Computer-assisted Anesthesia Care: Avoiding the Highway to HAL

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Among the cautionary tales of computer-assisted human activity, *2001:A Space Odyssey* is a standout. On a journey to Jupiter, HAL the computer kills most of the crew, forcing the survivor to deactivate HAL. Like space travel, while computer-assisted health care has great potential it also contains the full Rumsfeld range of knowns and unknowns. In this edition of ANESTHESIOLOGY, Joosten *et al.*[1] report a randomized trial of computer-assisted hemodynamic management for 38 patients at a hospital in Brussels, Belgium. The researchers tested the hypothesis that patients managed using a computer-assisted system would experience less intraoperative hypotension (defined as a mean arterial pressure less than 90% of the patient's baseline value) during intermediate- to high-risk surgery when compared to patients in whom vasopressor and fluid administration were controlled manually. Consistent with their hypothesis and results, they concluded that computer-assisted hemodynamic management clearly outperforms standard hemodynamic management in intermediate- and high-risk abdominal and orthopedic surgery.

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As experienced researchers in this field, Joosten *et al.* expect integrated blood pressure and volume status closed-loop systems in the near future. However, the computer-assisted system tested in their study had two separate components: (1) an investigator-developed closed-loop system for vasopressor administration; and (2) a commercial decision support system for administering fluid boluses. The computer-assisted closed-loop blood pressure system used a PID-type controller,[2] a widely used technology that continuously calculates the difference between a desired setpoint and a measured variable and apply corrections using proportional, integral, and derivative terms (P, I, and D) that provide a combination of absolute deviation, trend, and the sum of past deviations. An everyday experience of PID controllers is cruise control in cars. In this study, the primary variable was blood pressure measured through a radial arterial line and mediated through a specific proprietary monitoring system. The response limb was a computer-controlled norepinephrine infusion. In contrast, the assisted fluid management system was a proprietary system that had open feedback loops and machine learning. The system provided anesthesiologists with advice on timing and size of manual fluid boluses, which the anesthesiologists could accept or reject (decision support), unlike the closed system. The anesthesiologists' actions were entered to further inform the system. Like the pressure closed-loop system, the fluid management system had input from the same proprietary monitoring device with algorithm variables including heart rate, mean arterial pressure, stroke volume, and stroke volume variation.

So why did Joosten *et al.*[1] find superior hemodynamic performance in the computer-assisted arm of their trial? The investigators do not explicitly discuss this in the current paper, but in a previous review[3] suggested several factors including more precise continuous monitoring and more rapid, less variable, responses. In the manually adjusted comparator group in the current study, there was an average of 15 changes in the rate of the norepinephrine confusion per patient, while in the computer-assisted group, there were over 1,200, suggesting much more fine-tuning in the computer-assisted group. Further, there was less norepinephrine used and a lower fluid balance, both with narrower interquartile ranges (greater precision), in the computer-assisted group.

Image: STRATUS Center for Medical Simulation, Brigham and Women's Hospital.

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In a recent review in Anesthesiology, Ruskin *et al.*[4] discussed safe use of automated medical technology. While they recognized the benefits of these operating room autopilots, they also identified unintended consequences including automation bias, skill loss, and system failures. In response to these risks, they recommend enhanced training for anesthesiologists in human–system interactions including vigilance, managing system failures, and maintaining manual skills. This reflects recent commentary on aviation autopilots[5] that includes warnings that pilots must (1) have extensive understanding about specific autopilots, including limitations and malfunctions; (2) constantly check that the autopilot is performing as wanted; and (3) train to both disconnect the autopilot in different situations and manually fly the plane. The benefits of autopilots[4,5] include allowing pilots to reduce the number of tasks they must simultaneously deal with and more time to anticipate future actions, as well as enhanced fuel efficiency and reduced costs.

While still an area of considerable research, the most important advantage of aircraft autopilots is improved aircraft safety in the real world.[5] This leads to a central question about the current study[1]: Does computer-assisted hemodynamic management improve important patient-centered outcomes?[6] The study by Joosten *et al.*[1] is an efficacy study[7] that asked whether this can work under ideal conditions. The answer is, yes, it can, if the outcome is hemodynamics in a hospital in Brussels. Now we need pragmatic large randomized effectiveness studies[7] asking whether this works in the broader real world. That is, we need multicenter randomized trials asking questions such as this: Compared to usual care, does computer-assisted hemodynamic management increase days alive at home among patients at medium to high risk of perioperative complications? The key will be the right population, the right intervention, the right comparator, and the right outcome(s). Cost/benefit is a further consideration. The advanced monitoring systems have fixed and disposable costs but possible savings from fewer complications and lower norepinephrine and fluid use. We also need to consider environmental costs. Further, as exciting as these new technologies can be, there are patients who are too healthy and/or having procedures too minor to justify using these technologies. Identifying patients who have no added benefit from these technologies is another important part of the value proposition.

Now to the controversial point of industry involvement. The healthcare industry is the primary source of commercialized technology. In part because proprietary algorithms and technology are an increasingly common "black box" part of anesthesiology practice, Ruskin *et al.*[4] call on companies to provide *comprehensive* manuals on system failures, particularly for automated systems. Further, when the time comes for large multicenter pragmatic effectiveness randomized trials of computer-assisted hemodynamic management, it may be appropriate for trialists with some distance from the relevant industry to undertake these trials to limit concerns about possible biases.[8,9] However, it is likely that industry would need to be a significant funder of any such trials, adding governance complexity, which is not insurmountable and requires considerable transparency.[9]

As our pilot counterparts are doing in aviation,[5] anesthesiologists should anticipate training in crises while using computer-assisted technologies, as well as maintaining the skills to "fly" manually. As experts, Joosten *et al.* look forward to "…independently operating automated systems…that manage hypnosis, analgesics, fluid and vasopressor administration."[1] This added sophistication and breadth increase both possible benefits and risks.[4,5] We must remember the prime directive remains patient well-being, and change must incorporate human factors.[4,5] None of us wants to manage a deteriorating patient by trying to deactivate a malfunctioning computer-assisted anesthesia system, only to have it respond, "I'm sorry…I can't do that."

Competing Interests

Dr. Story's department has received funds from Grey Innovations (Richmond, Victoria, Australia), a technology commercialization company.

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