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ISOFLURANE ANESTHESIA IN FREE RANGING SEA LION PUPS

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ABSTRACT: California sea lion pups, *Zalophus californianus*, (n = 115), were captured and anesthetized for (mean ± SD) 17.6 ± 7.8 min on San Miguel Island, California (USA) in November of 1992. Mask isoflurane anesthesia allowed intubation in 7.1 ± 2.74 min. Pups recovered and walked in 7.32 ± 4.8 min. Mask anesthesia in pups resulted in relaxation in 45 ± 14 sec. Safe, brief anesthesia was delivered in support of weighing, medical evaluation, and short surgical procedures. Recovery character of all pups was sufficient to permit release to the free ranging state immediately after surgery, saving labor, supervision personnel, and postoperative time.

Key words: *Zalophus californianus*, sea lions, pinniped, equine foals, anesthesia, isoflurane.

INTRODUCTION

Anesthesia was needed in support of National Marine Fisheries Service field teams, who were studying and working with suspected disease problems in sea lion (*Zalophus californianus*) pups. We were asked if we could provide short periods of field anesthesia in remote field sites with back pack equipment. It was necessary to anesthetize a large number of pups for short surgery periods. Fast anesthetic recovery was needed to facilitate release of pups back to their wild state. Injectable agents could not be used to accomplish all of these objectives. Inhalation techniques previously published in pinnipeds relate longer periods of anesthesia in clinical settings for a few individuals and long surgeries. (Ridgway and Simpson, 1969; Gales, 1989; Gage, 1993; Work et al., 1993; Heath et al., 1996). Isoflurane inhalation techniques were chosen because of the cost, availability, and character of short induction and recovery. Halothane was too long acting and the newer agents sevoflurane, and desflurane were not suitable for field use or were more costly. Mask induction of anesthesia without any premedication drugs is commonly practiced in neonate and juvenile animals. Young animals are easily restrained manually, and the advantage of mask induction eliminates injectable agents and gains fast recovery from the volatile vapor. In our experience with animals of all sorts, sea lion pups experienced more rapid anesthetic induction and recovery than domestic animals. In this paper we document this finding of speed of mask induction and recovery times in sea lion pups. The only carefully controlled and timed mask anesthesia study published is in foals, (Steffey et al., 1991) which was chosen to compare with the masking and physiologic differences of marine mammals. (Reed et al., 1994).

MATERIALS AND METHODS

The study was conducted on San Miguel Island California (USA) (34°02'N, 120°26'W) in November 1992. One hundred and fifteen California sea lion pups, *Zalophus califorianus*, were captured by simply running up to them and grasping their rear flippers. They were maintained in large fenced pens with pools, shade, and wind protection for 4 days. During captivity they were evaluated by the biologic team for body fat content, diseases, and immunologic status. Multiple data from the extensive physical examination was collected and is being prepared for publication in other manuscripts. On the fourth day of captivity they were anesthetized. For anesthesia, pups were physically restrained by hand on wooden surgical tables in a field tent near the beach where they were captured. No premedications were given or found necessary. Anesthesia was induced with isoflurane (AErrane, Ohmeda PPD, Inc., Liberty Corner, New Jersey, USA) at 2.5 to 3% dial settings delivered from recently calibrated precision Ohio vaporizers (Anaquest Madison Wisconsin, USA). Aluminum "E" cylinders with Ohio flowmeters were backpacked to the site to provide 1 to 2 l per min oxygen. Masks were constructed from the tops of rubber traffic cones and attached to the "Y" piece of a standard Ohio small animal anesthetic circuit (Anaquest, Madison, Wisconsin). The vaporizer and anesthesia circuit was mounted to the frame of a standard hip slung back pack. The backpack, including monitoring, oxygen, vaporizer, and circuit weighed 26.5 kg. The pups were intubated with commercially available 7.5 to 9 mm cuffed endotracheal tubes (Anaesthesia Equipment Service, Denver, Colorado, USA). Intubation was facilitated by opening the mouth with short loops of cord and laryngoscopic visualization using a 19 cm straight blade. (McGrath et al., 1981).

After intubation the pups were maintained on 0.75% to 1.5% dial setting isoflurane at 800 ml to 1 l per min oxygen flows. Pups were continually evaluated by one of the authors for physical signs including head movement, jaw tone, palpebral reflex, eye position, iris appearance, respiratory character, capillary refill, recovery times, and recovery character. Masking time was the time from mask application to intubation. Anesthesia time was the time from placement of an endotracheal tube to its removal. Surgical time was the actual manipulation time by the surgical team. Anesthesia data recorded at 5 min intervals included all pertinent times of surgery and anesthesia, pulse rate, respiratory rate, vaporizer setting, oxygen flow rate, pulse oximetry reading, and oral temperature.

Electronic monitoring instruments, all battery powered, were applied as follows. Tissue oxygenation and cardiac pulse was monitored by pulse oximetry sensors placed on the tongue and shielded from sunlight, (Model N-10, Nellcor Incorporated, Pleasanton, California). Several pulse oximetry sensors and placement locations were tried. The best success was obtained with a C-clamp sensor on the tongue. (Nellcor Oxisensor II low noise cable with plastic holder) Cardiac electrical activity was monitored by electrocardiograph. (Medical Data Electronics, Arleta, California). Body temperature was monitored early and continuously by deep oral probe, (model G-08528-20 JKT digisense, Cole Parmer, Niles, Illinois, USA).

Collection of blood samples was from the caudal parasacral veins. Two-gram blubber samples were taken aseptically after shaving and surgical preparation, from a 2 cm surgical incision at the dorsal mid-cervical neck. Ocular, oral, rectal, and vaginal swabs were obtained for viral and bacterial culture, using sterile commercially available swabs. (Anaesthesia Equipment Service, Denver, Colorado).

During management and handling of sea lion pups, temperature changes were watched for as evidenced by malaise, mouth breathing, and weakness. Care was necessary to prevent hyperthermia from being a life threatening problem to the pups. Hyperthermia was controlled by working the animals quickly, early in the morning, and spraying with water to keep them cool. The breathing patterns of the pups was compared to the typical marine mammal apneustic plateau pattern described by Williams et al. (1990). Emergency drugs were not administered but were available in the anesthesia pack if necessary (Haigh, 1982).

RESULTS

The pups accepted masking with little or no resistance. Relaxation occurred at (mean ± SD) 45 ± 14 sec. Anesthesia sufficient to allow rectal probes, skin puncture, and blood sampling without a wriggling, respiratory, or pulse rate response on the part of the patient could be conducted in less than 2 min. Anesthesia sufficient to allow intubation occurred at 7.1 ± 2.74 min.

Pups had typical marine mammal apneustic plateau breathing patterns: exhalation first, then pause and hold in inspiration, while being held for examination and masking. After intubation in early anesthesia, pups would noticeably change over to the reverse of their normal pattern. During all of anesthesia they would use an inspiration, exhalation, pause in exhalation pattern, characteristic of land mammals.

Character of ventilation was judged by the anesthetist to be visually robust and spontaneous in all individuals. Mucous membranes were pink in all but three noticeably pale individuals. The three were anemic as evidenced by their packed red cell volume of 12 to 16 volume-%. The packed cell volume for the entire group of 115 was 31.4 ± 6.5 volume-%. Capillary refill times in all pups were 1 to 2 sec. Oxygen saturation of hemoglobin from oximetry readings stayed above 90% except for five readings below 85% obtained from the three anemic individuals.

During the volatile vapor anesthesia of the pups, no dysrhythmias were detected by electrocardiogram or pulse oximetry. No complications or deaths were experi-

TABLE 1. Measurements of anesthetic management and physiologic data from California sea lion pups, San Miguel Island, California, November 1992.

Parameter	Number sampled	Range	Mean	SD
Masking time (min)	115	2 to 20[a]	7.1	2.74
Anesthesia time (min)	115	5 to 45	17.6	7.78
Surgery biopsy time (min)	115	4 to 32	12.0	5.40
Extubate (from disconnect) (min)	115	0 to 17	3.8	2.64
Head up (from disconnect) (min)	115	1 to 18	5.31	2.75
Walking (from disconnect) (min)	115	2 to 46	7.32	4.8
Weight (kg)	115	9 to 24.5	13.94	3.06
Ambient temperature (C)	112	17.5 to 45.8	22.52	4.12
Body temperature pre anes (C)	113	34.6 to 39.9	37.32	1.9
Body temperature post anes (C)	105	34.8 to 40.4	37.33	2.16
Packed cell volume—%	113	12 to 45	31.49	6.46
Total plasma protein (gm—%)	113	5.2 to 8.6	6.96	0.88
White count per deciliter	106	3,100 to 24,475	12,157	4,808
Pulse rate (number per min)	600	78 to 183	116.6	17.42
Respiratory rate (number per min)	600	8 to 65	28.2	10.41
Pulse oximetry readings (%)	300	72 to 100	93.4	8.26

[a] One pup was not intubated; it was anesthetized by mask alone for 20 min.

enced due to the immediate manipulation, captive period or volatile vapor anesthesia in these sea lion pups. Pups were recovered by the anesthetist, near the beach on a canvas to prevent aspiration of sand. They were supervised until they coughed and were extubated. They awoke from anesthesia quickly, as evidenced by vocalizing and walking with full body movement at 7.32 ± 4.8 min. At this time, they were released. Pups immediately ran to the water and swam to the nearest group of sea lions.

DISCUSSION

The sea lion pups were easy and quick to mask to anesthesia depths, compared to our experience in masking domestic animals of all sorts. Pups would relax after three or four breaths, allowing the holder to also relax. To our knowledge the only published, controlled and timed mask anesthesia study is in foals; these relaxed after 20 to 30 breaths in 4.52 ± .28 min, a six-fold difference (Steffey et al., 1991). In *Zalophus* sp. sea lion pups, intubation, at 7.1 min, was nearly 2 1/2 min faster than intubation in foals. Intubation in isoflurane-masked foals occurred at 9.57 ± 0.58 min (Steffey et al., 1991). Anesthesia was sufficient to allow beginning surgical intervention in these pups after 2 min of masking, with or without intubation.

Respiratory exchange of gray seals (*Halichoerus grypus*) is 47% of total lung capacity with each breath (Reed et al., 1994). This compares to 16% for horses at rest (Steffey et al., 1991). The cardiac output of California sea lions, harbor seals and terrestrial animals is similar amongst animals of similar mass, (2.5 to 3.0 ml/kg^{-1} sec^{-1}) (Ponganis et al., 1991). Pinnipeds use their efficient ventilatory patterns and larger stores of oxygen and hemoglobin to accomplish deep extended dives. Pinniped individuals are able to spend up to 90% of their time submerged at sea and still function with an aerobic metabolism. (Williams et al., 1991).

These physiologic differences, which are not commonly known facts in veterinary anesthesia circles, allow the anesthetist to deliver inhalation agents to a marine mammal with greater efficiency than to terrestrial domestic mammals. Vigilance was necessary in early induction while masking, not to deliver too much anesthesia to the sea lion pups compared to other species commonly masked. The induction of, and recovery from, isoflurane was more rapid than our experience with foals, specifically, and all domestic animals in general. Walking and full body movement occurred at 7.32 ± 4.8 min in 115 *Zalophus* sp. pups after a 17.6 min mean anesthesia time. Foals, in comparison, required from 8 to 14 min to stand and nurse (Steffey et al., 1991).

Temperature changes in all anesthetized animals, large or small, tend toward the ambient temperature. Hyperthermia trends were seen in the *Zalophus* sp. pups and were controlled by working with animals early in the morning, working quickly, shading the animal and spraying with water to keep them cool. Hypothermia, which is common in stainless steel air-conditioned clinics, was not seen in the field conditions we encountered.

Monitoring with commercially available pulse oximeters which are calibrated in infra-red wavelength for human hemoglobin, give readings within a few percent. This is a reliable trend for domestic and wild animal use.

The difficulty of transporting and operating the inhalation anesthesia equipment in remote field sites, was outweighed by the convenience and safety of anesthesia provided to the field biologist. Isoflurane anesthesia actually saved time and labor of holders by allowing quick manipulation and surgical access to the animals. The objective of having essentially normal pups released safely to their environment of rocks and water and walking in minutes after anesthesia saved time in the field management of this large number of pups. Vocalization was consistent and loud as a sign of recovery in all pups. It was difficult to assess and relate long term follow up or survival data of anesthetized pups, due to the varied terrain and large number of individuals in these rookeries. None of the tagged surgical *Zalophus* sp. pups were found dead during the week following surgery by the regular biology personnel observing this large 25,000 animal rookery.

Isoflurane use was calculated to be 10 ml per pup. At the current cost of $0.41 (American $) per ml each pup's consumption of isoflurane cost $4.10.

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