The Early Intervention of Geniposide and PNS Combination Modulated Aβ Production and Synaptic Plasticity in Young APP/PS1 Transgenic Mice

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Abstract

Alzheimer’s Disease (AD) is a common neurodegenerative disease with age-related, which accounts for nearly 80% of dementia. Accompanied with aging population worldwide and clinical failures in AD drugs, early prevention and diagnosis are under main concern. Traditional Chinese Medicine (TCM) has a long history in the prevention of cognition declines. In clinic, the combination of geniposide and Panax notoginseng Saponin (PNS) is clinically efficacious in the treatment of ischemic cerebral stroke and vascular dementia. In vivo, under a preventive strategy, the combination can improve spatial learning and memory and reduce amyloid plaques in a variety of AD-like animal models. Therefore, in order to illustrate the neuroprotective role of geniposide and PNS combination, under an early intervention strategy, we medically administrated at one-month age of APP/PS1 transgenic mice for three months. In this study, firstly, we found that the ratio of Aβ$_{1-42}$/Aβ$_{1-40}$ in both cortex and hippocampus was significantly decreased under the treatment; secondly, the combination significantly increased dendrite spine density in hippocampus CA1 areas, and increased the protein level of PSD-95 (synaptic function-related protein in post-synapse). These results indicated that geniposide and PNS combination modulated Aβ production and synaptic plasticity in an early stage of AD processing.

Keywords: Aβ; Alzheimer’s disease; Geniposide; PNS; Synaptic plasticity

Introduction

Traditional Chinese Medicine (TCM) has experienced more than 2000 years in oriental countries, followed by a general principle referring to that compatible components of different herbal decoction may jointly play a role in synergistically enhance curative efficacy or reduce adverse effects. In the theory of TCM, the pathogenesis of dementia has been considered as the damage of brain collateral by toxins. Combined with the knowledge of AD pathological changes, inflammation, amyloid plaques could be the toxins in TCM, which resulted in the damage of synaptic plasticity and connections, and eventually leaded to cognition declines. Based on the theory, the formulae prescribed according to detoxification and collateral-dredging strategy has been administrated in dementia, such as the combination of Geniposide (GP) and Panax notoginseng Saponin (PNS). In clinic, the combination has been used in ischemic stroke patients and also whose memory declined [1]. GP is the main bioactive ingredient of Fructus Gardeniae, which is considered as a function of clearing away heat and toxic materials, also is regarded as diminishing inflammation in modern medicine [2,3]. PNS is the main bioactive ingredient of Panax notoginseng, which is considered as activating blood circulation to dissipate stasis [4,5]. In vivo, the combination improved spatial learning and memory and reduced amyloid plaques in several AD-like animal models [1,6-8]; in vitro, GP and PNS showed to protect neuronal damage caused by formaldehyde [9,10] and promoted the neurite outgrowth of rat hippocampal neurons under oxygen/glucose-deprivation conditions [11]. These data suggest that GP and PNS combination undergoes a potential role of neuroprotection in AD.

Due to further investigate the neuroprotective effect of GP and PNS at an early intervention, we make use of young APP/PS1 transgenic mice. The mice are widely used in AD studies for the robust AD pathological changes: at 3-4 month age, the Aβ is increasingly accumulated in both brains and serum; at 6-7 month age, the amyloid plaques are deposited at brains and cognitive impairments are occurred [12,13]. Then, in this study, we administrated at one-month age of APP/PS1 Tg mice, lasting for three months. The treatment is ended before the robust pathological changes occurred. We detected the morphology, dendritic spines in CA1 areas and the production of Aβ in both hippocampus and cortex.

Materials and Methods

Animals

APP/PS1 transgenic mice were purchased from Nanjing Biomedical Research Institute of Nanjing University (Cat. D000268), and bred in independent cages.

APP/PS1 mice were randomly divided into five groups, including transgenic model (Tg), Aricept, PNS, GP and GP+PNS group, and one littermate Wild Type control (WT) group. Each group contained fifteen mice. The animal housing rooms were maintained under standard laboratory conditions, 12 h/12 h light-dark cycle, 23 ± 1°C air temperature, and 55 ± 15% humidity, with access to water and food. All procedures concerning care, treatment and dissection are in accordance with the guidelines of National Institutes of Health and local institutional guidelines.

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with the regulations of ethical committee for use of experimental animals of the Chinese Academy of Sciences.

**Drugs**

GP and PNS were purchased from Nanjing Ze-Lang Pharmaceutical Company (Cat. 20110502, Cat. ZL20110620GNPG), administrated with 0.01927 mg/g/day and 0.01668 mg/g/day, respectively, according to our previous studies; Aricept was brought from Eisai China Inc. (Cat. 070624A), treated with 0.0000714 mg/g/day [6]. Drugs were dissolved in physiological saline and mixed in powdered food to form a drug ball. Before the drug feeding, the mice were fasted for 2-3 h. Treatments were administered at one-month age and lasting for three months.

**Hematoxylin and eosin staining**

Mice (n=3 per groups) were deeply anesthetized with 10% chloral hydrate (LG-00694, Biotopped), and perfused intracardially with ice-cold Phosphate Buffered Saline (PBS), followed by ice-cold 4% paraformaldehyde (P6148, Sigma) in 0.1M PBS. Brains were quickly removed from the skull and post-fixed in 4% paraformaldehyde overnight at 4°C. Brain samples were processed in paraffin embedding on the following day. Coronal brain sections were performed serially at 6 μm thick of each slide. Staining was performed as follows: 1) glass slides with paraffin sections were put in to a hot air oven at 60°C for 1 h; 2) process deparaffinization as following steps, each step last for 3 min: Xylenes, new Xylenes, 50% Xylenes/50% ethanol, 100% ethanol, new 100% ethanol, 95% ethanol, 70% ethanol, 50% ethanol, distilled water; 3) dip rehydrated slides 30 sec in Hematoxylin, then rinse with tap water until water runs clear, further dip slides 2 min in Eosin Y, then rinse with tap water until water runs clear; 4) run slides through a quick dehydro series, 3 quick dips in each of the following solutions: 50% ethanol, 70% ethanol, 95% ethanol, 100% ethanol, new 100% ethanol, then incubate slides 1 min in 50% Xylenes/50% ethanol, 3 min in Xylenes, 3 min in new Xylenes. Eventually, mount with neutral balsam sealed by cover glass. Sections were observed and photographed under the microscope (Nikon).

**Golgi staining**

The animals (n=4 per groups) were deeply anesthetized with 10% chloral hydrate (LG-00694, Biotopped). Monitor them until the point when the animal fails to respond to pinching of the foot. The brain tissue was prepared followed by Hito Golgi-Cox OptimStain Kit (Catalog number: HTKNS1125, Hitobiotec Inc.). Briefly, remove the brain tissue, carefully separate into two hemispheres (one for WB, one for Golgi staining). Rinse one hemisphere in double-distilled water for 2-3 seconds to remove blood from the surface. Transfer tissue in the impregnation solution and store at room temperature in the dark. Replace the impregnation solution after 18 h, and store at room temperature for fourteen days in the dark. Transfer tissue into Solution-3, and store at 4°C in the dark. Replace Solution-3 after 12 h, and continue to store at 4°C in the dark for 72 h. Freeze tissue in freezing isopentane (on dry ice) for 30 seconds to 1 min. Remove the frozen tissue and store at -70°C.

Prepare cryostat sections at 80 μm thickness. Air dry slides. Rinse slides in distilled water for 3 min, twice. Stain slices for 10 min in staining solution. Rinse slides in distilled water for 4 min, twice. Dehydrate slides followed by 50%, 75% and 95% ethanol for 5 min each. Dehydrate slides in 100% ethanol for 5 min, three times. Clear in xylene for 5 min, twice. Apply coverslip over sections using mounting medium. Dry and observe under a 100×oil-immersion objective lens (OLYPUS). Pyramidal cells in hippocampus CA1 area are selected, analyzing its apical and basal spine density in dendritic branch at the length of more than 10 μm. Data is quantified with ImageJ (1.48v).

**Western blotting**

Brain lysates (n=4) were prepared according to previous experiment. Briefly, hippocampus and cortex were separately homogenized by a mixture of RIPA (Cat. CW2336, CWBIO), PMSF (Cat. 0754-5G, Amresco) and phosphatase inhibitor cocktails as 100:1:1 ratio. The brain homogenate solutions were centrifuged at 15000 rpm for 30 min at 4°C. Then collect the supernatant for Western blot assay. Protein concentration was measured by protein assays (Cat. 23225, Pierce) following manufacturer’s instructions. Protein samples were electrophoresed through 12% SDS-polyacrylamide gels and transferred to Polyvinylidene Fluoride Membrane.

Membranes were blocked with 5% skim milk in PBST for 1 h at room temperature, then incubated with primary antibodies at 4°C overnight with shaking at 60 rpm/min. Primary antibodies used are: rabbit anti-PSD95 polyclonal antibody (Cat. P78352, Cell signaling) at 1:1000, mouse anti β-actin monoclonal antibody (Cat. CW0096, CWbio) at 1:2000. On the following day, wash with PBST for 5 min, 3 times. Then, incubate with secondary antibody for 1 h at room temperature. Secondary antibodies used are: HRP-conjugated goat anti-rabbit (Cat. CW0103, CWbio) at 1:5000 or goat anti-mouse (Cat. CW0102, CWbio) at 1:5000 or rabbit anti-goat (Cat. E030130-01, Earthbox) at 1:10000. Then, repeat washing step. Protein signals were detected with enhanced chemiluminescence reagent (Cat. 32109, Pierce), and exposed with X-ray film in dark room.

**Enzyme-linked immunosorbent assay**

Insoluble Aβ1-40 and Aβ1-42 were analyzed with enzyme-linked immunosorbent assay. Briefly, tissues (hippocampus or cortex, n=5) were dissolved in 98% of formic acid, split for 15 min on ice, then centrifuged at 17000 rpm for 1 h at 4°C. Collect the supernatants for later measurement, using Aβ1-40 and Aβ1-42 ELISA kit (Cat. KHB3482 and KHB3442, Invitrogen-Biosource). Measurement was normalized according to the manufacturer’s instructions.

**Statistical Analysis**

Data was analyzed by One-way ANOVA to compute statistical significance in each group compared with Tg group. All data were presented as mean ± Standard Error of the Mean (SEM) and p<0.05 was considered statistically significant. Analyses were carried out using SPSS 20.0.

**Results**

The morphology of pyramidal neurons in hippocampus CA1 area was abnormal in APP/PS1 mice, while it was improved under the early intervention of GP and PNS combination

Under an early intervention, GP, PNS and their combination has been administrated at one-month age of APP/PS1 transgenic mice, followed by 3-month long (Figure 1A). Firstly, by Hematoxylin and Eosin staining (HE staining), the morphology of pyramidal neurons in hippocampus CA1 area was detected. At four-month age, a severe condensed but uneven and thinner layer of pyramidal neurons was observed in 1-40 1-42 APP/PS1 mice, which was different from WT mice. Under all the intervention groups, a relative thicker and smoother but without severe condensed layer of pyramidal neurons has been found, which was similar to WT group (Figure 1B), shown in double-headed arrows). These observations indicated that the abnormal
The ratios of Aβ/Aβ in both hippocampus and cortex were evidently increased in APP/PS1 mice, while GP and PNS combination significantly reduced the ratios but adjusted the production of Aβ differently in hippocampus and cortex.

APP/PS1 mouse is one of the most widely used AD-like animal, since it develops amyloid plaques in brain by six to seven months of age [13], accompanied with an accumulating production of Aβ since three to four months of age [12]. At four-month age, we found that the ratios of Aβ1-42/Aβ1-40 in both hippocampus and cortex were significantly increased in APP/PS1 mice, while only the group of GP and PNS combination significantly reduced the ratios (Figures 2A and 2B). Furthermore, in order to illustrate the changes of Aβ1-42 and Aβ1-40 production in different brain areas, the levels of insoluble Aβ1-42 and Aβ1-40 were measured. Interestingly, in the hippocampus area, the production of Aβ1-42 was significantly reduced compared with APP/PS1 mice, while in the cortex area, the production of Aβ1-40 was significantly increased compared with APP/PS1 mice (Figures 2C and 2D). But in positive control group, Aricept did not show a significant change in their ratios or insoluble Aβ productions. These data indicated that GP and PNS combination showed a different pattern of Aβ production in different brain tissues, suggesting that different mechanisms of Aβ clearance may exist in different areas.

In Aricept group, compared with Tg mice, there is a reduction tendency observed in the production of both Aβ1-42 and Aβ1-40, but we did not find a significant change, as well as the ratio of Aβ1-42/Aβ1-40 did not decrease. This data showed that at four-month age of APP/PS1 Tg mice, Aricept did not reverse the Aβ production.

The number of dendritic spines was significantly increased in hippocampus CA1 areas of APP/PS1 mice, while GP and PNS combination significantly increased the number.

Accumulated Aβ peptides have been considered as a toxicant to neurons, especially in hippocampus related with learning and memory [14]. In vivo, we narrowed to hippocampus CA1 area to detect the synapse plasticity. Golgi silver staining has been used to label dendrites and quantify both apical and basal dendritic spines in hippocampus CA1 areas. At 4-month age, the dendritic spines at hippocampus CA1 area in WT mice are evenly dispersed with a high density. However, unlikely morphology of pyramidal neurons in hippocampus CA1 area occurred as early as four-month age of APP/PS1 mice, while GP and PNS intervention can reverse the abnormality.

The early intervention of geniposide and PNS combination modulated Aβ production and synaptic plasticity in young APP/PS1 transgenic mice. J Alzheimers Dis Parkinsonism 8: 448. doi: 10.4172/2161-0460.1000448

Figure 1: TLJN improves the abnormal morphology of pyramidal neurons in hippocampus CA1 area occurred in APP/PS1 Tg mice. A. The treatment strategy in APP/PS1 Tg mice. At one-month age, APP/PS1 Tg mice are randomly grouped into five groups: Tg, Aricept, PNS, GP, and PNS+GP. Their wild-type littermates are considered as control without drug treatment. The drug administration lasts for three months. At four-month age, exert a series of analysis. B. To exhibit the morphology of pyramidal neurons in hippocampus CA1 area, Hematoxylin and Eosin staining (HE staining) has been used. At 4-month old age, compared with Wild Type group (WT), an severe condensed layer of pyramidal neurons occurred in APP/PS1 Tg mice (Tg). The thick of this layer is uneven; and, some part of it is strikingly thinner in Tg compared with WT (shown in double-headed arrow). In treatment groups (Aricept, PNS, GP and PNS+GP), the condensed layer consisting pyramidal neurons is evidently thicker and smoother than Tg group, which is similar to WT. High magnifications of black squares exhibit in the right corner. Scale bar: 50 µm.

Figure 2: TLJN significantly reduces the ratio of Aβ1-42/Aβ1-40 in both hippocampus and cortex, but adjusts the production of Aβ differently.

(A) Due to detection of the level of Aβ1-42 and Aβ1-40 in both hippocampus and cortex, ELISA has been used. In hippocampus (n=5), we can’t detect Aβ1-40 in WT mice at 4-month age. The level of Aβ1-42 in Tg mice is strikingly higher. Compared with Tg group, only PNS+GP significantly decreased the production of Aβ1-42. Data are represented as mean ± SEM. *** p<0.001, ** p<0.01, * p<0.05.

(B) In hippocampus (n=5), there is a strikingly results of Aβ1-42/Aβ1-40 occurred in Tg mice. Again, compared with Tg, only PNS+GP significantly reduced the ratio of Aβ1-42/Aβ1-40. Data are represented as mean ± SEM. *** p<0.001, ** p<0.01, * p<0.05.

(C) In cortex (n=5), we can detect a slight amount of Aβ1-40 in WT mice at 4-month age. The level of Aβ1-40 in Tg mice is evidently higher. However, interestingly, compared with Tg group, PNS+GP significantly increases the production of Aβ1-40 in cortex. Data are represented as mean ± SEM. ** p<0.01, * p<0.05.

(D) Similar to hippocampus, in cortex (n=5), there is a strikingly higher ratio of Aβ1-42/Aβ1-40 occurred in Tg mice. What’s more, we observe a significant reduction of Aβ1-42/Aβ1-40 ratio occurred in PNS+GP group. Data are represented as mean ± SEM. *** p<0.001, ** p<0.01, * p<0.05.
to WT, in Tg mice, their dendritic spines occurred sporadically uneven with low density, suggesting an abnormal morphology of synapse in Tg at the age of four-month. In addition, under a three-month treatment of TLJN (PNS+GP), similar to WT, it shows a high density and evenly dispersed. But in Aricept, we did not observe a significant improvement in the density of dendritic spines (Figure 3A).

Due to statistic analyze the number of dendritic spines in hippocampus CA1 area, its number has been counted in both apical and basal ends. Compared with WT, the number of dendrite spines in both apical and basal ends is significantly decreased in Tg mice. After treatment, in term of apical dendrites, GP and PNS+GP groups significantly increase the number of dendrite spines compared with Tg (Figure 3B); in terms of basal dendrites, PNS, GP and PNS+GP groups significantly increase the number of their dendrite spines compared with Tg (Figure 3C). However, Aricept did not significantly increase the number of dendritic spines in both apical and basal ends. These results suggest that PNS, GP, PNS+GP can reverse the impaired morphology of synapses in terms of increasing both apical and basal dendrites spines, while Aricept has no evident effect on increasing dendritic spines number.

**TLJN (PNS+GP) increases the expression level of postsynaptic density protein 95 (PSD-95) in APP/PS1 hippocampus**

Synaptic disruption accompanies with AD pathogenesis; its impairment of synaptic plasticity indicates memory deficits, but occurred earlier than behavior symptoms [15,16]. Postsynaptic density protein 95 (PSD-95), a major scaffolding protein locating at excitatory synapses anchors synaptic proteins, regulates synaptic distribution, plays an important role in synaptic plasticity. Since the abnormal morphology of synapses observed in APP/PS1 Tg mice at four-month age, here, we further evaluate the protein level of PSD-95 (Figure 4). Compared with WT mice, the protein level of PSD-95 is significantly decreased in Tg mice. Under the treatment of PNS+GP, PSD-95 protein level is significantly increased compared with Tg. This data is consistent with Golgi silver staining in PNS+GP group with a higher dendritic spines (Figure 3), indicating that TLJN (PNS+GP) can improve synaptic plasticity by accelerating the expression level of postsynaptic related protein PSD-95 and dendritic spines. However, unfortunately, we found that Aricept further decreased the protein level of PSD-95 compared with Tg, suggesting that Aricept did not enhance the plasticity of synapses at four-month age of APP/PS1 Tg mice (Figure 4).
Discussion

Alzheimer Disease (AD) is a progressive neurodegeneration disease, accounting for 60% to 80% of all dementia patients worldwide (http://www.alz.co.uk/). However, their diagnoses are often missed or delayed due to the lower prevalence of dementia in younger people and large variability in etiologies [17,18]. And, non-effective drugs against AD in market approved accumulate the serious situation, which puts the prevention and treatment into an impending place [19]. Then, early this year, FDA proposed that the drug development and diagnosis of AD should be focused on the early stage before the onset of overt dementia [20].

TCM has a long history in oriental countries. Preventing Disease, an essential consideration of TCM treatment strategy, emphasizes the conception of prevention and early treatment of diseases. Based on this thinking, for the past ten years, we have been tried to find and explain the neuroprotective role of TCM in AD. According to previous studies, in vitro, we found that GP and PNS combination alleviated the damage of ischemia/reperfusion neurons by promoting the secretion of active substances from Brain Microvascular Endothelial Cells (BMECs) [21]; under oxygen/glucose-deprivation condition, the combination protected both primary rat hippocampal neurons and BMECs from cell death [11]; again, under formaldehyde stress, TLJN inhibited the cell apoptosis by modulating the expression of Bcl-2, P53, caspase 3 and caspase 9, and increasing the activity of intracellular superoxide dismutase and glutathione peroxidase [9,10]. These data suggest that it can prevent neurons from cell death, but also can protect BMECs. In vivo, to further verify its efficacy on learning and memory, we used a rat model and three other different AD Tg mice. In rat, after Aβ25-35 injection into the bilateral hippocampus CA1 areas, we found that GP and PNS prolonged a cavity delitescence, decreased arm entries in Y-maze test, and reduced amyloid plaques in rat brain by up-regulating insulin-degrading enzyme and neprilysin levels [1]; in APP/V717I Tg mice, GP and PNS improved their spatial memory deficits in both Water-Maze test and inhibitory avoidance test (Step-down test) at ten-month age [6]; in APP/PS1 Tg mice, we found that it improved the spatial learning and memory in Water-Maze test and reduced amyloid plaques in brain at 10-month age (data have not published yet); in APP23 Tg mice, we observed an inhibitory effect of the combination on amyloidogenic APP processing by down-regulating the cleavage enzymes BACE1 at twelve-month age [8]. These evidence showed that GP and PNS can improve learning and memory in different AD Tg mice, and reduce the deposition of amyloid plaques.

Based on these studies, we continued to investigate its neuroprotective role in an early stage. We used APP/PS1 Tg mice. These mice express human APP (695 Swedish mutation) and a mutant human presenilin1 (PS1-ΔE9). Both mutations are associated with early-onset AD. They develop beta-amyloid deposits in brain by six to seven months of age [13], but their memory deficits usually occurred at the age of nine-month and older [22]. APP/PS1 Tg mouse is one of the most widely used AD-like animal, due to the extensive Aβ deposition and synaptic deficit with aging, accompanied with memory deficits. At 4-months old of APP/PS1 Tg mice, there is an approximately 30% reduction in spine density as well as about 20% decrease in both dendritic area and dendritic diameter in the transgenic mice as compared with wild-type littermates [23]. In addition, Aβ accumulation in APP mutant neurons reduces PSD-95 and AMPA receptor (GluR1) in synapses [24]. Then, by using young APP/PS1 Tg mice, we focused on the prevention started from one-month age, lasting for four-month age, which is before formation of amyloid deposition.

In this study, we firstly detect the morphology in hippocampus CA1 areas. CA1 pyramidal neurons play a significant output pathway from hippocampus, which is required for contextual encoding and memory retrieval [25]. A 20–30% of neuronal loss was observed at 6-month age of APP/PS1 mice, and increased during AD processing [26]. Interestingly, at the early stage of AD in APP/PS1 mice, we found the pyramidal cell layer is severe condensed with uneven thickness in Tg group compared with WT mice. Further, in accord with the abnormal morphology in CA1, the number of dendritic spines is significantly reduced in Tg mice at four-month age, while GP and PNS promote the density of spines. Again, the protein level of PSD95, a synaptic-related protein, is significantly reduced in Tg, but significantly reversed under GP and PNS treatment. These data suggest that APP/PS1 Tg mice exhibited a neurodegeneration processing at an early age (four-month age) before the formation of amyloid plaques and cognition impairment occurred.

What's more, according to clinical studies, the loss of synapses has been considered as one of the most reliable index of cognition deficits in both post-mortem and biopsied AD brain [27], and amyloid deposition or Aβ peptide (either insoluble Aβ or soluble Aβ species) is associated with synaptic abnormalities, such as dendritic spine loss [28], breakeage of neuronal branches, spine dysfunction and collapse [24]. We detected the production of Aβ in both hippocampus and cortex. Both Aβ1-42 and Aβ1-40 are significantly increased in APP/PS1 Tg mice at four-month age. The ratio of Aβ1-42/Aβ1-40 is significantly increased as well compared with WT group. Secondly, to then, under the early treatment, GP+PNS significantly decreased the ratio of Aβ1-42/Aβ1-40 ratio in both hippocampus and cortex. Interestingly, in hippocampus, the production of Aβ1-42 was reduced under TLJN treatment; while in cortex, it was the production of Aβ1-40 significantly increased. Secondly, we focused on the changes of synaptic plasticity. We found that the number of dendritic spines in hippocampus CA1 areas was significantly increased in GP+PNS group compared with Tg group. In addition, due to detect synaptic plasticity, we examined the expression level of synaptic-related protein, such as PSD-95. Our data showed that the combination has an impact on increasing the protein level of PSD-95. These data suggest that GP+PNS can maintain the delicate balance of Aβ production in APP/PS1 Tg mice to reduce the ratio of Aβ1-42/Aβ1-40 in both hippocampus and cortex; and it can enhance synaptic plasticity at four-month age of APP/PS1 Tg mice (Figure 5).

In this study, we also used Aricept as a positive control group, since it is the first drug approved by FDA to treat AD in clinic. Aricept (also called donepezil), as a cholinesterase inhibitor, leads to a temporary slowdown in the loss of cognitive function by decreasing cholinesterase activity, resulting in higher Acetylcholine (Ach) levels and improved brain function with mild-to-moderate AD patients [29, 30]. However, we did not observe evident effects of Aricept on APP/PS1 Tg mice at four-month age. Firstly, Aricept did not significantly reduce the ratio of Aβ1-42/Aβ1-40 in both hippocampus and cortex; secondly, in terms of synaptic plasticity, Aricept did not significantly increase the number of dendritic spines in hippocampus CA1 areas compared with Tg mice; and, the protein level of PDS-95 was further decreased compared with Tg mice. There might be reasons: 1) Aricept is a cholinesterase inhibitor. In this study, we did not focus on the change of Ach level. But in terms of Aβ production, at an early age of APP/PS1, before the formation of amyloid plaques, Aricept did not show an evident effect to maintain the balance of Aβ production; 2) again, in terms of synaptic plasticity, before the cognition impairment occurred, Aricept did not show a positive role to enhance the health of synapses; 3) according to
Figure 5: The neuroprotective effects of TLJN on APP/PS1 at 4-month age. PNS+GP treatment starts at one-month age of APP/PS1 Tg mice lasting for three months, exhibits multiple functions in both cortex and hippocampus. In cortex, PNS+GP can increase the production of Aβ1-42 on the contrary, in hippocampus, PNS+GP decreases the production of Aβ1-40. These two different effects on Aβ production both leads to a reduction of Aβ1-42/Aβ1-40 ratio in the end. Furthermore, PNS+GP can improve synaptic plasticity in hippocampus of APP/PS1 Tg mice. Both apical and basal dendritic spines are significantly increased under PNS+GP treatment. And post-synaptic related proteins PSD-95 and AMPA are higher expressed in PNS+GP group.

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