Transesophageal Doppler ultrasound and hemodynamic monitoring during regional anesthesia in pediatrics

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Key points

The transesophageal Doppler is a minimally invasive method for the continuous monitoring of cardiac output in pediatric patients, neonates and infants. It is able to provide a useful clinical assessment of a great number of hemodynamic parameters and their changes during many anesthesiological procedures and pediatric intensive care. The literature recently published indicate that Doppler cardiac output measurements are acceptably reproducible in children with best results when used to track changes rather than absolute values and using the transesophageal approach.

Introduction

Pediatric and neonatal anesthesia has always been characterized as a subspecialty discipline so it must be practiced by physicians with proven expertise in the field. Achieving high levels of quality, professional qualifications and the application of advanced anesthetic techniques ensure safety and efficiency of care. The high technical level of a center of pediatric anesthesia is demonstrated by the application not only of common and standard techniques but through the execution of complex and innovative procedures. The application of ultrasound regional anesthesia techniques without endotracheal intubation in the newborn, for example, has a positive impact on users (parents and children) and on the levels of quality outcome. The intraoperative anesthetic management with the use of new technologies can ensure greater safety in these little patient. The application of modern systems of non-invasive monitoring, such as the use of ultrasound Doppler effect by transesophageal probe (CardioQP, Deltex Medical®) allows us to analyze in real time all hemodynamics changes during surgical procedures and represents the attainment of very high standard in anesthesia (Figure 1). At the same time, the combined application of advanced techniques of anesthesia and monitoring allows a scientific evaluation of the results obtained by analyzing some of the data and the comparison with standard procedures.

Pediatric transesophageal Doppler hemodynamic monitoring

Measurement of hemodynamic parameters can occur through a variety of methods both invasive and non-invasive. In pediatric age the use of non-invasive systems is certainly to be preferred, not only to avoid the well-known complications arising from all invasive instrumentation but also to extend its application in critical clinical situations. Hemodynamic monitoring through transesophageal pediatric doppler probes has seen its beginnings since 1996. They can be used over the whole range of pediatric reliably (1, 2). The use of pediatric probes, although they are non-invasive, requires some training and care (3) as can be used also in little neonates. The monitoring system most used (CardioQP, Deltex Medical®) is constituted by a
monitor which shows all the requested hemodynamic information both in numerical and graphical form-doppler and a probe specific for single-patient pediatric use (KDPn-Kinder Doppler Probe®). The probe contains two Doppler transducers (4 MHz) and a connector at the opposite end. The probe is equipped with a metal spring closed, which gives not only flexibility and mechanical strength but also the possibility of a certain torsion about its longitudinal axis. It has a length of 70 cm. and must be inserted orally under general anesthesia or deep sedation. The probe presents markers depth: the first and the last are situated at a distance of 15 and 40 cm from the tip and 5 cm. from each other. The depth of esophageal insertion is essential, particularly in the pediatric age, since the acquisition of the signal is related to the physical variables characteristics of children. In fact, the monitor must always be preset by entering the age, weight and height. For example, in a child of 50 cm. height the probe should be inserted to a depth of 15-20 cm. while in a child of 100 cm. the acquisition depth can reach 30 cm. This device takes advantage and use the ultrasonic Doppler effect and provides real-time data on the left ventricular outflow. According to the Doppler principle the perceived frequency of a sound wave or light reflected from a moving object changes in proportion to the relative speed between the object and the receiver. The esophageal probe directs a beam of ultrasonic wave at 4 MHz to the descending aorta blood flow. The movements of blood cells cause a variation of frequency of the reflected waves which is analyzed by the system as blood velocity per unit of time. The monitor displays a variable wave morphology specific for each clinical situation, analysis of which allows to extract a large number of cardiovascular parameters.

**Hemodynamic parameters**

This device can analyze a significant number of hemodynamic parameters listed below:

- Heart Rate (HR), the number of heartbeats per unit of time, widely variable from premature babies to older children.
- Stroke Distance (SD), is the distance in cm that a column of blood moves along the aorta with each contraction of the left ventricular of the heart
- Distance Minute (MD), distance a column of blood moves through the descending thoracic aorta per minute
- Stroke Volume (SV), blood volume ejected during each systolic phase
- Cardiac Output (CO), blood volume ejected by the heart in one minute.
- Cardiac Index (CI), the cardiac output normalized for body surface area.
- Stroke Volume Index (SVI), stroke volume normalized for body surface area.
- Peak Velocity (PV), peak velocity of blood flow in systolic phase
- Flow Time Corrected (FTc), systolic flow time corrected for heart rate
- Flow Time Peak (FTP), time in milliseconds between the beginning of the systolic phase and the point at which the maximum speed is detected.
- Mean Acceleration (MA), average acceleration of blood from start of systole to detected peak velocity
- Systemic Vascular Resistance (SVR), the resistance that the left heart pumps against; measure of left ventricular afterload. It’s important to measure central venous pressure (CVP) to get this data.
- Systemic Vascular Resistance Index (SVRI), systemic vascular resistance normalised for body surface area.

**Hemodynamic effects of epidural caudal anesthesia and transesophageal Doppler evaluation**

It has been well demonstrated that epidural caudal anesthesia ensures a good hemodynamic stability in pediatric patients. The reasons for this stability are based on two fundamental reasons:

1) a reduced sympathetic tone than adults
2) a reduced "handling" of blood volume relatively to the lower limbs denervated by the anesthetic block (4). These concepts have been repeatedly discussed by several authors in the literature over the years particularly about the role of sympathetic tone and vasoconstriction in areas not denervated and/or denervated by anesthetic block through a mechanism hemodynamic compensation (5, 6, 7). In fact one of the most interesting aspects is represented by the hemodynamic effects of pediatric neuroaxial and/or blended anesthesia on cardiac output (CO). As we affirmed, in pediatric age is hardly to use invasive methods in large-scale study or to analyze this type of problem. On the contrary, the use of monitoring systems that exploit the transesophageal Doppler effect allows to obtain interesting data not only on CO but also on all the numerous parameters that have been listed. In this way it is possible to have all the data to reach interesting conclusions and finally settle the question about the hemodynamic stability during continuous infusion of local anesthetics during epidural and caudal anesthesia in pediatric patients. During blended and combined anesthesia there may be non-negligible drugs interactions. The purpose of blended and combined anesthesia is to reduce the respective drugs dosages in order to limit undesirable toxic effects. Staying within a precise range in intraoperative anesthetic management, one can realize a technique of anesthesia with minimal concentrations of drugs useful in obtaining an excellent level of anesthesia and analgesia. The use of depth of anesthesia monitoring systems such as the BIS and Entropy, can help even if give questionable results especially with the use of Entropy and in younger children. It was agreed that the mean arterial pressure (MAP) and heart rate (HR) did not change significantly. Hemodynamic changes must be considered significant if we observe an increase or decrease in MAP and HR of more than 20% compared to baseline values at the time of the skin incision. For some authors is permissible to bring this limit even to 30% in view of the fact that these parameters could be influenced by adrenaline used for the execution of the epidural test dose. The role of adrenaline, in this context, it seems doubtful or at least irrelevant due to the effect of compensation exercised by halogenated and by opioids. The increase in both the blood flow of the descending aorta (ABF) and aortic stroke volume (ASV) may be the direct consequence of the reduction of the vascular resistance in the lower
body districts of children. This mechanism could be more evident with the use of old generation local anesthetics such as bupivacaine. Ropivacaine and levobupivacaine, at pediatric dosages and due to the sensorimotor dissociation that makes them unique and preferable together with the lower toxicity, may have a reduced influence on SVR and, consequently, on ASV and ABF. CO remains unchanged and this parameter is already a significant element of hemodynamic stability recorded especially during long-duration surgical procedures. In the adult, however, it has been demonstrated that epidural anesthesia may also reduce the CO of 20%. This aspect is confirmed by doppler transesophageal systems and by thermodilution technique. It is also useful to point out that the esophageal probe can be inserted with the baby in different positions on the operating table without producing artifacts or significant changes in the reliability of the signal wave reproduced on the screen. Moreover, the system is also useful to evaluate hemodynamics during postural changes that some surgical procedures require. An interesting study conducted by Monsel (8) has demonstrated a significant reduction of HR and an increase in terms of SV while the CO was unchanged. The common denominator is still represented by the stability of CO while the HR, stable in other studies, for Mansel is reduced. The increase of SV together with a reduction of SVR (9) could be related to a reduction in afterload versus an unchanged preload because of arterial vasodilation induced by epidural anesthesia.

It should be specified that in the pediatric patient, especially in little infants, the parameter SV is afterload-dependent due to the low weight of the myocardium, typical for this age group. Returning to the evaluation of heart rate (HR) and mean arterial pressure (MAP), it is our opinion that it is necessary to be careful to initial baseline parameters before starting a regional block anesthesia and avoid overdose of inhaled anesthetics and opioids which may interact with local anesthetic. It has been well demonstrated the mutually reinforcing effects of summation of local anesthetics, halogenated and opioids.

Conclusions

The use of neuraxial regional anesthesia techniques combined with an advanced non-invasive monitoring that uses the Doppler effect by transesophageal probe represents a demonstration of the highest professional standards that the pediatric and neonatal anesthesia has reached in recent years. Both techniques are safe, effective and applicable in routine situations while there is no doubt their benefit in acute life-threatening. The regional anesthesia in pediatric and neonatal and its safety is already well-established by international literature. Time is not far distant when, on the first books of pediatric anesthesia, we read “the child is an indication for general anesthesia.” All far from the truth. The availability of advanced monitoring allows us to give scientific demonstration in order to remove any doubt. The performance of regional anesthetic procedures on-site, especially on newborns and infants, and the application of advanced monitoring systems, necessarily requires high professional competence. It’s opinion of the scientific community that there cannot be improvised pediatric anesthetists especially in hospitals in which operations are performed on premature severe infants (VLBW - Very Low Birth Weight and ELBW - Extremely Low Birth Weight).

References