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Regional Anesthesia and Sedation. Monitoring with Oximetry and Capnography Increases Patient Safety During Procedure

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ABSTRACT

Regional anesthesia provides numerous benefits to patients throughout the perioperative period, including improved comfort and satisfaction with pain control, less nausea and vomiting, and expeditious recovery and discharge. Sedation during surgery undern regional anesthesia plays a central role in facilitating patient comfort and anxiolysis. In recent decades the commonest medications used for sedation are midazolam, propofol, ketamine, dexmedetomidine, remimazolam and each possesses well-known pros and cons. The phrase "while some sleep, others keep watch," along with monitoring, plays an important role in patient safety regarding sedation in regional anesthesia or other procedures. There are two important monitors during sedation: pulse oximetry and capnography. However, most anesthesiologists only use the pulse oximeter, even though capnographs are attached to all modern anesthesia machines. This article demonstrates the importance of using both pulse oximetry and capnographs for patient safety during sedation in regional anesthesia and other procedures. The combination of the two monitoring systems certainly increases patient safety.

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Introduction

When I did my residency in anesthesiology in 1975, we didn't have any monitors to track patients. Monitoring was done with a stethoscope on the precordium and in the ear, blood pressure was assessed with an old device, and a finger was placed on the temporal pulse, which would disappear when systolic blood pressure dropped to around 80 mmHg or less, and this has a physiological explanation. The temporal pulse is superficial and depends on systolic pressure being sufficient to generate a palpable pulse wave in a small, peripheral artery [1,2].

The phrase ***"while some sleep, others keep watch"*** attributed to Lao-Tse, a 5th century BC Chinese philosopher, was taught to me by my professors during my anesthesiology residency, as described above, and never leave the patient alone. In 1988, 14 cases of ***"Unexpected Cardiac Arrest During Spinal Anesthesia"*** were published, showing that there were four nurses and the anesthesiologist attending to several rooms, with cyanosis being detected by the surgeon four times and by the anesthesiologist or nurse three times [3]. In the editorial about these 14 cases, it was said that during sedation cyanosis preceded cardiac arrest, a fact cited in seven of the 14 patients, since it only occurred in one patient before the surgical procedure and in the remaining 13 after the start of surgery [3,4]. Perhaps a lack of monitoring and surveillance could explain the occurrence of cardiac arrests during the surgical procedure. And in the discussion, the authors state: "these observations suggest that respiratory changes produced by sedation may have played an important role in approximately one-half of arrests" [3].

Monitoring Respiratory System

Given the numerous cases of unexpected cardiac arrest during sedation, monitoring the respiratory system is essential for safe sedation during RA or other procedures performed with sedation [3]. The appearance of hypoxia during RA and sedation has been identified as the main cause of cardiac arrest, with hypoxia being difficult to detect clinically until an advanced state, which was better monitored with the advent of the pulse oximeter, initially in Japan, showing the need for continuous respiratory monitoring is necessary and fundamental during the surgical procedure and in transport to PACU [6,8,9]. Continuous use of a pulse oximeter assesses the following parameters: peripheral oxygen saturation (SpO_2), pulse rate and heart rate, pulse waveform, and perfusion index (**Figure 1, Table I**).

Figure 1: Oximetry and Pulse Waveform During RA Sedation

Table I: Monitoring with an Oximeter Assesses

Parameter	What it indicates
SpO_2 (oxygen saturation)	How well oxygen is being transported by the blood
Pulse rate (bpm)	How many heart beats per minute
Plethysmography waveform	Representation of the pulse over time
Perfusion index (PI)	Peripheral pulse strength

Capnography means the continuous recording of CO_2 partial pressure in inspiratory and expiratory gases. The $EtCO_2$ is the concentration of CO_2 measured at the terminal portion of the exhalation curve that represents gas coming from the alveoli [10]. This value has been shown to correlate closely with the $PaCO_2$ [10]. Capnography has been shown to be an excellent monitor for checking intubation, apnea, obstruction, pulmonary embolism, and malignant hyperthermia. Therefore, $EtCO_2$ monitoring should be part of all RA procedures with sedation (Figure 2, 3, Table II).

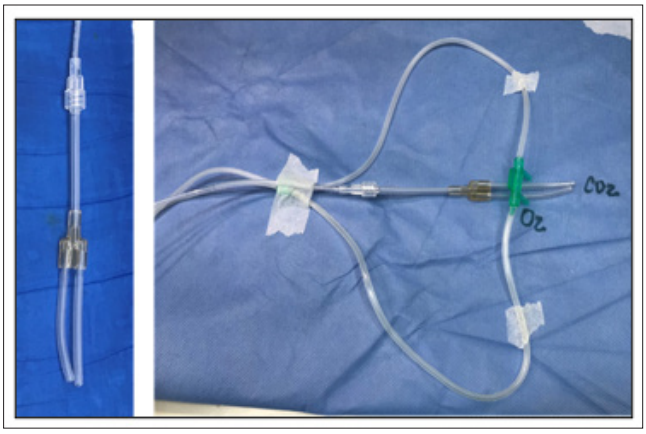

Figure 2: Set with O_2 Catheter and Nasal CO_2 Catheter, for Monitoring During Sedation

Figure 3: Ideal Set Designed by the Group and Capnography Curve During Sedation

Table II: Monitoring with an Capnography Assesses

Parameter	What does it represent?
$EtCO_2$ (End-tidal CO_2)	Partial pressure of CO_2 at the end of expiration
$FiCO_2$ (Inspired CO_2)	CO_2 present in the inspired gas
Capnographic curve (waveform)	Graphical of CO_2 throughout the respiratory cycle
Respiratory rate (RR)	Number of respiratory cycles per minute
Alveolar CO_2	CO_2 concentration in phase III of the curve
$PaCO_2$ – $EtCO_2$ gradient	Difference between arterial and end-expiratory CO_2
Estimated physiological dead volume	Portion of ventilation without gas exchange
Estimated minute ventilation	Product of respiratory rate and tidal volume

Confusion in Studies

The central issue with surveys stems from a recurring confusion, even in established publications, between sample size and response rate, two statistically distinct concepts that play completely different roles in the validity of a study [11,12]. The study by Auroy et al, frequently cited as a reference on serious complications in RA, exemplifies this methodological limitation [13]. Of the 4,927 anesthesiologists initially invited, only 736 responded to the preliminary questionnaire (rate of 14.9%) and agreed to participate in the subsequent prospective period, any calculated incidence refers only to the subset of anesthesiologists who self-selected for the study and cannot be extrapolated to the general population [11,12]. A total of 103,730 RA procedures were performed, including 40,640 spinal anesthesia (SA), 30,413 epidural anesthesia (EA), 21,278 peripheral nerve blocks (PNB), and 11,229 intravenous regional anesthesia (IV) procedures, with 32 cardiac arrests, 26 (0.063%=6.3% per 10,000 patients) of which were performed with SA, 3 with EP and 3 with IV (0.01%=1% per 10,000 patients) [13]. Sedation and various drugs used, and monitoring during the procedures was not reported in this study. Prospective surveys should be interpreted as descriptive instruments internal to the responding group, and not as epidemiological studies capable of quantifying the actual incidence of adverse events in regional anesthesia [14].

Sedation Drugs and Monitoring

Sedation administered with various drugs such as midazolam, propofol, dexmedetomidine, ketamine, remimazolam and others, during surgery under RA plays a fundamental role in providing comfort and anxiolysis for patients. A recent historical cohort study of 1,588 patients who underwent primary total knee and hip arthroplasty under SA showed that the use of dexmedetomidine was a strong risk factor for postoperative hypotension [15]. In this study, there is no description of EtCO2 monitoring.

In 2021 recommendations for monitoring during anesthesia and recovery, suggests for RA requires minimum monitoring of ECG, NIBP and SpO2 which should begin before the procedure, and should be continued for at least 30 min after block completion [16]. The capnography should be used in patients whenever there is loss or likelihood of loss of normal response to verbal contact [16]. In my experience, capnography has been used extensively during sedation in the RA, because this monitor is always connected to the anesthesia machine being used always associated with pulse oximetry monitoring, and because it increases patient safety under anesthesia (Figures 1,2,3).

In a systematic review using an electroencephalogram-based depth of anesthesia monitor provides an alternative method to monitor level of consciousness that can be used in addition to clinical observation, during sedation and analgesia [17]. In another systematic review aimed at verifying an important potential clinical benefit of using capnography monitoring during procedural sedation and analgesia, and whether this monitor could improve patient safety by reducing the adverse effects of sedation [18]. This review showed evidence of a significant clinical benefit with the continuous use of capnography with EtCO2 monitoring during sedation and analgesia in hospital settings.

By evaluating several articles on pulse oximetry and capnography, and various guidelines for monitoring during surgical procedures under sedation and regional anesthesia, the best parameters to be monitored, the methods used, and the important observations were identified (Table I).

In 2020, the Sociedade Brasileira de Anestesiologia (SBA) published an updated recommendation for safety in regional anesthesia through a systematic review [19]. This systematic review did not address monitoring for sedation safety during RA. Because the topic of sedation during RA was not addressed, which improves patient comfort, and because the use of pulse oximetry and capnography certainly increases the safety of sedated patients. In the latest standards for basic anesthetic monitoring developed by the ASA committee on practice parameters published in October 2025, it states that during all anesthetics, the patient's oxygenation, ventilation, circulation and temperature shall be continually evaluated [20]. The European Board of Anesthesiology recommends that during regional techniques and sedation for operative procedures, patients should be monitored with the following devices: pulse oximeter, non-invasive blood pressure monitor, electrocardiograph, capnography for moderate and deep sedation included from 2011 [21].

A modern and safe assessment of sedation for rheumatoid arthritis or other procedures such as endoscopies, colonoscopies, radiotherapy, magnetic resonance imaging, computed tomography, etc., should utilize both pulse oximetry and capnography (Table III). In mandatory basic monitoring during regional anesthesia, it is stated that capnography should be used continuously in all patients undergoing sedation in RA or other procedures, which is not actually the case in most of these procedures. This monitoring for sedation using both monitors should be part of the guidelines of all Anesthesiology Societies worldwide.

Table III: Mandatory Basic Monitoring During Regional Anesthesia and Sedation

Parameter	Method	Observations
Oxygenation	Pulse oximetry	Continuous with audible alarm
Ventilation	Capnography	Continuous in all patients
Circulation	ECG	Required for all patients
Blood pressure	NIBP	Every 5- minutes
Level of consciousness	Ramsay scale	Periodic evaluation
Deep sedation	Capnography + O_2	Mandatory + Supplemental O_2
High-risk patients	Capnography + O_2	Mandatory + Supplemental O_2

Conclusion

Pulse oximetry was first used in Japan. The clinical use of capnography had its beginning in World War II. The German Navy had excellent submarines, which could remain submerged for long periods, and each submarine was equipped with CO_2 absorbers, and it was already in use at the University Hospital of Utrecht in 1959 [7]. In an article on the history of capnography, he reported all the possibilities of monitoring with the aid of capnography: metabolism, circulation, lung perfusion, lung diffusion, position of the endotracheal tube, patency of the tube, quality of spontaneous respiration, patency of the airways, functioning of the ventilator, state of the connecting tubing, activity of the CO_2 absorber, effect of drugs used in anesthesia and position of the patient on the OR table [7]. Given all the monitoring possibilities with a capnograph that is always attached to the anesthesia machine, the question arises: why don't anesthesiologists use this monitor for patient sedation during regional anesthesia? It can't be a lack of

knowledge about the monitor for capnography, since it's used in all general anesthesia, and it certainly increases the monitoring of various parameters, and provides safer sedation for patients.

The combination of pulse oximetry and capnography during sedation in regional anesthesia, or sedation for other procedures, would likely greatly increase patient safety in preventing complications. The creation of a catheter that incorporates both pulse oximetry and capnography monitoring should be a future project for manufacturers. The existence of this potential catheter (suggested in Figure 2) would necessitate that all sedation procedures be monitored by pulse oximetry (SpO_2) and capnography ($EtCO_2$). Despite guidelines recommending oxygen use only during deep sedation or for high-risk patients, the use of pulse oximetry and capnography increases patient safety during procedures.

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