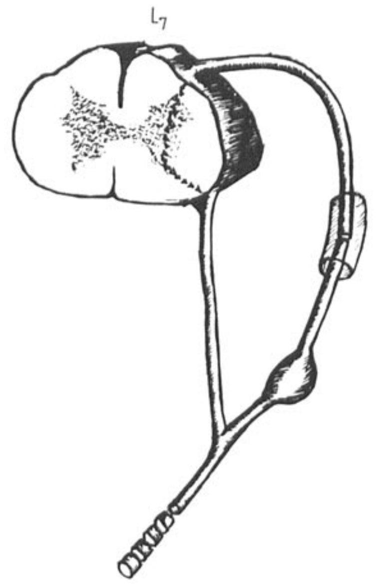

Fig. 1. A dorsal root anastomosis proximal to the dorsal ganglion.

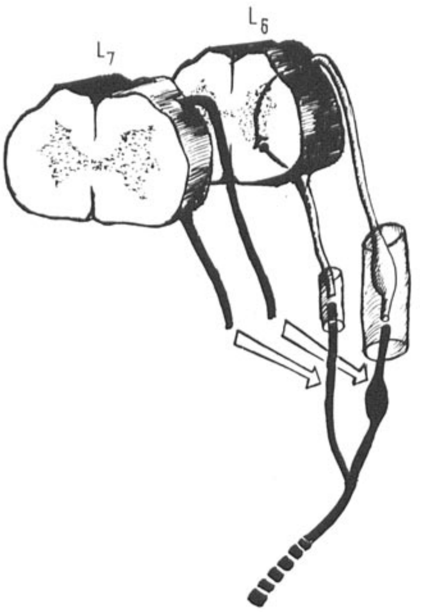

Fig. 2. A heterogeneous dorsal root anastomosis distal to the rostral dorsal ganglion. (The corresponding ventral roots were additionally reconstructed.)

centrifugal direction along the newly-constructed afferent pathway. The surgical procedure involved an additional anastomosis between corresponding ventral roots, the functional success of which has been previously reported (CARLSSON et al.[3], THULIN and CARLSSON[4]). After subsequent time for regeneration, the bioelectrical tests indicated functional restoration of the afferent and efferent pathways and their intersegmental connections.

This model of anastomosing dorsal roots constitutes a technique for by-passing afferent activity to levels proximal to a cauda lesion or a cord transection, which might be of clinical value in selected types of spinal injuries.

Résumé. La régénération des racines postérieures, précédemment sectionées, a lieu exclusivement dans leur parties neurilemmales. Se servant d'une méthode modifiée d'anastomose des racines, leur régénération fonctionelle est démonstrée par des techniques électrophysiologiques.

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Department of Neurosurgery, University of Gothenburg, Gothenburg (Sweden), October 6, 1966.

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Chronic Split Brain Stem Preparation: Effect on the Sleep-Waking Cycle

It has been possible to identify certain structures, important to the maintenance of the normal sleep-waking cycle, owing to observations following complete transections or localized lesions at various levels of the brainstem. However, if the same sections or lesions were executed unilaterally, after a medial sagittal section of the brainstem, it would allow electrophysiological comparison between 'normal' and experimental halves of the brainstem having the same 'milieu intérieur'. For this reason we carried out complete midline longitudinal sections of the brainstem. This report will be concerned only with the findings observed after this section.

Methods. In 25 cats under nembutal narcosis, we opened a 12 mm hole in the skull centered about the occipital crest, and aspirated 2–3 mm of the cerebellum on each side of the midline so that full visualization of the floor of the 4th ventricle was achieved from the opening of the aqueduct of Sylvius to the obex. We inserted a flexible blade edge (20 by 3 mm, attached to a light glass rod) in the midline, guiding its descent straight down until contact was made with the base of the skull, and gently moved it 2 or 3 times in a postero-anterior direction from the P8 (P12) to A5 (A7) levels. Electrodes were implanted bilaterally in both lateral geniculate bodies (LGB), over frontal, parietal and occipital areas of cortex and in posterior neck muscles. A precordial electrode monitored heart rate and respiration. Round-the-clock recordings were made during the entire survival period.

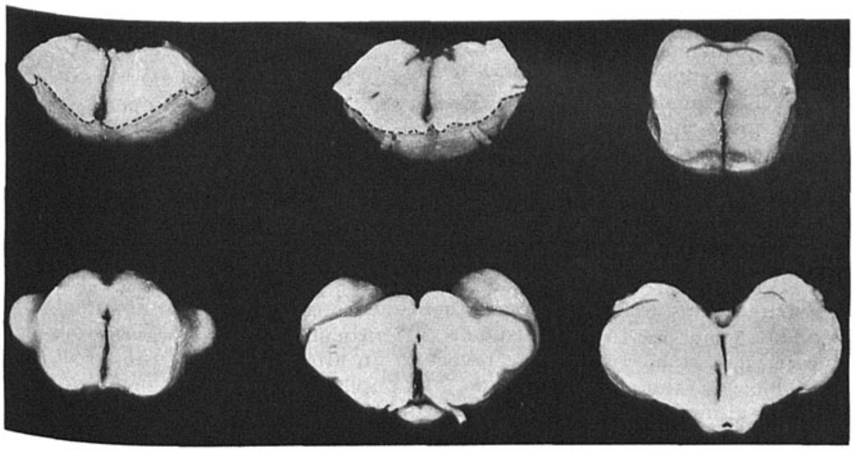

Fig. 1. Frontal views of various levels along the course of a representative midline section of the brainstem. (Drawn dashed lines indicate the true inferior boundaries of each section.)

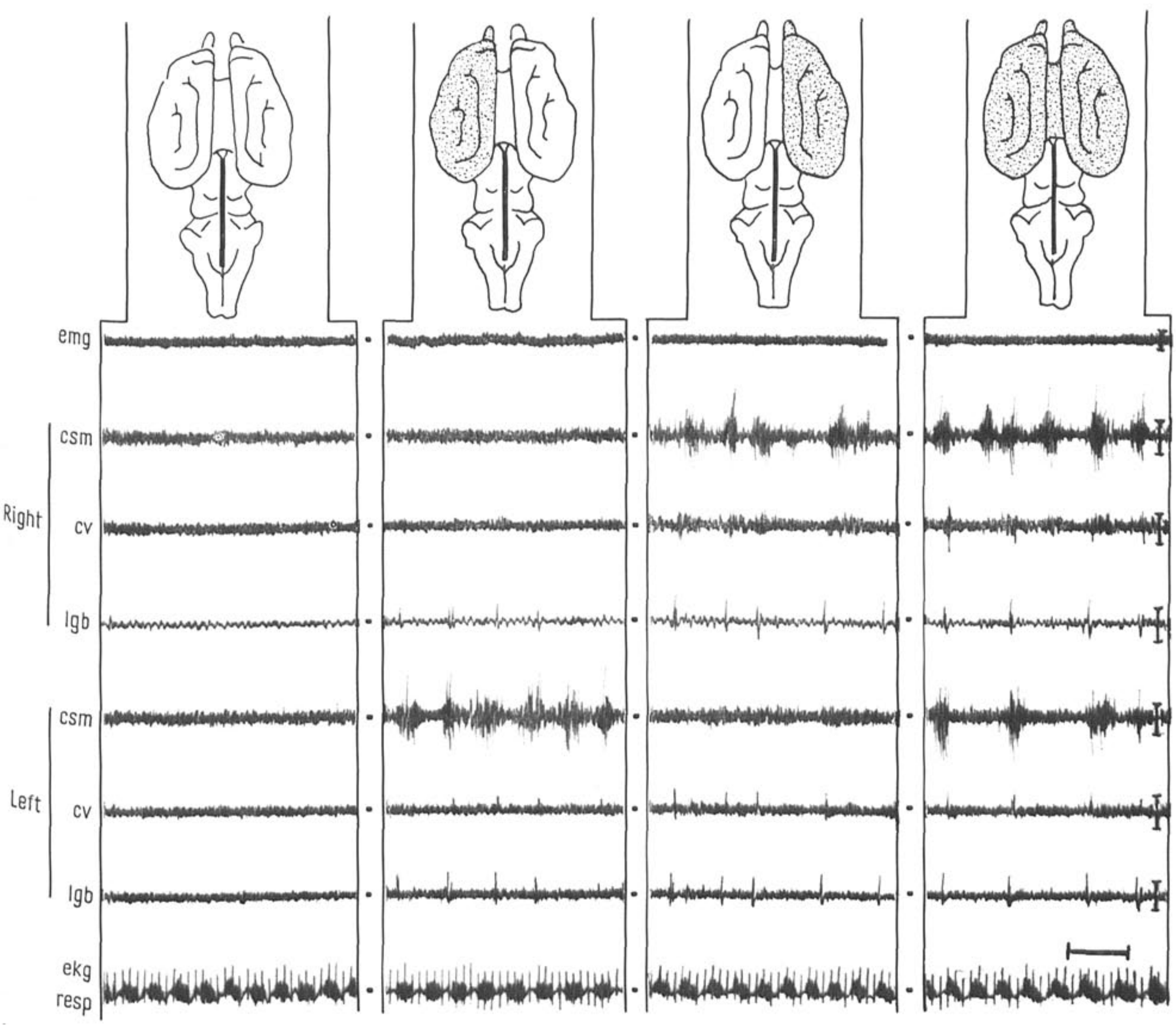

Fig. 2. 4 sequential samples of polygraphic recording from the split brainstem preparation shown in Figure 1. emg = electromyogram; csm = sensorimotor cortex; cv = visual cortex; lgb = lateral geniculate body; ekg = pulse; resp = respiration. Shading of a hemisphere indicates elaboration of a SWS pattern. From left to right the sections show: (1) bilateral electrocortical arousal; (2) unilateral arousal and SWS on the left; (3) unilateral arousal and SWS on the right; (4) bilateral SWS. Note the asymmetrical and alternating characteristics of the hemispheric patterns in the middle 2 tracings. Spike discharges are present in both LGBs when either one or both hemispheres show a spindle pattern. Scale = 3 sec; 50 μV.

Results. Of 25 cats, 14 died during the procedure or within 1 day. Death was usually attributable to hemorrhage or respiratory cessation if the section was extended to within 1–2 mm of the obex. The remaining 11 animals survived 3, 3, 3, 5, 10, 14, 23, 31, 31, 51 and more than 210 days, respectively. Most of the deaths were due to complications not related directly to the effects of the split, to secondary procedures, or to sacrifices for purposes of histological examination.

Sections were complete in the vertical plane, reaching the inferior limit of the brainstem (Figure 1). The commissure above the aqueduct of Sylvius was spared in most of the cats. Sections were between 0.5 and 1.5 mm in width. Their axes were usually purely vertical, but in several instances slightly oblique, reaching the base of the brainstem approximately 1 mm lateral to the midline. In 4 cats, the sections reached the posterior limit of the 3rd ventricle. The caudal aspect of the sections was generally extended to the P8 to P12 levels. No lesions were made between the mammilary bodies because the clivus prevented access of the blade.

Post-operatively, the animals retained movement in all extremities, but the considerable extensor rigidity and ataxia precluded walking or spontaneous eating. However, all the cats took nourishment well and some showed grooming and scratching behavior as well as righting posture for defense.

There was a lasting palsy of lateral ocular movements in all the cats, but recovery of vertical or rotatory movements was sometimes observed. Most animals showed paralytic mydriasis which frequently cleared with time on one side as a result of unilateral impairment of the 3rd nucleus. In most of the preparations, at least 1 pupil retained normal reactivity showing mydriasis with arousal and miosis with sleep. A striking feature was the apparent blindness of the animals. They did not respond to threat or to significant objects despite blink and pupillary responses to light. This has been previously seen with midline sections at the level of the 3rd N. nucleus[1,2].

As for the sleep-waking cycle, the animals' state alternated only between arousal and slow wave sleep (SWS) for 1–2 weeks following the procedure. In continuous 24 h recordings, the % of wakefulness was sustained at remarkably high levels: 80–92% the first 2 weeks and 75–80% during subsequent weeks. Paradoxical sleep was usually absent during the first week. Its proportion remained low (1–5%) thereafter and no 'rebounds' were observed. SWS occupied the remainder of the time (15–25%). These levels are strikingly different from normative data in the cat in which proportions of wakefulness and paradoxical sleep are 28–31% and 15–16% respectively[3,4].

Though the % of paradoxical sleep in the split brainstem preparation was small, its reappearance was very distinct, and it followed periods of SWS. It always appeared bilaterally and showed the typical characteristics of paradoxical sleep.

On the other hand, we have observed alternating and bilaterally asynchronous appearances of SWS in the 2 hemispheres in 6 of 11 surviving cats (Figure 2). The phenomenon of alternation was observed only in those preparations with the longest sections: either hemisphere might exhibit the spindles and slow waves before the other, though in some cats one side generally predominated in this initiation. There was clearly a gross mismatching of hemispheric EEG patterns for considerable periods of time (5–25 min). Over the course of many days, 1 hemisphere usually showed a higher SWS % than the other.

Spikes were present continuously in both LGBs and visual cortices during the first 2–3 post-operative days (Figure 2). These resembled the spikes induced by reserpine in intact cats[5]. Thereafter, the spikes were seen only during the brief periods of paradoxical sleep.

During the 75–92% of the time when both hemispheres manifested a desynchronized EEG, the animals were behaviorally awake. During asynchrony of the EEG pattern the animals were always behaviorally asleep. They lay motionless without meowing. In the event of stimulation, the hemisphere currently showing slow waves would immediately revert to an aroused pattern consistent with the other side. The pupils again would become mydriatic, and the animal would show evident waking behavior.

After the completion of our experiments, a report by BERLUCCHI[2] appeared which describes momentary asynchronies of specific wave forms in SWS after sectioning of the corpus callosum. In several cats in which the lesion was extended by him to the rostral brainstem, 1 hemisphere in particular always showed earlier synchronization and retarded desynchronization persisting up to 40 sec. But in our complete brainstem splits we observed that *either* hemisphere can lead with slow wave activity. The *alternation* of SWS patterns from one to the other hemisphere suggests that in our preparation an 'uncoupling' phenomenon is involved rather than asymmetrical injury.

Since the split brainstem cat is a very stable preparation, it may have useful applications in many types of neurophysiological interventions in the brainstem. With this preparation responses can be monitored in a symmetrical structure unilaterally and independently from responses in its opposite number[6].

Résumé. La préparation du chat à tronc cérébral dédoublé peut être conservée pendant plusieurs mois en bon état. Elle se caractérise par un très haut niveau de vigilance avec réduction du sommeil lent et du sommeil rapide. Lorsque la section sagitale médiane est très étendue, alternativement chaque hemisphère peut présenter un tracé lent tandis que l'autre hemisphère présente un tracé rapide; cette asynchronie peut durer jusqu'à 25 min.

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