

Robots Will Perform Anesthesia in the Near Future

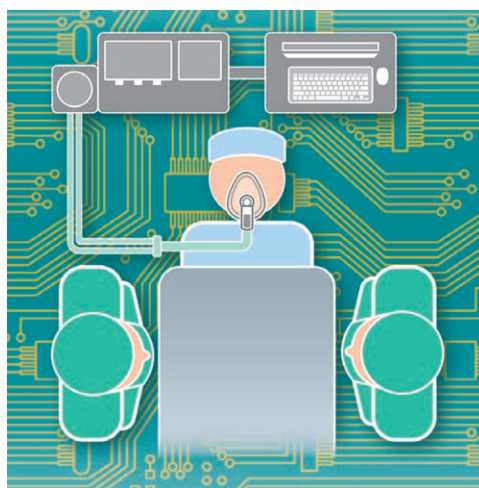
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In this month's edition, Joosten *et al.*¹ evaluated the performance of multiple closed loop systems for administration of anesthesia in 90 patients undergoing major noncardiac surgery in a single center. Anesthesia (hypnosis and analgesia), fluid administration, and ventilation were controlled by separate and independently working closed loop systems; the automated system outperformed manual control and had a significant, albeit minimal, beneficial impact on neurocognitive recovery after surgery.

In general, closed loop anesthesia control outperforms manual control²: anesthesia, sedation, fluid management, or ventilation all benefit from the use of automated systems. More recently, several of these closed loop systems have been investigated at the same time, with the study by Joosten *et al.*¹ being the first determining the superior performance of closed loop systems for all three components mentioned before.

A common theme of all these studies is that automated systems can keep a given target more closely than manual control, and this is not so much due to the specific form of algorithms or artificial intelligence used but simply due to automated systems more often changing the medication rate per unit of time. As Joosten *et al.*¹ show again, changes of propofol/remifentanyl infusions, fluid administration rates, or ventilation settings are much less frequently performed when humans control them.

The primary endpoint of this small study was the determination of cognitive function with automated *versus* manual control. There was significantly better cognitive function 1 week after surgery when closed loop control was used. With secondary analysis, the percentage of time of Bispectral Index lower than 40 was significantly correlated with a decrease in cognitive function, whereas end-tidal carbon dioxide less than 32 mmHg or mean arterial pressure less than 60 mmHg was not.



“When will robotic anesthesia become a daily reality?”

Independent from automated control, avoidance of low Bispectral Index values during surgery is an important message of this study, following the trend of recent findings.^{3,4} The wider question of this study seems to be the following: When will robotic anesthesia become a daily reality?

Robotic anesthesia, defined as anesthesia delivered by an automated control system, will soon be available. It is my opinion that closed loop devices will become available in the United States before target-controlled systems will be Food and Drug Administration–approved. I have used target-controlled system devices all my professional life, starting in the early 1990s; how-

ever, there are some important pitfalls. These devices appear like computer-driven anesthesia machines, but in fact running a target-controlled systems propofol pump without quantitative depth of anesthesia monitoring is challenging. Everyone who has used these devices over many years will have also noticed that their pharmacokinetic profile is slightly outdated by our modern patient population, who behave differently from the study population used to define the initial target-controlled systems algorithms.

One of the changes our profession has gone through is an ever-increasing demand to multitask, be it by running more than one operating room, or by simultaneously performing administrative or teaching tasks. In addition, the number of parameters to monitor has also increased. It is therefore not surprising that one of the common denominators of studies comparing closed loop control *versus* manual control is the finding that humans change a given target infusion rate far less frequently than closed loop devices do.

I have no doubt that the practice of running more than one operating room, common in the United States but less so elsewhere, will soon be an international standard. Closed loop devices will allow us to maintain a high standard of quality independent from the amount of physical presence.

Image: S. M. Jarret, M.F.A., C.M.I.

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Robotic anesthesia delivered in Washington by Dr. Smith would essentially be the same as robotic anesthesia performed in Chicago by Dr. Miller. Closed loop systems limit the influence of subjective knowledge or expertise to a minimum. Automated transmissions in cars have replaced the skill of manual shifting.

Anticipation of events as well as intuition is one of the biggest challenges when closed loop systems are designed: If one talks about the “human factor” of future developments, it will be our collaboration with robots by giving them valuable information only trained specialists are capable of providing. Indication of bleeding, surgical progress, or clinical observation of the patient’s status is just some information that is helpful and cannot be obtained by robots. When we developed our own closed loop robot, care was taken to allow input of the several surgical stages to adjust closed loop control similar to what a human would do: different stages, such as incision, or end of surgery can be put into the system.⁵

Closed loop systems will help us to perform better, allowing more standardized anesthesia delivery. Will we be replaced in the distant future? Maybe.

I think technology will advance similar to what we have seen and see in the car manufacturing industry. First, there was manual transmission, then automatic transmission, double clutch systems, navigation systems, all sorts of safety assist systems...soon, there will be self-driving cars.

Telehealth focuses on delivery of care of the highest standard anywhere at any time. It is obvious that in closed loop systems, pharmacologic robots have the potential to standardize anesthesia care throughout the world and make it accessible in areas where routine delivery of anesthesia by trained anesthesiologists is not available.

As interesting and promising as the future looks, there are some important avenues and technologic developments currently missing. We need more closed loop systems for sedation, and we need the development of truly “integrative” systems, since changes in ventilation, fluid, or anesthesia can impact each other. We need to find the best monitoring tool—and subsequent closed loop system—for pain control during unconsciousness. Most current systems confine themselves to Bispectral Index variability, and this author is not so sure that this is the best method. Maybe newer parameters, such as the nociception level index,⁶ might be a better parameter for pain?

How will we do anesthesia in the future? It is 2030 and I am scheduled to supervise anesthesia for a 40-yr-old patient undergoing laparoscopic cholecystectomy.

In the operating room, I tell my robot—let’s call it A-bot—about the surgery, the patient, and the type of anesthesia I would like performed. “Can I get a propofol, remifentanyl-based anesthesia? Can we target 45 as a Bispectral Index? A-bot, can you maintain mean arterial pressure around 65? Can you maintain cardiac index during surgery of more than $2.5 \text{ l} \cdot \text{min}^{-1} \cdot \text{m}^{-2}$? A-bot, I would

like to use rocuronium, bolus application is good enough, but please keep neuromuscular blockade lower than 25% at all times. Please choose a respiratory rate of 12 and adjust tidal volumes to maintain end-tidal carbon dioxide of 32 mmHg in 50% air! Let’s provide preemptive analgesia using morphine and ketorolac—usual dosages, A-bot, you know.”

A-bot answers: “Sure will, Tom—you keep me informed about surgical progress?”

“Yep.”

When I look at all the literature, including the fine work by Joosten *et al.*,¹ I have no doubt that closed loop anesthesia is at least as good as the best human anesthesia. And that, for me, would be good enough to use it every day.

Competing Interests

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