# Cessation of electroencephalographic activity in animals exposed to a lethal dose of succinyldicholine

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EEG recordings were obtained from anaesthetized elephant, buffalo, impala and rabbits before and after the administration of a lethal dose of scoline. All EEG activity ceased at an arterial haemoglobin-oxygen saturation of about 25% in the species studied. Unanaesthetized rabbits became unconscious at arterial $P_{O_2}$ of between 23 and 25 mmHg and died at arterial $P_{O_2}$ of between 19 and 23 mmHg. The margin between unconsciousness and death is thus narrow in rabbits and if this is generally true, the discomfort experienced after the administration of scoline will be perceived until shortly before death in any animal species.

*S. Afr. J. Zool.* 1985, 20: 123 – 128

EEG-golwe van genarkotiseerde olifante, buffels, impala en hase is geregistreer voor en na die toediening van 'n dodelike dosis skolien. In die spesies wat ondersoek is kon geen EEG-golwe meer verkry word na 'n hemoglobiensuurstofversadiging van 25% bereik is nie. Ongenarkotiseerde hase het bewusteloos geword by 'n arteriële $P_{O_2}$ van tussen 23 en 25 mmHg en dood het ingetree by 'n arteriële $P_{O_2}$ van tussen 19 en 23 mmHg. In hase is die spanwydte tussen bewusteloosheid en dood dus klein en indien dit oor die algemeen geld, sal die spanning weens die toediening van skolien tot net voor die dood ervaar word in enige dierespesie.

*S.-Afr. Tydskr. Dierk.* 1985, 20: 123 – 128

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Received 8 October 1984; accepted 15 January 1985

In a recent publication, the blood composition of elephant and buffalo culled with succinyldicholine (SDC) was investigated (Hattingh *et al.* 1984a). Values obtained were compared to those from undisturbed animals shot in the brain. Significant changes were observed in a number of variables including arterial blood $P_{O_2}$ and $P_{CO_2}$. As SDC paralyses skeletal muscle, the asphyxial changes observed are not surprising. The results suggested that the stress (discomfort) associated with the culling procedure is perceived for some time, which is probably longer in elephant than in buffalo. From cortisol and blood gas measurements, it has subsequently been shown that elephant should be killed by a shot into the brain on average within 16 min after darting with SDC to minimize the duration of this perception (Hattingh *et al.* 1984b; because buffalo die within a short time from the effects of SDC, they are not usually shot as part of the culling procedure).

In general, it is not known for how long animals consciously perceive the discomfort associated with the administration of a lethal dose of SDC. Button, Bertschinger & Mulders (1981) deduced from electroencephalographic recordings in calves, that the animals were probably conscious and under psychic stress for at least 4 min after the onset of SDC-induced apnoea. In a similar study on dogs, Hicks & Bailey (1978) found that the animals were conscious for long periods of time but the exact point of unconsciousness could not be ascertained from the electroencephalographic recordings (EEG). Cortical activity ceased between 390 and 517 seconds after administration of a lethal dose of SDC in different groups and a change in EEG from the normal awake pattern to one with lower voltage and higher frequency was noted between 5 and 72 s after apnoea. In neither of the two abovementioned studies is the interpretation of the EEG's clear, and high-voltage deflections owing to muscle fasciculations, blinking and general body movement may have contributed to the patterns. In addition, the usual EEG pattern (high voltage, low frequency: delta waves) associated with coma or unconsciousness in humans (Mountcastle 1980) was not observed.

One approach to the problem is to determine the arterial $P_{O_2}$ and $P_{CO_2}$ at which consciousness is lost and cortical activity ceases (brain death). The former is readily possible in laboratory animals and the latter in any anaesthetized animal. However, because species differ in the time they take to die following the administration of a lethal dose of SDC (Hattingh *et al.* 1984a; Button *et al.* 1981), results from one group are not necessarily applicable to another. The present paper reports on the arterial blood gas levels at which brain death occurs in four animal species and at which levels consciousness

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is lost in rabbits. After careful consideration, these experiments were agreed to by the Animal Ethics Committee of the University. From the results on rabbits it would seem that the margin between unconsciousness and death is narrow and that animals exposed to SDC consciously perceive until shortly before death.

## Methods

Blood samples were obtained from anaesthetized (darted) impala (*Aepyceros melampus melampus*), buffalo (*Syncerus caffer*), and elephant (*Loxodonta africana*) and from anaesthetized and conscious rabbits (New Zealand White). The latter were anaesthetized (intravenously) with urethane (25% ethyl carbamate, 1 – 1,6 g/kg) or alphaxalone-alphadolone acetate (Saffan, Glaxo; 6 – 9 mg/kg) and the other species with etorphine (M99, Reckitt) with animals receiving between 1 and 6 mg. For the one series of experiments anaesthesia was maintained and SDC (Scoline, Glaxo) was administered in lethal doses ranging from 0,1 mg/kg to 10 mg/kg depending on the species.

### Anaesthetized animals

Ear arteries in buffalo and elephant, superficial leg arteries in impala and the carotid artery in rabbits were cannulated. Animals were intubated when necessary. Blood pressure was recorded with an FC 135 coupler and a PT 400 pressure transducer, the ECG with an FC 123 coupler and limb leads with needle electrodes, respiration (only rate) with an FC 110 coupler and F53 thermistor and the EEG with an FC 121 coupler, bipolar leads and subcutaneous needle electrodes in contact with bone (all from Washington). In elephant, 10 cm deep holes were drilled into the skull and insulated electrodes (tips exposed) used. Electrodes were usually placed midway between the eyes and the ears with an indifferent electrode elsewhere. All recordings were made with a Washington 400 MD4 recorder.

Animals were allowed to stabilize, whereafter several control blood samples were obtained. A lethal dose of SDC was then administered subcutaneously and blood samples and recordings obtained until death.

### Conscious animals

Rabbits accustomed to handling and to a stock were anaesthetized and three screw electrodes inserted aseptically into the skull, one on each side midway between the eyes and ears and one midway between the eyes. The two recording electrodes just penetrated the cranial cavity. The EEG was recorded and the animals were given dihydrostreptomycin/procaine penicillin (125/600 mg intramuscular; Milvet) and pethidine hydrochloride (10 mg/kg subcutaneously before waking from anaesthesia; Roche).

Several days later a central ear artery was cannulated under local anaesthesia (Lidocaine, Xylonor-spray). The rabbits were then placed in a closed, transparent container whilst recording blood pressure and the EEG. The percentage oxygen in the container was continuously monitored with an S3A Oxygen Analyser (Applied Electrochemistry Inc., Sunnyvale, California) and the percentage carbon dioxide with a Cavitron PM – 20 N Neonatal $CO_2$ monitor (Anarad Inc., Santa Barbara, California). Respiratory rate was determined by observation. The percentage composition of air in the container was changed by pumping in oxygen, carbon dioxide and/or nitrogen. Exposure time to any particular composition of air was for a few minutes only.

### Analytical techniques

Blood and plasma samples were analysed for $P_{O_2}$, $P_{CO_2}$, pH, haematocrit, glucose, lactate, lipid, ACTH, cortisol, free $T_3$, TSH and catecholamines as reported previously (Hattingh *et al.* 1984b, 1985). Not all determinations were done on all samples. Results were analysed statistically using Student's *t* test where necessary and are reported as means ± S.D.

## Results

### Anaesthetized animals

The results obtained on rabbits are shown in Table 1 and Figure 1. Basal values in the former refer to pooled results obtained from blood drawn (ear vein) immediately before anaesthetization and control values to those obtained after all experimental procedures had been completed but prior to SDC administration. For clarity, results for the variables investigated from individual animals after SDC administration were plotted against arterial $P_{O_2}$ and the values at 60, 50, 40, 30 and 20 mmHg determined. These were pooled for the six animals and are presented in Table 1 as 'change with arterial $P_{O_2}$'. In all anaesthetized rabbits EEG waves were of greater amplitude and lower frequency than those of conscious

**Table 1** Effects of SDC on blood composition and EEG of rabbits ($N = 6$)

| Variable | Basal | Control | Change with arterial $P_{O_2}$ after SDC administration | | | | |
|---|---|---|---|---|---|---|---|
| Arterial $P_{O_2}$ mmHg | – | 70 ± 16 | 60 | 50 | 40 | 30 | 20 |
| Respiratory rate b/min | – | 58 ± 31 | 43 ± 5 | 47 ± 29 | 37 ± 23 | 18 ± 16 | *12 ± 12 |
| Arterial $P_{CO_2}$ mmHg | – | 27 ± 6 | 34 ± 19 | *45 ± 13 | *53 ± 16 | *68 ± 19 | *83 ± 21 |
| Arterial pH | – | 7,496 ± 0,078 | *7,340 ± 0,129 | *7,298 ± 0,128 | *7,230 ± 0,164 | *7,085 ± 0,180 | *6,960 ± 0,165 |
| Heart rate b/min | – | 247 ± 25 | 199 ± 54 | *162 ± 44 | *118 ± 50 | *80 ± 58 | *79 ± 44 |
| Mean arterial blood pressure mmHg | – | 96 ± 15 | 106 ± 5 | 102 ± 11 | 88 ± 19 | 50 ± 50 | *5 ± 6 |
| Haematocrit % | – | 40,6 ± 2 | | | No change | | |
| Lactate nmol/l | 5,96 ± 4,45 | 3,91 ± 3,30 | 7,5 ± 3,5 | 6,8 ± 3,4 | 6,4 ± 4,3 | 7,8 ± 4,3 | *12,6 ± 6,2 |
| Glucose mmol/l | 7,60 ± 1,69 | 14,1 ± 4,0 | *22,5 ± 2,1 | 20,6 ± 4,0 | 17 ± 6,7 | 17,1 ± 6,2 | 19 ± 7,7 |
| Cortisol nmol/l | 13 ± 5 | 25 ± 13 | 49,3 ± 41,2 | 47,7 ± 39,8 | 46,4 ± 33,9 | 36,2 ± 25,1 | 15,3 ± 10,0 |
| Free $T_3$ pmol/l | 10,3 ± 1,4 | 4,7 ± 1,8 | | | No change | | |
| Total lipids g/l | 3,52 ± 0,30 | 4,2 ± 0,8 | | | No change | | |
| EEG Frequency (waves/min) | – | 45 ± 8 | 50 ± 3 | 46 ± 4 | 52 ± 27 | 51 ± 28 | 0 ± 0 |
| Time (min)** | | | | | 9,0 ± 3 | | |

** From decrease in respiratory rate to cessation of EEG waves

* Significantly different to control values ($P < 0,05$)

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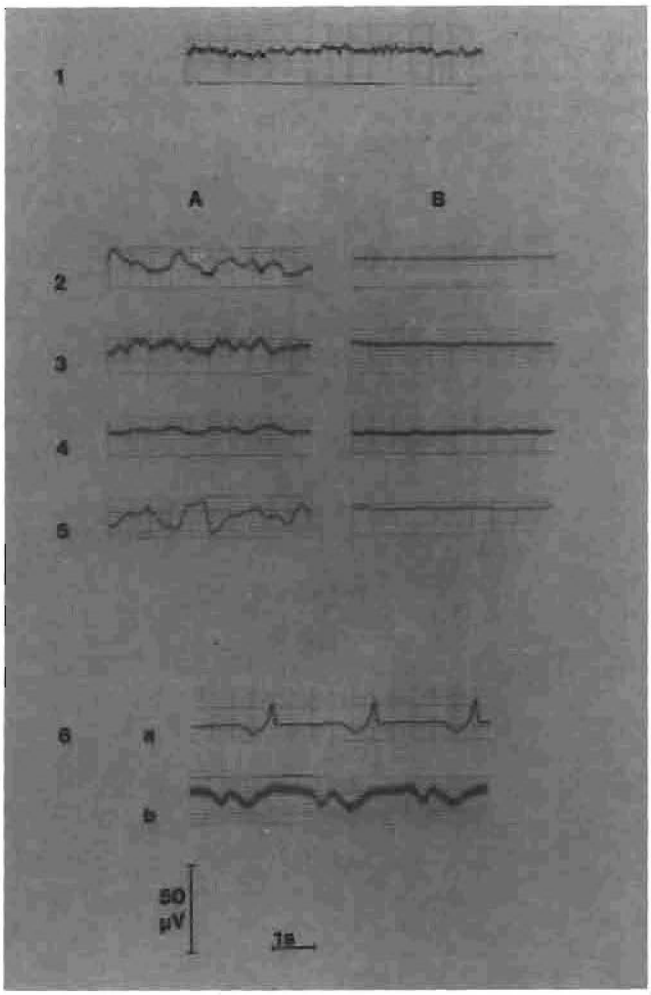


**Figure 1** EEG recordings of conscious rabbits (1) and anaesthetized (A) and dead (B) rabbits (2), impala (3), buffalo (4) and elephant (5). EEG recording (6b) after cessation of respiration and cortical activity in elephant showing deflections out of phase with ECG (6a) activity.

animals (Figure 1) and ceased (iso-electric recordings) at arterial $P_{O_2}$ between 20 and 30 mmHg. Graphical analysis (see above) indicated that brain death occurred at a $P_{O_2}$ of $22 \pm 3$ mmHg and a $P_{CO_2}$ of $75 \pm 13$ mmHg. All respiratory activity stopped soon after this and blood pressure dropped to zero. ECG activity continued (in altered form) for up to 30 min after the cessation of EEG waves. Mean blood glucose and lactate levels were raised throughout the experiment. Mean cortisol values decreased towards the end. Although not significantly different from control values, mean arterial blood pressure increased immediately after the administration of SDC as did EEG frequency, the latter remaining so until death. The mean time from the first observable decrease in respiratory rate (graphical analyses, see above) until cessation of EEG activity was $9{,}0 \pm 3$ min (Table 1).

Two further rabbits were examined as above but were connected to a respirator as soon as respiratory rate decreased after SDC administration. Respiration was maintained for some time and then gradually decreased (both rate and volume). In these animals the results obtained were similar to those found when events were allowed to follow their natural course.

In the cases of impala (Table 2), buffalo (Table 3) and elephant (Table 4), individual results are presented except for control values which were pooled. Also, 'change with respiratory rate' after SDC administration is indicated. In all three species, EEG frequency again increased before death but amplitude did not change (Figure 1). Wave forms were similar to those of the anaesthetized rabbit. In impala the EEG became iso-electric at an arterial $P_{O_2}$ of about 15 mmHg and an arterial $P_{CO_2}$ of about 70 mmHg, in buffalo at about 24 mmHg $P_{O_2}$ and 75 mmHg $P_{CO_2}$ and in elephant at about 12 mmHg $P_{O_2}$ and 87 mmHg $P_{CO_2}$ (estimated mean values from graphical analyses). The rest of the variables investigated showed similar tendencies to those observed in rabbits and time from a noticeable decrease in respiratory rate to cessation of EEG activity was shortest in buffalo and longest in elephant.

In most animals investigated, an 'ECG artefact' appeared in the EEG recording after cessation of the usual wave activity. These patterns were slightly out of phase with the ECG, an example of which is shown in Figure 1. The pattern disappeared when the ECG ceased.

## Conscious animals

An example of the EEG recordings obtained is shown in Figure 1. When the percentage oxygen in environmental air was decreased at constant (air) percentage carbon dioxide, consciousness was lost (no response to ear pinching) at between 4,5 and 7,5% $O_2$. The EEG pattern changed from high frequency low amplitude to low frequency high amplitude (1 and 2 in Figure 1) over a period of 20 to 30 s. Arterial $P_{O_2}$ was $23 \pm 2$ mmHg, $P_{CO_2}$ $9 \pm 3$ mmHg and pH, $7{,}476 \pm 0{,}172$ ($n = 4$). The EEG was iso-electric at 4,2 to 7,0% $O_2$ with arterial $P_{O_2}$ at $19 \pm 3$ mmHg, $P_{CO_2}$ at $10 \pm 6$ mmHg and pH, $7{,}390 \pm 0{,}281$. When the reverse experiment was performed, i.e. percentage $CO_2$ increased at constant (air) percentage oxygen, consciousness was lost, at 23 – 30% $CO_2$ with arterial $P_{O_2}$ at $86 \pm 18$ mmHg, $P_{CO_2}$ at $131 \pm 12$ mmHg and pH at $6{,}889 \pm 0{,}088$ ($n = 4$). The EEG pattern showed the same amplitude and frequency changes and respiration was very laboured. The EEG was iso-electric at about 40 – 50% $CO_2$ with arterial $P_{O_2}$ $39 \pm 14$, $P_{CO_2}$ above 200 and pH $6{,}620 \pm 0{,}604$. When the percentage oxygen was decreased and the percentage carbon dioxide increased in the same experiment, consciousness was lost at about 7% $O_2$ and 19,5% $CO_2$ with arterial $P_{O_2}$ at $25 \pm 1$ mmHg, $P_{CO_2}$ at $99 \pm 27$ mmHg and pH at $7{,}021 \pm 0{,}053$ ($n = 4$). Death ensued at arterial $P_{O_2}$ of $23 \pm 1$ mmHg, $P_{CO_2}$ at $113 \pm 32$ mmHg, and pH at $6{,}914 \pm 0{,}052$. Finally, the EEG was recorded in a conscious rabbit which was given a lethal dose of SDC. The conscious EEG pattern persisted for 12,5 min, then changed to the unconscious pattern for 0,5 min and became iso-electric at 13 min. All respiratory movements stopped at 13,25 min. Large amplitude deflections in the EEG recordings were noted occasionally and coincided in every instance with muscle fasciculations, general body movement, blinking, etc.

## Discussion

The EEG recordings obtained from conscious rabbits are similar in amplitude and frequency to those found by Nelson & Wulfsohn in the same animals (1963). Following anaesthetization and loss of consciousness the patterns changed to larger amplitude and lower frequency, similar to delta waves seen in humans (Mountcastle 1980). The waves were observed in all species studied and it is reasonable to conclude that they are indicative of the unconscious state, which agrees with the findings of Prynn & Redding (1968) on dogs.

Very few data are available concerning blood gas tensions at which loss of consciousness and death occur. The general impression is that consciousness will be lost when haemoglobin is 40 to 60% saturated with oxygen (Ganong 1981; Guyton

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**Table 2** Effects of SDC on blood composition and EEG of impala

| Variable | Control | Change with respiratory rate after SDC administration: Impala 1 | | | | | | | | | Impala 2 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Respiratory rate b/min | 13 ± 1 | 10 | 6 | 5 | 5 | 0 | 0 | 0 | 0 | 0 | 12 | 12 | 12 | 10 | 5 | 4 | 1 | 1 | 0 | 0 | 0 |
| Arterial $P_{O_2}$ mmHg | 54 ± 12 | 42 | 51 | 37 | 37 | 19 | 16 | 12 | 11 | 8 | 82 | 68 | 56 | 40 | 25 | 23 | 17 | 14 | – | – | 1 |
| Arterial $P_{CO_2}$ mmHg | 45 ± 4 | 49 | 45 | 51 | 50 | 57 | 57 | 61 | 62 | 68 | 39 | 47 | 53 | 60 | 69 | 69 | 78 | 81 | – | – | 1 |
| Arterial pH | 7,389 ± 0,024 | 7,375 | 7,405 | 7,371 | 7,375 | 7,341 | 7,324 | 7,305 | 7,289 | 7,261 | 7,448 | 7,418 | 7,351 | 7,312 | 7,268 | 7,266 | 7,240 | 7,216 | – | – | 1 |
| Heart rate b/min | 112 ± 53 | 144 | 132 | 144 | 156 | 228 | 204 | 84 | 96 | 96 | 108 | 96 | 96 | 84 | 108 | 132 | 180 | 48 | 36 | 12 | 36 |
| Mean arterial blood pressure mmHg | 151 ± 16 | 150 | 150 | 150 | 160 | 110 | 100 | 50 | 10 | 0 | 140 | 170 | 170 | 170 | 170 | 180 | 120 | 60 | 40 | 0 | 0 |
| Haematocrit % | 36 ± 2 | 34 | 34 | 34 | 35 | 36 | 37 | 37 | 37 | 37 | 37 | 41 | 40 | 41 | 39 | 41 | 43 | 44 | – | – | – |
| Lactate nmol/l | 6,3 ± 2,4 | 76 | 7,0 | 7,0 | 6,1 | 5,5 | 6,2 | 4,9 | 77 | 5,1 | 3,1 | 3,2 | 4,2 | 3,3 | 3,8 | 2,8 | 3,8 | 4,4 | – | – | – |
| Glucose mmol/l | 10,6 ± 1,5 | – | 11,2 | 11,9 | 11,5 | 11,6 | 10,4 | 11,6 | 12,1 | 13,7 | 10,2 | 11,6 | 11,6 | 11,4 | 11,6 | 11,9 | 11,9 | 11,1 | – | – | – |
| ACTH uIU/ml | 93 ± 28 | 78 | 92 | 92 | 95 | 100 | 110 | 126 | 130 | 126 | 95 | 110 | 173 | 190 | 218 | 240 | 240 | 240 | – | – | – |
| Cortisol nmol/l | 69 ± 14 | No change | | | | | | | | | No change | | | | | | | | | | |
| Free $T_3$ pmol/l | 2,2 ± 1,8 | No change | | | | | | | | | No change | | | | | | | | | | |
| TSH uU/ml | 2,1 ± 0,5 | No change | | | | | | | | | No change | | | | | | | | | | |
| Total Lipids g/l | 3,28 ± 0,73 | No change | | | | | | | | | No change | | | | | | | | | | |
| EEG frequency waves/min | 20 ± 10 | 24 | 24 | 24 | 36 | 60 | 48 | 0 | 0 | 0 | 36 | 60 | 60 | 72 | 72 | 72 | 48 | 36 | 0 | 0 | 0 |
| Time (mins)* | | 10 | | | | | | | | | 15 | | | | | | | | | | |

* from decrease in respiratory rate to cessation of EEG waves.

**Table 3** Effects of SDC on blood composition and EEG of buffalo

| Variable | Control | Change with Respiratory Rate after SDC administration: Buffalo I | | | Buffalo II | | | | Buffalo III | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Respiratory rate b/min | 16 ± 3 | 5 | 0 | 0 | 12 | 12 | 2 | 0 | 8 | 0 | 0 | 0 |
| Arterial $P_{O_2}$ mmHg | 43 ± 13 | 23 | 18 | 18 | 32 | 32 | 24 | 22 | 43 | 36 | 22 | 17 |
| Arterial $P_{CO_2}$ mmHg | 65 ± 12 | 55 | 59 | 63 | 81 | 78 | 87 | 86 | 82 | 88 | 79 | 87 |
| Arterial pH | 7,210 ± 0,093 | 7,308 | 7,290 | 7,286 | 7,130 | 7,131 | 7,111 | 7,111 | 7,117 | 7,116 | 7,130 | 7,127 |
| Heart rate b/min | 93 ± 30 | 120 | 60 | 48 | 108 | 108 | 36 | 10 | 24 | 36 | 96 | 36 |
| Mean arterial blood pressure mmHg | 187 ± 31 | 220 | 50 | 0 | 150 | 150 | 75 | 0 | 150 | 130 | 80 | 0 |
| Haematocrit % | 29 ± 4 | 32 | 28 | 25 | 33 | 33 | 35 | 35 | 32 | 35 | 34 | 36 |
| Lactate nmol/l | 1,6 ± 1,7 | 0,6 | 1,9 | 2,0 | 4,4 | 4,6 | 4,4 | 4,6 | 0,05 | 0,03 | 0,30 | 0,70 |
| Glucose mmol/l | 7,2 ± 1,3 | 6,6 | 7,4 | 7,3 | 9,4 | 10,0 | 10,3 | 10,2 | 4,1 | 6,7 | 7,3 | 7,8 |
| ACTH uIU/ml | 205 ± 102 | No change | | | No change | | | | No change | | | |
| Cortisol nmol/l | 90 ± 15 | No change | | | No change | | | | No change | | | |
| Free $T_3$ pmol/l | 1,9 ± 1,2 | No change | | | No change | | | | No change | | | |
| TSH uU/ml | 2,2 ± 1,0 | No change | | | No change | | | | No change | | | |
| Total lipid g/l | 3,8 ± 0,6 | No change | | | No change | | | | No change | | | |
| EEG frequency waves/min | 25 ± 4 | 48 | 0 | 0 | 24 | 36 | 0 | 0 | 36 | 36 | 0 | 0 |
| Time (min)* | | 3 | | | 10 | | | | 5 | | | |

* From decrease in respiratory rate to cessation of EEG waves.

1981; Mountcastle 1980). Davis, Davis & Thompson (1938) noted the appearance of delta waves in subjects after breathing 8% oxygen for 10 to 15 min. Christensen & Krogh (1936) showed that the average individual will lose consciousness when alveolar $P_{O_2}$ is 30 mmHg with minimal individual variation. The findings of Opitz (1950) agree with this and he showed that waves (3 c.p.s) appeared at an alveolar $P_{O_2}$ of about 28 mmHg but indicated that cerebral function may deteriorate at a considerably higher $P_{O_2}$ if hypoxia is combined with excessive ventilation and hypocapnia. As far

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**Table 4** Effects of SDC on blood composition and EEG of elephants

| Variable | Control | Change with respiratory rate after SDC administration | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Elephant 1 | | | | | | | | | | | | Elephant 2 | | | | | | | | | |
| Respiratory rate b/min | 12 ± 0,0 | 10 | 6 | 6 | 5 | 4 | 3 | 3 | 2 | 0 | 0 | 0 | 0 | 10 | 6 | 6 | 6 | 6 | 2 | 2 | 0 | 0 | 0 | 0 |
| Arterial $P_{O_2}$ mmHg | 92,3 ± 13,6 | 98 | 46 | 27 | 37 | 20 | 15 | 11 | 8 | 6 | 5 | 5 | 5 | 30 | 28 | 20 | 17 | 15 | 12 | 14 | 8 | 5 | 7 | 9 |
| Arterial $P_{CO_2}$ mmHg | 38,1 ± 4,6 | 35 | 42 | 49 | 29 | 56 | 72 | 75 | 83 | 83 | 81 | 90 | 92 | 49 | 48 | 55 | 57 | 61 | 71 | 77 | 92 | 105 | 96 | 78 |
| Arterial pH | 7,371 ± 0,019 | 7,370 | 7,310 | 7,271 | 7,311 | 7,250 | 7,202 | 7,151 | 7,112 | 7,098 | 7,081 | 7,081 | 7,059 | 7,318 | 7,319 | 7,279 | 7,261 | 7,240 | 7,163 | 7,147 | 7,038 | 6,970 | 6,938 | 6,938 |
| Heart rate b/min | 64,8 ± 16,1 | 36 | 24 | 18 | 18 | 20 | 20 | 23 | 12 | 25 | 24 | 24 | 12 | 36 | 36 | 24 | 36 | 36 | 24 | 48 | 24 | 48 | 36 | 0 |
| Mean arterial blood pressure mmHg | 190 ± 14,1 | 180 | 170 | 190 | 190 | 190 | 190 | 170 | 140 | 75 | 75 | 60 | 30 | 210 | 210 | 220 | 220 | 220 | 220 | 190 | 130 | 50 | 30 | 0 |
| Haematocrit % | 43,9 ± 6,7 | 46 | 50 | 50 | 35 | 51 | 56 | 55 | 57 | 53 | 50 | 59 | 56 | 39 | 39 | 39 | 39 | 40 | 41 | 42 | 43 | 40 | 40 | |
| Lactate nmol/l | 1,6 ± 0,3 | 1,9 | 1,9 | 1,9 | 1,7 | 1,7 | 2,2 | 2,8 | 3,6 | 3,0 | 4,9 | 5,6 | 4,0 | 1,5 | 1,3 | 1,9 | 2,0 | 2,0 | 4,0 | 4,8 | 6,9 | 8,2 | 8,5 | – |
| Glucose mmol/l | 4,8 ± 0,2 | 4,7 | 4,3 | 5,2 | 4,6 | 5,1 | 5,2 | 5,1 | 5,8 | 4,5 | 5,8 | 5,8 | 5,4 | 4,4 | 4,8 | 4,9 | 49 | 5,0 | 5,8 | 6,4 | 7,0 | 7,9 | 7,5 | – |
| ACTH uIU/ml | 68,5 ± 13,6 | 74 | 110 | 87 | 87 | 70 | 74 | 70 | 64 | 50 | 78 | 79 | 88 | 79 | 70 | 83 | – | 78 | 92 | 88 | 83 | 83 | 110 | – |
| Cortisol nmol/l | 50,6 ± 7,4 | 45 | 42 | 45 | 48 | 45 | 45 | 59 | 72 | 56 | 89 | 76 | 66 | 40 | 40 | 40 | 45 | 42 | 72 | 158 | 200 | 172 | 138 | – |
| Free $T_3$ pmol/l | 3,5 ± 0,6 | No change | | | | | | | | | | | | No change | | | | | | | | | | |
| TSH uU/ml | 1,0 ± 0,6 | No change | | | | | | | | | | | | No change | | | | | | | | | | |
| Total lipid g/l | 6,5 ± 1,7 | No change | | | | | | | | | | | | No change | | | | | | | | | | |
| Total catecholamine ng/ml | 3,4 ± 1,2 | – | – | – | – | – | – | – | – | – | – | – | – | 9,7 | 35,7 | 34,9 | 43,7 | 71,5 | 60,7 | 155,7 | 231.0 | 223.7 | 186,5 | – |
| Noradrenaline ng/ml | 1,7 ± 1,7 | – | – | – | – | – | – | – | – | – | – | – | – | 4,3 | 26,2 | 28,0 | 38,8 | 50,0 | 36,2 | 65,2 | 89,1 | 94,2 | 102,9 | – |
| Adrenaline ng/ml | 1,8 ± 1,7 | – | – | – | – | – | – | – | – | – | – | – | – | 5,4 | 9,5 | 6,9 | 4,9 | 21,5 | 24,5 | 90,5 | 141,9 | 129,5 | 83,6 | – |
| EEG frequency waves/min | 37 ± 10 | 36 | 36 | 36 | 36 | 36 | 36 | 60 | 0 | 0 | 0 | 0 | 0 | 48 | 60 | 48 | 72 | 60 | 48 | 36 | 0 | 0 | 0 | 0 |
| Time (min)* | | 34 | | | | | | | | | | | | 16 | | | | | | | | | | |

* From decrease in respiratory rate to cessation of EEG waves

as $CO_2$ is concerned, Sieker & Hickam (1953) showed that a semicomatose or comatose state was always observed in patients if the arterial $P_{CO_2}$ was above 130 mmHg and the pH below 7,14. Thirty percent carbon dioxide in air is sufficient to provide anaesthesia but the side effects are many and varied (Nunn 1977).

Exposure period to a lowered percentage oxygen or increased percentage carbon dioxide in air will obviously have an effect on the time of 'useful consciousness' which has been investigated in some detail (Guyton 1981; Mountcastle 1980). The values referred to in the previous paragraph apply to periods from 15 min to several hours or longer. In the present series of experiments, acute exposure times are important, and this relates to the situation under investigation. The results obtained are thus not directly comparable to those in the literature. Even so, it was found consciousness was lost in rabbits between 23 and 25 mmHg mean arterial $P_{O_2}$ and between 99 and 131 mmHg mean $P_{CO_2}$ depending on the experimental design. The possibility does exist that a cumulative effect of low oxygen and high carbon dioxide is involved, because when both gases were altered in the same experiment, loss of consiousness occurred at a higher $P_{O_2}$ and lower $P_{CO_2}$ than when only one variable was changed at a time. In addition, it would seem that arterial $P_{O_2}$ limits are narrower than those of $P_{CO_2}$ and that the critical level of oxygen tension is better defined than that of carbon dioxide (at the concentrations of the gases involved in the present study). The oxygen tensions (23 to 25 mmHg) reflect a haemoglobin saturation of about 30 to 35% which falls outside the lower limit reported (see above).

Cortical activity in anaesthetized rabbits ceased at a mean arterial $P_{O_2}$ of 22 mmHg and a mean $P_{CO_2}$ of 75 mmHg, the variation in the former again being smaller than in the latter. These values are similar to those found in buffalo, the oxygen-haemoglobin dissociation curve of which is probably not very different to that of the rabbit (Prosser 1973). If it is generally true that, upon exposure to low environmental oxygen such as that done in the present experiments, consciousness is lost at about 30 to 35% haemoglobin saturation and if hypoxia is the major determinant, then the margin between unconsciousness and death in rabbits and buffalo is very narrow, i.e. only a few mmHg arterial $P_{O_2}$. This suggestion is strengthened by the observation that after the administration of SDC to a conscious rabbit, EEG slow-wave activity only appeared shortly before death. In the case of elephant, 30% haemoglobin saturation occurs at a $P_{O_2}$ of about 15 mmHg, while no data are available as to the properties of impala haemoglobin. Cortical activity ceased in both species at about 12 to 15 mmHg arterial $P_{O_2}$. If the above assumptions are correct, the same principle would apply, i.e. consciousness would only be lost at a $P_{O_2}$ of a few mmHg above that at which brain death occurs. It is also interesting to note that EEG activity ceased in all species at approximately the same level of haemoglobin saturation with oxygen, i.e. about 25%.

Finally, mean arterial $P_{O_2}$ in anaesthetized elephant and buffalo is 59 and 57 mmHg respectively (Hattingh *et al.* 1984b). After darting with SDC during culling, the mean $O_2$ decrease in arterial blood is at a rate of 3,1 and 3,4 mmHg/min respectively (Hattingh *et al.* 1984b). This implies that, on average, brain death will occur within 11 min in buffalo and within 17 min in elephant from the time SDC has an effect on the respiratory muscles and consequently blood gas tensions. Usually, this effect is almost immediate in buffalo whereas it occurs between 5 to 8 min in elephant (Hattingh *et al.* 1984a). Thus, on average, buffalo would die within 11 min from darting but elephant would die within 22 to 25 min. Because it is probable that the associated discomfort is experienced until shortly before death, the recommendation that elephant should be shot within 16 min of *darting*, is valid (Hattingh *et al.* 1984b).

## Acknowledgements

The financial assistance of the University of the Witwatersrand, National Parks Board and the CSIR; and the help provided by Mr Ben de Klerk, Dr L. van der Klasshorst and others are gratefully acknowledged.

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