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EDITORIAL

Clinical reasoning in anaesthesia includes but is not replaced by sophisticated monitoring

In this issue of the Journal, Schwartz et al. [1] investigated in an observational study the capacity of the BIS monitor to estimate the adequacy of anaesthesia in infants, children and adults that underwent general anaesthesia. They measured the BIS values for 10 minutes in patients for which the anaesthesiologists "believed" that anaesthesia was adequate while the patient was in a "steady state", that is approximately 15 minutes after incision for a variety of surgical procedures. They found that in 42% of infants (less than 1 year-old) and in 38% of children aged 1 to 10 years, but also in adults (16%), the BIS values were above 60 (a value of BIS below 60 is considered to be associated with a probability of nearly 100% of loss of consciousness) although they seemed adequately anaesthetized by other criteria such as lack of movement, haemodynamic stability and lack of bucking. Of interest, one adult (1%), 13 (21%) infants and 18 (10%) children had a BIS level $\geq$ 70. They concluded that in many children but also in a non negligible percentage of adults, BIS values above 60 were associated with clinical signs of adequate anaesthesia.

There are two issues concerning this study that are of potential interest for the readers of the journal: (i) what can explain these results; (ii) what should one do with this information for routine clinical practice.

There are several explanations for these results. The first of them concerns the development of BIS. From a complex signal, the electroencephalogram (EEG), the BIS algorithm, that underwent several revisions, used mathematical and statistical tools to derive a unique numerical descriptor, the BIS value [2]. Both mathematical and statistical approaches were necessary to obtain a (nearly) monotonous linear relationship between on one hand the concentrations of hypnotic drugs (both intravenous and inhaled) and on the other hand the BIS values and clinical estimation of the depth of sedation [2]. Several subsequent studies demonstrated that the probability of loss of consciousness was nearly 100% for BIS values below 50 to 60 [3, 4]. This is the origin of the "magic" BIS value of 50-60.

The fact of defining a value (for any monitor) and dichotomizing anaesthesia according to this value into adequate or inadequate is by itself a conceptual and practical problem. Routine clinical practice demonstrates that anaesthesia is a continuum of states that depend on the pharmacology but also on the level of nociceptive stimulation. Since the level of nociceptive stimulation is not constant and is difficult to measure, it seems difficult to categorize anaesthesia as adequate or inadequate using a single criterion.

In addition to this conceptual limitation, it must be remembered that the BIS monitor was never developed in children or in infants and its use was "extended" to the paediatric population with very altered diagnostic performance in infants less than 1 year-old and reasonable diagnostic performance for children above 2 years, when the EEG is similar to the adult EEG pattern [5]. It is therefore no surprise that in the article of Schwartz et al. in infants and children there was a discordance between BIS values above 60 and anaesthesia considered as adequate by clinical and haemodynamic signs. The authors correctly investigated the possibility that the doses of opioids or the level of nociceptive stimulation induced by the type of airway control device (tracheal intubation versus laryngeal mask) could influence the BIS value but they found no statistically significant differences for these variables in infants and children with BIS values below or above

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60. Therefore, the most obvious explanation of the results presented by Schwartz et al. is that given the mathematical and statistical approaches that contributed to the development of the BIS algorithm, its use cannot be extrapolated to infants and can be extrapolated with caution in children. Nevertheless, there were also adults for which anaesthesia seemed adequate by clinical signs despite BIS values above 60. This is probably explained by other factors such as the study design, the presence of opioids that would subtly alter the hypnotic concentration versus BIS relationship or a short duration of BIS values above 60 or the inaccuracy of clinical signs in estimating anaesthesia. Indeed, it has been shown that clinical signs by themselves are not a gold standard and the patients can have signs of adequate anaesthesia and some form of preserved consciousness [6].

What are the practical clinical implications of these results? Despite its complexity, the BIS monitor, like any other monitor used in anaesthesia, cannot be a substitute for clinical reasoning. Inadequate anaesthesia is a diagnosis and there are very few diagnoses that are made in medicine on a single criterion. Anaesthesia is no exception to this. As the authors correctly state in their conclusion, the diagnosis of adequate/inadequate anaesthesia should be made on several criteria that can include the BIS values. Such criteria should be clinical, haemodynamic, pharmacological and EEG-derived. In addition to the technological sophistication that allowed the transformation of the complex EEG signal into a unique numerical descriptor, the BIS monitor provides the analogue EEG signal and several other processed information that can allow the user to identify artefacts or situations where the relationship between the concentrations of anaesthetic drugs, the level of nociceptive stimulation perceived by the cortex (which is attenuated in the presence of regional anaesthesia for instance) is altered. The higher the number of confounding factors (chronic medication, haemodynamic instability) the more difficult it is to diagnose adequate/inadequate anaesthesia on single or few criteria.

In conclusion, the results of Schwartz et al. demonstrate that one should not use or use very cautiously a monitor that was not validated in a specific population of patients (in this case the BIS monitor in infants and children) and that one should not make diagnoses of complex clinical situations (such as adequate/inadequate anaesthesia) with single criteria.

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