THE USE OF FOURIER TECHNIQUES IN THE ANALYSIS OF PRE- AND POST- STUN ELECTROENCEPHALOGRAMS

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SUMMARY

Electroencephalograms (EEGs) were recorded before and after stunning (electrical or captive bolt) of adult cattle. Fourier techniques were used to construct periodograms of selected 8.5 second segments (epochs) of the EEG signal. A comparison of both consecutive and non-consecutive pre-stun epochs indicated that, within an animal, the pre-stun EEG signal had a consistent frequency pattern. The comparison of pre- and post-stun epochs from electrically stunned animals indicated that this form of stunning caused an increase in the power of frequencies in the range 4-12 Hz. Following captive bolt stunning there was an increase in the power of frequencies in the range 4-8 Hz. Fourier techniques can be used to provide objective evidence of changes in the EEG signal following stunning.

INTRODUCTION

The electroencephalogram (EEG) and the electrocorticogram (ECoG) have been used extensively in the assessment of the effectiveness and humaneness of various stunning procedures. Some of the procedures assessed include electrical stunning of sheep, calves, pigs and cattle (Blackmore and Newhook 1982; Gregory and Wotton 1985; Hoenderken 1978; Devine et al. 1986a), captive bolt stunning of sheep and cattle (Lambooy and Spanjaard 1981; Daly 1986) and carbon dioxide stunning of pigs (Forslid 1987).

An EEG signal has both amplitude and frequency components. Signal amplitude is invariably measured and used to assist in the interpretation of the EEG. Frequency analysis of the post-stun signal of individual animals has been reported (Hoenderken 1978; Lambooy and Spanjaard 1981; Swatland et al. 1984; Devine et al. 1986b). However, in many studies, it would appear that the frequency component of the EEG signal is not evaluated objectively. One notable exception is the study on carbon dioxide stunning of pigs (Forslid 1987) in which the Fast Fourier Transform (FFT) was used during a computerised analysis of the changes in the EEG signal following exposure to carbon dioxide.

To obtain maximum information from an EEG signal a detailed knowledge of both the amplitude and frequency components is desirable. This information, initially obtained from individual animals, can be combined for a group of animals stunned using the same method. It should then be possible to reveal, by statistical analysis, any evidence of changes in the EEG signal produced by the stunning method.

EXPERIMENTAL METHODS

Stunning

Adult cattle (liveweight 300-450 kg) of various breeds and including both cows and steers were used. Ten animals were stunned electrically, four animals were stunned mechanically. The electrical stun was "head-only", using constant current (3 amp, 50 Hz) stunning equipment. The duration of current flow was 4 s. In the mechanical stunning experiments a Cash X captive bolt pistol (purple cartridges, 2.5 grain), placed in the frontal position, was used to stun the animals.

EEG recording

The EEG recording technique and the equipment used have been described previously (Jones et al. 1988). Approximately 30 s of EEG signal was recorded from the normal, conscious animal prior to stunning. Artefact-free epochs of approximately 8.5 s duration, consisting of 1024 values, were used for pre- and post-stun comparisons. For the electrically stunned animals, the mean time between the initiation of the stun and the commencement of the post-stun epochs was 13 s, for the captive bolt stunned animals the mean time between the stun and the commencement of the post-stun epochs was 6.5 s. In all electrically stunned animals the post-stun epochs were recorded during the high amplitude phase of the EEG signal. The mean time between the start of the pre-stun epochs and the start of the post-stun epochs was 27 s (electrically stunned animals) and 25 s (captive bolt stunned animals). In other stunning experiments, where delays before the application of the stun occurred, control comparisons were made between non-consecutive epochs of the pre-stun EEG signal. The mean time between these epochs was 33 s.

Statistical analysis

The Fast Fourier Transform (FFT) was computed for pre- and post-stun epochs of the EEG signal and the periodogram of each epoch calculated. Ratios of periodogram ordinates were then tested for significance in terms of reductions in power at frequencies up to 40 Hz (Jones et al. 1988). The significance levels for each of 10 animals (4 in the case of mechanical stunning) were combined using a probability transformation (Rao 1952). Chi-squared values, df = 20 (8 for mechanical stunning), were used to ascertain the statistical significance of these combined values over the range of frequencies.

RESULTS

The combined significance values are plotted against frequency in Fig 1. Fig 1a and 1b show the comparisons for electrical stunning and captive bolt stunning respectively, while Fig 1c and 1d show the comparisons for consecutive and non-consecutive pre-stun epochs. It can be seen that electrical stunning causes a significant increase in the power of frequencies in the range 4-12 Hz while captive bolt stunning causes a significant increase in the power of frequencies in the range 4-8 Hz. Frequency differences for comparisons of pre-stun epochs were, in general, not statistically significant.

DISCUSSION

Following electrical stunning there was a marked increase in the power of frequencies in the range 4-12 Hz. Hoenderken (1978) presented an illustration of the frequency analysis of the EEG before and after effective electrical stunning of a pig. There was a marked increase in the power of the frequencies in the range 4-8 Hz following the stun. However, Swatland et al. (1984) found

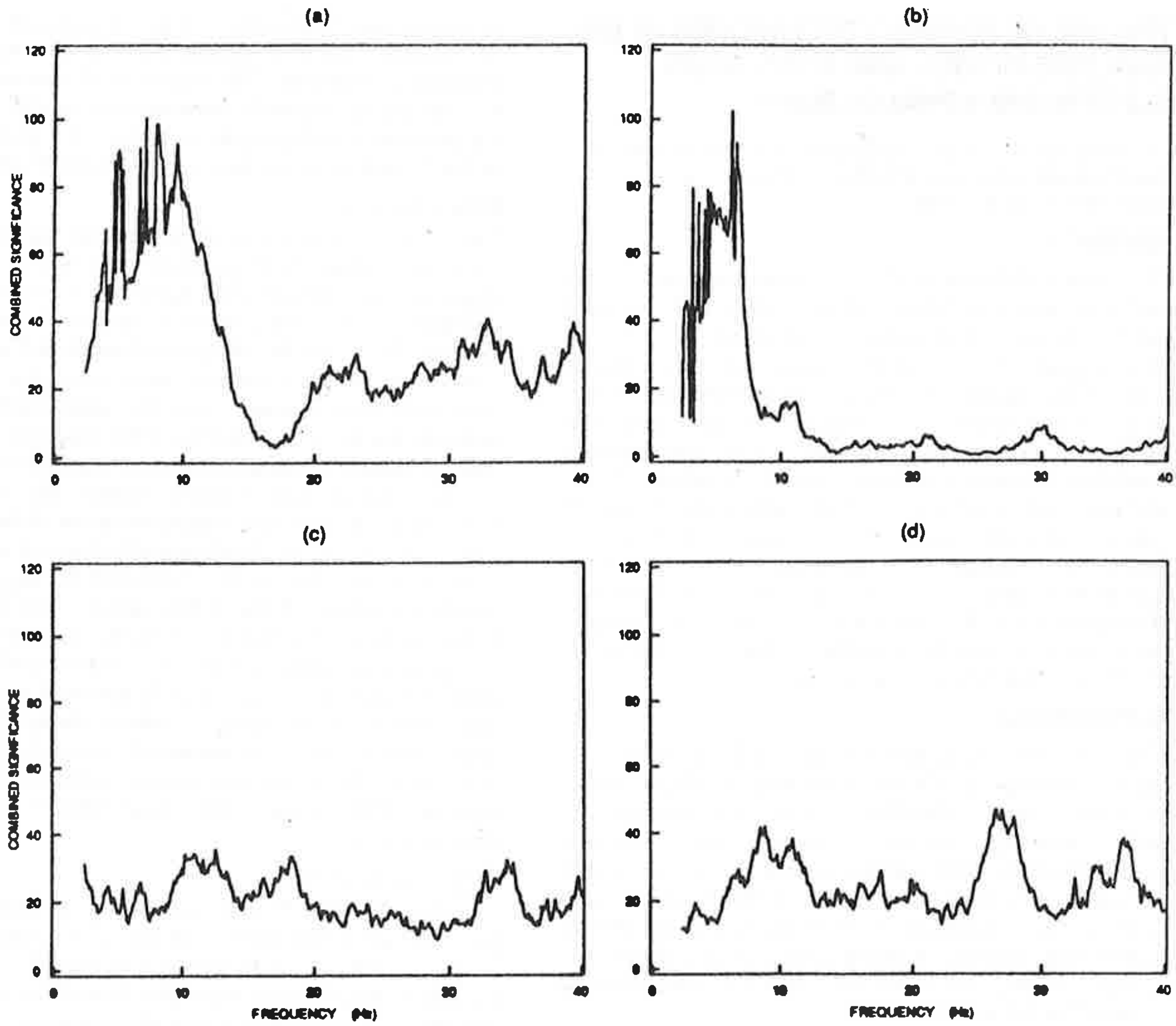

Fig 1: Combined significance levels for testing periodogram ratios (χ^2 df in brackets).

(a) Pre- vs post-stun (electrical) epochs (20)
(b) Pre- vs post-stun (mechanical) epochs (8)
(c) Consecutive pre-stun epochs (20)
(d) Non-consecutive pre-stun epochs (20)

no significant differences in ECoG frequency following electrical stunning of pigs. Devine et al. (1986b) used the FFT to compare EEGs recorded from calves exsanguinated with or without a preceding electric stun. With the calves that received the electric stun there was a frequency component between 15-40 Hz which persisted until the EEG fell below 10 uV. They did not comment on any other frequency ranges. Their EEG recording equipment incorporates a 10 Hz (-3dB) lower frequency filter (Devine et al. 1986a) and thus some of the low frequency changes resulting from the stun may not have been detected.

Following captive bolt stunning there was an increase in the power of frequencies in the range 4-8 Hz. The onset of low frequency delta (< 4 Hz) or theta (4-8 Hz) waves following captive bolt stunning is well documented (Fricker and Riek 1981; Lambooy and Spanjaard 1981). Tidswell et al. (1987) observed 8 Hz cyclical activity in one sheep following captive bolt stunning.

Daly (1986) has reported that following captive bolt stunning of cattle the ECoG waveform remains unchanged for an average duration of 11 s (maximum 25 s). He concluded that the ECoG is of limited use in the evaluation of captive bolt stunning of cattle. It is possible that our analytical techniques may have detected subtle, but significant, changes in the ECoG immediately following the stun.

CONCLUSIONS

A comparison of pre- and post-stun epochs from the EEG signal indicated that electrical stunning caused an increase in the power of frequencies in the range 4-12 Hz. Following captive bolt stunning there was an increase in the power of frequencies in the range 4-8 Hz. If maximum information is to be derived from a post-stun EEG signal it is essential that the EEG recording system be capable of recording, without significant attenuation, frequencies in the range 4-12 Hz. Fourier techniques can be used to provide objective evidence of changes in the EEG signal following stunning.

ACKNOWLEDGEMENTS

This work was supported in part by funds provided from meat industry research levies administered by the Australian Meat and Livestock Research and Development Corporation.

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