

Technical note

Electroencephalographic power spectral analysis of
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Received 19 August 2004; received in revised form 18 July 2005; accepted 17 August 2005

Available online 10 October 2005

Abstract

Neuronal differentiation and maturation of the brain follow distinctive ontogenetic sequences that are characteristic for each animal specie.

The present study was designed to investigate the developmental aspects of the electroencephalogram (EEG) in growing male and female goat kids, using power spectral analysis to assess useful indicators for estimating brain activity in young goats. Moreover, the spectral analysis results could be used as standard for evaluating abnormal brain activity in goats. Seven healthy Saanen kids were selected 2 days after birth. Kids were tested at 15 (T1), 30 (T2), 45 (T3), 60 (T4) and 75 (T5) days of age, respectively. The EEG sessions recorded lasted 20 min and during the session the kids were physically separated from their dams by a wire mesh. Wakefulness and drowsy states in the animals were observed. Visual examination of the EEG revealed an high voltage–low frequency background activity during the wakefulness state. Vertex waves, k-complexes and spindle activity were detected with the high voltage–low frequency background activity during the drowsy state. Spectral analysis of the EEG (q-EEG) was performed in order to assess the quantitative parameters of the background activity in the wakefulness state. q-EEG analysis was performed using Fast Fourier Transform; the spectral bands delta (0.5–4.0 Hz), theta (4.1–8.0 Hz), alpha (8.1–12.0 Hz) and beta (12.1–30.0 Hz) were calculated and expressed as relative power (%). Results were compared for each age stage and each scalp area, using an ANOVA for repeated measures. A significant decrease in the slow theta rhythms and an increase of fast beta rhythms was recorded. The distribution of the four frequency bands was posterior for delta, frontal and central for theta, as well as for beta and most of alpha patterns. These quantitative data may be useful indicators for assessing brain function of young goats and as standard data for evaluating abnormal brain activity in goats.

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Keywords: Goats; Development; Electroencephalography; Power spectrum analysis**1. Introduction**

The maturation of the electroencephalogram (EEG) patterns run parallel with the anatomical and physiolog-

ical development of the brain. Goats, as well as species of sheep, show a predominantly prenatal brain development, evolving earlier than in man (Barlow, 1969). As neuronal maturation proceeds, faster, low voltage activity becomes more prominent. In mammals, the alpha rhythm particularly occurs between 8 and 13 Hz and can be associated with the normal developmental process for functional maturation of the brain (Okuma, 1966).

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Nevertheless, differences in the pattern of neuronal growth exist in various animal species. In rabbits, e.g. neuronal differentiation occurs before birth (Timiras and Nzekwe, 1989). Conversely, newborn cats essentially have an isoelectric EEG (Klemm, 1969) and dogs a fairly fully developed EEG pattern at approximately 5 months of age (Fox et al., 1966)—indicating a postnatal development of the neocortical neurons. In newborn foals, mature-like EEG patterns have been observed at 100–200 days of age (Mysinger et al., 1985). In calves it has been suggested that the brain stem function matures before birth, although cortical functions continue to develop for at least the first 10 weeks following birth (Takeuchi et al., 1998).

There is extensive literature on EEG recordings in foetal and newborn lambs (McNervey and Szeto, 1990; Shinozuka and Nathanielsz, 1998; Schmidt et al., 2002), compared to goat kids. The surgically instrumented foetal sheep is the species most commonly used to study foetal physiology, as it is possible to implement electrodes which enable longitudinal studies of the unanaesthetised foetus in utero, over many weeks. This procedure is not used in other species. The foetal sheep brain develops cyclic electro-cortical activity from day 115 to 120 of gestational age, alternating between a high voltage, low frequency electro-corticogram state (non-REM sleep) and a low voltage, high frequency electro-corticogram state (REM sleep) (Szeto and Hinman, 1985). In addition, power spectral analysis was used to provide quantitative information on maturation changes in the electro-corticogram waveforms in the third-trimester fetal lamb (Szeto et al., 1985) as well as spectral edge frequency (Szeto, 1990). It has been reported that maturational changes in the third-trimester foetal lamb occur primarily in the low voltage, fast, activity periods, with a decrease in power density in the delta band and an increase in the maximum frequencies detected in the beta band. In addition, these changes continue throughout the rest of the gestation (Szeto et al., 1985).

Foetal lambs have been used to study the effects of hypoxia-ischemia induced by umbilical cord occlusion, a more realistic model of birth asphyxia, compared to cerebral artery occlusion (Mallard et al., 1995). In these studies, EEG was recorded to monitor the brain activity following brain damage (Thorngren-Jerneck et al., 2001). However, descriptive data concerning the amount of the frequency band power and their topography are sparsely available in the literature. EEG maturational changes related to the sleep state are always interpreted on the basis of comparative changes in the EEG recorded in other species, such as rat, cat and sometimes humans.

Pampiglione (1977) reported the brain of the newborn lamb to be already rich in convolution and myelination is comparably advanced similar to that of other mammals reasonably independent soon after birth, e.g. the young pig. In the young lamb, the EEG is well-organized in the first postnatal week, while in the fourth postnatal week a rhythmic activity occurred within seconds after passive eye closure.

EEG recordings have been used in 4-week-old lambs to assess the effect of pain associated with husbandry procedures (Jongman et al., 2000). Even in this study, the experiment set was based on a pain model previously developed for adult sheep (Morris et al., 1997; Ong et al., 1997)—which was in turn based on a human pain model. Changes in the EEG bandwidths related to painful stimulation have been reported on the basis of comparative changes in the EEG of adult sheep, and humans (Chen et al., 1989; Chen and Rappelsberger, 1994). In addition, data on the EEG baseline were referred to the control group formed by lambs subjected to handling.

Regarding EEG studies in goats, Bell (1960) reported the EEG of fully grown alert goats to be similar to the asynchronous pattern noted in other species. Although there are reference values of electrodiagnostic studies reported by Steffen et al. (1996), they refer to anaesthetised young goats.

As a result, data regarding the use of power spectral analysis to quantify the EEG in normally growing goats are not available. The aim of the present study was to investigate the developmental aspects of EEG in growing goat kids using power spectral analysis to assess useful indicators for estimating brain activity in young goats. Moreover, the spectral analysis results could be used as standard for evaluating abnormal brain activity in goats.

2. Materials and methods

2.1. Animals

Seven Saanen single-born kids were selected at Centro Interdipartimentale Servizio Ricoveri (C.I.S.R.A.) of the Faculty of Veterinary Medicine, University of Turin (Italy) and studied in an indoor-pen. The mean birth weight of the kids was 2.18 kg (range 1.5–3.3 kg) and there were 6 females and 1 male. The growth and behaviour of the kids were normal and kids were allowed to spend all the time with their dams, except during the experimental sessions. Water was available ad libitum.

Before the trials, the kids were submitted to preliminary habituation sessions in order to get the animals used to handling and electrode placement. During the experimental sessions the kids were housed in a wire mesh

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