USE OF ELECTROENCEPHALOGRAM TECHNOLOGY TO DETERMINE THE STATE OF MARKET HOG CONSCIOUSNESS

Benjamin T. Klinkner[1], Richelle L. Miller[1], Roberta B. A. Dahlen[1], Luciana Bergamasco[2], and David J. Newman[1]

[1]Department of Animal Sciences, North Dakota State University, Fargo, North Dakota, USA, 58102; and [2]College of Veterinary Medicine, Kansas State University, Manhattan, KS, USA, 66506.

Abstract – Animal welfare continues to impact many practices that pork producers and processors utilize. One major issue that is being subjected to animal welfare scrutiny is animal euthanasia. Some principle areas of important research within this field include state of unconsciousness and ability to feel pain. This study was developed to measure baseline electroencephalogram (EEG) values for both conscious and unconsciousness market hogs. Crossbred market hogs (n=12; 121.9 ± 6.90 kg) were used to establish baseline EEG recordings from four different channel leads (L1, L2, R1, and R2) located on the head. In addition, heart rate was recorded. Hogs were placed in a chute and EEG was recorded continuously for five minutes through the conscious state. Next, hogs were anesthetized and another five minutes of EEG recordings were taken during unconsciousness. aEEG measurement decreased significantly (*P* < 0.01) from the conscious to unconscious state (13.07 vs. 5.73μV, respectively). Likewise, EEG FFT-Power measurement for all four channels significantly decreased (*P* < 0.01) from the conscious to unconscious state (35.20 vs. 5.69 μV^2, respectively). Conscious heart rate was significantly higher (*P* < 0.01) in conscious (128) vs. unconscious (106 bpm) hogs. This research will help establish an objective measurement tool for use in determining unconsciousness and pain in hogs.

Key Words – euthanasia, hogs, welfare.

I. INTRODUCTION

The brain is constantly engaged in monitoring and responding to internal and external environments. This activity produces electricity from billions of neurons producing action potentials that can be measured on the scalp of humans and other mammals [1]. Electroencephalogram (EEG) is a common method used to measure brain activity in both humans and animals [2]. While many subjective measurements such as failure to respond to verbal commands, loss of muscular tone, and loss of eyelash or corneal reflex are factors used to determine the consciousness of animals, EEG quantitative parameters are known to more objectively assess this state [3]. In addition, EEG can also be effectively used to assess pain [4]. In that study, calves were used as a model for determining pain during ventral-neck incision followed by non-penetrative captive-bolt stunning. Results showed periods of active EEG readings in some calves, which ceased after non-penetrative captive-bolt stunning in most of the calves [4]. EEG recordings allow us to determine the brains state of activity (conscious vs. unconscious) and neural response to pain. Quantitative EEG values (qEEG) can be obtained from EEG recordings allowing us to numerically compare the different states of brain activity. EEG response after slaughter of calves by ventral-neck incision was due primarily to noxious sensory input caused by incision of ventral-neck tissues and not to loss of cerebral perfusion following severance of the carotid arteries and jugular veins [5]. This suggests that if animals are rendered unconscious prior to exsanguination, no pain would then be felt. By working with EEG technology, an animal's ability to feel pain and their state of consciousness can be obtained, which should provide researchers and industry stakeholders with valuable information regarding animal welfare.

Lambooij et al. [6] stated that observation of behavior and reflexes in relation to stunning experiments is complicated by the fact that they do not give a definite answer about unconsciousness. Furthermore, a combination of EEG and observation of behavior and reflexes can provide sufficient scientific information concerning the consciousness of the animal and the effectiveness of the stunning method. Therefore, this preliminary research with EEG technology is valuable information for investigating factors such as novel euthanasia methods. With this in mind, the objective of this study was to establish baseline EEG values in conscious vs. unconscious states of market hogs.

II. MATERIALS AND METHODS

The study was approved by the North Dakota State University (NDSU) Institutional Animal Care and Use Committee (IACUC) and conducted at the NDSU Animal Nutrition and Physiology center in Fargo, ND. Crossbred market hogs (n=12) with an average weight of 121.9 ± 6.90 kg, ranging from 105.7 to 133.8 kg, were used to establish baseline conscious and unconscious qEEG values. In addition, heart rate was recorded using a polar heart rate monitor (Polar Vantage NV heart rate monitor, Model RS800sd; Polar Electro Oy, Kempele, Finland). Prior to the study, all hogs were acclimated to a restraining chute for 14 days to assure that they would remain calm and minimize movement. Using the Trackit™ Sleep Walker recorder (Lifelines Neurodiagnostic Systems, Inc.; Troy, IL), four leads were placed intradermal in the scalp of the hogs positioned as L1, L2, R1, and R2 in order to obtain readings for four EEG channels (Fig. 1). Once animals were calm, five minutes of EEG recordings were collected for the conscious state of the hogs. Next, hogs were anesthetized (Telazol + Xylazine; 0.05 mL/kg) and another five minutes of EEG recordings were taken during the unconscious state. Raw EEG data were analyzed by an expert and artifact free data were gathered in both conscious and unconscious stages. EEG data were processed with Magic Marker (Persyst Insight II; Persyst Development Corporation, Prescott, Arizona) in order to obtain quantitative EEG (qEEG) parameters. qEEG parameters used were Amplitude-integrated EEG (aEEG) and Fast Fourier Transform Power Spectrum (FFT-Power). Data were analyzed using generalized least squares (PROC MIXED, SAS Institute, Cary, NC). The model included state of consciousness (TRT) and channel nested within TRT as main effects. Hog ID was used as random effect.

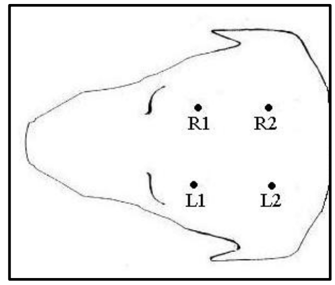
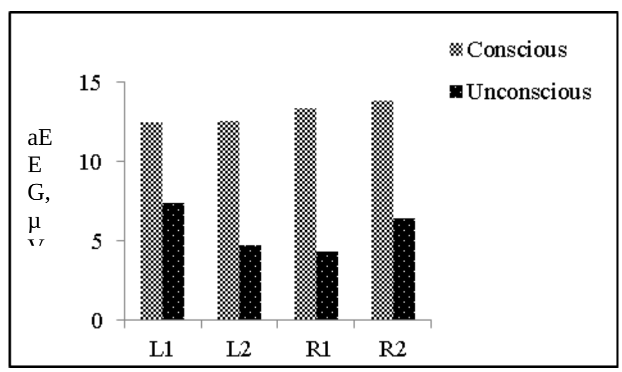


Figure 1. Anatomical location of EEG leads on the head of hogs.

III. RESULTS AND DISCUSSION

Based on the EEG recordings from all 12 market hogs, baseline values were established for the market hog's in conscious and unconscious states. aEEG measurement decreased significantly ($P < 0.01$) from the conscious to unconscious state (13.07 vs. 5.73 µV, respectively). Additionally, there were no differences ($P = 0.38$) among channel nested within the conscious state. aEEG values for each one of the channels in the conscious state were 12.47, 12.54, 13.40, and 13.86 µV for L1, L2, R1, and R2; respectively. In the unconscious state, aEEG values for each one of these same channels were 7.37, 4.75, 4.35, and 6.47 µV; respectively (Fig. 2).

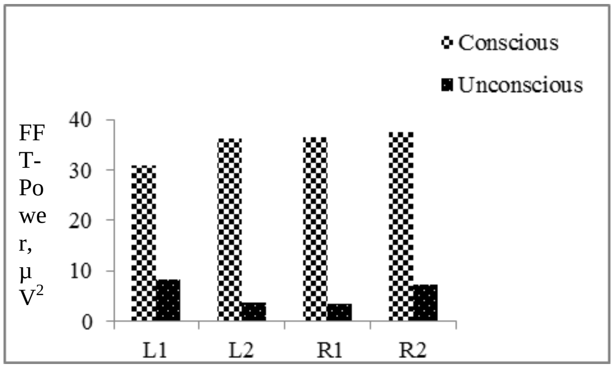
Figure 2. aEEG values in each specific EEG channel in market hogs (n=12). TRT: $P < 0.001$, SEM = 0.688. Channel(TRT): $P = 0.38$, SEM = 1.156



Likewise, EEG FFT-Power measurement decreased significantly ($P < 0.01$) from the conscious to unconscious state (35.20 vs. 5.69 μV^2, respectively). Similarly to the aEEG, there were no differences ($P = 0.97$) among channel nested within the conscious state for the FFT-Power.

FFT-Power values for each one of the channels in the conscious state were 30.87, 36.07, 36.52, and 37.35 µV^2 for L1, L2, R1, and R2; respectively. In the unconscious state, FFT-Power values for each one of these same channels were 8.39, 3.66, 3.39, and 7.32 µV^2; respectively (Fig. 3).

Figure 3. FFT-Power values in each specific EEG channel in market hogs (n=12). TRT: P < 0.01, SEM = 3.304. Channel(TRT): P = 0.97, SEM = 6.046.



These aEEG and FFT-Power values can be used as a baseline for determining the conscious and unconscious state of hogs. The EEG amplitude is the amount of energy produced from neurons. The more synchronized these neurons are responding to a specific task the higher the amplitude will be. Based on the current study a 56% reduction in aEEG and 84% reduction in FFT-Power from conscious to unconscious state was achieved. Thus, we believe that qEEG is an effective tool for objectively assessing animal consciousness. This is due to less synchronized neuron activity which to a large degree decreases an animal's state of consciousness and ability to feel pain. Moreover, results showed that the average heart rate was much greater (P<0.01) in conscious hogs compared with unconscious hogs (128 and 106 bpm, respectively). Values obtained using BIS index showed that to some extent, an unconscious state can be predicted in human subjects when a decreased heart rate is observed [7].

IV. CONCLUSION

By using EEG technology, baseline recordings for conscious and unconscious market hogs were obtained. These data are the basis for establishing threshold values that are acceptable for rendering animals unconscious and free of pain. With further research in this area, there is possibility for improvements in animal welfare and euthanasia research.

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