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FIELD USE OF ISOFLURANE AND AIR ANESTHETIC EQUIPMENT IN WILDLIFE

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Abstract: Conventional inhalation anesthesia of wildlife species within natural habitats presents significant practical problems. Heavy cylinders of medical grade oxygen are often unavailable in field situations. Equipment has been modified to permit the delivery of isoflurane in ambient air as the carrier and to be fitted with circuitry adaptable for different species and anesthetic situations. Preliminary empirical studies at low altitude in a range of small mammalian and avian species demonstrate the suitability of this combination and these techniques for inducing and maintaining anesthesia in clinically normal patients undergoing relatively minor procedures. The equipment has also been used to deepen and prolong anesthesia in several larger species, including great apes and large cats, after induction with injectable agents. These techniques, in combination with pulse oximetry to detect hypoxemia, provide a cheap, robust, and portable inhalation anesthetic system for field situations that is not dependent on compressed gasses.

Key words: Isoflurane, air, field anesthesia, inhalation anesthesia, primate, carnivore.

INTRODUCTION

Field anesthesia requires simple, high quality, and safe equipment and techniques. As a result, most wildlife biologists or veterinarians use injectable anesthetic agents alone, although these techniques may lack flexibility with respect to anesthetic depth or duration. Incremental injections of anesthetic agents to deepen or prolong anesthesia may significantly increase recovery times, resulting in danger for the animal and inconvenience for workers. Reversal agents may cause ataxia and potentially hazardous recoveries. It is also difficult to control anesthesia of very small animals using injectable agents—reversible anesthetics are not cost-effective and nonreversible agents often cause long recovery times.[12] Relatively simple field gas anesthesia equipment can provide solutions to these problems,[5,12,15,16] permitting induction and maintenance in smaller species and allowing rapid recovery and early safe return to the wild. Inhalation agents can be used to deepen and maintain injectably induced anesthesia in larger and more dangerous species without significantly prolonging recovery time. This can decrease the need for prolonged monitoring and retention of animals before release, thereby saving time and improving safety.

Field gas anesthetic equipment should be light, robust, simple in construction, and inexpensive.[5,12,15,16] Small, lightweight, portable cylinders of oxygen can, however, have insufficient capacity for prolonged use. Medical grade oxygen is not available in all countries, and large cylinders may be heavy and unsafe to transport over off-road conditions or to store. However, available anesthetic equipment that replaces oxygen with air as the carrier[17] offers a solution.

Anesthesia carrier gas mixtures containing less than 35% oxygen may present an unacceptable risk of hypoxemia, at least partly due to the respiratory and cardiovascular depressant qualities of volatile anesthetic agents.[1,13,14] However, air may be a suitable vehicle for maintaining oxygenation provided adequate ventilation is ensured,[3,19] and there has been extensive military use of anesthetic equipment using air as the carrier gas with minimal oxygen supplementation. The British armed forces have used one such system (Tri-Service Anaesthetic Kit, Penlon Ltd., Abingdon, Oxfordshire OX14 3PH, U.K.)[6] for 25 yr in military actions in Belize, the Falkland Islands, Northern Ireland, and Oman.[8,9,19] A modified Tri-Service Anaesthetic Kit described has been used in some veterinary situations,[11] and additional suitable uses in a range of field situations are described in this study.

MATERIALS AND METHODS

An isoflurane and air apparatus was based on the Tri-Service version of the stainless steel, draw-over, Oxford Miniature Vaporizer 50 (OMV 50, Penlon Ltd.) with a 50-ml anesthetic liquid reservoir.[6] This vaporizer can be used equally well with halothane, enflurane, or isoflurane.[10] Although the vaporizer may be tilted through 60° without spillage of the anesthetic agent or alteration of output concentrations,[6,17] extra stability under field conditions was provided by a 15-cm by 15-cm by 6-mm aluminum base plate, which replaced the folding stand of the OMV 50 unit. The base plate was held in place centrally by a single retaining hand screw, and an adjustable foot at each corner of the plate allowed leveling on uneven surfaces. Where the risk of up-

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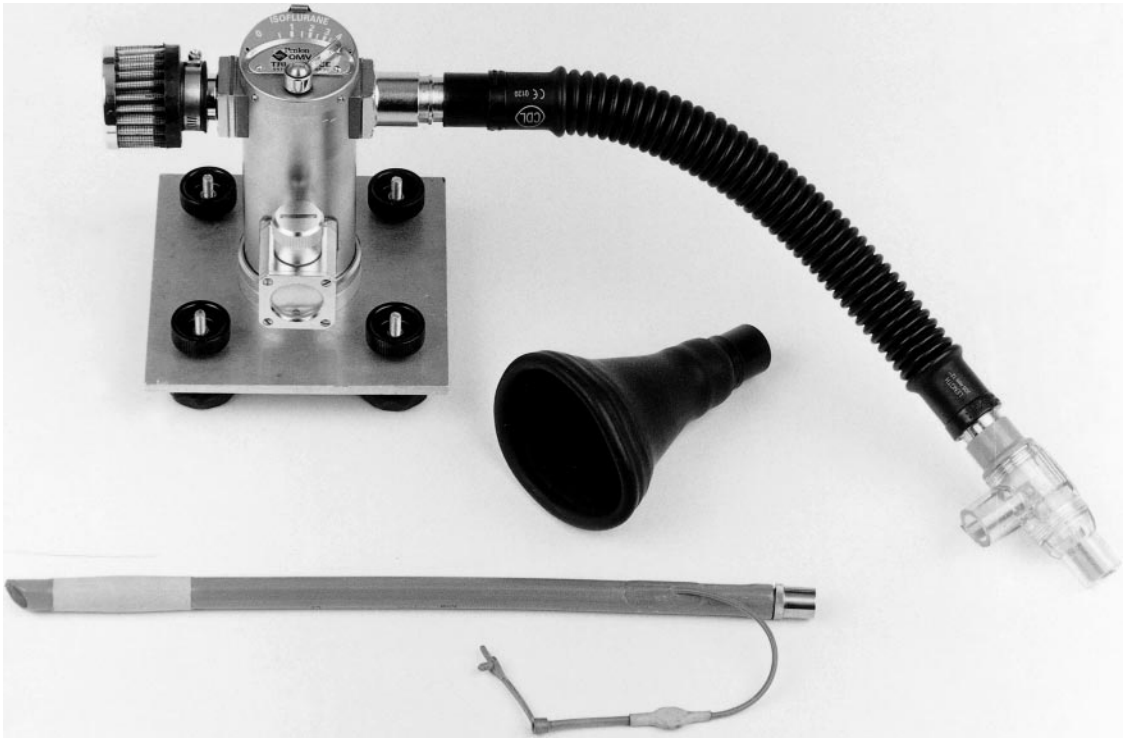

Figure 1. Isoflurane and air anesthetic equipment in configuration 1.

setting the unit was particularly high the retaining screw was replaced with a 17-cm tapered steel spike that could be driven into the ground. Ingress of dust, sand, insects, and other foreign material into the vaporizer was prevented by fitting a high-performance motorcycle carburetor air intake filter (RC2540, K & N Engineering Inc., Riverside, California 92502, USA) over the vaporizer's air intake. Such filters have an extremely low resistance and therefore do not limit airflow through the system. To ensure that the OMV 50 worked in draw-over mode, a 23-mm/22-mm male–male adaptor (Burtons Medical Equipment Ltd., Marden, Kent TN12 9QJ, U.K.) fitted with a lightweight plastic one-way directional valve (Intersurgical, Wokingham, Surrey RG41 2RZ, U.K.) was pushed tightly into the outlet of the vaporizer. The standard halothane–trichloroethylene anesthetic gas concentration scale of the OMV 50 was replaced by an isoflurane scale (Penlon Ltd.) and the rear mounting bracket removed. Calibration of the unit's isoflurane output under different vaporizer settings and draw-over airflow rates was carried out commercially using infrared mass spectrometry (Burtons Medical Equipment Ltd.). Various anesthetic circuits were fitted to the 23-mm/22-mm outlet adaptor of the modified vaporizer to suit the needs of anesthetized species.

Configuration 1

The simplest anesthetic circuitry using the least amount of equipment was considered suitable for prolonging or deepening anesthesia in large animals (<250 kg) that had been anesthetized with injectable agents and were breathing spontaneously (Fig. 1). Depending on the operator's needs and species being anesthetized, a suitable length of 22 or 15 mm corrugated hose fitted with male and female hose adaptors was connected to the vaporizer outlet adaptor. A lightweight plastic nonrebreathing anesthetic valve (E-valve, Ambu International A/S, Copenhagen, DK-2750 Denmark) connected to the free end of the corrugated hose allowed attachment directly to an endotracheal tube or face mask. The face mask was fitted snugly against each animal's face to produce an airtight seal. This allowed the animals to move air through the vaporizer on inspiration and prevented dilution of the inhaled isoflurane–air mixture. Rebreathing was prevented by the E-valve at all times.

Configuration 2

This configuration was designed for intubated large animals requiring intermittent positive pressure ventilation (IPPV). A self-inflating adult re-

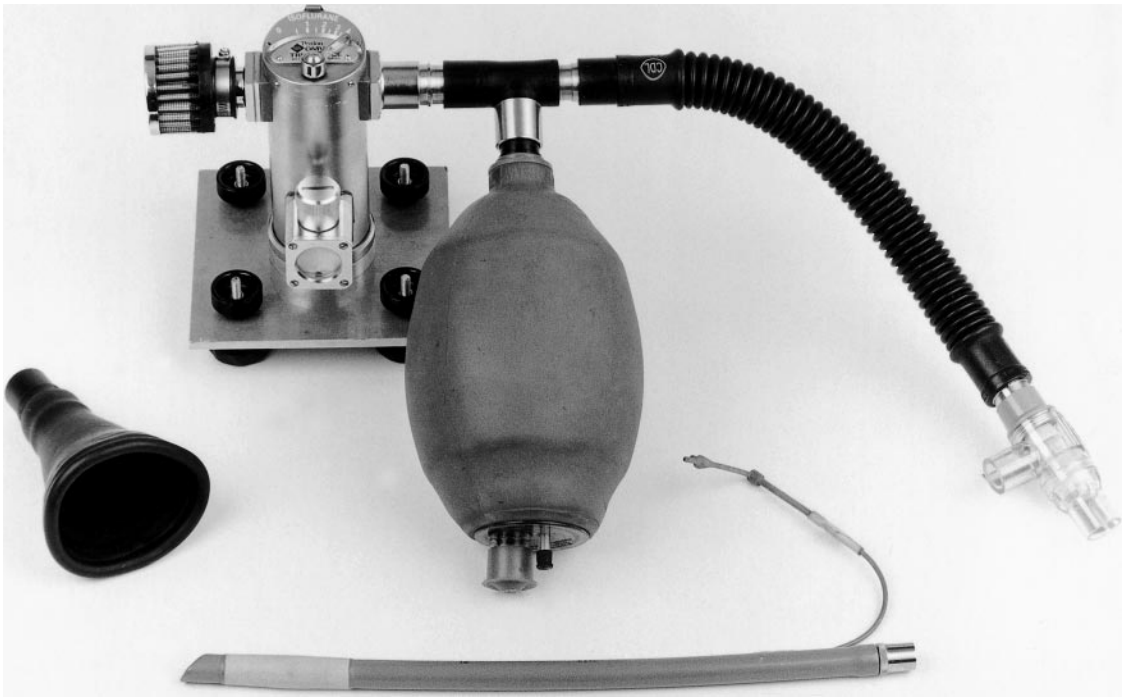

Figure 2. Isoflurane and air anesthetic equipment in configuration 2.

suscitation bag (Mercury Medical Products, 11300–49th Street North, Clearwater, Florida 33762, USA) attached to a Magill T mount was inserted between the vaporizer outlet adaptor and the corrugated hose (Fig. 2). The gas intakes at the bottom of the resuscitation bag were occluded to prevent dilution of the anesthetic mixture. For ease of operation in the field, an extra section of corrugated hose was sometimes included between the vaporizer outlet adaptor and the T mount. The original Tri-Service Anaesthetic Kit uses an inline resuscitation bag with an inlet valve, but it was more convenient to use a valve in the vaporizer outlet adaptor and connect the resuscitation bag to a T mount. A similar arrangement is standard in the multiagent portable battlefield anesthetic unit produced by Ohmeda (Military PAC, Ohmeda, Hatfield, Hertfordshire AL9 5EN, U.K.), which is also based on a draw-over vaporizer using air as the carrier gas. Configuration 2 used with a loose-fitting face mask was also used to induce and maintain medium- or small-sized animals that could be manually restrained. Although somewhat wasteful of isoflurane, intermittent compression of the resuscitation bag produced an adequate flow of isoflurane and air to allow effective anesthesia and prevent rebreathing. Overinflation of the patient during this procedure was avoided by the loose fit of the face mask.

Configuration 3

An alternative system for small animals weighing <5 kg, including birds and very small mammals, was provided by using an Ayres T-piece anesthetic circuit (Fig. 3). A resuscitation bag and T mount was attached to the vaporizer outlet adaptor as in configuration 2. An Ayres T-piece anesthetic circuit (Burtons Medical Equipment Ltd.) was then connected to the outlet of the T mount through an adaptor fitted with a lightweight one-way plastic valve, which prevented refilling of the resuscitation bag from the patient's side. Slow intermittent compression of the resuscitation bag provided sufficient gas flow to prevent rebreathing. This configuration could be used with a face mask or endotracheal tube.

Animal Trials

One hundred and forty-nine mammalian and eight avian anesthetic episodes with the isoflurane and air equipment were carried out in a variety of species (Tables 1–3) under field conditions in temperate and tropical climates within 500 m above sea level. Animals were mostly clinically normal or re-

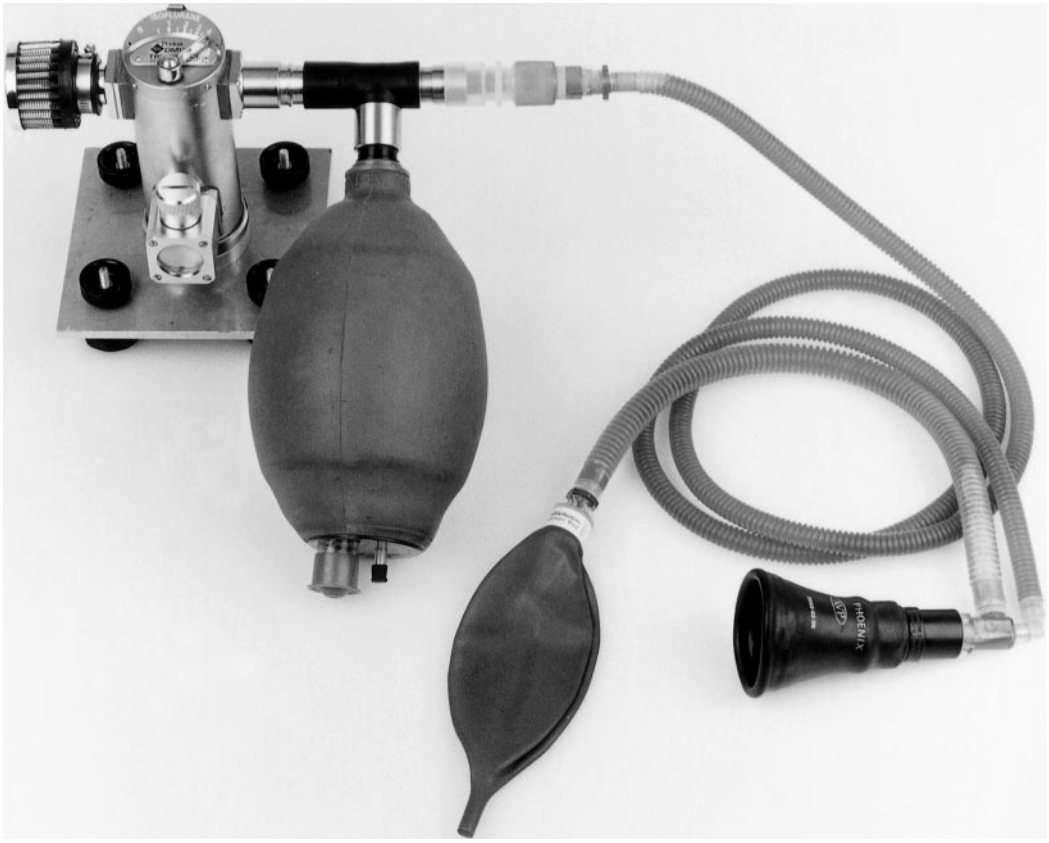

Figure 3. Isoflurane and air anesthetic equipment in configuration 3.

quired only minor surgical or investigative procedures. Although all trials were conducted with oxygen available, it was never used. Induction and anesthesia protocols are given in Tables 1–3. Anesthesia of the larger or more dangerous species was induced with injectable agents. In smaller species that could be restrained by hand or in a net, induction was achieved by isoflurane and air using a face mask, with the maximum isoflurane setting on the vaporizer and flow rates greatly in excess of four times the estimated minute volume. It was difficult to achieve lower gas flow rates by intermittent compression of the resuscitation bag. Isoflurane and air was used for maintenance in all cases with the lowest vaporizer setting necessary to achieve the required anesthetic depth. All animals were monitored clinically, and during the longer procedures, SpO_2 was recorded every 5 min when pulse oximeters were available. During maintenance, attention was paid to the clinical result and not to vaporizer control settings because these were not necessarily comparable with those that would be expected to be effective using conventional isoflurane vaporizers with oxygen as the carrier gas.

RESULTS

Tables 1–3 present the durations of time the animals remained under isoflurane and air anesthesia and, where available, the SpO_2 values.

Calibration tests showed that vaporizer output varied markedly with airflow rate. At very low flow rates (0.5–1 L/min), substantially lower isoflurane concentrations were delivered than those set on the vaporizer, except at the maximum setting with airflow of 1 L/min, where a concentration of 5.6% was achieved. At 10-L/min airflow, output concentrations were fairly accurate below the 2% setting but slightly lower than set above this level. At 5-L/min airflow, output concentrations accorded fairly accurately with those set on the vaporizer.

All three configurations were easy to use. Inductions and recoveries were uneventful, and maintenance was fairly straightforward. Configuration 3 required a degree of operator experience to achieve

Table 1. Preliminary field trials with isoflurane and air—carnivores.[a]

Species	Latin name	No.	Age	Sex[b]	Indication	Induction[c]	Equipment	Time i–a[d] (min)	SpO_2
Amur leopard	*Panthera pardus orientalis*	1	Ad	M	Maintain for examination	50 μg/kg M + 2.5 mg/kg K	Con 1, ET	23	>90 at all times
Asiatic lion	*Panthera leo persica*	1	Ad	M	Maintain in transport after surgery	30 μg/kg M + 2 mg/kg K	Con 1, ET	9	NR
Binturong	*Arctictis binturong*	1	Ad	M	Deepen for examination	100 μg/kg M + 4 mg/kg K	Con 2, mask	10	NR
Clouded leopard	*Neofelis nebulosa*	1	Ad	M	Prolong for electroejaculation	50 μg/kg M + 3 mg/kg K	Con 1, ET	40	NR
Geoffroys cat	*Oncifelis geoffroyi*	1	Ad	M	Examine and BS	Iso/air	Con 2, mask	7	NR
Eurasian badger	*Meles meles*	4	Ad	M/F	Deepen for examination and BS	100 μg/kg M + 4 mg/kg K	Con 2, mask	10 ± 2.2	>90 at all times
Eurasian otter	*Lutra lutra*	5	Ad	M/F	Deepen for examination, BS, and microchipping	100 μg/kg M + 5 mg/kg K or 4 mg/kg TZ	Con 3, mask	12.8 ± 1.7	NR
Fossa	*Cryptoprocta ferox*	1	SA	F	Examine and BS	Iso/air	Con 2, mask	16	NR
Persian leopard	*Panthera pardus saxicolor*	3	Ad	M/F	Prolong anesthesia for minor surgery	50 μg/kg M + 2.5 mg/kg K	Con 1, mask and ET	18.3 ± 2.6	Mean = 91 (80–98)
Red fox	*Vulpes vulpes*	10	Ad	M/F	Examine, BS and minor surgery	Iso/air	Con 2 or 3, mask	18.8 ± 4.6	>85 at all times

[a] Ad, adult; SA, Subadult; Con 1, configuration 1; Con 2, configuration 2; Con 3, configuration 3; ET, endotracheal tube; BS, blood sampling; NR, not recorded.

[b] M, male; F, female.

[c] Induction doses given are approximate. M, medetomidine (Zalopine; Orion Corporation, Espoo, Finland); K, ketamine (Narketan; Vetco Ltd., Cougar Lane, Naul, County Dublin, Republic of Ireland); Iso/air, isoflurane and air; TZ, tiletamine and zolazepam (Zoletil; Vibrac Laboratories, 06516 Carros, France).

[d] Time on isoflurane and air. Where more than one animal is included, time is expressed as the $x \pm$ SD.

a near-constant flow of isoflurane and air by intermittent resuscitation bag compressions at a rate that produced anesthesia, yet limited waste.

Pulse oximetry was used during 24 mammalian and 0 avian anesthetic episodes. In Amur leopard (*Panthera pardus orientalis*), barbirusa (*Babyrousa babyrussa*), Eurasian badger (*Meles meles*), and lar gibbon (*Hylobates lar*), SpO_2 values were consistently greater than 90% throughout the procedures undertaken. In the chimpanzee (*Pan troglodytes*), gorilla (*Gorilla gorilla gorilla*), orangutan (*Pongo pygmaeus*), and Persian leopards (*Panthera pardus orientalis*), mean SpO_2 values of >90% were achieved, but values of 80–89% were occasionally recorded. All red fox (*Vulpes vulpes*) SpO_2 values were greater than 85%.

The barbirusa and Brazilian tapir (*Tapirus terrestris*) relaxed profoundly with isoflurane and air

Table 2. Preliminary field trials with isoflurane and air—primates.[a]

Species	Latin name	No.	Age	Sex[b]	Indication	Induction[c]	Equipment	Time i–a[d]	SpO_2
Black mangabey	*Cercocebus aterrimus*	1	Ad	F	Examine and BS	Iso/air	Con 2, mask	5 min	NR
Capuchin	*Cebus paella*	1	SA	M	Examine and BS	Iso/air	Con 2, mask	7 min	NR
Cherry-capped mangabey	*Cercocebus torquatus*	4	SA	M/F	Examine, BS, and TBT	Iso/air	Con 3, mask	9 min ± 1.4 min	NR
Chimpanzee	*Pan troglodytes*	1	Ad	M	Deepen for skin biopsies	20 μg/kg M + 1.5 mg/kg TZ	Con 1, ET	56 min	Mean = 90 (84–97)
Fat-tailed dwarf lemur	*Cheirogaleus medius*	1	Ad	F	Amputate tail	Iso/air	Con 3, mask	25 min	NR
Lar gibbon	*Hylobates lar*	1	Ad	F	Deepen for surgery	100 μg/kg M + 4 mg/kg K	Con 3, ET	32 min	>90 at all times
Lowland gorilla	*Gorilla gorilla*	1	Ad	M	Prolong for examination	20 μg/kg M + 1.5 mg/kg TZ	Con 1, ET	29 min	Mean = 95 (85–99)
Mona monkey	*Cercopithecus mona*	6	Ad	M/F	Examine, BS, and TBT	Iso/air	Con 3, mask	17.5 ± 1.7 min	NR
Orangutan	*Pongo pygmaeus*	1	SA	F	Anesthesia during treatment of laryngeal edema	20 μg/kg M + 1.5 mg/kg TZ	Con 1, ET	Intermittent for 6 hr—10 min on, 10 min off	Mean = 93 (89–97)
Patas monkey	*Erythrocebus patas*	17	Ad, SA	M/F	Examine and microchip	Iso/air	Con 2, mask	12.4 ± 1.9 min	NR
Red-eared guenon	*Cercopithecus erythrotis*	4	Ad	M/F	Examine, BS, and TBT	Iso/air	Con 3, mask	17.5 ± 2 min	NR
Ruffed lemur	*Varecia variegata*	2	Ad	M	Castration	Iso/air	Con 3, mask	23.5 ± 1.5 min	NR
Spider monkey	*Ateles paniscus*	1	Ad	F	Minor surgery	Iso/air	Con 2, mask	12 min	NR
Squirrel monkey	*Saimiri sciureus*	8	Ad	M/F	Examine and BS	Iso/air	Con 2, mask	4.5 ± 0.5 min	NR
Stump-tailed macaque	*Macaca arctoides*	4	Old	M/F	Anesthetic induction	Iso/air	Con 2, mask	4.6 ± 0.4 min	NR

[a] Ad, adult; SA, subadult; BS, blood sampling; TBT, intradermal tuberculin test; Con 1, configuration 1; Con 2, configuration 2; Con 3, configuration 3; ET, endotracheal tube; NR, not recorded.
[b] M, male; F, female.
[c] Induction doses given are approximate. M, medetomidine; K, ketamine; TZ, tiletamine and zolazepam; Iso/air, isoflurane and air.
[d] Time on isoflurane and air.

Table 3. Preliminary field trials with isoflurane and air—miscellaneous species.[a]

Species	Latin name	No.	Age	Sex[b]	Indication	Induction[c]	Equipment	Time i–a[d] (min)	SpO_2
Mammals									
Barbirusa	*Babyrousa babyrussa*	2	Ad	M	Deepen for hoof trimming	20 μg/kg M + 1 mg/kg TZ	Con 1, mask	27.5 ± 2.5	>90 at all times
Brazilian tapir	*Tapirus terrestris*	2	Ad	F	Deepen for examination	20 μg/kg M + 2 mg/kg TZ	Con 1, mask	30 ± 2	NR
European hedgehog	*Erinaceus europaeus*	64	Ad	M/F	Examination and minor surgery	Iso/air	Con 3, mask	13 ± 1.9	NR
Birds									
Barn owl	*Tyto alba*	1	Ad	U	Implant transponder	Iso/air	Con 3, mask	4	NR
Channel-billed toucan	*Ramphastos vitellinus*	2	Ad	M/F	Surgical sex determination	Iso/air	Con 3, mask	14 ± 1	NR
Hooded vulture	*Necrosyrtes monachus*	1	Ad	F	Examine eyes	Iso/air	Con 3, mask	10	NR
Red-necked ostrich	*Struthio camelus*	1	Ad	M	Replace cloacal prolapse	100 μg/kg M + 10 mg/kg K	Con 2, ET	23	NR
Sacred ibis	*Threskiornis aethiopica*	2	Ad	M/F	Surgical sex determination	Iso/air	Con 3, mask	9.5 ± 1.5	NR
Saker falcon	*Falco vespertinus*	1	Ad	U	Examine and BS	Iso/air	Con 3, mask	8	NR

[a] Ad, adult; BS, blood sampling; Con 1, configuration 1; Con 2, configuration 2; Con 3, configuration 3; ET, endotracheal tube; NR, not recorded.
[b] M, male; F, female; U, undetermined sex.
[c] Induction doses given are approximate. M, medetomidine; K, ketamine; TZ, tiletamine and zolazepam; Iso/air, isoflurane and air.
[d] Time on isoflurane and air.

after induction with injectable agents (Table 3). In these species, injectable agents alone often produce stormy or poorly relaxed anesthesia. The apparatus proved especially useful in the orangutan that was intubated for 6 hr and for which injectable agents were considered inappropriate.

DISCUSSION

Although the use of air as a carrier gas to deliver inhalation anesthetics is not new, the technique offers substantial advantages in low-altitude wildlife anesthesia. Field gas anesthesia equipment should be stable, have the facility for ventilation, and present the patient with low inspiratory resistance and freedom from rebreathing. The equipment described met these requirements.

Human patients presented to military anesthetists often have high oxygen requirements as a result of traumatic injuries involving significant blood loss, shock or compromise of the respiratory tract, whereas wildlife subjects are generally clinically normal. The simple isoflurane and air equipment described is suitable for induction and maintenance of short-term anesthesia in a wide range of small avian and mammalian species undergoing relatively minor procedures and for deepening or prolonging anesthesia in larger or more aggressive species after induction with injectable agents. Relaxed field anesthesia in the Suidae or Tapiridae can be difficult to achieve with injectable agents alone. Excitement during induction or recovery can be smoothed by the judicious use of isoflurane and air. Postrelease ataxia, predation, or trauma may be minimized in larger species by reversing the effects of induction agents immediately after stabilization on isoflurane and air because the effects of isoflurane wear off more rapidly than do those of some induction agents. Isoflurane and air anesthesia can be maintained during transport when crating is not possible. Even when injectable anesthetic agents are used to immobilize dangerous captive individuals, the isoflurane and air equipment can be maintained nearby in case of unexpected changes in anesthetic depth. Configurations 1 and 2 used with an endotracheal tube use isoflurane efficiently for a nonrebreathing system because the isoflurane–air mixture is only produced during an animal's inspiratory efforts or during IPPV. In configuration 2 used with a loosely fitting face mask and in configuration 3, the isoflurane–air mixture is generated constantly by the operator and hence is more wasteful of anesthetic agent. The equipment is robust, lightweight (approximately 3 kg excluding isoflurane), and unaffected by rough conditions during transport. Other anesthetic circuit configurations and anesthetic agents such as halothane or sevoflurane could be used with the apparatus depending on operator preference. Scavenging of exhaled anesthetic gas should be unnecessary when the apparatus is used outdoors for short-term procedures, although laws requiring waste gas scavenging under all circumstances may exist in some countries.

This equipment does have practical and theoretical limitations. It is intended to provide short periods of anesthesia only. However, most veterinary interventions with wild animals are limited in scope and duration and do not require prolonged anesthesia. Induction with isoflurane and air alone in smaller species may allow sufficient time to collect measurements and samples. As with halothane and trichloroethylene in the OMV 50 and ether or halothane in the Military PAC draw-over system,[2,18] the vaporizer is affected by changes in airflow rates, with lower than expected concentrations of isoflurane being produced at low flow rates and at settings greater than 2% at high flow rates. Uncertain calibration at low flow rates is a particular problem with very small species.[12] Operators must ensure adequate flow rates, assess anesthetic depth by observing the patient, and prevent rebreathing. Rebreathing could lead to hypoxia and contamination of the equipment with respiratory microorganisms. Configurations 1 and 2 with an endotracheal tube prevent rebreathing with a valve, but in configuration 2 used with a loosely fitted face mask and in configuration 3, rebreathing is only prevented by maintenance of adequate flow rates.

With clinically normal subjects anesthetized for short periods at low altitudes, there is limited risk of hypoxia. The lowest concentration of isoflurane consistent with anesthetic requirements should be used, however, especially when induction agents such as alpha-2-agonist combinations may cause respiratory depression. Pulse oximetry provides a sensitive indicator of hypoxemia when subjects are breathing air as opposed to oxygen,[7] and it should be used during isoflurane and air anesthesia. Momentary decreases in SpO_2 to less than 90% in the chimpanzee, orangutan, gorilla, and Persian leopards were easily corrected by adjusting the vaporizer output control or providing brief periods of IPPV. Many of the other animals were only anesthetized with isoflurane and air for short periods, and pulse oximetry was either not available or not used for other reasons. However, although no clinical evidence of significant respiratory depression was seen in these subjects, pulse oximetry would have been reassuring. For long procedures under isoflurane and air, pulse oximetry is essential, and where the risk of hypoxemia is high, it is useful to

have a small, lightweight oxygen cylinder at hand to supplement oxygen intake should a problem arise.

Although temperature buffering is provided in the OMV 50 by a sealed antifreeze reservoir at the vaporizer's base, the unit does not have true thermocompensation.[17] The OMV 50 output scales are calibrated at an ambient temperature of 22°C, and output is known to rise at higher environmental temperatures, presumably due to an increased efficiency of vaporization.[6] Conversely, output would be expected to fall in lower ambient temperatures as in other draw-over vaporizers using halothane and ether.[2] However, the Tri-Service Anaesthetic Kit has been used to maintain human halothane and air anesthesia with minimal oxygen supplementation at near-zero ambient temperatures.[8] Very low ambient temperatures may limit the vaporization of isoflurane to such an extent as to preclude easy induction if not maintenance.

At high altitudes, lower partial pressure of oxygen in air might lead to hypoxemia. Clinical trials with similar systems using halothane and air in mountainous areas have demonstrated the need for oxygen enrichment during spontaneous or controlled ventilation.[2] Oxygen supplementation may be advisable with draw-over systems using air as the carrier gas at altitudes greater than 2,000 m.[4] However, the problem may not be so critical for species that are adapted to high altitudes with higher hemoglobin oxygen affinities. Anesthetic output concentrations may also be difficult to control at high altitude because they tend to increase as barometric pressure falls.[6]

Isoflurane and air equipment has great potential in wildlife anesthesia. Used in combination with pulse oximetry to permit early detection of hypoxemia, the apparatus offers a cheap, safe, robust, and portable system that permits the use of modern inhalation anesthetic techniques in a wide variety of low-altitude field situations where compressed oxygen is unavailable or difficult to transport. Further studies are necessary to investigate the physiologic responses of animals under isoflurane and air and to define the ranges of ambient temperature and altitude within which safe operation is possible.

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