Effect of inhalation of isoflurane at end-tidal concentrations greater than, equal to, and less than the minimum anesthetic concentration on bispectral index in chickens

Olga Martin-Jurado, DVM; Rainer Vogt, DVM; Annette P. N. Kutter, DVM; Regula Bettschart-Wolfensberger, PhD; Jean-Michel Hatt, DVM

Objective—To determine the effect of inhalation of isoflurane at end-tidal concentrations greater than, equal to, and less than the minimum anesthetic concentration (MAC) on bispectral index (BIS) in chickens.

Animals—10 chickens.

Procedures—For each chicken, the individual MAC of isoflurane was determined by use of the toe-pinch method. After a 1-week interval, chickens were anesthetized with isoflurane at concentrations 1.75, 1.50, 1.25, 1.00, and 0.75 times their individual MAC (administered from higher to lower concentrations). At each MAC multiple, a toe pinch was performed and BIS was assessed and correlated with heart rate, blood pressure, and an awareness score (derived by use of a visual analogue scale).

Results—Among the chickens, mean ± SD MAC of isoflurane was 1.15 ± 0.20%. Burst suppression was detected at every MAC multiple. The BIS and awareness score were correlated directly with each other and changed inversely with increasing isoflurane concentration. Median (range) BIS values during anesthesia at 1.75, 1.50, 1.25, 1.00, and 0.75 MAC of isoflurane were 25 (15 to 35), 35 (25 to 45), 35 (20 to 50), 40 (25 to 55), and 50 (35 to 65), respectively. Median BIS value at extubation was 70 ± 9. Values of BIS correlated with blood pressure, but not with heart rate. Blood pressure changed with end-tidal isoflurane concentrations, whereas heart rate did not.

Conclusions and Clinical Relevance—Assessment of BIS can be used to monitor the electrical activity of the brain and the degree of unconsciousness in chickens during isoflurane anesthesia. (Am J Vet Res 2008;69:1254–1261)

Assessment of the effects of anesthetic agents on the CNS is an important undertaking in anesthesia. In human medicine, monitoring the electrical activity of the brain by determination of BIS to assess drug effects has become common practice over the last 2 decades. Bispectral analysis is a complex statistical evaluation of human EEG data that was developed to obtain an index of the level of hypnosis. The BIS is a dimensionless value from 0 (cortical silence) to 100 (awake). In humans, an optimal degree of general anesthesia was defined as that associated with a BIS within the range of 40 to 60.

The quality of the EEG signal is evaluated by combining the SQI and the EMG variables. The SQI is calculated on the basis of impedance data, artifacts, and other variables. It is scaled from 0 (no quality) to 100 (maximal quality). An EMG is also scaled from 0 (minimal) to 100 (maximal) and indicates the power in the high-frequency range as well as muscle activity. Suppression ratio, which ranges from 0 (no suppression) to 100 (maximal suppression or isoelectric EEG), is the proportion of signals over the last 63-second period for which the EEG signals are considered to be suppressed or inactive (so-called flat line).

ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIS</td>
<td>Bispectral index</td>
</tr>
<tr>
<td>EEG</td>
<td>Electroencephalography</td>
</tr>
<tr>
<td>EMG</td>
<td>Electromyography</td>
</tr>
<tr>
<td>FICO2</td>
<td>Fractional concentration of carbon dioxide in expired gas</td>
</tr>
<tr>
<td>FEISO</td>
<td>Fractional concentration of isoflurane in expired gas</td>
</tr>
<tr>
<td>HR</td>
<td>Heart rate</td>
</tr>
<tr>
<td>MAC</td>
<td>Minimum anesthetic concentration</td>
</tr>
<tr>
<td>NIBP</td>
<td>Noninvasive blood pressure</td>
</tr>
<tr>
<td>SpO2</td>
<td>Oxygen saturation as measured by pulse oximetry</td>
</tr>
<tr>
<td>SQI</td>
<td>Signal quality index</td>
</tr>
<tr>
<td>SR</td>
<td>Suppression ratio</td>
</tr>
<tr>
<td>VAS</td>
<td>Visual analogue scale</td>
</tr>
</tbody>
</table>
In veterinary medicine, BIS monitoring has been limited to research studies involving various species and anesthetic protocols. Overall, BIS values correspond with clinical signs for anesthesia depth in goats, dogs, cats, rabbits, and pigs. However, in horses, pigs, and dogs, BIS did not correspond to clinical signs. In dolphins, the asymmetric electrical activity of each cerebral hemisphere was successfully recorded with a BIS monitor. In a report of a study in alpacas, the authors suggested that more animals were needed for a meaningful interpretation of the results. To our knowledge, there are no published reports of studies involving BIS assessment in an avian species, and the BIS monitor that was designed for humans has not been validated for use in birds.

Isoflurane is a volatile anesthetic that induces concentration-dependent depression of the CNS with proportional suppression of the EEG trace. The MAC of isoflurane has been determined for various avian species, and the end-tidal concentrations of isoflurane between the lowest and highest MAC determined among avian species can vary by as much as 0.37%. Therefore, it is difficult to predict the safe, effective MAC of isoflurane in birds. Use of an index that indicates the degree of consciousness (ie, BIS) in individuals of such diverse species would increase the safety of inhalational anesthetic agents in birds.

The purpose of the study reported here was to evaluate the effect of isoflurane at end-tidal concentrations greater than, equal to, and less than the MAC on BIS in anesthetized chickens. We hypothesized that BIS would be inversely and linearly correlated with multiples of MAC of isoflurane and would also be correlated with other indicators of anesthesia depth such as HR, NIBP, and the state of awareness (determined by use of a VAS).

Materials and Methods

Ten adult hybrid chickens (Gallus domesticus) were used in the study; there were 5 males and 5 females (mean ± SD weight, 2.8 ± 0.2 kg and 1.7 ± 0.2 kg, respectively). The study was approved by the animal care and use committee (animal experiment No. 87/2,006). It was conducted in compliance with cantonal guidelines governing animal care and housing.

Procedures—Food was withheld 2 hours prior to anesthesia. Each chicken was anesthetized on 2 occasions at the veterinary hospital of Zurich (altitude, 436 m). After mask induction with isoflurane in oxygen, each chicken was positioned in right lateral recumbency. The trachea was intubated with a noncuffed Cole endotracheal tube; for end-tidal gas sample collection, a spinal needle was introduced in the endotracheal tube and extended to the tip of the tube. Intratracheal samples of 70 mL/min were collected to measure $F_{ECO2}$ and $F_{ESO}$ by use of a calibrated microstream airway adapter for children and neonates. The sample obtained from the intratracheal component was analyzed by use of a gas analyzer. Anesthesia was maintained with isoflurane in oxygen by use of a precision vaporizer and a pediatric closed rebreathing circuit on an anesthesia machine. Ventilation was controlled with a mechanical ventilator and adjusted to maintain normocapnia ($F_{ECO2}$, 30 mm Hg$^2$). Heart rate was monitored via ECG (lead II), as described by Casares et al. An esophageal temperature probe was placed to monitor body temperature. Pulse oximeter measurements were obtained from a universal Y-sensor adapted with a clip that was placed on a distal phalange of the left leg. Noninvasive blood pressure (systolic, diastolic, and mean arterial values) was measured by use of a pediatric cuff fitted around the tarsometatarsus. An electrical heating pad was used to help maintain body temperature at 40° to 41°C.

During the first anesthetic episode, the individual MAC for isoflurane was determined by use of a method for use in birds described by Nagano et al. Anesthesia was maintained at a constant $F_{ESO}$ for 15 minutes, at which time noxious stimulation was performed with a hemostat forceps. The clamp was fully closed in the interphalangeal fold and the pressure maintained for 60 seconds. The reaction of each chicken was recorded; a slight retraction of the leg was considered a positive response. The $F_{ESO}$ was subsequently increased by 10% if a positive response was observed; if there was a negative response (no movement), $F_{ESO}$ was decreased by 10%. After adjustment of the $F_{ESO}$, 15 minutes was allowed for equilibration before retesting. Two negative responses were needed to define the isoflurane concentration as the MAC. The MAC was determined as the mean of the lowest concentration that prevented a positive response to noxious stimulation and the highest concentration that allowed a negative response to noxious stimulation. After the MAC determination, administration of isoflurane was discontinued and the chickens were allowed to recover.

After 1 week, each bird was anesthetized a second time and instrumented for assessments of BIS, HR, NIBP, esophageal temperature, $Sp_{O2}$, $F_{ECO2}$, and $F_{ESO}$, as previously described. Each chicken was anesthetized with isoflurane at concentrations that were 1.75, 1.50, 1.25, 1.00, and 0.75 times their individual MAC (administered in sequence from higher to lower concentrations). After an equilibration period of 15 minutes at each multiple of MAC, noxious stimulation was performed as described; BIS, HR, and NIBP were recorded, and awareness was assessed by use of a VAS.

At the time points at which BIS was determined, assessment of awareness by use of a VAS was performed. The VAS was a straight 10-cm-long line with extremes that were limited by perpendicular lines. The left and right ends of the scale were marked as 0 (representing a deep plane of anesthesia) and 10 (representing a fully awake state), respectively. The stage of hypnosis was subjectively determined by the same anesthetist (OMJ) through evaluation of a modified reflex score (palpebral opening and reflex, pupil size, corneal reflex, head position, neck and leg tone, and patagium and cloacal reflexes), as described by Korbel; this person then marked the line at a position corresponding to that assessment. The distance along the line from the 0 point to where the mark was made provided an awareness score.

During both anesthetic episodes at 1.00 MAC, a 0.1-mL sample of venous blood was withdrawn from the ulnar vein to determine the respiratory status of the
chickens. The blood was analyzed for pH, partial pressure of carbon dioxide (venous), and partial pressure of oxygen (venous) by use of a point-of-care analyzer that has been validated for chickens.

Times to intubation and extubation and duration of recovery were recorded during both anesthetic episodes. Intubation time was the interval from the beginning of the mask induction until intubation was achieved. Extubation time was the interval from discontinuation of inhalation of isoflurane until the trachea was extubated. Recovery time was the interval from extubation until the chicken moved into a sternal or standing position.

**BIS monitoring**—Every 5 seconds during anesthesia, BIS was monitored. The BIS value displayed represented the mean of the maximum and minimum index of the last 15 seconds (short smoothing rate). After an equilibration period of 15 minutes at each multiple of MAC, recorded values were obtained during a 1-minute period following noxious stimulation (values were registered every 5 seconds with a total of 12 measurements in a minute). The EEG filters were set at 2 to 70 Hz. Values of BIS with an SQI value < 50 or an EMG value > 50 were treated as unreliable measurements and excluded from further analysis.

To obtain BIS measurements, 3 modified electrodes fitted with 24-gauge needles were used as sensors via a modified patient interface cable. Compared with a human, the head of a chicken is smaller and the brain position and size differ, resulting in neuroanatomic and neurophysiologic differences between these species. Therefore, needles were placed SC according to the recommended locations for humans, but with some modifications (Figure 1). The impedances for sensors 1 and 3 and for sensor 2 were always < 7.5 kΩ and < 30 kΩ, respectively.

**Statistical analysis**—The data were evaluated for normal distribution by use of the Kolmogorov-Smirnov test. Results for HR, NIBP, SR, and VAS scores were reported as mean ± SD; values obtained at the various multiples of MAC were compared. Bispectral index values are reported as the median and range to establish a suggested BIS range for chickens. Normally distributed data were analyzed by use of an ANOVA for repeated measurements to evaluate HR, NIBP, BIS, and VAS scores during anesthesia at each MAC multiple and at extubation and attainment of sternal recumbency. Because SR, by definition, influences BIS values (mainly at increasing levels of depression of brain activity [ie, BIS < 30]), these variables were not compared statistically. However, the changes in SR and BIS at every MAC multiple were simultaneously evaluated. The difference in MAC between sexes and differences in venous blood pH, blood gas variables; and induction, extubation, and recovery times during the first and second anesthetic episodes were analyzed by use of a paired t test. A value of P < 0.05 was considered significant. Regression analysis was performed to study the correlation of HR and NIBP with BIS during administration of isoflurane at multiples of MAC. Statistical analyses of data were performed by use of computerized software.

**Results**—Among the 10 chickens, mean MAC of isoflurane was 1.15 ± 0.20%. Mean MAC did not differ significantly (P < 0.05) between females (1.14 ± 0.15%) and males (1.16 ± 0.27%). At 0.75 MAC, a positive response to the noxious stimulation was detected in all chickens.
During the first anesthetic episode, the MAC value was determined after a mean interval of 99 ± 52 minutes. During the second anesthetic episode, the various multiples of MAC (1.75, 1.50, 1.25, 1.00, and 0.75 MAC) were achieved after intervals of 17 ± 5 minutes, 35 ± 5 minutes, 56 ± 8 minutes, 73 ± 8 minutes, and 87 ± 9 minutes, respectively. 

For anesthesia at 1.75, 1.50, 1.25, 1.00, and 0.75 MAC and at extubation, median (range) BIS values were calculated and did not differ significantly (Table 1). The value of BIS was numerically the lowest at 1.75 MAC and the highest at extubation; these values were significantly different. Heart rate, mean NIBP, SR, and awareness (VAS scores) were assessed during conditions of 1.75, 1.50, 1.25, 1.00, and 0.75 MAC and at extubation and attainment of sternal recumbency. In each chicken during anesthesia at every MAC multiple, EEG signal suppression was evident (range of mean SR, 6 to 50). In addition, the relationship of HR and NIBP to MAC multiples was evaluated. Although no correlation ($r^2 = 0.2$) between HR and MAC multiples was identified, a negative correlation ($r^2 = 0.92$) between NIBP and increasing MAC multiples was evident. Similarly, VAS scores for awareness numerically decreased as the MAC multiple of isoflurane increased (Table 1). The awareness score at 0.75 MAC was significantly different from the values at 1.75, 1.5, and 1.25 MAC. A positive correlation ($r^2 = 0.95$) between BIS and awareness score was detected during both anesthetic episodes.

Mean HR increased and mean NIBP decreased with increasing end-tidal isoflurane concentrations (Table 1). Heart rate values at 1.0 and 1.25 MAC differed significantly as did values at 0.75 MAC multiple and extubation. At 1.25 MAC, NIBP differed significantly from values at 1.0 and 0.75 MAC and at extubation. Similarly, at 1.75 MAC, NIBP was significantly different from the value at 0.75 MAC and at extubation. A positive correlation was identified between BIS and NIBP ($r^2 = 0.8$), but not between BIS and HR ($r^2 = 0.03$).

During the 2 anesthetic episodes, venous blood pH and blood gas variables did not differ significantly (Table 2). The SpO$_2$ remained constant at 98% to 99%, and esophageal temperature remained at 40° to 41°C.

Induction, extubation, and recovery times were not significantly different between the first and second anesthetic episodes. For the first and second anesthetic episodes, intubation time was 5.6 ± 2.6 minutes and 4.0 ± 1.5 minutes, respectively; extubation time was 3.8 ± 2.4 minutes and 3.6 ± 3.6 minutes, respectively; and recovery time was 1.8 ± 1.5 minutes and 1.7 ± 1.5 minutes, respectively. Mean duration of the first anesthetic episode was 118 ± 47 minutes, whereas duration of the second episode was significantly shorter (86 ± 11 minutes). During extubation, chickens shook their heads without displacement of the electrodes, and alterations in SQI and EMG were gradually observed until the electrodes were removed and the chickens were allowed to recover. No adverse effects were observed in any of the chickens after completion of the study. The chickens were relocated to a private farm after 1 month of follow-up observation.

**Discussion**

To assess whether monitoring BIS is an objective and helpful tool for assessment of depth of anesthesia, a comparison with other objective methods to determine the degree of hypnosis in anesthetized individuals should be performed. However, such objective methods are lacking, and the anesthesia depth in birds has been traditionally monitored via assessment of palpebral and corneal reflexes, pupil dilatation, and the withdrawal reflex. $^{20}$ Noxious stimulation is performed in anesthetized birds to evaluate the anesthetic potency of inhalational anesthetic agents. $^{21}$ In our opinion, changes of BIS values with multiples of individual MAC to monitor anesthesia depth would be a reliable method with which to validate the BIS monitor. Individual MAC determination enabled us to achieve an equivalent degree of anesthetic depth that could be compared among individuals. $^{22, 23}$

In the 10 study chickens, any factor that could affect the MAC during the 2 anesthetic episodes (eg, body temperature, PaCO$_2$ > 95 mm Hg, PaO$_2$ < 40 mm Hg, arterial blood pressure < 50 mm Hg, and age$^{28}$) was
strictly controlled to avoid additional effects on depth of anesthesia. The MAC of isoflurane has been determined for chickens (Gallus gallus; 1.25%),32 cockatoos (Cacatua spp; 1.44%),33 sandhill cranes (Grus canadensis; 1.34%)34; Pekin ducks (Anas platyrhynchos domestica; 1.30%);35 and thick-billed parrots (Rhynchopsitta pachyrhyncha; 1.07%).4 The mean MAC for isoflurane determined in the chickens of the present study (1.15 ± 0.20%) was in the lower range of values reported for other bird species.

In agreement with the formulated hypothesis, increasing BIS values were associated (albeit not significantly) with decreasing end-tidal concentrations of isoflurane (over the range from 1.75 to 0.75 MAC) in anesthetized chickens. Although randomization of the order in which the chickens were anesthetized at the various MAC multiples of isoflurane would have been optimal, it was not performed because of the technical aspects of the experiment. At lower multiples of MAC, a positive response to stimulation (defined by purposeful movement) would have resulted in displacement of the electrodes. Following this, the recordings of BIS would have been interrupted, and further measurements would not have been possible within acceptable time limits. Thus, randomization of the treatment order was avoided, and a decreasing sequence of MAC multiples was followed. In addition, a blinded study would have been ideal, but this was not possible because of a limited number of personnel available and the need for continuous and close control of the anesthetic vaporizer to achieve a specific MAC multiple.

In the present study, BIS measurements were registered with a good signal quality (ie, SQI > 50) and free of potential artifacts as shown in recorded EMG values < 50 dB. As EMG contains power from muscle activity as well as power from other high-frequency artifacts, values > 50 dB would lead to unreliable BIS measurements. The BIS value displayed every 5 seconds was the mean value for the preceding 15-second period (short smoothing rate). If the SQI and EMG value remain stable, this delay does not directly affect the interpretation of BIS values35 over the range of 1.75 to 0.75 MAC. At the moment of extubation, a head shake occurred in every bird; the electrodes were not displaced, and the SQI and EMG values were > 50 and < 50, respectively, at this time point. Nevertheless, the SQI and EMG values subsequently deteriorated gradually to unacceptable values for BIS measurement. Therefore, the last time point at which BIS was evaluated was the moment of extubation. After noxious stimulation during anesthesia at the various MAC multiples of isoflurane, the electrical activity of the brain was measured. Interestingly, SR values differed from 0 at every MAC multiple, indicative of suppression of brain activity. However, no degree of brain activity suppression (SR = 0) is expected in clinically normal anesthetized humans in a deep hypnotic state (BIS > 40).31 The importance of SR in the BIS algorithm has been proposed.32 In that study, an absence of correlation between BIS and SR but continued detection of SR at BIS > 40 was believed to be associated with the transition between moderate sedation or light anesthesia into deep anesthesia. It was suggested that there is a zone in which some levels of EEG suppression do not result in a decrease in BIS and that a revision of the algorithm to measure a more accurate BIS value, especially for the interval of the BIS values of 30, should be performed. A similar phenomenon was observed in the present study, in which SR changed with BIS at values < 35. Moreover, BIS values at 1.75, 1.5, and 1.25 MAC of isoflurane were recorded in this interval of BIS values around 30, in which the most meaningful variable may be the SR. This suggests that at BIS values < 35, the variable that defines the depth of anesthesia is the SR. In our study, SR values significantly increased with every increase of end-tidal isoflurane concentration.

It is thought that burst suppression is dependent on the anesthetic drugs administered and on the species undergoing anesthesia and that it becomes apparent at end-tidal anesthetic concentrations of 1.5 MAC or higher.33 However, suppression at an end-tidal isoflurane concentration > 1.25 MAC in pigs has been reported.34 In the chickens of the present study, suppression was apparent at 0.75 MAC. March and Muirc35 postulated that burst suppression may not be associated with surgical depth of anesthesia in isoflurane-anesthetized cats. In chickens, burst suppression may also not be associated with surgical depth of isoflurane anesthesia because SR values > 0 were associated with MAC multiples of isoflurane < 1.0.

The wide range of BIS values recorded during the various MAC multiples of isoflurane in the present study has to be taken into consideration. These fluctuations could be reduced by use of a longer smoothing rate in which the BIS value displayed every 3 seconds would be the mean value for the preceding 30-second interval, instead of the preceding 15-second interval (short smoothing rate). A longer smoothing rate would decrease variability in BIS values and diminish the influence of artifacts on those measurements. Because of the high interindividual variability in BIS detected among the study chickens, a hypnotic scale based on BIS measurements was difficult to establish. Nevertheless, the BIS range described for humans in various hypnotic states was compared with the BIS values obtained in the present study. The median and range of the BIS values obtained after noxious stimulation at each MAC multiple of isoflurane were calculated to assess changes in BIS in chickens during different levels of hypnosis. The suggested ranges for chickens were wider than those for humans because of the difficulties in differentiating hypnotic states via BIS assessment in chickens. In a given anesthetized bird in the present study, values that could have been associated with more than 1 hypnotic state were included in the level that was considered most safe. In humans, BIS < 30 corresponds to a deep hypnotic state and values of 45 to 60 correspond to a moderate hypnotic state. If deep anesthesia is assumed to be achieved at 1.75, 1.5, and 1.25 MAC multiples of isoflurane, then BIS ≤ 50 would be considered representative of a deep hypnotic state in chickens. In humans, BIS values of 60 to 80 are considered the light hypnotic state or moderate sedation. If moderate sedation is assumed to be achieved at 1.00 and 0.75 MAC multiples of isoflurane, then a BIS range of 50 to 65 would be considered representative
of a light hypnotic state in chickens. In 1 chicken, the maximal BIS value was 70, which was not included in the range. Humans with BIS values > 80 are expected to be awake, whereas data obtained in the present study indicated that chickens with BIS values > 65 are possibly awake. The comparatively lower limit for chickens may be attributable to the difficulty in recognizing and confirming awareness in nonhuman animals.

In the study of this report, the proposed BIS scale was based on 20 anesthetic episodes performed in 10 chickens that were anesthetized with isoflurane and assessed with a BIS monitor validated for use in humans. Despite the satisfactory results, further research studies of this anesthesia monitoring technique are strongly encouraged. However, the reliability of the BIS monitor as a tool to measure the depth of anesthesia has been questioned. Individual differences in BIS values of sevoflurane-anesthetized dogs have been reported, and similar results were obtained in pigs during anesthesia with isoflurane, sevoflurane, or propofol infusion. Bispectral index was not a reliable indicator of CNS depression in isoflurane-anesthetized horses.

In the chickens of the present study, blood pressure was measured by use of a noninvasive oscillometric blood pressure monitor because of the difficulties in catheterizing arterial vessels in birds and possible influences of invasive manipulation. Although HR was not correlated with MAC multiples of isoflurane, NIBP measurements correlated inversely with increasing MAC multiples. Similar results regarding a lack of change in HR with varying MAC multiples during isoflurane and sevoflurane anesthesia in psittacines have been reported. In addition, a study determined the depth of anesthesia in dogs during isoflurane anesthesia revealed no changes in HR with increasing multiples of MAC.

In other bispectral analysis studies, a correlation between hemodynamic variables (HR and NIBP) and BIS was not detected in dogs or pigs. In similar studies in anesthetized pigs and cats, HR was correlated with increasing MAC multiples of the inhalational anesthetic. During anesthesia in dogs, a negative correlation between blood pressure and MAC multiples has been identified, and similar findings in pigs and cats have been described. In the present study, NIBP recordings appeared largely to decrease with increasing MAC multiples of isoflurane; this pattern is similar to those determined via invasive and noninvasive techniques in other species. Moreover, hemodynamic responses are primarily subcortical and do not depend on corticocerebral input. Consequently, autonomic nervous responses may or may not indicate the conscious perception of noxious stimuli. Thus, the absence of variation in HR at the different end-tidal isoflurane concentrations in the chickens used in the present study is in agreement with reported data.

Blood gas, electrolyte, and hematologic variables are used to assess the efficiency of ventilation and to assess tissue oxygenation, acid-base balance, and the cardiovascular system in chickens of the present study. The portable analyzer used for blood gas analysis has been validated for use in chickens. Reference values for arterial and venous blood gas variables in birds are available. In the present study, venous blood samples were obtained to confirm the absence of acidosis and extreme values of PCO2 that can influence MAC. Alterations in the MAC value would affect the relationship between MAC multiples of isoflurane and BIS and influence the assessment of BIS as an indicator of depth of anesthesia.

The evaluation of the reliability of BIS as a method to measure depth of anesthesia in chickens was based on its correlation with a VAS-derived awareness score. According to the statistical results of our study in chickens, BIS and the awareness score correlated not only at the moment the individual MAC was determined, but also during the second anesthetic episode with isoflurane. Bispectral index and awareness scores during isoflurane anesthesia of chickens in our study changed inversely with increasing end-tidal concentrations of isoflurane. Values of BIS at the various MAC multiples did not differ significantly. However, the awareness score at 0.75 MAC did differ significantly from values at 1.75, 1.50, and 1.25 MAC. The fact that VAS-derived awareness score at 0.75 MAC was significantly different from values at the higher end-tidal isoflurane concentrations suggests that the awareness score was affected by the positive response (retraction of the leg), whereas BIS was not. This observation supports the observations of Martin-Cancho et al. and also suggests that BIS may not predict movement because it reflects processes happening in the brain.

In the present study, a VAS was used to transfer the subjective measurement of depth of anesthesia into standardized data via determination of a reflex score described by Korbel. Among the variety of methods described by Huskisson to quantify subjective measurements, a VAS was chosen because of its high sensitivity and reports of successful use of the technique in other studies. However, other alternative visual scales (eg, a simple descriptive scale has been used in pigs anesthetized with desflurane) have been used to assess anesthesia depth, and those data appear to correlate well with BIS.

On the basis of results of the present study, it can be concluded that data obtained by use of the human BIS monitor can be used to assess CNS depression in chickens. However, it was not possible to distinguish minor differences in the degree of hypnosis by use of the VAS-derived awareness score or the BIS monitor. Nevertheless, evaluation of BIS appears to be useful for monitoring the electrical activity of the brain and degree of unconsciousness. Further studies are encouraged to investigate the potential of BIS monitoring during anesthesia of veterinary species, but specifically during anesthesia of birds.


b. Attane TM, Provot AG, Lyssach, Switzerland.
c. V-PAT-50 and V-PAT-40, for males and females, respectively, Cook, Steinhausen, Switzerland.
e. Multi-parameter monitor, Nihon Kohden, Artema Medical AB, Sundbyberg, Sweden.
f. Life Scope, 920RA/RK, Nihon Kohden GmbH, Rosbach, Germany.
g. Life Scope, 920RA/RK, Nihon Kohden GmbH, Rosbach, Germany.
References


23. Korbel R. Comparative investigations on inhalation anesthesia with isoflurane (Forene) and sevoflurane (SEV/Orane) in racing pigeons (Columba livia Gmel., 1789, var. domestica) and presentation of a reference anesthesia protocol for birds [in German]. Tierarztl Prax Ausg K Klientiere Heimtierre 1998;26:211–223.


