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AN EVOKED POTENTIAL MAPPING OF TRANSCALLOSAL PROJECTIONS IN THE CAT

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SUMMARY — In ten adult cats anesthetized with ketamine hydrochloride the neocortex was exposed and rectangular pulses (1msec, 0.5 Hz and variable intensity) were applied to discrete points of one side and transcallosal evoked potentials were recorded from the other. The stimulation and recording positions were determined on a cartesian map of most of the exposable neocortical areas and the potentials were analysed as to their components, voltage and latency. Passive spread and electrotonic potentials and the effects of increasing frequency were also analysed. The results showed large transcallosal potentials in some areas and an increase of potentials in the caudorostral direction, attaining the highest values in anteromedial areas of the suprasylvian gyrus. Confirming anatomical studies, a few silent spots were found in the motor and somesthetic cortex and in restricted posterior regions of the visual cortex, where small or zero voltages occurred. While causing weak contralateral potentials, stimulation of some posterior sites provoked high voltage potentials in anterior regions of the side being stimulated and in the corresponding area of the opposite site. These posterior sites are poorly interconnected by the corpus callosum. The L-shaped indirect connection described in this work may be involved in some types of epilepsy and may explain the effectiveness of partial callosotomy in their treatment.

Mapeamento por potencial evocado das projeções transcalosas no gato.

RESUMO — Em dez gatos anestesiados com cetamina (Ketalar) o neocórtex foi exposto e pulsos retangulares (1 ms, 0,5Hz e intensidade variável) foram aplicados a pontos discretos de um lado enquanto se registravam os potenciais evocados no outro lado. As posições de estimulação e registro eram determinadas em mapa cartesiano que abrangia quase todo o neocórtex. Os potenciais foram analisados quanto aos seus componentes, voltagem e latência. A difusão passiva, potenciais eletrotônicos e os efeitos do incremento da frequência de estimulação sobre os vários componentes foram analisados. Os resultados mostram a presença de grandes potenciais evocados transcalosos em algumas regiões, com incremento de sua amplitude no sentido caudo-rostral, sendo máximos em áreas anteromediais do giro suprasilviano. Confirmando estudos anatômicos, em algumas regiões do córtex somatomotor e visual foram registrados potenciais bastante reduzidos ou ausentes. A estimulação de algumas áreas posteriores causava o aparecimento de pequenos potenciais em sua área homóloga contralateral ao mesmo tempo em que grandes potenciais eram registrados em áreas anteriores ipsi- e contralateralmente, constituindo uma conexão em L ainda não descrita. É possível que tal conexão esteja implicada em alguns tipos de epilepsia e possa explicar em parte a eficácia de calosotomias parciais para seu tratamento.

The corpus callosum, which is the largest brain commissure, plays a key role in interhemispheric integration and as a pathway mediating the spread of secondarily generalized seizures [11,17,19-21,25]. Its relevance in pathology of the brain led to several experimental and clinical studies [1,9,16,27,28]. Of great significance also have been those related to anatomical distribution and topography of callosal fibers, made in the rat [12],

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cat [6,8,10,24], monkeys [13-15,23], and humans [26]. Transcallosal evoked potentials were first studied by Curtis [4,5] by the time oscillographic recording of EEG and evoked potentials had been introduced in neurophysiology. He mapped most of the exposable convexity of the cortex in terms of amplitude of the symmetrical contralateral transcallosal evoked potentials and their topography and time course in a few cortical sites. Morphology and origin of transcallosal evoked potentials were studied much later[2,3].

In this paper a detailed analysis of the location of transcallosal evoked potentials in the cat is reported, including a novel type of projection.

MATERIAL AND METHODS

Ten adult cats of either sex were anesthetized with ketamine hydrochloride and, after having been fixed to a stereotaxic instrument were subjected to an extensive bilateral craniotomy to expose most of the neocortex. Only a narrow saggital strip of bone about two mm wide was left intact above the longitudinal sinus. For localization purposes a map was prepared as a Cartesian matrix made up of one milimeter squares, which were defined as sites for stimulation and contralateral recording. With two electrode holders the system was stereotaxically calibrated so that the real cortical sites would match the Cartesian matrix. This procedure allowed plotting a detailed distribution of the stimulation sites and of those from which the potentials were recorded (Fig. 1).

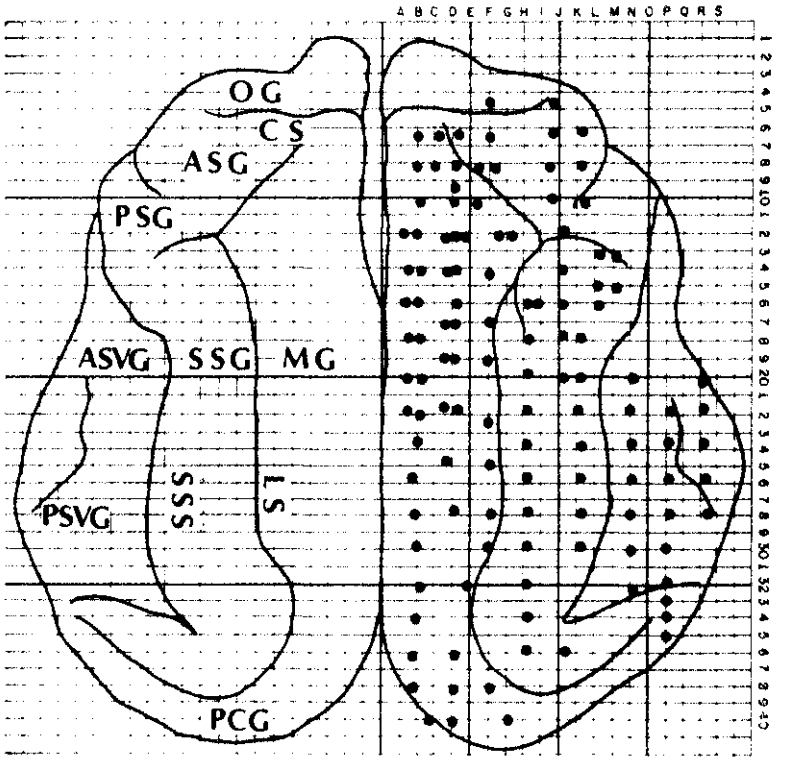

Fig. 1 — Schematic representation of the cat neocortical areas. Left: OG, orbital gyrus; ASG, anterior sigmoid gyrus; PSG, posterior sigmoid gyrus; MG, marginal gyrus; SSG, suprasylvian gyrus; ASVG, anterior sylvian gyrus; PSVG, posterior sylvian gyrus; PCG, posterior compositus gyrus; CS, cruciate sulcus; LS, lateral sulcus; SSS, suprasylvian sulcus. Right: dots representing sites of stimulation. Letters from A to S: meridians. Numbers from 1 to 40: parallels.

Stimulation of 138 sites with rectangular pulses of variable frequency (0.5 to 10 Hz), duration (0.1 to 3 ms) and current (0.5 to 6 mA) was performed through bipolar silver ball electrodes 0.8 mm in diameter, 1 mm apart. For mapping purposes only 1 Hz, 0.5 ms and 4 mA pulses were used. The recording electrode was also a silver ball 0.8 mm in diameter. The electrodes could be placed, by means of an electrode carrier, on well defined sites of most of the neocortex according to the Cartesian map. For each stimulated site an evoked potential was first recorded from the homologous contralateral area. Afterwards, potentials were recorded from sites along the anteroposterior parallels and then from the dorsoventral meridians, having the homologous locus as its center. For each site 20 potentials were electronically averaged.

RESULTS

Morphology of the transcallosal evoked potentials was in general similar to those reported by other authors (*2-5*). As seen in Fig. 2 a high amplitude zone was found in the middle and anterior parts of the cortex, comprising the marginal and suprasylvian gyri, in which the voltage diminished in both anterior and posterior directions. The lowest amplitudes were recorded from the visual and more rostral cortical areas. The

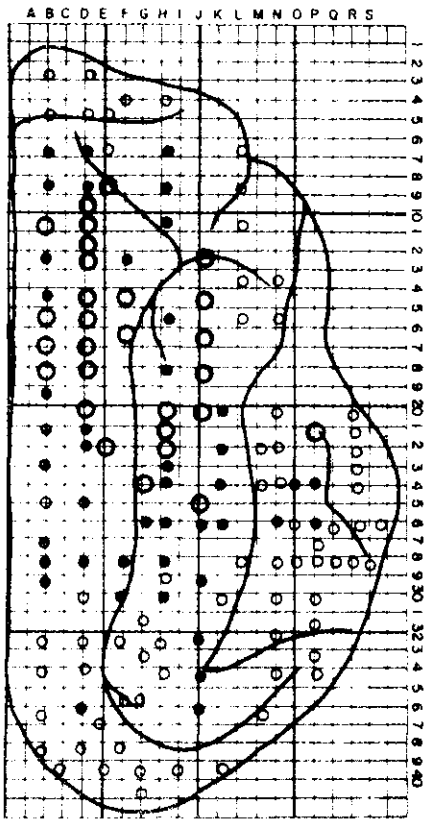

Fig. 2 — Relative amplitude of transcallosal evoked potentials as a function of their location on the cortex. °, *low voltage;* •, *medium voltage;* ○, *high voltage.*

potentials had an early and a late component. The former, generally biphasic or triphasic, started after a short latency, ranging from 2 to 10 ms and stood frequency increments up to 50 Hz or more without changing its morphology. The late component was more homogeneous, lasted longer (15 to 30 ms) and appeared 10 to 25 ms after the stimulus.

Slight increases in frequency, just above 1 Hz, reduced its amplitude. It was virtually abolished by stimuli delivered at frequencies beyond 10 Hz.

In what spatial distribution of the evoked potential is concerned, two patterns were found. In one, the potentials had the highest voltages over or near the contralateral site homologous to the stimulation locus, declining in the anterior, posterior, medial and lateral directions (Fig. 3). As to the other, stimulation of a few sites located posteriorly at the marginal and suprasylvian gyri evoked small responses from the homologous areas while large potentials were elicited over anterior areas, mainly in the medio-anterior region of the marginal and suprasylvian gyri (Fig. 4). These responses were evoked from areas poorly interconnected by the corpus callosum, according to Ebner and Myers (6) map (Fig. 5).

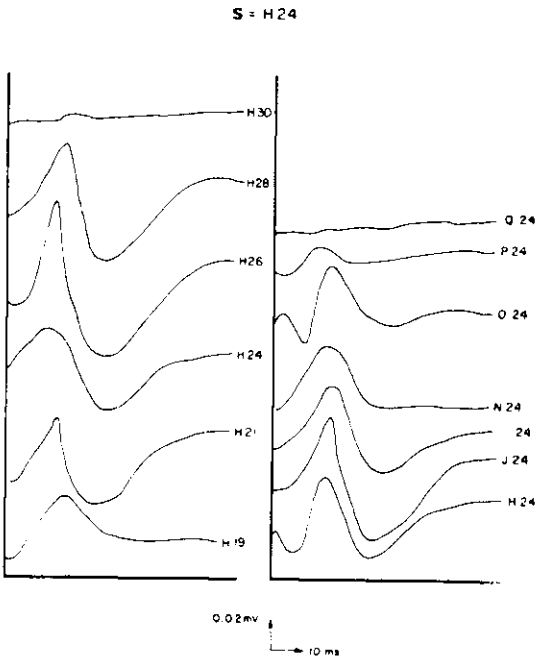

Fig. 3 — Left: transcallosal evoked potentials as a function of position along one of the cortical meridians (H, see fig. 1) in response to stimulation of the square H.24. Right: potentials recorded from parallel 24; notice the increase in voltage and decrease in latency from H.30 and H.19 toward H.26.

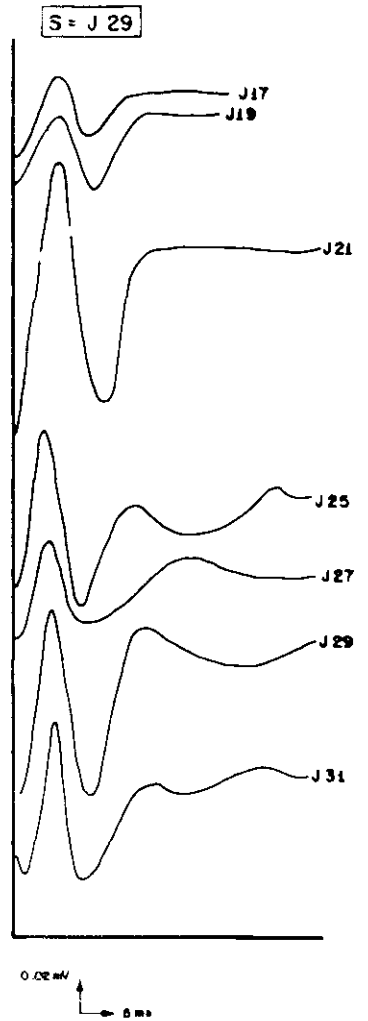

Fig. 4 — Time course of the transcallosal potentials evoked non-symmetrically from a contralateral area. Notice the deviation of the higher amplitude zone from J.29 to J.21. Stimulus (S) at J.29.

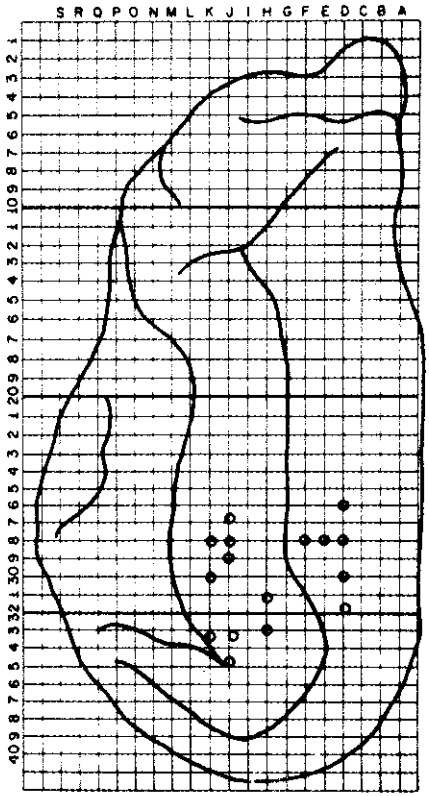

Fig. 5 — Areas whose stimulation provoked non-symmetrical transcallosal responses.

COMMENTS

The above described experiments showed that single pulse stimulation of discrete sites of one side of the cerebral cortex in the cat causes complex evoked potentials on the corresponding site of the contralateral hemisphere. The transcallosal evoked potentials are distributed across and along the cerebral cortex essentially in agreement with Curtis [4,5]. The high voltage potentials found in some areas are conceivably related to a high density of callosal fibers and/or special intracortical connectivity that recruits a larger number of neurons. The early and late components reflect most probably, the involvement of mono and polisynaptic pathways, respectively, inasmuch as the first showed a marked resistance to increasing frequencies and appeared after short latencies, being always present, in sharp contrast to the longer latency, frequency sensitivity and instability of the late component.

Studying the electrophysiological properties and mechanisms was not a main concern of the present research. Accordingly, the subject will not be discussed at length here. It is noteworthy, however, that the first component of the evoked transcallosal potentials displays some features compatible with the hypothesis that they reflect the activation of axons of the projecting contralateral neurons. This is in partial agreement with the accepted origin of the early sensory evoked potentials as presynaptic in nature. The late component is surely due to the activation of post-synaptic neurons, as seen by its susceptibility to increasing frequencies of stimulation and instability, in addition to its longer latency in relation to the early component.

The unexpected response pattern disclosed by recording from rostral areas of the neocortex while stimulating the more posterior parts deserves a proper study to be fully understood. The potentials recorded from non-symmetrical lateral areas indicate that information from a specific site may be transferred to non-symmetric, distant

areas through indirect connections. That might be explained by assuming that the thalamus, receiving information from both the ipsilateral and the contralateral cortex, activates the cortical area far from the symmetric locus. There could be a massive oblique callosal interhemispheric connection between anterior areas of one side and posterior areas of the other. A thalamic-mediated process, if involved, would be difficult to recognize in our experiments. An oblique direct connection of the corpus callosum cannot either be invoked to explain the non-symmetric callosal response since recent anatomical data have shown it to have not this type of connection [17]. The assumption of an intrahemispheric pathway linking the ipsilateral posterior and anterior areas has to be demonstrated by means of callosal and percortical sectioning experiments. It is noteworthy also that areas thus interconnected coincide with those poorly interconnected by the corpus callosum, revealing the possibility of non- symmetric callosal activation by means of transcallosal pathways (from one side to the other) in series with intrahemispheric pathways (mainly in the postero- anterior direction). Such a connection would provide the anatomical substrate for integration of several functions which require, for instance, visuomotor interplay.

Severing the corpus callosum has been used as a palliative surgery for polifocal and/or frontal epilepsies non-responding to drugs. Selective anterior and total callosotomy have been advocated [7,9]. The present study suggests that, it connections similar to those hereby described do exist in man, some precisely located posterior foci could project anteriorly via this postero-anterior pathways and drive anterior epileptic bursts in polifocal epilepsies. Marcus [18], when studying the interaction between foci created in both hemispheres at the same time, had already noted in monkeys that parietal foci trigger spike and wave discharges that predominate in more anterior rather than in parietal regions. This fact might be explained by the pathway hereby proposed. Put together all this would suggest that it is not necessary to perform a whole callosotomy to treat drug-intractable epilepsies. Also our data would suggest that seletive anterior callosotomy may interfere with the interhemispheric integration of areas posterior to the limit of the commissurotomy, which may result in disconnection syndromes not expected from the extent of the lesion made.

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