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Halothane inhalation anaesthesia in reptiles and its clinical control

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The physiological events which take place during pain conduction and pain perception in lower vertebrates are mostly still unresolved (Spray, 1976). However, the fact that the thalamus, the most important centre for sensory and sensitive signals in lower vertebrates, is very poorly developed, suggests that the sense of pain is less than that of higher vertebrates. On the other hand the intensity of avoidance reactions demonstrates that reptiles do indeed react to restraint and to veterinary and experimental manipulation with pain, fear and stress, thus indicating the necessity of having suitable anaesthetic procedures for reptiles.

One of the most commonly used immobilisation procedures for reptiles has been *hypothermia. Temperatures of between 2–5°C lead to numbness* within 10–20 minutes. The lack of reaction (lack of movement) in these animals during painful manipulation may well be mistaken for analgesia,

although the sense of pain probably remains (Bonath, 1977). Thus, compared to physical methods, *medicinal anaesthesia* is the preferred method of pain suppression for reptiles; inhalation anaesthesia is very frequently employed. Its controllability allows an easy return to the unanaesthetised state. This is particularly important for those species whose reaction to anaesthesia is unknown, and is an advantage which does not exist if the anaesthetic is administered by injection (Bonath, 1975, 1977).

This report concerns itself with the practice of inhalation anaesthesia as applied to small and medium-sized reptiles and use of an anaesthesia chamber. Inhalation anaesthesia after premedication with a muscle relaxant and intubation of an endotracheal catheter is proposed and discussed as a suitable method for large reptiles. Possible methods of monitoring the depth of anaesthesia by simple reflex tests, as well as circulatory and respiratory reactions are described. Procedures for reanimation, the duration of narcosis and the factors which influence it are reported. Owing to peculiarities of their respiratory physiology, the Chelonia cannot be anaesthetised by inhalation anaesthesia and will not be considered here.

THE PRACTICE OF INHALATION ANAESTHESIA

Because inhalation anaesthesia is controllable, the circulatory and respiratory depression which occurs during anaesthesia generally may be rapidly and simply regulated. When compared to inhalation anaesthesia in mammals and birds, allowance must be made for peculiarities of the respiratory physiology and the metabolism of reptiles which can complicate the procedure. For instance spontaneous respiratory standstill is commonly observed in the stage of induction. This can lead to severely delayed uptake of the anaesthetic and a considerably extended induction stage, so that a surgical anaesthesia stage often is not reached. Because even the smell of the anaesthetic can cause respiratory standstill, anaesthesia must be started gently with only a few drops of the anaesthetic and then slowly increased over a period of minutes to the desired concentration. By adding 5–10% carbon dioxide to the anaesthetic–oxygen mixture, Calderwood (1971) was able to prevent respiratory stagnation by stimulating the respiratory centre, thus increasing the frequency of respiration and the uptake of the anaesthetic.

Halothane, ether and methoxyflurane are employed for the inhalation anaesthesia of reptiles; trichloroethylene and chloroform are occasionally used. Details of the anaesthetic concentration, their use with different reptile species, the duration of narcosis and other particulars are given in Table 1.

Small and medium sized reptiles may be anaesthetised in an anaesthesia chamber (e.g. a cat anaesthesia box) or in a bell jar. The anaesthetic is applied drop by drop to a gauze or sprayed into the chamber using an atomiser, or alternatively introduced into the box *via* a vaporiser. Repeated shaking prevents the accumulation of toxic concentrations of the anaesthetic in the lower regions of the chamber. Medium-sized reptiles can be sedated in this manner, before intubation and connection to a half-open or closed anaesthesia machine.

Up to now inhalation anaesthesia of *large reptile species* has seldom been performed. Thus the following text refers only to theoretical recommendations for a *combination anaesthesia* for which little practical experience has as yet been gained. Klide & Klein (1973) and Loveridge & Blake (1972) have been able to achieve an excellent muscle relaxation in crocodiles of up to 312 kg body weight (Table 2) after administration of the muscle relaxants gallamine triethiodide or suxamethonium (succinylcholine). (see also Loveridge, pp. 103–112).

The *muscle relaxant* can be injected i.m. at the base of the tail, if necessary with an anaesthetic pistol or rifle. The jaws can then be opened slightly in order to expose the cranially situated larynx. After local anaesthesia of the larynx region with a mucous membrane local anaesthetic spray intubation can be started. After connection to an anaesthesia machine equipped with an automatic respirator, the inhalation anaesthesia can be performed with Fluothane/oxygen or halothane/nitrous oxide/oxygen mixtures. The inhalation frequency, depending on the size of the animal, varies between 5–10 breaths/min in the induction stage subsequently decreasing with lowered anaesthetic concentration (Table 1) to 4–7 breaths/min. The breathing pressure must be chosen carefully, so that the observable expansion of the cranial two-fifths of the thoracic abdominal

INHALATION–ANAESTHETIC (product, manufacturer)	CONCENTRATION, APPLICATION, ENVIRONMENTAL TEMPERATURE (°C)	TESTED IN (number and species of anaesthetised individuals)	ANAESTHESIA SLEEPING TIME (mean, standard deviation) SPECIAL REACTIONS	REFERENCE
		CROCODILIA		
Halothane (Hoechst; Fluothane, ICI-Pharma)	Vaporiser and anaesthetic inhaler. Induction concentration 3 vol %; maintenance concentration 1·5 vol %	*Alligator*	Induction stage depends on breathing frequency	Calderwood (1971)
		SAURIA		
Chloroform		Australian Sauria: (species as described under ether, see below)	Unsuitable, causes tonoclonic spasms	Brazenor & Kaye (1953)
Ether for anaesthesia	Gauze, soaked with 20–30 ml ether in an A.C. with a volume of 30 l; 27·5°C	3 *Calotes versicolor* 3 *Mabuya* sp.	I. 41·8 ± 5·8 min A. 1·5–21 min R. 41·5 ± 4·9 min	Bonath (1977)
	Induction inside an A.C., in which ether stream introduces from a vaporiser; followed by application with an inhaler. Concentration depends on reactions. Administration is problematical, because the high effective concentration is difficult to control	*Diplodactylus spinigurus*, *Gymnodactylus platurus*, *Amphibolurus muricatus*, *Tiliqua scincoides*, *Egernia cunninghami*		Brazenor & Kaye (1953)
	Induction with 22 mg/kg pentobarbital i.m. and ether administered with an inhaler. Maintenance with trichloroethylene administered with an inhaler	*Iguana iguana*	R. 16 h	Cooper (1971)
Halothane (Hoechst; Fluothane, ICI-Pharma)	Blown into an A.C. from a vaporiser. Suitable concentration: 5–6·5 ml/30 l volume of A.C., at an environmental temperature of 23–27°C. Following individual concentrations and environmental temperatures were tested:		At room temperature: I. 24 ± 11 min A. 9 ± 10 min R. 35 ± 25 min if Fluothane application is stopped at the beginning of the deep anaesthesia stage	Bonath (1977)
	8 ml, 18–28°C	5 *Agama bibronii*		
	5–8 ml, 16–29°C	29 *Calotes versicolor*		
	4–6 ml, 24–25°C	8 *Sphenops sphenopsiformis*		

INHALATION–ANAESTHETIC (product, manufacturer)	CONCENTRATION, APPLICATION, ENVIRONMENTAL TEMPERATURE (°C)	TESTED IN (number and species of anaesthetised individuals)	ANAESTHESIA SLEEPING TIME (mean, standard deviation) SPECIAL REACTIONS	REFERENCE
	2·5–8 ml, 23–25°C	31 *Chalcides mionecton*	Anaesthesia could not be reached in 15 animals, independent of concentration	
	5–8 ml, 16–29°C	16 *Mabuya* sp.		
	8–13 ml, 18–28°C	4 *Cordylus* sp.		
	4 ml, 24°C	1 *Lacerta agilis*	Superficial sedation only	
	5–11 ml, 25–26°C	15 *Lacerta muralis*		
	3·5 ml, 24°C	1 *Lacerta vivipara*	Superficial sedation only	
	7–8 ml, 24–25°C	20 *Acanthodactylus scutellatus*		
	5 ml, 24°C	1 *Ophisaurus apodus*		
	6·5 & 7·0 ml, 24–25°C	2 *Anguis fragilis*		
	After induction with ketamine hydrochloride (25 mg/1·2 kg body weight) inhalation anaesthesia with halothane (1%)–O_2	1 *Iguana iguana*		Robinson (1973)
Trichloroethylene	See ether	1 *Iguana iguana*	See ether	Cooper (1971)
		SERPENTES		
Chloroform		Australian snakes (species as described under ether, see below)	Unsuitable, causes tonoclonic spasms	Brazenor & Kaye (1953)
		Poisonous snakes	Chloroform unsuitable	Gans & Elliott (1968)
	Difficult to administer	Snakes	May necessitate resuscitation by artificial respiration. Recovery time is relatively short, in comparison to injectible anaesthetics	Kaplan (1969)
	See ether	*Crotalus* sp.	See ether	Tait (1938)
Ether for anaesthesia	Induction in an A.C. followed by application with an inhaler. Concentration depends on reactions	Reptiles		Bellairs (1967)
	Gauze soaked with 20–30 ml ether in an A.C. with a volume of 30 l. Environmental temperature 25·4 ±2·5°C	5 *Corallus enydris* 8 *Natrix piscator*	I. 45·0 ±5·3 min A. 16·1 ±8·4 min R. 35·4 ±28·1 min Deep stage of anaesthesia could not be reached in 4 of 13 animals tested	Bonath (1977)
	Induction in an A.C., in which ether stream introduces from a vaporiser; followed by	In each case one individual of *Typhlops polygrammicus*, *Morelia spilotes*, *Liasis olivaceus*,		Brazenor & Kaye (1953)

continued

INHALATION–ANAESTHETIC (product, manufacturer)	CONCENTRATION, APPLICATION, ENVIRONMENTAL TEMPERATURE (°C)	TESTED IN (number and species of anaesthetised individuals)	ANAESTHESIA SLEEPING TIME (mean, standard deviation) SPECIAL REACTIONS	REFERENCE
	application with an inhaler. Concentration depends on reactions. Administration is problematical, because the high effective concentration is difficult to control	*Dendrelaphis punctulatus*, *Boiga fusca*, *Notechis scutatus*, *Pseudechis porphyriacus*, *Demansia textilis*, *Denisonia superba*, *Denisonia flagellum*		
		Snakes	Pathological reactions are to be expected	Clark (1937)
		Poisonous snakes	Ether unsuitable	Gans & Elliott (1968)
	Difficult to administer	Snakes	May necessitate resuscitation by artificial respiration; occasionally causes relapses during recovery. Recovery time is relatively short, in comparison to injectible anaesthetics	Kaplan (1969)
	Ether soaked gauze in an A.C.	30 *Notechis scutatus*	I. 15–30 min	Kellaway (1937)
	Ether soaked gauze in an A.C., room temperature	Small snakes	I. 3 min A. 15 min	Lumb (1963)
	Induction with chloroform in an A.C. followed by endotracheal intubation and ether anaesthesia with an anaesthetic apparatus	*Crotalus* sp.	Inhalation anaesthesia is preferred because in comparison to injectible anaesthetics recovery time is relatively short	Tait (1938)
		65 *Natrix natrix*		Wright & Jones (1957)
Halothane (Hoechst; Fluothane, ICI-Pharma)	Blown into an A.C. from a vaporiser. Suitable concentration: 5–8·0 ml/30 l volume of A.C., at an environmental temperature of 23–27°C. Following individual concentrations and environmental temperatures were tested:		At room temperature: I. 35 ± 9 min A. 13 ± 10 min R. 25 ± 20 min if Fluothane application is stopped at the beginning of deep anaesthesia period	Bonath (1977)
	6·5–7·0 ml, 22°C	2 *Python regius*		
	8–9 ml, 23–33°C	10 *Corallus enydris*		
	3·3–7 ml, 22–24°C	2 *Boa constrictor*		
	8 ml, 22·5°C	1 *Natrix natrix*		

INHALATION–ANAESTHETIC (product, manufacturer)	CONCENTRATION, APPLICATION, ENVIRONMENTAL TEMPERATURE (°C)	TESTED IN (number and species of anaesthetised individuals)	ANAESTHESIA SLEEPING TIME (mean, standard deviation) SPECIAL REACTIONS	REFERENCE
	8–10·5 ml, 12–23°C 8 ml, 18–33°C 9 ml, 26°C 7 ml, 22·5°C 7 ml, 22°C 1·5–13 ml, 12–25·5°C 7 ml, 22°C	6 *Natrix maura* 9 *Natrix piscator* 3 *Conophis lineatus* 1 *Naja melanoleuca* 1 *Dendroaspis viridis* 16 *Vipera berus* 1 *Trimeresurus gramineus*		
	After induction with ketamine hydrochloride (200 mg) endotracheal intubation and halothane–O_2–inhalation anaesthesia (8 breaths/min)	1 *Boa constrictor* (juv.)		Frye & Dutra (1973)
	Concentration depends on the species: Elapidae 5 ml/27 l volume of the A.C., Viperidae 12–15 ml/27 l	Colubridae, Elapidae, Hydrophiidae, Viperidae, Crotalidae	Duration of anaesthesia depends on halothane concentration. Induction to complete recovery may require from a few min up to one hour	Gans & Elliott (1968)
	Gauze soaked with 5 ml halothane in an A.C. (author did not name the volume of A.C.). Room temperature	16 *Crotalus horridus*	Suitable. I. 5 min A. 5–20 min R. 10 min Rapid exposure to high concentration causes apoea, which delays induction time as long as 20 min	Hackenbrock & Finster (1963)
	Inhaler that encloses the neck and is coupled to an anaesthesia apparatus: 3 vol % halothane, flow rate 1 l/min. Environmental temperature 24–27°C	Snakes	I. 9 min Duration of anaesthesia period increases with environmental temperature. Artificial O_2-respiration has to be carried out in the recovery period	Jackson (1970, 1974)
	After induction with ketamine hydrochloride (110 mg/kg i.m.) gauze soaked with halothane in an A.C. or endo-tracheal intubation and inhalation anaesthesia with halothane (3%)–nitrous oxide (48%)–O_2 (49%)	Snakes		Stunkard & Miller (1974)
	After induction with metomidat (Hypnodil vet., Janssen; 8 mg/kg)	10 *Thamnophis sirtalis*	Short induction and recovery periods	Zwart & Lagerweij (1971)

continued

INHALATION–ANAESTHETIC (product, manufacturer)	CONCENTRATION, APPLICATION, ENVIRONMENTAL TEMPERATURE (°C)	TESTED IN (number and species of anaesthetised individuals)	ANAESTHESIA SLEEPING TIME (mean, standard deviation) SPECIAL REACTIONS	REFERENCE
	intubation and inhalation anaesthesia with halothane (1·5 vol %)–nitrous oxide (flow of 2 l/min)–O_2 (flow of 1 l/min), administered by Ayre's y-system			
Methoxyflurane (Penthrane, Abbott)	Induction within an A.C., containing a gauze, soaked with 8–10 ml. Followed by endotracheal intubation and inhalation anaesthesia with an anaesthesia apparatus	1 *Boiga dendrophila* 3 *Crotalus adamanteus*	E. 20–25 min surgical intervention 45 min	Burke & Wall (1970)
		2 *Naja naja* 1 *Ophiophagus hannah*	Death occurred some hours after surgical intervention; environmental temperature 27°C	
	Induction inside a plastic bag, followed by endotracheal intubation	1 *Python molurus*	Breathlessness necessitated artificial respiration with 2 breaths/min	Jacobson & Ingling (1976)
	5 ml in an A.C. with a volume of 34 l. Environmental temperature 26–27°C	1 *Python molurus* 1 *Ophiophagus hannah*	I. 8–20 min. Light anaesthesia for 10–30 min. Breathlessness may necessitate artificial respiration. O_2-application shortens recovery period	Gandal (1966a, b)
	For longer periods of surgery endotracheal intubation and inhalation anaesthesia with an anaesthesia apparatus; alternatively spraying through the endotracheal catheter into the trachea may be employed (0·2–1 ml methoxyflurane dependent on body length of the snake)			

Table 1. Inhalation anaesthetics and their use in reptiles (Crocodilia, Sauria, Serpentes).
A.=Anaesthesia period, A.C.=anaesthetic chamber, I.=induction period, R.=recovery period.

cavity is not exceeded. With this form of combination anaesthesia the depression of breathing under the influence of the muscle relaxant must be taken into consideration. In all cases an anaesthetic machine must be used which allows automatic inspiration of the anaesthetic oxygen mixture.

Muscle relaxants act by causing a blockage of neuromuscular transmission, which has the advantage that less anaesthetic is required. One may assume that after premedication with muscle relaxants about half the halothane concentration stated in Table 1 is necessary to induce a deep narcosis in reptiles.

NEUROMUSCULAR BLOCKING AGENT (product and manufacturer)	DOSE, APPLICATION, ANTIDOTE, ENVIRONMENTAL TEMPERATURE	TESTED IN (number and species of treated individuals)	DURATION OF NEUROMUSCULAR BLOCKING (mean, standard deviation) SPECIAL REACTIONS	REFERENCE
Gallamine triethiodide (Flaxedil, Abbott)	0·6–4·0 mg/kg i.m. Antidote: Prostigmin (Hoffmann–La Roche) 0·03–0·15 mg/kg	26 *Crocodylus niloticus*, body weight 1·75–312 kg	Muscular relaxation reached within 20 ± 10·5 min. First spontaneous motions within 10–20 min after antidote application	Loveridge & Blake (1972)
	1·0–1·25 mg/kg i.m. Antidote: Prostigmin (Hoffmann–La Roche) 0·25 mg/kg. Environmental temperature 25·4°C	4 *Crocodylus niloticus*, body weight 2·4–3·8 kg	Muscular relaxation reached in 30 min. After antidote application first spontaneous motions within 5 min; without antidote in 45 min	Woodford (1972)
Suxamethonium (succinylcholine) (Brividil, May & Baker)	Smallest effective dose 0·5 mg/kg i.m.	9 *Alligator mississippiensis*, body weight 2–5 kg		Brisbin (1966)
	3–5 mg/kg i.m.		Complete muscular relaxation within 4 min. Recovery period 7–9 hours	
	2·2 mg/kg	1 *Caiman crocodilus*	Muscular relaxation in 6 min, duration of relaxation 35 min, shortness of breath for 20 min	Klide & Klein (1973)
	0·7 mg/kg	1 *Caiman crocodilus*	Muscular relaxation in 7 min, duration 26 min	
	0·35 mg/kg	1 *Caiman crocodilus*	Muscular relaxation in 5 min, duration 35 min	

Table 2. Neuromuscular blocking agents and their use for the immobilisation of crocodiles. Recommended use for premedication before endotracheal intubation and inhalation anaesthesia.

The administration of suxamethonium to humans and mammals leads to disorders of the nervous conduction system in the heart, to bradycardia as well as the occurrence of asystole and extrasystole. This may also occur in reptiles and can be prevented to a large extent by premedication with atropine. However, if galamine triethiodide is employed, atropine should not be administered since both galamine and atropine give rise to tachycardia. Table 1, with the help of few examples, shows that intubation can also be performed on reptiles which have been treated with parenterally administered sedatives.

Brazenor & Kaye (1953) have used funnels placed over the heads of reptiles and loosely fitted to the neck with a rubber cuff. This funnel may be linked up to an anaesthesia machine by means of a tube or, alternatively, be attached to a balloon containing a gauze soaked in the inhalation anaesthetic. An additional opening in the funnel for the introduction of oxygen or fresh air allows regulation of the depth of anaesthesia.

Closed system anaesthesia machines are only suitable for reptiles above 5 kg body weight. For smaller animals half-open systems without a rebreathing system are recommended (Calderwood, 1971). In this manner the anaesthetic mixture is actively inhaled by the subject; the expired air can be collected in a container or diverted into the atmosphere.

Particular attention must be paid to the care of reptiles after inhalation anaesthesia. The administration of pure oxygen prevents respiratory depression. If *artificial respiration* is used it must be remembered that hardly any data are available on suitable breathing pressures for reptiles. For

this reason the respiration of intubated reptiles is achieved manually with the help of a rubber balloon attached to an endotracheal catheter. The pressure on the balloon may be exerted only to the extent that a visible expansion of the cranial two-fifths of the thoracic abdominal cavity occurs. In this manner oxygen can be pumped two to three times/min into the lungs until the animal shows motor activity and spontaneous respiration. In the case of small reptilian species the oxygen is allowed to flow into the anaesthesia chamber; alternatively a funnel through which oxygen is fed may be placed over the nose of the animal and respiration achieved by manual compression (4–6 times/min) of the cranial two-fifths of the thoracic abdominal cavity. The use of analeptics may be tried; however to my knowledge there is not sufficient practical experience for the use of this on reptiles.

MONITORING THE DEPTH OF ANAESTHESIA

Several factors have to be taken into account when estimating the depth of anaesthesia in reptiles. For the Sauria and Serpentes it can be determined with the help of the following tests:

Pain reflex: The affected part of the body is retracted after pinching either the toes or tail.

Body righting reflex: The animal attempts to regain its belly position after being placed on its back.

Muscle relaxation: The degree of muscular relaxation. Complete muscle relaxation is frequently not reached in snakes.

Snake reflex: Posturing of the body into a typical S-form (snake-form) after tactile or painful excitation.

Head-raising reflex: The animal raises the head/neck region after being held by the tail in a vertical position for several seconds.

Tongue withdrawal reflex: The tongues of snakes are withdrawn into the mouth after careful extraction with fine anatomical forceps.

'Bauchstreich' reflex (abdominal scales stroking reflex): Snakes placed on their backs move the wall of the thorax and abdomen if the scales of the ventral body surface are stroked with the finger in a longitudinal direction.

Corneal reflex: Closing of the eyelids after touching the cornea with a blunt glass rod or a similar object. This reflex never disappears completely even in deep narcosis. It is lost only when an irreversible stage of anaesthesia has been reached.

On the basis of these reactions the following scheme for monitoring anaesthesia may be drawn up:

Stage I=superficial sedation (early induction or late recovery phase):

After administration of the inhalation anaesthetic in an anaesthesia chamber Sauria show intensive excitation-like movements; snakes exhibit frequent searching and creeping movements accompanied by tongue movements, which become slower and result in uncoordinated motions. The body righting reflex is still positive.

Stage II=deep sedation (late induction and early recovery phase):

Decreasing spontaneous movement. Body righting reflex severely delayed; the animal is mostly unsuccessful in attempts to right itself. The tongue withdrawal reflex is slightly to moderately delayed in snakes.

Stage III=tolerance stage (surgical stage):

Lizards:

(1) Moderate muscle relaxation. No body righting reflex. Snake reflex moderately to extremely damped. Head-raising reflex slightly to moderately damped. Corneal reflex unchanged or slightly delayed.

(2) Complete muscle relaxation. No snake reflex or head-raising reflex. Corneal reflex severely delayed.

Snakes:

(1) Slight to moderate muscle relaxation. Slight pain reflex generally may still be elicited. No body righting reflex. Snake head-raising and 'Bauchstreich' reflex slightly to moderately damped. Tongue withdrawal reflex severely delayed.

(2) Moderate to complete muscle relaxation. As a rule the pain reflex can no longer be induced. Snake reflex and 'Bauchstreich' reflex moderately damped to lacking. Head-raising reflex severely damped or lacking, tongue withdrawal reflex severely delayed.

Stage IV=irreversible stage of anaesthesia:

Further deepening of the anaesthesia can lead to a completely reflex-free stage, and in reptiles may mean that the irreversible stage of asphysia has already been reached.

Individual and species determined deviations occur. Apart from the reflexes mentioned in the anaesthesia monitoring plan, the circulatory and

	VOL % HALOTHANE	ENVIRONMENTAL TEMPERATURE (°C)	INDUCTION TIME (min)	RECOVERY TIME (min)
Sauria	5·8 ±0·2	25·0 ±0·6	24·0 ±10·6	35·2 ±25·2
Serpentes	5·7 ±0·4	22·4 ±0·6	35·3 ± 9·4	24·5 ±19·5

Table 3. Mean and standard deviation of induction and recovery times determined in halothane anaesthetised reptiles.

	ENVIRONMENTAL TEMPERATURE (°C)	ANAESTHESIA SLEEPING TIME (min)
Induction stage	12	68·3 ±21·8
	16·9 ±0·8	58·9 ±36·3
	24·8 ±0·7	25·5 ±11·3
	28·4 ±0·4	31·9 ±20·2
	33	43·2 ±32·7
Recovery stage	12	116·4 ±146·9
	16·9 ±0·8	92·6 ± 87·4
	24·8 ±0·7	33·6 ± 25·1
	28·4 ±0·4	23·7 ± 16·7
	33	93·8 ± 99·8

Table 4. Influence of different environmental temperatures (mean and standard deviation) on the duration of the induction and recovery stage, determined in 11 different species of Sauria and Serpentes anaesthetised with halothane (6·1 ±1·2 vol%).

respiratory reactions (see below) must be kept under observation.

As far as the anaesthesia of *crocodiles* is concerned very little practical experience is available, so that the monitoring of the depth of anaesthesia must be carried out according to the plan outlined for lizards and snakes. In particular the pain and body righting reflex as well as spontaneous movements and muscle relaxation must be considered.

The *duration of anaesthesia* in reptiles is generally longer than in higher vertebrates (Table 3). One important reason for this is the ability of reptiles, in particular those which swim and dive, to hold their breath for long periods during the induction phase of inhalation anaesthesia so that the uptake of the anaesthetic is delayed and the induction period is lengthened. This is so pronounced in the case of the Chelonia that it is not possible to perform inhalation anaesthesia at all. In cases where such extended induction phases occur the injection of the anaesthetic is recommended (Bonath, 1977).

Temperature also has a substantial influence on the duration of the stages of anaesthesia (Table 4). The anaesthesia of reptiles is performed at ambient temperatures of between 24–27°C; higher and lower temperatures result in unusually long induction and recovery periods. High ambient temperature in the recovery period must be avoided, as it frequently results in a relapse into a deep stage of anaesthesia (Kaplan, 1969; Brazenor & Kaye, 1953) and the death of the animal.

CLINICAL CONTROL

Very little is known about the *circulatory reactions* of anaesthetised reptiles. External observation of the heart action through the thoracic abdominal cavity wall, as well as the few ECG measurements which have up to now been made, demonstrate that the anaesthetic induced changes of heart actions reflect the specific circulatory action of the anaesthetic in terms of their known action in mammals. For instance halothane leads to lowered blood pressure in mammals and birds (Bonath, 1972) as a result of peripheral vascular dilation. This action is coupled with a lowered heartbeat, which is also observed in reptiles (Table 5). In contrast, as in mammals, an increase in heartbeat occurs under ether anaesthesia. It may be assumed that the circulatory reactions of reptiles correlate

	ANAESTHETIC, CONCENTRATION (environmental temperature)	HEART FREQUENCY
Vipera berus	Halothane, 5·6 ± 2·4 vol % (24·1 ± 1·1°C)	Induction stage: 52·7 ± 7·3/min Anaesthesia stage: 40·5 ± 8·4/min
Pseudemys spp	Ether, high initial concentration (23°C)	Increase from 23·9 ± 12·9/min to 43·6 ± 5·4/min by the 45 min of anaesthesia, followed by a decrease to 20·3 ± 6·6/min

Table 5. Influence of halothane and ether on heart frequency (mean and standard deviation).

SPECIES HALOTHANE CONCENTRATION ENVIRONMENTAL TEMPERATURE (Mean ± standard deviation)	REFLEX ACTION	MEAN RESPIRATORY FREQUENCY/ MIN	STANDARD DEVIATION	NUMBER OF MEASUREMENTS
Chalcides mionecton	good	19·6	11·9	21
3·7 ± 0·6 vol %	damped	18·1	15·9	16
23·8 ± 0·8°C	none	10·6	11·5	13
Lacerta muralis	good	45·5	21·6	17
5·1 ± 1·2 vol %	damped	28·2*	23·2	18
25·7 ± 0·5°C	none	46·8**	17·3	22
Natrix piscator	good	13·1	6·9	10
6 vol %	damped	6·8*	4·3	15
31·0 ± 2·8°C	none	4·7	2·3	17

*= $P < 0.05$; **= $P < 0.01$ (analyses of variance)

Table 6. Influence of reflex action (anaesthetic stage) on respiratory frequency.

to those of higher vertebrates which have been anaesthetised with the same anaesthetic.

Respiration by reptiles is as a rule subjected to anaesthetic determined changes. This is particularly true for inhalation anaesthesia for both the frequency and the depth of respiration in the induction stage are irregular. For different reptile species the respiratory frequency in the induction phase decreases at significantly different rates (Table 6). The rate of decrease is determined by the increase in respiratory pauses during the induction phase. Respiratory pauses in stage II (damped reflex reactions) of an inhalation anaesthesia occur twice as frequently (Table 7) as in stage I (good reflex reaction). Because the respiratory pauses occur very irregularly and their duration varies, the minute frequencies are subject to large deviations. Thus they are of little diagnostic value for the monitoring of anaesthesia in reptiles. On the other hand the frequency and duration of the respiratory pause which can be part of the normal picture during inhalation anaesthesia should be particularly watched. Respiratory pauses become more frequent and longer in the induction stage leading to varying uptake of the inhaled anaesthetic and determining the length of the induction stage. Dissimilar and irregular breathing action increases at first but

Stage I	(good reflex action)	21·4%
Stage II	(damped reflex action)	40·3%
Stage III	(no reflex action)	29·8%

Table 7. Observed cases of respiratory stagnation in % of total respiratory measurements performed on reptiles in different anaesthetic stages.

ANAESTHETIC	ENVIRONMENTAL TEMPERATURE (°C)	HEART FREQUENCY/MIN	RESPIRATORY FREQUENCY/MIN
	18	45·5 ± 8·4	
Halothane	23	47·7 ± 2·0	
(6 vol %)	28	68·3 ± 5·8	28·0 ± 8·3
	33	87·1 ± 9·8	33·0 ± 5·8
	16	30·8 ± 1·3	
	17		17·0 ± 7·1
Ether	18	37·5 ± 3·4	
(20 vol %)	23	59·4 ± 6·6	10·3 ± 5·6
	28	74·3 ± 11·0	
	33	112·8 ± 7·8	33·8 ± 8·9

Table 8. Influence of environmental temperature on heart and respiratory frequency of *Natrix piscator* anaesthetised with halothane and ether (mean ± standard deviation).

decreases during the stage of surgical anaesthesia. Breathing can be so superficial that inhalation and exhalation can no longer be recognised.

Temperature is the most important environmental factor for the amplitude of heart and breathing frequency in unanaesthetised reptiles. This is also valid for anaesthetised reptiles. Table 8 shows that heart and breathing frequency increase with rising environmental temperature. Thus the recommendation to anaesthetise reptiles at temperatures less than 27°C remains valid in order to avoid circulation-straining high temperatures.

CONCLUDING REMARKS

The particular advantages of inhalation anaesthesia lie in its controllability; unforeseen pathological anaesthesia reactions can be relatively easily reversed. This is especially important for reptiles, for so little practical experience is available that anaesthetic depression must be considered. This contrasts with the situation when the anaesthetic is administered parenterally, for here too no experimentally verified dosages are available and the anaesthetic must be dosed empirically; moreover there is a lack of fast-acting antidotes for relief of anaesthetic depression.

The anaesthetic chamber is of especial interest for small and medium sized reptiles. It allows the operator to perform, simply and unassisted, anaesthesia even of poisonous species. The inhalation anaesthesia of large reptiles involves more substantial difficulties. Because anaesthesia chambers are usually too small, the only way of administering the anaesthetic is by intubation of the animal after premedication. However it should be remembered that, because of the unknown action of injected sedatives on reptiles, sedation carries the same risks as the injection of an anaesthetic. On the other hand use of the collected data given in Table 2 for the action of muscle relaxants on a relatively large number of crocodiles can be employed as the theoretical basis for the practical application of inhalation anaesthesia after intubation. After premedication with a muscle relaxant it is possible to perform a gentle intubation in large reptiles followed by connection to an anaesthetic machine.

The combination of muscle relaxant and inhalation anaesthesia has been shown in humans and other mammals to have the advantage that less anaesthetic agent is required; thus the combined administration of both preparations lessens the strain due to side effects. The simultaneous administration of halothane and galamine triethiodide can be seen as being especially advantageous for halothane reinforces the neuromuscular action of the muscle relaxant and this in turn relieves the halothane induced bradycardia. According to Barth & Meyer (1965) the dose of the muscle relaxant is generally inversely proportional to the amount of narcotic administered. An increased requirement for muscle relaxant in animals anaesthetised in this manner should be seen as a sure sign of insufficient depth of narcosis; this can be relieved by increasing the concentration of the anaesthetic.

It is true that performing anaesthesia on large reptiles is an exceptional event even in zoological veterinary practice. A sufficient level of experience enabling anaesthesia of fully grown crocodiles, varanids and large snakes to be given under ideal conditions will not be reached; thus each case must be treated empirically. However the good clinical experience which has been obtained with higher vertebrates using such an anaesthetic combination should be kept in consideration. Comparison of the known physiological actions of anaesthetics on reptiles with those on mammals, suggests that their influence on the circulation and respiration is similar for both classes of animals; this is indicated in reports from Bonath (1977), Hunt (1964), Betz (1962), Young & Kaplan (1960) and Kaplan & Taylor (1957). Clinical reservations about the combined application of muscle relaxant and inhalation anaesthetic to large reptiles may be unfounded in so far as the animals are intubated and the respiratory frequency and volume can be regulated automatically by an anaesthetic machine.

Peculiarities of respiration and metabolism in reptiles result in a considerable extension of the individual stages of anaesthesia as compared to mammals and birds. Owing to the low breathing volume of small species, the uptake of anaesthetic cannot be achieved with an anaesthetic machine with an automatic respirator and the anaesthetic must be inhaled spontaneously in an anaesthetic chamber. Even the smell of the inhaled anaesthetic can lead to arbitrary respiration failure (respiratory standstill). In experiments which we have performed with over 200 individual animals, we never observed extremely long respiratory pauses, although the reptiles, especially those which live in water, can hold their breath for an exceptionally long period. Thus the simple form of administering the inhalation anaesthetic could be used in all cases.

Iguana iguana has been observed to hold its breath up to four-and-a-half hours (Moberly, 1968). Thus here, as with the Chelonia, inhalation anaesthesia cannot be performed and there is no alternative but to inject the anaesthetic (Bonath, 1975, 1977). Such arbitrary respiratory pauses differ in any case from respiratory failure which may occur in deep anaesthesia. Reptiles do not possess a diaphragm which is morphologically and functionally comparable to that in mammals. Therefore, the anaesthesia induced loss of the activity of those muscle groups involved in respiration is not replaced by diaphragmatic movement. In stage III of anaesthesia temporary breathing stagnation may occur, followed eventually by complete apnoea, which reptiles survive without pathological consequences due to the fact that they can tolerate longer respiratory pauses than mammals.

In addition to the peculiarities of their respiration, the extremely temperature dependent metabolism of poikilothermic animals determines the duration of anaesthesia. The preferred environmental temperature of reptiles lies – according to species, age, habit, space and geographic location – between $33{\cdot}0 \pm 2{\cdot}5$ and $45{\cdot}6 \pm 1{\cdot}1$°C (Herter, 1940). At 33°C an enhanced oxygen requirement may be recognised; this can result in death because the frequent occurrence of respiratory stagnation induced by the anaesthetic prevents this requirement being satisfied. On the other hand at temperatures below 22°C reptiles are no longer in the position to eliminate the anaesthetic rapidly; the recovery period is extremely long and the animal may succumb. Moderate temperatures between 24–27°C have proved to be particularly practical for the anaesthesia of reptiles. At these temperatures the induction and recovery stages are the shortest, a satisfactory oxygen supply is achieved and toxic influences are avoided.

SUMMARY

Inhalation anaesthesia is recommended for small and medium-sized reptiles (Sauria, Serpentes, Crocodilia). For large reptiles medicinal muscle relaxation followed by endotracheal intubation and inhalation anaesthesia using an anaesthesia machine is suggested and discussed. Possible methods of monitoring the depth of anaesthesia by means of simple reflex tests are summarised in an anaesthesia monitoring plan and the simple circulatory and respiratory reactions of anaesthetised reptiles are described; the determining influence of the environmental temperature on the course of anaesthesia and possibilities for reanimation of reptiles under inhalation anaesthesia are reported.

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