Rapid Communication

Phosphatidylinositol Kinase Is Reduced in Alzheimer’s Disease

J. Jolles, J. Bothmer, M. Markerink, and *R. Ravid

Department of Neuropsychology and Psychobiology, University of Limburg, Maastricht; and *The Netherlands Institute for Brain Research, Amsterdam, The Netherlands

Abstract: Phosphatidylinositol (PI) kinase and PI phosphate (PIP) kinase activities were measured in postmortem samples of brain tissue from patients with Alzheimer’s disease and nondemented control subjects. A membrane-free cytosolic fraction from four neocortical locations, with exogenous inositol lipids as the substrate, was used. Tissue from patients with Alzheimer’s disease was characterized by reduced PIP formation; the reduction was 50% in prefrontal cortex, temporal cortex, and parietal cortex and 80% in precentral gyrus. In contrast, no alterations were found in PI bisphosphate formation in these four neocortical locations. The specific changes in PI kinase but not PIP kinase activity suggest that the findings may have functional relevance to the involvement of brain membrane processes in Alzheimer’s disease. Key Words: Phosphatidylinositol kinase—Phosphatidylinositol phosphate kinase—Brain cortex—Alzheimer’s disease. J. Neurochem. 58, 2326–2329 (1992).

Alzheimer’s disease (AD) is a neurodegenerative disease and the most common cause of adult-onset dementia. The etiology and pathogenesis are presently not known. Interest in brain membrane phospholipids was aroused several years ago in relation to the hypothesis of a cholinergic dysfunction in AD (see, e.g., Barbus et al., 1982) and the notion that these neurons utilize choline for the formation of the membrane phospholipid phosphatidylcholine (Wurtman et al., 1990). Alterations in phosphatidylcholine and its metabolites and in other phospholipids in AD brains have now been described (see, e.g., Miotto et al., 1986; Pettegrew et al., 1989; Blusztajn et al., 1990). Changes in other phospholipids, notably phosphatidylinositol (PI) and its breakdown product, myo-inositol, have also been investigated in AD and in normal aging (Stokes et al., 1983; Stokes and Hawthorne, 1987). Such findings may have functional significance because the interconversion of PI into PI phosphate (PIP) and PI bisphosphate (PIP₂) and the breakdown of the latter substance into diacylglycerol and inositol triphosphate are key processes in neuronal function (for review, see Abdel-Latif, 1986; Betridge, 1987; Downes and MacPhee, 1990).

The present study was undertaken to investigate whether inositol phospholipid phosphorylating activity is different in brains from patients with AD as compared with brains from nondemented control subjects. Considering the rapid breakdown of inositol phospholipids after death (Lin et al., 1990) and after low-energy periods in vitro (Jolles et al., 1981), we chose to measure enzyme activity rather than analyze phospholipid contents. Brain samples were obtained by rapid autopsy (within 4–6 h after death). AD and control subjects were matched for age to reduce possibly confounding factors such as duration of disease and interaction between age and disease. Four neocortical locations were compared to detect possible regional variations like those observed in old animals (Bothmer et al., 1990a). PI kinase and PIP kinase were studied in a membrane-free supernatant of AD and control brain, with exogenous PI and PIP as lipid substrates.

MATERIALS AND METHODS

Subjects

Brain samples from five patients with AD (three males and two females; mean age, 65.2 years) and five control subjects (three males and two females; mean age, 69 years) were used in this study (Table 1). Patients and controls were individually matched for age and postmortem interval. Brain tissue was obtained from The Netherlands Brain Bank (The Netherlands Institute for Brain Research). The mean postmortem interval was 5 h for AD subjects and 5 h 15 min for the controls. The patients with AD were clinically diagnosed as “probable Alzheimer’s disease” (McKhann et al., 1984; American Psychiatric Association, 1987), and this was verified by postmortem neuropathological examination. Control subjects had no history of dementia or any other neurological or psychiatric disorder.

Brain dissection

Brain specimens for analysis of inositol phospholipid kinase activity were obtained from four neocortical locations.
in the right hemisphere: (a) the frontal superior gyrus, (b) the precentral gyrus, (c) the medial temporal gyrus, and (d) the parietal lobe. The leptomeninges were removed, and samples were excised. These samples were sealed in plastic, rapidly frozen by immersion in liquid nitrogen, and stored at −80°C until use.

Preparation of crude enzyme fraction

Pieces of ~0.5 g were excised from the tissue samples and thawed in a water bath at 0°C (20 min). The tissue was homogenized in a medium consisting of 0.32 M sucrose, 1 mM EGTA, and 30 mM Tris-HCl (pH 7.4) in a total volume 10 times the brain tissue volume, by 12 up-and-down strokes of a Potter-Elvehjem Teflon-glass homogenizer (radial clearance, 0.125 mm; 700 rpm), followed by homogenization by hand in a glass-glass homogenizer with 3 up-and-down strokes. The homogenate was centrifuged for 60 min at 100,000 g, and the resulting membrane-free supernatant was used as the crude enzyme fraction. This fraction was stored at −80°C. There was no decline in enzyme activity after 1 month of storage.

PI kinase and PIP kinase assay

Inositol phospholipid kinase activity was measured as described before (van Dongen et al., 1986; Moritz et al., 1999), with some modifications. The incubation volume (normally 25 µl) was doubled for the PI kinase assay to reduce interassay variability. Supernatant fractions of 15 or 30 µl (10 and 20 µg of protein, respectively) were preincubated for 2 min. Lipid precursors [20 µM PI or 20 µM PIP (Sigma), solubilized in 0.1% Triton X-100, 50 mM Tris-HCl, and 1 mM EGTA, pH 7.4] were added 15 s before the phosphorylation reaction was started by addition of ATP. The reaction lasted 1 min. Incubations were performed under the following conditions: 7.5 µM ATP, 2–3 µCi of [γ-32P]ATP (~3,000 Ci/mmol; Amersham, U.K.), 50 mM Tris-HCl (pH 7.4), 10 mM MgCl2, 1 mM EGTA, and 0.02% Triton X-100. The reaction was terminated, and the extraction and further analysis of the [32P] incorporated into PIP and PIP, were performed, as described elsewhere (Jolles et al., 1981; Bothmer et al., 1990). Protein content was determined according to the method of Lowry et al. (1951).

RESULTS

The results of the PI kinase assay in brain samples from patients with AD and controls are shown in Fig. 1A. A significant difference between AD and control patients was found in the four necortical locations tested (p < 0.01 by multivariate analysis of variance (MANOVA)). The AD group was characterized by a reduction in [32P]PIP formation by

![FIG. 1. PI kinase (A) and PIP kinase (B) activities in crude cytosolic fractions from four necortical regions of AD brains and age-matched controls, expressed as picomoles of P, incorporated into PIP monophosphate per milligram of protein. Data were analyzed by one-way analysis of variance: *p < 0.01.](image-url)
The change in PI kinase activity is of potential relevance because of the large effect found: A reduction of 50% in enzyme activity is substantial in view of the fact that neocortical tissue can be expected to be composed of mainly the types that do not degenerate in AD. Thus, if the reduced PI kinase activity is confined to a particular cell type or types, the effect may be still greater. Furthermore, inositol phospholipids play a key role in impulse initiation and propagation and thus with intrinsic neuronal and brain functions (for reviews, see Abdel-Latif, 1986; Berridge, 1987). A large decrease in PIP formation can therefore be expected to have a widespread influence on membrane function because the pathway that leads to PIP₂ formation is blocked. This may result in a blockade of PIP₂ hydrolysis and thus inhibit the formation of the second messengers inositol triphosphate and diacylglycerol. It is relevant in this respect that reduced numbers of inositol trisphosphate binding sites have been found in the parietal cortex and hippocampus of patients with AD (Young et al., 1988).

With respect to the biochemical mechanisms underlying the reduced incorporation of ³²P into PIP, it is possible that the AD brain samples are characterized by a reduced quantity of PI kinase, by changes in enzyme kinetics, or by the presence or absence of cofactors. Questions as to the type of PI kinase involved are also relevant in view of the fact that two different types of PI kinase are known, namely, the kinase that phosphorylates PI at the 4 position of the inositol ring (the so-called "PI 4-kinase") and the one that phosphorylates the 3 position ("PI 3-kinase"). This difference is of importance because the two kinases are implicated in different functions in the cell (Downes and MacPhee, 1990).

Involvement of the PI 3-kinase would be of great relevance because this kinase is suggested to be involved in cell growth and in the maintenance of the cytoskeleton (Carpenter and Cantley, 1990). The fact that the present findings were obtained with a membrane-free supernatant suggests that the kinase responsible for these findings might be the PI 3-kinase. Research is in progress to investigate whether the present findings are due to changes in the activity of PI 3-kinase or PI 4-kinase.

The finding that the differences between AD brains and control brains were quite similar for the four structures tested is indicative of a global degeneration of the neocortex. Indeed, the patients were in the terminal stage of the disease, i.e., stage 7 on the Global Deterioration Scale (Reisberg et al., 1983) when most neocortical tissue is known to be involved. Research is planned to compare the tertiary association zones investigated in the present study with the primary sensory cortex and limbic zones and with the cerebellum. A comparison with the latter structure is judged to be especially relevant because this region is not pathologically affected in AD. In addition, other neurological disease groups (Parkinson's disease and multi-infarct dementia) are investigated in order to ascertain the specificity of the observed changes in PI kinase activity. In conclusion, specific alterations in inositol phospholipid phosphorylation have been found in the present study. The findings may be important because of the key role played by inositol phospholipids in neuronal functioning.

REFERENCES

INOSITIDE KINASES IN ALZHEIMER’S DISEASE


