxygen concentration in order to prevent the creation of a hypoxic inspired gas mixture.

Biro et al. [7] compared the volatile agent consumption as displayed on the Draeger Primus anesthesia machine, a calculated value, with actual consumption data determined by weighing the vaporizer before and after an anesthetic with a high-precision balance. The differences between displayed vapor consumption and actual consumption was small (7.6 % overestimation of sevoflurane consumption, 6.2 % underestimation of desflurane consumption). This degree of precision is adequate for individual cost analysis and for estimation of the pharmacoeconomic impact of strategies aiming to reduce overall cost. The presented cost analysis should be taken with a grain of salt, because the fresh gas flow with sevoflurane was more than twice that with desflurane. With current CO_2 absorbers, there is no reason not to drastically reduce fresh gas flow with sevoflurane. In addition, it was not determined whether potent inhaled anesthetic is lost from mounting and unmounting the vaporizer.

3 Monitoring anesthetic depth

Monitoring depth of anesthesia hinges on the definition of anesthesia. This definition is set to evolve as we gain a better understanding of what constitutes unconsciousness. In the meantime though, clinicians need a workable definition of anesthesia: a state of reversible drug-induced suppression of proper response to verbal command or shake and shout; immobility in response to a noxious stimulus (such as skin incision); and suppression of adrenergic response to an intense noxious stimulus (such as laryngoscopy). A combination of a hypnotic (propofol, inhaled agent) and opioid is most often used to achieve these goals, with or without the use of muscle relaxants. Confusion arises when the term "analgesia is used, because unconsciousness implies the inability to perceive pain. Clinicians might benefit form a monitor that helps them titrate hypnotics (EEG derived parameter, e.g. BIS) and opioids (anti-nociception monitors). Anti-nociception monitors most often display a parameter thought to reflect an aspect of autonomous nervous system activation that can be blunted with opioids. What have contributions to the journal in 2015 taught us about monitoring anesthetic depth?

Chang et al. [8] reviewed to what extent technology has succeeded in automating agent delivery using the targets defined above. They focus on intravenous agents—the use and value of end-expired agent monitoring is not addressed. It is written in a manner that remains accessible to the clinician, allowing the reader to place new devices discussed in the next paragraphs into the proper context. Present shortcomings and pitfalls are discussed, but it is concluded that, even though it may take a few more decades, technology ***will*** automate delivery of anesthesia.

In children, hyperventilation did not affect BIS nor blood pressure and heart rate during the induction period [9]. The work by Sachiko et al. serves as a reminder that ketamine does not affect the BIS, contrary to auditory evoked potentials [10]. Bollag et al. [11] found that a small dose of ketamine (0.5 $mg.kg^{-1}$) given after endotracheal intubation but before surgical incision did not influence the analgesia nociception index (ANI) either because it has no autonomic stimulation at this dose. The latter is important, because an effect on heart rate and/or blood pressure would have indicated autonomic nervous system activation, which would have interfered with the ANI being used as a nociception monitor.

Castro et al. [12] studied the effect of remifentanil and propofol on the amplitude and interpeak latency of cortical somatosensory evoked potentials (SEPs) after a painful median nerve stimulation in an attempt to discern the effects of these drugs on these parameters as an indicator of anti-nociception. "Pain" was assessed both as a subjective pain rating scale (NRS) and a normalized composite index of cortical SEPs amplitude and interpeak latency, R_{Norm}. The usefulness of the parameter as an index of anti-nociception was examined by linear correlation between the NRS and R_{Norm}. Significant correlation between R_{Norm} and NRS evaluations was observed in only 3 of the 9 volunteers; propofol also affected SEPs, interfering with the relationship between remifentanil concentrations and R_{Norm}. The approach is invasive (needle electrodes are need to monitor SEPs). As corroborated by Chang, more work is needed to define the ultimate place of anti-nociception monitors.

Eekevist and Johansson [13] found that the amplitude of the plethysmograph of the pulse oximeter (PV) had returned to baseline at the time of eye opening after anesthesia had been maintained with sevoflurane/N_2O, while the BIS had not; the processing delay of the raw EEG into a BIS value could explain this. The correlation (r^2) between PV and BIS during emergence was only 0.36, which may not be unexpected because PV and BIS are mediated by different neuroanatomical tracts and neurophysiological systems. Exploring whether a multimodal index incorporating additional "depth of anesthesia" parameters like return of pulse may further optimize prediction of wake up times seems like a rational thing to do.

4 Intraoperative neuromonitoring

Each of the three original intraoperative neuromonitoring (IONM) papers published in JCMC this year broke new ground in our understanding of IONM application [3, 5, 6, 14–16]. And each raised new questions. For example, how should we determine IONM clinical effectiveness in the future? [1, 17].

One limitation of transcranial motor evoked potential (TcMEP) recording is the variability of the response, including its amplitude (often measured in µVs up to a few mVs). The usual inability to record anything close to a supramaximal response has made the establishment of a generally agreed-upon alert criterion very problematic. Especially in patients with serious underlying neuropathology or non-ideal anesthetic conditions, baseline single pulse train recordings may be very low amplitude, poorly repeatable, or absent. Journee has quantified TcMEP amplitude enhancement by conditioning the test stimulus, using so-called double-train stimulation (DTS) [2, 18]. Tsutsui et al. [3, 14], using the Journee data, recorded abductor hallucis (AH) and quadriceps femoris (Q) responses after multiple pulse train stimulations (30 spine deformity patients). Each train consisted of five biphasic constant current pulses (500 µs duration). Remarkably, at each tested inter-train interval (500, 200, 100 ms), the AH and Q were steadily enhanced through the maximum of seven trains. No ill effects (tongue bite or seizure, e.g.) were encountered. The responses were best facilitated at the 200 ms inter-train interval. The significant risk of multi-train TcMEP is that the resultant enhanced body twitch (combined with surgical manipulation near the spinal cord) could result in serious injury. The authors did not encounter this potential problem. In our institution (Skinner), the most common reasons we deploy DTS are difficult anesthetic conditions, underlying dysfunction of the monitored motor pathway, or the need to record a proximal muscle (like the Q) which may respond poorly to single train TcMEP. Given the remarkable augmentation of TcMEP with DTS or multi-trains, a question arises: should investigators routinely deploy this conditioning technique in clinical effectiveness studies?

Total intravenous anesthesia (TIVA) has been recommended when recording TcMEP in a variety of IONM settings [4, 19]. Nevertheless, many anesthesiologists would prefer a background of low dose inhalational agent if it were feasible. Sloan et al. retrospectively examined patients that received either TIVA (propofol/opioid) or INHAL (propofol/opioid supplemented by 0.5 MAC/3 % desflurane) [5]. The anesthetic approach varied non-randomly by anesthesiologist preference in this observational study. "The TIVA group may have preferentially included patients with preexisting neurological or vascular compromise…". Also, three patients originally subject to INHAL, were switched to TIVA when no baseline SEP or TcMEP could be recorded. Nevertheless, the findings at least suggest similarity of (1) the required TcMEP stimulation voltage, (2) the scalp SEP and muscle TcMEP amplitudes, and (3) the trial-to-trial variability in each group. Also, INHAL may avoid the non-linear/on–off effect of higher dose inhalants. Despite many confounders, the authors tentatively conclude that, "… 3 % desflurane can be used *in some patients* [italics added] during the monitoring of cortical SSEPs and the muscle responses of TcMEPs." However, biased treatment selection, the many case exclusions, and other confounders may indicate the need for a large randomized controlled trial (TIVA vs. INHAL), which the authors specifically suggest.

Spine surgeons find the lateral, retroperitoneal approach increasingly attractive as an alternative to a standard anterior approach to the upper lumbar spine. But "trans-psoas" exposure can be fraught with danger to the upper lumbar plexus. Quadriceps (Q) weakness due to femoral nerve or more proximal plexus injury should be anticipated in a small fraction of cases. Therefore, many surgeons navigate this approach using free-run and stimulated EMG. The Chaudhary group has reported three cases which illustrate the utility of TcMEP to predict and prevent Q weakness in this setting [6, 16]. Two cases sustained unrecovered loss of the Q TcMEP during retractor opening near the spine. Both awakened with significant Q weakness. In a third patient, an alert (Q TcMEP loss) was followed in 3 min by retractor removal and Q TcMEP recovery (reversible TcMEP loss). That patient's motor function was intact post-operatively. Free-run Q EMG did not fire in any case. Stimulated EMG alert thresholds for dilators and retractors were not met but may have been set too low (dilator = 5 mA; retractor blades = 2 mA). Nevertheless, the authors' case report highlights the major rationale for IONM: early intervention to recover a lost signal and prevent neurological injury.

As IONM and other diagnostic test/monitoring applications in medicine improve, we are increasingly obliged to demonstrate their clinical effectiveness. In certain settings, randomized controlled trials can provide less confounded evidence for IONM effectiveness (as recommended by Sloan and colleagues) [5, 15]. However, understandable fear of patient harms associated with ill-considered randomization suggests alternative approaches that are currently under review [7, 8, 20, 21].

5 Locoregional anesthesia

With ultrasound imaging (US) becoming readily available in several operating rooms, it is bound to be applied in settings where it may have previously been considered superfluous. One such example is its use to determine the optimal site for needle insertion for epidural or spinal anesthesia. Nassar et al. found that US guidance of needle placement for combined spinal-epidural anesthesia improved incidence of proper placement on the first attempt (67 vs. 40 % for palpitation only), fewer punctures attempts (1.2 vs. 2.3) and fewer needle redirections (1.4 vs. 2.8) [22]. If better patient outcome (including discomfort during and after placement) can be confirmed in larger trials, the use of US might be worth the extra few minutes taken to perform the procedure.

Pressure monitoring during injection of a local anesthetic mixture when performing a peripheral nerve block may decrease the risk of intra-neural injection. Patil et al. [23] describe a simple yet reliable pressure gauge system made of readily available material: a three way stopcock and a 1 mL syringe placed in-line with the tubing used to inject the mixture. The degree of compression of the air bubble in the syringe proved to be a good guide to the injection pressure. Elementary physics, my dear Watson. An accompanying editorial suggests that the availability of such an inexpensive and reliable pressure monitoring device no longer gives us an excuse not to monitor the injection pressure when performing a peripheral nerve block [24].

6 Analgesia/pain control

Czerniki et al. [25] reviewed various aspects of intrathecal drug delivery for chronic pain patients. Gürkan et al. [26] found that echo-guided superficial cervical plexus blocks after thyroid surgery have a small effect on morphine.

7 Conclusion

The width of topics relating to anesthesia published in the journal in 2015 reflects the fact that anesthesia involves monitoring the integrity of every organ system in the body. The journal looks forward to continue to receive manuscripts relating to monitoring, and encourages authors to also consider the journal for work related to anesthesia equipment.

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