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REVIEW ARTICLE

Interactive technology in obstetric anaesthesia and analgesia: exploring seamless solutions to jagged problems

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ABSTRACT
Perioperative care often involves treating rapid changes in a patient's physiological profile that requires timely intervention by anaesthetists. Interactive technology and closed-loop systems are currently developed in obstetric anaesthesia and analgesia for maintaining parameters during caesarean section and epidural analgesia. This review discusses the principles of interactive systems and the use of patient feedback to integrate these interactive systems. The components of an interactive system such as the input sensor or device, microprocessor-based control unit and the effector are introduced. Developments in continuous, non-invasive blood pressure monitoring, control algorithms and smart pump technology would help to redefine how technology can assist obstetric anaesthetists to provide better care and improve clinical outcomes for pregnant women.
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Introduction

Maintaining physiological parameters within tight limits in situations when rapid changes in physiological profile occur has always been a constant challenge to the anaesthetist. The effectiveness of therapy is often dependent on timely interventions and continual measurements of the desired physiological responses. The time lag and noise inherent to the monitoring systems employed can sometimes pose challenges that would undermine optimal treatment in this context. This situation is further complicated by the wide inter- and intra-individual variability in responsiveness to physiological alterations during anaesthesia and analgesia.

Anaesthetists are increasingly inundated with multiple obligations in an increasingly complex and demanding work environment; indeed, studies have shown that attention and reactions degrade as the number of tasks performed increases.[1,2] Therefore, the benefits of an automated and interactive system, including a closed-loop one, are relevant as this could potentially improve the efficacy and safety of treatment. The ability to automate previously manual tasks with constant repeatability, devoid of the risk of distraction, is an added advantage. Also, a closed-loop system renders a potentially cost-effective and efficacious way of providing individualised medicine; therapy could then be customised to the patient's needs.

A closed-loop system utilises a negative-feedback mechanism that ensures the constancy of any set variable or target pertaining to bodily functions; it essentially monitors a variable and intervenes as necessary to keep the variable at, more or less, a particular set value. Ideally, one such system would be able to achieve an optimal drug delivery of the right amount at the right time to increase efficacy and improve safety. Outside of anaesthesia, these systems are already ubiquitous in everyday life, from maintaining a set temperature in central air-conditioning to keeping a jumbo-jet at a specific cruising altitude in autopilot systems. In medicine, they are used in implantable pacemakers and defibrillators.

At present, most aspects of perioperative care require manual involvement of the anaesthetist. Fully automated closed-loop systems are rarely used for a multitude of reasons, including the challenges posed by the great complexity of the human biological system, inaccuracies in the actual measurements of the parameters, the multiple processes required by regulatory approval and the barrier of peer acceptance of new technologies.[3,4] The landscape is gradually changing as automated systems have been developed to maintain neuromuscular blockade,[5] insulin therapy,[6] surgical anaesthesia,[7] and ventilation and oxygenation.[8]

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Recent advances in real-time non-invasive monitoring and microprocessors suggest that the use of interactive systems in perioperative care, intensive care and pain management is becoming an achievable goal. In this review, we describe the interactive systems that have been developed for epidural analgesia that are regulated by patients' feedback to individualise drug delivery during labour.[9–12] We examine current literature on novel systems which have been recently developed to automatically select and administer vasopressors to maintain patients' blood pressure while undergoing caesarean section under spinal anaesthesia.[13,14] We also discuss the general principles of these interactive systems and explore ways in which these systems, which were developed based on integrating information obtained from patients' feedback, might be potentially useful and implementable in obstetric anaesthesia and analgesia.

Overview of the control methods of interactive systems

An interactive system can be conceptualised as a three-link chain, with the effectiveness of the entire system dependent on the integrity of the weakest link: (1) an input measurement sensor or device; (2) microprocessor-based control unit; and (3) an effector that attempts to return the measured variable to the set-point (Fig. 1). Conversely, in our current practice, input and effector components exist separately in an open loop, with the anaesthetist closing the loop by performing analysis of the input data and controlling the effector.

The first link requires a device that measures the variable and exports reliable data to the microprocessor controller unit. In the context of obstetric anaesthesia and analgesia, the device should suitably procure data non-invasively while permitting a relatively hands-free operation. Apart from being easy and quick to set up, this device should also desirably be able to provide continuous, accurate and precise data.

Data are then utilised by the second link: a microprocessor-based controller, which uses an algorithm to determine if intervention is required. An ideal controller achieves the set point with minimal delay and with little deviation, including overshoot, from the set-point, producing a stable output over time. As physiologic systems have little tolerance for rapid fluctuations or deviations from the target, the controller must meet very strict performance criteria in order to be clinically useful. Being the 'brains' of the system, the type of control method and algorithm used have a large impact on the reliability, efficacy and limitations of the whole system.

Lastly, it behoves the effector to execute the required intervention to attempt to restore the variable to the original set-point. This usually takes the form of adopting and adapting currently existing therapy in accordance with best clinical practice. The closed-loop system usually seeks not to exact treatments which are in significant departure from the current; instead it provides an

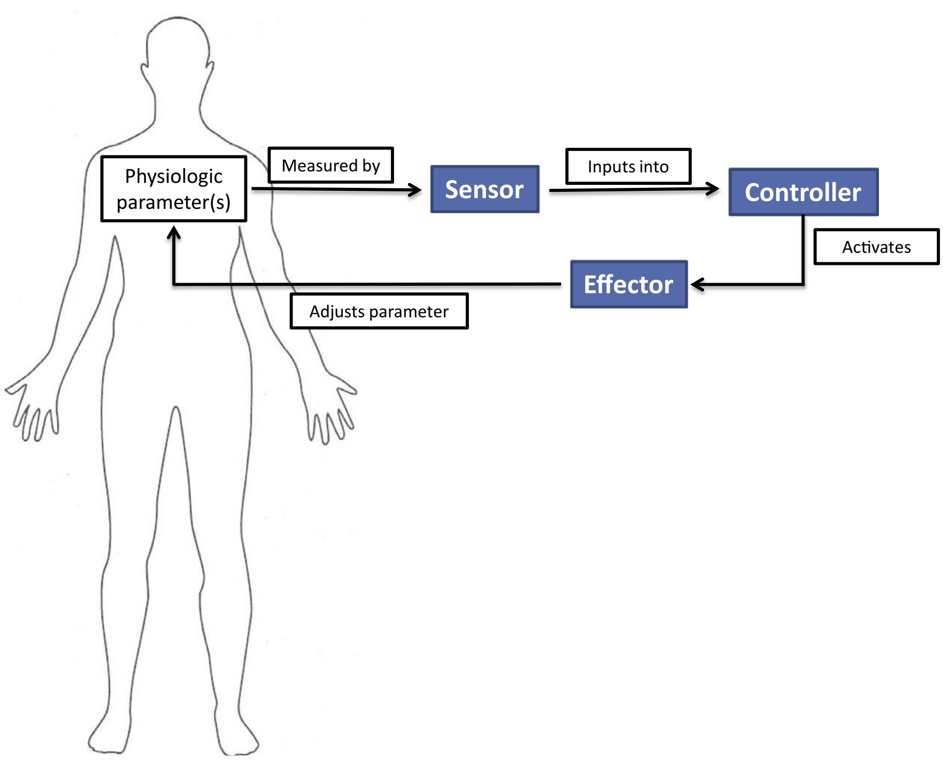

Fig. 1 The three-link chain of an interactive system demonstrating the sensor, controller and effector

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