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EFFECTS OF UNILATERAL SECTION OF THE BRAIN STEM AFTER MESIAL CEREBRAL INCISION

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Recently, seven young, healthy chimpanzees were subjected to an experimental surgical procedure known as mesial cerebral incision.[1] This procedure consists of incision and separation of corpus callosum, lamina terminalis, floor of third ventricle, pineal region, pons, cerebellum, and medulla oblongata. Actually, it is staged in two parts. The first, a parasagittal craniotomy, provides access to corpus callosum, the third ventricle and its floor, as well as the pineal regions. In this first stage, the diaphragma sellae can be visualized if care is taken during the incision of the third ventricular floor (FIGURE 1). Some time after recovery, a suboccipital craniectomy is performed (FIGURE 2). This is the second stage of mesial cerebral incision and provides exposure of vermis and medulla, both of which are incised under direct vision (FIGURE 1). The pons must be separated indirectly through the rostral apex of the suboccipital craniectomy on the caudal part of the exposure provided in stage 1. The basilar artery can be felt pulsating at the lowest extremity of this incision. In all stages and parts of mesial cerebral incision, gentle blunt separation of white fibers with the Sachs dissector permits almost bloodless access to the various anatomical levels and structural areas. For example, the dissector is introduced into the full depth of the callosum through a small incision in the pia. Then it is drawn slowly backward (or forward) with pressure sufficient to separate the white fibers but not to tear blood vessels. The resistance of the latter is greater, and, with some practice, vessels can be spared in a series of fenestrations while the surrounding fibers are clearly and cleanly cut.

Five more chimpanzees have undergone this procedure since the original report, bringing the total to twelve.

The techniques of mesial cerebral incision have been extended by microdissection in the macaque so as to expose the contents of the third ventricle and thus expose the anterior and mesial parts of the thalamus.[2] Thereafter, the rostral thalamus was sucked out by micropipette. This local unilateral microexcision resulted in a chronic epileptic animal, which has been described in detail by Milhorat and Baldwin.[2,3]

The primates subjected to mesial cerebral incision recover promptly and can return to usual cage or run activity within ten days after either operative stage. These chimpanzees have exhibited normal bilateral synergistic motor activity except in two cases, in which a monoparesis of right or left upper extremity occurred.

Five such animals that did not show any neurological deficit after mesial cerebral incision were also subjected to unilateral incisions of the brain stem on right or left sides. The incision was made just below the inferior colliculus and calculated so as to extend to, but not across, the midline, while sparing the cerebral peduncle. In order to accomplish this brain-stem section, the animal was carefully anesthetized with endotracheal halothane and, after shaving of the head, was postured for a left (or right) occipitoparietal craniotomy. Following aseptic preparation, the scalp was infiltrated with 1/1,500 nupercaine solution containing

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1/200,000 of adrenalin. Once draped, the craniotomy was done so that the occipital dura was exposed in a triangular opening, with the lateral sinus at its base. Then, 60 mg of urea were given (intravenously), and the dura was incised so as to create a flap and expose the lowermost gyri of lateral occipital cortex. This was covered with moist plastic, with the lower edge inserted between the occipital lobe and tentorium. In the head position designed for the procedure, there is some "fall away" of brain from tentorium at this stage. As this occurs, the plastic is gently extended toward the brain stem and along the inferior occipital cortex, which it protects. Next, spontaneous "fall away" of brain from tentorium is encouraged by gently pushing moist packs of cotton inwards along the tentorium. These cannot touch the cortex because of its protecting plastic, but they do serve as soft retractors. Once the effect of urea extends this brain displacement, a vein

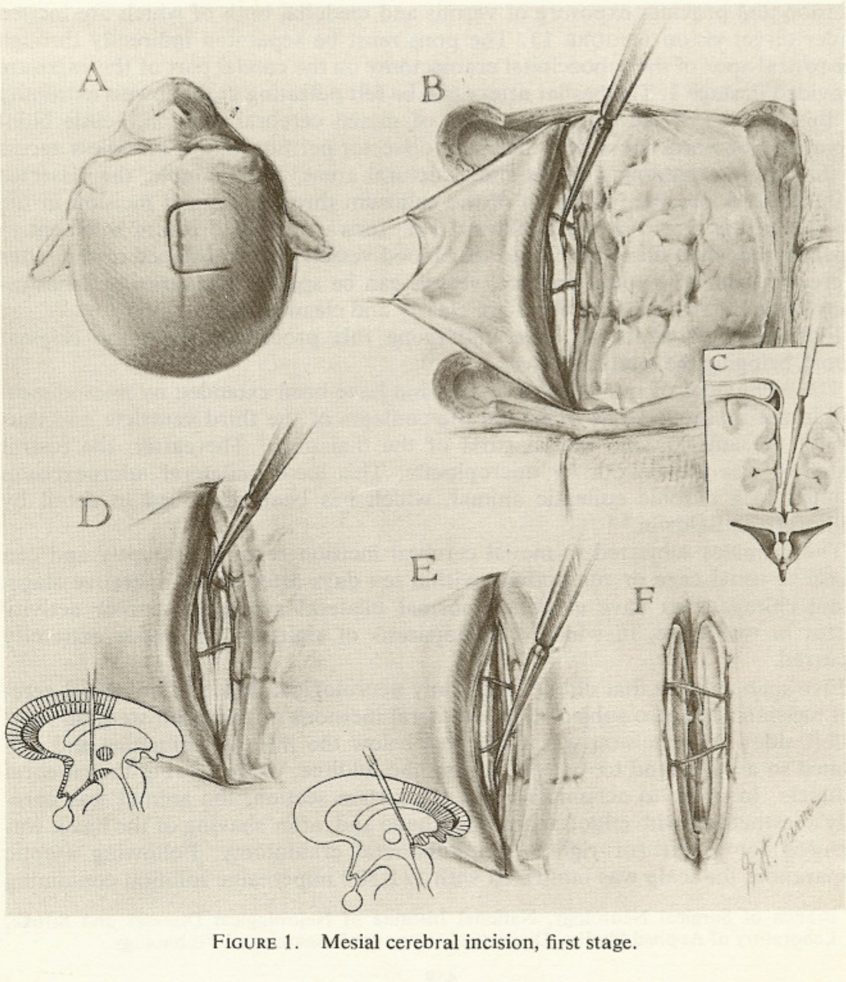

FIGURE 1. Mesial cerebral incision, first stage.

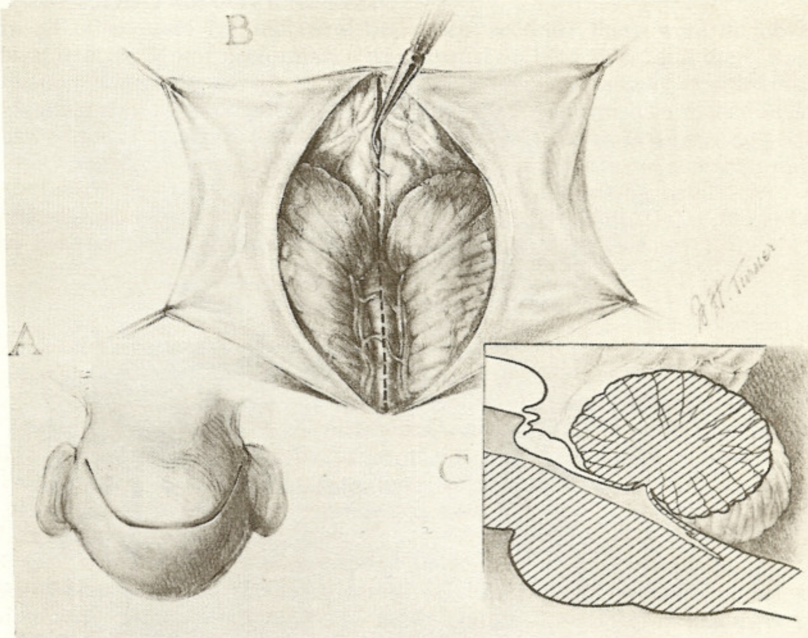

FIGURE 2. Mesial cerebral incision, second stage.

draining lower occipital cortex into lateral sinus is placed on stretch. It must be incised between clips (or cauterized) in such a way as to further the exposure and reach the tentorial edge. Once this edge has been visualized, additional gentle retraction may be necessary to identify the stem and expose an area adequate for incision. This manual retraction, however, need not be long sustained, because further insertion of cotton pads in depth provides an adequate and safer substitute. Finally, the pia of the brain stem is punctured with a no. 15 blade, and then the section is carried out by Sachs dissector. This instrument can be inserted gently to the desired depth and drawn from dorsal to ventral. In so doing, it is not difficult to avoid the pyramidal fibers, as shown by the artist in one part of FIGURE 3.

After subtotal hemisection of the brain stem, these animals made an uneventful recovery, except in one case. In this subject, the procedure was repeated on the left side one week after its successful completion on the right. Immediately after recovery from the last general anesthetic, this animal had the appearance of a patient with brain-stem injury, which Cairns described as akinetic mutism.[4] It lay supine, with little or no spontaneous movements, but seemed to follow noise and light with conjugate movements of the eyes. Pupils were small and equal, and reacted sluggishly, but equally, to light, Chewing movements followed installation of semisolid food in the mouth at first, but soon a tracheostomy and tube feeding were required. There was bilateral increase in tone without hyperextension, and the plantar responses were in flexion. Abdominals were absent. The animal did not move in response to pain, heat, or cold, but would readjust posture after passive flexion or extension of extremities. Occasionally, extremity movements seemed purposeful, and the animal always gave the impression of wakefulness.

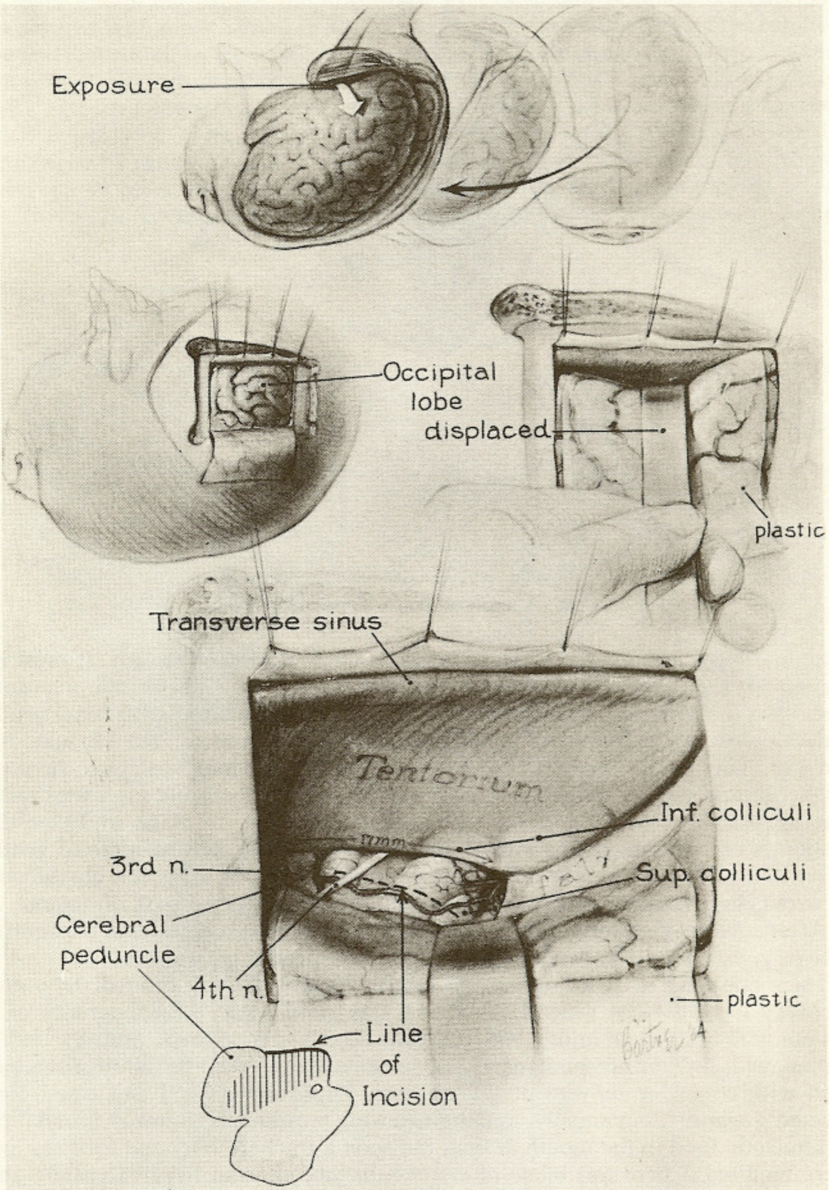

FIGURE 3. Subtotal hemisection of brain stem.

There was no evidence of decerebrate state. Despite intensive nursing care, postoperative survival was only three weeks.

In all other cases (of unilateral brain-stem section) there were no obvious clinical deficits. Motor performance was normal on both sides, and there was no indication of sensory deficits by observation. (Adequate sensory examination in the waking state is impossible.) Nor was there any evident disturbance in individual or social behavior (FIGURES 4A and 4B). Moreover, their sleeping habits did not change postoperatively, and their day/night cycle remained the same as that of their unoperated peers. Indeed, feeding and drinking habits were also unchanged, and there was no significant weight change. Similarly, serum electrolytes were comparable in value before and after operation (TABLE 1).

Electroencephalographic Examinations

At least three weeks after brain stem section (or previous mesial cerebral incision), electroencephalographic records were made in each case. The subject was immobilized by intravenous succinylcholine and ventilated by endotracheal air provided by a pump. Needle electrodes were driven into the periostium after local anesthesia and aseptic preparation of the scalp. These were carefully placed in frontal, parietal, and occipital positions, so as to assure symmetry in each set of placements. An electrocardiogram was also recorded on one channel of the Offner machine.

Once the preparation was considered stable, as indicated by pulse rate, blood pressure, and skin and rectal temperatures, the EEG and EKG were recorded continuously for approximately one hour. During this time, six channels were recorded on strip charts at a paper speed of 15 mm/second. Some records were also made on analog tape. An Ampex FR 1300 portable analog recorder was used for signals obtained from the preamplifiers of the Offner with a tape frequency band width of 1250 Hertz.

Strip charts were digitized by means of a Gerber X-Y Scanner, thus obtaining punch-card output suitable as input for the IBM 360/50. As many as six traces were digitized simultaneously with a sampling rate of approximately 60 samples/trace/second. The data recorded on analog tape were digitized via a LINC computer, which controls the analog to digital conversions and writes a digital magnetic tape suitable as input to the IBM 360/50. Again, six channels were digitized simultaneously, with use of sample and hold electronics. A sampling rate of 200 samples/channel/second was utilized.

A spectral analysis[5] was performed. A covariance function:

$$\Phi_{12}(\tau) = \lim_{T \to \infty} \frac{1}{2T} \int_{-T}^{T} f_1(t)\ f_2(t+\tau)\ dt \qquad (1)$$

was calculated for a pair of EEG signals f_1 and f_2. A spectral estimate:

$$G(\omega) = \frac{1}{2\pi} \int_{-\infty}^{\infty} \Phi_{12}(\tau)\ e^{-i\omega t}\, d\tau \qquad (2)$$

was then computed:

A preoperative control record is shown in FIGURE 5. Auto- and cross-spectral control estimates that have been smoothed or hanned[6] are also shown. FIGURE 6 illustrates comparable estimates for a primate that had undergone a mesial cerebral incision.

After recovery from this interhemispheral separation, five animals also under-

FIGURE 4A. A, after mesial cerebral incision (Napoleon); B, after mesial cerebral incision and subtotal hemisection of brain stem (Napoleon).

FIGURE 4B.

TABLE 1

ELECTROLYTE STUDY: PRE- AND POSTOPERATIVE VALUES IN MILLIEQUIVALENTS/LITER*

		4/5/67		4/6	4/7	4/8	4/12	4/19	4/26	5/3	5/10	5/17	5/19/67
	Preop.	1 hr	4 hr	24 hr	48 hr	72 hr	7 days	14 days	21 days	28 days	35 days	42 days	44 days
Na.	139	139	134	139	135	135	135	136	135	135	140	142	134
K	4.4	3.7	4.9	3.6	4.1	3.7	4.2	4.1	2.9	2.7	4.3	3.4	3.6
Cl.	110	112	109	QNS	110	100	105	110	105	100	100	100	92

* Chimpanzee, Napoleon. Surgery on April 5, 1967.

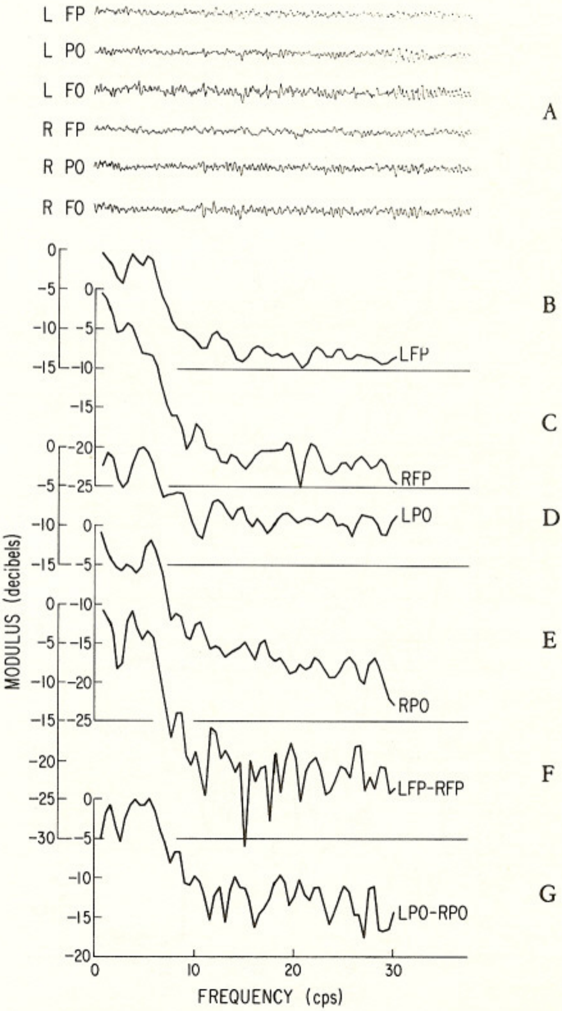

FIGURE 5. Preoperative control record and spectral estimates. A, electroencephalograph; B, autospectrum for left frontoparietal; C, autospectrum for right frontoparietal; D, autospectrum for left parietooccipital; E, autospectrum for right parietooccipital; F, cross-spectrum for left frontoparietal and right frontoparietal; G, cross-spectrum for left parietooccipital and right parietooccipital.

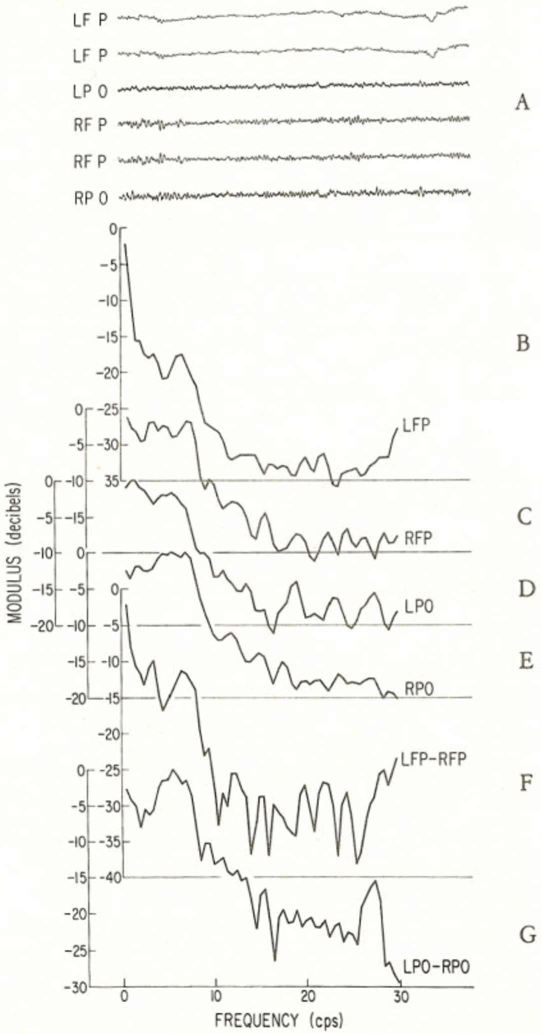

FIGURE 6. Record after mesial cerebral incision with corresponding spectral estimates. A, electroencephalograph; B, autospectrum for left frontoparietal; C, autospectrum for right frontoparietal; D, autospectrum for left parietooccipital; E, autospectrum for right parieto-occipital; F, cross-spectrum for left frontoparietal and right frontoparietal; G, cross-spectrum for left parietooccipital and right parietooccipital.

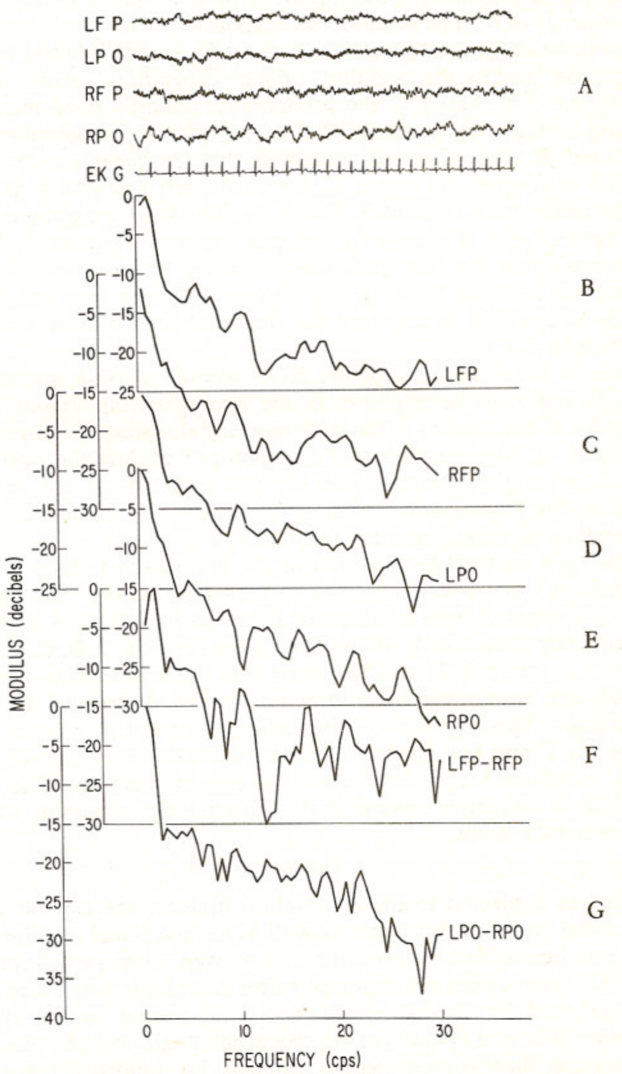

FIGURE 7. Record and spectral estimates subsequent to right subtotal hemisection of the brain stem after mesial cerebral incision. A, electroencephalograph; B, autospectrum for left frontoparietal; C, autospectrum for right frontoparietal; D, autospectrum for left parietooccipital; E, autospectrum for right parietooccipital; F, cross-spectrum for left frontoparietal and right frontoparietal; G, cross-spectrum for left parietooccipital and right parietooccipital.

went unilateral subtotal hemisection of the brain stem. FIGURE 7 presents the EEG record and spectral distribution of such a chimpanzee with the brain-stem section on the right side. In each case, the spectral amplitudes in decibels are shown relative to maximum power present plotted versus frequency. A fundamental frequency of 0.5 cps was used throughout.

The preoperative (control) record (FIGURE 5, A) has a broad frequency content, as demonstrated by the modulus of the autospectra in various traces (FIGURE 5, B, C, D, and E). Actually, the preoperative records have more frequencies contributing significantly to the EEG than any of the postoperative records that were analyzed. It is also interesting to note that the control record has a larger contribution of frequencies above 12 cps in the left (FIGURE 5, B and D) than in the right hemisphere (FIGURE 5, C and E). The frequency content common to both the hemispheres is shown by the cross spectra (FIGURE 5, F and G). It should be noted that the frequency content of the left parietooccipital and right parietooccipital (FIGURE 5, G) are in better synchrony over the full frequency band of .5–30 cps than is apparent for the left frontoparietal and right frontoparietal (FIGURE 5, F).

After mesial cerebral incision, the EEG records show a marked asymmetry between left and right hemispheres in the frontoparietal regions (FIGURE 6, B and C), which is not evident in the parietooccipital regions (FIGURE 6, D and E). An analysis of the frequency content common to both left and right hemispheres shows that the parietooccipital region (FIGURE 6, G) has a symmetry from .5–8 cps, while in the frontoparietal region, the amplitude attributable to common frequencies falls off sharply at 3 cps (FIGURE 6, F).

After the right subtotal hemisection of the brain stem (which followed mesial cerebral incision), there was a marked slowing down in the EEG (FIGURE 7, A). The spectral content of both frontoparietal and parietooccipital is now dominated by low frequency components of less than 4 cps (FIGURE 7, B, C, D, and E). The cross spectra (FIGURE 7, F, and G) show that the frequencies common to both hemispheres are dominated by components below 4 cps and decrease sharply above that point. Spectra from corresponding preoperative records (FIGURE 5, F and G, and 6, F and G) illustrate a sharp decrease in amplitude at twice that frequency, or about 8 cps. Once more the synchronization of left and right is more obvious in frequency content in the parietooccipital region, as compared to the frontoparietal regions.

Summary

Chimpanzees subjected to mesial cerebral incision are capable of synergistic and other usual motor performance as well as normal social reactions despite severance of interhemispheral connections. Moreover, subsequent subtotal hemisection of the brain stem does not materially alter neurological or social performance, nor is it followed by disturbance of nocturnal-diurnal cycles. However, both operations are followed by marked electroencephalographic changes. After mesial cerebral incision, there is an evident asymmetry, but following brain stem section, the record is comparatively slower, particularly on the side of section.

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