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Therapeutic Intervention of Curcumin on Interleukin-6 and Oxidative Stress Induced by Paraquat Toxicity of Lung and Liver in Rats

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Redox equilibrium is altered due to elevation of reactive oxygen species (ROS) or inadequate antioxidant defense, therapeutic effects of natural antioxidant such as curcumin (CMN) have been investigated. The aim of this study was to investigate the beneficial effects of curcumin (a natural polyphenol) on oxidative status of lung and liver and assessment of level of interleukin-6 (IL-6) in rats against paraquat toxicity. Forty adult male wistar rats were divided into five groups with eight animals each as followed: Group 1: control, Group 2: rats received olive oil. Group 3: rats received curcumin (CMN) (200 mg/kg body weight in olive oil) orally. Group 4 (model group): rats were given a single oral dose of paraquat (PQ) 50 mg/kg body weight dissolved in distilled water intra-peritoneally (I.P) Group 5: rats received CMN orally daily for 10 days prior to PQ administration with the same previous doses and after PQ. After forty eight hours of PQ administration, rats were sacrificed and lung and liver tissues samples were examined for detection of biochemical parameters and histopathological changes. Significant histopathological changes had resulted from PQ administration in lung and liver tissues in addition to significant increase in malondialdehyde (MDA), and significant decrease of catalase (CAT), superoxide dismutase (SOD) and glutathione reductase (GR). However, treatment with CMN produced increasing antioxidant markers and depletion of MDA compared to the model group. Also there is significant increase in serum IL-6 after PQ administration compared to control group. However, the level of IL-6 significantly decreased in treated group with curcumin compared to the model group. Curcumin possesses remarkable protection of the altered lung and liver tissues in paraquat intoxicated rats and could reduce the damaging effect by increasing antioxidant activity and decreasing lipid peroxidation, oxidative stress and IL-6.

Keywords: Paraquat; curcumin; oxidative stress; interleukin-6; reactive oxygen species.

Pesticides, herbicides and chemical fertilizers are used in modern agriculture and these are the most important causes of toxicity to humans and animals. Paraquat is a herbicide used commonly in agriculture for higher quality crop [1]. Its toxicity explained by intervening with the electron transfer photosystem intracellularly resulting in hindrance of the oxidized nicotinamide adenine dinucleotide phosphate (NADP+) reduction to reduced nicotinamide adenine dinucleotide phosphate (NADPH). Also PQ ion is reduced to PQ monocation radical which reacts currently with oxygen resulting in formation of reactive oxygen species (ROS)[2]. In addition, radical forms of PQ cause lipid perioxidation, injury to membrane, multi-system damage, and cell death. Oxidative

stress has been reported that enhanced production in cytokines (such as IL-6 and tumour necrosis factor alpha (TNF-a)). IL-6 plays an important role in regulation of hepatocytes, hematopoietic progenitor cells, cardiovascular system, placenta, nervous and endocrine system[3]. Moreover, PQ can cause toxicity for lungs, liver, kidney and brain in human and experimental animals[4]. It is generally accepted that PQ can affect multiple organ dysfunctions leading to complications such as acute pulmonary fibrosis, cardiogenic shock, renal and hepatic failure and death[5]. There are no antagonists for PQ so its management has remained supportive and directed toward decreasing its absorption or increasing its elimination[6, 7]. Curcumin (CMN) also called diferuloyt methane, is the main natural polyphenol[8]. Curcuma longa is a medicinal plant used due to its antioxidant, anti-inflammatory[9] antimutagenic, antimicrobial[10,11], anticancer[12,13], antiapoptotic and anti-coagulation[14-16]. Also CMN has an effective role against diabetes, allergies, arthritis, Alzheimer's disease[17] and other chronic diseases[18]. It has been reported that the antioxidant activity of CMN equivalent to vitamin C and E[19]. In addition CMN reduces lipid peroxidation and injuries by hindrance of superoxide radicals, hydrogen peroxide and nitric oxide radicals in lung and hepatic tissues[20-22]. Therefore, the present study was designed to detect the effect of antioxidant activity of CMN against PQ intoxication of lung and liver tissues in rats.

MATERIALS AND METHODS

Experimental Study

Animals

The study was ethically approved by the Institutional Animal care and use committee (CU-IACUC), Faculty of Medicine, Cairo University (CU-111-F-6-19).

Forty adult male wistar rats (weights ranged from 180-200 gm) were included in this study, kept under standard laboratory conditions, and permitted free access to standard dry pellet diet and water ad libitum. Rats were acclimated for one week before divided into groups.

Experimental design

Rats were caged into five groups (eight rats for each) as followed: Group 1: control group, Group 2: rats were given olive oil (vehicle of CMN) Group 3: (CMN group) rats received only CMN (200 mg/kg body weight in olive oil) orally[23] Group 4: rats received one dose of PQ 50 mg/kg body weight dissolved in distilled water intraperitoneally (I.P) Group 5: rats received CMN orally daily for 10 days prior to PQ administration with the same previous doses and after PQ spaced[57]. After two days (48h) from PQ adminstration, rats were sacrificed after I.P. injection of sodium phenobarbital anaesthesia. Liver and lung tissues were separated from each group. Then the specimens prepared and stained according to Bancroft *et al*, 1996[24].

Chemicals

Paraquat (PQ) and curcumin (CMN) were purchased from sigma-Aldrich CO, St Louis, MO, USA.

Kits for malondialdehyde (MDA), catalase (CAT), glutathione reductase (GR) and superoxide dismutase (SOD) were purchased from Biodiagnostic, Egypt.

Assessment of oxidative stress biomarkers in liver and lung tissues

In liver and lung tissues lipid peroxidation, MDA level, and antioxidant emzymes activities (CAT, SOD, GR) were estimated by (Boeco S-20 spectrophotometer, Hamburg, Germany) following Okhawa[25], Aebi[26], Nishikimi *et al* [27], Goldberg and Spooner[28] respectively.

Detection of Interleukin-6

IL-6 was determined in serum of experimental rats using ELISA kit (ELabscience Biotechnology Co. Ltd, USA) following the manufacturer's instructions.

Statistical analyses

Data was analyzed by SPSS statistical package, version 20 with Excel computer program which was used to tabulate the results and represent them. The significant difference between groups was noted using one-way analysis of variance (ANOVA) test followed by multiple comparison test to show the significance between each of the two groups. P- values < 0.05 were considered significant.

RESULTS

The level of MDA in the lung tissue was significantly elevated to 38.12 + 7.58 nmoL/g in PQ intoxicated group (group 4) compared to the

control group (group 1), group 2 and 3, 17.62 + 1.92 nmoL/g, 17.12 + 1.55 nmoL/g and 17.50 + 1.77 nmoL/g respectively. The fifth group, showed significant reduction of the level of MDA to 31.50 + 550 nmoL/g compared to group 4 as shown in table 1.

While enzymatic antioxidant parameters in the lung tissue as CAT showed significant decrease in PQ intoxicated group (group 4) compared to groups 1,2 and 3 (0.29 + 0.09 U/g) versus 0.77 + 0.03 U/g, 0.76 ± 0.02 U/g and 0.75 ± 0.03 U/g respectively. Rats in group 5 which received PQ and CMN showed significant elevation in CAT to 0.44 ± 0.10 U/g compared to model group (group 4) as shown in table (1).

Also, the SOD was significantly decreased to 309.62 ± 6.96 U/g compared to groups 1,2 and 3 (319.62 ± 1.06 U/g, 319.00 ± 1.30 U/g and 319.50 ± 1.19 U/g) respectively. In the treated group (group 5) the SOD was significantly increased in comparison to PQ intoxicated group (group 4) 3.15 ± 2.60 U/g versus 309.62 ± 6.96 U/g as shown in table (1). In the fourth group the level of GR in the lung tissues was significantly reduced in comparison to groups 1,2 and 3 (51.86 ± 6.59 U/g versus 79.52 ± 2.65 U/g, 79.05 ± 2.19 U/g, 79.22 ± 2.16 U/g) respectively as shown in table 1. Also, the treated group (group 5) showed significant increase in the GR to 66.55 ± 6.02 U/g compared to model group (group 4) as shown in table 1. In addition, the level of MDA in the liver tissue in PQ intoxicated group (group 4) was significantly elevated to 35.37 ± 4.06 nmoL/g in comparison to groups 1,2 and 3 (17.87 ± 1.80 nmoL.g, 17.75 ± 1.66 nmoL/g and 17.50 ± 1.60 nmoL/g) respectively. The treated group (group 5) showed significant reduction of the

Table 1. Biochemical Markers of oxidative stress measured in lung tissue of the studied groups

Biochemical Markers value	Mean	Std. Deviation	Minimum	Maximum	P
MDA nmol/g					
Group 1 (Control Group)	17.6250	1.92261	15.00	20.00	!**4,5
Group 2	17.1250	1.55265	15.00	20.00	2**4,5
Group 3 (Normal Rats+ CMN)	17.5000	1.77281	15.00	20.00	3**4,5
Group 4 (PQ) (Model Group)	38.1250	7.58641	28.00	50.00	4**1,2,3,5
Group 5 (PQ+ CMN)	31.5000	5.50325	22.00	40.00	5**1,2,3,4
Total	24.3750	9.82067	15.00	50.00	
Catalase U/g					
Group 1 (Control Group)	.7750	.03423	.70	.81	!**4,5
Group 2	.7650	.02777	.71	.80	2**4,5
Group 3 (Normal Rats+ CMN)	.7588	.03357	.71	.80	3**4,5
Group 4 (PQ) (Model Group)	.2950	.09562	.20	.51	4**1,2,3,5
Group 5 (PQ+ CMN)	.4400	.10515	.31	.60	5**1,2,3,4
Total	.6068	.21331	.20	.81	
SOD U/g					
Group 1 (Control Group)	319.6250	1.06066	318.00	321.00	!**4,5
Group 2	319.0000	1.30931	317.00	321.00	2**4,5
Group 3 (Normal Rats+ CMN)	319.5000	1.19523	318.00	321.00	3**4,5
Group 4 (PQ) (Model Group)	309.6250	6.96804	300.00	321.00	4**1,2,3,5
Group 5 (PQ+ CMN)	315.7500	2.60494	312.00	320.00	5**1,2,3,4
Total	316.7000	5.05964	300.00	321.00	
GR U/g					
Group 1 (Control Group)	79.5250	2.65639	74.40	83.30	!**4,5
Group 2	79.0500	2.19610	75.50	82.30	2**4,5
Group 3 (Normal Rats+ CMN)	79.2250	2.16844	75.50	82.40	3**4,5
Group 4 (PQ) (Model Group)	51.8625	6.59241	40.70	60.30	4**1,2,3,5
Group 5 (PQ+ CMN)	66.5500	6.02068	60.00	75.10	5**1,2,3,4
Total	71.2425	11.76814	40.70	8 3 . 3 0	

** Significant difference p value less than 0.05.

level of MDA to 25.00 ± 3.42 nmoL/g compared to the model group (group 4) as shown in table 2. Also, enzymatic antioxidant parameters in the liver tissue showed that CAT was significantly decreased in PQ intoxicated group (group 4) compaed to groups 1,2 and 3 (0.24 ± 0.06 U/g versus 0.77 ± 0.04 U/g, 0.73 ± 0.06 U/g, 0.75 ± 0.03 U/g) respectively. In the fifth group the level of CAT was significantly increased to 0.53 ± 0.07 U/g in comparison to the model group as shown in table 2. The level of SOD in the liver tissue in PQ intoxicated group (group 4) was significantly reduced compared to groups 1,2 and 3 (305.12 ± 9.65 U/g, versus 319.62 ± 1.40 U/g, 318.75 ± 1.58 U/g, 319.62 ± 1.06 U/g) respectively. While, in the treated group who received PQ and CMN the level of SOD showed significant elevation to 312.87 ± 2.74 U/g compared to PQ intoxicated group as shown in table 2. The level of GR in the fourth group in the liver tissues was significantly decreased to 45.75 ± 10.09 U/g compared to groups 1,2 and 3 (76.86 ± 3.55 U/g, 77.46 ± 2.77 U/g and 76.67 ± 3.27 U/g respectively. In the fifth group the level of GR ws significantly elevated to 62.37 ± 9.09 U/g in comparison the model group as shown in table 2.

Administration of PQ 50 mg/kg BW induced a significant increase in serum IL-6 ($P<0.001$) when compared with group 1 (control group). On the contrary, the treated group with CMN (group 5) the level of IL-6 was significantly decreased ($P<0.001$) compared with the model group (group 4) the group that received PQ alone as depicted in figure 1.

Histopathological examination of lung and liver tissues

In groups 1, 2, 3 normal histological structure of alveolar wall and bronchial epithelial

Table 2. Biochemical Markers of oxidative stress measured in liver tissue of the studied groups

Biochemical Markers	Mean	Std. Deviation	Minimum	Maximum	P value
MDA Nmol/g					
Group 1 (Control Group)	17.8750	1.80772	20.00	15.00	!**4,5
Group 2	17.7500	1.66905	20.00	15.00	2**4,5
Group 3 (Normal Rats+ CMN)	17.5000	1.60357	20.00	15.00	3**4,5
Group 4 (PQ) (Model Group)	35.3750	4.06861	42.00	30.00	4**1,2,3,5
Group 5 (PQ+ CMN)	25.0000	3.42261	30.00	20.00	5**1,2,3,4
Total	22.7000	7.48400	42.00	15.00	
Catalase U/g					
Group 1 (Control Group)	.7713	.04390	.81	.67	!**4,5
Group 2	.7375	.06882	.80	.60	2**4,5
Group 3 (Normal Rats+ CMN)	.7563	.03249	.80	.71	3**4,5
Group 4 (PQ) (Model Group)	.2475	.06541	.32	.12	4**1,2,3,5
Group 5 (PQ+ CMN)	.5337	.07269	.63	.41	5**1,2,3,4
Total	.6093	.21049	.81	.12	
SOD U/g					
Group 1 (Control Group)	319.6250	1.40789	322.00	318.00	!**4,5
Group 2	318.7500	1.58114	321.00	316.00	2**4,5
Group 3 (Normal Rats+ CMN)	319.6250	1.06066	321.00	318.00	3**4,5
Group 4 (PQ) (Model Group)	305.1250	9.65753	314.00	285.00	4**1,2,3,5
Group 5 (PQ+ CMN)	312.8750	2.74838	316.00	309.00	5**1,2,3,4
Total	315.2000	7.18688	322.00	285.00	
GR U/g					
Group 1 (Control Group)	76.8625	3.55766	80.20	70.30	!**4,5
Group 2	77.4625	2.77434	80.10	71.40	2**4,5
Group 3 (Normal Rats+ CMN)	76.6750	3.27665	80.10	70.50	3**4,5
Group 4 (PQ) (Model Group)	45.7500	10.09597	60.00	30.00	4**1,2,3,5
Group 5 (PQ+ CMN)	62.3750	9.09423	75.10	50.50	5**1,2,3,4
Total	67.8250	14.02304	80.20	30.00	

** Significant difference p value less than 0.05.

lining in lung tissue. The lung vasculature showed normal intact basement membrane and endothelial lining as show in Fig. 2A. However, in PQ intoxicated group (Group 4) showed congestion of both peri-alveolar and peri-bronchial blood vessels. The bronchioles showed desquamation of its epithelial lining and hyperactivity of goblet cells with excessive mucous as shown in Fig. 2B. Also, hyperplasia of lymphoid follicles was considered as prominent lesions in the most of examined animals. Marked thickening of pulmonary blood vessels with protrusion of endothelial were seen Fig. 2C. In addition, the treated group with CMN (Group 5) revealed thickening of alveolar wall and congestion of peri-alveolar capillaries Fig.2D. Peri-bronchial and peri-arteriolar oedema and leukocytic infiltration mainly lymphocytes, macrophages and few number of neutrophils were noticed Fig. 2E.

Observation of liver tissue by light microscope revealed normal liver architecture in groups 1, 2, 3 in the form of normal large polygonal cells with prominent round nuclei and eosinophilic cytoplasm, and few spaced hepatic sinusoids arranged with kupffer cells Fig. 3A. While in PQ intoxicated group the hepatic tissue section of rats revealed fatty degeneration of peripheral and mid zonal hepatocytes which characterized by numerous number of empty vacuoles. The hepatic parenchyma showed centro-lobular necrosis Fig. 3B. Some cases in group 4 revealed apoptotic activity in form of deeply eosinophilic apoptotic bodies. Hyperplasia of bile duct and newly formed bile ductules were noticed. Mononuclear infiltration at the portal area mainly lymphocytes and macrophages were also observed Fig. 3C. While, in the treated group who received CMN showed congestion and dilatation of both central veins and hepatic sinusoids Fig. 3D. The hepatic cells showed swelling and granularity of its cytoplasm. Hyperplasia of kupffer cells was seen. The portal area showed dilatation of hepatic artery and portal vein with few number of mononuclear cell infiltration Fig. 3E. Also the hepatic cords showed organization of hepatocytes without necrosis or apoptosis.

DISCUSSION

In developing countries, toxicity of PQ remains a major health problem and mortality rate is still tragically high. Generation of ROS and oxidative damage which is stimulated by redox cycle may be due to PQ toxicity[29]. This study revealed that MDA level was significantly increased in PQ intoxicated group and significantly decrease in treated group by CMN in lung and liver tissues which was in accordance with previous studies. These studies reported that MDA acts as a marker of lipid peroxidation and oxidative

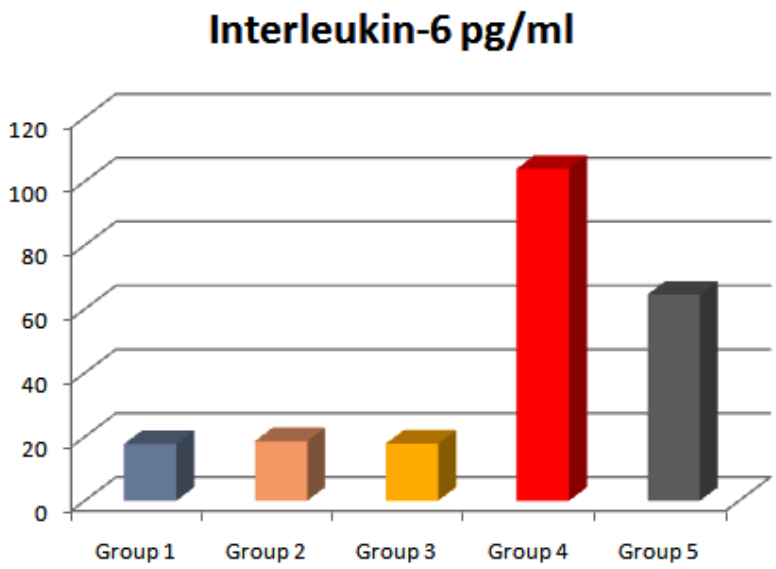

Fig. 1. Effect of curcumin on the level of Interleukin-6 after Paraquat toxicity

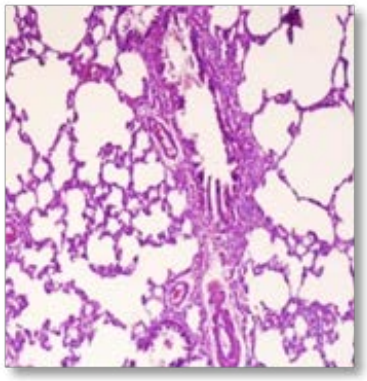

Fig. 2A. Photomicrograph of lung section (control group): showing normal histological structure of alveolar wall and bronchial epithelial lining (H&E x200)

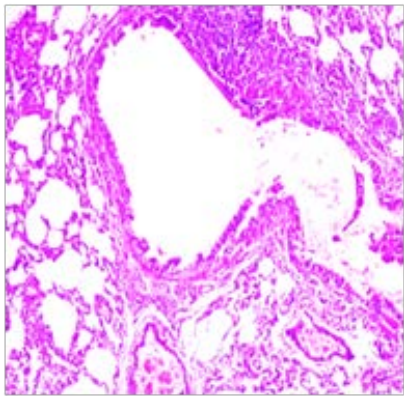

Fig. 2B. Photomicrograph of lung section (group 4): showing congestion of blood vessels with desquamation of bronchioles epithelial lining arrow (H&E x200)

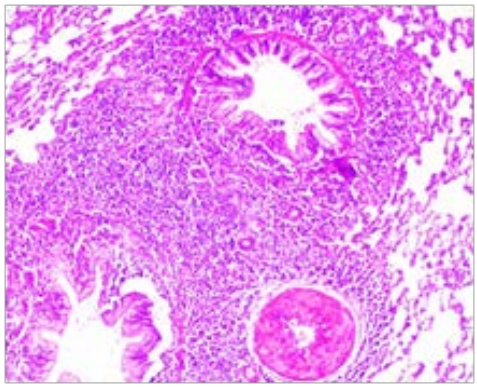

Fig. 2C. Photomicrograph of lung section (group 4): showing hyperplasia of lymphoid follicles arrow (H&E x200)

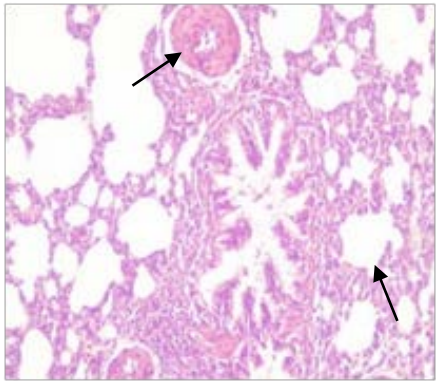

Fig. 2D. Photomicrograph of lung section (group 5): showing thickening of alveolar wall and congestion of peri-alveolar capillaries arrow (H&E x200)

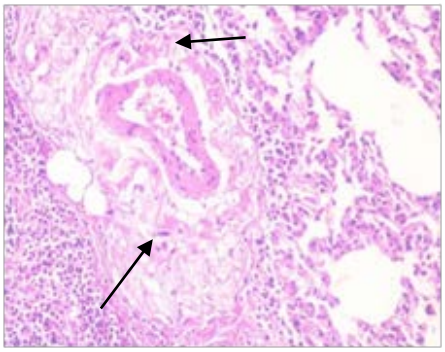

Fig. 2E. Photomicrograph of lung section (group 5): showing Peri-bronchial and peri-arteriolar oedema and leukocytic infiltration arrow (H&E x200)

Fig. 2. Histopathological changes in lung tissue of different groups

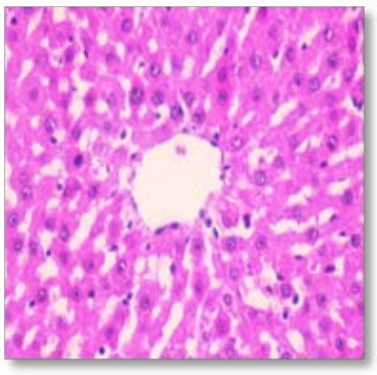

Fig. 3A. Photomicrograph of liver section (control group): showing normal histological structure of hepatic lobules (H&E x200)

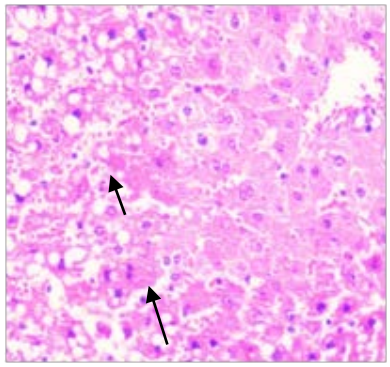

Fig.3B. Photomicrograph of liver section (group 4): showing fatty degeneration of hepatocytes and necrosis arrow (H&E x200)

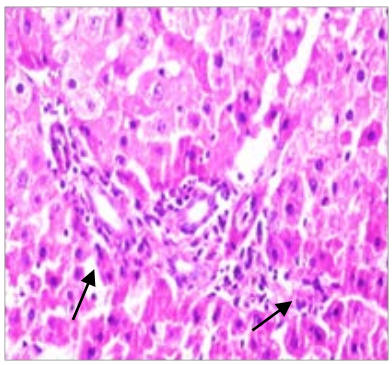

Fig.3C. Photomicrograph of liver section (group 4): showingapoptotic bodies, hyperplasia of bile duct and mononuclear infiltration arrow (H&E x200)

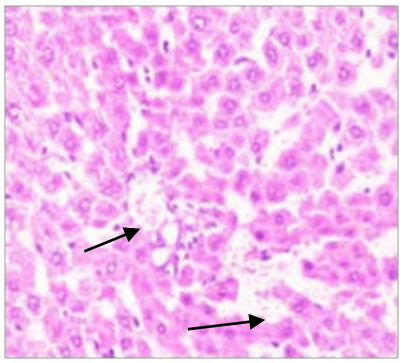

Fig.3D. Photomicrograph of liver section (group 5): showingcongestion and dilatation of both central veins and hepatic sinusoidsarrow (H&E x200)

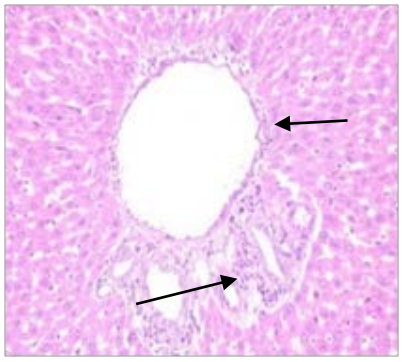

Fig.3E. Photomicrograph of liver section: showing dilatation of hepatic artery and portal vein with few number of mononuclear cells infiltrationarrow (H&E x200)

Fig. 3. Histopathological changes in liver tissue of different groups

stress[30,31]. Also, Atashpour *et al*[32] found significant increase in MDA level in PQ group and decrease in PQ treated by salep in comparison to PQ group alone. Our results are compatible with those found by Blanco Ayala *et al*[33] who showed that PQ induces oxidative stress through modulation of redox cycling which increase in oxidative parametes and leads to reduction of endogenous antioxidant levels. In addition, many studies showed that the PQ promotes ROS via reduction of PQ, inhibition of mitochondrial, and interaction with nitric oxide syntheses (cytosolic)[34- 38].

Furthermore, the present work reported that the level of antioxidant parameters CAT, SOD and GR were significantly reduced in PQ intoxicated group and significantly elevated after treatment by CMN in liver and lung tissues. These results coincided with those of Lee and Steinert[39] who showed that antioxidant enzymes mainly SOD, CAT and GR are the main defence against free radicals[40]. Our data is in line with several studies which reported on experimental animals showing significant decrease in CAT, SOD and GR activity as a result of exposure to PQ and organophosphate insecticides[41- 43]. In addition Park *et al*[44] found that PQ accumulates in the lung, liver, kidney and brain and causes its toxicity[45, 46]. Furthermore, Huang *et al*[47] reported that lung cells release cytokines/chemokines in oxidative stress which induces neutrophil recruitment and enhancement of transcription factor such as nuclear transcription factor be (NF-be) and activator protein-1 (AP-1) resulting in increasing the inflammation and lung damage. As one of the pro-inflammatory mediators, IL-6 showed inflammatory activation, differentiation of cells, promotes neutrophil respiratory outbreaks and degranulation to produce oxygen free radicals resulting in organ injuries. Also, liver plays a key role in the metabolism of xenobiotic compounds with biochemical changes occurring in toxic conditions[48]. Cytochrome P450 (CYP) have been shown to facilitate formation of ROS during xenobiotic metabolism induces oxidative stress and damage[49- 51]. In comparison to PQ intoxicated group, our results showed that CMN can ameliorate PQ toxicity in the form of decreased oxidative parameter (MDA) and increased antioxidant parameters CAT, SOD and GR in liver and lung tissues. These results are compatible with Kim *et al*[52] who noted that in animals CMN has high ROS scavenging capacity therefore reduces oxidative stress. Also, He *et al*[53] found that the antioxidant effect of CMN is due to increasing nuclear factor erythroid like-2 (NrF2) which enhances the transcription through antioxidant response elements (ARE) resulting in an increasing antioxidant activities[54-56]. Also, CMN can decrease the oxidant-burden with stimulation of lung glutathione which plays a key role in shielding from PQ lung damage[57- 59]. It can also enhance glutathione and SOD levels in the liver tissues[59]. Moreover, CMN can reduce the iron-induced hepatic damage by reducing LPO, enhance xenobiotic detoxifying enzymes activity, the hepatic total antioxidant capacity[60- 62] and finally CMN can activate the cytoprotective enzyme HO-1 in the liver[63]. On the other hand, there is accumulating evidence that CMN may not be so effective and safe. Some studies demonstrated that CMN can inhibit the activity of the drug metabolizing enzymes cytochrome P450, glutathione-S-transferase and UDP-glucuronosyl-transferase[64, 65]. The inhibition of these enzymes by CMN may result in an unfavorable increase in the plasma concentration of some drugs and cause toxicity[64]. The histopathological changes induced by PQ in the present work of lung tissues were examined precisely and the findings were in agreement with those of other investigators[66,67] who observed sever congestion, edema, prominent peribronchiolar round cell infiltration and connective tissue proliferation. The observed PQ effect in lung tissue was evident in Rezayat *et al*[68] and Smith and Heath[69] studies. They reported that PQ intoxication produced swelling and fragmentation of the alveolar epithelium followed by acute inflammatory exudate leading to infiltration into the alveolar spaces of fibroblasts to produce intra alveolar fibrosis. While, CMN exerted protective effect against PQ intoxication in lung tissue as shown in Avasarala *et al* [70] and Tyagi *et al*[71] studies. They observed that CMN attenuated multiple markers of inflammations and injury including pulmonary edema, neutrophil infiltration and inhibit fibrotic lesion development. They also revealed mild congestion, edema, peribronchiolar round cell infiltration suggesting amelioration after CMN administration.

In addition, PQ intoxicated group showed marked histopathological changes in liver tissues.

Similar results were found by Lalruatfela *et al*[72] who noted that bile duct hyperplasia, granular and degenerative changes in liver parenchyma with infiltration of mononuclear cells, congestion of central veins, focal areas of necrosis around central veins and reticular cells hyperplasia.

The observed PQ effect in liver tissues was reported in Chohan *et al*[73] and Ahmad *et al*[74] studies. They showed in PQ intoxicated group excessive infiltration of lymphocytes, macrophages in the liver parenchyma, necrosis in hepatocytes and activation of kupffer cells, inflammatory cells, and inflamed fibrotic bridges between liver lobules[75]. Recovery nearly to normal liver histology in PQ + CMN treated group may suggesting that ameliorative role of CMN against PQ induced liver injury. These results are in accordance with those noted by many investigators. Atashpour *et al* [32] found that CMN showed hepatoprotectived and reduced damage effect of PQ on hepatic tissue in the form of decrease of inflammation around portal vein and in sinusoids, organization of hepatocytes with little necrosis and improved congestion of central veins and sinusoids. These findings coincided with those of Singh *et al*[76], Salama *et al* [77] and Baxla *et al*[78] who showed also, that CMN was a hepatoprotective against CCL4, ethanol, thioacetamide, lead acetate and organophosphate insecticides[37] the mechanism of hepatoprotective effect of CMN may be due to CMN improved mitochondrial function, decreased mitochondrial ROS, down regulation of NF-kB transcription factor, and lower levels of TNF-a[79,80].

However, we need further studies to detect the ameliorative and antioxidant effect of CMN in humans.

CONCLUSION

Curcumin possesses remarkable protection of the altered lung and liver tissues in paraquat intoxicated rats and could reduce the damaging effect by increasing antioxidant enzymes and decreasing lipid peroxidation, oxidative stress and IL-6.

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