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Effects of formaldehyde intoxication on liver of Swiss albino mice

Afrin M[1], Amin T[1], Karim R[1]and Islam MR[1]
[1]*Department of Anatomy and Histology, Faculty of Veterinary Science, Bangladesh Agricultural University, Mymensingh, Bangladesh*

Abstract:*Formaldehyde (FA) is a very reactive one-carbon compound, can react with lipids, proteins, and nucleic acids which are cellular components.FA induces cellular toxic effects in the liver by damaging hepatic parenchyma and impairment of functions. This study was carried out to evaluatethe serum biochemical changes and cytotoxic effects on liver in Swiss albino mice caused by FA toxicity. For this purpose, mice were divided into threeequal groups i.e. Control, oral andintraperitoneal.Oral and intraperitonealgroups were further divided into three subgroups which were subjected to exposure of FA for 30 and 10 consecutive days respectively. After exposure, blood and liver samples were collected and analyzed for biochemical and morphological studies. The serum biochemical parameters like Aspartate Transaminase (AST) and Alanine Transaminase (ALT) were increased significantly (P‹0.05) in mice after FA exposure. The anatomical results revealed gross morphological changes i.e. congestion and petechial hemorrhages on the liver. Histologically, the liver showedscattered lymphocytic infiltration, dilatation of sinusoids, necrosis and degeneration of parenchymatous cells in orally exposed mice (10 mg/kg) and diffuse lymphocytic infiltration, necrosis were seen in intraperitoneallyFA injectedmice at the rate of 7 and 10 mg/kg body weight.All these findings revealed that, FA depending on specific dose leads to an irritant toxic effects on the liver of mice.*

Keywords:*Formaldehyde, Histomorphology, Liver, Mice, Serum biochemical test.*

I. Introduction

Formaldehyde (FA) is colorless, flammable and highly reactive substances at normal temperature and pressure [1, 2]. Although it is readily broken down bysunlight in air but very stable in liquid over time [2, 3]. It is quickly diffuses in any tissues i.e. Liver when exposed by oral or intraperitoneal route[4] because it interacts with different cellular components [5]. While the main route of exposure is air [6], FA is also entering into body by food and drinking water. Using of formalin was started as fixative and embalming fluid, but nowadays it is using in all sphere of day to day life. The most alarming use of formalin (37% aqueous solution of FA) is as food preservative [7, 8] and that's why exposing to the risk of formalin intoxication is increasing.After ingestion,FAis readily absorbed from gastrointestinal tract [1]. Recent studies (FA exposure on animal) showhepatotoxicity and abnormal histopathological alteration in gastrointestinal tract [9]. FA is a mutagenic and carcinogenic even at low concentrations andproduce toxicity in a variety of organisms [10]. There is also evidence of gastrointestinal cancer if FA taken in high concentration through drinking water [11].

In developing country like Bangladesh, indiscriminate use of FA in the form of formalin in different food items and in drinking water exposing a huge number of people to a great health hazard [12, 13]. Bangladesh is a country of tropical region where its weather is hot and humid. As a result, vegetables and perishable food items are tent to decay quickly. There is a report on wide range using of formalin in fruits, vegetables, perishable food items to keep them fresh [14]. The widespread use of 37% FA solution, in preservation of fish, fruit and other food items is posing a threat to public health. Although Bangladesh government issued a formalin control law in 2014 because of widespread use of FA to preserve food, it is using indiscriminately till today.

This study was conducted to investigate the serum biochemical, gross and histopathological changes in liver that can be caused by FAexposure and that reflect to create awareness by presenting the real health hazard.

II. Materials And Methods

2.1 Research animals and their management

The experimental Swiss albino mice (*Musmusculus*),weighing30±7 g and 100-120 days aged were collected fromInternational Center for Diarrheal Disease Research (icddr'b), Mohakhali, Dhaka having apparently good health and devoid of any external deformities certified by the registered veterinarian from icddr'b.The mice werekept in cage made of galvanized iron sheet having 2 inches thick saw dust litter. Mice were reared under normal condition of temperature (23-25°C) and humidity with a provision of feed and water *ad libitum.* All mice were handled according to the animal care in compliance with the Department of Anatomy and Histology under the Institutional Board Guidelines of Bangladesh Agricultural University on the care and use of laboratory animals.

2.2 Chemical preparation

FAsolution was prepared from stock paraformaldehydepowder (Merck, Darmstadt, Germany) by thermal depolymerization according to the method described by Chang *et al* [15].

2.3 Experimental Design

For experimental purpose, the mice were randomly divided into three groups like; control (group A), oral and intraperitonealgroups. Each group had 5 mice. In oraland intraperitoneal groups, mice were exposed to toxic dose of 5.0 mg/kg (group B), 7.0 mg/kg (group C) and 10.0 mg/kg body weight (group D) FA solution once daily for 30 and 10 days respectively.

2.4 Serum biochemical assay

Mice were anaesthetized with ether during sacrifice. Thoracotomy was performed. Blood was directly collected from heart. Test tube containing blood with anticoagulant was placed in ice for 30 minutes. Sera were separated from unclotted blood by centrifuge at 3000 rpm for 20 minutes and again for 10 minutes. Then supernatant was collected in eppendrof tube by micro-pipette and stored in refrigerator at -20°C until use for biochemical test.

2.5 Histomorphological study

After completion of experimental period,liver was collected as soon as possible with the help of sharp scalpel and scissors without wreckage of the organ. Grossly observable abnormalities (shape, size, color, consistency) were taken into consideration and compared with the control by eye observation. Liver of each group were fixed in 10% FA for processing for light microscopy [16]. Hematoxylin and Eosin stain was done for preparing permanent slide. Necessary photographs were taken with Olympus BX 51 photographic light microscope and placed for better illustration of the result.

2.6 Statistical analysis

The data are presented as mean±SD. All the collected data from control and FA exposed mice were analyzed (student's `t'-test; one and two way ANOVA) to find the significant differences between values of various parameters. The differences will consider to statistically significant when the *P* values obtained will less than 0.05 or 0.01.

III. Results

3.1 Clinical signs

In the present study, no signs of irritation or intoxication, such as lacrimation, nasal secretion, or regurgitation was seen either during the exposure session or thereafter. Also no defensive or aggressive behavioral changes in the mice were evident. The clinical signs begun to appear after I week of experiment and included decreasing feed and water intake, dullness, staggering gait, sitting with closed eyes and decreased response on disturbance. These signs were more pronounced in morning soon after exposure to FA compared with rest of the day.

3.2 Serum biochemical assay

Thepresent study was put in to assess hepatic function parameters (AST and ALT) using biochemical test and compared to control group. The mean concentrations of AST and ALT were significantly increased ($p<0.05$) for 66.12±0.43 and21.43±0.56respectively in 10 mg/kg treated intraperitoneal group (Fig.1).There were also significant ($p<0.05$) increased in AST in the oral group exposed to 10 mg/kg FA. The value was 59.43±3.(Fig.2)

3.3 Gross effects

The morphological appearance of the liver of control group A revealed normal brown color of the examined lobes. There is no change in size and consistency. The liver had smooth regular borders and normal shape of both the dorsal and ventral surfaces in all lobes. (Fig.3A and 4A)

The gross morphological changes in the liverof group D (10 mg/kg oral and intraperotoneal FA exposure) micerevealeddark color and decreased liver weight with irregular surfaces.Increased congestion in all lobes with petechial hemorrhages on the dorsal and ventral surfacesindicated prominent liver vasculature. (Fig.3D and 4D)

3.4 Histomorphological effects

Liver sections of hematoxylin and eosin stain of control group A revealed normal hepatic tissue architecture. There were no degeneration or necrotic changes observed in the liver of control group (Fig.5A and 6A).

Among the oral groups, only the liver of 10 mg/kg treated mice showedcentrilobular necrosis and degeneration of parenchymatous cells.Dilated sinusoidal spaceswere accompanied by vasculitis, this vascular reactivity characterized by scattered aggregation of lymphocytes(Fig.5B).

Among the intraperitoneal groups no observable histopathological lesions were found in liver of 5 mg/kg treated group (Fig.6B). There was a piecemeal necrosis in 7 mg/kg treated group by lymphocyte infiltration extends from portal areas and disrupts the limiting plate of hepatocytes undergoing necrosis (Fig.6C). There was diffuse aggregation of lymphoid cells found inthe liver parenchyma of both 7 mg/kg (Fig.6C) and 10 mg/kg treated groups (Fig.6D).

IV. Discussion

Liver has a central role in intermediary metabolism of carbohydrates, proteins, lipids, and amino acids in the body.In addition, liver renders a lot of processed metabolites for bioavailabilityin other tissues. Therefore; FA intoxication at different doses and routes affect that metabolic pathway of the liver.In the present study, revealed arelation between FA exposure and liver healthby taking into account the biochemical, histological and the toxicological effects.

The study reported decreasing liver weight due to decreased body weight of mice after FA exposure which is consistent with that obtained by [17, 18] in rat. Mice fed or injected 10mg/kg FA, showed more pronounced clinical signs like depression, staggering gait, decreased food and water intake.Similar clinical signs were reported by Babar *et al* [19] in broiler chicken while rat showed decreased responsiveness after FA exposure in drinking water [20].

Liver functions and tissue damage were determined by an increase in the activities of enzymes such as AST, ALT[21, 22] which are consistent with the findings of present study. The statistically significant differences in AST and ALT in comparison to control group showed impairment of liver functions.

Grossly in 10 mg/kg treated oral and intraperitoneally injected groups, presence of petechial hemorrhages and congestion in liver of mice are suggestive of a irritant effect of FA. Similar lesions in liver following oral administration of FA have been reported in rats [23, 17, 18].

FA causes cytotoxicity by presumably reacting directly with tissue constituents [24]. After intraperitoneal, oral, or inhaler administration, FA rapidly diffuses into many tissues including the liver, brain and testis [15].In the present study, oral administration of FAcauses lymphocytic aggregations, dilated sinusoidal spaces, centrilobular necrosis and degeneration of parenchymatous cells in liver. In FA exposed rat liver tissue, there were mild edema, mild degeneration in hepatocytes, and Kupffer cell hyperplasia evident. These findings obtained in the experiment of Uçmakli*et al* [25]. Indeed, in other studies of light and electron microscopy, FA exposed liver cells revealed: flat endoplasmic reticulum, hypertrophy and hyperchromaticnucleus [26], rough endoplasmic reticulum and mitochondrial damage [27] and impairment of membrane integrity [28]. It was also evident that FA caused damage to hepatocytes, intrahepatic and extrahepatic bile ducts [29]. This is due to its metabolic reactivity. We found that, in all animal species, FAis an essential metabolic intermediate in all cells and in the biosynthesis of purines, thymidine and certain amino acids [30]. Under physiological conditions, the level of endogenous FAis maintained at a low concentration being regulated by the expression and activity of both FA-generating and FA-degrading enzymes [31]. Free and reversibly bound FAis readily absorbed in the gastrointestinal tract when ingested and joins the pool of endogenous FA[32]. FAis rapidly oxidized in blood and liver to formic acid by the NAD-dependent FAdehydrogenase through a glutathione (GSH)-dependent process. In turn, formic acid partially enters the one-carbon pool of the body or is further oxidized to carbon dioxide and water in the liver and in the erythrocytes. In primates, this reaction occurs more slowly than in dogs or rats. The residual non-metabolized formic acid and other minor metabolites are excreted via urine, feces or expired air [33] and the relative amounts depending on the route of administration [34, 35, 36]. Owing to its chemical reactivity, FAis essentially present in reversibly and irreversibly bound forms, as free FA, representing 1 to 2% of total measurable amounts in tissues, and as FAirreversibly bound to proteins and nucleic acids, accounting for between 50% - 80% of endogenous FA[37]. General signs of toxicity occur if the exposure conditions (e.g. Concentrations in food and drinking water) lead to an extent of local lesions, which subsequently impair the general health of the exposed animals. This applies for the hepatotoxic effects after in vivo exposure [20].

Among the intraperitoneal groups necrosis and diffuse lymphatic aggregation in the liver parenchyma revealed in the result of present study being severe in mice of 10 mg/kg treated group. This is due to systemic toxicity and a local irritant effect of FA.

When using dose as a factor, histologicalchanges found in groups D (10 mg/kg) were moreintensive than in groups B (5 mg/kg) and C (7 mg/kg) in both oral and intraperitoneal groups. The resultsobtained in this study, pertaining to the relationshipbetween histological changes and exposure dose,are in agreement with the study obtained by Babar *et al*[19] on broiler liverwho determinedthe histological changes i.e. Hepatocytes have

foamy cytoplasm and scattered aggregation of lymphoid cells in the liver parenchyma, cytoplasm has multiple vacuole, sinusoidal spaces contain erythrocytes at highest exposure group of FA.

V. Conclusion

The present study revealed that FA exposure leads to irritant toxic effects on the liver of Swiss albino mice and the biochemical as well as histological changes had direct relationship with FA exposure concentrations.

Acknowledgements

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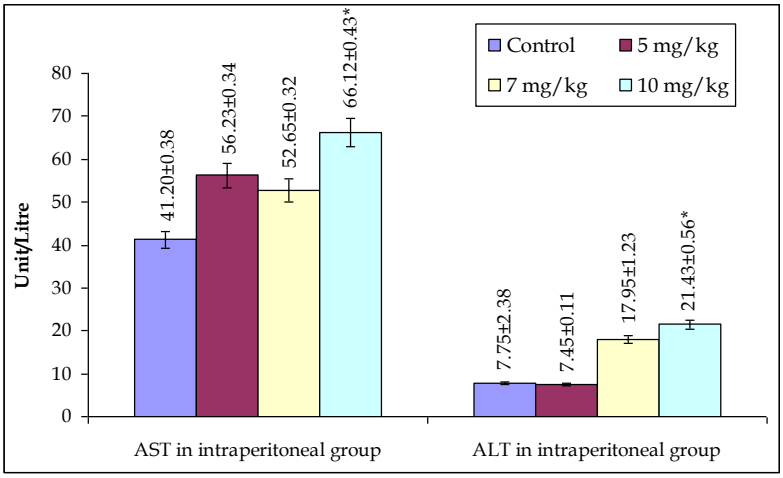
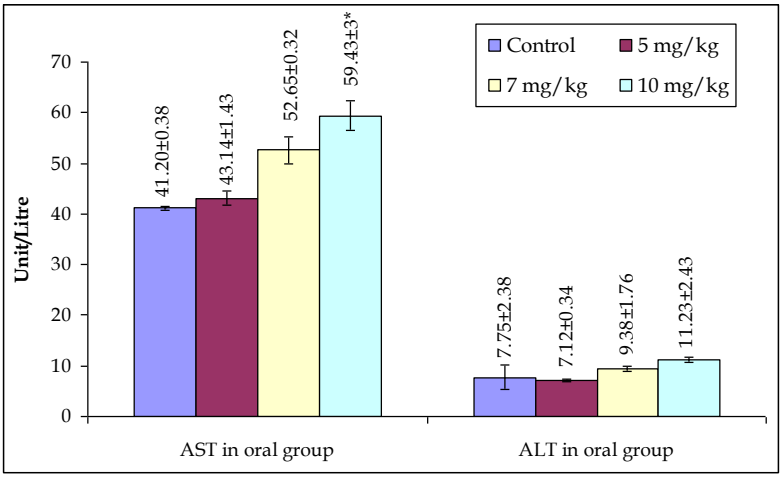


Mean±Standard deviation; * 5% level of significance (p<0.05)

Fig. 1 Mean concentration of AST and ALT in the control & FA exposed intraperitoneal group mice.



Mean±Standard deviation; * 5% level of significance (p<0.05)

Fig. 2 Mean concentration of AST and ALT in the control & FA exposed oral group mice**.**

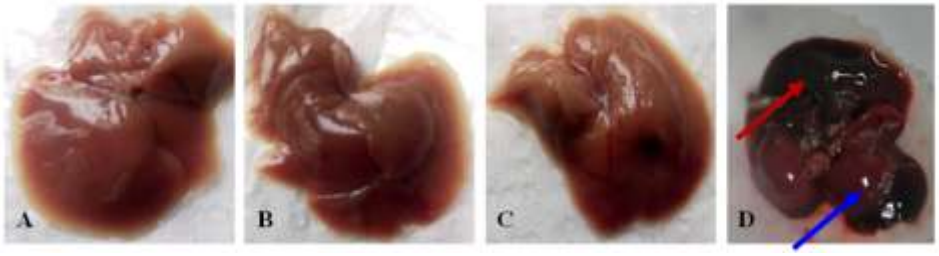


Fig. 3 Gross study of liver of control (A) and oral grouped (B-D) mice.

(A) Control (B) 5mg/kg and (C) 7mg/kg FA treated oral groups showing normal gross morphology of liver. No congestion and hemorrhage is found in those groups. (D) Dark coloration of liver. Liver showing congestion (red arrow) and petechial hemorrhages (blue arrow) in 10mg/kg FA treated oral grouped mice.

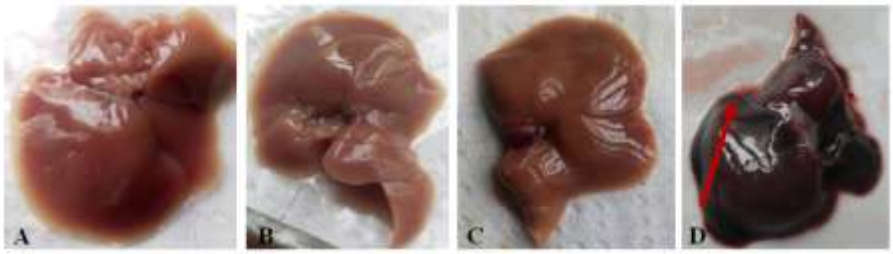


Fig. 4 Gross study of liver of control (A) and intraperitoneal grouped (B-D) mice.

(A) Control (B) 5mg/kg and (C) 7mg/kg intraperitoneally FA treated groups showing normal gross morphology of liver. No congestion and hemorrhage is found in those groups. (D) Dark color liver showing congestion (red arrow) and petechial hemorrhages in10mg/kg FA exposedintraperitoneal grouped mice.

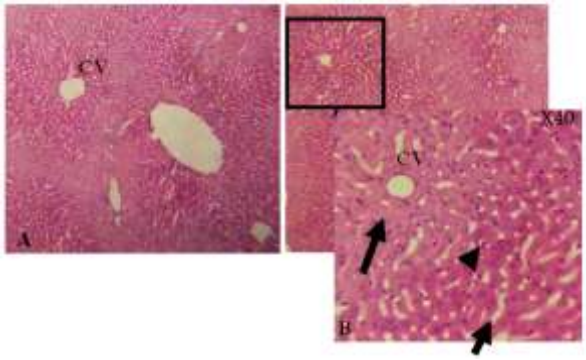


Fig. 5(A-B) Histological features in liver of control and oral grouped micein H and E stain (X10). CV = Central vein.

(A) No change observed in control mice liver. (B) The representative figure of 10 mg/kg FA treated oral group liver and showing centrilobular necrosis and degeneration of parenchymatous cells(long arrow), dilatation of sinusoids (short arrow) and scattered lymphatic aggregation (arrow head).

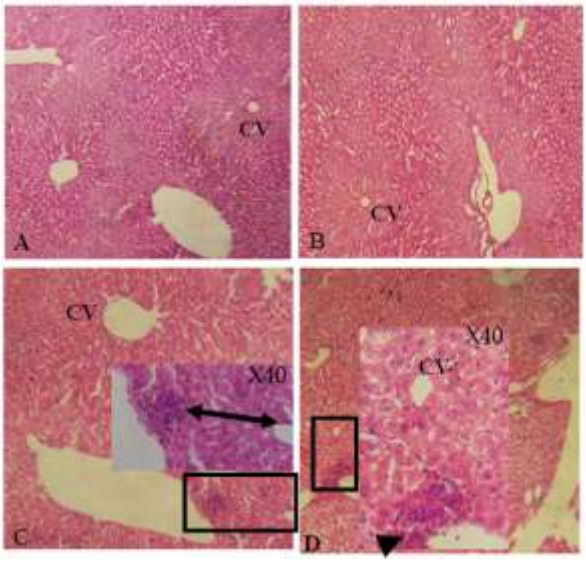


Fig. 6(A-D) Histological features in liver of control and intraperitoneal grouped micein H and E stain (10X). CV = Central vein.

(A) Normal architecture of liver in control group. (B)Liver showing normal architecturein 5mg/kg FA exposed group. (C)In 7mg/kg FA treated group, liver showing diffuselymphatic aggregation (arrow head) and piecemeal necrosis (two headed arrow). (D)Liver showing diffuselymphatic aggregation (arrow head)in 10mg/kg FA treated group.