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Effects of Cadmium on Kidney Function of the Freshwater Turtles *Mauremys reevesii*

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Abstract

This research studied the effects of cadmium on kidney function of the freshwater turtles *Mauremys reevesii*. Turtles were injected intraperitoneally with 0, 7.5, 15, and 30 mg kg^{-1} cadmium separately for once. The samples were gathered to check the kidney index, the contents of TP in kidney tissue, and the levels of CRE and BUN in the plasma of the turtles. Results showed that the concentration of TP was overall decreased with the extension of cadmium exposure time and the increasing of the exposure dose of cadmium. The CRE content in the plasma of each treatment group increased with the prolongation of exposure time in a dose-dependent, and the BUN levels of all poisoned groups showed a trend of increasing. The kidney index of treated turtles increased. In summary, cadmium could induce the increase of turtle kidney index, the content of CRE and BUN in plasma, and the decrease of TP content in the kidney.

Keywords Cadmium · Turtle *Mauremys reevesii* · Kidney · Function

Introduction

Cadmium (Cd) is an essential pollution in aquatic-ecosystem restoration [1]. Cd can pass through the food chain and accumulate in animals at the top of the food web [2].

Some researches of the effect of metals (such as mercury and lead) on turtles have been made [3–7]. High levels of Cd have been found in marine turtles in some areas [8–10]. But researches about the effect of cadmium on turtles in freshwater are lacking. So more researches of cadmium on turtles toxicology should be carried out.

Cd is a widespread environmental pollutant in freshwater systems [11–15], as it is discharged into the environment due to mining, smelting, and burning of coal in power stations [16, 17]. The surveys on Cd accumulation in the Sinopotamon henanense habitat of the Qin River show that Cd levels can reach 10.6–14.3 mg/kg in surface sediments [18]. In some valleys near Cd-rich mines, the content of Cd in suspended materials has been reported to be as high as 232 mg/kg [19]. Furthermore, in some places, Cd contamination caused by human activity is much more prominent than those by the natural erosion process [20].

Turtle have long been present as food, medicine, and pets in many parts of the world [21–23]. The omnivorous and longevity properties of the turtle make it ideal for monitoring heavy metal pollutants in a certain piece of water. In addition, turtle *Mauremys reevesii* is easy to handle because the size of this turtle is moderate and the turtle is poorly aggressive [24]. The turtle community lies in the upper part of the food chain of the aquatic system. However, toxicological information about Cd pollution in freshwater turtles is little [25–34].

Endogenous creatinine (CRE) is a product of muscle metabolism. It is released into the blood and eliminated by glomerular filtration. CRE will accumulate in the body in renal insufficiency. Blood urea nitrogen (BUN) is one of the major final products of animal metabolism of proteins, and the kidney is one of the primary excretory organs of the animal body. BUN levels can rise rapidly with kidney damage [35].

Before this, we have studied the toxicology dynamics of Cd in turtle *Mauremys reevesii*, and the kidney is discovered

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to be one of the poisoning target organs of Cd [33]. In this context, we conducted the research to examine the kidney index, the content of TP in kidney tissue, and the content of CRE and BUN in the plasma of treated turtles *Mauremys reevesii* exposure to Cd.

Materials and Methods

Materials

Cadmium chloride ($CdCl_2 \cdot 2.5H_2O$, batch number: 20150504) was purchased from Tianjin Guangfu Technology Development Co., Ltd. *Mauremys reevesii* with 130 ± 10 g in weight was purchased from Taiyuan birds and fish market.

Animals Treatment

Fifty *Mauremys reevesii* turtles were divided into two groups, which included the control group and experiment groups. The control turtles were injected intraperitoneally with sodium chloride solution (0.85%). The experiment turtles were injected intraperitoneally with 7.5, 15, and 30 mg/kg Cd, respectively, for once.

Samples Collection

Five animals in every group were sacrificed after 1 week (1w), 2 weeks (2w), and 3 weeks (3w) of Cd treatment. Kidney was excised and weighed. By weight (g): volume (ml) is equal to the proportion of 1:9, add nine times medium (0.85% saline solution) to kidney tissue, homogenizing, centrifuging at 2500 r/min at 4 °C for 10 min. The supernate was reserved at − 80 °C for detecting kidney function.

Biochemical Assays

The content of CRE, BUN, and the content of total protein (TP) in plasma were measured with kits (Nanjing Jiancheng Bioengineering Institute, Nanjing, China) following the manufacturer's protocols. All measurements were carried out with a microplate reader (Spectra max M5; Molecular Devices, USA).

Calculated Kidney Index

$$\text{Kidney index (\%)} = (\text{wet kidney weight}/\text{body weight}) \times 100\%$$

Statistical Analysis

Statistical analyses were performed with SPSS 20.0 software package. The data was representative of the mean values of five animals in each group, and the results were shown as means ± standard deviations (SD). The probability value of less than 0.05 was statistically different. If the probability value was less than 0.01, the difference was statistically significant.

Results

Correlations Between the Content of TP and Cd Treatments in Kidney Tissues

From Fig. 1, we could see that the effect of Cd on TP content in renal tissue was related to the dose and time. The TP content in the 7.5 mg/kg group was markedly decreased after exposure for 1 and 2 weeks ($P < 0.01$). But at 3 weeks after exposure, the content of TP in the 7.5 mg/kg group was markedly increased ($P < 0.01$). Overall, the TP concentration was raised in the 7.5 mg/kg group along with the prolonged cadmium exposure time. The TP content in renal tissue increased first, then decreased, and then expanded to regular range in the 15 mg/kg group. Compared with the control group, the TP content of 15 mg/kg group was increased after exposure for 1 week ($P < 0.05$); however, the content of TP decreased after exposure for 2 weeks ($P < 0.01$). But after 3 weeks of exposure, there was no significant difference in TP content between the 15 mg/kg group and the control group. The level of TP in the kidney of the 30 mg/kg group at 1, 2, and 3 weeks was markedly lower than that of the control group ($P < 0.01$). The concentration of TP was overall decreased with the extension of cadmium exposure time and the increasing of the exposure dose of cadmium.

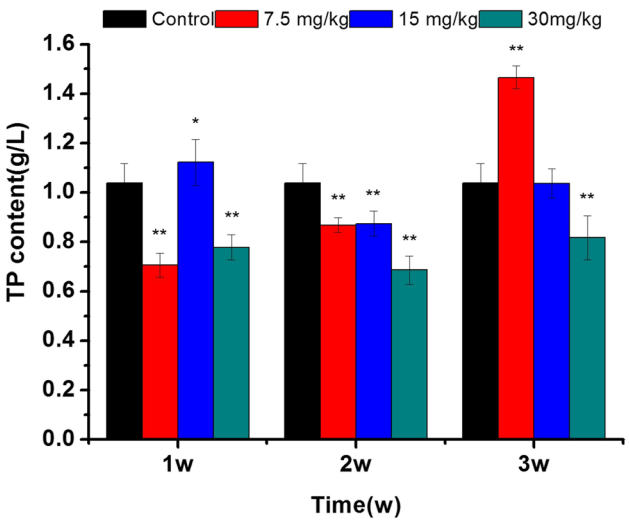

Fig. 1 The content of TP in kidney of turtles treated with Cd. In comparison with the control group, $^*P < 0.05$, $^{**}P < 0.01$

Correlations Between the Content of CRE and Cd Treatments in Plasma of Treated Turtles

As could be found in Fig. 2, the content of CRE in the blood serum of each treatment group increased with the prolongation of exposure time in dose-dependent. The level of CRE in plasma of the 7.5 mg/kg group was markedly increased at 2 and 3 weeks after exposure ($P < 0.01$). CRE contents in the plasma of the 15 and 30 mg/kg groups were increased significantly at 1, 2, and 3 weeks ($P < 0.01$).

Correlations Between the Content of BUN and Cd Treatments in Plasma of Treated Turtles

From Fig. 3, we could see that BUN levels in the plasma of all poisoned groups showed a trend of increasing. BUN contents of the 7.5 mg/kg group were increased significantly at 2 and 3 weeks after exposure ($P < 0.01$). Plasma BUN levels of the 15 mg/kg group at 1, 2, and 3 weeks were significantly increased ($P < 0.01$). BUN contents of the 30 mg/kg group were increased significantly at 1 and 3 weeks ($P < 0.01$).

Correlations Between the Kidney Index and Cd Treatments

There was no significant difference in the kidney index between the 7.5 mg/kg group and the control group at 1, 2, and 3 weeks after exposure (Fig. 4). But the kidney index of the 15 mg/kg group after exposure for 1 and 3 weeks was increased ($P < 0.05$) (Fig. 4). The kidney index of the 30 mg/kg group was also increased after exposure for 1 and 2 weeks ($P < 0.05$) (Fig. 4).

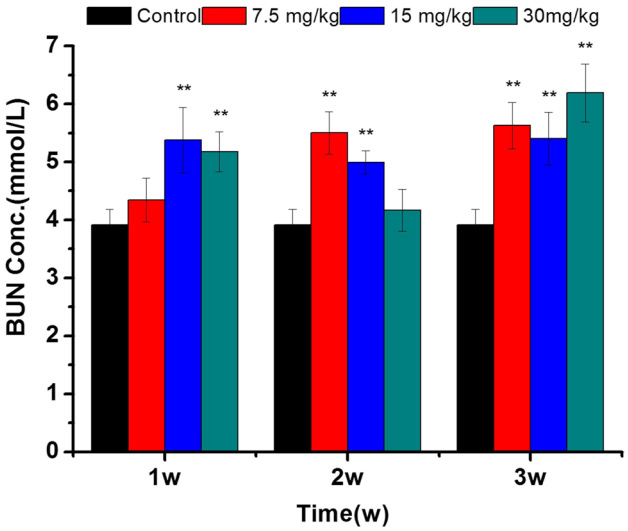

Fig. 3 The content of BUN in plasma of turtles treated with Cd. In comparison with the control group, $^{*}P < 0.05$, $^{**}P < 0.01$

Discussion

There are some reports on the effect of Cd on the levels of TP in the kidneys. Aldulaimi reports that there is a significant decrease ($P < 0.05$) in the values of TP compared with the control group [36]. The exposure to $CdCl_2$ exhibits marked destruction in kidney function characterized by a decrease of TP levels [37]. Consistent with these, our results suggested that the content of TP was overall decreased with the extension of cadmium

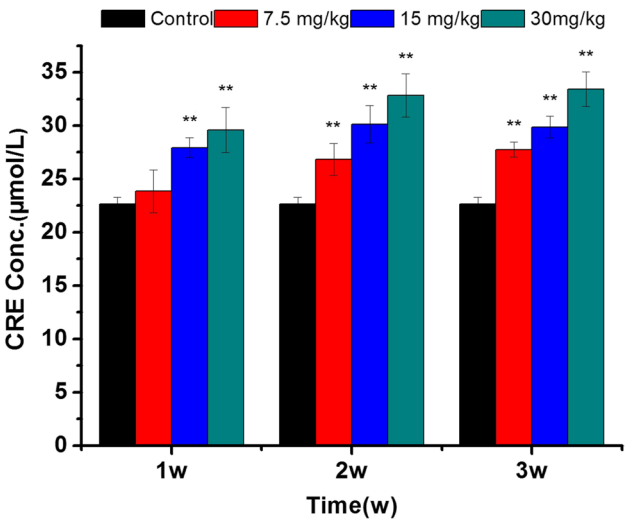

Fig. 2 The content of CRE in plasma of turtles treated with Cd. In comparison with the control group, $^{*}P < 0.05$, $^{**}P < 0.01$

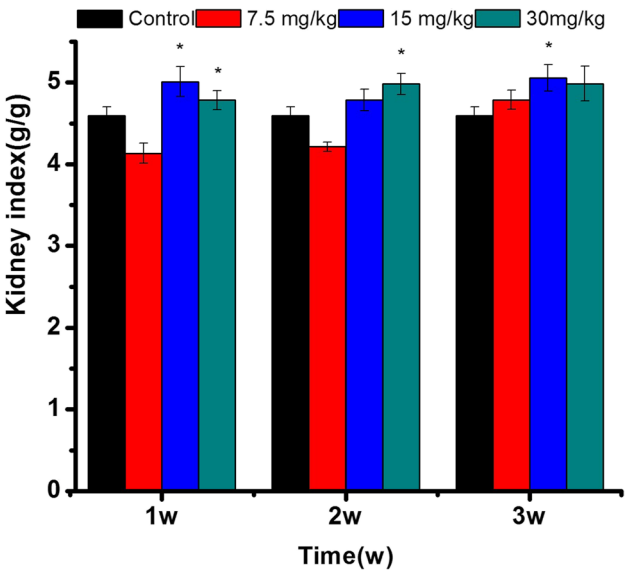

Fig. 4 The kidney index of turtles treated with Cd. In comparison with the control group, $^{*}P < 0.05$, $^{**}P < 0.01$

exposure time and the increasing of the exposure dose of cadmium. From Fig. 1, we could see that the TP content in the 7.5 mg/kg group was markedly decreased after exposure for 1 and 2 weeks ($P < 0.01$). But at 3 weeks after exposure, the content of TP in the 7.5 mg/kg group was markedly increased ($P < 0.01$). The TP content in the 7.5 mg/kg group was increased with the extension of cadmium exposure time. The reason for this may be that low concentrations of cadmium can stimulate TP synthesis in the turtle kidney.

There are some reports on the effect of Cd on the contents of CRE in plasma. Cd exposure significantly elevates the levels of CRE in the serum of rats [38–56]. Cd significantly increases the levels of CRE in the serum of mice [57]. The renal function indicator of CRE in laying hens is significantly increased in Cd supplemented groups compared with the control group ($P < 0.05$) [58]. The level of CRE in Japanese quail exposed to dietary Cd rose significantly ($P < 0.05$) [59]. Consistent with these, our results suggested that the CRE content in the plasma of each treatment group increased with the prolongation of exposure time in dose-dependent.

There are some reports on the effect of Cd on the contents of BUN in plasma. Cd exposure significantly elevates the levels of BUN in the serum of rats [38–55, 60–65]. Cd significantly increases the levels of BUN in the serum of mice [57, 66–68]. The renal function indicator of BUN of laying hens is significantly increased in Cd supplemented groups compared with the control group ($P < 0.05$) [58]. The level of BUN in Japanese quail exposed to dietary Cd rose significantly ($P < 0.05$) [59]. On average, an interquartile range (IQR) higher of Cd is associated with a 0.65 mmol/L increment of BUN among 35 healthy adults before-, intra-, and after-the 2019 Wuhan Military World Games [69]. RodríguezLópez observes inverse associations between dietary Cd exposure and kidney function parameters such as BUN in 601 9-year-old Mexican children [70]. Consistent with these, our results suggested that the BUN levels in the plasma of all poisoned groups showed a trend of increasing. But there is one report that serum BUN levels are reduced in rats [56]. Pollack et al. report that each twofold increase in Cd is associated with a negative 4.9% change in BUN in premenopausal women [71].

There are some reports on the effect of Cd on kidney index. Kidney index in mice exposed to Cd increases [72]. The organ indexes in all Cd groups do not change significantly, but the kidney organ indexes in Cd groups are increased [73]. Consistent with these, our results suggested that the kidney index of treated turtles was increased. However, there has one report to the contrary. Huang et al. [74] report that kidney index in rats exposed to Cd is decreased.

Conclusions

Our study showed that the content of TP was overall decreased with the extension of cadmium exposure time and the increasing of the exposure dose of cadmium. The CRE content in the plasma of each treatment group increased with the prolongation of exposure time in a dose-dependent, and the BUN levels in the plasma of all poisoned groups showed a trend of increasing. The kidney index of treated turtles was increased. In summary, Cd could induce the increase of turtle kidney index, the content of CRE and BUN in plasma, and the decrease of the content of TP in the kidney.

Author Contribution AD and JH designed the study, performed the research, analyzed the data, and wrote the paper. HD, HH, AD, and JY were major contributors in writing the manuscript. All authors read and approved the final manuscript.

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Data Availability Not applicable.

Declarations

Ethics Approval and Consent to Participate This study was approved by Shanxi University of Chinese Medicine (permit number: 2018LL054).

Conflict of Interest The authors declare no competing interests.

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