ABSTRACT

Aims: To investigate the relation of liver status and pancreatic function to disorders of the central nervous system during early abstention from alcohol. Methods: Sixty-seven alcohol-dependent patients (47 male) with a mean age of 42.3 ± 12.5 years, were assessed by clinical history, abdominal sonography, computerized tomography of the brain and with neuropsychological and serum enzyme tests. Patients with sonographically diagnosed cirrhosis were excluded. Results: Patients with fatty liver had more previous complicated detoxifications, but not more current signs of brain atrophy or impairment on neuropsychological tests. However, elevations in alpha amylase (AA), and gamma glutamyl transpeptidase (GGT) were associated with signs of cerebral atrophy. Higher serum GGT was related to impaired score on a number sequencing task (NST), and high AA with impairment on NST and on two tests of speed and perception. GGT and AA levels tended to be higher in older subjects. Conclusions: After detoxification from alcohol even mildly disturbed liver and pancreatic parameters, but not fatty liver itself, are associated with signs of brain atrophy and impaired psychometric performance. Age may be a confounding or contributing factor.

INTRODUCTION

Chronic alcoholism is associated with cognitive dysfunction that affects the patient beyond detoxification (Beatty et al., 2000). During abstinence the amount of neuropsychological disturbance usually declines quickly (John et al., 1991; Mann et al., 1999), although some deficits persist (Yohman et al., 1985).

Alcoholic and non-alcoholic liver cirrhosis often is accompanied by a wide variety of neuropsychological disturbances (Tarter et al., 1986a; Arria et al., 1991) even without clinically apparent hepatic encephalopathy (Gilberstadt et al., 1980). It is not clear, however, whether already minor derangements of hepatic function or morphology during and after detoxification from alcohol are associated with disturbed neuropsychological function or brain atrophy. Because, in their study, the rate of neuropsychological deficits was higher than the rate of liver cirrhosis, Lee et al. (1979) concluded that liver damage probably is not the cause of neuropsychological disturbance. While they did not investigate milder forms of liver disturbance, another study came to the conclusion that a liver derangement without cirrhosis does not play a part in the genesis of chronic alcohol-related brain impairment (Walton and Bowden, 1997). The results of the latter study are based on functional rather than morphologic parameters (i.e. assessment of the liver was based on the assessment of serum liver enzymes). Sonographic evaluation of the liver morphology was not performed. Such an assessment allows for a safer exclusion of liver cirrhosis and a further sub-differentiation of patients with and without alcoholic fatty liver. It therefore was one aim of this study to further differentiate between patients with an alcoholic fatty liver and those without while excluding those with liver cirrhosis. We were particularly interested to find out whether patients with an alcoholic fatty liver (F) showed more neuropsychological performance deficits than those without (NF).

Pancreatic dysfunction as in acute pancreatitis seems to be associated with an increased risk of neuropsychological dysfunction such as delirium (Heiberg, 1969; Benos, 1976; Menza and Murray, 1989). It has not been investigated as yet, however, whether such an association between pancreatic function and neuropsychological status holds also for mild pancreatic dysfunction. We therefore investigated as well the relation between the pancreatic enzymes alpha amylase (AA) and lipase and brain morphology and psychometric performance.

Brain atrophy during early abstinence is not necessarily associated with disturbed neuropsychological performance (Calà et al., 1978; Calà, 1987; Blansjaar et al., 1992; Di Scalfani et al., 1995). As with impaired neuropsychological performance, such brain atrophy seems to be reversible to some degree (Carlen and Wilkinson, 1987). The association of such a reversible atrophy with liver status has been shown by Mutzel on a group of patients with a combined drug and alcohol abuse (Mutzel, 1992). As studies on alcohol dependent patients without another substance abuse are still lacking, we wanted to further investigate this issue in the present study.

In summary then, the present study focussed on alcoholics with only mild liver injury and explored whether an alcoholic fatty liver (F), mild metabolic dysfunctions, the duration of harmful alcohol consumption or the number of previous detoxifications are associated with neuropsychological deficits and/or with brain atrophy during early abstention from alcohol.
PATIENTS AND METHODS

The study started after approval through the local ethics committee. All subjects gave their written informed consent to participate. They fulfilled the DSM-IV criteria for alcohol dependence (American Psychiatric Association, 1994) and were recruited from a bigger sample (194 subjects) of patients consecutively referred to a psychiatric ward specializing in inpatient detoxification and 3-week motivation enhancement treatment. The patients were free of any clinical symptoms of alcohol withdrawal at the time of inclusion into the study. They had to have no major organic comorbidity apart from liver disorder and had to be unmedicated for at least 1 week. A complete medical and psychiatric history including data on the duration of dependence and detoxification and a complete physical examination were performed. All participants were interviewed for tobacco and illicit drug use. There was no indication of the latter. Sustained abstinence was confirmed by repeated breathalyzer tests during inpatient treatment.

All subjects willing to participate underwent an extensive internal, neurological and psychiatric examination including cranial computed tomography (CT), EEG, ECG, abdominal sonography, and biochemical serum analysis (electrolytes, liver and pancreatic enzymes). The medical history was assessed with a semi-structured interview according to the guidelines of the German Society for Addiction Research and Therapy (DGSS, 1991). In order to reduce confounding results of neuropsychological testing, subjects with a history of child behaviour disorder (hyperactivity or minimal brain dysfunction), of head trauma with unconsciousness, meningoencephalitis, Wernicke-encephalopathy, Korsakoff’s syndrome, depression, or schizophrenia were excluded from the study. For the same reason subjects with alcohol withdrawal delirium during the detoxification immediately preceding the study, with sonographically proven liver cirrhosis or acute pancreatitis, or with circumscribed brain lesions on CT scan, an education below ordinary school level (regular school in Germany), or an antisocial personality disorder were excluded.

Sixty-seven patients were thus included, 20 of them being women (mean age: 45.3 ± 15.0 years) and 47 men (mean age: 41.0 ± 11.3 years). The difference of age was not significant (Student’s t-test).

The participating subjects were administered the following battery of neuropsychological tests.

1. The d2-test (Brickenkamp, 1981), assessing sustained attention and visual scanning ability. This is a paper and pencil cancellation test composed of 14 lines with 47 letters each. From these lines the letter ‘d’ with two quotation marks must be crossed out. The test is widely applied in Germany. The number of correctly cancelled letters was used as the comparative measure in this study.

2. A number-sequencing test (NST) (Zahlen-Verbindungs-Test, Oswald and Roth, 1997), which is similar to the Trail Making Test (Reitan, 1985) evaluating mainly perceptual speed, sequencing, and mental flexibility. This test usually gives disturbed results in alcoholics, as demonstrated in several studies. In the applied form it consists of four sub-tests that are evaluated together in a sum score.

3. The digit–symbol test (DST) from the Wechsler Adult Intelligence Scale, revised (WAIS-R, German version, Wechsler, 1981), a sub-test belonging to the performance tests of the test battery.

4. The sub-test ‘observation’ of the Wilde Intelligence Test (WIT) (Jaeger and Althoff, 1983) to estimate the speed of perception. In this sub-test the subjects are presented with a number of three-line drawings of faces with one of them slightly differing from the two identical others. The subjects are asked to find the differing line drawing as quickly as possible.

5. The revised Benton Visual Retention Test (BVRT) to assess visual memory, perception and visuo-constructive abilities (Benton, 1974). The scores of correct reproductions of the visual presentations and the error score were used for assessment.

In order to have a comparison of the psychometric results with a healthy sample, each participating subject was paralleled with an artificial subject representing the age and, where possible, the school adjusted German norm, of each of the tests. This made possible a comparison between those patients with (F) and without (NF) a fatty liver on one hand, and the respective normative values of healthy controls on the other, via analysis of variance with post hoc Scheffé test.

Cranial CT scans were performed with a Siemens Somatom DR2. The CT scans were evaluated with a Siemens Evaluscop according to a planimetric method (Meese et al., 1980). In order to avoid early volume effects (Carlen et al., 1987) the scans were not performed before two weeks after cessation of alcohol consumption. Mean duration of abstinence at CT scanning was 19.6 ± 14.3 days.

The CT scans were evaluated for atrophy with horizontal scans at the level of the Foramen of Monro and at the level of the cella media. Brain atrophy was evaluated with the following commonly used indices for the width of the subarachnoid space.

Evans’ index (maximal distance of the anterior horns of the lateral ventricles divided by the maximal inner calottal diameter and multiplied by 100), the bicaudate distance, the Huxkman number (size of the third ventricle plus the maximal distance of the anterior horns of the lateral ventricles).

Furthermore the following indices were assessed as indicators of brain atrophy: (i) the cella media index (the maximal outer calottal diameter divided by the cella media distance and multiplied by 10); (ii) the width of the third ventricle; (iii) the maximal width of the sagittal fissure between the frontal lobes; and (iv) the maximal width of the sylvian fissure.

The neuropsychological testing, as well as the abdominal sonography, were performed within 3 days prior or post CT-imaging. Abdominal sonography was performed and evaluated by one of the authors (J.D.) experienced in abdominal sonography. Evaluation of the liver was done according to the sonographical guidelines with increased echo density, liver enlargement, changed liver contour and rarefied vascularization as criteria of fatty liver (Pickuth et al., 1995).

The evaluation of the CT scans and the sonography of the liver took place without knowledge of the other data on the respective patient.
Depending on the results of the Kolmogorov–Smirnov test for normal distribution, parametric and nonparametric tests were used for statistical analysis. As age is a major contributing factor to cranial morphology we applied univariate analyses of variance with age as a covariate for comparison between patients with a fatty liver and those without.

For comparison of independent samples t-tests and U-tests were applied where appropriate. Correlation analyses were done with Spearman’s rho, because at least some of the correlated parameters turned out not to be normally distributed. All statistical tests were calculated with a two-sided alpha of 0.05. The calculations were done with the statistical program SPSS version 11.0 (Chicago).

RESULTS

Twenty-two (32.8%) of the 67 selected patients had a fatty liver according to the sonographic analyses with no evidence of further alcohol-related abdominal organ damages. Five of these were women and 17 were men.

Those alcoholics with a fatty liver had previously experienced more complicated withdrawals. They did not differ with respect to age, duration of school education, daily alcohol consumption nor duration of alcohol dependence (see Table 1).

Mean daily alcohol consumption was significantly lower in women than in men (179.4 ± 105.0 g alcohol per day compared to 229.6 ± 116.6 g in men, \( P = 0.04 \), U-test) and the duration of alcohol dependence was not significantly shorter (6.2 ± 4.9 vs. 9.4 ± 7.4 years, \( P = 0.141 \), U-test). Nonetheless, the proportion of women with fatty liver did not differ from the proportion of men (chi-squared >0.05).

Compared with NF patients, patients with a fatty liver had higher levels of serum alanine aminotransferase (ALT), aspartate aminotransferase (AST) and gamma glutamyl transpeptidase (GGT), and significantly increased serum levels of bilirubin and triglycerides. Serum cholesterol showed a trend towards increased levels (Table 2). AA and GGT correlated with age (rho 0.340 and 0.369, respectively, \( P < 0.01 \) for both), while AST and ALT showed a trend towards such a correlation (rho 0.230 and 0.225, \( P = 0.061 \) and 0.067, respectively).

Liver morphology and brain atrophy

CT scan results did not discriminate between F and NF, after partialling out (via analysis of covariance, ANCOVA) the confounding effect of age.

Liver and pancreatic tests and brain atrophy

There were significant correlations between GGT, AST, ALT and AA and several measures of brain atrophy (see Table 3).

Parameters of drinking and brain atrophy

The number of days since the last alcoholic drink correlated negatively with the width of the anterior horns of the lateral ventricles (rho \(-0.264,\ P = 0.04\)) and the Evans’ Index (\(-0.298,\ P = 0.038\)); the reported amount of daily alcohol consumption before abstention correlated negatively with the width of the anterior horns of the lateral ventricles (rho \(-0.281,\ P = 0.028\)) and the duration of alcohol dependence correlated with the Evans’ Index (rho 0.295, \( P = 0.031 \)) and with the cella media index (rho \(-0.416,\ P = 0.001\)). The other

Table 1. Sociodemographic data in relation to sonographically diagnosed fatty liver

<table>
<thead>
<tr>
<th></th>
<th>Fatty liver</th>
<th>No fatty liver</th>
<th>Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age (years)</td>
<td>45.5 ± 11.6</td>
<td>40.7 ± 12.8</td>
<td>( P = 0.147 )</td>
</tr>
<tr>
<td>Education (school years)</td>
<td>9.9 ± 1.5</td>
<td>9.2 ± 0.9</td>
<td>( P = 0.122 )</td>
</tr>
<tr>
<td>Alcohol dependence (years)</td>
<td>10.4 ± 7.8</td>
<td>7.5 ± 6.3</td>
<td>( P = 0.142 )</td>
</tr>
<tr>
<td>Grams alcohol per day</td>
<td>235.7 ± 109.5</td>
<td>204.4 ± 117.4</td>
<td>( P = 0.166 )</td>
</tr>
<tr>
<td>Previous inpatient withdrawals</td>
<td>6.1 ± 12.3</td>
<td>1.3 ± 1.7</td>
<td>( P = 0.120 )</td>
</tr>
<tr>
<td>Previous complicated withdrawals</td>
<td>0.6 ± 0.9</td>
<td>0.1 ± 0.5</td>
<td>( P = 0.005 )</td>
</tr>
<tr>
<td>Duration of last withdrawal syndrome (days)</td>
<td>10.8 ± 21.7</td>
<td>2.8 ± 3.4</td>
<td>( P = 0.156 )</td>
</tr>
</tbody>
</table>

\( U \)-tests; except for age (t-test).

Table 2. Laboratory tests in relation to sonographically diagnosed fatty liver (means and SD)

<table>
<thead>
<tr>
<th></th>
<th>Fatty liver</th>
<th>No fatty liver</th>
<th>Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>GGT (U/L)</td>
<td>153.9 ± 194.4</td>
<td>53.3 ± 120.6</td>
<td>( P = 0.001 )</td>
</tr>
<tr>
<td>AST (U/L)</td>
<td>38.7 ± 39.2</td>
<td>15.6 ± 13.7</td>
<td>( P = 0.001 )</td>
</tr>
<tr>
<td>ALT (U/L)</td>
<td>44.9 ± 53.6</td>
<td>14.7 ± 13.8</td>
<td>( P = 0.001 )</td>
</tr>
<tr>
<td>MCV (U/L)</td>
<td>93.2 ± 5.6</td>
<td>93.9 ± 5.6</td>
<td>( P = 0.105 )</td>
</tr>
<tr>
<td>Total Bilirubin (µmol/L)</td>
<td>144.3 ± 84.1</td>
<td>87.3 ± 57.1</td>
<td>( P = 0.004 )</td>
</tr>
<tr>
<td>Triglycerides (mg/dL)</td>
<td>242.2 ± 142.5</td>
<td>166.6 ± 89.8</td>
<td>( P = 0.029 )</td>
</tr>
<tr>
<td>Cholesterol (mg/dL)</td>
<td>638.4 ± 134.8</td>
<td>573.4 ± 132.3</td>
<td>( P = 0.066 )</td>
</tr>
<tr>
<td>AA (U/L)</td>
<td>79.6 ± 52.2</td>
<td>75.6 ± 36.7</td>
<td>( P = 0.826 )</td>
</tr>
<tr>
<td>Lipase (U/L)</td>
<td>131.1 ± 82.8</td>
<td>108.5 ± 84.3</td>
<td>( P = 0.103 )</td>
</tr>
</tbody>
</table>

Statistics: \( U \)-tests; except for MCV and cholesterol (t-tests).
parameters of brain morphology did not correlate with these parameters of drinking.

**Neuropsychology and liver morphology**

Compared to age adjusted standards, the alcohol dependent subjects as a whole performed worse in all neuropsychological tests (see Table 4). Only for the d2-test did this difference not reach statistical significance: results were within two standard deviations of the age adjusted norm. The BVRT average error score showed a disturbed test performance (mean 4.6 ± 1.5, cut-off: 4 errors).

There was no correlation between the duration of harmful alcohol consumption and alcohol dependence and amount of daily alcohol consumption on the one hand, and psychometric test performance on the other ($P > 0.05$). Furthermore the comparison of group F and NF with the age- and education-adjusted standard values via univariate analyses of variance did not reveal significant differences between the F and NF groups.

**GGT, amylase and psychometric test performance**

As GGT and AA values strongly correlated with the investigated parameters of brain morphology but not with each other, these two enzymes were in turn assessed for a possible association with the five psychometric tests. GGT correlated with the score on NST (rho 0.276, $P = 0.026$ before and rho 0.307 and $P = 0.014$ after exclusion of two outliers) but with no other psychometric test. AA, however, correlated with scores on three tests (digit symbol test: $r = -0.306, P = 0.013$; WIT: $r = -0.309, P = 0.013$; NST: $r = 0.262, P = 0.036$).

At least one previous complicated withdrawal (seizures or delirium) had been experienced by 12 subjects. They did not show a poorer test performance or more brain atrophy on CT scan than those without previous complicated withdrawals.

**DISCUSSION**

This study performed many analyses and there is the possibility that some apparently significant results occurred by chance. However, we think that one significant result in five tests involving GGT and three in five for alpha amylase are ratios that make chance the unlikely explanation, at least for those test results. We suggest that the study shows the following:

During early abstention from alcohol, psychometric performance is impaired. As the mean score on the d2, which is a measure of the attentional capacities, was still within the lower normal range, an attention deficit is probably not responsible for the poor performance in the other tests. The disturbance we found during early abstention is in accordance with other studies (for overview see Parsons, 1986; Parsons and Nixon, 1998).

While severely deranged liver morphology is associated with disturbance of brain-morphologic and psychometric parameters (Tarter *et al.*, 1986a, 1986b, 1987), no clear association of psychometric test results with mildly deranged liver morphology (i.e. with fatty liver) was found.

Increases in serum GGT were associated with impaired performance on the NST, but not with impairment on other psychometric tests. Walton and Bowden (1997), who found no association between liver enzyme tests and any of the neuropsychological tests they used, did not apply a test similar to the NST. Their study and ours have the DST in common and

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### Table 3. Association of hepatic and pancreatic tests with signs of brain atrophy

<table>
<thead>
<tr>
<th></th>
<th>GGT</th>
<th>AST</th>
<th>ALT</th>
<th>AA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signs of subcortical atrophy or ventricular enlargement</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3rd ventricle</td>
<td>0.400***</td>
<td>0.266**</td>
<td>0.235**</td>
<td>0.203</td>
</tr>
<tr>
<td>Bicaudate distance</td>
<td>0.359***</td>
<td>0.279**</td>
<td>0.218</td>
<td>0.235*</td>
</tr>
<tr>
<td>Huckman number</td>
<td>0.309*</td>
<td>0.200</td>
<td>0.173</td>
<td>0.148</td>
</tr>
<tr>
<td>Cella media index</td>
<td>0.492***</td>
<td>0.315**</td>
<td>0.247</td>
<td>0.096</td>
</tr>
<tr>
<td>Signs of sulcal enlargement</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sagittal fissure</td>
<td>0.286***</td>
<td>0.199</td>
<td>0.146</td>
<td>0.385***</td>
</tr>
<tr>
<td>Sylvian fissure</td>
<td>0.441***</td>
<td>0.262**</td>
<td>0.287**</td>
<td>0.334***</td>
</tr>
</tbody>
</table>

(Spearman’s rho). *$P = 0.057$; **$P < 0.05$; ***$P < 0.01$.

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### Table 4. Psychometric performance (means and SD): relation to sonographically diagnosed fatty liver

<table>
<thead>
<tr>
<th>Test procedure</th>
<th>Sample as a whole (W)</th>
<th>Age-matched norm (N)</th>
<th>Statistics W vs. N</th>
<th>Fatty liver (F)</th>
<th>No fatty liver (NF)</th>
<th>F vs. NF (post hoc tests)</th>
</tr>
</thead>
<tbody>
<tr>
<td>d2 (percentage rank)</td>
<td>74.6 ± 21.6</td>
<td>50.0</td>
<td>Within 2 SD of norm</td>
<td>77.8 ± 20.0</td>
<td>72.9 ± 22.5</td>
<td>NS</td>
</tr>
<tr>
<td>WIT</td>
<td>10.2 ± 3.7</td>
<td>18.9 ± 1.3</td>
<td>$P &lt; 0.001$</td>
<td>11.14 ± 3.6</td>
<td>9.71 ± 3.7</td>
<td>NS</td>
</tr>
<tr>
<td>DST</td>
<td>39.9 ± 12.2</td>
<td>44.6 ± 5.8</td>
<td>$P &lt; 0.01$</td>
<td>39.33 ± 9.1</td>
<td>40.18 ± 13.6</td>
<td>NS</td>
</tr>
<tr>
<td>BVRT</td>
<td>6.7 ± 1.5</td>
<td>7.4 ± 0.9</td>
<td>$P &lt; 0.01$</td>
<td>7.18 ± 1.4</td>
<td>6.50 ± 1.6</td>
<td>*</td>
</tr>
<tr>
<td>NST</td>
<td>94.9 ± 33.8</td>
<td>74.3 ± 6.2</td>
<td>$P &lt; 0.001$</td>
<td>100.43 ± 29.8</td>
<td>92.25 ± 35.5</td>
<td>NS</td>
</tr>
</tbody>
</table>

Comparison between the whole group of patients (W) and age-matched norms (N): $t$-tests. Comparison between patients with fatty liver (F) and without fatty liver (NF) and N: univariate analysis of variance and post hoc tests ($*P = 0.085$, NS, not significant). BVRT, revised Benton visual retention test; DST, digit–symbol test; NST, number-sequencing test; WIT, Wilde intelligence test.
on this test neither found any association between liver enzyme tests and psychometric results.

Psychometric impairment was more associated with elevated serum AA levels than with elevated serum GGT levels. Unfortunately we did not assess serum isoamylases and thus we cannot know whether it is the pancreatic isoamylase that is responsible for this association. All we can state is that AA values in our sample were largely within the normal range and that sonographically we had no signs of ongoing pancreatitis among the participating patients. As the more pancreas-specific serum lipase correlated with AA while the liver enzymes GGT, AST and ALT did not, we would assume that it is probably a mild pancreatic dysfunction that is the cause of the association, the pancreatic dysfunction in turn signalling a higher toxic effect of alcohol on both pancreas and brain function. We believe that these data should give rise to further studies on a possible association of pancreatic function and neuropsychological disturbance in alcohol-dependent patients. In this case a morphologic assessment of the pancreas in addition to the serum levels of its enzymes seems warranted. Sonography, however, might have to be replaced by more accurate techniques like magnetic resonance imaging.

There was an association of elevated levels of GGT, AA and to a lesser degree of AST and ALT with several of the CT estimates of brain atrophy. Such an association has not been previously reported and merits further investigations with techniques that allow for a more precise and reliable assessment of brain morphology. Although the CT technique we used does not allow reliable differentiation between cortical and subcortical atrophy, it is assumed from neuropathological data on alcoholics that the atrophy is mainly due to a loss of subcortical white matter (Harper et al., 1985). The present data on possible brain atrophy are to some degree substantiated by some other studies. Thus, Mutzell (1992) reported on a group of patients with alcohol and drug use who had increased serum levels of GGT, AST and ALT together with several signs of brain atrophy. He did not report on AA nor on correlational analyses. Pfefferbaum et al. (1988) found an association between mean corpuscular volume of erythrocytes (MCV) with ventricular atrophy but not with sulcal enlargement. They postulated a dose–effect relationship between ethanol exposure and changes in brain morphology with a different time course of response for subcortical and cortical atrophy. In two later studies they could not demonstrate such a dose–effect, however, but saw an association with age and postulated an age-related increase in brain vulnerability to chronic alcohol use (Pfefferbaum et al., 1992, 1993). In accordance with this, Bergman et al. (1980) previously reported cortical and subcortical enlargements in alcoholic patients with differing time courses for these two kinds of atrophy. They suggested differing psychometric consequences. Because we found an association of GGT and AA with brain atrophy and as both GGT and AA showed an association with age that was not found by Persson et al. (1990) and Mundle et al. (1999) for GGT and tends to be low for AA (Kohn et al., 1982), we think that our results indirectly support the hypothesis of an age-related increased vulnerability to alcohol not only of brain morphology, but also of neuropsychological, pancreatic and hepatic function. In view of the studies of Pfefferbaum et al. and our present data showing a low association of some of the parameters of drinking (duration of abstention, duration of alcohol dependence and daily alcohol consumption before the last detoxification) with signs of atrophy in the area of the lateral ventricles, we speculate that this increased vulnerability finds expression in cortical more than in periventricular atrophy, while periventricular atrophy is a dose-related effect of alcohol that is partly reversible with abstinence. However, further studies with a controlled design, and technology offering a more precise assessment of brain morphology, are necessary to verify this hypothesis.

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