Acta Paediatrica Hungarica 30 (3-4), pp 403-422 (1990)

EEG SPECTRAL ANALYSIS IN NEWBORNS WITH AND WITHOUT SEVERE BRAIN DAMAGE AT DIFFERENT CONCEPTIONAL AGES. A PRELIMINARY REPORT

M. ROTHER, Barbara TEUBNER, Petra WINKLER, M. EISELT
U. ZWIENER, Barbara CLAUSNER[1]

Institut für Pathologische Physiologie, Friedrich-Schiller Universität, Jena und
Abteilung für Neonatologie der Universitätskinderklinik, Friedrich-Schiller-Universität, Jena

Received 31 Oct 1988

Spectral power (SP) analysis of neonatal discontinuous EEG pattern of bilateral F_p-T and T-O derivations has been performed in 5 newborns with no or mild brain damage and in 5 newborns with severe brain damage matched for conceptional age (30.-39. week). Discontinuous EEG was separated in interburst and burst intervals. SP of all frequency bands was depressed in newborns with severe brain damage, with the depression being more pronounced during interburst intervals. Surprisingly, a prominent depression of the SP of the derivations of the right hemisphere and of the delta frequency bands of severely handicapped newborns was found. Calculation of coherence between homologous bipolar derivations does not improve the possibilities to separate both groups.

INTRODUCTION

The prognostic significance of the visual analysis of neonatal EEG has been shown by different groups at least since 1972 /11, 20/. But the extensive use of the EEG in any newborn-at-risk is handicapped by a) the difficult recording conditions during intensive care, b) the relatively long recording intervals which were necessary for correct classification and c) the features of neonatal EEG which demand especially trained examiners for interpretation. Most neonatologists and neurologists are not experienced in neonatal EEG technology. Automatical and computerassisted devices for EEG classification and monitoring on the base of quantitative and objective criteria may solve these problems in part. First successful attempts were made by means of the cerebral function monitor /1,

Akadémiai Kiadó, Budapest

18/. The cerebral function monitor describes amplitude changes of the EEG only. Glaria and Murray /6/ had recommended on the base of a comparison of 5 different methods of EEG analysis that techniques analysing both amplitude and frequency changes such as spectral analysis should be used.

Richards et al /13/ differentiated successfully in a retrospective study neonates with varying risk and developmental outcome by the help of spectral analysis of infant EEG related to the characteristic EEG patterns. They examined EEG records in term babies and preterms at term. But quantitative description of EEG in preterms before term seems necessary for earlier therapeutic intervention and for control of therapeutic effects.

For this reason in this preliminary study we examined newborns at different conceptional ages with no or mild and with severe brain damage. It is an attempt to find out whether spectral analysis is able to differentiate these two groups even at different conceptional ages.

SUBJECTS AND METHODS

5 newborns with no or mild brain damage and 5 newborns with severe brain damage evaluated by follow-up examinations and autopsies were included in this study.

Case histories (N = newborns with no or mild brain damage; S = severely brain damaged newborns):

N1: Conceptional age (CA): 31 weeks; birth weight: 1200 g; APGAR 6-8-8; diagnosis: RDS III-IV^{o}, pyocyaneus sepsis; 21 days on ventilator; autopsy: bronchopulmonary dysplasia

S1: CA: 30 weeks; 910 g; APGAR 2-7-7; diagnosis: RDS III-IV^{o}; 16 days on ventilator; autopsy: intracranial hemorrhage, bronchopulmonary dysplasia

N2: Ca: 32 weeks; 1520 g; APGAR 8-10-10; diagnosis: RDS I^{o}, hyperbilirubinaemia; 3 days CPAP; follow-up: normal

S2: CA: 33 weeks; 1320 g; APGAR 1-6-6; diagnosis: RDS III-IV^{o}, renal failure; autopsy: intracranial hemorrhage

N3: CA: 34 weeks; 2000 g; APGAR 5-6-8; diagnosis: Rh incompatibility, RDS I^{o}, IVH I^{o}; 3 days CPAP; follow up: till the 8th month minimal motoric retardation then normal

S3: CA: 34 weeks; 1390 g; APGAR 6-8-9; diagnosis: intrauterine asphyxia, consumptive coagulopathy, pulmonary hemorrhage; 9 days on ventilator; autopsy: intracranial hemorrhage

N4: CA: 36 weeks; 2250 g; APGAR 7-8-9; diagnosis: immaturity; no ventilator treatment; autopsy: till the 4th month mild spasticity then normal
S4: CA: 36 weeks; 2500 g; APGAR 1-7-7; diagnosis: intrauterine asphyxia, seizures, amnionitis, hyperbilirubinaemia, 12 days on ventilator; follow-up: spastic hemiplegia
N5: CA: 39 weeks; 2370 g; APGAR 10-9-10; diagnosis: intrauterine retardation, geminus; no ventilator treatment; follow-up: mild spasticity
S5: CA: 39 weeks; 3500 g APGAR 6-8-8; diagnosis: intrauterine asphyxia, seizures, hygroma; 14 days on ventilator, follow-up: microcephaly, epilepsia, spastic tetraplegia

Because all children were examined during intensive care, the denotation "normals" was avoided. Two newborns received phenobarbital medication during time of examination but in low dosages (4 mg per kg body weight and day). No phenobarbital medication was given immediately before or during polygraphic recordings Pancuronium bromide was given to 4 severely brain damaged newborns. The same newborns received dopamine. None of the newborns received theophyllin. The newborns were matched for conceptional age (30/31; 32/33; 34/35; 36/37; 38/39 weeks).

60 - 120 minute recordings including 8-channel EEG, heart rate and respiration (thermistor and impedance) were performed. EEGs were recorded by surface disc electrodes positioned according to the international 10 - 20 system adapted for newborns /8/ at the F_p1, F_p2, C3, C4, T3, T4, O1 and O2 location. Bipolar recordings were used as follows F_p1-C3, C3-O1, F_p1-T3, T3-O1, F_p2-C4, C4-O2, F_p2-T4 and T4-O2. All data were recorded continuously on paper (polygraph BST-1) and FM tape recorder (EAM 500, TESLA). Movements and behaviour were observed continuously and recorded by an event marker on the paper chart.

Right and left fronto-temporal (F_p1-T3, F_p2-T4) and temporo-occipital (F_p2-T4, T4-O2) derivations were chosen for subsequent computerized analysis.

Discontinuous EEG pattern was classified by two observers (M.R.; M.E.). Burst and interburst intervals of this pattern were differentiated visually (see Fig. 1). 15 bursts and 15 interburst intervals within one period of discontinuous pattern were selected in every newborn. The EEG was filtered (cut-off frequency 25.0 Hz, active Butterworth low-pass filtering, 120 dB/decade) and digitized using a sampling rate of 50 Hz (burst) and 100 Hz (interburst). That lead to intervals of analysis with a duration of 10.24 sec (burst) or 5.12 sec (interburst).

Fast Fourier Transformation of the data was performed using a PDP-8 compatible computer system (KSR 4100, ROBOTRON; for further description of computation procedure /14, 23/). Power spectra of the bipolar EEG derivations and coherence spectra of homologous derivations of both hemispheres were calculated for the 15 bursts and 15 interburst intervals in every newborn. Spectral power (SP) and coherence were summarized for the following frequency bands: total power (0.5 - 25 Hz), delta power (0.5 - 3.5 Hz), theta power (3.5 - 7.5 Hz), alpha power (7.5 - 12.5 Hz) and beta power (12.5 - 25.0 Hz).

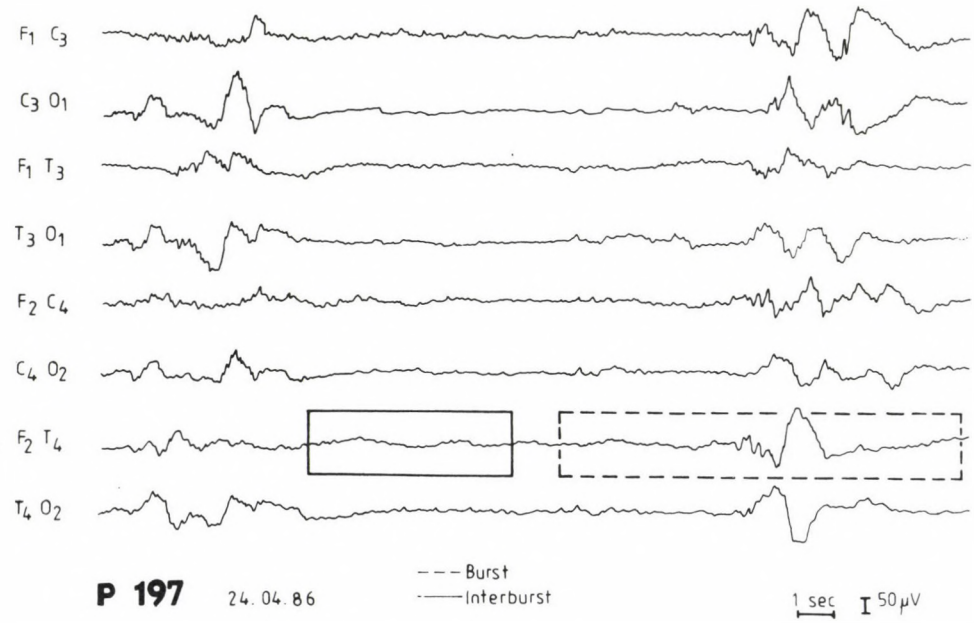

Fig. 1. Example for differentiation of burst and interburst intervals in a newborn with no or mild brain damage at the 34th week of conceptional age.

The following parameters were calculated in a postprocessing procedure: a) relative delta, theta, alpha and beta SP in percentage (e.g. relative delta = delta power) total power 100 %), b) sum of SP within the corresponding frequency bands of all four derivations examined (Fp1-T3 + T3-01 + Fp2-T4 + T4-02), c) sum of SP within corresponding frequency bands of left and right hemisphere (Fp1-T3 + T3-01 and Fp2-T4 + T4-02) and d) sum of SP within the corresponding frequency bands of fronto-temporal and temporo-occipital derivations (Fp1-T3 + Fp2-T4 and T3-01 + T4-02).

Newborns were ranged pairwise according to the conceptional age for statistical comparison. Two-way analysis of variance (ANOV 2) was chosen to exclude effects of different conceptional age. Only F - values of the analysis were considered for the comparison of newborns with no or mild and severe brain damage. Analysis was performed by means of the statistical software package ABSTAT using a microprocessor computing system (K 1510; ROBOTRON).

RESULTS

Interburst intervals

The SP of the interburst intervals of newborns with severe brain damage is diminished in the Fp2-T4 and T4-O2 derivations. Significant differences were found for the total SP and delta SP of Fp2-T4 and theta SP, alpha SP and beta SP of T4-O2 (Fig. 2). Fp1-T3 and T3-O1 show no significant differences between both groups examined.

This corresponds with the diminished SP of all frequency bands summarized for the right hemisphere (Table I) in the newborns with severe brain damage (without exception). Sum of SP of the fronto-temporal derivations, temporo-occipital derivations and derivations of left hemisphere show no significant differences between both groups.

There were no significant differences in parameters of coherence (Table II).

Relative SP of delta frequency bands of all derivations is diminished in newborns with severe brain damage, but only Fp1-T3 shows a significant difference (Table III). In contrary to the absolute SP, relative SP of theta, alpha and beta frequency bands is higher in newborns with severe brain damage than in newborns with no or mild brain damage (exception alpha frequency band of Fp2-T4) because of the more pronounced depression of absolute SP of the delta frequency band. Significant differences were found only for relative SP of theta frequency band of T4-O2.

Burst

The SP of the burst intervals of newborns with severe brain damage is also diminished in Fp2-T4 and T4-O2 derivations (Fig. 3). Statistically significant differences were found for total SP and delta SP of Fp2-T4 and delta SP of T4-O2. Fp1-T3 and T3-O1 show no significant differences between newborns with no or mild and newborns with severe brain damage.

The sum of SP within corresponding frequency bands of the right hemisphere reflects the differences between both groups

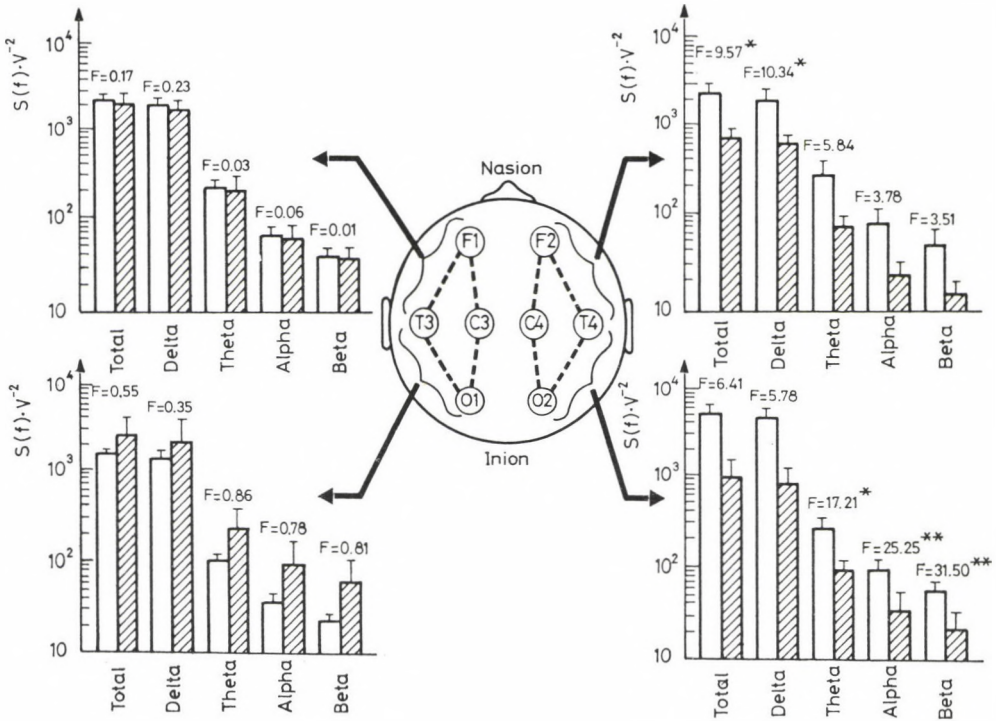

Fig. 2. Absolute spectral power (mean and S.E.M.) during interburst interval of the Fpl-T3, T3-01, Fp2-T4 and T4-02 derivations of the newborns with no or mild brain damage (blank columns) and newborns with severe brain damage (hatched columns) for the different frequency bands (F = F-value of ANOV2 statistical analysis, x = $p < 0.05$, xx = $p < 0.01$).

TABLE I

Absolute spectral power of interburst intervals for selected frequency bands and location in newborns with no or mild brain damage (N) and severe brain damage (S); M = mean value; SEM = standard error of the mean; F = F-value of ANOV2 analysis; x = $p < 0.05$)

			total	delta	theta	alpha	beta
Sum	N	M	11452	10210	898.0	293.1	177.1
		SEM	1624	1620	146.0	71.7	37.6
	S	M	6515	5525	638.4	218.8	144.0
		SEM	2447	2003	266.0	113.0	64.4
		F	3.18	3.43	1.06	0.69	0.39
Right	N	M	7740	6841	565.4	187.7	113.6
		SEM	1417	1355	138.0	59.8	29.0
	S	M	1750	1479	179.0	60.2	39.4
		SEM	657	546	67.3	27.6	14.7
		F	19.54^{x}	15.09^{x}	14.39^{x}	8.72^{x}	12.03^{x}
Left	N	M	3736	3367	332.8	105.4	63.4
		SEM	314	237	25.4	14.3	9.2
	S	M	4765	4045	459.2	158.6	104.6
		SEM	1882	1541	207.0	86.7	51.8
		F	0.29	0.18	0.36	0.46	0.81
Fron. - Temp.	N	M	4497	3805	470.3	142.7	86.9
		SEM	749	586	111.0	43.4	26.4
	S	M	2680	2279	237.5	82.5	53.0
		SEM	617	513	80.5	36.9	12.9
		F	5.70	6.07	3.52	2.32	2.44
Temp. - Occi.	N	M	6528	6068	372.2	132.2	80.6
		SEM	1485	1518	55.0	34.4	14.1
	S	M	3490	2951	328.6	138.4	85.2
		SEM	2126	1785	192.3	90.0	58.1
		F	1.28	1.54	0.07	0.01	0.01

TABLE II

Coherence between homologous derivations for selected frequency bands during interburst intervals in newborns with no or mild brain damage (N) and severe brain damage (S); M = mean value; SEM = standard error of the mean; F = F-value of ANOV2 analysis; x = $p < 0.05$)

			total	delta	theta	alpha	beta
	N	M	0.2239	0.2726	0.1801	0.1454	0.1588
Fp1-		SEM	0.038	0.033	0.043	0.045	0.064
T3/							
Fp2-	S	M	0.1893	0.2363	0.1708	0.1329	0.0086
T4		SEM	0.036	0.039	0.038	0.033	0.025
		F	0.42	0.46	0.04	0.05	1.16
	N	M	0.2389	0.2712	0.1831	0.2264	0.2650
T3-		SEM	0.039	0.039	0.031	0.050	0.084
O1/							
T4-	S	M	0.3246	0.3652	0.2743	0.2486	0.2948
O2		SEM	0.057	0.051	0.064	0.065	0.095
		F	1.89	1.79	1.10	0.04	0.05

regarding Fp2-T4 and T4-O2 derivations (Table IV). Sum of total variability and sum of delta SP of right hemisphere is significantly diminished in newborns with severe brain damage. No significant differences can be demonstrated for the sum of SP of the fronto-temporal derivations, temporo-occipital derivations and derivations of the left hemisphere.

No parameter of coherence shows significant differences between both groups examined (Table V).

Relative SP of delta frequency band of all derivations is diminished in newborns with severe brain damage (Table VI). Significant differences can be shown for relative delta SP of T3-O1. Relative SP of theta, alpha and beta frequency bands is higher (but not significant) in newborns with severe brain damage in contrary to the newborns with no or minimal brain damage.

TABLE III

Relative spectral power of interburst intervals for selected frequency bands and location in newborns with no or mild brain damage (N) and severe brain damage (S); M = mean value; SEM = standard error of the mean; F = F-value of ANOV2 analysis; x = $p < 0.05$)

			delta	theta	alpha	beta
Fp1-T3	N	M	83.69	10.90	3.24	2.22
		SEM	1.57	0.77	0.53	0.43
	S	M	82.76	11.12	3.51	2.69
		SEM	1.46	0.99	0.29	0.69
		F	13.49^{x}	0.11	0.47	0.68
Fp2-T4	N	M	82.88	11.77	4.38	2.04
		SEM	2.28	1.36	1.09	0.41
	S	M	81.44	11.83	4.08	2.68
		SEM	1.95	1.61	0.46	0.30
		F	0.24	0.01	0.07	1.50
T3-O1	N	M	85.40	9.59	2.93	2.12
		SEM	1.43	0.73	0.39	0.49
	S	M	82.67	11.42	3.43	2.53
		SEM	0.53	0.60	0.40	0.31
		F	3.12	3.01	0.76	0.55
T4-O2	N	M	87.66	7.27	2.91	2.20
		SEM	3.06	1.44	0.86	0.99
	S	M	81.77	11.38	4.05	3.46
		SEM	1.86	0.60	0.45	0.70
		F	3.73	8.62^{x}	1.17	2.73

TABLE IV

Absolute spectral power of burst intervals for selected frequency bands and location in newborns with no or mild brain damage (N) and severe brain damage (S); M = mean values; SEM = standard error of the mean; F = F-value of ANOV2 analysis; x = $p < 0.05$)

			total	delta	theta	alpha	beta
Sum	N	M	94535	86440	5358.6	1179.5	554.9
		SEM	16244	16845	1463	181.0	106.4
	S	M	62887	55628	5470.3	1303.9	483.5
		SEM	12528	11042	1596	349.0	142.2
		F	2.90	4.04	0.01	0.07	0.13
Right	N	M	48928	45110	2831.7	666.3	316.7
		SEM	6226	6351	864.0	166.0.	92.6
	S	M	22891	20525	1692.4	444.2	225.1
		SEM	5462	4797	574.2	190.2	106.1
		F	10.70^{x}	10.82^{x}	0.78	0.62	0.45
Left	N	M	45607	41330	2526.9	513.2	237.2
		SEM	11221	11141	697.2	77.8	25.7
	S	M	39996	35103	3777.9	857.6	258.4
		SEM	8401	7366	1211.0	216.7	52.8
		F	0.26	0.46	0.50	2.05	0.09
Fron. - Temp.	N	M	47838	43356	3429.2	728.6	325.4
		SEM	7953	7441	870.6	133.7	67.5
	S	M	43110	37811	4013.4	949.3	338.3
		SEM	8794	7960	1304.1	268.9	112.7
		F	0.18	0.33	0.09	0.36	0.08
Temp. - Occi.	N	M	46697	43084	1929.3	450.8	229.4
		SEM	11526	10732	640.0	86.1	57.0
	S	M	19776	17817	1456.4	354.6	145.2
		SEM	5567	5138	398.3	91.0	37.3
		F	3.58	5.22	0.25	0.43	1.13

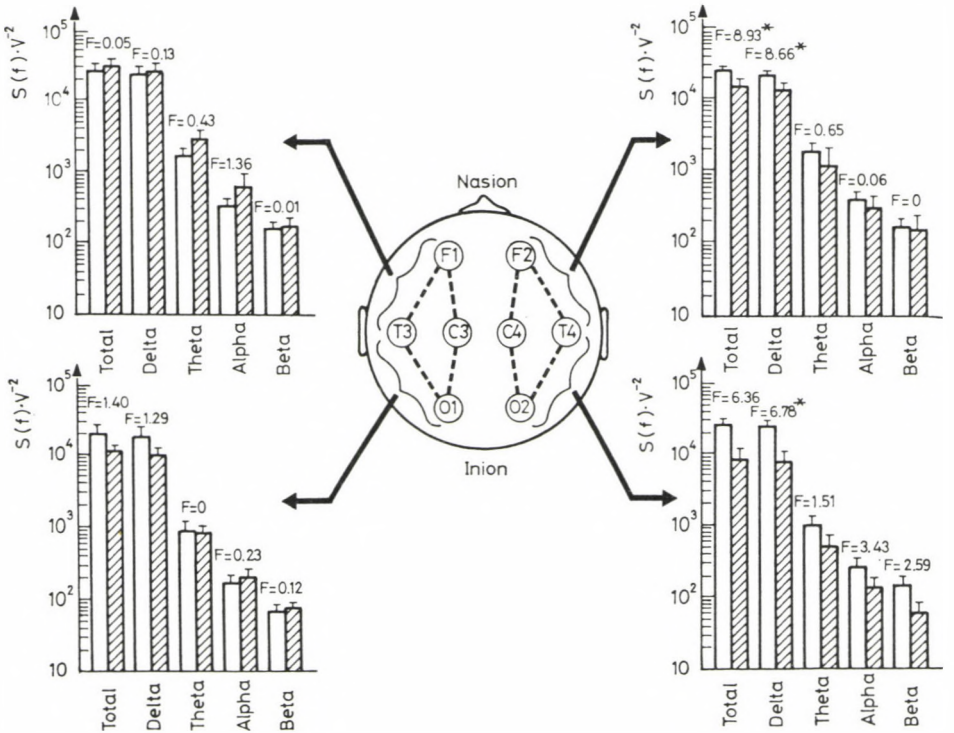

Fig. 3. Absolute spectral power (mean and S.E.M.) during burst interval of the Fpl-T3, T3-01, Fp2-T4 and T4-02 derivations of the newborns with no or mild brain damage (blank columns) and newborns with severe brain damage (hatched columns) for the different frequency bands (F = F-value of ANOV2 statistical analysis, x = $p < 0.05$).

TABLE V

Coherence between homologous derivations for selected frequency bands during burst intervals in newborns with no or mild brain damage (N) and severe brain damage (S); M= mean value; SEM = standard error of the mean; F = F-value of ANOV2 analysis; x = $p < 0.05$)

			total	delta	theta	alpha	beta
	N	M	0.2384	0.2646	0.1989	0.1624	0.1588
Fp1-		SEM	0.040	0.036	0.036	0.027	0.022
T3/							
Fp2-	S	M	0.2768	0.3057	0.2265	0.1347	0.1031
T4		SEM	0.054	0.054	0.015	0.018	0.036
		F	1.13	1.82	1.41	0.04	0.02
	N	M	0.2186	0.2364	0.0899	0.1277	0.1182
T3-		SEM	0.036	0.036	0.013	0.027	0.031
01/							
T4	S	M	0.2987	0.3187	0.2435	0.2299	0.2282
02		SEM	0.036	0.013	0.027	0.031	0.036
		F	0.66	0.84	1.59	0.64	0.96

Comparison of Tables I and IV shows that spectral power of interburst intervals of newborns with severe brain damage is more depressed than spectral power of burst intervals.

DISCUSSION

The study was performed to prove the ability of computerized (spectral) analysis of neonatal EEG for the differentiation of newborns with no or mild brain damage and newborns with severe brain damage at different gestational ages. Thus the study was based consequently on the results of the follow-up examinations or the autopsy findings despite well defined differences with respect to the other clinical data between both groups.

Only four EEG derivations were selected for further data processing to restrict computation time and resulting data. By analysis of right and left fronto-temporal and temporo-

TABLE VI

Relative spectral power of burst intervals for selected frequency bands and location in newborns with no or mild brain damage (N) and severe brain damage (S); M = mean value; SEM = standard error of the mean; F = F-value of ANOV2 analysis; x = $p < 0.05$)

			delta	theta	alpha	beta
Fp1-T3	N	M	90.11	7.35	1.63	0.89
		SEM	1.14	0.79	0.17	0.29
	S	M	86.05	10.84	2.38	0.71
		SEM	2.43	2.04	0.35	0.11
		F	3.91	4.07	5.66	0.01
Fp2-T4	N	M	89.80	7.83	1.61	0.74
		SEM	2.00	1.49	0.35	0.26
	S	M	88.02	8.95	2.03	0.98
		SEM	2.58	2.12	0.57	0.34
		F	1.02	0.73	1.36	1.14
T3-O1	N	M	93.51	4.73	1.16	0.58
		SEM	0.66	0.40	0.25	0.19
	S	M	86.83	10.01	2.21	0.93
		SEM	2.66	2.22	0.36	0.16
		F	7.40^{x}	5.78	6.57	2.89
T4-O2	N	M	93.77	4.29	1.25	0.68
		SEM	1.24	0.73	0.38	0.19
	S	M	88.30	8.78	2.02	0.88
		SEM	2.81	2.38	0.35	0.07
		F	6.39	5.19	5.61	1.67

occipital, at one hand, or right and left fronto-central and centro-occipital derivations, on the other hand, it is possible to achieve information about the frontal and occipital activity of both hemispheres using four derivations. Right and left fronto-temporal and temporo-occipital derivations were chosen for subsequent computerized analysis because temporo-occipital predominance can be found during the earlier conceptional ages /21/.

Spectral power analysis of neonatal EEG had been performed by a lot of groups using different groups of subjects and incomparable methods of recording, computing and interpretation (for a short review see Table VII). To our knowledge, no study examined such severely damaged newborns as we did. Furthermore, no other study used the same separate analysis of burst and interburst intervals. For that reason a direct comparison with the results of other papers seems impossible.

Our study indicates that spectral analysis of neonatal EEG is an adequate statistical procedure to characterize newborns with severe brain damage. The EEG - SP of all frequency bands is reduced in newborns with severe brain damage in comparison to newborns with no or mild brain damage. This could be due to depressed activity of cortical neurons as a result of hypoxia /3/, reduced perfusion of cortical areas after asphyxia /19/ and/or morphological defects. No decision can be made by means of our data and study design. For such pathogenetical research EEG recordings must be performed in combination with methods measuring morphological defects (CT, ultrasound), metabolism and regional cerebral blood flow (NMR, PET), etc.

In contrary to experimental findings in adult animals /3/ the slow wave activity is more depressed than faster activity in our damaged newborns. This was shown by the depressed relative SP of the delta frequency band and the simultaneous increase of relative SP of the theta, alpha and beta frequency bands. But the time schedule of acute experimental hypoxia in the adult cat is incomparable with the often unknown moment of perinatal brain damage in clinical studies. Species differences and the changes of dominant activity of EEG recordings from delta to alpha (beta) frequency range in the course of human

TABLE VII

Methodological details from selected papers dealing with spectral analysis of neonatal EEG

Paper	Subjects	Samp. rate (Hz)	Intervals	Deri-vation	Freq. bands
Wille-kens et al. 1984	healthy fullterm	102.4	mean of 20 sec. intervals of 9 beha-vioural states	bilateral F-C; C-P; P-O; T-T	0-2;2-4 4-6;6-8 8-10 10-12; 12-14; 14-17; 17-22; 22-30
Rich-ards et al. 1986	5 groups with dif-ferent outcome and risk	100	3 x 20 sec for different EEG pat-terns	bilateral F-T; C-O T-O	0.1-3.5 4.0-7.5 8.0-12.5 13-25 11-16
Havli-cek et al. 1975	normal full- and pre-term	50	sum of 10.24 sec for dif-ferent behavioral states	C4-A1 C3-A2	Delta 1/2 Theta 1/2 Alpha 1/2 Beta 1/2 Total
Schulte Bell 1973	normals between 34 weeks and 4 y.	?	3 min. for active and quiet sleep	bilateral F-C; C-O O-T	continu-ous
Prechtl Vos 1973	healthy and at risk	?	3 min. of 1-2 sleep cycles	bilateral F-C; C-P	continu-ous
Gia-quinto et al. 1977	normal full-term	125	64 sec of high volt. slow and "activity moyenne"	bilateral F-C; C-O	0.5-4; 4-8; 8-12; 12-16; 16-20
Crowell et al. 1978	LBW pre-term and AGA term	30	4 sec pre and post stimuli	bilateral C-A; O-A	6 AR-coeffi-cients

Table VII continued

Sterman et al. 1982	controls and siblings of SIDS	64	10 min. during quiet sleep	C1-C5; C2-C6	0-3; 4-7; 8-12; 12-15; 16-19;
Hollmen et al. 1985	normal full-term different anaesthesy for ceas. section	?	5 sec for 2 hour recordings	Fp1-Fp2	0.6-4; 4-8; 8-12; 12-16; 16-20

development /10/ had to be considered.

Prominent depression of SP of the right hemisphere represents a surprising result. No corresponding clinical result was found in the literature. Thiringer et al /17/ demonstrated the persistence of some electrical activity left in a part of neonatal lambs exposed to experimental asphyxia. The electrical activity from the brain was completely abolished in the remaining group of lambs. These results also might indicate that the right hemisphere is more sensitive to brain damaging factors in the perinatal period. The cause of the phenomenon is unknown and the results had to be verified in experimental and clinical studies focused on that special question. It is unlikely that artefacts increasing SP as EOG interferences /23/ should influence only the left hemisphere or that systemic administration of phenobarbital as in two of our severely damaged newborns should reduce only the activity of the right hemisphere because this phenomenon could be described in all five newborns with severe brain damage. Influence of transients with strong effect to SP as spikes or sharp waves has been excluded by visual inspection of the selected intervals. An accidental incidence of local disturbances (infarction, hemorrhage, degeneration, ischemia) in the small group of our severely handicapped newborns could explain the prominent depression of SP of the right hemisphere. But no evidence was found in autopsy and the transfontanell ultrasound examination was not performed in all cases. Because EEG

activity was depressed in only one hemisphere at least two intrahemispheric derivations are necessary for sufficient neonatal EEG monitoring.

No general differences were found for interhemispheric coherence between groups of severely damaged newborns and newborns with no or mild brain damage. Coherence can be strongly influenced by visible and non-visible ECG-interferences /23/ which were often found in neonates. One question remains open, whether coherence between bipolar derivations allows useful physiological interpretation of this coherence per se in contrary to the coherence between unipolar derivations. We used the coherence because of optimistic evidences in the literature /12, 22/ in an empirical manner to search for differences between newborns with no or mild and severe brain damage. Because no differences were found even in such markedly different pathology we recommended that calculation of coherence between homologous bipolar derivations is not necessary in studies dealing with spectral analysis of neonatal EEG and characterization of severe brain damage. Value of coherence between unipolar derivations has to be demonstrated in further studies.

The discontinuous EEG pattern was chosen for analysis because this EEG pattern can be demonstrated in preterms and term newborns (trace alternant) and were found both in normals and handicapped infants /21/. The separation of burst and interburst intervals seems useful because spectral power of burst intervals is tenfold higher than spectral power of interburst intervals in both groups examined. For this reason spectral power of discontinuous EEG - pattern is mainly determined by the burst intervals. Different numbers of bursts during constant intervals of examination could lead to erroneous results. Visual analysis of neonatal EEG demonstrated that interburst intervals (background activity) are of special importance to define prognosis of newborns-at-risk /20/. This corresponds to our findings that spectral power of interburst intervals of severely handicapped newborns is more depressed than spectral power of the bursts. But methods of segmentation /2, 24/ are necessary to use selective spectral analysis of

interburst intervals for monitoring devices.

Only small groups were used for our statistical analysis. But to our knowledge no parameter independent statistical procedure exists corresponding to the two way analysis of variance for independent samples. For that reason we used this method despite the small groups. Significant differences were found only for these parameters which were in general lower or higher in newborns with no or mild brain damage than in newborns with severe brain damage.

In summary it can be concluded, that a) newborns with no or mild brain damage and newborns with severe brain damage can be differentiated by spectral analysis even in such small groups of subjects and b) objective parameters can be chosen for such a difference between two groups. The study has to be extended to groups of newborns with different diagnosis and to follow-up studies of single newborns during therapy to confirm these findings.

REFERENCES

1. Archbald F, Verma UL, Tejani NA, Handwerker SM: Cerebral function monitor in the neonate. II: Birth asphyxia Develop Med Child Neurol 26: 162, 1984

2. Barlow JS: Computer characterization of trace alternant and REM sleep patterns in the neonatal EEG by adaptive segmentation - an exploratory study. EEG clin. Neurophysiol 60: 163, 1985

3. Creutzfeld O, Kasamatsu A, Vaz-Ferreira A: Aktivitaetsaenderungen einzelner corticaler Neurone im akuten Sauerstoffmangel und ihre Beziehungen zum EEG bei Katzen. Pfluegers Archiv 263: 647, 1957

4. Crowell DH, Kapuniai LE: Autoregressive spectral estimates of newborn brain maturational level: Classification and validation. Psychophysiology 15: 204, 1978

5. Giaquinto S, Marciano F, Monod N, Nolte G: Application of statistical equivalence to newborn EEG recordings. EEG clin Neurophysiol 42: 106, 1977

6. Glaria AP, Murray A: Comparison of EEG monitoring techniques: An evaluation during cardiac surgery. EEG clin Neurophysiol 61: 323, 1985

7. Havlicek V, Childiaeva R, Chernick V: EEG frequency spectrum characteristics of sleep states in full-term and preterm infants. Neuroped 6: 24, 1975

8. Hellstroem B, Karlsson B, Muesbichler H: Electrode placement in EEG of infants and its anatomical relationship studied radiographically. EEG clin Neurophysiol 15: 115, 1963

9. Hollmen AI, Eskelinen P, Tolonen U, Sulg I, Jouppila R, Jouppilla P: Effects of anaesthesia for Ceasarean section on the computerized EEG of the neonate. Europ J Anaesthesiol 2: 39, 1985

10. Matousek M, Petersen I: Frequency analysis of the EEG in normal children and adolescents. In: Automation of clinical electroencephalography. Eds. Kellaway, P, Petersen I. 75-102, Raven Press, New York 1973

11. Monod N, Pajot N, Guidasci S: The neonatal EEG: Statistical studies and prognostic value in full-term and preterm babies. EEG clin Neurophysiol 32, 529, 1972

12. Prechtl HFR, Vos JE: Verlaufsmuster der Frequenzspektren und Kohaerenzen bei schlafenden Normalen und neurologisch abnormalen Neugeborenen. In: Die Quantifizierung des Elektroenzephalogramms, Ed. Schenk GK. 167-188, AEG Telefunken, Zuerich 1980

13. Richards JE, Parmele AH, Beckwith L: Spectral analysis of infant EEG and behavioral outcome at age five. EEG clin Neurophysiol 64: 1, 1986

14. Rother M, Zwiener U, Eiselt M, Witte H, Zwacka G, Frenzel J: Differentiation of healthy newborns and newborns-at-risk by spectral analysis of heart rate fluctuations and respiratory movements. Early Hum Developm 15: 349, 1987

15. Schulte FJ, Bell EF: Bioelectric brain development. An atlas of EEG power spectra in infants and young children. Neuroped 4: 31, 1973

16. Sterman MB, Mc Ginty DJ, Harper RM, Hoppenbrouwers T, Hodgman JE: Developmental comparison of sleep EEG power spectral patterns in infants at low and high risk for sudden death. EEG clin Neurophysiol 53: 166, 1982

17. Thiringer K, Hrbek A, Karlsson K, Rosen GK, Kjellmer I: Postasphyxial cerebral survival in newborn sheep after treatment with oxygen free radical scavangers and a calcium antagonist. Pediatr Res 22: 62, 1987

18. Verma U, Archbald F, Tejani NA, Handwerker S: Cerebral function monitor in the neonate. I: Normal patterns. Med Child Neurol 26: 154, 1984

19. Vope JJ, Herscovitch P, Perlman JM, Kreusser KL, Raichle ME: Positron Emission Tomography in the asphyxiated 2 newborn: Parasaggital impairment of cerebral blood flow. Ann Neurol 17: 287, 1985

20. Watanabe K, Miyazaki S, Hara K, Hakamada S: Behavioral state cycles, background EEG and prognosis of newborns with perinatal hypoxia. EEG clin Neurophysiol 49: 618, 1980

21. Werner SS, Stockard JE, Bickford RG: Atlas of neonatal electroencephalography. Raven Press, New York 1977

22. Willekens H, Dumermuth G, Duc G, Mieth D: EEG spectral power and coherence analysis in healthy fullterm neonates. Neuroped15: 80, 1984

23. Witte H, Glaser S, Rother M: New spectral detection and elimination algorithms of ECG and EOG artefacts in neonatal EEG recordings. Med & Biol Eng & Comput 25: 127, 1987

24. Witte H, Zwiener U, Michels W, Griesbach G, Hoyer D: Power spectral mapping (PSM) of neonatal EEG - progress by using intelligent instrumentation. In: Progress in function analysis by computer technologies, Eds. Willems JL, Van Bemmel JH, Michel J, Elsevier, North Holland. 351, 1988

M. ROTHER, M.D.
Löbderstr. 3.
6900-Jena, GDR