TABLE 1

Mean Rate Pressure Products ($x10^3$)

Pre Induction and Peak Post Intubation

	Pre-induction	Peak Post Intubation
Control	8.85	12.85
Midazolam	8.80	11.80
Diazepam	7.90	12.35
Fentanyl	8.80	10.85
Alfentanil	8.30	8.85

ANAESTHESIA IN ZOO UNGULATES

R. A. Kock,
Zoological Society of London,
Whipsnade Park, Dunstable,
Bedfordshire, LU6 2LF

and

P.C. Pearce,
MRC Clinical Research Centre,
Northwick Park Hospital, Watford Road,
Harrow, Middlesex

INTRODUCTION

Wild ungulates represent one of the most problematic groups of animals regarding their immobilisation and anaesthesia. In zoos and other institutions where specimens are closely confined, more animals have died as an immediate consequence of restraint and immobilisation irrespective of predisposing disease than from any other single cause (Sedgewick, 1979). Out of 921 ungulate sedations at Whipsnade, where animals are able to live in relatively unrestricted circumstances and therefore possess fairly natural behavioural characteristics, 18 animals died, 53 had prolonged recovery and 56 had complications requiring immediate termination of the procedure. Deaths have included important breeding stock, for example the loss of the only breeding stallion Mountain Zebra (Equus zebra) in Britain,

while travelling from London Zoo to Marwell Zoo in 1977, meant that no foals were produced from the six available mares until another male became available three years later. One replacement died in transit from the United States. Other important losses have included white and black Rhinoceroses, Grevy's Zebras, Przewalski Horses, Scimitar-horned Oryx, Waterbuck and Giraffe.

Various sedatives and tranquillisers, used alone or in combination, are available for immobilising zoo and wild ungulates (Jones, 1977) (Table 1). None are perfect and many mortalities have been recorded with etorphine (Wiesner et al, 1984; Kock and Pearce, 1985), xylazine (Alford et al, 1974; Gibson et al, 1982) and carfentanil (Seal et al., 1985). The requirments of a drug used in zoo and wild animal immobilisations are that it must be potent and concentrated so as to ensure rapid absorbtion and effect and to allow the use of small and therefore more accurate projectiles. The animal must be returned to a normal state of activity and able to fend for itself as soon as possible after termination of the procedure. Drugs which are considered suitable for use in domestic or tame animals are not necessarily appropriate for wild ungulates. One which produces safe recumbency and few adverse effects may only achieve inco-ordination and panic in a wild animal, leading to death through trauma, exhaustion, myopathy or cardiac arrest. For example, xylazine (Rompun, Bayer) has been advocated for use in certain wild species such as Fallow deer (Hall and Clarke, 1983) at a dose of 4-8 mg/kg. Experience at the Zoological Society of London has shown

that a wild Fallow deer (Dama dama) remains extremely mobile and awake with doses as high as 10 mg/kg. Tame Pere David's deer (Cervus elaphus davidanus) yearlings (hand reared) can be sedated and made recumbent with as little as 0.15 mg/kg, but their wild counterparts are only slightly inco-ordinated at doses of 2 mg/kg. Further to this, some of the effects of xylazine, even in tame deer, can be detrimental if not closely controlled (Gibson et al, 1982). On the other hand, etorphine, a drug producing adverse physiological effects which might be considered unsuitable for domestic stock, can achieve rapid immobilisation which in the long run is safer for wild animals as long as the side-effects are rapidly controlled. The use of this drug alone is acceptable for short term procedures, such as capture for transport or marking, total examination, the taking of samples and minor surgery, although quite often the animal is not sufficiently relaxed for even simple procedures such as auscultation.

The ethics of carrying out lengthy surgical, painful or fear-inducing procedures with sedative tranquillisers are in question when the sensory deprivation is minimal or unknown. There are added risks of aspiration of ruminal contents and death due to the adverse physiological effects. Basal narcosis, the state produced by a number of immobilising drugs, is a stage of central nervous depression in which the animal is unconscious but responds to painful stimuli. In order to perform surgery or a thorough examination, the animal must be fully anaesthetised and relaxed. This requires the addition of an inhalation anaesthetic agent. Drugs such as barbiturates, xylazine or chloral hydrate might be useful, but

in combination with immobilising agents are highly unsatisfactory for purposes of general anaesthesia since the doses required present practical difficulties and recovery can be prolonged. This paper describes some of the physiological changes encountered with certain immobilising drugs and anaesthetics in ungulate species. The use of certain immobilising combinations, the provision of oxygen and the induction of general anaesthesia are advocated for handling wild and zoo ungulates.

Materials and methods

Animals Experimental sedations have carried out on Scimitar-horned oryx (Oryx tao) and Black Fallow deer (Dama dama), both in a near-wild situation in large paddocks at Whipsnade Park and in controlled conditions at Regent's Park. The Scimitar-horned oryx was chosen for study as it is a rare sub-Saharan antelope, currently being bred in captivity with a view to a future re-introduction into the wild. Surplus males were used. The Black Fallow deer was selected as it is particularly susceptible to anaesthetic problems; approximately one in seven, when taken from their enclosure at Whipsnade, have died. It is not known whether this is because of some inherent problem in the sub-species or because they are the most wild group of animals at Whipsnade, normally having no contact with humans.

Opportunistic monitoring during sedation was also carried out in Przewalsksi horses, Grevy and common Zebras, Onager, Arabian/Bactrian camel, White and Indian

Rhinoceroses, African elephant, Yak, Buffalo, Gaur, Pere David, Axis, Red and Sika deer, Moose and Arabian oryx.

In order to allow rapid and repeated catheterisation of an artery, the experimental animals were prepared in advance by carrying out carotid exteriorisations. The right-sided artery was positioned just below the surface of the skin and kept in position by cradle sutures. Problems were sometimes encountered in mature males in which the skin was very thick, and catheterisation of the artery was difficult. In other animals, superficial arteries were used; for example, the digital, transverse facial or facial in equids, and the volar metacarpal or external submaxillary in ruminants.

Measurements The parameters measured when possible were ECG and heart rate, body temperature, respiration rate, systemic and pulmonary arterial pressures and blood gases. Two Albury Instruments LT24 monitors were used to monitor ECG, pressures and deep and surface body temperatures and recordings made on a Schiller Cardiovit 3 portable electrocardiograph. An internal 12 volt battery and a power connection ensured that the monitors could be used both in an operating theatre and in the field.

The pulmonary artery was cannulated with a 7F Swann-Ganz balloon catheter introduced via the jugular vein, using the Seldinger technique. During all pressure monitoring, the catheters were continuously flushed. Blood gas analysis was carried out using a Corning 165 analyser.

Drugs and Administration Etorphine was the most widely used immobilising drug, either alone, as Immobilon (with

acepromazine), or in combination with xylazine. In general, the addition of xylazine was necessary when dealing with either excitable or aggressive animals, and certain species.

Techniques employed for drug administration were dependent on a number of factors: species, the behavioural response of the individual or group to the operator's approach, flight distance and the volume of the drug required. Three basic pieces of equipment were used:

1. The blowpipe (Telinject), ideal for low volume, short range darting with an atraumatic administration of the drug, is dependent on air pressure for both discharge and projection. It could only be used for animals with a flight distance of less than 10 metres in the open or where the enclosure restricted the animal to within that range.

2. A hand made pole syringe, with up to 20 ml of the drug, was used on animals tolerant of an approach to within 4 metres, but which could resist or react violently to a closer approach or manipulation. Camels, elephant, hippopotamus, some equids, cervids, bovids and tamer ungulates were suitable candidates for this technique.

3. The Dart Rifle (Distinject, model 50) and pistol (Palmer Capture) for darting over long distances. The Dart Rifle was used for flight distances of 30 - 50 metres where 2 - 3 ml volume darts were optimal for the necessary accuracy (for example in Black Fallow Deer). The capture pistol was employed for situations where a blowpipe was unsuitable as might be the case in thick skinned animals such as rhinoceros, hippopotamus and elephant, the maximum volume being

15 ml. The rifle and pistol rely on a regulated CO_2 gas pressure for projection of the dart and an explosive cap for discharge.

The use of a high velocity rapid discharge system (rifle of pistol) stimulates a flight response in the majority of timid species which, together with pain, causes release of catecholamines. The blowpipe and pole syringe are relatively atraumatic, and there is a minimal visible response from the animals to their use.

Protocol After darting, the animals were left alone and usually became recumbent within ten minutes. Their eyes were covered and, if a long procedure was anticipated, opthalmic ointment was administered. The trachea was routinely intubated, as regurgitation can be a severe problem (Pearce et al, 1985). Oxygen and a volatile anaesthetic, usually methoxyflurane, could then be administered. A stomach tube was inserted in ruminants. First, venous blood samples were taken and ECG leads applied, LA to the front sternum, RA above the last rib on the upper side, and LL to the left rear leg. A temperature probe was inserted into the rectum. An 18 or 20 g catheter or needle was placed into the available artery, and a sample withdrawn for blood gas analysis. Monitoring tubes were then connected, flushed and blood pressure measured, taking care that the transducer was positioned at the appropriate height. In the experimental animals, the Swann-Ganz catheter was then positioned for CVP and pulmonary pressure monitoring.

RESULTS

Results are presented in Tables 2-5. Data from

Cervidae (Table 2) show results from uncomplicated sedations and some of the abnormalities found. All the species apart from the Red Deer and Moose were very timid, living in a semi-wild situation. Of the deaths which occurred in Cervidae, seven were during the induction phase, before any monitoring could take place, and eight during the sedation procedure where hypoxia was implicated. The majority of deaths in the induction phase occurred during the second sedation after a stressful period following capture of the animal from the herd and during its acclimatisation to a new enviroment.

Table 3 shows mean values (± SD) for Scimitar horned oryx sedations. The results of a more detailed study on this species are to be published at a later date. A wide range of doses were used to sedate these animals. Without the presence of xylazine, induction was accompanied by excitement and violent and lateral recumbancy was not achieved. A dose of 0.5 mg/kg bodyweight xylazine alone produced sedation in the quieter individuals, but 1.2 mg/kg had very little effect in a wilder counterpart. The major problem encountered was the developement of hypothermia, 36-33°C in fifty per cent of sedations, despite the supply of heat on several occasions. Respiratory depression was significant but not severe, with a reduction in the depth of respiration rather than rate. Regurgitation proved to be a severe problem and two animals were lost through inhalation pneumonitis (Pearce et al, 1985).

Table 4 compares data from the domestic horse (Riebold et al, 1982) under halothane anaesthesia with that from zoo

equids at Whipsnade. Przewalski horses responded poorly to etorphine but no better alternative was availble. Tremors were such that very little data was obtained until relaxation developed with the use of methoxyflurane. The high heart rates and high blood pressures were observed after sufficient relaxation with methoxyflurane to enable sampling but before diprenorphine was administered, or complete anaesthetic induction achieved.

Despite the supply of oxygen on a to-and-fro gaseous anaesthetic system, respiratory acidosis developed during the sedation period. Grevy zebra responded less drastically to etorphine but, despite apparent relaxation, heart rate and systemic blood pressure could be high. Hypotension was observed on one occasion after the administration of methoxyflurane. Before a field inhalation anaesthetic system had been developed, deaths occurred in two Przewalski and two Grevy zebra during the same study period.

Table 5 presents data from other species sedated with etorphine with or without acepromazine and xylazine. It is important to note the persistently high heart rates which were seen in animals the size of the rhinoceros. Intubation was not possible in these species but as the majority of the breathing is performed through the naso-pharynx, oxygen was supplied through the nostrils. Hypoxia was less severe when this was performed.

Case Reports

Electrocardiograph and pressure traces from a female Black Fallow deer which developed cardiac arrest during anaesthesia are shown in Figures 1a and 1b. An atrio-

ventricular heart block developed after 60 minutes of sedation which led to a three second cardiac arrest. Sporadic heart beats then followed which led to a short period of tachycardia, three slower beats and then arrest. Subsequent analysis of blood gases from an arterial sample taken a few seconds before the block became apparent, shown a pH of 7.32, a partial pressure of CO_2 of 78.3 mm Hg and a partial pressure of O_2 of 13.4 mm Hg. Severe hypoxia rather than respiratory acidosis was therefore responsible for these events. The animal was already intubated and positive pressure oxygen ventilation was immediately initiated. Heart beats returned after 45 seconds and the animal survived. Full details of this case have been reported elsewhere (Pearce et al, 1985).

Figures 2 and 3 show ECG traces from two excitable species in which several anaesthetic deaths have occurred: the Black Fallow deer and Axis deer. Both were recorded as soon as the animal was recumbent and approachable. Severe bradycardia and atrio-ventricular heart block were seen in the Fallow deer (Fig. 2) where initially, two out of three P-waves were not followed by contraction. The trace from the Axis deer (Fig. 3) showed severe bradycardia with heart blocks following a period of tachycardia of approximately 300 beats per minute. The arterial oxygen tension preceding this event was 31 mm Hg.

Figure 4 illustrates the dangers of relying on an ECG signal especially if a digital rate meter is being used. On four occasions, including the Black Fallow deer illustrated, animals died but the ECG trace signal showed a heart beat.

On the occasion illustrated, death occurred after intravenous topping up dose of etorphine. Again the arrest followed a period of bradycardia which was preceded by a period of tachycardia. No block was seen on this occasion.

Discussion

Cervidae, under the techniques of capture and sedation used at Whipsnade, suffered a variety of adverse physiological effects. These included severe respiratory depression leading to hypoxia, respiratory acidosis and other changes such as cardiac dysrhythmias and changes in blood pressure. Temperature was generally elevated in the more excitable animals after capture as noted by other authors (Gericke et al; 1978, Alford et al, 1974) but on occasions was depressed after a period of sedation. The greatest percentage mortality occurred during induction in animals which had been under a certain degree of stress for a period of time (for example, a week of confinement in a loose box). The effects of chronic and acute capture stress on the sympathetic adrenal axis may well be critical to the death or survival of individuals under these circumstances. Deaths also occurred during sedation and this appeared to be associated with severe hypoxia.

In general, the Scimitar-horned oryx tolerated immobilisation and subsequent sedation relatively well. Inhalation pneumonitis was a danger when animals were not intubated. Respiratory depression was less severe and although moderately high carbon dioxide levels were recorded, no problems were associated with this. Body temperatures declined markedly during sedation and temperatures

as low as 33° were noted.

Zoo equidae were not consistent in their physiological responses to sedation under etorphine and acepromazine. The Przewalski wild horse behaved very much like a thoroughbred domestic horse, suffering severe muscle tremors and tachycardia. Temperature varied but, under conditions of high ambient temperature, hyperthermia was common. Respiratory depression marked by hypoventilation rather than any decrease in breathing rate was present. Due to difficulty in obtaining arterial samples with the muscle tremors under etorphine alone, all the data obtained was after the administration of a volatile anaesthetic (methoxyflurane) and oxygen. This ensured relaxation for sampling and hence reduction of the heart rate and blood pressure after induction. The partial pressure of carbon dioxide tended to continue to rise if the ventilation was inadequate. Grevy zebras, although not demonstrating the severity of muscle of muscle tremors, suffered tachycardia and/or raised blood pressure under the effects of etorphine and acepromazine. In all other respects they were similar to the Przewalski. It is interesting that, from the limited information available on rhinoceroses, their physiological response appeared to be very similar to that seen in equidae.

Over the study period there were mortalities in both the Przewalski horse and the Grevy Zebra. The animals died from cardiogenic shock, and histological investigation has demonstrated cardiomyopathy. The development of these lesions appeared to be associated with a low plasma vitamin E level at the time of sedation. The conditions of hypoxia,

acidosis, tachycardia and low plasma vitamin E were probably conducive to the development of myocarditis and cardiomyopathy. The cases which died under sedation did not receive supplemental oxygen and methoxyflurane during the procedure and the time spent under the effect of drugs varied between 30 and 60 minutes. The improvement of cardiac function with the administration of oxygen and volatile anaesthetics is probably adequate to prevent cardiomyopathy in the majority of circumstances and is advocated as a routine procedure where periods of immobilisation exceed 15 minutes.

The physiological data presented in this paper give some insight into the complexities of the physiological response to immobilisation with etorphine, acepromazine and xylazine in a number of zoo ungulates. It has been suggested that all these changes in cardiovascular function under etorphine sedation, at least in the horse, are caused by increased activity in the peripheral sympathetic nervous system, but the sites of action of etorphine have not been established (Lees and Hillidge, 1976). The precise mechanisms that are at work in zoo ungulates are open to speculation; the additional effects of the flight response in conjunction with the effect of the sedative drugs must be considered in these circumstances. The findings reported in this paper allow us to make some general conclusions.

Amongst the cervidae, the Black Fallow deer are the most sensitive and timid of the species immobilised in the Park. They are the subject of a detailed study to be published at a later date. The flight response of these

animals is very strong and catecholamine release is probably considerable, both in response to fright and to the pain of capture injection. Where animals have been stressed for a considerable period of time, this would put an extra burden of the adrenal gland and may affect its functional capacity. A possible sequence of events can be described (Figure 5). The cardiovascular system is under the influence of both sympathetic and parasympathetic stimulation. During the early induction phase which involves flight, there is a very strong sympathetic drive through the effects of catecholamines, leading to tachycardia and, in certain circumstances, hyperkalaemia (Gericke, 1978). This, combined with respiratory depression and hypoxia induced by the drugs and the resultant hypercapnia and lowered pH, causes irritability of the heart muscles which may give rise to dysrhythmia. This could cause stimulation of the vagus by a negative feedback system, resulting in a reduction in heart rate. With this sequence of events, it is possible for asystole to occur and this may be the ultimate cause of death in the Fallow deer during the induction period. The data demonstrates that tachycardia, dysrhythmia and bradycardia do occur during induction and this is indictive of a vagosympathetic imbalance. The effect of hyperkalaemia at this stage, which has varied between 5.1 and 9.4 mmols/litre in all cervid deaths, may be very significant. Deaths in the Black Fallow deer which have occurred during sedation where no supplemental oxygen has been provided clearly relate to the severe degree of hypoxia which was allowed to develop. In other cervidae which are less timid, it is less likely that the cardiovascular system will suffer the same nervous imbalance.

There is some indication that a similar situation can arise in Axis deer, with periods of tachycardia and bradycardia during induction. The respiratory depression in the other cervid species studied was severe and the same risks are likely to occur with long term sedation without oxygen supplementation in these species. This is confirmed by high mortality in the Axis deer.

The Artiodactyls encompass a large range of ungulate species, from the timid to the very bold. The Scimitar-horned oryx can be a very aggressive animal although it will show a flight response. This species under sedation with etorphine and xylazine appeared to maintain adequate cardiac and respiratory function, although there was some indication of raised carbon dioxide levels when sedation was prolonged. Heat loss was more of a problem in this species, although no subsequent fatalities were experienced. One possible explanation for this anomaly is that, in a desert adapted animal, the ability to radiate heat through a complex of capillaries in the skin may be highly developed. Under the effects of tranquillisers and narcotics, the animal may suffer a more rapid heat loss than might be expected in a domestic ruminant.

In the equidae, although there is no flight response, severe tachycardia and respiratory depression may act together to push the cardiac reserve to its limit. Certainly, where there is underlying weakness in the heart muscle and inability to deal with hypoxia and lactic acid accumulation, cardiomyopathy is a likely sequel. The tachy-

cardia seen in equidae under the effect of etorphine appears to be a response to the drug induced hypoxia (Lees and Hillidge, 1975). In other species the tachycardia must to some degree be the result of the hypoxia.

A number of questions arise in zoo ungulates: is there a species specificity of physiological response to etorphine? There would appear to be significant differences between cervidae and some other artiodactyls. Is this difference related to comparative wildness or to a species factor? Certainly, within a group such as the cervidae the relative wildness is significant regarding the extent of physiological change under sedation. Are the effects of the flight response a major factor in the abnormal physiology or is it the inability to achieve a flight response which is liable to produce complications? Stress of a chronic nature would appear to compromise the animal's ability to maintain normal physiology under the effects of sedation. Is it possible to control the sympathetic and parasympathetic responses during induction without pre-medication which is clearly impossible in the field? Daniel and Ling in 1972, using pre-medication in equids with propanolol, were able to reduce the hypertension and tachycardia induced by etorphine but were unable to reproduce these results using propanolol in the initial immobilising drug combination.

Since the majority of induction deaths reported in this paper appeared to be associated with chronic stress, the avoidance of that stress may in itself reduce complications. There is some evidence (Gericke et al, 1978) that the use of tranquillisers such as haloperidol at the time of

capture may reduce stress effects. The hypoxia with etorphine is more easily resolved. Since most ungulates can be intubated, the administration of oxygen where possible during capture procedures would seem to be the most sensible course of action. In the case of equidae, the administration of a volatile anaesthetic to produce muscle relaxation and reduce blood pressure and heart rate is advisable when drugs such as etorphine are used. Since the narcotic tranquilliser combinations are not true anaesthetics, it is also ethically important to provide anaesthesia. One suggested protocol is as follows:

Chronically stressed animals should not be sedated if at all possible. Pre-capture excitement should be kept to the minimum. Once the animal is immobilised, external stimuli should be reduced by covering the head with a cloth sacking. Intubation should be performed as soon as is practical and oxygen provided with or without a gaseous anaesthetic. Atropinisation has been recommended in certain circumstances (Fowler, 1978) but its use is equivocal. All the available parameters such as heart rate, respiratory rate, temperature, etc should be monitored and the immobilising agent reversed if the effect of the gaseous anaesthetic is considered inadequate. In order to achieve this, positive pressure ventilation may be necessary where respiratory depression is very severe. This will have the added advantage of reducing the hypercapnia which occurs under the effects of these drugs despite the provision of oxygen. Once the narcotic is reversed, spontaneous ventilation may be adequate to maintain normal physiology. The

fact that the ruminants are intubated will reduce the likli-hood of inhalation of regurgitant which is also an added advantage. Ruminants should also be stomach tubed to reduce the likelihood of bloat. In these circumstances, the anaesthetist has control which, under the effect of a chemical anaesthetic, is not always the case.

To conclude, it is hoped that through the judicious use of powerful immobilising agents and careful anaesthesia, mortality rates in zoological parks and in the wild can be kept to a minimum.

Table 1

DRUGS FOR WILD UNGULATES

IMMOBILISING AGENTS	SEDATIVES/TRANQUILLISERS
Etorphine/M99	Promazine + Derivatives
Fentanyl	Xylazine
Carfentanyl/R33799	Droperidol
Ketamine	Haloperidol
REVERSING AGENTS *	Diazepam
Diprenorphine	Azaperone
Nalorphine	Metomidate
Naloxone	R51703

* Reversing agents are only used with the morphine derivatives and not ketamine.

Sources: Jones, 1977; Wiesner, 1984.

Captions to Tables 2 - 5:

H.R. = Heart rate b.p.m.

R.R. = Respiration rate/min.

PO_2, PCO_2: mmHg.

B.P. = systemic arterial pressure mmHg.

P.P. = pulmonary arterial pressure mmHg.

Data in the boxes marked * record the extreme values measured during this study. All the figures are associated with the effects of the immobilising agents alone except for the equids where, in the majority of cases, it was necessary to relax the animal with a gaseous anaesthetic for recording. In these cases the values were obtained as early as possible in the procedure.

RANGES OF PHYSIOLOGICAL PARAMETERS UNDER ETORPHINE/ACEPROMAZINE/XYLAZINE SEDATION.

2. Cervidae

	Black Fallow		Pere David		Axis		Sika		Moose	Red
Approx. dose a,b,c **	0.06,0.26,1.0		0.02,0.1,0		0.03,0.13,0		0.03,0.13,0		0.15,0.07,0	0.03,0.13,0
Number of Sedations	57		15		78		8		2	1
% Fatalities	16		0		8		0		0	0
% with anaesthetic complications	53		50		100		100		50	0
H R	78-45	280 *	50-60	250 *	60-90	276-32 *	40-70	140-26 *	50-115	44
R R	18-8	0	0-30		30-20	0	0-10		0-40	18
T°C	38.5-37.3	42	39-40	41.4	39-40		39-37	35		39
pH	7.23-7.3	6.9 *	7.25	6.9 *	7.35	6.9	7.1-7.2	*		7.35
PO_2	38-50	18	65		60	33	30-60	10		75.7
PCO_2	58-62	133	40-60	137	50	126	65-90	111		45.9
B P Systolic	86	253 *	113-140	220 *	93	60 *				173
Diastolic	63-56	139	73-93	160	67	47				87
Mean	73-70	177	90-122	180	75	51	110-80			116
P P Systolic	40-27				30-22					
Diastolic	25-16				22-11					
Mean	31-21				25-14					

** a = etorphine mg/kg; b = acepromazine mg/kg; c = xylazine mg/kg

RANGES OF PHYSIOLOGICAL PARAMETERS UNDER ETORPHINE/ACEPROMAZINE/XYLAZINE SEDATION

3. Artiodactyla

	Scimitar-horned Oryx		Arabian Oryx
	Confined	Open Paddock	
Dose range Etorphine	0.01 - 0.03	0.015 - 0.03	0.11
Acepromazine	0.04 - 0.13	0.06 - 0.13	0.5
Xylazine	0.05 - 0.28	0.17 - 0.46	0.4
Number of sedations	36	12	1
% Fatalities	5 *	0	1
% with anaesthetic complications	53	58	100
H R	60±13 - 70±19	66±5 - 60±18	60 - 50
R R	40±20 - 30±19	37±16 - 40±5	70
T°C	37±1 - 5±1	38.5±1 - 35±2	36 - 35.4
pH	7.41 ± 0.06	7.35 ± 0.03	7.35
PO_2	65±15 - 70±12	60±18 - 65±9	50
PCO_2	60 ± 14	50±9 - 55±11	43
B P Systolic	105±18 - 80±16	127±20 - 90±9	90 - 113
Diastolic	80±25 - 60±19	85±20 - 60±9	66 - 80
Mean	90±23 - 70±1	95±16 - 70±9	74 - 91
P P Systolic	26±1 - 16±2	22 ± 5	
Diastolic	18±3 - 9±1	13 ± 3	
Mean	21±2 - 12±1	16 ± 4	
C V P	0 - 8	0.14	
P W P	4 - 13	4 - 12	

* the fatalities shown here were due to inhalation pneumonia.

RANGES OF PHYSIOLOGICAL PARAMETERS UNDER SEDATION.

4. Equidae

	Domestic Horse	Przewalski Horse		Grevy Zebra		Common Zebra		Onager
Approx. dose a,b,m	Halothane	0.02,.1,m		0.02,.1,m		0.02,.1		0.02,.1
Number of sedations		15		10		3		1
% Fatalities		13		20		0		0
% with anaesthetic complications		70		50		33		100
H R	30-50	60-80	190 *	40-80	210 *	60-100	0 (10 sec.) *	158-109
R R	6-12	5-30	70	10-20		12-20		14-20
T°C		38-40	41	38-37.5		38-36		38-37
pH	7.35-7.45	7.1-7.3		7.2-7.4		7.4		7.3-7.1
PO_2	90	120-300(O_2)		50-70		85		56-(400 on O_2
PCO_2	40	55-80		40-60		67		64-78
B P Systolic	90-130	100-130	253 *	100-170	50-300 *			178-124
Diastolic	65-85	60-70	133	50-80	40-165			111-80
Mean	75-100	80-90	173	100-120	44 206			126-95
P P Systolic				40				30-22
Diastolic				30				23-16
Mean				33				25-18

RANGES OF PHYSIOLOGICAL PARAMETERS UNDER ETORPHINE/ACEPROMAZINE/XYLAZINE SEDATION.

5. Others

	Domestic Cattle	African Buffalo	Yak	Gaur	African Elephant	Indian Rhino	White Rhino
Dose a,b,c,	Halothane	0.01,0.04,0.1	0.01,0,0.15		0.02,0,0.2	0.04,0.02,0	0.004,0,0
Number of sedations		1	1	2	2	2	2
H.R.	80-130	120-60	80	40-70	36	120	120
R.R.	20-40	40	26			12	6
T°C			39	38-37		36	35-37
ph		7.3	7.2	7.4	7.3	7.3	7.2-7.3
PO_2		55	53	65	50-60	50 (143 O_2)	40-60
PCO_2		82	55	74	50-70	60	50-60
B.P. Syst.	150-180		213-140				200
Dia.	100-150		133-73				180
Mean	110-140		160-95				187

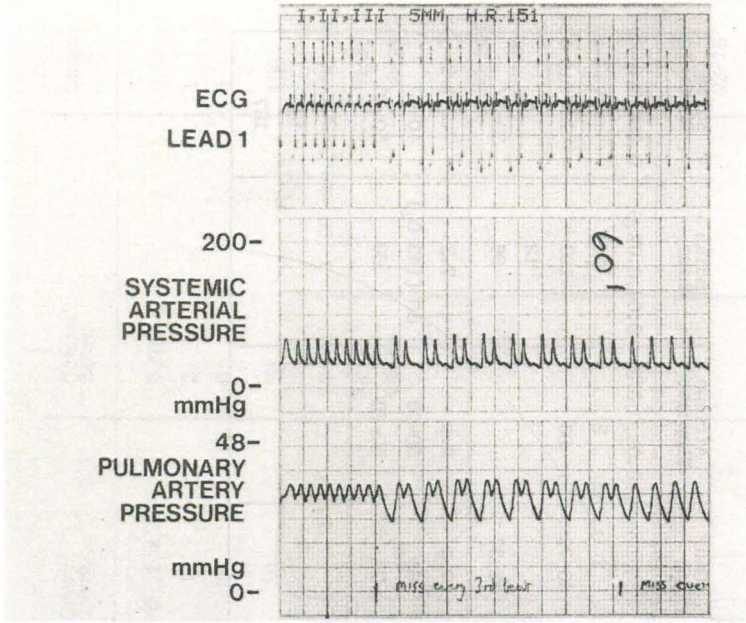

Fig. 1 (a) Black Fallow Deer Developement of A-V Block.

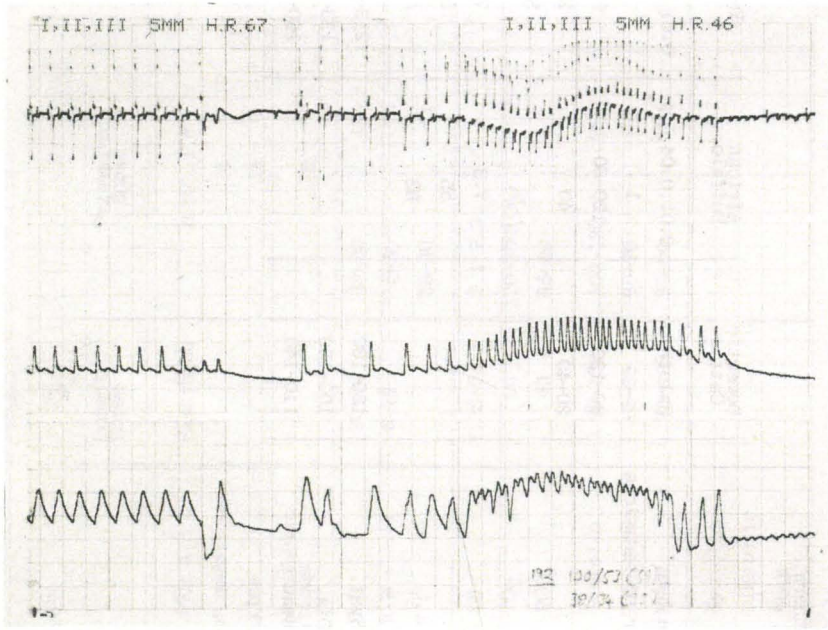

Fig. 1 (b) 2nd degree A/V heart block. Cardiac arrest.

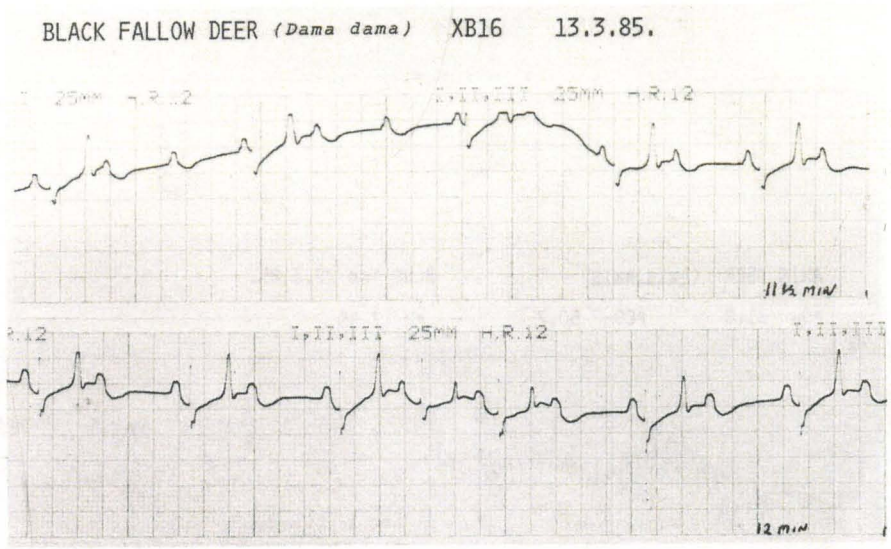

Fig. 2 Advanced second degree heart block

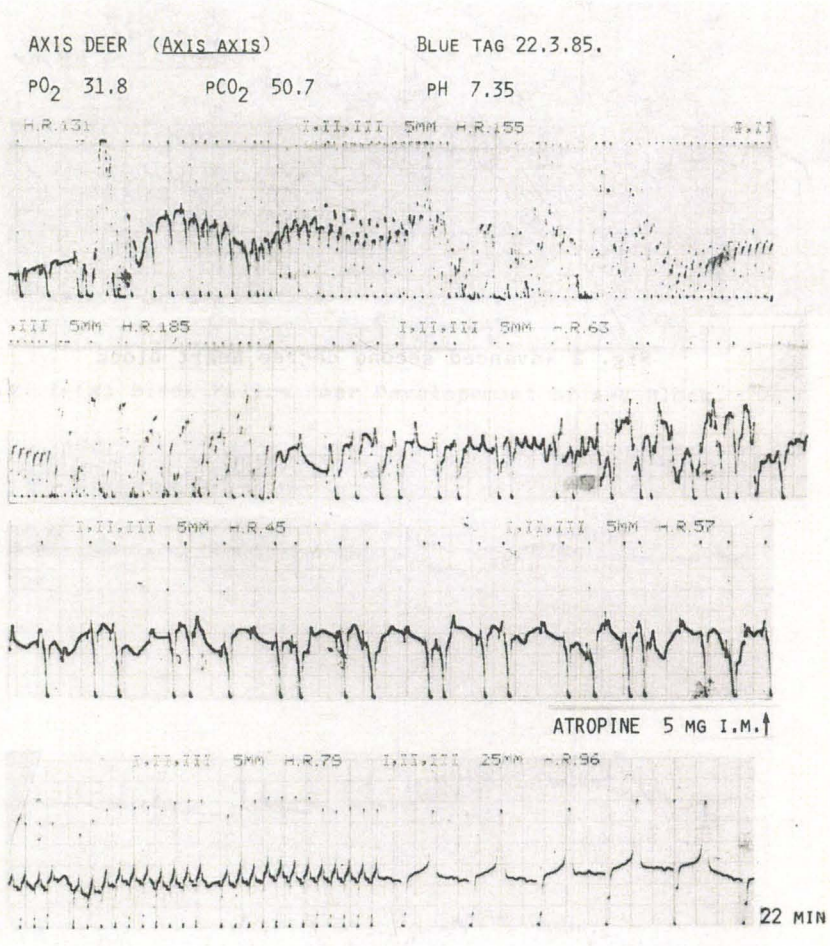

Fig. 3 Severe bradycardia with heart block following tachycardia

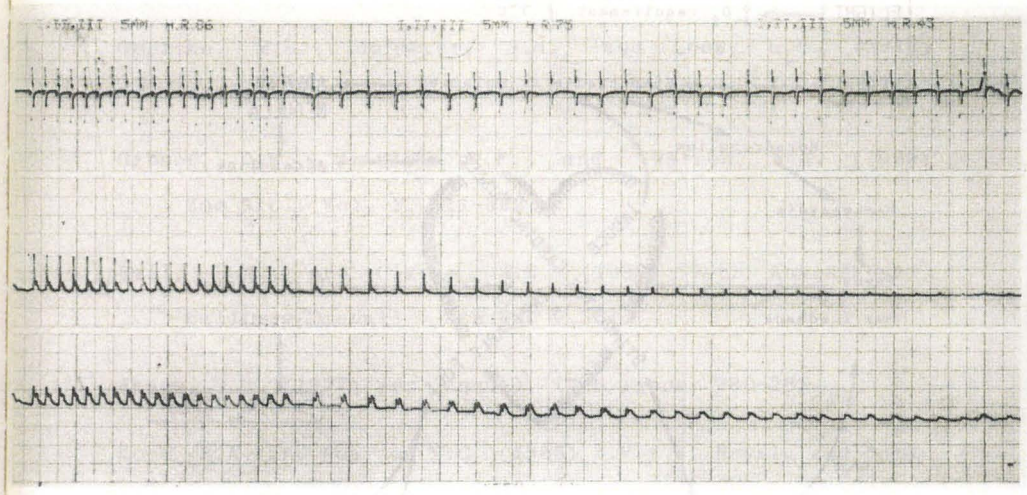

Fig. 4 Cardiac arrest with normal electrocardiograph.

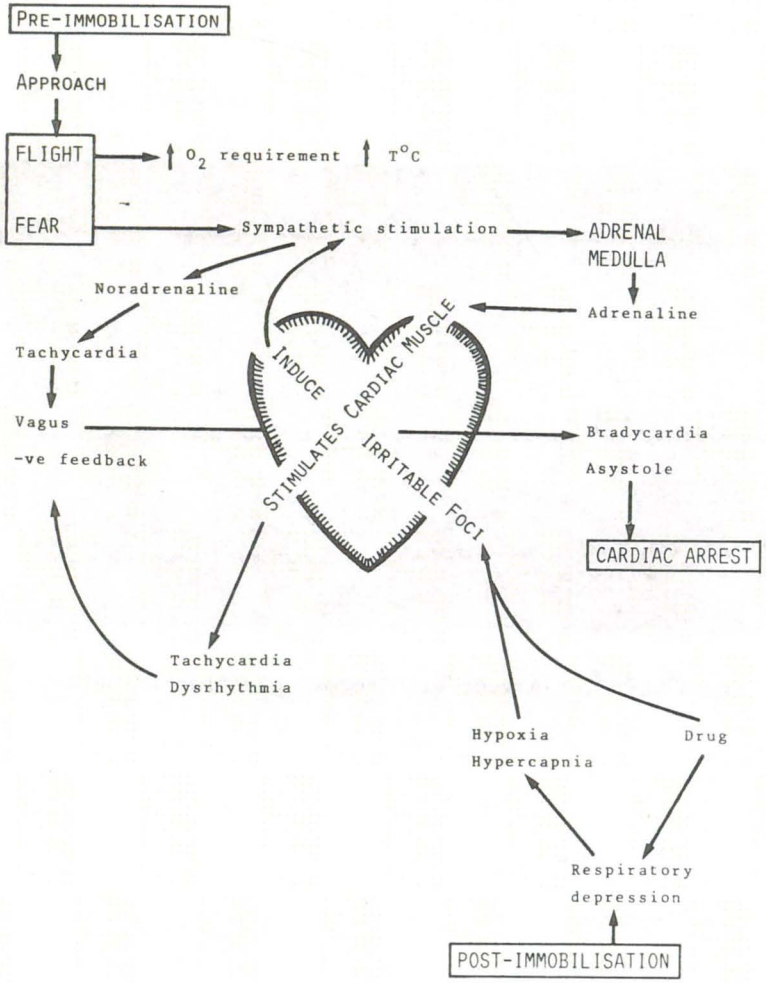

Fig. 5 Proposed events leading to cardiac arrest.

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RECENT ADVANCES IN OPIOID PHARMACOLOGY

A. Livingston

Department of Pharmacology

The Medical School, BRISTOL, BS8 1TD

In some ways it can be considered that all research on opioid receptors and endogenous opioids is recent, since it is just over a decade since the studies of Pert and Snyder (1973) and Terenius (1973) demonstrated that a specific opioid receptor existed in nervous tissue and consquently strengthened the earlier suggestions of not only a specific receptor site for morphine-like drugs but also the likelihood of an endogenous ligand for these receptors in brain tissues.

Opioid Receptors

Early studies on the relative potencies of opioids had suggested that more than one receptor type might exist, but the experiments of Martin et al (1976) formed the basis of the currently used classification. They found that by using a series of substitution tests on opioid-dependant dogs they could classify the opioid receptors into three groups: the mu receptor relating to morhpine and analgesia; the kappa receptor relating to ketocyclazocine and sedation ;and the sigma receptor relating to SKF 10,047 (n-allyl-normetazocine) and psychotomimetic effects.

This classification charaterises the majority of morphine-like compounds quite satisfactorily. However,