

Comparative Protective Effect of Zileuton and MK-886 against Acute Kidney Injury Induced by Doxorubicin

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Abstract

Objective: To determine the protective effects of the leukotriene inhibitors MK-886 and Zileuton on doxorubicin (DX)-induced acute kidney damage in a rat model.

Methods: A rat model of acute kidney injury (AKI) was established by a 3-day regimen of DX. The animals were suitably treated with MK-866 or Zileuton, and untreated DX injected and healthy controls were also included. The rat sera were analyzed for the levels of creatinine and urea as markers of renal injury and for the levels of the oxidative stress markers GSH and MDA using standard assays. In addition, the renal tissues of the rats were processed and histo-pathologically analyzed by HE staining.

Results: DX injection significantly increased the levels of creatinine and urea, indicating dysfunctional kidneys. The levels of both metabolites were restored to baseline levels by MK-866 while Zileuton significantly affected only urea levels. In addition, the GSH levels were significantly decreased and that of MDA was increased upon DX exposure, indicating oxidative damage. While MK-866 treatment significantly reversed the status of both GSH and MDA compared to the DX group, Zileuton had no significant effects on the levels of either. Finally, DX caused extensive renal tissue damage, which was rescued by MK-866 and to a lesser extent by Zileuton.

Conclusions: Zileuton and MK-886 have a protective effect against AKI induced by doxorubicin, with MK-886 performing better than Zileuton.

Keywords: Leukotriene inhibitors MK-886; Zileuton; Doxorubicin (DX)-induced acute kidney damage; Dysfunctional kidneys; Creatinine; Urea; Acute renal failure

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Citation: Sultan AM, Sahib HH, Saheb HA, et al. (2019) Comparative Protective Effect of Zileuton and MK-886 against Acute Kidney Injury Induced by Doxorubicin. *Prensa Med Argent*, Volume 105:5. 155.

Received: August 25, 2019; **Accepted:** October 02, 2019; **Published:** October 07, 2019

Abbreviations: AKI: Acute kidney injury; CKD: Chronic kidney disease; ARF: Acute renal failure; DX: Doxorubicin; LT: Leukotrienes; Cys-LTs: Cysteinylleukotrienes; PMN: Polymorphonuclear neutrophil

Introduction

Acute kidney injury (AKI) is characterized by a sudden (about several hours to several days) decline in renal tissue function [1]. Several studies have shown that AKI often progresses to chronic kidney disease (CKD), resulting in high mortality and morbidity [2]. Despite treatment options, development of acute renal failure (ARF) is associated with increased mortality rates from 40% to 90%, as well as non-renal complications [3]. The increasing prevalence of AKI has been reported in both developing and developed countries and is consistently associated with increased mortality and morbidity, as well as increased incidence of CKD [4]. Every year, 2 million people die of AKI worldwide [5].

Doxorubicin (DX) has been used for cancer treatment since 1969. However, due to its considerable renal, cardiac, pulmonary, hematological, and testicular toxicities [6], its use in chemotherapy has greatly decreased. The toxic effects of DX are attributed to increased

oxidative stress due to lipid peroxidation and protein oxidation that leads to tissue injury [7]. Although the exact underlying mechanism of DX-induced nephrotoxicity is not yet known, it is likely related to the generation of free radicals, and oxidative damage of iron-dependent macromolecules, membrane lipid peroxidation and protein oxidation [8].

Leukotrienes (LT) are pro-inflammatory lipid mediators produced by 5-lipoxygenase-mediated arachidonic acid oxidation [9]. Zileuton is a strong inhibitor of 5-lipoxygenase and can block the formation of cysteinylleukotrienes (Cys-LTs) and LTB₄. It is also used to ameliorate the symptoms of asthma [10,11]. MK-886 is a suppressor of LT production in vitro and in vivo and inhibits the activation and translocation of 5-lipoxygenase by inhibiting LT biosynthesis indirectly by a membrane-bound 5-lipoxygenase-activating protein [12].

Materials and Methods

Animals

Thirty healthy adult male albino rats weighing on an average 220 ± 20 g were housed at the animal facility of the College of Pharmacy,



University of Al-Qadisiyah under 12 hours light/12 hours dark cycle at $28 \pm 2^\circ\text{C}$. The animals were given standard rodent chow diet and tap water.

Materials

Doxorubicin Ebewe (50 mg in 25 ml) was purchased from EBEWE PharmaGes. MBH (4866-AUnterach, Austria). Zileuton (Lot A2513) and MK-886 (Lot H3116) were purchased from Santa Cruz Biotechnology.

Experimental design

The rats were randomized into five groups (n=6): a) control untreated rats with free access to water and standard diet, b) vehicle group-ethanol injection i.p, c) DX group daily single dose of DX (15 mg/kg i.p) [13] d) MK group-0.6 mg/kg i.p. MK-886 30 minutes before DX administration [12] and e) Z group-10 mg/kg i.p. Zileuton 30 minutes before DX administration [14]. After three days of DX regimen, all rats were sacrificed by intraperitoneal injection of sodium thiopental (70 mg/kg) [15].

Determination of serum urea and creatinine levels

Blood was drawn and placed immediately in gel separator tubes and allowed to clot at 25°C . The blood samples were centrifuged at 3000 rpm for 10 minutes at 3000 rpm , and the supernatant layer of the serum was carefully aspirated with a pipette into another dry tube. The sera were frozen at -30°C till further analysis.

Determination of GSH and MDA levels

Serum glutathione (GSH) levels ($\mu\text{g/ml}$) were measured using GSH ELISA Kit Catalog No: E-EL-0026 (96T), and serum malondialdehyde (MDA) levels (ng/ml) with MDA ELISA Kit Catalog No: E-EL-0060 (96T) from Elabscience Biotechnology Inc. according to the manufacturer's instructions.

Histopathological examination

Right kidneys were removed from each rat and fixed in 10% neutral buffered formalin and embedded in paraffin. Histopathological evaluation was done using a semi-quantitative scale as follows: 3+ = severe, 2+ = moderate, 1+ = mild, 0= not found [16].

Statistical analysis

SPSS 12.0 program for windows was used for statistical analysis. Results were presented as means \pm SE using a one-way analysis and Dunnett's test with significance threshold at $p < 0.05$.

Results

Effect of Zileuton and MK-886 treatment on the functional biomarkers of kidney

DX resulted in a significant increase in creatinine and urea levels compared to the untreated controls ($P < 0.05$). MK-886 treatment significantly decreased creatinine and urea levels ($p < 0.05$) compared to the DX group rats. Zileuton, on the other hand, significantly decreased serum urea ($P < 0.05$), but only moderately decreased the serum creatinine levels compared with the DX group. The vehicle did not affect study parameters (Figure 1).

Effect of Zileuton and MK-886 treatment on GSH and MDA levels

DX-treated rats showed a significant decrease in GSH levels compared to the untreated controls. While MK-866 treatment significantly increased GSH levels compared to the DX group, no significant changes were seen after Zileuton treatment. In contrast, the MDA levels were significantly higher in the DX group compared to untreated control group. MK-866 treatment significantly reduced the MDA levels compared to the DX group while Zileuton did not result in any significant change. The vehicle did not have any effect on MDA and GSH levels (Figure 2).

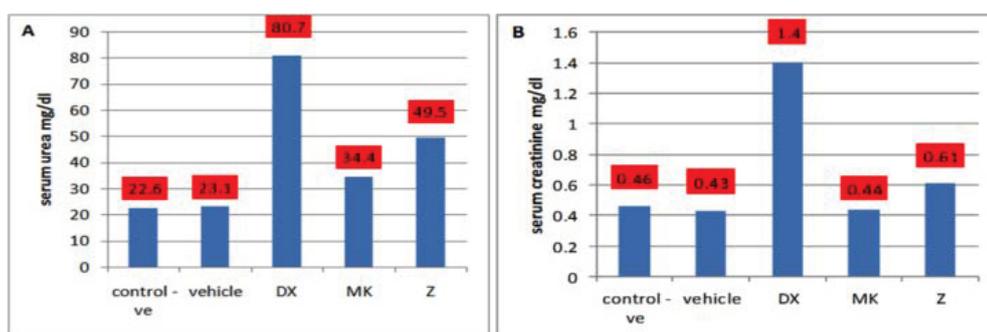


Figure 1: Kidney function test A. Mean serum urea (mg/dl). B. Mean serum creatinine (mg/dl).

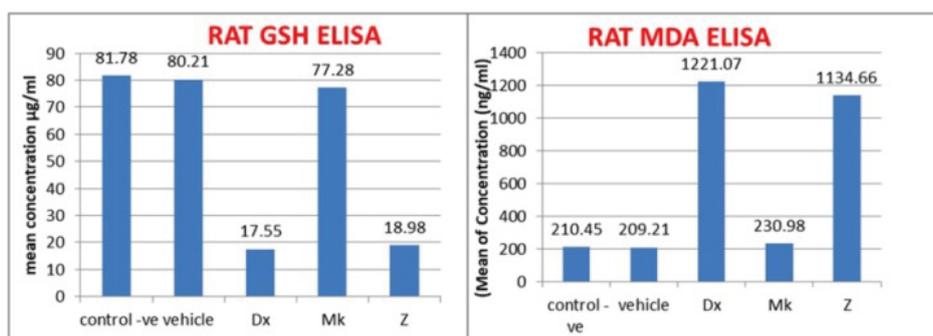


Figure 2: Oxidative markers in rats. A. Rat GSH Elisa mean concentration in $\mu\text{g/ml}$. B. Rat MDA Elisa mean concentration in ng/ml .



Effect of Zileuton and MK-886 treatments on kidney histopathology

The untreated control and vehicle groups showed normal kidney tissue architecture (Figures 3A,3B). Renal tissues of the DX group showed varying degrees of damage (Figures 3C-3E) while that of the Z group had mild to moderate proteinaceous accumulation in tubular lumen, mild necrosis, and mild to moderate tubular congestion (Figure 3F). Finally, the MK-886 treated group showed mild proteinaceous accumulation without tubular congestion or necrosis (Figure 3G).

Discussion

Anti-cancer drugs usually target some physiological functions that may also affect healthy tissues. For example, the use of anthracyclines like DX is limited due to its significant toxicity in several organs such as kidneys [17]. Nephrotoxic effects of DX are correlated with free

radical induction [18]. In our study, DX mediated nephrotoxicity was indicated by the significant increase in the levels of the serum creatinine and urea, sensitive indicators of renal function [19] along with histopathological injuries. DX mediates its nephrotoxic action by decreasing the rate of glomerular filtration which leads to increased levels of these markers, consistent with previous studies [20].

GSH is an antioxidant produced by the GST and GPx enzymes that quenches the O₂ generated from the DX [21]. Consistent with other studies [22], we found that GSH levels were significantly decreased in the sera of rats treated with DX compared to untreated controls. Oxidative stress results in cellular dysfunction by lipid peroxidation of cellular membranes. One of the end products of lipid peroxidation or - oxidation is MDA [23]. Concomitantly, we also found significantly high levels of MDA upon DX treatment, as reported previously by Yagmurca [24].

MK-886 is an inhibitor of leukotriene B₄ (LTB₄) and cysteinylleukotrienes (cysLTs) biosynthesis. Şener discovered its protective role in a rat model of renal ischemia [25], where it blocked polymorphonuclear neutrophil (PMN) infiltration in the ischemic tissues and prevented ROS production. Furthermore, MK-886 also inhibits iNOS, thereby blocking NO production, protein and DNA damage and lipid peroxidation, which prevents oxidative damage and dysfunction of the renal tissue [26]. In agreement with the above, MK-886 administration resulted in a significant decrease in serum urea and creatinine levels, along with higher GSH and lower MDA levels when compared to the DX-treated group.

Zileuton, an inhibitor of 5-lipoxygenase and LTs, has also been shown to decrease MDA levels in rats. It also blocks NF-κB and iNOS activation, which down regulates inflammatory response and oxidative stress response, respectively [27]. Najah demonstrated that Zileuton also significantly reduced the serum GSH titer [10]. In contrast, Zileuton had no effect on the oxidative stress markers in our study.

Noiri et al. showed that LTB₄ was an important factor in activation of the PMNs in ischemic kidneys, and LTB₄ receptor-antagonists prevented PMN infiltration [28]. Furthermore, inhibiting LTB₄ biosynthesis by MK-886 also decreased PMN activation and infiltration by reducing the expression of cell-adhesion molecules and endothelium layer attachment, and blocking the release of proteases, ROS, cytokines, myeloperoxidase (MPO) and elastase [29]. Daglar et al showed similar results in ischemic hepatic tissue in rats and found that LT inhibition by MK-886 or montelukast had therapeutic and protective effects against I/R injury by decreasing apoptosis and inhibiting ROS formation [30].

We also demonstrated that the Zileuton-treated rats had mild to moderate kidney damage while the MK-886 treated ones showed mild kidney damage compared to the DX group. Nimesh et al showed a reduction in the renal I/R injury in the 5-lipoxygenase knockout mice by Zileuton [31]. Finally, this is the first study to show any beneficial effect of MK-886 on kidney damage.

Conclusion

Zileuton and MK-886 have a protective effect against AKI induced by doxorubicin, with MK-886 performing better than Zileuton.

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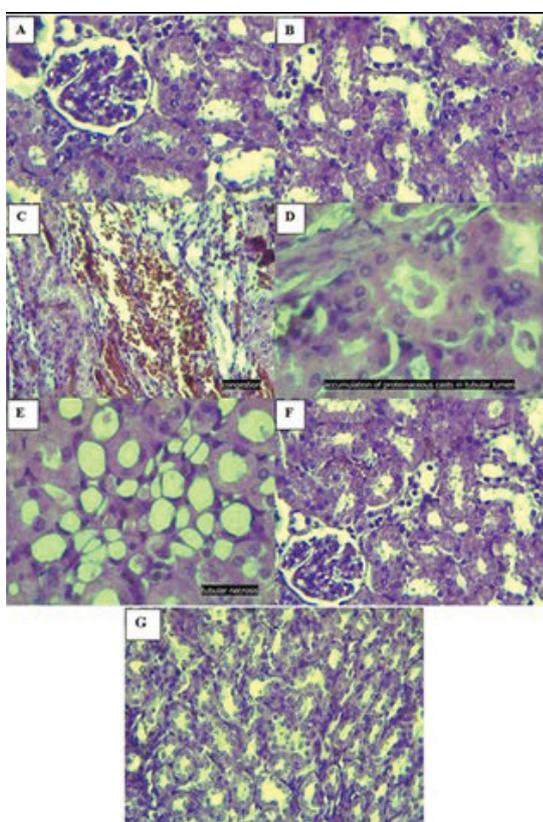


Figure 3: Effect of Zileuton and MK-886 treatments on kidney histopathology. A: Untreated healthy control. B: Vehicle group. (C, D and E): DX-treated group. F: Zileuton treated group. G: MK-886 treated group.

Table 1: Kidney histological evaluation of the rats [Severity scores: 0=Not found; 1+ = Mild; 2+ = Moderate; 3+ = Severe].

Findings	-Ve control gr.	Vehicle gr.	DX-treated gr.	Z plus DX-treated gr.	MK plus gr.	DX-treated
Accumulation of Proteinaceous casts in the tubular lumen	0	0	+2 (3/6)	0 (3/6)	0 (4/6)	
			+3 (3/6)	+1 (2/6)	+1 (2/6)	
				+2 (1/6)		
Tubular necrosis	0	0	+1 (4/6)	0 (3/6)	0 (6/6)	
			+2 (2/6)	+1 (3/6)		
Congestion	0	0	+1 (2/6)	0 (2/6)	0 (4/6)	
			+2 (4/6)	+1 (3/6)	+1 (2/6)	
				+2 (1/6)		



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