Acute and Chronic Effects of 3-4, Methylenedioxymethamphetamine on Pyramidal Cells of Hippocampus

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1. Background

Ecstasy or 3-4, methylenedioxymethamphetamine (MDMA), as an amphetamine derivate, could lead to learning and memory impairment. Ecstasy or 3-4, methylenedioxymethamphetamine (MDMA), is a substituted amphetamine with very high abuse liability in the world (1). It is a widely abused drug, especially among adolescents and young adults. According to the United Nations, in 2009 the worldwide prevalence of MDMA use ranged from 11 to 28 million individuals who were between the ages of 5 and 64 years (2). Moreover, MDMA leads to elevated mood, feeling of closeness to wards others and a desire to touch others. After-effects can be sleep problems, anxiety and depression (3). It has been reported that repeated use of ecstasy produces long-term neurotoxicity in humans and primates (4, 5). It can induce pathological cerebrovascular responses (6) and affect the immune system (7). In addition, MDMA can produce both irreversible and reversible brain changes, such as expression of microglia cells and hypertrophy of astrocytes, and neuronal degeneration in various areas of the brain (8). Some studies have reported that ecstasy has neurotoxic effects on serotonergic, dopaminergic and adrenergic endings (9). It causes acute release of serotonin from nerve endings, binds to the serotonin transporter (SERT), and inhibits serotonin reuptake, which leads to serotonin reduction and memory impairment (8, 10). In a previous study, we showed that acute and chronic administration of MDMA induced deficits in passive avoidance and Morris water maze tasks that were more exaggerated in acute-treated rats (11). In another study, MDMA treatment caused a decrease in novel object recognition and anxiety in the elevated plus maze (12). It has been reported that different doses of MDMA impaired locomotor activity and allocentric learning, dose dependently and acutely in rats (13).

2. Objectives

Since MDMA decreases serotonin in the hippocampus and causes memory impairment, and because the hippocampus is an important structure that involves spatial memory, the main objective of this study was to elucidate the effects of acute and chronic dosages of MDMA on the structure of the CA1 area of the hippocampus.

3. Materials and Methods

3.1. Animals

Fifteen male Wistar rats (weighting 200-250 g) were obtained from the animal house of Hamadan University of
Medical Sciences (Hamadan, Iran) and kept in a colony room at a temperature of 21 ± 1°C (50 ± 10% humidity) on a 12-hour light-dark cycle with access to water and food ad libitum. All experiments were approved by the Ethical Committee of Hamadan University of Medical Sciences.

3.2. Treatment Groups and Drug Administration

The rats were randomly classified into three groups (n = 5 per group), as follows:
1. The control or intact group was left undisrupted.
2. Acute MDMA group received intraperitoneal (IP) injection of 10 mg/kg MDMA once.
3. Chronic MDMA group received IP injection of 10 mg/kg MDMA during the weekend for three weeks (1, 2, 8, 9, 15, 16 days).

Body weight was recorded on first and last days of drug administration.

3.3. Tissue Preparation for Cresyl Violet (Nissl) Staining and Histological Study

The day after the last administration, rats from each group were deeply anesthetized with ketamine (100 mg/kg) and xylazine (10 mg/kg) and transcardially perfused with a mixture of 4% paraformaldehyde in phosphate buffer (0.1 mol/L). Next, brains were removed from the skulls and post-fixed in the same fixation solution. The brains were dehydrated in ethanol, cleared in xylene, and embedded in paraffin. Furthermore, 10 µm coronal sections from bregma: 1.34 mm to bregma: -2.54 mm were prepared by a microtome (Leica, IL, USA). The sections were then deparaffinized, rehydrated, and stained with 0.1% cresyl violet solution (Nissl stain). The pyramidal intact cells of CA1 with defined cell bodies and nuclei were counted using a light microscope (Olympus Provis, AX70, Japan) attached to a digital camera (Olympus, DP II, Japan). For each animal, the average neuronal counts were obtained by counting five serial sections at 400 × magnification.

3.4. Statistical Analysis

Statistical analyses were performed by the SPSS 16 software. Analyses of cell density and body temperature were performed using one-way and two-way repeated measurement analysis of variance (ANOVA), respectively. All results were expressed as mean ± SEM. Values of P < 0.05 were considered significant.

4. Results

4.1. Effect of MDMA on Body Weight

For the body weight, the intact and acute groups did not perform different, thus we considered them as one. As shown in Figure 1, repeated administration of MDMA caused a reduction in body weight when compared to the intact group, but this was not significant.

4.2. Effect of MDMA on Cell Density in CA1 Hippocampus

Figure 2 A-C shows coronal sections of cells in the CA1 hippocampus. Light microscopy of the sections stained with Nissl stain showed that pyramidal intact cells had defined cell bodies and nuclei. Administration of MDMA caused neuronal cell death and dark neuron formation. As shown in Figure 2 B and C, dark neurons were characterized by neuronal shrinkage, cytoplasm hyperstainability, and nuclear pyknosis. Analysis of variance of cell count showed that MDMA reduced neural density in the CA1 hippocampus compared to the intact group. Administration of multiple doses of MDMA significantly led to cell loss when compared with intact (P < 0.001) and acute (P < 0.01) groups (Figure 3).
Taken together, it seems that MDMA treatment reacts with glutathione, subsequently generating ROS metabolized in the presence of NADPH into quinine, which plays an important role in maintaining homeostasis and protecting cells against oxidative and toxic factors. Moreover, GSH depletion causes spatial memory impairment that lead to neurotoxic effects. It has been shown that the MDMA-induced toxicity in chronic-treated rats is more exaggerated than chronic effects.

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