Histopathological and Biochemical Effects of Acute and Chronic Tramadol Drug Toxicity on Liver, Kidney, and Testicular Function in Adult Male Albino Rats

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Abstract

Background: Tramadol is becoming abused among teens, especially between males. The study aimed to investigate the histopathological and biochemical profiles of acute and chronic toxic effects of tramadol on hepatic, renal, and testicular functions. Materials and Methods: A total of 60 male adult albino Sprague-Dawley rats were used. Rats were divided into three groups: Group I: Control, Group II: Representing acute tramadol toxicity, and Group III: Representing tramadol dependent use for 60 days. Results: Group II displayed hemorrhage and cytology in the hepatocytes. Group III showed complete cell membrane degeneration of hepatocytes. Renal tissues revealed glomerular hemorrhage in Group II and atrophied glomeruli with collapsed tufts, degenerated tubules, and cellular infiltration in Group III. The testicular tissues revealed atrophy of seminiferous tubules with interstitial calcification in Group II. Focal testicular degeneration, with a little evidence of spermatogenesis in Group III. Biochemical indices showed a significant increase in liver enzymes, serum bilirubin, creatinine, and blood urea nitrogen levels. The sex hormones levels were significantly increased for estradiol and prolactin, while there was a significant decrease in testosterone with a gradual reduction in luteinizing and follicular-stimulating hormones. Recommendations: Designing a national awareness campaign to the youth to spotlights on the health hazards of tramadol abuse.

Keywords: Biochemical indices, histopathological, rats, sexual dysfunction, tramadol

Introduction

Nowadays, addiction is an increasing social and health problem worldwide despite all efforts to prevent and control it. Analgesics are among the most popular drugs, which are being abused.¹ Tramadol is a centrally acting opioid analgesic which is mainly used for the treatment of moderate to severe pain.² Its efficiency and potency range between weak opioids and morphine.³ Tramadol is rapidly absorbed orally, tramadol has extensive tissue distribution. The bioavailability of tramadol is 70% its bioavailability is more than that of morphine (15-65%) when tramadol is used in multiple or repeated doses, the bioavailability increased to 100%. The complete absorption of tramadol takes place in the upper part of the small intestine. The plasma concentration of tramadol varies with its form to reach a peak concentration within 2 h in capsule form and five for tablets. Tramadol metabolism occurs in the liver by the cytochrome P450 enzyme system, and its by-products are excreted unchanged through the kidneys. Repeated tramadol administration might lead to accumulation of toxic metabolites in the body, increase the risk for its toxicokinetics effects, and/or decrease the clearance of tramadol, thus increasing its potential for toxicity.⁴

Tramadol abuse, dependence as well as acute overdose-related deaths have been increasingly reported, especially in young male adults.⁵ Being an opioid, tramadol carries all the possible risks known from other opiates.⁶ Tramadol can cause psychological and physical addiction similar to that seen with other opiates and opioids.⁷ Recently, young addicts typically substituted tramadol for heroin. Repeated tramadol administration in such patients might lead to accumulation of toxic metabolites in their bodies, increase the risk for pharmacokinetics interactions, and/or decrease the clearance of tramadol, thus increasing its potential for toxicity.⁸

So, the aim of this work was to investigate the impact of acute and chronic administration of tramadol hydrochloride on the histopathological and biochemical profiles in hepatic, renal, and testicular functions in adult male albino rats.

Materials and Methods

Drug

Tramal® (Tramadol HCl), 50 mg capsules, was obtained from Mina-Pharm, Egypt. Its chemical name is (+) cis-2-[(dimethylamino)methyl]-1-(3-m ethoxyph-enyl) cyclohexanol hydrochloride.

Animals, dosing, and experimental design

A total of 60 male adult albino Sprague-Dawley rats, their body weight ranged from 180 to 200 g purchased from Center for Experimental Animals, Faculty of Veterinarian Medicine, Zagazig University, were used in the study. This study was performed in accordance with the guide for the ethical care and use of laboratory animals.⁹ All rats
were left to acclimatize for 1 week before the experiment and were housed in plastic cages maintained at controlled room temperature (22-24°C) with 12 h diurnal (day and night change) with free access to standard pellet animal diet and tap water.

The animals were divided into three main groups. Each group contained 20 rats for each group as follows:

**Group I**
The control group that is further subdivided into subgroup IA and IB. Subgroup IA (n = 10 rats): Animals received 1 ml/day normal saline (0.9% NaCl) orally by gavage. They were kept for 24 h as the rats of Group II.

Subgroup IB (n = 10 rats): Animals received 1 ml/day normal saline (0.9% NaCl) orally by gavage. They were kept throughout the experiment under the same conditions for 60 days as the rats of Group III.

**Group II (tramadol acute toxicity group n = 20 rats)**
Animals received a single lethal dose 50 dose (300 mg/kg body weight) of tramadol hydrochloride orally by gavage.[12]

**Group III (tramadol dependent group n = 20 rats)**
Animals received tramadol hydrochloride in gradually increasing doses until it reached the dependent dose in 60 days. Dependence was induced by giving the therapeutic dose of tramadol hydrochloride which was calculated according to Paget’s equation. The therapeutic dose for rat weighing 200 g = 18/1000 X adult human therapeutic daily dose (400 mg) = 7.2 mg.[13] Then, the dose was gradually increased by adding the initial calculated therapeutic dose every 3 days till reaching (144 mg) at the end of 60 days.

The calculated tramadol hydrochloride doses were delivered in normal saline and given orally to each animal by a curved needle-like oral tube that was introduced directly into the stomach (a gavage process). At the end of the experiment, surviving animals of all groups were sacrificed by cervical dislocation at 24 h after a single dose for Group II (acute toxicity group) and their control Group IA and after the last dose at the end of the 60 days for Group III (dependent group) and their control Group IB. Autopsy was carried out for all animals of all groups. The hepatic, renal, and testicular tissues were fixed in 10% formalin solution for histopathological examination.

**Histopathological examination**
The selected organs for each rat were received at the Pathology Department, Faculty of Medicine; Port Said University preserved in 10% formalin solution and dehydrated in ascending grades of alcohol. After xylene treatment, the specimens were embedded in paraffin blocks. 5 µ thick; serial sections were cut by microtome and stained with hematoxylin and eosin. The stained sections were examined using light microscope according to Bancroft and Gamble.[14] Microscopic examinations were carried out in all selected organs of acute tramadol toxicity and dependent group. Unintentional bias was prevented by coding rats’ tissue samples. Liver sections were assessed for the followings: (a) Parenchymal changes including steatosis, feathery degeneration, necrosis, congestion, hemorrhage, interface hepatitis, Kupffer cell hyperplasia, and sinusoidal dilation and (b) portal changes including inflammatory cellular infiltrates, fibrosis, and bile duct proliferation. Kidney sections were assessed for the following glomeruli, visceral, and parietal layers of Bowman’s capsule. Testicular section was assessed for spermatogenic cells and the number of spermatozoa in seminiferous tubules.

**Biochemical indices**
Blood samples were collected in dry centrifuge tubes for serum preparation, sera were separated and preserved at −20°C till used for biochemical analysis to detect liver, kidney, and sexual hormonal levels.

A. Liver function indices: Aminotransferases, alanine aminotransferase (ALT), and aspartate aminotransferase (AST) enzymes activities were measured in IU/L using the method of Thomas, 2007.[13] Serum alkaline phosphatase (ALP) enzyme in IU/L and bilirubin level in mg/100 ml were measured based on the method of Ohkubo et al. 1997[14] and Perry et al. 2000.[15]

B. Kidney function indices: Creatinine (Cr.) level in mg/dl was determined using the method of Fossati et al., 2008.[16] Blood urea nitrogen (BUN) measurement in mg/dl was assessed based on the cleavage of urea with urease (Berthelot’s reaction) according to Orsonneau et al., 1992.[17]

C. Sex hormones assay: Luteinizing hormone (LH) and follicle-stimulating hormone (FSH) in IU/ml, prolactin (PRL) in mg/ml, testosterone in pg/ml, and estradiol (E2) in pg/ml were determined using enzyme-linked immunosorbent assay kits according to manufacture structure.

**Statistical analysis**
All the data were expressed as mean ± standard deviation and analyzed using Statistical Package for Social Sciences (SPSS) program version 20. Data were considered statistically significant with P < 0.05.

**Results**

I. Histopathological results (Figures 1-3):
A. Regarding the liver tissue
B. Kidney histopathological results
C. Testicular histopathological results.

II. Biochemical indices results

Table 1 shows a highly significant increase in the mean values of serum AST, ALT in Group II and III when compared with Group I.

Table 2 shows a highly significant increase in the mean ALP enzyme and bilirubin levels in Group II and III when compared with Group I.

Table 3 shows a highly significant increase in the mean values of serum creatinine level in Group II and III when compared with Group I.

Table 4 shows highly significant increase in the mean values of serum ALP enzyme and bilirubin levels in Group II and III when compared with Group I.

Table 5 shows a highly significant decrease in LH, FSH, testosterone hormones in Group II and III when compared with Group I. There is a highly significant increase in the mean value of estradiol and PRL levels in Group II and III when compared with Group I.
**Table 1:** Effects of tramadol acute toxicity and daily dosing for 60 days on liver enzymes (AST and ALT) in adult albino rats

| Studied groups | Liver enzymes level in IU/L | F | P | LSD |
|---------------|-----------------------------|---|---|-----|
|               | Mean±SD                     |   |   |     |
|               | AST IU/L                    |   |   |     |
| Group I (N=20)| 34.7±2.8                    |   |   |     |
| Group II (N=20)| 66.45±2.35                | 9.4|   |     |
| Group III (N=20)| 79.80±1.25                |   | 45.1|     |
| **P<0.01 highly significant,** F=One-way analysis of variance (Fissure test), LSD difference shows a significant difference between, N=Number of rats in each group. SD: Standard deviation, AST: Aspartate aminotransferase, ALT: Alanine aminotransferase |

**Table 2:** Effects of tramadol acute toxicity and daily dosing orally for 60 days on serum creatinine level in adult male albino rats

| Studied groups | Phosphatase enzymes (ALP) and bilirubin levels in adult albino rats | F | P | LSD |
|---------------|---------------------------------------------------------------|---|---|-----|
|               | Mean±SD                                                       |   |   |     |
|               | ALP IU/L           | Billirubin (mg/100 ml)                                      |   |   |     |
| Group I (N=20)| 50.3±0.30                        | 0.21±0.05                                   | 50.09|   |     |
| Group II (N=20)| 83.1±0.29                         | 0.65±0.03                                   | 82.6| 0.001**| II versus I |
| Group III (N=20)| 94.8±0.62                         | 0.65±0.03                                   | 94.1| 0.000***| III versus I |
| **P<0.01 highly significant,** F=One-way analysis of variance (Fissure test), LSD difference shows a significant difference between, N=Number of rats in each group. SD: Standard deviation, ALT: Alanine aminotransferase |

**Table 3:** ANOVA for the effects of tramadol acute toxicity and daily dosing for 60 days on the serum creatinine level in adult male albino rats

| Studied groups | Serum creatinine level in mg/dl Mean±SD | F | P | LSD |
|---------------|----------------------------------------|---|---|-----|
| Group I (N=20)| 0.42±0.19                               | 0.6|   |     |
| Group II (N=20)| 0.60±0.32                              | 2.8| 0.001**| II versus I |
| Group III (N=20)| 0.63±0.35                              | 2.9| 0.001**| III versus I |
| **P<0.01 highly significant,** F=One-way ANOVA (Fissure test), LSD difference shows a significant difference between, N=Number of rats in each group. SD: Standard deviation, ANOVA: Analysis of variance |

**Table 4:** ANOVA for the effects of tramadol acute toxicity and daily dosing for 60 days on blood urea level in adult male albino rats

| Studied groups | Mean blood urea level (mg/dl) Mean±SD | F | P | LSD |
|---------------|--------------------------------------|---|---|-----|
| Group I (N=20)| 34.3±2.15                             | 9.6| 0.001**| II versus I |
| Group II (N=20)| 44.7±7.7                              | 12.7| 0.001**| III versus I |
| **P<0.01 highly significant,** F=One-way ANOVA (Fissure test), LSD difference shows a significant difference between, N=Number of rats in each group. SD: Standard deviation, ANOVA: Analysis of variance |

**Discussion**

Analgesics are the most commonly consumed over-the-counter preparation all over the world. Tramadol hydrochloride, a synthetic analog of codeine, is a centrally acting analgesic drug. [1] After its introduction in the 70s, tramadol gained great interest because it is prescribed for moderate to severe pain. [18] Nowadays, tramadol is becoming abused more popular among teens in most countries worldwide and especially between males. Hence, the present study was conducted to investigate the histopathological and biochemical profiles of acute and chronic toxic effects of tramadol hydrochloride in liver, kidneys, and testicular functions on adult male albino rats.
Table 5: ANOVA for the effects of tramadol acute toxicity and daily dosing orally for 60 days in the sex hormones levels on adult male albino rats

| Studied groups | Sex hormones | Mean±SD | F | P | LSD |
|---------------|-------------|---------|---|---|-----|
|               | LH (IU/ml)  | FSH (IU/ml) | Testosterone (mg/ml) | Estradiol (pg/ml) | PRL (µg/ml) |
| Group I (N=20)| 2.40±0.20   | 2.20±0.15 | 4.40±0.44 | 46.30±1.55 | 6.90±1.35 |
| Group II (N=20)| 1.35±0.35  | 0.85±0.30 | 1.80±0.60 | 53.95±0.19 | 15.95±0.12 |
| Group III (N=20)| 0.76±0.15  | 0.55±0.11 | 0.85±0.13 | 62.0±2.05 | 19.00±1.55 |

**P<0.01 highly significant, F=One-way ANOVA (Fissure test), LSD difference shows significant difference between N=Number of rats in each group, SD: Standard deviation, ANOVA: Analysis of variance, PRL: Prolactin**

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The present study revealed that histopathological examination of liver tissue of Group II displayed necrosis and cytolysis, whereas liver tissue of Group III showed complete cell membrane degeneration of hepatocytes when both groups compared with control Group I.

These results could be explained by the fact that the liver is responsible for the metabolism and excretion of tramadol. Tramadol hydrochloride is mainly metabolized in the liver by N-and O-demethylation followed by conjugation with glucuronic acid and sulfate. The active metabolite, O-desmethyl tramadol, shows higher affinity for mu-opioid receptors and has twice the analgesic potency of the parent drug.

Similar results were demonstrated by experimental studies of acute and long-term treatment of morphine in mature albino rats which revealed that morphine could produce hepatotoxic effects during its metabolism in the form of necrosis, hemorrhage, and cytolysis was also documented in morphine-treated rats. However, they noted only perivenular hydropic degeneration in the hepatic tissue.

Another study demonstrated that the post-operative effects of morphine and tramadol on the histopathology of liver in rabbits which had undergone isoflurane anesthesia, hepatocyte degeneration, central vein dilatation, and mononuclear cellular infiltration in the morphine and tramadol group were more severe than those of the control group. In addition, sinusoidal dilatation and cell membrane degeneration of the hepatocytes were more in tramadol group than that of the morphine group. These results suggest that morphine and tramadol may lead to some changes in liver tissue.

The liver histopathological changes in the current study proved the acute and chronic hepatotoxic effects of tramadol in adult albino rats. The hepatic histopathological results in the present study pointed out the risk of increased hepatic damage due to acute and chronic use of tramadol.

The liver histopathological effects of acute and chronic tramadol toxicity in the current study were supported by the liver function indices results. There was a highly significant increase in serum AST, ALT, ALP enzyme, and bilirubin levels in Group II and III when compared with Group I.

These results were comparable with the findings of Harries et al. (2011), who reported increased ALT, AST activities in rats after acute and long-term administration of morphine-like agent levo-alpha-acetyl methadol HCL and also among heroin users and similar to the results of El-Gaafarawi et al., who recorded a significant increase in the ALT and AST activities in rats after administration of 40 mg/kg b.wt. and 80 mg/kg b.wt. tramadol than control ones. ALP enzyme presents in cell surface in most human tissues. The highest concentration is found in the intestine, liver, bone, spleen, and kidney. Also Moss and Handerson.

The specific location of the enzyme with both sinusoidal and bile canalicular membranes accounts for the most predominant elevations in certain disorders as observed in the present study with tramadol administration. Impaired secretion of hepatic ALP may be accompanied by acute cell necrosis, so liberation of ALP in the circulation is elevated. The cellular injury may persist as indicated by increased AST, ALT, ALP, and bilirubin activities. The findings of the current investigation were in agreement with those of Sebnem et al. (2005), who reported that the levels of ALT, AST, ALP, and bilirubin were significantly higher in rats exposed to acute and gradual increasing doses of morphine till reaching dependency when compared to the control group.

Studying of the histopathological effects of acute and chronic toxicity of tramadol on kidney tissue of Group II revealed glomerular hemorrhage, whereas kidney tissue of Group III showed atrophied glomeruli with collapsed tufts, wide Bowman’s space, degenerated tubules, and cellular infiltration when compared with control Group I.

This could be explained by the toxicokinetics process of tramadol since 30% of the drug is excreted through the kidney.
in an unchanged manner. While the rest are changed into active metabolites by the liver. Metabolites of the drug that are excreted via kidneys may also cause cellular damage leading to kidney dysfunction.\(^{[25]}\)

The kidney histopathological results of the present work were supported by the kidney function indices results which showed a highly significant increase in the mean values of serum creatinine and blood urea BUN levels in Group II and III when compared with Group I.

This increase in serum creatinine and BUN levels with acute and chronic tramadol dosing is also by results of Atici et al., 2012.\(^{[20]}\) in rats receiving morphine for a month. Similarly, El-Gaafarawi et al., 2013,\(^{[22]}\) stated that morphine and codeine administration for a long period resulted in an increased creatinine and BUN values. The above observations may be confirmed by the suggestions of Wu et al., 2012, who stated that liver and kidney are responsible for tramadol metabolism and excretion, so it may cause hepatotoxicity and nephrotoxicity.

Testicular tissue of Group II in the current study showed atrophy of seminiferous tubules with interstitial calcification, whereas testicular tissue of Group III showed focal testicular degeneration with single or multiple layers of vacuolated spermatocytes with a little evidence of spermatogenesis.

The wide abuse of tramadol drug among young people, especially male gender led to investigate the histopathological effects of acute and chronic use of tramadol in the testicular function in adult male albino rats. The present study showed atrophy of seminiferous tubules with interstitial calcification among Group II and focal testicular degeneration with single or multiple layers of vacuolated spermatocytes with a little evidence of spermatogenesis among Group III.

This is in agreement with Caju et al., 2012,\(^{[26]}\) who observed reduction of Sertoli and Leydig cells in mature albino rats exposed to acute and chronic doses of morphine. They explained this testicular changes by disorders in the endocrine and paracrine functions that can indirectly influence the final size of Sertoli cell population through disordered LH, estradiol, somatotropin, PRL, and gonadotropin-releasing hormone acted upon either on the hypothalamus or directly on pituitary glands. In addition to opiate-induced reduction of serum testosterone level, there are abnormal structural and functional abnormalities of the secondary sex organs. It seems that probably opiates could affect testicular volume and induce arrested spermatogenesis, sloughed germinal epithelium, destroyed Sertoli cells, and thickened and irregular basement membrane as well as signs of apoptosis.\(^{[27]}\)

Recent studies by El Fatoh et al., 2014,\(^{[24]}\) revealed that the testes undergo severe diffused testicular degeneration with numerous spermatocytes and spermatid giant cell formation (the cells might be fused together to form such giant cells) without spermatogenesis after tramadol in a dose of 40 mg/kg b.wt. The spermatocytes were mostly necrotic.

The abnormalities observed in the testicular structures in the present study including atrophy of seminiferous tubules with interstitial calcification in Group II and focal testicular degeneration with single or multiple layers of vacuolated spermatocytes with a little evidence of spermatogenesis in Group III might be attributed to the oxidative damaging effect of free radicals since the testicular cells and sperms contain abundant polysaturated fatty acids in their plasma membranes. Lipid peroxidation induced by tramadol can eventually result in dysfunction and structural damage of cells.\(^{[29]}\)

The testicular histopathological results of Group II and III in the current study were supported by sex hormonal dysfunction evident by a highly significant decrease in LH, FSH, and testosterone hormones and a highly significant increase in the mean value of estradiol and PRL levels when compared with Group I.

Opiate use is known to decrease the levels of male sex hormones, and this lowered hormonal level is thought to be responsible for the diminished fertility of male opiate users Yassa et al., 2010.\(^{[30]}\) In the present study, gonadal examinations revealed that administration of acute toxic dose of tramadol and daily doses for 2 months influenced reduced sex hormones activity of male rats compared to control group. Tramadol influenced this activity where there was a reduction in the levels of LH, FSH, and testosterone with induction of PRL and E2 levels. Previous studies concerned with gonadal activity during drugs abuse have been supported the present results where Tennese and Wevrick, 2011\(^{[31]}\) reported decreased levels of LH and testosterone with increased PRL hormone after morphine and methadone administration. Furthermore, El-Gaafarawi et al., 2013,\(^{[22]}\) observed the reduction of serum levels of LH, FSH, and testosterone and the induction of PRL hormone and E2 secretions after cannabis use. Similar results for reduced testosterone and elevated E2 have been reported by Abdellatif et al., 2014.\(^{[32]}\)

Conclusion

The current study proved that tramadol has acute and chronic toxic effects on the structure and function of hepatic, renal, and testicular tissues of male albino Sprague-Dawley rats. Therefore, it is suggested that tramadol as reported more effective in pain management, yet its toxic effects should be kept in mind.

Recommendations

The potential effects of long-term tramadol therapy on the liver, kidney, and testes should be explained to patients who are under treatment with tramadol for long time before the therapy is commenced.

Monitoring of liver and kidney functions tests as well as sex hormones are recommended. If there are abnormalities, tramadol hydrochloride should be tapered and withdrawn if this is clinically acceptable. If opioid therapy has to continue, male sex hormone replacement therapy should be initiated and monitored by an endocrinologist.

There is a necessity of designing a national awareness campaign to the youth to spotlights on the health hazards of tramadol abuse.

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