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Xenon as an anesthetic of choice for full mouth debridement in a child with drug-resistant epilepsy: A clinical case

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ABSTRACT

BACKGROUND: Outpatient dental care in children with epilepsy (particularly drug-resistant epilepsy) is challenging for anesthesiologists in terms of selecting appropriate anesthesia methods and agents, as well as for dentists in terms of improving treatment efficacy and quality while minimizing intervention time. General anesthetics may trigger seizures in patients with epilepsy, including those with drug-resistant epilepsy. As a result, selecting the appropriate anesthetic is critical during preparation stages and anesthetic management in these patients.

CASE DESCRIPTION: A clinical case of full mouth debridement in a 3-year-old child with drug-resistant epilepsy is presented to demonstrate the efficacy of xenon as an inhalational anesthetic in patients with drug-resistant epilepsy. Combination inhalation anesthesia with xenon was used.

There were no signs of seizures during surgery and within two days after anesthesia.

CONCLUSION: Xenon may be a viable inhalational anesthetic for patients with drug-resistant epilepsy.

Keywords: anesthesia; xenon; drug-resistant epilepsy; children; dentistry.

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Ксенон как препарат выбора анестезии при санации ротовой полости у ребёнка с фармакорезистентной формой эпилепсии (клинический случай)

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АННОТАЦИЯ

Обоснование. Необходимость оказания стоматологической помощи в амбулаторных условиях пациентам детского возраста, страдающим эпилепсией, особенно в фармакорезистентной форме, ставит перед анестезиологом трудную задачу по выбору метода и средств адекватной анестезии, а перед стоматологом — по повышению эффективности и качества лечения при минимизации времени вмешательства. Общие анестетики могут провоцировать судорожный статус у больных эпилепсией, в том числе с фармакорезистентными формами, в связи с чем выбор конкретного препарата является ответственной процедурой в подготовке и проведении анестезии у данной категории пациентов.

Описание клинического случая. С целью демонстрации эффективности применения ксенона в качестве ингаляционного анестетика у пациента с фармакорезистентной формой эпилепсии представлен клинический случай санации полости рта ребёнку трёх лет с фармакорезистентной формой эпилепсии. Применяли комбинированную ингаляционную анестезию с использованием ксенона.

У пациента отметили отсутствие судорожной активности как в интраоперационном периоде, так и на протяжении двух дней после проведения анестезии.

Заключение. Представляется перспективным использование ксенона в ингаляционной анестезии у пациентов с фармакорезистентной формой эпилепсии.

Ключевые слова: анестезия; ксенон; фармакорезистентная эпилепсия; дети; стоматология.

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INTRODUCTION

Outpatient dental care in children with epilepsy (particularly drug-resistant epilepsy) is challenging for anesthesiologists in terms of selecting appropriate anesthesia methods and agents, as well as for dentists in terms of improving treatment efficacy and quality while minimizing intervention time.

Sevoflurane is commonly used for anesthesia in children due to favorable tolerability and safety profiles, well-controlled anesthesia, no upper respiratory tract irritation, and rapid induction [1]. S. Tanaka et al. found that sevoflurane caused a dose-dependent increase in activity peaks on electroencephalogram (EEG) in children with epilepsy [2]. Seizure patterns in children without epilepsy have also been reported when using sevoflurane at a dose of 7–8 vol.% [3]. Epileptiform activity on ECG in children with epilepsy when using sevoflurane for general anesthesia is associated with cognitive impairment and delirium [2, 4]. Propofol, an intravenous sedative agent, can also cause seizures, according to ECG findings [5].

Drug resistance is reported in one-third of epilepsy patients. However, its prevalence varies depending on the location of epileptogenic activity source, causes of epilepsy, age of onset, and concomitant cognitive impairments [6]. Thus, selecting the best antispasmodic therapy can be difficult.

Xenon is a monatomic inert gas that is non-toxic, neuroprotective, and cardioprotective, and has no systemic metabolism. Moreover, it is non-teratogenic [7, 8]. Given its neuroprotective properties and lack of toxicity, xenon can be used during full mouth debridement in children with nervous system disorders.

CASE DESCRIPTION

Parents of patient N. (female, 3 years old) presented to the Dental Forte Elite clinic (Naberezhnye Chelny) for full mouth debridement. During the preoperative examination, the following diagnosis was made based on imaging and laboratory findings: Epileptic encephalopathy, genetic etiology. Drug resistant form. Psychomotor retardation. Spastic quadriplegia.

Physical examination, laboratory, and imaging findings

Magnetic resonance imaging of the brain revealed callosal agenesis. EEG revealed multiregional epileptiform activity, more pronounced in the left hemisphere, with a higher activity amplitude in the right hemisphere. Genetic testing revealed mutations in the *BCKDK* gene (dehydrogenase deficiency); in the *NAXD* gene (early-onset progressive encephalopathy, leukoencephalopathy); in the *BLM* gene (Bloom syndrome); and in the *CPLANE 1* gene (Joubert syndrome).

According to the medical history, the patient received valproic acid, topiramate, and levetiracetam, with no effect. At the time of the study, the patient received vigabatrin 1,500 mg/day and levetiracetam 600 mg/day. The frequency of seizures reached 60 per day.

Treatment

Combination general anesthesia with xenon was used.

The following parameters were used to assess the efficacy and safety of anesthesia during surgery:

- Systolic and diastolic blood pressure, mean blood pressure, and heart rate assessed using the STAR8000C monitor (COMEN, China);
- Bispectral index (BIS) assessed using the anesthesia depth monitor MGA-06 (Triton, Russia);
- Pulmonary ventilation parameters: respiratory rate, airway pressure (Paw, mm Hg), minute ventilation (MV, L/min), expiratory volume (Vte), inspiratory volume (Vti), fraction of inspired oxygen (FiO_2), and end-tidal carbon dioxide ($EtCO_2$) assessed using an integrated module of the anesthesia apparatus;
- Capillary blood gases assessed using the iStat analyzer (USA);
- Cuff pressure assessed using the Portex cuff pressure monitoring device (UK).

Prior to anesthesia, the patient was premedicated with atropine 0.01 mg/kg and diazepam 0.2 mg/kg IV. Preoxygenation was performed at a gas flow rate of 5 L/min for 5 minutes with FiO_2 100%, using the Venar Libera Screen anesthesia apparatus (Chirana, Slovakia) (TS + AGAS). Tracheal intubation was performed on the first attempt, without complications, using a 4 mm endotracheal tube (BIS 50 c.u.). Mechanical ventilation was performed in the pressure support ventilation (PSV) mode.

Xenon inhalation began immediately after tracheal intubation, at a flow rate of 2 L/min, FiO_2 30%. Xenon was administered until the inspired xenon concentration reached 50% on the GKM-03-INSOVT analyzed (GRANAT, Russia). Following that, the flow rate was reduced to 200 mL/min, and FiO_2 was maintained at 30% in a closed-circle system. During anesthesia, the concentration of xenon in the fresh gas mixture was maintained between 40% and 45%, and the BIS-based depression of consciousness level was maintained between 40% and 60%. Ten minutes before the end of surgery, the xenon supply was switched off, with a flow rate of 2 L/min, FiO_2 100%. Tracheal extubation was performed when the inspired xenon concentration reached 10%, without complications. The time from the end of xenon supply to tracheal extubation was 1 minute and 30 seconds. The patient opened her eyes when called by name 3 minutes after the treatment was completed. The patient went

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home with her parents 20 minutes after the treatment was completed. Changes in assessed parameters during anesthesia are presented in Table 1.

Outcome and follow-up findings

The treatment duration was 1 hour and 50 minutes, the anesthesia duration was 2 hours, and the total xenon consumption was 10 L. During anesthesia, all assessed parameters were within the reference range for age; there were no seizures.

A neurologist documented seizure syndrome at the end of the second day after anesthesia. The patient resumed levetiracetam and vigabatrin therapy on the day of anesthesia, at the doses specified above.

Table 1. Changes in assessed parameters during anesthesia

Parameter	Before induction of anesthesia	Induction of anesthesia	After tracheal intubation	Anesthesia maintenance			Before tracheal extubation	Before transfer to recovery ward
				after 30 min	after 60 min	after 90 min		
SpO2, %	99	99	99	99	99	99	99	99
HR, bpm	120	130	140	130	125	125	130	115
Blood pressure, mm Hg:								
systolic	100	105	105	100	90	95	90	90
diastolic	50	60	55	50	55	50	50	50
mean	67	75	72	67	67	65	63	63
Respiratory rate, bpm	20	22	25	27	30	26	27	25
Xeex, %	—	—	—	45	45	50	45	0
BIS, c.u.	98	75	40	45	50	45	50	92
pH	—	—	7.2	—	—	—	7.2	—
pCO2, mm Hg	—	—	45	—	—	—	44	—
pO2, mm Hg	—	—	89	—	—	—	95	—
HCO3, mmol/L	—	—	24.4	—	—	—	23.1	—
BE, mol/L	—	—	–2	—	—	—	–3	—
tCO2, mmol/L	—	—	25	—	—	—	26	—
EtCO2, mm Hg	—	44	42	44	43	44	44	—
Minute ventilation, L/min	—	4	3.2	3.4	3.5	3.4	3.3	—
TV, mL	—	100	90	95	90	95	90	—
Paw, mm Hg	—	20	15	16	17	16	15	—
Cuff pressure, cm of water	—	—	19	18	19	19	20	—

Note: SpO_2, oxygen saturation; HR, heart rate; Xe_{ex}, expiratory xenon concentration; pCO_2, carbon dioxide partial pressure; pO_2, oxygen partial pressure; HCO_3, plasma bicarbonate; BE, base deficit; tCO_2, total carbon dioxide; $EtCO_2$, end-tidal carbon dioxide; TV, tidal volume; Paw, airway pressure.

DISCUSSION

Xenon plays a vital role in regulating and inhibiting glutamate transport. Impaired glutamate transport leads to acute neuron damage, seizures, and epilepsy [9, 10]. Thus, xenon can significantly decrease neuron damage caused by overexcitation [11]. Hyperactivation of NMDA receptors caused by elevated glutamate levels may result in neurotoxicity and neuron damage, which plays a critical role in the development and progression of seizure syndrome [8]. It was recently found that xenon activates the *TREK-1* gene, which is thought to be associated with Ca^{2+} channel activation, decreased glutamate release, and excitotoxicity inhibition [12]. New evidence suggests that xenon decreases glutamate levels, inhibits NMDA receptors, and reduces oxidative stress caused by neuroexcitotoxicity [13]. Of special concern are drug-resistant epileptic syndromes, which are now frequently treated using surgical methods, such as frontal temporal lobectomy, limited temporal resection, extratemporal neocortical resection, and vagal nerve stimulation. However, the results are not always conclusive [14]. Given the mechanisms of action of xenon, its use for anesthesia in patients with various forms of epilepsy, including drug-resistant epilepsy, appears relevant and significant.

CONCLUSION

Xenon, as a safe, effective, and environmentally safe gas, can become a promising, innovative alternative option for anesthesia in epilepsy patients, particularly in drug-resistant epilepsy. The presented clinical case demonstrates that xenon has high anticonvulsant efficacy during and shortly after anesthesia in a pediatric patient with drug-resistant epilepsy.

ADDITIONAL INFORMATION

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