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Effect of nerve block combined with superficial general anaesthesia on anaesthetic dosage and anaesthetic awakening in paediatric surgery

Fu Yao[1*], Gang Zhang[1], Bo Yang[1] and Jilin Xiang[1]

Abstract

Background To compare the effects of nerve block composite general anesthesia and general anesthesia on the dosage of anesthetics and anesthesia awakening in pediatric orthopedic injury patients under anesthesia depth monitoring.

Methods Forty pediatric patients with external humerus condylar fractures were randomly distributed into general anesthesia (GA) and nerve block combined with general anesthesia (GNA) groups. Patients in the GA group had induction of anesthesia with propofol at 2.5 mg/kg and remifentanil at 0.6 ug/kg. The Angel-6000D EEG anesthesia depth multi-parameter monitor maintained the EEG awareness index (IOC1) between 40 and 60 and the injury sensitivity index (IOC2) between 30 and 50.

Results Both intraoperative propofol maintenance in the GA group (6.74 ± 0.93) and propofol maintenance in the GNA group (5.16 ± 0.76) were significantly different upon comparison between the groups ($p < 0.05$). Intraoperative remifentanil maintenance differed significantly ($p < 0.05$) between the GA group (0.26 ± 0.04) and the GNA group (0.10 ± 0.04). Comparison of awakening time: the time of eyelid opening, time of completion order, extubation time, and time of recovery of positioning function in the GNA group were markedly shorter than that of the GA group ($p < 0.01$) with a high level of significance.

Conclusion Nerve block composite general anesthesia under multi-parameter monitoring of depth of anesthesia by Angel-6000D electroencephalogram can lead to a significant reduction in the dosage of propofol and remifentanil, advancement of awakening and extubation time and an increase in the safety of anesthesia in pediatric surgery patients.

Keywords Nerve block, General anesthesia, Pediatric patients, Awakening time, Depth of anesthesia

*Correspondence:
Fu Yao
YaoF_SC@163.com
[1]Department of Anesthesiology, Sichuan Orthopedic Hospital, No. 132, West Section 1, 1st Ring Road, Wuhou District, Chengdu, Sichuan Province 610041, China

Introduction

Anesthesia might, therefore, be broadly classified as local and general anesthesia based on its site of application and the patient's perception of consciousness. General anesthesia applies to manifest awareness and the perception of pain either through direct intravenous administration or through tracheal intubation. However, general anesthesia is not without possible complications, including pulmonary problems, intraoperative blood loss, perioperative cardiac ischemia, thrombosis, and postoperative cognitive dysfunction [1, 2]. Some studies suggest that some general anesthetic agents act on the developing nervous system of a neonate. In studies quoted, agents appear to impair growth factor signaling and mitochondrial function, resulting in cell death and reduced neurogenesis or altered synapse formation [3]. This has led some doctors to view local anesthesia as a better alternative compared to general anesthesia for lower limb surgery and surgery on the extremities [4].

Local anesthesia involves injecting a drug into the local tissues to block nerve conduction; for instance, nerve blocks or infiltration are examples of local anesthesia [4]. A common practice is its application to oral and ophthalmic minor surgical procedures. However, there is a high risk of central nervous system toxicity even in low dosages of local anesthetics, evident through perioral numbness, dizziness, tinnitus, restlessness, or slurred speech in some patients [5]. Other short-acting local anesthetics, such as lidocaine, can hypothetically cause bradycardia hypotension or even cardiac arrest. In contrast, bupivacaine and ropivacaine, linked to the conduction of T-wave spiking and ventricular arrhythmia, have been shown to act more favorably because of their long duration of action [5]. Nerve block techniques have gained acceptance mostly as a means to deliver the anesthetic drug closer to nerve bundles, reducing the odds of systemic toxicity.

Nerve blocks use neurostimulation or ultrasound guidance to locate nerve bundles for accurate delivery of anesthetics [5]. Neurostimulation is an electric stimulation of nerve cells, whereby depolarization is induced by propagating electrical impulses and the stimulation of muscle contractions, which confirm the correct placement of the anesthetic. They have gained momentum in pediatric anesthesia recently as ultrasound technology enabled real-time visualization of needle positioning related to the nerve bundles and distribution of local anesthetics; this vastly reduces the dosage, success rates, time taken in the surgical theater, and the number of punctures [6].

Pediatric patients are also different since they have immature liver and kidney function along with a central nervous system and an endocrine system that does not work quite like that of the adult, resulting in poor drug metabolism and low tolerance, which cyclically raises the chances of delayed awakening after general anesthesia [7]. Discrepancies in the neurodevelopment of pediatric and adult patients pose a dilemma in directly applying adult anesthesia-related research to care for children. In adults, this local process usually combines only mild sedation, allowing the patient to alert the anesthetist about any pain or abnormality as it arises [8]. Children, in contrast, cannot articulate their complaints because of their foreignness to needles or other forms of mobility. Therefore, it is also not uncommon that combined general anesthesia is being increasingly indicated to reduce neurological toxicity [9].

To my knowledge, this study reports the novel use of the Angel-6000D electroencephalographic multiparameter monitor for proper monitoring of sedation and depth of pain. This cutting-edge process minimizes circulatory and respiratory effects and ensures safe and speedy discharge/awakening, thus reducing the prospect of intraoperative awareness. This study uses these features to investigate the combined nerve block and general anesthesia effects in the context of reduced sedation and analgesia doses and early awakening from the anesthesia in pediatric surgical patients.

Materials and methods

Study design and participants

A prospective, randomized study was conducted on 40 pediatric patients with elbow fractures requiring surgical fixation at our hospital. The patients were randomized into two groups: group GA-simple general anesthesia and group GNA-peripheral block general anesthesia. Each consisted of 20 patients. Randomization was done using a computer-generated randomization sequence to ensure allocation concealment.

Inclusion criteria were pediatric patients aged 7–14 years, ASA Standard Class I or II. Written informed consent was obtained from the parents or guardians of each participant, and the Research Ethics Committee, Sichuan Orthopaedic Hospital, approved the study. It was conducted according to international ethical guidelines in the Declaration of Helsinki, in compliance with ethical standards.

Exclusion criteria were children with cardiopulmonary diseases, liver or kidney dysfunction, or coagulation disorders. The rationale for exclusion was to set the ground for a more homogenous sample of subjects and reduce potential confounding factors.

Anesthesia protocol

Preoperative monitoring

Per standard preoperative monitoring protocols, all patients were monitored in the operating room after admission. Parameters included ECG, heart rate, pulse oximetry, and BP. The depth of anesthesia was measured

using the Angel-6000D EEG anesthesia depth multi-parameter monitor (Shenzhen Weihao Kang Medical Equipment Co., Ltd.) for the electroencephalographic index of consciousness (IOC1) and the index of injurious sensitivity (IOC2).

General anesthesia protocol (Group GA)

Patients in the GA group received induction of anesthesia with propofol, 2.5 mg/kg; remifentanil was used at a concentration of 0.6 μg/mL with the laryngeal mask placed to maintain IOC1 40–60 and IOC2 30–50. Patients remained under mechanical ventilation. Anesthesia was maintained with propofol infusion rates of 4–8 mg/(kg/h), remifentanil 0.1–0.3 μg/min, and dose adjustments based on IOC1 and IOC2 were made in real-time.

Peripheral block general anesthesia protocol (Group GNA)

In the GNA group, anesthesia induction and maintenance were managed the same way as in the GA group. In addition, high-frequency ultrasound probes were used to perform an axillary nerve block after anesthesia induction. The brachial plexus was identified under ultrasound guidance, and 0.2% ropivacaine (1 mL/kg) was injected into the nerve bundle. Before any injection was done, blood was not found in the puncture site to guarantee safety. Delivering one anesthetic using this ultrasound-assisted nerve block technique offered precise placement and a reduced chance of systemic toxicity.

Recovery and outcome measurements

Intraoperative parameters, dosage of propofol, and remifentanil were recorded for both groups. Recovery parameters, such as the eye-opening time, time to follow commands, regain cognitive function, and extubation time, were measured at the end of surgery.

Indices of observation

The study gathered data on participant characteristics (age, weight, SBP, DBP, HR, and operation times), anesthetic monitoring indices (IOC1 and IOC2 values), intraoperative anesthetic dosages (propofol and remifentanil), and recovery-related times (eye-opening time, instruction completion time, positioning recovery time, and extubation time). These parameters assessed the effectiveness of the anesthesia protocols.

Table 1 Comparison of general conditions and IOC1, IOC2 and operation time between the two groups ($\bar{x}\pm s$)

Group	GA group	GNA group
Age (years)	10.74 ± 2.45	11.21 ± 1.99
Weight (kg)	30.37 ± 5.45	32.26 ± 5.67
Systolic blood pressure (mmHg)	104.21 ± 11.72	106.95 ± 9.58
Diastolic blood pressure (mmHg)	66.95 ± 7.89	69.11 ± 8.75
Heart rate (beats/min)	81.05 ± 4.96	80.63 ± 5.01
IOC1	52.89 ± 3.23	51.37 ± 3.02
IOC2	40.32 ± 2.79	39.42 ± 3.78
Surgical time (min)	27.95 ± 2.76	28.32 ± 2.56

Statistical analysis

All statistical analyses were performed using SPSS 25.0. Continuous variables were expressed as means ± standard deviation (SD). The independent sample t-test was used to compare the two anesthesia protocols to assess differences. A p-value of <0.05 was considered statistically significant, while a p-value of <0.01 indicated a highly significant difference. These statistical methods allowed reliable and reproducible analysis of collected data.

Results

Comparison of the general situation

This study comprised 40 patients with humeral internal epicondylar fractures requiring surgical fixation, randomly assigned to two groups: GA and GNA-20 patients in each group. There were no significant differences between the groups in terms of baseline characteristics: age (GA: 10.74 ± 2.45 years; GNA: 11.21 ± 1.99 years), body weight (GA: 30.37 ± 5.45 kg; GNA: 32.26 ± 5.67 kg), time of operation (GA: 27.95 ± 2.76 min; GNA: 28.32 ± 2.56 min), systolic blood pressure (GA: 104.21 ± 11.72 mmHg; GNA: 106.95 ± 9.58 mmHg), diastolic blood pressure (GA: 66.95 ± 7.89 mmHg; GNA: 69.11 ± 8.75), heart rate (GA: 81.05 ± 4.96 bpm; GNA: 80.63 ± 5.01 bpm), IOC1 (GA: 52.89 ± 3.23; GNA:51.37 ± 3.02), and IOC2 (GA: 40.32 ± 2.79; GNA: 39.42 ± 3.78) ($p>0.05$). This confirmed the comparability of the two groups concerning their baseline characteristics (as indicated in Table 1).

Comparison of the intraoperative maintenance doses of propofol

The intraoperative maintenance of propofol was, respectively, 5.16 ± 0.76 mg/kg·h for GNA and 6.74 ± 0.93 mg/kg·h in the GA group, highly significant difference ($p<0.05$). The intraoperative maintenance dose of remifentanil was 0.10 ± 0.04 μg/kg·min in the GNA group and 0.26 ± 0.04 μg/kg·min in the GA group, showing a significant difference ($p<0.01$). The findings may support the idea that the nerve block decreases the requirement for sedatives and analgesics during surgery, likely due to diminished nociceptive input (See Tables 2 and 3).

Comparison of recovery times

The recovery times of the GNA group were significantly shorter than those of the GA group. The eye-opening time was reduced from 11.63 ± 2.19 min in the GA group to 5.00 ± 1 min in the GNA group ($p<0.01$). Equally, instruction completion time was reduced from 14.84 ± 2.03 min in GA to 7.95 ± 1.84 min in GNA ($p<0.01$). The time

Table 2 Comparison of anaesthetic dosage between patients in the GA and GN groups ($\overline{x}\pm s$)

Group	GA group	GNA group
Propofol maintenance mg/kg·h	6.74 ± 0.93	5.16 ± 0.76*
Remifentanil maintenance μg/kg·min	0.26 ± 0.04	0.10 ± 0.04**

Note: *$p < 0.05$, **$p < 0.01$ for the GNA group compared to the GA group

Table 3 Comparison of awakening time of patients in GA and GNA groups ($\overline{x}\pm s$)

Group	GA group	GNA group
Eyes open/min	11.63 ± 2.19	5 ± 1.83*
Completion of command /min	14.84 ± 2.03	7.95 ± 1.84*
Extraction /min	16.84 ± 2.09	9 0.84 ± 1.98*
Positioning function recovery /min	12.11 ± 2.08	8.89 ± 2.21*

Note: *$p < 0.05$, **$p < 0.01$ for the GNA group compared to the GA group

to extubate was also shorter in the GNA group- 9.84 ± 1.98 min- compared to 16.84 ± 2.09 min in the GA group ($p < 0.01$). The time to recover positioning function was shorter in the GNA group (8.89 ± 2.21 min) than the GA group (12.11 ± 2.08 min) ($p < 0.01$). These results suggest nerve block may aid quicker recovery from general anesthesia by reducing its depth and duration.

Graphical representation of key findings

The differences in anesthetic dosage and recovery time between the two groups have been represented graphically by line diagrams or bar charts. These graphs demonstrate the superiority of outcomes obtained with nerve block-assisted general anesthesia.

Discussion

Pediatric patients face very specific challenges during their surgical procedures because of their immature physiology, such as underdeveloped liver, kidney, and central nervous systems. These developmental incapacities greatly cross the pathways of drug metabolism and excretion, leading to shut off its recovery and the possible emergence of adverse outcomes post-surgery. Thus, modification to a safe anesthetic regimen is crucial in minimizing the risk. Low levels of anesthesia might result in intraoperative awareness and emotional distress; however, excessive levels of anesthesia might lead to delayed recovery and neurologic sequelae [10, 11].

An EEG monitoring. The Angel-6000D EEG anesthesia depth multi-parameter monitor provides a safe and reliable method of managing anesthesia. This high technology, through principles of consciousness and pain indices derived from the EEG signal analysis, allows for primed control of the anesthetic and analgesic dosing, continuously monitoring anesthetic delivery [12]. In this study, Angel-6000D monitoring was applied to nerve block and general anesthesia concerning children. The results show that by putting together nerve block and general anesthesia, intra-operative drug doses are significantly reduced, with propofol decreased by 23.4% and remifentanil decreased by 61.5%, compared to general anesthesia alone [13]. Controlling nociceptive input leads to decreased anesthetic depth and faster recovery in awake functional patients, thereby speeding postoperative discharge [14].

The limitations of this study should also be acknowledged. Further investigation might address challenges from the small sample size and limited heterogeneity. Crude estimates of the required large and heterogeneous multicenter cohorts are required for validation of these findings and their applicability under different demographic determinants and surgical settings [15, 16]. Aside from those, varying surgical techniques and varied individual-status comorbidities may serve as potential confounding factors and should not be overlooked in subsequent experiments to allow the advanced monitoring and nerve block techniques to be more clinically transferrable.

The use of local anesthetics under investigation, particularly ropivacaine-also warrants further exploration. The sodium channel blockade and the potentiation of inhibitory synapses may contribute to the observed reductions in anesthesia given [17, 18]. In addition, this paper shines light on the novelty of introducing a nerve block with EEG-based monitoring of anesthetic depth, which is a safer and more efficient approach to perioperative care for surgical patients.

This is the first study integrating nerve blocks with EEG-based monitoring using Angel-6000D equipment in pediatric surgery. The significance of such innovation constitutes new advances in pediatric anesthesia, paving the way for continued studies and clinical applications. Hiroki et al. have confirmed similar drug dosage reduction and rescue observations in recovery that combine nerve block and general anesthesia run with Angel-6000D [19, 20]. Future work could advance these findings to determine the technology more suitable for clinical applications [21–24].

Conclusion

In conclusion, this study revealed the superiority of the anesthesia method of using Angel-6000D electroencephalographic anesthesia depth multiparameter monitor to monitor the depth of sedation and pain, and at the same time combining nerve block and general anesthesia, which provided good sedation and analgesia, and at the same time markedly reduced the dosage of intravenous anesthetics, which led to a significant reduction in the dosage of intra-operative propofol and remifentanil, an advancement of the time for awakening and extubation, an increase in the safety of anesthesia, and no increase

in the number of intra-operative complications such as knowledge and a reduction in the resultant anesthesia risk, and provided new ideas for the selection of a suitable anesthesia method for the medical staff.

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Author contributions
FY is responsible for the guarantor of integrity of the entire study, study concepts & design, the definition of intellectual content, literature research, clinical studies, experimental studies, and data acquisition; GZ and BY are responsible for the study concepts & design, the definition of intellectual content, clinical studies, experimental studies, data acquisition; JLX is responsible for the study design, definition of intellectual content, clinical studies, data acquisition. All authors read and approved the final manuscript.

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Data availability
All data generated or analysed during this study are included in this. Further enquiries can be directed to the corresponding author.

Declarations

Ethics approval and consent to participate
Informed consent was obtained from the patient's parents or legal guardians, and the Medical Ethics Committee of Sichuan Orthopaedic Hospital approved the study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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