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Correlation between Monitoring Practices during Anesthesia and Patient Recovery after Complicated Surgeries-Anesthesia

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Abstract

Introduction: The monitoring in anesthetic practice is referred to the observation and assessment of several physiological variables of the patients such as cardiac output, depth of anesthesia, stroke volume, cerebral and tissue oxygen, joined with parameters evaluating the technological monitors of anesthesia measurement such as EEG or AEP. The frequency of severe complications related to Anesthesia seems to have diminished lately. However, anesthetic accidents remain occurring as well as a prolonged state of unconsciousness from anesthesia continues to be one of the severe challenges that involving an anesthesiologist.

Aim and objectives: The current study primarily aims to describe the role of anesthesia and patient monitoring; some of the available monitors and indicate how their combined use might be beneficial in managing the morbidity and mortality in patients undergoing complex surgeries.

Methodology: The current study adopts a method of critical review for evaluation of literature by referring to various electronic sources including Google Scholar, PubMed, PubMed Central, Cochrane Library, Science Direct, etc. for studies between the period of 2002 and 2019. Specific search terms of "anesthesia," "anesthesia monitoring" and "surgery" are used to retrieve articles.

Results: It was found that the research in anesthesia and patient monitoring has immensely reduced the mortality and morbidity in patients. Further, the majority of publications considered the bispectral index as an anesthesia monitor and only a few publications that reported improved monitoring methods.

Conclusion: In conclusion, although there is research evidence proposing that the use of individual new monitors such as assessment of bispectral index, depth of anesthesia, tissue oxygenation and blood flow can affect the patient outcomes, it will only be their combination that will enormously improve the pre, intra- and postoperative complications, pain management and clinical outcomes of high-risk patients undergoing complicated surgeries.

Keywords: Anesthesia; Monitoring; Awareness; Surgery; Ventilation; Circulation

Introduction

Anesthesia is characterized as a balance between the measure of the administered drug(s) and the patient's state of arousal [1]. Monitoring practices during anesthesia are required for preventing associated risks such as awareness or excessive anesthetic depth and for improving patients' outcomes [2]. It encompasses both the technical process of monitoring and its purpose, which is primarily 'regulation and control' as part of a complex feedback and control system. Despite advances in anesthesia and surgery, perioperative morbidity and mortality remain essential health care problems [3]. According to a study conducted at Harvard, 8 out of 11 intraoperative accidents could have been prevented by earlier detection with pulse oximetry, capnography and analysis of inspired oxygen content, i.e. by following better monitoring practices [4].

Recently, a study recognized three factors as critical autonomous predictors of patient co-morbidity, mortality, cumulative deep hypnotic time (BIS<45) as well as intraoperative systolic hypotension [5]. Their study revealed that death during the first year after surgery is primarily related to the natural history of previous conditions. However, intraoperative hypotension, as well as cumulative deep hypnotic time, were likewise critical contributors, independent predictors of increased mortality. These correlations propose that intraoperative management of anesthesia may influence the outcomes of patients over more extended periods than previously estimated. Also, the critical differences, as well as imbalances, can be observed between the anesthetic requirement and drug administration due to the fluctuating intensity of surgical stimulation during surgery as well as hemodynamic effects exhibited by anesthetic drugs. Further, under dosing might be a direct result of the failure of equipment or the occurrence of an error [6]. On the other hand, improper titration of the sleep-inducing components, prompting an increased depth of anesthesia (DOA), may compromise patient outcome [5]. Therefore, the review aims to evaluate strategies consisting of monitoring of depth of anesthesia and to provide assistance for the intraoperative use of different monitoring tools for patient safety after complicated surgeries.

Research Aims and Objectives

The current review is aimed at investigating and identifying the risk factors that may be associated with intraoperative awareness. The objectives of the study are to monitor in depth of the anesthesia

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and reducing in a number of high-risk patients subjected to different surgery where anesthesia is tailored.

- To study and identify the risk factors that may be associated between anesthesia and mortality.
- To study the data that must show the relationship between anesthesia and mortality.
- To qualitative study the cases of complicated surgery associated with anesthesia that should give a clear idea of the overall improvement of the patients.

Critical Review of Literature

During anesthesia the patient, the anesthetist and the monitors all structure some portion of an intricate feedback loop. The monitors show physiological factors to the anesthetist, who additionally gets data on different factors, for example, the operation phase, and processes this information alongside parameters, for example, the patient's medical history to choose whether any interventions are required. In the case of requirement of immediate action or intervention, the anesthetist implements on the information and then estimates the impact, to decide whether any repetition or further interventions are required. Along these lines, in most cases, the monitoring is utilized as a significant aspect of an unpredictable input control framework to keep the patient in a safe physiological 'envelope', and not fundamentally as a warning system to alert the anesthetist when the patient's physiology falls outside the 'envelope' [7].

Standards

The presence of an adequately prepared and experienced anesthetist is the principal determinant of patient well-being and safety during anesthesia. Nonetheless, errors are inescapable, and numerous investigations have demonstrated undesirable occurrences, and mishaps are as often as possible inferable, at a minimum to some degree, to faults caused by anesthetists [8,9]. Subsequently, monitoring is an essential segment of anesthesia care. Anesthesia clinicians must monitor patient physiologic factors and anesthesia equipment during a wide range of anesthesia, as anesthesia and medical procedure can cause quick changes in imperative functions of patients. The monitoring of patient as well as equipment is utilized to titrate the administration of an analgesic drug, to distinguish physiologic disturbances and deviations, and permit intervention before the patient endures pain, and to identify and address the glitch in the equipment. Therefore, the European Board of Anesthesiology (2012), the American Society of Anesthesiologists (2011) and the Australian and New Zealand College of Anesthetists (2013) have published rules on standards of clinical monitoring in anesthesia.

Depth of anesthesia

In medicine, one of the present difficulties is the monitoring of the depth of general anesthesia (DGA) in patients. A study stated that the accurate assessment of the extent of anesthesia adds to tailored administration of the drug to the individual patient, in this way inhibiting the patient's awareness or excessive depth of anesthesia and improving the patients' outcomes.

A study mentioned that the fundamental characteristics demonstrated by a patient in case of successful general anesthesia are a reversible loss of consciousness with an absence of movement, unresponsiveness to excruciating stimulus, an absence of awareness, as well as a lack of recall of the surgical intervention [10]. Further, Insufficient general anesthesia may prompt intraoperative awareness alongside the recalling ability of patient because of patient under dosage or due to delayed recovery and an elevated risk of postoperative complexities for the patient due to over dosage. A significant contributing element to deficient general anesthesia is the present restricted ability to assess the consciousness level.

It was uncovered that the research for a DGA monitor that would empower objective, reproducible and persistent estimation of analgesic depth has led to the improvement of electroencephalogram (EEG) or acoustic evoked potential (AEP) based monitors [11]. These empower continuous monitoring also during conditions during which a patient has lost all response to outside stimulus from non-excruciating to painful. When deciphering the outcomes of EEG or AEP based monitors, it is critical to recognize the effects on the activity of EEG from the effects on the measurements of EEG [12].

Further, a study carried out a randomized controlled clinical trial on patients undergoing noncardiac surgery for the assessment of monitoring depth of anesthesia by evaluating the bispectral index [13]. The sample of the study consisted of 40 patients aged between 65 to 75 years which were subjected to anesthesia balanced with either sevoflurane (n=20) or xenon (n=19) in minimum 30% oxygen and remifentanil titrated accordingly. The results found that BIS values in the xenon group were similar to sevoflurane during induction and maintenance of anesthesia and at the lower limit of the recommended range for deep anesthesia. Further, the rapid emergence to complete orientation was observed in the xenon group compared to sevoflurane. BIS values were substantially reduced during emergence from xenon anesthesia as well as showed adequate concordance with clinical signs of the depth of anesthesia.

A clinical trial was conducted to assess the performance of a new monitor to evaluate the depth of anesthesia (DOA) on 144 patients undergoing complicated surgeries [14]. Various parameters were evaluated that included Depth of Anesthesia index (Ai) based on sample entropy (SampEn), 95% spectral edge frequency (95% SEF), as well as burst suppression ratio (BSR) in comparison to Bispectral Index (BIS) during total intravenous anesthesia [15]. The primary outcomes of the study between Ai and BIS consisted of the limits of agreement as -17.68 and 16.49, that were respectively, -30.0% and 28.0% of the mean value of BIS. The study concluded that as a DOA monitor, Ai consists of the same characteristics of BIS and demonstrated the benefit of indicating conscious level by SampEn.

Researchers have carried out a study on the monitoring of depth of anesthesia for patients experiencing postoperative delirium [16]. The study was a randomized clinical trial, including a patient group that was planned for surgery lasting longer than 60 minutes and belonging to the age group of 60 years or older. The study included a total of 1277, of which 638 patients were subjected to open trial and 639 were blinded, patients. One group of the patients were analyzed by mode of bispectral index monitoring, and in the other group, the supervision was blinded. Elderly patients frequently experience the complication of postoperative delirium following surgery. Often, postoperative delirium is presented in patients with inadequate surgical outcome. Surgery and anesthesia administration are considered the most important modifiable perioperative precipitants. Recovery of patients may be positively impacted by effective neuromonitoring of anesthesia. Bispectral index (BIS) monitoring, which provides the outcome of the depth of anesthesia in a single value result [16]. It is obtained through an analysis of data derived from electroencephalogram (EEG). The typical range for acceptable BIS levels in post-surgery patients is considered to be between 40 and 60 [16]. Adequate monitoring of BIS levels aids in the determination of the appropriate depth of anesthesia to be monitored for each patient. The impact of BIS guiding for the administration of anesthesia on mortality and cognitive functioning in postoperative patients' needs to be investigated to avoid adverse effects. It included patients above the age of 60 years who underwent elective surgery. The procedures of surgery included urologic, thoracic, maxillofacial, vascular, orthopedic, otorhinolaryngological, and abdominal interventions. Patients groups were divided into stratified sections based on their physical status. The study groups were randomized through electronic means. The selected patients received treatment at preoperative, perioperative, and postoperative stages. Administration of midazolam needs to be carried out as per the stratification and observations in individual patients. In the BIS monitoring group, bilateral electrodes were used at the skin site of the forehead region. Blinded group patients underwent screened BIS value monitoring with the visible indications of signal quality and strength only. Psychiatric assessment of delirium incidence was performed in the postoperative patients. Incidence of cognitive dysfunction was also monitored among the patients through the assessment of attention span, memory parameters such as visual and verbal. Primary findings of this study showed a marked reduction in postoperative delirium in elderly patients who underwent BIS-guided anesthesia vs routine care. The reduction of extremely low values of BIS results in the subsequent decline of delirium incidence. They found that a value of BIS, which was lower than 20, was associated with postoperative delirium. Values of BIS lower than 30 have a linear relationship with the ratio of burst suppression. Their findings suggest that BIS monitoring aids in the prevention of values which are extremely low. Response in patients to values which are extremely low leads to increased susceptibility in patients for comorbidity and mortality.

Burst suppression

A research featured that during deep anesthesia, the EEG may build up a characteristic pattern that is characterized as burst suppression (BS) [17]. The characterization of burst suppression is done by alternating time periods of typical to high voltage activity altering to low voltage. This sort of activity is normally observed when the centralization of anesthetic medication is high [18]. To evaluate this impact, the burst suppression ratio (BSR) is determined. BSR is determined as a proportion between the span of suppression and the length of bursting.

Postoperative delirium is more frequently in postoperative patients of cardiac surgery [19]. Postoperative delirium is constantly associated with a higher incidence of morbidity and mortality. In this study, 81 patients who underwent cardiac surgery to assess postoperative delirium. Bilateral bispectral index monitoring was followed in patients during the phases of preoperative, perioperative, and postoperative surgery. Their vital findings indicated that the delirium group of patients had a lower level of ASYM, while the non-delirium group had higher values. Burst suppression state was found to have a longer duration in patients having delirium as compared to the non-delirious group. They concluded that risk identification of postoperative delirium is facilitated by monitoring of burst suppression, which needs to be further evaluated [19].

Signal Quality Index (SQI%)

A randomized, double-blind, controlled trial investigated the effects of regional anesthesia on the bispectral index [20]. The study substituted spinal anesthesia with the administration of different classes of sedatives during the daytime. Patients were monitored for BIS values during night time to study the effect of sedation. This was correlated with a patient response in postoperative stages. Patients selected in the study comprised of elderly males having undergone transurethral prostatic resection (TURP). There were a total of 111 patients of which the control group intravenous saline infusion, while two separate patient groups were administered with dexmedetomidine and midazolam respectively. Results indicated that the BIS values for dexmedetomidine were lower than those of control and midazolam groups. Sleep duration for the midazolam group was found to be longer by an approximate of 237.8 minutes as compared to the other two groups. This suggests that sleep preservation is higher in postoperative TURP male patients being administered with midazolam.

Classification of methods of monitoring the depth of anesthesia

The bispectral index monitored through electroencephalography (EEG) is said to be the first commercial monitoring parameters [10]. The BIS monitoring system was utilized for the first time in the year 1992, followed by the gradual development of similar bispectral monitoring approaches such as CSM, AEP-Monitor/2, Narcotrend, PSA etc. by 1999. BIS monitor is being used widely due to its applicability in analyzing the bispectral parameter. Measurement of EEG signals obtained in the format of a single channel is collected through measurement at the site of the forehead of patients. The analysis of these EEG signals is made through the evaluation of phase relations for these signals. The index values obtained for BIS are in numerical form ranging from 0 to 100 and lacking a dimension. BIS index provides a specific measurement of the level of postoperative complication incidences. Therefore, several studies have been performed for the monitoring of depth of administered general anesthesia through the mode of AEP. First generation AEP technology was later updated to AEP-Monitor/2 which includes parameters of EEG which have inclusive spectral dimensions. The latest advancement was the development of ARX or models of autoregression, which contains input of exogenous dimensions, thereby rendering swift responsiveness in the monitoring system.

A study was conducted, that aimed to validate a novel generation of a monitoring system for consciousness level, known as the index of consciousness (IoC) [21]. This monitor was initially introduced as a derivative of EEG signal monitoring by Morpheus Medical Company. Functionally, the IoC system involves the recording of EEG signals by the placement of surface electrodes at skin detection points at the forehead. Symbolic dynamics are incorporated to measure the primary parameters of the IoC. Signals of EEG are mainly measured as divisions with finite dimensions. Each partition is assigned with a specific symbol. The method of symbolic dynamics is used for the detection of properties of EEG which belong to the non-linear area. The measurements of the depth of anesthesia correlate with the signals obtained through EEG.

The techniques mentioned above for monitoring the depth of anesthesia are essential for the prevention of postoperative complications.

Methods

Blood oxygenation

A randomized controlled trial was conducted to analyze the effects of minimal-and high-flow anesthesia on cerebral oxygenation during septorhinoplasty with controlled hypotension employing near-IR

Authors	Study design	Treatment	Scale	Type of Intervention	Population	Patient Outcomes	Conclusion
Leake et al. [23]	Single-centre randomized, placebo-controlled, double-blinded	Local Anesthesia and conscious sedation vs Local Anesthesia	Iowa Satisfaction with Anesthesia Scale (ISAS)	Inguinal hernioplasty	N=171	ISAS, p = 0.009 for LACS, p = 0.016 for LA	Conscious sedation with local anesthesia is safe, comparative lower pain experience and severity
Kazancioglu et al. [22]	Randomized clinical trial	General Anesthesia with Desflurane and Remifentanyl: High Flow and Minimal Flow	Aldrete Score	Septorhinoplasty	N=80	No statistical differences in haemodynamic parameters, end-tidal CO2 and cerebral oxygen saturation	MF anesthesia may be used as safely as HF anesthesia
Fu et al. [14]	Multi-centre randomized trial	General anesthesia with stepwise-increased target-controlled infusion (TCI) of propofol	Depth of Anesthesia index (Ai) based on sample entropy (SampEn),95% SEF, BSR compared to BIS	Depth of Anesthesia	N=144	decrease or an increase of Ai was significantly greater than that of BIS when consciousness changes	
Fahlenkamp et al. [13]	Randomized controlled clinical trial	Balanced anesthesia with either xenon (n=19) or sevoflurane (n=20) in min 30% oxygen and remifentanil titrated to clinical needs	Bispectral Index Monitoring	Depth of Anesthesia in elderly patients	N=40, Age=65-75 years	BIS values were significantly lower during emergence from xenon anesthesia	BIS-values showed sufficient concordance with clinical signs of anaesthetic depth
Myles [11]	A prospective, randomized, double-blind, multicentre trial	BIS-guided anesthesia or routine care	Bispectral Index Monitoring	Analysis of reduced awareness after administration of BIS-guided anesthesia	N=2463;	BIS-guided anesthesia reduces the risk of awareness in at-risk adult surgical patients undergoing relaxant general anesthesia.	
Radtke et al. [16]	randomized single-blinded clinical trial	BIS-guided anesthesia vs routine care	bispectral index (BIS)	Lower incidence of postoperative delirium	n=638 open, n=639 blinded	Delirium incidence was lower in patients guided with BIS	high-risk surgical patients this may give the anesthesiologist a possibility to influence one precipitating factor in the complex genesis of delirium.
Soehle et al. [19]	Prospective, observational study	BIS monitoring through EEG asymmetry	BIS and Burst suppression ratio (BSR)	EEG asymmetry showed a lower incidence in the delirium group as compared to the non-delirium group	n=81	EEG asymmetry showed a lower incidence in the delirium group as compared to the non-delirium group	BSR monitoring identifies patients having the risk of postoperative delirium.
Tan et al. [20]	A randomized, double-blind, controlled trial	Night Bispectral Index After Daytime Sedation	BIS	patients undergoing TURP were enrolled and received intravenous saline infusion (control group), dexmedetomidine (dexmedetomidine group), or midazolam (midazolam group) for sedation during the spinal anesthesia procedure.	n=111		midazolam combined with spinal anesthesia might preserve the sleep quality of elderly male patients immediately after TURP

Table 1: A summary of the relevant studies and parameters reviewed.

spectroscopy [22]. A total no. of 80 patients were randomized into two groups, minimal-flow (MF) or high-flow (HF). The study included the use of desflurane anesthesia to maintain bispectral index values at 40%-50% as well as 0.25-0.5 µg kg−1 min−1 i.v. remifentanyl infusion to maintain mean arterial blood pressure between 55 and 65 mmHg in both groups. It was found that there were no statistical differences in hemodynamic parameters, end-tidal CO_2 and cerebral oxygen saturation. MF anesthesia may thus be used as safely as HF anesthesia.

Ventilation

A single-center randomized, placebo-controlled trial was conducted that was double-blinded on patients undergoing inguinal hernioplasty [23]. The study consisted of 149 patients randomized into two groups that were 78 patients receiving local anesthesia (LA) alone versus 71 patients receiving local anesthesia as well as conscious sedation (LACS). The study employed Iowa Satisfaction with Anesthesia Scale (ISAS) for the assessment of patient outcomes for patient satisfaction. The results of the study established that the mean ISAS score was significantly greater in the LACS group with p equivalent to 0.009 and the experience and severity of pain was greater in the LA group $p = 0.016$ and $p = 0.0162$ respectively. Further, the study concluded that the use of conscious sedation with local anesthesia for inguinal hernioplasty is safe, resulting in comparative lower pain experience and severity and is related with improved patient satisfaction. In addition, it doesn't delay patient discharge (Table 1).

Research Gap

Constant electronic patient monitoring may not generally be advantageous due to the reason that the quick acknowledgement of anomalous physiology may caution the clinician that the patient is at risk, however, this information will only assist the patient if there is a compelling treatment for the latent cause of deterioration [24-26]. Regardless of whether a treatment is accessible, early acknowledgement of physiological anomalies is only of significant worth if the treatment is increasingly successful when it is rapidly delivered. Most of the studies are, therefore, focused on the patient recovery on anesthesia, are scarce in the information for the improved variables or novel anesthetic drugs that can not only improve patient recovery from anesthesia but also could improve long-term recovery and minimize side-effects. Therefore, research surrounding the anesthetic monitoring largely consists of information about the quantitative variables which can't influence the patient outcomes in long-term and they may build our insight into mechanisms of diseases, yet does not legitimately benefit the monitored patient. A critical assessment of the benefit to the patient undergoing anesthetic monitoring tailored according to patient preoperative and intraoperative assessment, previous clinical studies, advanced predictive algorithms by automation and artificial intelligence, will be largely beneficial which is missing from current research as they are preliminary stages of development.

Conclusion

In summary, numerous anesthetists have referred to improved monitoring as one reason for a decrease in anesthesia related mortality throughout the years that is dependent upon the obviously high and critical utilization of monitoring and decline in perioperative morbidity and mortality rates. It was observed that alterations in monitoring occur due the DOA monitoring by using the processed EEG signal that has been routinely used as a monitoring device; also the majority of studies employed the bispectral index monitor (BIS). Other developments noticed in this area were the simple, relatively non-invasive devices to measure cardiac output and stroke volume in anaesthetized patients such as depth of anesthesia based on entropy. It can be further concluded that the novel research in patient monitoring has immensely reduced the mortality and morbidity in patients as there were no studies that reported patient mortality and morbidity.

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