The effect of current intensity during ”head-only” electrical stunning on brain function in force-fed ducks

C. Beyssen, R. Babile, Xavier Fernandez

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Original article

The effect of current intensity during 'head-only' electrical stunning on brain function in force-fed ducks

Clotilde BEYSSEN[a], René BABILÉ[a], Xavier FERNANDEZ[a,b]*

[a] ENSA Toulouse, Laboratoire de Zootechnie et Qualité des Produits Animaux, avenue de l'Agrobiopole, BP 107, 31326 Auzeville Tolosan, France
[b] INRA, Département ENA, Centre de Rennes, 35590 Saint-Gilles, France

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Abstract – A preliminary study was carried out to determine the minimum current required for head-only electrical stunning of force-fed ducks. Forty-five force-fed ducks were implanted with electrocorticogram (ECoG) recording electrodes, and the changes occurring in the ECoG frequencies were quantitatively evaluated with *Fast Fourier Transformations* (FFT) to determine the effectiveness of a range of electrical stunning currents. A 50 Hz alternating current (AC) was used to apply a constant current of 100 (n = 4), 200 (n = 12), 300 (n = 13), 400 (n = 9) or 600 mA (n = 7) for 4 seconds via electrical tongs (spiked electrodes) placed firmly on the ears. The feathers on the head were wetted using saline water to improve the current flow through the skull. The birds were manually bled out within 15 seconds from the end of the stun by severing the carotid arteries and jugular veins in the neck. The calculated impedance of the wet head was $296 \pm 21\ \Omega$. The results showed that the application of 100 to 400 mA failed to stun some birds and some others regained consciousness before death occurred from bleeding. After a 600 mA stun, however, all the birds were rendered unconscious until death occurred. At this intensity, the birds showed mild clonic convulsions after the tonic phase, and then an exhaustion phase. None of them were killed by the current application. Therefore, to ensure a human slaughter in force-fed ducks, a minimum head-only stunning current of 600 mA followed by severance of all the major blood vessels in the neck would be recommended if the preliminary results obtained in the present experiment are confirmed.

duck / head-only stunning / current intensity / welfare / spectral analysis

Résumé – **Effet de l'intensité du courant au cours de l'électronarcose 'tête seulement' sur l'activité cérébrale chez le canard gavé.** Une étude préliminaire a été réalisée afin de définir le courant minimum requis pour obtenir un étourdissement efficace chez le canard gavé, après électronarcose 'tête seulement'. Des électrodes d'enregistrement de l'électrocorticogramme (ECoG) ont été implantées chez quarante-cinq animaux, et l'évolution des fréquences de l'ECoG a été observée afin d'estimer le degré de conscience des animaux après un choc électrique. Un courant alternatif de 50 Hz a été appliqué à l'aide de pinces électriques bi-temporales (électrodes pointues), centrées sur les ouïes, pendant 4 secondes, utilisant des intensités croissantes de 100 à 600 mA. Les canards ont été saignés 15 secondes après la fin du choc électrique. L'impédance moyenne des têtes

* Corresponding author: fernandez@ensat.fr

mouillées était de 296 ± 21 Ω. Alors que certains animaux n'ont pas été étourdis ou ont recouvré la conscience après des chocs allant jusqu'à 400 mA, l'électronarcose 'tête seulement' de 600 mA a étourdi efficacement tous les animaux, depuis la fin du choc jusqu'à la mort de l'animal. A cette intensité, les animaux ont présenté de faibles convulsions cloniques après la phase tonique, suivies d'une période d'épuisement et aucun canard n'a succombé au choc électrique. Si les résultats préliminaires de cette étude sont confirmés, une intensité de 600 mA est donc recommandée pour satisfaire les contraintes relatives à la protection des animaux au cours de l'électronarcose 'tête seulement' des canards gavés.

canard / électronarcose 'tête seulement' / intensité du courant / bien-être / analyse spectrale

1. INTRODUCTION

Stunning animals before slaughter is a legal requirement from the point of view of animal welfare. Poultry, like any other food animal species, must be rendered unconscious, i.e. insensible to pain, before death occurs from bleeding. In France, electrical waterbath stunning is the only method used to stun force-fed ducks under commercial conditions. In Europe, the minimum current recommended for water-bath stunning of ducks is 130 mA delivered using a 50 Hz alternating current (AC). In force-fed ducks, however, this current parameter results in various downgrading conditions, such as red coloration of lobe tips and petechial haemorrhages, in the fatty liver. The fatty liver is a product with a high added value and the occurrence of downgrading induces economic losses to the industry. Therefore, there is a need for an alternative stunning method that would fulfil the requirements of both animal welfare and product quality.

According to Woolley et al. [13], the majority of current applied during water-bath stunning flows through the muscles and heart and about 10% of the current also passes through the liver. By contrast, during head-only stunning, the current is focally applied across the head (and brain) and therefore little, if any, current would flow through the body [12]. This method would thus be expected to improve product quality, as compared to water-bath stunning. The electrical parameters necessary to achieve efficient head-only stunning have been investigated in various species (calves, pigs, sheep, turkeys, chickens, ostriches, fishes), however, to the best of our knowledge, no experiment has ever been carried out on the head-only stunning in waterfowl species, and especially in force-fed ducks.

The changes occurring in the somatosensory evoked responses and/or the frequency of electrocorticogram (ECoG) signals are the most common methods used to estimate the depth and duration of consciousness after electrical stunning [1, 2, 4, 5, 14]. The present work was carried out to determine the minimum current required for efficient head-only stunning in force-fed ducks, using the spectral analysis of the ECoG.

2. MATERIALS AND METHODS

2.1. Animals

Forty-five 12-week old male mule ducks (cross between Barbarian males and Pekin females) were used in this study. They were force-fed with 25 meals (2 meals per day) of soaked corn and their mean live weight at slaughter was 5.5 kg (S.E. = 0.2). The ducks were fasted overnight prior to experimentation.

2.2. Surgical procedure

Under isoflurane anaesthesia, the birds were implanted with three ECoG recording electrodes via holes drilled in the cranium. The negative recording electrode was placed on the surface of the cortex in the right hemisphere, 5-mm lateral to the midline and 3-mm caudal to the rear margin of the eyes. The positive electrode was implanted symmetrically on the opposite side of the brain, and the ground electrode 3-mm behind it. The complete surgical procedure has been previously described [2]. The birds were allowed to recover for at least 2 hours before the experiments.

2.3. Stunning and slaughter

Before shackling, and in order to avoid wing flapping, the wings were immobilised using adhesive tape. The birds were hung head downwards in a shackle that was electrically grounded. The feathers on the head were wetted using saline water to improve the current flow through the skull. A 50 Hz AC was applied for 4 seconds via two 2-cm diameter spiked electrodes fixed on a scissors-type tong. The electrodes were placed on either side of the head, centred on the ears. A root mean square (RMS) current of 100 (4 birds), 200 (12 birds), 300 (13 birds), 400 (9 birds) or 600 mA (7 birds) was delivered using a variable voltage per constant current stunner. During the course of this experiment, the applied current level was progressively increased from 100 to 600 mA in order to determine the threshold above which all the animals would be rendered unconscious by the stun. The birds were manually bled out within 15 seconds from the end of the stun, by severing the carotid arteries and jugular veins. The stunner used in this study was designed and provided by DLC Instrumentation[1].

2.4. ECoG analysis

The ECoG were digitally recorded using the NeuroScan interface[2] and a preamplifier (model p511)[3]. The data were stored on a computer and analysed off-line. The ECoG were recorded one minute before and two minutes after the stun and the recording equipment was isolated during the application of the stunning current.

The artefact-free ECoG were subjected to Fast Fourier Transformations (FFT) to calculate frequency power spectra using NeuroScan software. The pre-stun power content was calculated using a 10 second epoch that was recorded 40 seconds after the start of the recording. The power spectra were computed for each 10 second period from the end of the stun until 120 seconds, using a Hanning window and characterised by a 4096 points spectrum between 0.01 and 30 Hz. On a Microsoft Excel spreadsheet, the total power content (2.5–30 Hz) in the ECoG signals was calculated as follows: post-stun power/pre stun power × 100. According to Bager et al. [1], bleeding without prior stunning induces cerebral anoxia, responsible for the decrease in the high frequency band, which is associated with sensibility, whereas the low frequency band is associated with insensibility. However, after electrical stunning, a decrease in the whole frequency band was observed, and unconsciousness was recognised when the total power content (2.5–30 Hz) decreased just after the end of the stun and remained at an ultimate low level until death. Lukatch et al. [8] considered that loss of consciousness occurs when the total power content decreases below 10% of the pre-treatment level, which corresponds to an isoelectric state. Since the loss of somatosensory evoked responses (i.e. loss of sensibility) in lean ducks after water-bath stunning has been found to be associated with decreases in total power content to below 10% of the pre-stun levels [2], in the present study it was assumed that an efficient head-only stunning should also result in the decrease of total power content to below 10% of the pre-stun values, from the end of the stun until the death of the bird.

[1] DLC Instrumentation, 86530 Naintré, France.
[2] Neuroscan Inc., Herndon, VA, US.
[3] Grass Instrument Division, Astro-Med Inc., West Warwick, RI 02893.

Table I. The effect of current intensity during the 'head-only' stunning of force-fed ducks (50 Hz AC, 4 s) on the stun efficiency.

Current intensity	Number of birds per treatment	Efficient stun[1]	Inefficient stun	
			From the end of the stun[2]	Regain of consciousness[3]
100 mA	4	1	2	1
200 mA	12	7	1	4
300 mA	13	10	1	2
400 mA	9	6	1	2
600 mA	7	7	-	-

[1] When the ECoG relative power ranges below 10% of the pre-stun level throughout the whole post-stun period; [2] when the ECoG relative power stands above 10% of the pre-stun level during several tens of seconds after the end of the stun; [3] when the ECoG relative power shows a brief increase above 10% of the pre-stun level after an isoelectric trace (<10%).

3. RESULTS

The voltage (U) necessary to deliver each of the constant current settings used in this study was recorded on the circuit during current application, and the impedance (Z, Ω) of the wetted head was calculated for each bird as Z = U / I. The overall impedance observed in this study was on average 296 ± 21 Ω (mean ± SD). The pre-stun ECoG amplitude ranged from 15 to 25 µV for all the birds. Because of the protection of the recording apparatus during the current application and the delay in switching them on again, the ECoG signals were lost for up to 20 s post-stun in most of the birds.

The results of the stun efficiency for the various current levels are presented in Table I. An efficient stun was characterised by a decrease in total power content to below 10% of the pre-stun level in the whole post-stun period and untill death occurs. Total power above this limit during several tens of seconds after the end of the current delivery implied ineffective stunning. The recovery of consciousness corresponded to a brief increase of the total power above the 10% of pre-stun levels. The proportion of ducks that were found to be effectively stunned increased with the current intensity, except for the 400 mA.

The total power content of each duck stunned with 200, 400 or 600 mA is presented in Figure 1. After a 200 mA head-only stunning, one bird was not stunned at all, and four regained consciousness between 40 and 70 seconds after the end of the stun. In the 400 mA treatment, one duck was not rendered unconscious following the stun, and two others regained consciousness between 50 and 60 seconds after the stun. By contrast, all the birds stunned with 600 mA had total power contents below 10% of the pre-stun level throughout the all post-stun period, until death occurred through bleeding.

The head-only stunning plus bleeding induced wing flapping and/or convulsions of various intensities during 30 and 40 seconds post-stun. The convulsions were severe in ducks that were stunned with 100 mA, and they decreased in force and duration as the stunning current was increased. The 600 mA head-only stunning resulted in very mild and spaced out convulsions. The duration of the tonic phase was recorded after the 400 and 600 mA stun, and it lasted on average 7 and

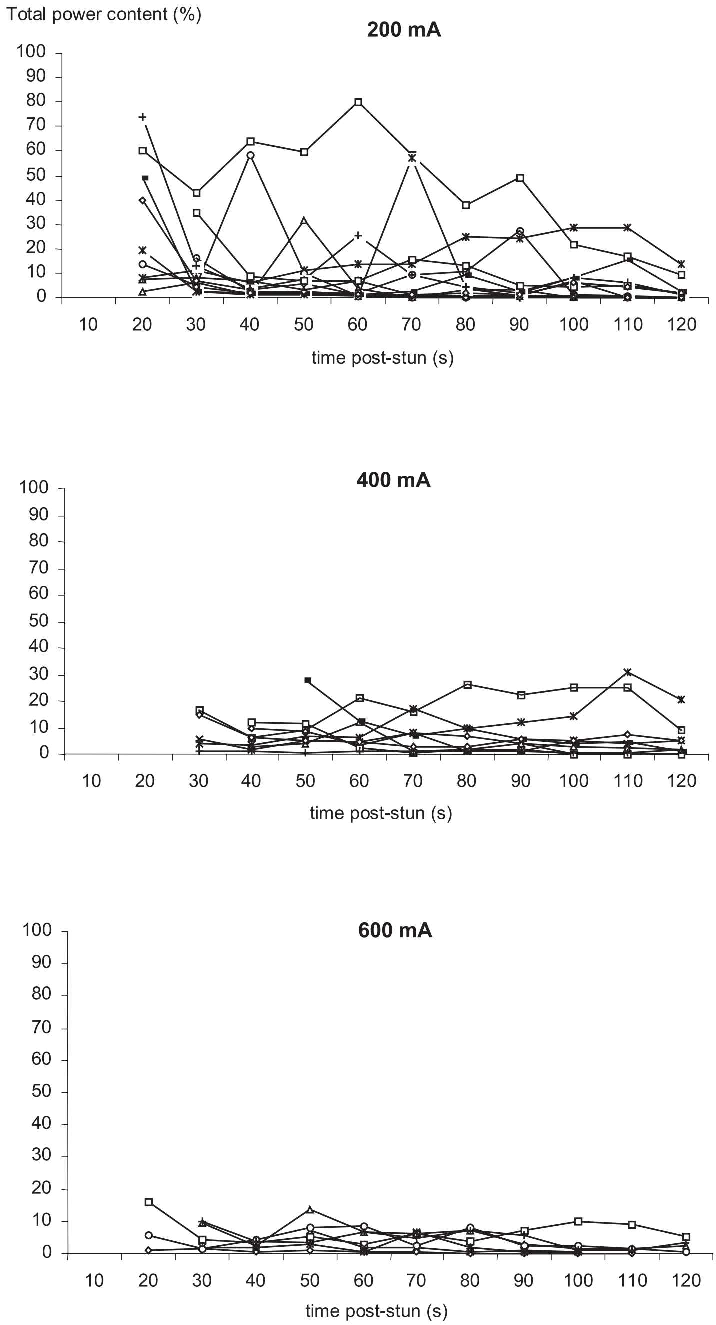

Figure 1. Changes in the total power content (2.5–30 Hz), expressed as the percentage of the pre-stun level, after an electrical head-only stunning in 12, 9 and 7 force-fed ducks using a 50 Hz AC of 200, 400 and 600 mA, respectively, during 4 seconds. A bird is considered unconscious when its relative power is maintained under 10% throughout the post-stun period.

10 seconds, respectively. None of the birds were killed by the current delivery.

4. DISCUSSION

According to Schütt-Abraham et al. [11] and Raj [9], an adequate stun induces an epileptiform activity in the brain, characterised by a pattern on the ECoG of polyspike bursts followed by an isoelectric line. However, because of the protection of the recording apparatus during the current delivery and that the ECoG signal did not return before 20 s post-stun, the occurrence of polyspike activity in the ECoG resulting from the stun could not be systematically observed.

To the authors' knowledge, no scientific publication concerning the minimum current necessary for head-only electrical stunning of lean or force-fed ducks exists. Therefore, it was not possible to compare the results of this study with the literature. However, in each of the current levels from 100 to 400 mA, some birds either maintained a total power content above 10% of pre-stun levels or rapidly regained consciousness after the stun or during bleeding. By contrast, a 600 mA head-only stunning rendered all the birds unconscious from the end of the stun until death, and this current would therefore be required for an adequate stun. Minimum currents of 400 mA and 500 mA have been shown to be required for an efficient head-only stun in turkeys and ostriches, respectively [6, 7].

Increasing the current magnitude increased the proportion of birds adequately stunned, from 7/12 with the 200 mA treatment to 10/13 at 300 mA and 7/7 with a 600 mA current. Only 6 out of 9 birds were adequately stunned after the 400 mA head-only stunning, which is a lower proportion compared to the 300 mA treatment. However, the two birds that regained consciousness 50 and 60 seconds after the 400 mA stun did not lose consciousness again before 110 seconds. These results were most likely due to a poor bleeding efficiency in these two animals. Excluding them from the analysis would increase the proportion of birds adequately stunned with 400 mA to 8 out of 9.

Woolley et al. [12] reported that the skull bone is highly resistant to current flow, and its resistivity differs markedly between birds. Stunning ducks with 300 to 400 mA may induce an efficient stun in force-fed ducks; however, these current levels would fail in birds with a higher skull resistivity.

Some ducks were effectively stunned but they regained consciousness between 40 to 70 seconds post-stun. This corresponds to the critical period during which the stun is no more efficient whereas the bleeding has not yet induced unconsciousness. Indeed, we observed in ducks that bleeding without prior stunning led to loss of spontaneous activity in the brain after 50 to 70 seconds (unpublished data). Gregory and Wotton [3] also showed that unconsciousness occurred in ducks 52 seconds (± 9 SD) after bilateral cutting of carotid arteries and jugular veins. In the present experiment, the neck cutting occurred 15 seconds after the end of the stun, which would induce a loss of brain activity approximately 70 seconds after the end of the stun. Therefore, the regain of consciousness observed in the 40–70 seconds post-stun period results from a too short-lasting stun efficiency.

In some ducks that were judged to be effectively stunned with 100 mA but regained consciousness sensibility during bleeding, the stun efficiency possibly lasted for up to 40 s and this duration of unconsciousness increased to 60 s at 400 mA. This longer duration of the stun can be explained by the increasing current magnitude. Indeed, many authors have observed on various species such as fishes [10] and broilers [5] that increasing the intensity of the applied current results in an increased stun duration.

Though no objective behavioural recordings were carried out, it was clear that increased current magnitudes during the head-only stunning resulted in a decrease in force and duration of wing flapping and/or convulsions following the stun. Wing flapping is usually associated with an insufficient stun [12], and bleeding ducks without prior stunning also led to vigorous post-stun movements (unpublished data). After the efficient 600 mA treatment, the convulsions following the tonic spasms were of much lower intensity than for the other current intensities, and they were followed by an exhaustion phase. According to Lambooij et al. [7], these physical events are the sign of an efficient stun.

5. CONCLUSION

The preliminary results obtained in this experiment suggest that a current of 600 mA (AC 50 Hz, 4 s) was required to induce an irreversible loss of brain function in all the birds. On a practical point of view, such a high current cannot be applied through a hand-operated system. Automation of the current application is absolutely necessary if this head-only method is to be used under commercial conditions.

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