Malvadin Prevents Kidney from Renal Ischemia-Induced Oxidative Damage in Rats. Running Title: Malvidin and Acute Renal Failure

Sarvenaz Emadi [1], Iman Sadeghi [2], Hossein Khastar [3*]

[1] School of Medicine, Alborz University of Medical Sciences, Karaj, Iran.
[2] CEINGE-biotecnologie Avanzate, Naples, Italy
[3] School of Medicine, Shahroud University of Medical Sciences, Shahroud, Iran

ABSTRACT

Background: Oxidative stress is one of the suggested causes of renal ischemia reperfusion (IR) injury. Malvidin is an important anthocyanin which exhibits significant antioxidant properties. Here, we aimed to study the effect of Malvidin on oxidative stress status *in vivo*.

Materials and Methods: 30 Male Wistar rats were randomly assigned to three groups: (1) Sham operated, (2) renal IR (45 min ischemia followed by 24 h of reperfusion), (3) renal IR + Malvidin (100 mg/kg, P.O, 21 days). In IR group, rats were anesthetized and renal arteries occluded for 45 min followed by 24 h reperfusion. Sham-operated Rats underwent a surgical procedure identical to those of IR rats except that clamps were not applied. Then, renal functional indices (fractional excretion of sodium, plasma (blood urea nitrogen) BUN, creatinine (Cr), urine flow rate, creatinine clearance) and oxidative stress indices such as catalase (CAT), superoxide dismutase (SOD) and malondialdehyde (MDA) were evaluated in blood and kidney tissue.

Results: Malvidin caused a fall in fractional excretion of Na, plasma BUN, Cr and rise in urine flow rate, Cr clearance in malvidin group compared with IR group. In addition malvidin administration resulted in an increase in CAT and SOD and decrease in MDA in contrast to IR group.

Conclusion: malvidin consumption has protective effect against renal IR induced acute kidney injury, partly by inhibiting oxidative stress in renal tissues.

Keywords: Renal ischemia reperfusion, acute kidney injury, Malvidin, anthocyanin, Oxidative stress.

INTRODUCTION

Acute kidney injury (AKI) is a major clinical problem that occurs in some of the hospitalized patients especially in intensive care units. Renal ischemia reperfusion (IR) is one of the most important causative mechanisms of AKI and is associated with various clinical settings including shock, sepsis, kidney transplantation, vascular surgery, and elective urological operations [1, 2]. Although the exact mechanism of renal IR injury is not explained completely, the renal IR injury has multifactorial and interdependent causes such as inflammatory responses, leukocyte infiltration and oxsidative stress. Oxidative stress has been identified to play key role in this process. The abundance of polyunsaturated fatty acids makes the kidney an organ particularly vulnerable to reactive oxygen species (ROS) attack [2, 3].

Compounds in some plants and fruits have significant antioxidant properties [4-7]. Phytochemicals are most potential antioxidant [8-11] such as Anthocyanins. Anthocyanins are a group of red, purple, violet and blue pigments that contribute to the bright colors of plant components and are broadly distributed in many fruits, vegetables and flowers that have antioxidant, Antiproliferative and anti-inflammatory properties [12-14]. Jiang et al. showed Purple potato anthocyanins could be an

* H_khastar@yahoo.com
Received on 23/7/2019 and Accepted for Publication on 26/11/2019.

important therapeutic agent in alcohol-induced liver injuries by inhibiting CYP2E1 expression and therefore reinforcement antioxidant defenses [12]. Cyanidin-3-O-glucoside is an anthocyanin that protects the rat heart from ischemia/reperfusion-induced apoptosis and necrosis because of the ability to reduce cytosolic cytochrome C [15]. It was demonstrated that Korean black bean anthocyanins have neuroprotective effects against kainic acid-induced excitotoxicity due to inhibiting the reactive oxygen species (ROS) accumulation [16]. Blueberry anthocyanins is effective in ameliorating radiation-induced lung injury in rats [17]. Malvidin, as an anthocyanin, is responsible for the color of red wine and blueberries, together with other anthocyanidins. Malvidin has antioxidant activity with free radical scavenging properties. It has four hydroxyls group, leading to a powerful antioxidant capacity [18, 19]. Malvidin has antihypertensive properties by inhibiting angiotensin I converting enzyme [20]. It has important role in preventing chronic inflammation by inhibiting monocyte chemotactic protein-1 (MCP-1), intercellular adhesion molecule-1 (ICAM-1), and vascular cell adhesion molecule-1 (VCAM-1) production in the NF-κB pathway [21-27].

This study was designed to investigate the protective effects of malvidin on renal ischemia reperfusion induced acute kidney injury in rats. The present research is being carried out to highlight the possible useful effects of the usage of malvidin as a natural antioxidant in order to improve the side-effects of various clinical settings including kidney transplantation, vascular surgery, and elective urological.

Materials and Methods:

This study was approved by Shahroud University of Medical Sciences Ethics Committee by Etic CODE: IR.SHMU.REC.1396.164.

So, 30 Male Wistar rats (weight =200-250 g) were Maintained at room temperature (22 ± 2°C) in a 12:12-hour light–dark cycle and with free access to standard diet and water. Animal care was in compliance with the guidelines of the animal and human ethics committee of Shahroud University of medical sciences. The rats were randomly assigned to three groups (n=10):

(1) Sham operated (2 ml/kg bw/day salin trough feeding tube for 21 days before IR), (2) renal IR (45 min bilateral ischemia), (3) renal IR + malvidin (100 mg/kg bw/day in 2 ml/kg saline for 21 days before IR).

An established model of renal IR injury in rat was used [1, 28]. Briefly, rats were anesthetized with intraperitoneal pentobarbital sodium. A midline incision was made and the renal pedicles were bluntly dissected and occluded with nontraumatic vascular clips for 45 min. Then, clamps were removed gently and the kidneys were observed for a further 5 min to ensure reflow process. Then, the incision was closed in two layers with a 4-0 silk suture. The animals were then returned to their cages and allowed to recover. During the period of renal ischemia, the animals were covered with plastic wrap to prevent evaporation. In addition, animals were kept well hydrated with warm sterile saline and were maintained at a constant body temperature (~37 °C) on a heating pad. Sham-operated rats underwent surgical procedure identical to those of IR rats except that clamps were not applied. In renal IR + malvidin group, oral malvidin (Sigma) administrated 100 mg/kg intraperitoneal in 2 ml/kg saline for 21 days before IR. At the end of the reperfusion period (24 hr), the animals were anesthetized. Blood and 24-h urine samples were collected using metabolic cages for evaluation of renal functional indices: fractional excretion of sodium, plasma BUN, creatinine, urine flow rate and creatinine clearance [29]. Creatinine clearance helps to estimate the glomerular filtration rate (GFR). Kidney tissues removed for oxidative stress indices measurement. For this, we evaluated catalase (CAT), malondialdehyde (MDA) and superoxide dismutase (SOD). In order to measure sodium concentration of the plasma and urine, flame photometer apparatus was used. Plasma and urine creatinine, plasma BUN were measured by autoanalyzer. CAT activity was

determined by Aebi's method. According to this method, activity of CAT can be measured by decomposition of H2O2. The remaining substrate concentration at a given moment of the reaction can be determined by UV spectrophotometry at 240 nm [30]. Malondialdehyde (MDA) level was evaluated in renal tissue according to the Esterbauer and Cheeseman method (spectrophotometry at 532 nm).

[31]. SOD activity was determined by the method of Paoletti and Mocali In this method superoxide anions are generated from oxygen molecules in the presence of EDTAMnCl2 and mercapto-ethanol. NAD(P)H oxidation is linked to the availability of superoxide anions in the medium. As soon as SOD is added to the assay mixture, it inhibits nucleotide oxidation. Therefore, at high concentration of the enzyme the absorbance at 340 nm remains unchanged [32].

Statistical analysis

The statistical analysis between different groups was performed using ANOVA followed by Tukey's post-hoc test. Results with a $p < 0.05$ were considered as significant. The data are expressed as means ± S.E.M. All the analyses were conducted using Graphpad Prism 6 (GraphPad Software, Inc, La Jolla, Ca,, USA).

Results

45 minutes renal ischemia followed by 24 hours reperfusion induced renal functional damage. Briefly, renal IR significantly increased fractional excretion of sodium, plasma BUN and creatinine levels and decreased urine flow rate and creatinine clearance in the IR group compared with sham (Table 1).

Renal oxidant - antioxidant indices showed an oxidative stress in renal tissues. In IR group, renal MDA increased and CAT and SOD decreased significantly compared with sham group (Figures 1-3).

Oral Malvidin administration partly improved renal functiona injury. Malvidin decreased plasma BUN and creatinine, fractional excretion of Na. in addition; creatinine clearance and urine flow rate were increased in malvidin group contrast to IR group (Table 1). Moreover malvidin protected renal tissues from oxidative stress damage. In this group, significant increase in SOD and GSH activity and decrease in MDA compared to IR group were observed (Figures 1-3).

Discussion

Renal ischemia reperfusion injury is one of the most common causes of AKI and occurs in some clinical situations.

In the present study, 45 min bilateral renal ischemia followed by 24 hr reperfusion resulted in increased fractional excretion of sodium, plasma BUN and creatinine levels and decreased urine flow rate and creatinine clearance in IR group demonstrated acute renal failure. Regarding the decrease in the renal tissue CAT and SOD levels and increase in MDA in IR group compared with sham group, it can be stated that renal oxidative stress was inducted. Tavafi et al. have shown renal IR caused functional damage and oxidative stress induction in kidney. They have evaluated urea, creatinine and serum malondialdehyd [33]. Moreover, our previous studies have shown that renal IR resulted in renal functional damage and induced oxidative stress in kidney [34].

Oral malvidin administration improved functional and oxidative stress indices. Briefly, malvidin diminished the renal IR-induced increase in plasma BUN, creatinine, fractional excretion of sodium, creatinine clearance and urine flow rate in IR + malvidin group. In addition, CAT and SOD significantly elevated and MDA significantly decreased in this group compared with renal IR group. These tissues protective effects of malvidin may due to its antioxidant properties and scavengering of reactive oxygen species. Then, protection of renal tissue resulted in improvement of renal functional indices.

Anthocyanins, such as malvidin, belong to the flavonoids polyphenols and they are water soluble natural

pigments with red, purple and blue color from fruits, vegetables and flowers [35, 36].

Anthocyanins belong to a large group of secondary plant metabolites and occur in all forms

of plant tissue. Anthocyanin pigments consist of either two or three chemical units, these

being aglycon bases or fl avylium rings (anthocyanidin), sugars or (potentially) acylating

groups. In fact, anthocyanins and other phenols have been the focus of ever greater attention

in health and medicine due to their anti-carcinogenic, anti -allergic, anti -ulceric, anti -arthritic,

-infl ammatory, and anti-oxidant properties [37].

A colored fruit-rich diet and moderate red wine consumption protect the heart against ischemia reperfusion injury, because of the several flavonoids polyphenols such as malvidin [38].

Bognar et al. demonstrated malvidin attenuated lipopolysaccharide-induced nuclear factor-kappaB, mitogenactivated protein kinase activation and reactive oxygen species production. They concluded that malvidin, the most abundant polyphenol in red wine, has beneficial effects on inflammation-mediated chronic disease such as diabetes and cardiovascular disease [18]. Huang et al in 2016 have shown blueberry malvidin significantly attenuated oxidative stress in human umbilical vein endothelial cells. They assayed xanthine oxidase-1 and superoxide dismutase as antioxidant indices [19].

Baba et al. in 2017 indicated blueberry and malvidin are potent STAT-3 inhibitors that prevent proliferation and induce apoptosis of oral cancer cells in vitro and in vivo. Blueberry and malvidin suppressed STAT-3 phosphorylation, blocked nuclear translocation of the active dimer and prevented transactivation of STAT3 target genes that play crucial roles in cell proliferation and apoptosis [39].

Tomankova et al. in 2016 demonstrated malvidin, as major wine dye, has higher antioxidant activity than Vitisin A and it was related to higher ability of malvidin to scavenge of free radicals [37].

Conclusion:

Generally, our data showed that bioactive anthocyanin malvidin in red wine, some fruits and vegetable can improve the treatment of AKI by attenuating the oxidative stress.

Table 1.Biochemical parameters of rats in sham, IR and IR + Malvidine groups.

	IR + Malvidine	IR	Sham
fractional excretion of Na, %	1.75 ± 0.08#	2.11 ± 0.1*	0.59 ± 0.03
Plasma BUN, mg/dl	94.71 ± 6.31#	121.42 ± 8.55*	23.28 ± 1.55
Plasma creatinine, mg/dl	2.9 ± 0.18#	3.6 ± 0.15*	0.28 ± 0.7
Urine flow rate, µl/min.bw	22.42 ± 1.17#	16 ± 0.75*	31.85 ± 1.07
Creatinine clearance, µl/min	3.62 ± 0.22#	2.52 ± 0.16*	7.9 ± 0.33

* Denotes $p < 0.001$ compared with sham and

# Denotes $p < 0.05$ compared with IR, n = 10.

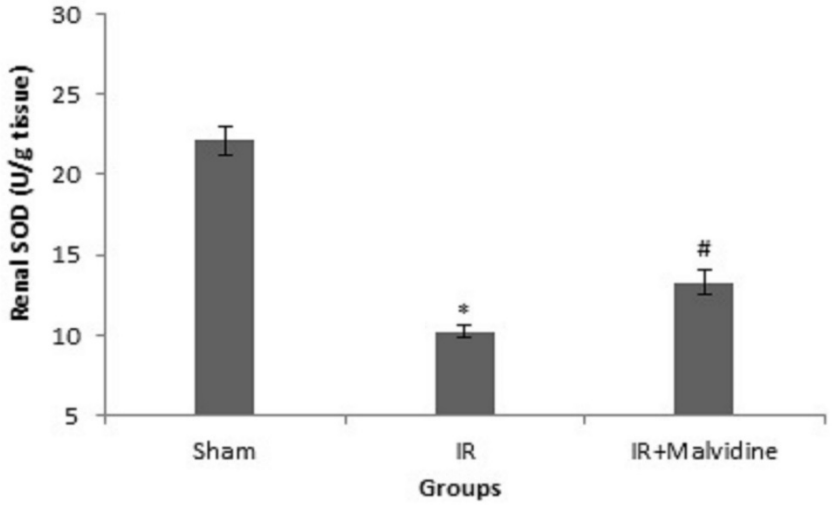

Figure 1. Renal SOD (Mean ± SEM): In IR group, renal SOD decreased significantly compared with sham group. In IR + malvidin group, significant increase in SOD compared to IR group was observed.

Note: *Denotes $p < 0.001$ versus sham group and # Denotes $p < 0.05$ versus IR group.

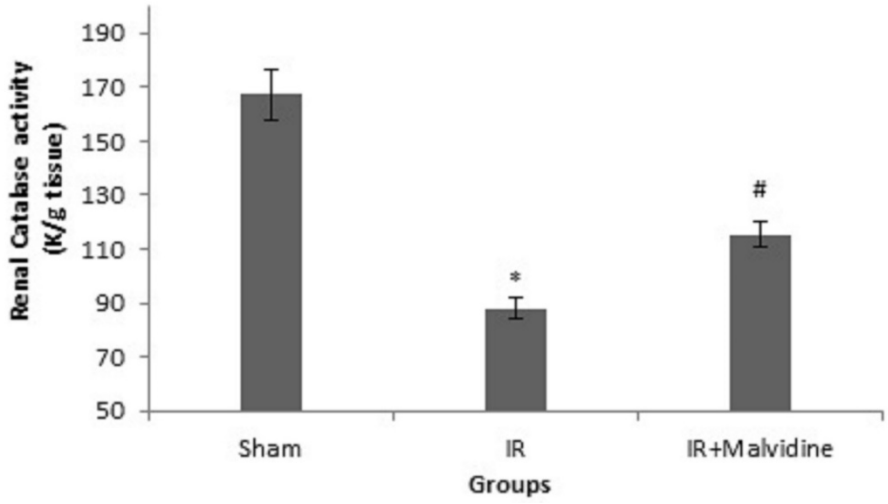

Figure 2. Renal CAT (Mean ± SEM): In IR group, renal CAT decreased significantly compared with sham group. In IR + malvidin group, significant increase in CAT compared to IR group was observed.

Note: *Denotes $p < 0.001$ versus sham group and # Denotes $p < 0.05$ versus IR group.

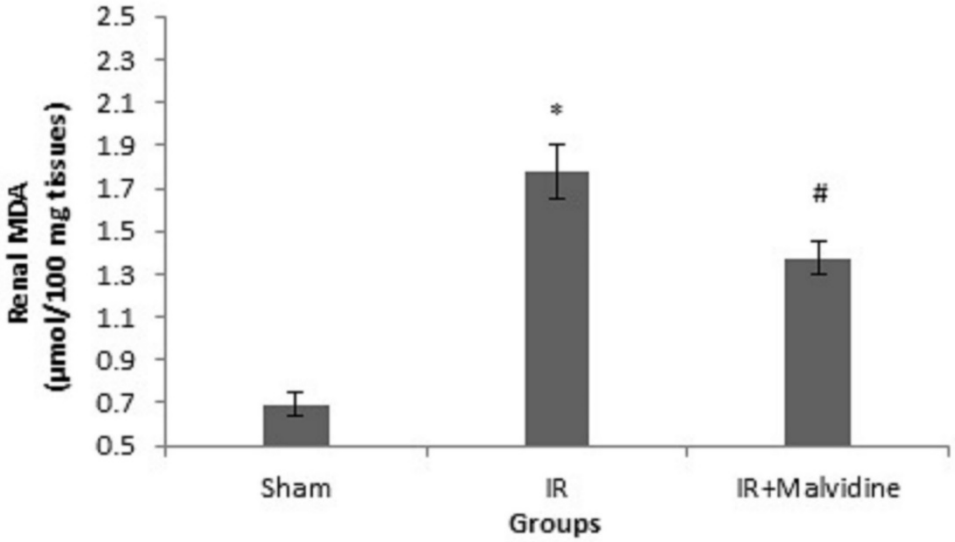

Figure 3. Renal MDA (mean ± SEM): In IR group, renal MDA increased significantly compared with sham group. In IR + malvidin group, significant decrease in MDA compared to IR group was observed.

Note: *Denotes $p < 0.001$ versus sham group and # Denotes $p < 0.05$ versus IR group.

REFERENCES

(1) Kadkhodaee, M., et al., Renal oxidative injury after leukocyte transfer from ischemia-reperfusion-induced kidney damage in Balb/c mice. Acta Physiologica Hungarica, 2013. 100(1): p. 99-106.

(2) Kadkhodaee, M., et al., Recipient kidney damage after leukocyte transfer from inbred mice with renal ischemia-reperfusion injury. Tehran University of Medical Sciences, 2012. 70(2).

(3) Khastar, H., Protective effects of vitamin E against liver damage caused by renal ischemia reperfusion. Renal failure, 2015. 37(3): p. 494-496.

(4) Bajes, H.R. and E.A. Al-Dujaili, Polyphenolic-rich Fruits and Supplements Enhance Exercise Performance; General Review. Jordan Journal of Pharmaceutical Sciences, 2017. 10(3).

(5) Ghosh, S., et al., Antioxidant Properties and Phytochemical Screening of Infusion and Decoction Obtained from Three Cultivated Pleurotus Species: A Comparative Study. Jordan Journal of Pharmaceutical Sciences, 2020. 13(2).

(6) Karmakar, U.K., S. Akter, and S. Sultana, Investigation of Antioxidant, Analgesic, Antimicrobial, and Anthelmintic Activity of the Aerial parts of Paederia foetida (Family: Rubiaceaea). Jordan Journal of Pharmaceutical Sciences, 2020. 13(2).

(7) Rashed, K., et al., Study of the Antioxidant and Anti-Inflammatory Potential of the Aerial Parts of Ficus nitida L.(Moraceae) and its Phytochemical Composition. Jordan Journal of Pharmaceutical Sciences, 2018. 11(2).

(8) Shariatifar, N., et al., Study on diuretic activity of saffron (stigma of Crocus sativus L.) Aqueous extract in rat. Journal of advanced pharmaceutical technology & research, 2014. 5(1): p. 17.

(9) Jafarisani, M., S.Z. Bathaie, and M.F. Mousavi, Saffron carotenoids (crocin and crocetin) binding to human serum albumin as investigated by different spectroscopic methods and molecular docking. Journal of Biomolecular Structure and Dynamics, 2017(just-accepted): p. 1-26.

(10) Khalili, S., et al., Structural analyses of the interactions between the thyme active ingredients and human serum albumin. Turkish Journal of Biochemistry, 2017. 42(4): p. 459-467.

(11) Lahazi, V., G. Taheri, and M. Jafarisani, Antioxidant enzymes activity of Ferula flabelliloba and Ferula diversivitata extracts / Ferula flabelliloba ve Ferula diversivitata ekstraktlarının antioksidan enzim aktiviteleri. Turkish Journal of Biochemistry, 2015. 40(4): p. 310-315.

(12) Jiang, Z., et al., Purple potato (Solanum tuberosum L.) anthocyanins attenuate alcohol-induced hepatic injury by enhancing antioxidant defense. Journal of natural medicines, 2016. 70(1): p. 45-53.

(13) Aqil, F., et al., Antioxidant and antiproliferative activities of anthocyanin/ellagitannin-enriched extracts from Syzygium cumini L.(Jamun, the Indian Blackberry). Nutrition and cancer, 2012. 64(3): p. 428-438.

(14) Zhao, Z., et al., Brassica napus possesses enhanced antioxidant capacity via heterologous expression of anthocyanin pathway gene transcription factors. Russian journal of plant physiology, 2013. 60(1): p. 108-115.

(15) Škėmienė, K., et al., Protecting the heart against ischemia/reperfusion-induced necrosis and apoptosis: the effect of anthocyanins. Medicina, 2013. 49(2): p. 84-88.

(16) Ullah, I., H.Y. Park, and M.O. Kim, Anthocyanins Protect against Kainic Acid□induced Excitotoxicity and Apoptosis via ROS□activated AMPK Pathway in Hippocampal Neurons. CNS neuroscience & therapeutics, 2014. 20(4): p. 327-338.

(17) Liu, Y., et al., Blueberry anthocyanins ameliorate radiation-induced lung injury through the protein kinase RNA-activated pathway. Chemico-biological interactions, 2015. 242: p. 363-371.

(18) Bognar, E., et al., Antioxidant and anti-inflammatory effects in RAW264. 7 macrophages of malvidin, a major red wine polyphenol. PLoS One, 2013. 8(6): p. e65355.

(19) Huang, W., et al., Effect of blueberry anthocyanins malvidin and glycosides on the antioxidant properties in endothelial cells. Oxidative medicine and cellular longevity, 2016. 2016.

(20) Lee, C., et al., Antioxidant and anti□hypertensive activity of anthocyanin□rich extracts from hulless pigmented barley cultivars. International Journal of Food Science & Technology, 2013. 48(5): p. 984-991.

(21) Huang, W.-Y., et al., Inhibitory effect of Malvidin on TNF-α-induced inflammatory response in endothelial cells. European journal of pharmacology, 2014. 723: p. 67-72.

(22) Jafarisani, M., et al., The siRNA-Mediated Down-Regulation of Vascular Endothelial Growth Factor Receptor1. Iranian Red Crescent medical journal, 2016. 18(4): p. e23418-e23418.

(23) Zarei Mahmudabadi, A., et al., Inhibition of AGS Cancer Cell Proliferation following siRNA-Mediated Downregulation of VEGFR2. Cell journal, 2016. 18(3): p. 381-388.

(24) Foroughi, K., et al., Survivin as a Target for Anti-cancer Phytochemicals According to the Molecular Docking Analysis. International Journal of Peptide Research and Therapeutics, 2019.

(25) Hosseini, E., et al., The importance of long non-coding RNAs in neuropsychiatric disorders. Molecular Aspects of Medicine, 2019.

(26) Salehi, M., et al., Vaspin Exert Anti-Inflammatory and Antioxidant Effects on Renal and Liver Injury Induced by Renal Ischemia Reperfusion. International Journal of Peptide Research and Therapeutics, 2019: p. 1-6.

(27) Lahazi, V., G. Taheri, and M. Jafarisani, Antioxidant enzymes activity of Ferula flabelliloba and Ferula diversivitata extracts/Ferula flabelliloba ve Ferula diversivitata ekstraktlarının antioksidan enzim aktiviteleri. Turkish Journal of Biochemistry, 2015. 40(4): p. 310-315.

(28) Khastar, H., et al., Liver oxidative stress after renal ischemia-reperfusion injury is leukocyte dependent in inbred mice. Iranian journal of basic medical sciences, 2011. 14(6): p. 534.

(29) Chashmi, N.A., S. Emadi, and H. Khastar, Protective

effects of hydroxytyrosol on gentamicin induced nephrotoxicity in mice. Biochemical and Biophysical Research Communications, 2017. 482(4): p. 1427-1429.

(30) Aebi, H., [13] Catalase in vitro. Methods in enzymology, 1984. 105: p. 121-126.

(31) Esterbauer, H. and K.H. Cheeseman, [42] Determination of aldehydic lipid peroxidation products: malonaldehyde and 4-hydroxynonenal. Methods in enzymology, 1990. 186: p. 407-421.

(32) Paoletti, F. and A. Mocali, [18] Determination of superoxide dismutase activity by purely chemical system based on NAD (P) H oOxidation. Methods in enzymology, 1990. 186: p. 209-220.

(33) Tavafi, M., et al., Antioxidant effect of rosmarinic acid against renal ischemia reperfusion injury in rat; a histopathological study. Annals of Research in Antioxidants, 2016. 1(2).

(34) Khastar, H., et al., Leukocyte involvement in renal reperfusion-induced liver damage. Renal failure, 2011. 33(1): p. 79-83.

(35) Putta, S., et al., Anthocyanins: Possible role as Multitarget therapeutic agents for prevention and therapy of chronic diseases. Current pharmaceutical design, 2017.

(36) Isaak, C., O. Karmin, and Y.L. Siow, Lingonberry (Vaccinium vitis-idaea) anthocyanins protect cardiomyoblasts against ischemia-reperfusion injury (973.1). The FASEB Journal, 2014. 28(1 Supplement): p. 973.1.

(37) Tománková, E., et al., Colour and antioxidant properties of malvidin-3-glucoside and Vitisin A. Acta Alimentaria, 2016. 45(1): p. 85-92.

(38) Quintieri, A.M., et al., Malvidin, a red wine polyphenol, modulates mammalian myocardial and coronary performance and protects the heart against ischemia/reperfusion injury. The Journal of nutritional biochemistry, 2013. 24(7): p. 1221-1231.

(39) Baba, A.B., et al., Blueberry and malvidin inhibit cell cycle progression and induce mitochondrial-mediated apoptosis by abrogating the JAK/STAT-3 signalling pathway. Food and chemical toxicology, 2017. 109: p. 534-543.

المالفيدين (Malvidine) يمنع الكلى من التلف التأكسدي الناجم عن نقص التروية الكلوي في الفئران

سارفيناز عميدي[1]،ايمان صديقي[2]،حسين خستار[3]

[1]كلية الصيدلة،جامعة البرز للعلوم الصيدلانية،ايران

CEINGE[2]،ايطاليا

[3]كلية الصيدلة ،جامعة شهرود للعلوم الصيدلانية،ايران

المقدمه: الإجهاد التأكسدي هو أحد أسباب الضرر الناجم عن نقص التروية الكلوي. Malvidin هو أنثوسيانين مهم وله خصائص قوية مضادة للأكسدة. كان الهدف من هذه الدراسة هو تقييم تأثير مالفيدين على حالة مضادات الأكسدة في الجسم الحي.

المواد والأساليب: تم تقسيم ثلاثين من جرذان الصحراء ويستار بشكل عشوائي إلى ثلاث مجموعات. 1- مجموعة الشام 2- مجموعة نضح نقص تروية الكلى (45) (IR دقيقة من نقص التروية ثم 24 ساعة من إعادة ضخ الدم) و3- مجموعة IR الكلوية + مالفيدين (100 مجم/ كجم عن طريق الفم لمدة 21 يومًا). في مجموعة الأشعة تحت الحمراء، تم تخدير الفئران وسد الشرايين الكلوية لمدة 45 دقيقة ثم تم تأسيس تدفق الدم لمدة 24 ساعة. في المجموعة الزائفة، كانت جميع العمليات الجراحية هي نفسها كما في مجموعة الأشعة تحت الحمراء، باستثناء أن الشرايين الكلوية لم تسد. مؤشرات وظائف الكلى (جزء إفراز الصوديوم، نتروجين يوريا الدم (BUN)، الكرياتينين (Cr)، معدل تدفق البول والتصفية الكلوية) ومؤشرات الإجهاد التأكسدي مثل الكاتالاز (CAT)، ديسموتاز الفائق الأكسيد (SOD) والمالديالديهيد (MDA) تم تقييمه في أنسجة الدم والكلى.

النتائج: انخفض Malvidine من إفراز BUN للصوديوم والبلازما والكرياتينين وزيادة تدفق البول، وتصفية الكرياتينين في مجموعة malvidin مقارنة بمجموعة IR. كما زاد Malvidine من CAT و SOD وخفض MDA مقارنة بمجموعة الأشعة تحت الحمراء.

خاتمة: لدى Malvidine تأثيرات وقائية ضد الإصابة الكلوية الحادة بسبب IR IR، والذي يرجع جزئيًا إلى تثبيط الإجهاد التأكسدي في الأنسجة الكلوية.

الكلمات الدالة: إعادة ضخ الإقفار الكلوي، إصابة الكلى الحادة، مالفيدين، أنثوسيانين، إجهاد أكسدي.

تاريخ استلام البحث 2019/7/23 وتاريخ قبوله للنشر 2019/11/26.