Bispectral index reveals death-feigning behavior in a red kite

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Bispectral index reveals death feigning behavior in a red kite (*Milvus milvus*)

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Short title: BIS and feigning death

Abstract

Red kites (*Milvus milvus*) are raptors known to feign death in the presence of humans. An adult wild red kite (*Milvus milvus*), ASA II, underwent coelioscopy. Butorphanol was administered before induction of anesthesia which was maintained with 1.5% isoflurane in oxygen. Intraoperatively, heart rate and respiratory rate ranged from 240 to 260 bpm and from 16 to 28 brpm, respectively. Pupil and corneal reflexes were always present. Body temperature was maintained at 40.4°C. Suppression ratio was 0 during the whole anesthesia. Bispectral index was 44 immediately after intubation, ranged from 44 to 57 during maintenance of anesthesia and at the moment of extubation it was 59. The index rose up to 85 within a minute while the kite remained immobile under the suspicion of feigning death in sternal recumbence. The bird was perched keeping immediately the upright position. This fact confirmed the correspondence of the BIS value (85) with a fully conscious patient. Whereas behavioral or cardio-respiratory variables remained unchanged, the degree of hypnosis was uncovered by BIS, which anticipated a possible sudden awakening episode of the kite.

Keywords: Feigning death, playing possum, red kite, bispectral index, isoflurane.

Case description

An adult wild red kite (*Milvus milvus*), weighing 650 g and classified according to the American Society of Anesthesiologists physical status as II underwent coelioscopy for sex determination. The raptor was premedicated with butorphanol (0.4 mg/kg s.c. Morphasol®, Graeub AG, Bern, Switzerland) 15 minutes before incision. At this moment, baseline values of heart rate and respiratory rate were obtained. Anaesthesia was induced with 5% isoflurane (Attane™, Provet AG, Lyssach, Switzerland) in 100% oxygen (1 l/min) using a face mask. Subsequently, the trachea was intubated with a non-cuffed Cole endotracheal tube (V-PAT-40 4.0 mm I.D. and 9.6 mm O.D. Cook, Steinhausen, Switzerland). The animal was positioned in lateral recumbency. Maintenance of anesthesia was performed with 1.5% isoflurane and 0.6 l/min oxygen using a pediatric circle system connected to an anesthetic machine (Dräger Medical Fabius® - CE, Software 4.0, Lübeck, Germany). The kite was allowed to breathe spontaneously during the whole procedure. A multi-parametric device (Nihon Kohden GmbH, Rosbach, Germany) was used to monitor physiological parameters. Three toothless clips placed on the left and right prepatagium and on the left thigh were used to obtain continues ECG readings.[1] A clip pulse oxymeter placed around the phalange II of the right leg recorded the haemoglobin oxygen saturation (SpO_2). A multigas unit (920RA/RK, Nihon Kohden GmbH, Rosbach, Germany) registered respiratory rate (RR) and the expired fraction of carbon dioxide ($FECO_2$) and isoflurane (FEiso) at the end of the Y-piece. Temperature was measured with an esophageal probe and it was controlled with an electric blanket (Solis CE. Lyssach, Switzerland) located underneath the patient. Pupil and corneal reflexes were checked every 5 minutes.

The electrical activity of the brain was monitored and computerized with bispectral index (A-2000 XP. Bispectral Index™- Aspect medical systems AG, Diessenhofen,

Switzerland). The BIS value displayed every five seconds represents the mean of the last 15 seconds (short smoothing rate). The BIS values reported here are the mean of a minute. Filters were set at 2-70 Hz to screen out undesirable interference from the raw EEG signal displayed. Values with low signal quality (< 50%) and/or high electromyography (EMG) (> 50%) were not included for further data analysis. Three modified electrodes (fitted with 24G needles with impedance under 7.5 kilo ohms) were subcutaneously placed between the eyes on the frontal area, over the left temporal musculature and immediately behind the left eye angle, respectively as described elsewhere.[2]

Heart rate (HR) and respiratory rate before induction (baseline) were 180 beats per min (bpm) and 28 breaths per minute (brpm), respectively. Induction of anaesthesia was uneventful. After intubation, HR increased to 260 bpm and RR decreased to 16 brpm. Heart rate remained constant until discontinuation of isoflurane when it decreased to 240 bpm. Respiratory rate increased up to 24 brpm eight minutes after intubation and remained constant until the end of anesthesia and during recovery (Figure 1).

Hemoglobin oxygen saturation, as well as F_ECO_2 and $F_E$iso remained constant over time (SpO_2 95%, F_ECO_2 50 mmHg and $F_E$iso 1.5%). Pupil and corneal reflexes were always present. Esophageal temperature was maintained at 40.4 ºC. Total anaesthesia time from induction to extubation was 26 minutes of which coelioscopy lasted 16 minutes.

The first BIS and SR recordings corresponded to the first minute after intubation. Suppression ratio was always 0, assuming therefore no inactivation of the raw EEG over time. The first BIS value obtained was 44. Intraoperative BIS values ranged from 44 to 57. At the moment of extubation BIS was 59. During the following minute, BIS raised up to 85 (Figure 1). According to the suggested range for BIS in the avian

92 species,[2] BIS > 65 would correspond to a possibly awake individual, indicating the kite
93 to be fully conscious. The bird was repositioned on sternal recumbence and remained
94 immobile. The suspicion that an awake raptor was lying on the table but stayed
95 immobile feigning death ('playing possum') was confirmed when the bird was perched
96 (lifting the bird by holding its feet) and stood upright immediately. This response
97 revealed the correspondence of the BIS reading with the fact it was completely awake.
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Discussion

Traditionally, heart rate, respiratory rate, arterial blood pressures, corneal, and pupil reflexes have informed anesthesiologists about variations on the degree of hypnosis and the health condition of avian patients.[3] In human medicine, the cortical activity of the brain has been additionally monitored to detect alterations on cerebral activity and optimize anesthetic titration.[4-7] A complex statistical evaluation of human electroencephalography data is performed by the bispectral index (BIS) monitor and it is displayed as a dimensionless value from 0 (cortical silence) to 100 (awake).[4,5,7,8] The BIS monitor has been recently validated for the avian species suggesting a range for deep hypnotic state (BIS < 50), light hypnotic state (BIS between 50 and 65) and possibly awake (BIS > 65) chickens under isoflurane anesthesia.[2] The suppression ratio (SR) or EEG proportion of a 63 second-period that has been suppressed (flat line) is also recorded and displayed by the BIS monitor. Suppression ratio, which ranges from 0 (no suppression) to 100 (isoelectric EEG), can be present at all planes of anesthesia in chickens.[2]

Among the birds of prey, kites are well-known for their behavioral strategy of feigning death when being cornered or in response to prolonged manual restraint.[9,10] Actually, there are anecdotes where wounded wild birds presented to a veterinarian were euthanized because their condition was judged hopeless, due to their immobility (Hatt, pers. comm.). In the anesthetic context, this behavior can result in an unrecognized inadequate plane of anaesthesia, unnecessary long recovery phase or sudden awakeing of the wild animal.

The case reported here is an example of the use of BIS in avian practice; unmasking playing possum behavior in a red kite. During recovery of anesthesia, information of the

142 degree of hypnosis of the patient was derived from BIS, while it could not be detected
143 from heart rate, respiratory rate or behavioral responses (i.e. BIS value of 85 suggesting
144 the kite was conscious). The increase of the heart rate observed during anesthesia was
145 probably a compensatory mechanism secondary to isoflurane-associated peripheral
146 vasodilation.[11] After discontinuation of anesthesia, heart rate decreased confirming this
147 well-known dose-dependent effect of isoflurane. Respiratory rate increased eight
148 minutes after induction and remained mostly unchanged during maintenance and
149 recovery of anesthesia. A respiratory depressant effect of isoflurane has been described
150 at all end-tidal anesthetic concentrations in a dose-dependent manner.[12] It is likely that
151 we did not see depressed ventilation due to the carbon dioxide level (F_ECO_2 50 mmHg),
152 which may have stimulated central, peripheral and intrapulmonary chemoreceptors.
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154 In human medicine, BIS has been reported to be a sensitive and specific measure of
155 adequate anesthesia, predicting unconsciousness, awareness and allowing anaesthesia
156 titration.[13,14] Therefore, the use of BIS as an additional monitoring has become a
157 common practice over the last 15 years. In veterinary medicine, the use of this
158 technology is gaining importance in clinical scopes of exotic animal anesthesia as
159 recognition of the degree of hypnosis in these species is still challenging.[15-18]
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161 The limitations of bispectral index are well described. Electromyographic activity can
162 interfere with high frequency EEG signals and consequently result in falsely elevated
163 BIS values. Similarly, high electrode impedances (due to improper electrode placement)
164 and high-frequency emission of other electric devices (such as water conducting heating
165 pads) can also cause interferences; the use of ketamine as part of balanced anesthesia
166 leads to paradoxical increase of BIS in that it is associated with a deepening level of

hypnosis.[19] Especially this last limitation represents a major constraint in the use of BIS in veterinary medicine.

The BIS values obtained from the red kite were not influenced by any of these limiting circumstances. Although an electric blanket was used to maintain body temperature, it was found not to interfere with BIS measurements (O. Martin-Jurado, pers. obs.).
Among other drugs, isoflurane in combination with nitrous oxide and sufentanil has been reported to cause paradoxical increases of BIS in surgical patients.[20] The authors attributed these misleading readings to continuous pre-burst EEG patterns consisting of high-frequency activity. The red kite received butorphanol on the top of isoflurane. Based on this anesthetic protocol, the absence of high-frequency interferences, the high quality of the signal and the inexistency of EMG disturbances, we confirm the reliability of BIS during maintenance and recovery of anesthesia in this patient.

The present case is the first report of BIS monitoring in a clinical avian patient. The use of BIS to monitor the degree of hypnosis added a safety value: the death-feigning behavior of the red kite was uncovered by bispectral index, which helped to avoid unexpected events during the recovery phase. We predict that the BIS monitor could also prove to be particularly useful in anaesthesia of other wild animal species known for a similar behavior, i.e. opossums (*Didelphis marsupialis*),[21] species with prolonged anesthetic apnea due to a diving reflex, such as pinnipeds,[22] or in potentially dangerous animals such as large felids or ursids in which sudden awakenings are particularly hazardous for involved personnel. Further experiences are needed to establish the utility of the bispectral index in the large variety of exotic animal and wild species.

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Figure 1. Bispectral index (BIS), respiratory rate (RR) and heart rate (HR) of a red kite (*Milvus milvus*) during a sixteen-minute coelioscopic intervention. Skin incision corresponds to minute 0. Extubation (minute 17) is marked with an arrow.