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Original Contribution

Pediatric patients on ketogenic diet undergoing general anesthesia—a medical record review☆

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Abstract
Study objective: To identify guidelines for anesthesia management and determine whether general anesthesia is safe for pediatric patients on ketogenic diet (KD).
Design: Retrospective medical record review.
Setting: Postoperative recovery area.
Patients: All pediatric patients who underwent general anesthesia while on KD between 2009 and 2014 were reviewed. We identified 24 patients who underwent a total of 33 procedures. All children were on KD due to intractable epilepsy. The age of patients ranged from 1 to 15 years.
Intervention: General anesthesia for the scheduled procedures.
Measurements: Patients' demographics, seizure history, type of procedure; perioperative blood chemistry, medications including the anesthesia administered, and postoperative complications.
Main results: Twenty-four patients underwent a total of 33 procedures. The duration of KD treatment at the time of general anesthesia ranged from 4 days to 8 years. Among the 33 procedures, 3 patients had complications that could be attributable to KD and general anesthesia. A 9-year-old patient experienced increased seizures on postoperative day 0. An 8-year-old patient with hydropcephalus developed metabolic acidosis on postoperative day 1, and a 7-year-old patient's procedure was complicated by respiratory distress and increased seizure activity in the postanesthesia care unit.
Conclusion: This study showed that it is relatively safe for children on KD to undergo general anesthesia. The 3 complications attributable to general anesthesia were mild, and the increased seizure frequencies in 2 patients returned back to baseline in 24 hours. Although normal saline is considered more beneficial than lactated Ringer's solution in patients on KD, normal saline should also be administered carefully because of the risk of exacerbating patients' metabolic acidosis. One should be aware of the potential change of the ketogenic status due to drugs given intraoperatively.

1. Introduction

Among the patients who have epilepsy, up to 30% cannot be controlled by medical therapy. The ketogenic diet (KD) is an alternative treatment to medically refractory epilepsy and has been used successfully in pediatric patients with since the 1920s [1]. The classical KD consists of high fat, low

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carbohydrate, and adequate protein, which establishes a ketogenic state due to the decreased glucose levels stimulating ketone production. A 4:1 ratio of fat to protein and carbohydrate (grams) is usually used in pediatric patients, mimicking the biochemical state of starving. Children on KD usually have additional medical problems, frequently requiring surgical procedures under general anesthesia (GA). It is important to maintain the ketogenic status during GA; however, many of the drugs used in the operating room contain glucose and other substances, which might shift the patients out of ketosis and therefore increase the risks of seizures. There is a lack of literature describing perioperative guidelines for anesthesia management in children on the KD. Valencia et al [2] described 9 procedures ranging from central line placement to hemispherectomies, and there are 2 case reports by McNeely [3] and Ichikawa et al [4] on patients undergoing surgery for thoracolumbar scoliosis and dental caries, respectively. Although very few complications have been reported, the purpose of this study is to examine how GA has been managed for this particular subgroup of patients.

2. Methods

All pediatric patients who underwent GA at our institution while on KD between 2009 and 2014 were retrospectively reviewed. We identified 24 patients who underwent a total of 33 procedures. The following data were obtained: patients' demographics, seizure history, type of procedure; perioperative blood chemistry, medications including the anesthesia administered, and postoperative complications. Seizure history included seizure type, age of onset, etiology, and associated conditions. The reviewed time frame for postoperative complications was the first 24 hours after the anesthesia finish time.

3. Results

There were 11 female and 13 male patients, with ages ranging from 1 to 15 years. Nineteen of the children had their seizure onset before age 1, three had their onset at 2 years of age, and 1 had onset at 3 years of age. Eleven children had mixed seizure types, including focal and generalized convulsive epilepsy, and myoclonic and absence seizures; one currently had infantile spasms, one malignant migrating epilepsy, and two generalized convulsive seizures. Five were being treated for partial epilepsy and epileptic syndromes with focal seizures with impaired consciousness, and one without impaired consciousness. The remaining 4 children's seizure types were unspecified. All of the children were being treated with KD due to intractable epilepsy. All except 1 were taking antiepileptic medications in addition to the KD. Table 1 lists antiepileptic

Table 1

Patient no.	KD duration	KD ratio	Additional antiepileptic treatments
1	7 d	4	Valproic acid, VNS (decreased functioning), felbamate, topiramate, lorazepam, clonazepam
2	8 y	3.5	Levetiracetam, lamotrigine, rufinamide, phenytoin
3	7 y	1.25	Clonazepam
4	22 mo	4	VNS, phenobarbital, lamotrigine, valproic acid
5	2 y	4	Divalproex, levatiracetam, zonisamide
6	2 y	4	Topiramate, lamotrigine, clonazepam
7	13 mo	3	Oxcarbazepine, valproic acid
8	20 mo	3	None
9	4 d	4	Phenobarbital, valproic acid, topiramate
10	1 y	4	Valproic acid, KD, vigabatrin
11	7 mo	4	Lamotrigine, topiramate
12	3 mo	4	Rufinamide
13	5 y	4	Zonisamide
14	14 mo	2.5	None
15	2 y	-	Divalproex, topiramate, diazepam
16	3 mo	4	Levatiracetam, phenobarbital, phenytoin, lacosamide, topiramate, VNS
17	6 mo	4	Clobazam, phenobarbital, topiramate
18	7 mo	4	Clonazepam, diazepam, zonisamide
19	9 mo	3	Zonisamide, levetiracetam, medical marijuana
20	9 mo	4	Rufinamide, clonazepam, diazepam
21	18 mo	4	Valproic acid, diazepam, clobazam
22	6 mo	4	Pregabalin, rufinamide, zonisamide, felbamate
23	14 mo	4	Vigabatrin, phenobarbital, topiramate
24	4 mo	3.5	Phenobarbital, topiramate, B6, Lamotrigine