WEIGHT RATIO BETWEEN THE INFRATENTORIAL AND SUPRATENTORIAL PORTIONS OF THE CENTRAL NERVOUS SYSTEM

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ABSTRACT

The ratio (infratentorial weight \times 100)/total brain weight is easily calculated and is significant in evaluating both development and disease of the central nervous system, particularly cerebral cortical atrophy. This determination can also be of value in the study of other diseases. The study shows that carcinoma may cause loss of cerebral tissue by unknown remote factors.

INTRODUCTION

Large numbers of measurements have been made of various portions of the CNS (1); their significance has not always been appreciated. The weights of infra- and supra-tentorial portions of the brain are easily obtained and their respective values give some indications as to involvement by disease processes.

MATERIAL AND METHODS

The weights of infra- and supra-tentorial portions were recorded for fixed brains examined over a period of approximately three years. The ratio, expressed as (infratentorial weight \times 100)/total brain weight, was arbitrarily chosen because it is easily calculated. The data were analyzed by various groupings. Means and standard variations were determined for each group and the groups compared by “Student’s” t-test or variance analyses as appropriate.

The data were obtained for fixed brains; the total weights differed significantly from the fresh weights obtained at the time of autopsy. An analysis of these differences is beyond the scope of this report. No indication was found that the weight changes due to fixation occur at a different rate below or above the tentorium (3).

RESULTS

All cases in which lesions, such as infarcts, neoplasms or hemorrhages, could obviously distort weight were eliminated from this series. Because swelling of the granule cell layer of the cerebellum also distorts weight significantly, all such cases, whether pre- or post-mortem in origin, were excluded from our evaluations.

Growth Rate: Values for newborns and infants are presented in Fig. 1. The ages are in weeks of gestation, from less than 28 weeks to term. The last group comprises those who survived to two weeks after term birth. Numbers of cases in each group is given. Mean values and two standard deviations for each group are shown. The validity of the age groupings is questionable because the timing of gestational age is unreliable. Deviations from mean values, particularly in the groups nearing term, are considerable.
Bartlett's test for homogeneity of variances was not significant ($p > 0.05$). Accordingly, a one-way analysis of variance was performed to test the equality of the population means of the eight groups. The results are given in Table 1; the F value was significant ($p < 0.01$). A Scheffé type multiple comparison (5) was performed by contrasting the average of the first five (youngest) groups

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>$SS$</th>
<th>$df$</th>
<th>$MS$</th>
<th>$F$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>22.88</td>
<td>7</td>
<td>3.27</td>
<td>4.15 $p &lt; 0.01$</td>
</tr>
<tr>
<td>Within groups</td>
<td>76.37</td>
<td>97</td>
<td>0.787</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>99.25</td>
<td>104</td>
<td></td>
<td></td>
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$SS$: sum of squares. $df$: degrees of freedom. $MS$: mean square.
with the average of the last three (near term) groups. This contrast was significant ($p < 0.05$). It is apparent that the cerebellum begins to grow at a faster rate at or after the 36th week of gestation.

Next we compared the newborn with those who survived longer than two weeks. The steep slope of the growth spurt is shown in Fig. 2, which includes newborns, the group between 2 weeks and 4 months survival, and those older than 1 year—grouped as “adult”, and described below under “normal adult ratio”. The analysis of variance was done ($F = 290, df = 2,246, p < 0.01$). The infratentorial portion of the brain undergoes a very rapid growth period, beginning shortly before term birth and ending before 1 year of age. The adult ratio is achieved at one year, then both portions of the brain continue to grow at the same rate, as shown by the data below.

**Normal Adult Ratio**: Included in this group were all cases which did not show gross lesions and did not have a diagnosis of degenerative disease of the CNS or of carcinoma anywhere in the body. They were analyzed for differences due to age by grouping by decades. Barlett’s test for homogeneity of variance

![Diagram](image_url)

**Fig. 2.** Weight ratios (infratentorial expressed as per cent of total brain weight) for newborns, two weeks to four months, and older than 1 year are compared.
was not significant ($p > 0.05$). One-way analysis of variance for these groups revealed no significant difference ($p > 0.05$), that is, the ratio between the infratentorial and supratentorial portions of the brain remains stable and any variation in weight affects both portions equally. Therefore, age was not considered a significant factor and was disregarded in all subsequent analyses.

The mean value for the “adult” group was 12.45%, variance 0.91, and standard deviation 0.95. Mean plus two standard deviations is 14.35% and minus two standard deviations 10.45%. In our material we found no normal case with a ratio above 14%. Viewing this group of normal individuals as a random sample from the normal population, we can be 99% confident that no more than 5% of the normal population of individuals will be found to have ratios above 13.9% (the highest ratio observed in our sample). Thus, it appears reasonable to use a ratio of 14% as an easily remembered reference point in future observations.

Deviations From Normal: The two groups mentioned above as excluded from the “normal” population, i.e., those with diagnoses of carcinoma or degenerative disease, showed deviations from the normal ratios (Fig. 3). The first group comprised 14 cases with histologic evidence of Alzheimer’s disease, with a mean value of 13.7%. “Student’s” t-test comparing the “normal” and Alzheimer’s groups disclosed a highly significant difference between the two groups ($t = 4.52; df = 150; p < 0.01$). When seven cases with other degenerative diseases of the CNS (Discussion) are added to the Alzheimer’s cases, the mean ratio rises to 14.0%, an even more significant value.

A second group with significant difference in the value of the ratio comprises cases in which a diagnosis of carcinoma was established at the time of autopsy. This includes all malignant epithelial neoplasms and excludes sarcomas, lymphomas and leukemias. The mean value for this group was 13.59%, and the “Student’s” t-test confirmed that the deviation from the mean value for the normal group was highly significant ($t = 7.65, df = 104; p < 0.001$). As a subgroup, we treated those patients in whom a clinical history of dementia or other disturbed CNS function was recorded; the mean ratio was above 14%.

A number of cases was encountered for which the ratio was higher than normal, not because of low cerebral weight but because of increase in infratentorial portion or for unexplained reasons (Table 2).

DISCUSSION

Variability in data may result from cutting the midbrain at various levels and from varying the length of the attached spinal cord segment. The maximum weight of midbrain is 4 gms, and 3 cm segment of spinal cord 3 gms. Thus, the maximum possible error introduced by variation in the cut may amount to 7 gms. For an adult it would introduce a deviation from the ratio of 0.5%. Such variations in data can be minimized by uniformity of procedures followed in brain cutting and by weighing all specimens on the same balance.

A second, more important factor to be considered is the weight of the fluid filling the ventricular system. In normal brains the ventricular volume is small.
Fig. 3. Weight ratios (infratentorial expressed as per cent of total brain weight) for "normal", Alzheimer's disease, all degenerative diseases, carcinoma, and carcinoma with dementia groups.

### TABLE 2
Miscellaneous Cases With Higher Than Normal Ratio

<table>
<thead>
<tr>
<th>Anatomical findings and/or diagnosis</th>
<th>Ratio per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Lupoid hepatitis&quot;. Central pontine myelinolysis</td>
<td>14.2</td>
</tr>
<tr>
<td>Central pontine myelinolysis. Alcoholie</td>
<td>14.8</td>
</tr>
<tr>
<td>Central pontine myelinolysis. Alcoholie</td>
<td>14.8</td>
</tr>
<tr>
<td>Central pontine myelinolysis. Alcoholie</td>
<td>14.0</td>
</tr>
<tr>
<td>Heterotopic cerebellar cortex</td>
<td>16.3</td>
</tr>
<tr>
<td>Heterotopic cerebellar cortex</td>
<td>14.5</td>
</tr>
<tr>
<td>Anorexia nervosa</td>
<td>14.3</td>
</tr>
<tr>
<td>Three year old; uremia, seizures</td>
<td>14.1</td>
</tr>
<tr>
<td>Turner's syndrome. Etat crible</td>
<td>14.6</td>
</tr>
</tbody>
</table>
and the fluid drains easily through the aqueduct of Sylvius. In severely atrophied brains the ventricular volume may enlarge significantly and the fluid does not drain as easily. It is necessary, therefore, to reweigh the cerebrum after the ventricles have been emptied.

The present data corroborate the data of Ellis (3) and Krogman (5). The cerebellum lags in growth during the last trimester of fetal life and amounts to approximately 5% of the total intracranial mass. Its growth rate increases during the first 12 months of postnatal life, catching up to that of the cerebrum. Thereafter, the rates of growth as well as of loss of weight are alike for both parts of the brain. Our numerical values differ from those of Ellis (3) because the brain stem was weighed along with the cerebellum. This does not change the interpretation, however, since the brain stem represents 1.5% of the total intracranial weight at birth and 1.4% at 1 year of age (5). It is thus obvious that the change in ratio is accounted for by the cerebellum. Other studies (4) have shown that the period of rapid growth of the cerebellum corresponds to the growth of the molecular layer to adult dimensions which, in turn, represents maturation of the neuronal cell bodies and synaptic organization.

One of the reasons for undertaking this study was the hope of obtaining a reliable measure of cerebral cortical atrophy. The data indicate that the Alzheimer's disease group has a significantly higher ratio than the "normal" population, although cases with ratios well within normal limits were encountered. It seems possible that the cortical atrophy may not always occur in the course of the disease. Analysis of the cases in this series did not reveal any correlation between weight ratios and age, duration, or clinical or histologic severity of the disease. Other degenerative diseases of the CNS also lead to loss of cerebral substance. Among the cases in our material were one patient with Huntington's chorea (16.5%) and one with holotopic striatal degeneration (15.9%), suggesting that lesions of the basal ganglia will significantly affect cerebral weight. Of four cases of Parkinson's disease, the ratios were normal for two and high for two. Similarly, of two cases of amyotrophic lateral sclerosis, one had a normal and one a high ratio. These observations suggest that various degenerative diseases of the CNS may lead to loss of cerebral tissue regardless of the preponderance of histologic lesions in other parts of the system.

The findings in the carcinoma group, which excluded cases of direct involvement of the CNS by malignancy, were of particular interest. The apparent loss of cerebral substance is thus an indirect effect of carcinoma elsewhere in the body. Review of the cases did not reveal that any particular type of carcinoma, or site or origin, is more likely to produce atrophy than another, nor was there correlation with the severity of the disease or intensity of metastatic spread. The most significant correlation was found between clinical observation of dementia or other diffuse cerebral dysfunction and severity of cerebral atrophy. Carcinomas are known to produce cerebral dysfunction without direct involvement of the brain (2), and our observations give an indication of underlying anatomical changes.
Cerebral atrophy has been suspected in alcoholics, but we observed no deviation from normal weight ratios in eighteen cases, indicating no significant loss of cerebral tissue. This series may not be sufficient, however, and the population we examined may not be truly representative of chronic alcoholics.

A deviation from normal ratio might be expected in cases of Down's syndrome, where the cerebellum is frequently described as small. The patients in this series presented values at the lower limits of the normal for their age, but the number examined does not permit statistically meaningful analysis.

The ratio may also be influenced by an increase in the mass of the infratentorial structures. Two groups of patients are of particular significance: those with central pontine myelinolysis (CPM) and those with cerebellar cortical heterotopias. It appears likely that significant swelling, which may not be recognized morphologically, occurs in the hindbrain in conjunction with CPM, either as a causative or resulting factor. Cortical heterotopias (islands of cerebellar cortex in white matter, not in continuity with the rest of the cortex) evidently represent an enlargement of the cerebellum rather than disarrangement of the tissue elements normally present.

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ADDENDUM

Since the submission of this paper, a report by Crome et al (Crome, L., Cowie, V., and Slater, E.: A statistical note on cerebellar and brain stem weight in mongolism. J. Ment. Defic. Res., 10: 69–72, 1966) has come to our attention. These authors examined the weights of the brains of 19 children with Down's syndrome and came to conclusions in essential agreement with our findings.

REFERENCES