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RESEARCH ARTICLE

# IMPACT OF EMPAGLIFLOZIN ON BIOCHEMICAL, INFLAMMATORY, AND OXIDATIVE STRESS MARKERS IN CONTRAST-INDUCED ACUTE KIDNEY-INJURED ALBINO RATS

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## Abstract

Contrast-induced acute kidney injury (CI-AKI) is a critical clinical issue associated with increased morbidity and mortality. This study evaluated the renoprotective effect of empagliflozin, a sodium-glucose co-transporter 2 (SGLT2) inhibitor, in non-diabetic albino rats. Twenty-four rats were divided into four groups, receiving varying doses of empagliflozin and contrast media. Key biochemical markers, including serum creatinine (SCr), blood urea nitrogen (BUN), inflammatory cytokines, and oxidative stress indicators, were analyzed. Empagliflozin significantly mitigated increases in SCr and BUN levels compared to the contrast media group, suggesting improved renal function. Although reductions in TNF-Alpha and modulations in malondialdehyde (MDA) levels were observed,they were not statistically significant. These findings highlight empagliflozin's potential anti-inflammatory and antioxidative effects. The study underscores empagliflozin's promise as a therapeutic agent for CI-AKI and calls for further investigations into its molecular mechanisms and clinical applications.

**Keywords:** Empagliflozin, Sodium-glucose co-transporter 2 (SGLT2) inhibitors, Renoprotective, Contrast media, Acute kidney injury.

## 1. Introduction

Acute kidney injury (AKI) is a significant global health concern, causing an estimated 1.4 million deaths annually and posing a serious threat to patient morbidity in both developed and developing nations [1]. It is characterized by a rapid decline in the kidneys' ability to perform their excretory functions [2]. The use of iodinated contrast agents has been linked to the onset of AKI since their introduction. Numerous observational studies have reported a substantial risk of AKI following the intravenous or intra-arterial administration of contrast media (CM).

CM enhances imaging clarity, differentiates abnormal tissues from healthy ones, and provides detailed visualization of vascular systems. While CM can be delivered intravenously, orally, or through other luminal organs, its nephrotoxic effects are minimal when administered non-intravascularly [3] The term **contrast-induced acute kidney injury (CI-AKI)** describes a sudden decline in kidney function occurring shortly after the administration of iodinated contrast materials [4].

CI-AKI is typically identified by elevated blood urea nitrogen (BUN), serum creatinine (Scr), or a reduction in estimated glomerular filtration. It affects up to 30% of patients receiving iodinated contrast media and is regarded as the third leading cause of hospital-acquired AKI [5], [6]. Initially considered a mild condition with temporary and asymptomatic rises in blood creatinine levels, recent research has revealed significantly higher short- and long-term mortality rates among patients with CI-AKI compared to those without [7]. Beyond increased mortality, CI-AKI has been shown to prolong hospital stays, raise healthcare costs, and heighten the likelihood of requiring renal replacement therapy [6].

Additionally, a history of CI-AKI may increase the risk of developing chronic kidney disease (CKD) and progressing to end-stage renal disease (ESRD) over time [8], [9]. The precise pathophysiological process behind CI-AKI is unknown and involves intricate cascades of

occurrences. The medullary hypoxia caused by CM-induced medullary vasoconstriction appears to be one of the key components of the pathophysiological process of CI-AKI [10].

Sodium-glucose co-transporter 2 (SGLT-2) inhibitors, a novel class of anti-diabetic medications, work by blocking SGLT-2 activity in the proximal convoluted tubules of the kidney, thereby preventing sodium and glucose reabsorption [11]. These drugs, including empagliflozin, have demonstrated substantial cardiovascular and renal benefits in diabetic patients. Empagliflozin inhibits the reabsorption of approximately 90% of filtered glucose, promoting mild glucose disposal without causing hypoglycemia due to the natural regulation of plasma glucose levels. Additionally, it induces osmotic diuresis and increases sodium excretion, contributing to beneficial effects on cardiac function [12].

Recent studies, such as those by Moein Ala and colleagues, have shown that empagliflozin mitigates renal histological damage and improves kidney function following ischemia-reperfusion (I/R) injury [13]. As far as we are aware, no research has been done on the effects of empagliflozin on CI-AKI. Thus, the aim of the current investigation was to elucidate the likely impact of empagliflozin on CI-AKI. The study's findings might provide useful information in the field.

## 2. Materials & Methods

### *2.1. Study Duration and Setting*

The study was carried out in the Pharmacology lab at the Faculty of Pharmacy, University of Aden during the period from September 2023 to March 2024.

### *2.2. Study design*

The type of design was an experimental study, where quantitative and qualitative variables were included.

### *2.3. Study Animals*

Twenty-four healthy Female albino rats weighing (125-180 gm) divided into 4 groups 6 rats for each group were used in this study.

### *2.4. Materials*

#### *2.4.1 Chemicals*

The chemicals used in the experiment were normal saline 0.9% solution (Amanta Healthcare Limited – India), 10% formalin (Isochem – Laboratories- India), Paraffin (Numaligarh Refinery Limited – India), Ketamine (Rotix-medica – Germany), Hematoxylin and eosin Kit (Benz microscopic optic – Ireland) Carboxymethyl cellulose (CMC) (Loba Cheme PVT. LTD -India)

#### *2.4.2. Drugs*

The drugs for the experiment were Jardiglose® (Empagliflozin) 10mg tablets (Zein Pharma-Syria) was received as a gift from Himam Hadramout For importing medicine and medical appliances, (Iohexol 350) solution (Unique pharmaceutical labs – India),Entix® (Frusemide) 20mg ampule (BASI –Portugal).

### *2.5. Instruments and Equipment*

The instruments used were Electronic balance (Spanish - LABORCOM), Sensitive Electronic balance (Spanish – P SELECTA), Centrifuge (Spanish – P SELECTA) Screen master plus - Biochemical system international SrI(Italy- IVD), Eliza ( USA - Star Fax (4700).

### *2.6. Treatment of Animals*

Albino rats were housed in cages under standard laboratory conditions (temperature-controlled environment (20 -25°C) with a 12:12-hour cycle for light and dark with a relative humidity of (55-60%). They were handled according to the animal ethics guide. [14], [15] Standard diet and tap water ad libitum were available without charge. In addition, they were adapted to this condition for 1 week before starting the procedure. The accommodation period was in the pharmacology lab at the Faculty of Pharmacy - Aden University

### *2.7. Methods*

#### *2.7.1 Drugs/sample preparation*

#### *2.7.1.CMC solution preparation*

Five hundred milligrams of CMC powder was dissolved slowly into 100ml of distillated water with hard and long mixing and stay for 24 hours for complete dissolving [16].

#### *2.7.1.2 Empagliflozin preparation*

Empagliflozin was prepared by accurately weighing 10 tablets, which were then finely crushed using a mortar and pestle. The resulting powder was dissolved in 100 mL of a 0.5% carboxymethyl cellulose (CMC) solution, ensuring thorough mixing. The prepared suspension was used immediately to maintain stability and prevent any degradation. [11], [17]

#### *2.7.2 Experimentation*

The study was conducted using 24 rats, which were randomly assigned to four groups, each consisting of six rats, as follows:

Group I (Control - C): Rats received normal saline throughout the experiment.

Group II (Contrast Media group - CM): Rats were deprived of water for 48 hours, followed by an intramuscular injection of 10 mg/kg furosemide. Twenty minutes later, they were administered contrast media

Iohexol (15 mL/kg body weight) via the tail vein slowly. [18]

Group III (Contrast Media + Single Dose of Empagliflozin - ECM): Rats were given a single oral dose of empagliflozin (10 mg/kg body weight) 1 hour prior to the administration of furosemide. [14]

Group IV (Contrast Media + Five Doses of Empagliflozin - E5CM): Rats were treated with oral empagliflozin (10 mg/kg body weight) daily for five consecutive days before furosemide administration

#### *2.7.3. Experimental methods*

#### *2.7.3.1. Spectrophotometer Test*

#### *2.7.3.1.1. Renal Function tests*

Serum creatinine (Scr) and blood urea nitrogen (BUN) were measured before the experiment and after 48 hours from administration of CM following the steps of the instruction manual supplied by AGAPPE Lab by using a spectrophotometer. Samples of venous blood were drawn via a capillary tube from the orbital-sinus capillary vein. The blood was put into the test tubes, allowed to clot for 20 minutes, and then centrifuged at 4000 g for 20 minutes. The (Scr) and (BUN) levels in the serum were analyzed later after collection and storage at 4°C. [19]

#### *2.7.3.2 Eliza Test*

#### *2.7.3.2.1. Determination of proinflammatory cytokine in the serum of the rats*

Serum tumor necrosis factor-alpha (TNF-α) was measured following the steps of the instruction manual supplied by the BT- LAB ELISA kits**.**

#### *2.7.3.2.2. Determination of oxidative stress markers in the serum of rats*

Serum malondialdehyde (MDA) were measured following the steps of the instruction manual supplied by the BT- LAB ELISA kits**.**

### *2.8. Statistical Analysis*

Data were checked then entered into the Statistical Package for Social Sciences (SPSS) software version 25 (IBM SPSS Inc. Chicago, Ill, USA)). All results were presented as the mean ± SD. Treatment group means were compared by one-way ANOVA followed by post hoc Tukey's test for pair-wise comparisons. P ≤0.05 was considered statistically significant for all tests.

### *2.9. Ethical Consideration*

This study was approved by the Ethical Committee at the Faculty of Medicine and Health Sciences –University of Aden (REC- 158-2023). Animal handling was done according to The Norwegian National Research Ethics Committees. Ethical Guidelines for the Use of Animals in Research. 1st edition, 2018. Available at: www.etikkom. After scarifying , the animals's bodies were buried.

## 3. Results

Twenty-four non-diabetic healthy albino rats were utilized in this in vivo experimental study to evaluate the biochemical and histopathological effects of empagliflozin on contrast-induced acute kidney injury (CI-AKI). Following a one-week acclimatization period, the body weight of each rat was measured three times, and the mean weight was calculated. The results are presented in Table 3.1. The rats were then randomly assigned to four groups, each comprising six rats, with the mean body weight for each group also summarized in Table 3.1.

### *3.1. Rats weight*

A total of 24 female albino rats were weighed at the start of the study. Their mean weight was 146.67 ± 13.48 g, with a minimum weight of 125 g and a maximum weight of 178 g across all groups.

### *3.2 Effect of Empagliflozin on Serum Creatinine (SCr):*

Baseline SCr levels were comparable across groups: 0.93 ± 0.18 µmol/L (control), 0.87 ± 0.42 µmol/L (CM), 0.60 ± 0.30 µmol/L (ECM), and 0.75 ± 0.21 µmol/L (E5CM).

At 48 hours, there was a statistically significant increase in SCr of the CM group compared to the control group, 2.18 ± 0.95 µmol/L versus 0.90 ± 0.18 µmol/L, with P=0.005. On the other hand, The ECM group showed a slight reduction in SCr (1.38 ± 0.30 µmol/L) in comparison to the CM group (2.18 ± 0.95 µmol/L, which showed a statistically insignificant difference (P=0.462). Moreover, the E5CM group exhibited a further drop in SCr to 1.2 ± 0.22 µmol/L, which was significantly lower than the CM group (2.18 ± 0.95 µmol/L; P=0.029). Percentage changes from the CM group to (232.60 ± 209.22%) were 179.56 ± 123.88% for the ECM group, and 121.08± 146.34% foe E5CM group Table 3.2.

### *3.3 Effect of Empagliflozin on Blood Urea Nitrogen (BUN):*

Baseline BUN levels were highest in the ECM group (101.83 ± 60.03 µmol/L) compared to E5CM (38.17 ± 19.88 µmol/L), CM (49.33 ± 19.65 µmol/L), and control (29.67 ± 12.02 µmol/L). After 48 hours, the E5CM group exhibited a reduction to 35.67 ± 11.36 µmol/L, while the ECM group decreased to 61.00 ± 29.84 µmol/L. The CM group showed a significant rise to 77.67 ± 34.38 µmol/L. The percentage change of the CM group above baseline control was (100.08 ± 97.78%), while the ECM group reduced the elevated percentage of the CM group to (39.23 ± 22.04%) and a further reduction produced by the E5CM group to (24.10 ± 23.11%).

**Table 3.1:** Body weight of rats among groups

| Groups n=6 | C (gm) | CM (gm) | ECM (gm) | E5CM (gm) |
|---|---|---|---|---|
| 1 | 167.00 | 178.00 | 125.00 | **144.00** |
| 2 | 140.00 | 147.00 | 133.00 | **135.00** |
| 3 | 158.00 | 151.00 | 145.00 | **136.00** |
| 4 | 153.00 | 130.00 | 148.00 | **154.00** |
| 5 | 164.00 | 160.00 | 148.00 | **129.00** |
| 6 | 148.00 | 125.00 | 151.00 | **151.00** |
| Means±SD | 155.00±10.12 | 148.50±19.52 | 141.67±10.30 | **141.50±9.81** |

**Table 3.2:** Distribution of serum creatinine levels among the control and treated groups. (n=6)

| Groups | Control Means±SD | CM Means±SD | ECM Means±SD | E5CM Means±SD |
|---|---|---|---|---|
| SCr at baseline (μmol/L) | 0.93±0.18 | 0.87±0.42 | 0.60±0.30 | **0.75±0.21** |
| SCr at 48 h after CM injection (μmol/L) | 0.90±0.18 | 2.18±0.95 | 1.38±0.30 | **1.2±0.22** |
| Change in SCr (%) | 6.38±7.39 | 232.60±209.222 | 179.56±123.88 | **121.08±146.34** |
| P value | | 0.005 | 0.462 | **0.029** |

**Table 3.3:** Distribution of blood urea nitrogen (BUN) levels among the control and treated groups. (n=6)

| Groups | Control Means±SD | CM Means±SD | ECM Means±SD | E5CM Means±SD |
|---|---|---|---|---|
| BUN at baseline (μmol/L) | 29.67±12.02 | 49.33±19.65 | 101.83±60.03 | **38.17±19.88** |
| BUN at 48 h after CM injection (μmol/L) | 30.50±14.68 | 77.67±34.38 | 61.00±29.84 | **35.67±11.36** |
| Change in BUN above baseline (%) | 28.70±29.35 | 100.08±97.78 | 39.23±22.04 | **24.10±23.11** |
| P value | | 0.32 | 0.63 | **0.23** |

### *3.4. Effect of Empagliflozin on Contrast-induced inflammatory biomarker, TNF-α*

The effect of empagliflozin on serum levels of the inflammatory biomarker tumor necrosis factor-alpha (TNF-**α**) was assessed in various experimental groups. The results are summarized in Table 3.4. In the control group, which was not exposed to contrast media or empagliflozin, the mean serum TNF-Alpha level was 19.53 ± 8.14 ng/L, representing the baseline inflammatory status. The CM group (contrast media alone) exhibited a significant increase in serum TNF-Alpha level to 46.10 ± 8.10 ng/L compared to the control group, with a *P*-value of 0.004. Treatment with empagliflozin in the ECM group (empagliflozin + contrast media) resulted in a reduction in TNF-Alpha levels to 33.13 ± 1.58 ng/L compared to the CM group. Although this represents a notable attenuation of the inflammatory response, the difference did not reach statistical significance compared to the CM group (P-value = 0.134).

In the E5CM group (high-dose empagliflozin + contrast media), TNF-Alpha levels were further reduced to 32.92 ± 1.83 ng/L. However, similar to the ECM group, the reduction in TNF-Alpha levels was not statistically significant when compared to the CM group (P-value = 0.128).

**Table 3.4:** Effect of Empagliflozin on serum TNF-Alpha (n=6)

| Groups | TNF-Alpha (ng/L) Mean ±SD | P Value |
|---|---|---|
| Control | 19.53± 8.14 | |
| CM | 46.10±8.10 | **0.004** |
| ECM | 33.13± 1.58 | **0.134** |
| E5CM | 32.92±1.83 | **0.128** |

### *3.5 Effect of Empagliflozin on Serum Malondialdehyde (MDA) Levels*

The findings of the MDA serum test, summarized in Table 3.5, show significant variations in MDA levels across the different groups.

In the control group, baseline MDA levels were 0.95 ± 0.48 nmol/mL representing normal oxidative balance without experimental intervention. Exposure to contrast media alone (CM group) caused a marked decrease in MDA levels to 0.20 ± 0.13 nmol/mL, with a highly significant P-value of 0.000 compared to the control group. This unexpected reduction may point to alterations in lipid peroxidation pathways due to contrast media exposure.

In the ECM group, where empagliflozin was administered with contrast media, MDA levels increased slightly to 0.52 ± 0.07 nmol/mL. However, this increase was not statistically significant compared to the CM group (P-value = 0.09), suggesting that empagliflozin might play a partial role in restoring oxidative balance.

Similarly, the E5CM group (high-dose empagliflozin + contrast media) exhibited MDA levels of 0.50 ± 0.08 nmol/mL, closely aligning with the ECM group. The P-value of 0.113 indicates no significant difference in MDA levels between these groups, highlighting a minimal impact of the increased empagliflozin dose.

**Table 3.5:** Effect of Empagliflozin on serum Malondialdehyde (MDA). (n=6)

| Groups | MDA (nmol/ml) Mean ±SD | P Value |
|---|---|---|
| Control | 0.95± 0.48 | - |
| CM | 0.20±0.13 | **0.000** |
| ECM | 0.52±0.07 | **0.09** |
| E5CM | 0.50±0.08 | **0.113** |

## 4. Discussion:

The findings of this study underscore the potential of empagliflozin in mitigating contrast-induced acute kidney injury (CI-AKI) in non-diabetic rats through its effects on renal function, inflammation, and oxidative stress markers. These results align with and expand upon existing literature, providing new insights into empagliflozin's multifaceted renoprotective mechanisms.

In this study, the CM group exhibited significant increases in serum creatinine (SCr) and blood urea nitrogen (BUN) levels as seen in literature [13], [19], [20], [21], [22] , consistent with renal impairment triggered by contrast media. The E5CM group (high-dose empagliflozin) demonstrated the most substantial reduction in these markers, suggesting a dose-dependent renoprotective effect. This observation aligns with findings by Ala et al., who demonstrated that empagliflozin significantly lowered SCr and BUN levels in a renal ischemia/reperfusion (I/R) injury model by promoting mitochondrial biogenesis and autophagy while attenuating oxidative stress and apoptosis [13]. Moreover, similar results have been observed with beta-glucan and statin treatments in CI-AKI models [19], [23], where these agents reduced renal dysfunction markers, highlighting shared protective mechanisms.

The reduction in renal dysfunction markers with empagliflozin may be attributed to its role in improving renal hemodynamics and reducing tubular stress. This aligns with the reported ability of empagliflozin to decrease sodium reabsorption in the proximal tubule, thereby preserving renal blood flow and mitigating hypoxia-induced injury.

The CM group also exhibited significantly elevated TNF-Alpha levels, indicative of contrast-induced systemic and renal inflammation. Empagliflozin treatment resulted in reductions in TNF-Alpha levels in both the ECM and E5CM groups, although these changes were not statistically significant, which might be due to the low sample size.

TNF-Alpha is a critical pro-inflammatory cytokine implicated in the pathogenesis of contrast-induced nephropathy and systemic inflammation. Empagliflozin's anti-inflammatory effects are well documented. For example, Ala et al. reported a significant decrease in TNF-Alpha and interleukin-1β levels in empagliflozin-treated rats, attributing these effects to enhanced autophagy and decreased oxidative stress [13]. Similarly, studies with beta-glucan and statins have highlighted reductions in inflammatory markers, emphasizing the role of inflammation in CI-AKI pathogenesis. [19], [23].

The trend toward decreased TNF-Alpha levels observed here suggests that empagliflozin may modulate upstream inflammatory pathways, such as nuclear factor-kappa B (NF-κB) signaling [14], [17]. Further studies are needed to validate these findings and elucidate the precise mechanisms involved.

This result highlights the inflammatory response triggered by contrast media administration, supporting its role in inducing systemic inflammation.

On the inflammatory marker side, the observed decrease in serum MDA levels in the CM group contrasts with the typical expectation of increased oxidative stress following contrast media exposure. This paradoxical finding challenges prior research, which generally reports elevated MDA levels as a marker of oxidative stress induced by contrast media. Instead, the significant reduction in MDA levels observed here may indicate disruption or modulation of lipid peroxidation pathways, possibly through activation of compensatory antioxidant mechanisms. Further investigation is needed to validate this hypothesis, particularly through studies with larger sample sizes and additional oxidative stress markers. Empagliflozin-treated groups (ECM and E5CM) exhibited slight but non-significant increases in MDA levels compared to the CM group. This suggests a potential role of empagliflozin in partially restoring oxidative balance, though its effect on MDA levels in this study was not robust. Previous research by Ala et al. demonstrated that empagliflozin significantly reduced MDA levels in renal ischemia-reperfusion (I/R) injury models by upregulating nuclear factor erythroid 2-related factor 2 (Nrf2), a master regulator of the antioxidant defense system [13]. Similarly, agents like beta-glucan and nebivolol have been shown to attenuate oxidative stress by reducing MDA levels in contrast-induced acute kidney injury (CI-AKI) models [23], [24].

The findings of this study, while unexpected, open avenues for exploring the complex interplay between contrast media, oxidative stress, and antioxidant responses. Understanding these mechanisms in greater depth may elucidate the protective role of empagliflozin and similar agents in oxidative stress-related conditions.

The observed renoprotective effects of empagliflozin align with those reported for other nephroprotective agents, such as beta-glucan and statins. Studies have shown that beta-glucan reduces renal dysfunction and histopathological damage in CI-AKI by modulating

oxidative stress and inflammation. Similarly, atorvastatin and rosuvastatin have been found to lower SCr, MDA, and inflammatory cytokine levels in CI-AKI models [19], [23], [25]

Empagliflozin's unique ability to enhance autophagy and mitochondrial function sets it apart from other agents. Ala et al. demonstrated that empagliflozin upregulated PGC-1α, a key regulator of mitochondrial biogenesis, and increased the LC3-II/LC3-I ratio, reflecting enhanced autophagy. These mechanisms may contribute to its superior efficacy in preserving renal function and reducing tissue damage [13].

The ability of empagliflozin to mitigate renal dysfunction, inflammation, and oxidative stress highlights its potential as a therapeutic agent in preventing CI-AKI, particularly in high-risk patients with chronic kidney disease or diabetes. Its established safety profile and efficacy in diabetic nephropathy support its translation to clinical settings.

However, further studies are needed to establish optimal dosing strategies and investigate their long-term effects on renal outcomes. Comparative studies with other nephroprotective agents could help elucidate its relative efficacy and identify patient populations most likely to benefit.

The present study investigated the effects of empagliflozin on contrast-induced acute kidney injury (CI-AKI) in non-diabetic albino rats, focusing on renal function markers, inflammatory cytokines, and oxidative stress indicators.

## 5. Conclusion

Empagliflozin exhibits potential renoprotective effects in the context of contrast-induced acute kidney injury, as evidenced by attenuated increases in serum creatinine and reductions in inflammatory markers. While the reductions in TNF-Alpha and modulations in MDA levels were not statistically significant, the trends suggest that empagliflozin may confer anti-inflammatory and antioxidative benefits. These findings are consistent with existing literature highlighting the renoprotective, anti-inflammatory, and antioxidative properties of empagliflozin. Further research is warranted to elucidate the underlying mechanisms and to explore the clinical applicability of empagliflozin in preventing CI-AKI.

## 6. Recommendations

Based on the findings of this study, the following recommendations are proposed:

Conduct studies to evaluate the dose-response relationship of empagliflozin in mitigating contrast-induced acute kidney injury (CI-AKI).

Explore the timing of empagliflozin administration (pre- or post-contrast exposure) to determine the most effective therapeutic window.

Investigate the precise molecular mechanisms by which empagliflozin reduces oxidative stress and inflammation, focusing on pathways related to TNF-Alpha and malondialdehyde (MDA).

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مقالة بحثية

# تأثير إمباغليفلوزين على المؤشرات البيوكيميائية والالتهابية والإجهاد التأكسدي في الفئران البيضاء المصابة بإصابة الكلى الحادة الناجمة عن استخدام المواد التباينية

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## المُلخّص

تُعتبر إصابة الكلى الحادة الناجمة عن استخدام المواد التباينية (CI-AKI) مشكلة سريرية حرجة ترتبط بزيادة معدلات الاعتلال والوفيات. تم في هذه الدراسة تقييم التأثير الحامي للكلى لدواء إمباغليفلوزين، وهو مثبط لناقل الجلوكوز والصوديوم 2 (SGLT2)، في الفئران البيضاء غير المصابة بالسكري. تم تقسيم أربع وعشرين فأرًا إلى أربع مجموعات تلقت جرعات مختلفة من إمباغليفلوزين والمواد التباينية. تم تحليل المؤشرات البيوكيميائية الرئيسية، بما في ذلك الكرياتينين في الدم (SCr)، واليوريا في الدم (BUN)، والسيتوكينات الالتهابية، ومؤشرات الإجهاد التأكسدي. أظهر إمباغليفلوزين تخفيفًا ملحوظًا لزيادة مستويات الكرياتينين واليوريا في الدم مقارنة بمجموعة المواد التباينية، مما يشير إلى تحسن في وظيفة الكلى. على الرغم من ملاحظة انخفاض في TNF-Alpha وتغيرات في مستويات المالونديالدهيد (MDA)، إلا أنها لم تكن ذات دلالة إحصائية. تسلط هذه النتائج الضوء على الإمكانات المضادة للالتهابات والمضادة للأكسدة لإمباغليفلوزين. وتؤكد الدراسة على وعد إمباغليفلوزين كعامل علاجي لإصابة الكلى الحادة الناجمة عن استخدام المواد التباينية وتدعو إلى مزيد من التحقيقات حول آلياته الجزيئية وتطبيقاته السريرية.

**الكلمات المفتاحية:** إمباغليفلوزين، مثبطات ناقل الجلوكوز والصوديوم النوع الثاني، حماية الكلى، المواد التباينية، إصابة الكلى الحادة.

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