References


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Increase of Regional Cerebral Blood Volume during REM-Sleep in Man

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Introduction

Studies of brain blood flow and oxygen metabolism during sleep have not shown any consistent differences between slow-wave sleep and relaxed wakefulness [Mangold et al., 1955]. During rapid eye movement (REM) sleep, however, an increase of cerebral blood flow has been reported both in relation to wakefulness and to slow-wave sleep [Kanzow et al., 1962; Reivich et al., 1968]. In a preliminary study by the present authors, regional cerebral blood volume (rCBV), which is a relative measure of blood flow, was measured during paradoxical sleep in normals [Risberg et al., 1969b]. The results showed a regional ‘pattern’ of rCBV increases during REM

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sleep and a positive correlation between the REM density and the cerebral blood volume. The present investigation is an extension of the previous study.

Material and Methods

The measurements were made in 7 healthy, slightly sleep-deprived young volunteers who slept in the laboratory for a single night without any medication. The rCBV measurements were made by means of a y-emitting intravascular indicator, 100 nCi of 131I-labeled human serum albumin, injected intravenously [Risberg and Ingvar, 1968]. The subjects slept 4-8 h in a specially constructed bed which enabled a mild fixation of the subject’s head in relation to 8 scintillation detectors mounted within the headrest in lead collimators. Relative blood volume was measured during the night by continuous recording of the radiation from different regions of the head by means of the 8 scintillation detectors. The impulses from the detectors were accumulated during 1-min epochs in 8 registers and then stored in a magnetic core memory. The main problem during the measurements was to keep a constant position of the subject’s head in relation to the detectors during the recordings, a prerequisite of the method. Movements of the head terminated usable recording periods. In three cases, the transition from slow-wave sleep to REM sleep was accompanied by head movements; thus, data concerning rCBV differences between these sleep stages were obtained only from four recordings.
In addition to the rCBV measurements, EEG and polygraphic recordings were made for classification of different sleep stages.

Results

The results from four transitions from orthodox sleep to paradoxical sleep are shown in figure 1. The rCBV level during tonic (no REMs) paradoxical sleep is used as a reference level (100%), and it is seen that the rCBV level is slightly lower during slow-wave sleep. The difference is, however, not statistically significant. During phasic paradoxical sleep (with REMs) the cerebral blood volume is increased especially in frontal regions (1 and 2) and parieto-occipital regions (7 and 8), significant at the 1- to 5-percent levels. It is evident from figure 1 that the mean rCBV level is increased in periods of high REM density. This is shown in more detail in figure 2 for four of the recordings.

Discussion

It has been shown in animal experiments that a linear relationship exists between changes of cerebral blood flow and cerebral blood volume.
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Fig. 1. Regional differences in cerebral blood volume (rCBV) during sleep in 7 normals. Note the increases over frontal and parieto-occipital regions during paradoxical (para.) sleep with high frequency of REM. Ortho. = orthodox sleep.

[Risberg et al., 1969a]. The rCBV changes demonstrated in this study are thus most likely to reflect changes of regional cerebral blood flow. The experimental results also show that volume changes are of much smaller magnitude than the flow changes (approximate relation 1 : 7). The small changes of rCBV demonstrated in the present study have, thus, to be interpreted in view of these data, and the variations recorded (up to 5 %) indicate flow changes of about 30%. Such changes are of the same size as changes reported during mental activity in awake man [Ingvar and Risberg, 1967; Risberg and Ingvar, 1968].

The cranial skin, muscle and bone blood volume is also 'seen' by the detectors during the rCBV measurements. There is, however, considerable evidence indicating that the extracranial blood pool is by and large constant during the present experimental conditions [Risberg and Ingvar, 1968]. Increases in orbital and temporal muscle blood volume might, however, contribute to the rCBV increases found during REM.

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Fig. 2. Changes of mean regional cerebral blood volume (rCBV, mean of 8 regions) during sleep in four normal subjects. Note the relationship between the REM frequency and the height of the rCBV increase. Para = paradoxical sleep, Ortho = orthodox sleep.

sleep in the fronto-orbital region. The other significant rCBV increases found were, however, situated in regions where the extracranial contamination must have been very small.

Respiratory and systemic circulatory changes may cause alterations of the cerebral blood flow and cerebral blood volume. Such factors have probably not been of importance for the present results. During REM sleep there is often a slight hypocapnia [Bülow, 1963], which should lead to a general reduction and not regional increases of the cerebral blood flow and volume. The increase in heart rate and blood pressure which might occur during paradoxical sleep should also, due to vasoconstriction, cause a general decrease of rCBV.

The present results thus confirm the results from previous studies showing increase of cerebral blood flow and metabolism during REM.
sleep (see above). However, with the present technique it has been shown for the first time that brain circulation changes markedly within the REM sleep period in accordance with the appearance of phasic events (REM). The rCBV changes also show a regional pattern with the largest increases in frontal and parieto-occipital regions. Similar patterns have been found in the awake man during mental activity [Risberg and Ingvar, 1968].

References


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