Title: PARADOXICAL EEG AROUSAL PHENOMENON FOLLOWING ANESTHESIA WITH ISOFLURANE

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Introduction. The electroencephalogram shows a paradoxical arousal reaction at low end-tidal concentrations of isoflurane[1]. The present study was undertaken to examine the EEG during recovery from anesthesia with isoflurane (I), halothane (H) or enflurane (E) at MAC 0.5 for this paradoxical EEG arousal reaction and a possible correlation with awakening from anesthesia.

Methods. With written informed consent and approval by the local ethical committee of human research twelve unpremedicated healthy volunteers (21-32 years) underwent three different experimental anesthesias by breathing spontaneously I, H, or E in oxygen at MAC 0.5. Time course: control (15min), increasing I, H, or E up to MAC 0.5 (15 min), equilibration (10 min), steady state (15 min), recovery (40 min). Parameters measured: ECG, blood pressure, $p_{ET}CO_2$, p_{ET}(I, H, or E), EEG derivations F3C3 and C3P3, 'raw' EEG and simultaneous compressed spectral array (CSA). Subjects were also tested for response (awakening) and recall of verbal stimulation every minute. Data were correlated by regression analysis and statistical evaluation was by the paired t-test.

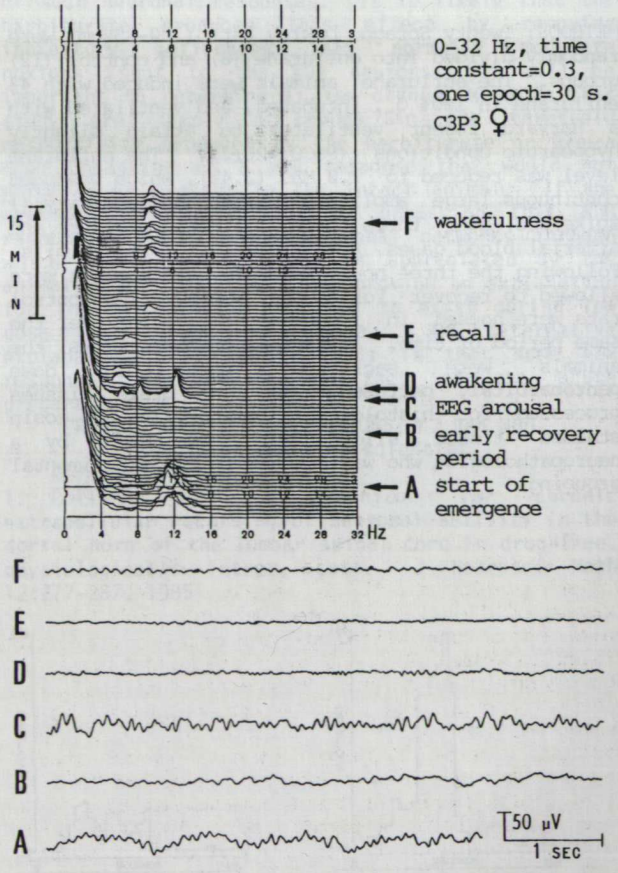
Results. A paradoxical EEG arousal phenomenon was observed in each subject during recovery from anesthesia with isoflurane, in 3 of 12 cases with halothane and none with enflurane. The 'phenomenon' was observed 2 to 15 min after starting emergence of isoflurane and 0 to 2 min prior to awakening ($p<0.05$) but up to 10 min before recall ($p<0.01$). Correlation was close between the EEG phenomenon and awakening ($r=0.99$) and it was poor with recall ($r=0.60$). Detailed data are given in Table 1. Fig 1 shows a typical CSA during recovery from anesthesia with isoflurane and corresponding 'raw' EEGs at selected times.

Discussion. Arousal in the EEG is characterized by amplitude reduction, frequency increase, and desynchronization[2]. At low concentrations of I however Clark et al reported a paradoxical EEG arousal reaction showing increasing EEG synchronization with increased attention[1]. As far as we know the EEG phenomenon we observed has not been reported before. It resembles the paradoxical EEG arousal reaction[1] but appeared spontaneously and independent of verbal stimulation. In the course of recovery from I during transitional low amplitude random activity the EEG abruptly changed and for approx. 20 to 30 s showed 5 to 15 Hz activity at increased power with synchronization and a few seconds thereafter showed transitional activity as before. We found this phenomenon in each subject during recovery from experimental anesthesia with I at MAC 0.5, only in 3 cases during recovery from H, but never with E. Meanwhile we saw the paradoxical EEG arousal phenomenon in fentanyl/isoflurane anesthesia as well. We consider it a reliable and easily detectable sign specific for awakening from anesthesia with isoflurane.

Table 1. Time in minutes for awakening (I), paradoxical EEG arousal phenomenon (II), and recall (III) after isoflurane MAC 0.5 in 12 subjects (A-M). Visibility of the EEG arousal in 'raw' EEG (IV) and CSA (V) is quoted + = unequivocal or (+) = good.

	A	B	C	D	E	F	G	H	I	K	L	M
I	14	6	12	12	10	6	9	4	15	13	15	5
II	13	5	11	12	10	6	9	2	15	12	15	4
III	20	12	13	15	12	6	9	8	12	20	25	16
IV	+	+	+	+	(+)	+	+	(+)	(+)	+	+	+
V	+	+	+	+	(+)	+	+	+	(+)	+	+	+

Fig 1. EEG changes during recovery (40 min) from anesthesia with MAC 0.5 isoflurane (CSA and corresponding 'raw' EEGs).



References.
1. Clark DL, et al. Anesthesiology 39:261-270, 1973
2. Martin JT, et al. Anesthesiology 20:359-376, 1959