Ketamine Anesthesia in a Hydranencephalic Infant

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It has been proposed that ketamine produces anesthesia by dissociating the cerebral cortex from the limbic system.1 It has also been observed in cats that during maximal ketamine effect seizure-like activity occurs in the limbic system and cortex, with suppression of the EEG response to sensory stimuli.2 The following case report of a hydranencephalic infant with no cortex who was successfully anesthetized with ketamine suggests that the precise mechanism has not yet been elucidated.

REPORT OF A CASE

A full-term male infant weighing 9 lb, 6 oz, was delivered by cesarian section because of cephalopelvic disproportion. Macrocephaly and hypospadias were found on physical examination. The circumference of the head was 42 cm, the fontanelles were open, and there was almost complete transillumination of the cranial vault. The baby appeared completely normal on routine newborn neurologic examination. It was later observed that the child did not extinguish responses to stimuli. He responded in a stereotyped way to repeated nonpainful stimuli. A normal newborn infant “learns” that the stimulus is not injurious and will extinguish his response. The infant’s body temperature was normal and he responded normally to pain and hunger. He had a diffusely abnormal low-voltage electroencephalogram (EEG).

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Pneumoencephalography and cerebral angiography were performed at the ages of 4 and 12 days, respectively. General anesthesia was necessary for these procedures, since the patient was large and active. The reasons for the studies were threefold. If the diagnosis was hydrocephalus, some operative correction would be feasible. Second, if hydrocephalus was diagnosed a prognosis could be established from the amount of cerebral cortex present. Third, it was important to distinguish between hydrocephalus and hydranencephaly in order to counsel the parents. Hypospadias and hydrocephaly can occur together as an inheritable defect.

Preanesthetic medication for both procedures was atropine, 0.1 mg, im. Pulse rate and ventilation were monitored throughout with a precordial stethoscope. Blood pressure monitoring was not practical in this infant, who was completely swaddled in elastic bandages, and whose body position was frequently changed. On the first occasion, ketamine, 5 mg, was given intravenously for induction of anesthesia. The mouthing movements, searching eye movements and salivation typical of ketamine anesthesia followed. The baby was immobilized in a modified infant seat, and 15 minutes after induction a lumbar puncture needle was inserted into the subarachnoid space. Anesthesia was deemed adequate since he did not move or cry. One and a half hours were required for the pneumoencephalography, and a total dose of 10 mg of ketamine was used. Pulse rates ranged from 120 to 160 beats/min. The infant “awoke” suddenly about 45 minutes after the procedure, and cried until he was fed.

Eight days later cerebral arteriography was performed using ketamine, 40 mg, iv, and 20 mg, im. The intravenous infusion set became nonfunctional during the procedure, and it is not clear how much of the iv dose was delivered. Pulse rates ranged from 140 to 150 beats/min during the procedure, which lasted 2½ hours. Recovery was slower after
this procedure, the baby sleeping for several hours, suggesting that too large a total dose was used.

The pneumoecephalogram showed free air under the frontal, occipital, and parietal calvaria, with no evidence of a cerebral cortex except in the medial occipital region. Both right and left internal carotid arteries were of small caliber, with atrophic anterior and middle cerebral arteries which terminated several centimeters before the inner table of the calvarium. The thalamus was present and had an adequate blood supply. The venous system in the occipital region was present. Both studies were compatible with a diagnosis of hydranencephaly.

**DISCUSSION**

Classic inhalational anesthetics produce anesthesia by generalized suppression of normal cerebral activity, as evidenced by depressed EEG activity in the brainstem and cortex. Ketamine has been termed a “dissociative anesthetic” because different EEG patterns are observed in the cortex and hippocampus.\(^1\)\(^2\) In cats depression of the association area of the cortex has been observed while there was activation in the hippocampus. This was considered to suggest dissociation of the two areas of the brain. Ketamine was also shown to cause dissociated electrical activity within the cortex itself, with prominent delta-wave activity in the frontal association areas, but normal waves elsewhere in the cortex.

Kayama and Iwama have suggested that dissociation of the cortex from the limbic system may not be the mechanism by which ketamine causes anesthesia.\(^2\) They observed very similar EEG patterns in the cortex and hippocampus of the cat. These consisted of slow waves, spikes, and spike-and-wave complexes, all of which are EEG seizures. Occasionally the cats were observed to have twitching movements correlating with the EEG seizures in the cortex. The authors concluded that ketamine acts by stimulating the cortex and hippocampus simultaneously until a seizure-like state is reached. This leads to the altered level of consciousness seen with petit mal seizures, and changes perception of sensory stimuli.

It was of interest to us that Kayama and Iwama reported different EEG responses to sensory stimuli depending upon the depth of ketamine anesthesia. Soon after ketamine was given they found an enhanced response in the visual cortex when the optic chiasm was stimulated. During the period of maximal ketamine effects the evoked response was diminished, and there were EEG seizures. We hypothesize that the initial increased response to stimulation was analogous to the enhanced responses to auditory and visual stimuli seen as hallucinations in patients in the lighter stages of ketamine anesthesia. The existence of EEG seizures and diminished evoked potentials seemed to correlate with the deeper level of consciousness associated with surgical anesthetic levels.

The successful use of ketamine in a patient with no cortex, but with apparent sensitivity to pain, shows that dissociation of the cortex and limbic system is not essential for ketamine general anesthesia. Furthermore, ketamine produced a state of anesthesia clinically identical to that seen in patients with normal cortices, presumably by acting on subcortical structures. This suggests that desynchronization within the hippocampus or the midbrain reticular activating system alone may sufficiently alter the level of consciousness to account for the anesthetic effect of ketamine.

We did not record the EEG during the procedures described, so we cannot report the effect of ketamine on the electrical activity of the brain. We cannot differentiate among effects on the reticular activating system, hippocampus, and thalamic nuclei. However, we observed that the combined effect on these structures was sufficient to produce general anesthesia, and suggest that they might be the primary site of action of ketamine.

**CONCLUSION**

The successful induction of anesthesia with ketamine in a hydranencephalic infant shows that dissociation of the cortex from subcortical structures is not the only mechanism of action of the drug. It proves that simultaneous disruption in both the cortex and subcortical structures is not necessary. Seizure-like activity in the brainstem alone, as is seen with petit mal seizures, would account for the altered level of consciousness and response to pain.
Encephalitis and a Hyperkalemic Response to Succinylcholine

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Hyperkalemic responses secondary to the administration of succinylcholine have been observed in patients with traumatic or burn injuries to muscle, muscular dystrophies, spinal cord lesions, and upper motor neuron disease associated with strokes. This case study documents a heretofore unreported association of succinylcholine-induced hyperkalemia with encephalitis.

REPORT OF A CASE

A 26-year-old woman had been in good general health until five months prior to hospitalization, when she sought medical help because of emotional problems. Shortly after admission to another hospital, she developed weakness of the left leg, followed by confusion, incoherent speech, and incontinence. There was no history of drug abuse or poisoning. Analysis of blood for heavy metals, routine bacteriologic evaluation, and serum viral titers were negative. Roentgenograms of the skull, a pneumoencephalogram, brain scan, and bilateral carotid arteriograms were all normal. Serial electroencephalograms revealed nonspecific, diffuse slowing. Lumbar puncture disclosed leukocytosis, erythrocytosis, decreased alpha-globulin, and normal CSF pressure. The tuberculin skin test was positive. Treatment with isoniazid was begun; this, in addition to dexamethasone, was continued to the time of her transfer to the Hospital of the University of Pennsylvania for further evaluation, including a brain biopsy.

On admission the patient was unable to follow simple commands and had increased tone and hyperactive deep tendon reflexes in both arms and the left leg. Generalized muscle atrophy was apparent. Response to pin prick was normal, as was the cranial nerve examination.

The clinical impression was that of a progressive, degenerative brain disease. Immediate preoperative studies included serum glucose, BUN, sodium, potassium, chloride, and bicarbonate—all of which were normal. Roentgenograms of the chest revealed no active disease; an electrocardiogram showed sinus tachycardia with occasional premature atrial contractions and S-T elevation in leads V₁-V₄, suggestive of early repolarization. Hemoglobin was 13.4 g/100 ml. Leukocyte count was 9,500/mm³.

Prior to biopsy of the brain the anesthesia was induced with sodium thiopental, 150 mg, and nitrous oxide—oxygen, 4:2 l/min. Succinylcholine, 80 mg, was administered intravenously and the trachea was intubated without difficulty. The electrocardiogram was monitored; an immediate progressive increase in the height of the T-waves was noted (fig. 1). Blood samples for potassium analysis were obtained from a 16-gauge intracath placed in the basilic vein prior to induction of anesthesia (fig. 1). Ninety seconds after succinylcholine administration serum K⁺ increased from a control value of 3.59 to 10.52 mEq/l. After 5 and 30 minutes values were 7.29 and 6.13 mEq/l, respectively. Immediate treatment consisted of controlled hyperventilation, which resulted in a rapid decline in the amplitude of the T-wave. Cardiovascular stability was evident throughout the episode and it was not necessary to administer additional treatment. After a few minutes of hyperventilation,