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Role of Tomato Extract in Protection against Damage Caused by Mesenteric Ischemia/ Reperfusion Induced in γ-Irradiated Rats

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THE OBJECTIVE is, the protective effects of turmeric (Tur) as well as tomato extract (TE) against whole γ-irradiation injury of rats subjected to mesenteric ischemia/reperfusion (I/R). Male Wistar rats were divided into shame and irradiated groups.

Normal group subjected to sham-operation. Vitamin E (VE) treated-group served as a positive control. Ileal tissue samples were obtained to investigate glutathione (GSH), thiobarbituric reactive substances (TBARS), nitrite contents as well as activity of lactate dehydrogenase (LDH). In addition, cytokines; tumour necrosis factor-alpha (TNF-α) and interleukin-6 (IL-6) were measured.

Intestinal I/R injury revealed a marked depletion in GSH, elevated TBARS and nitrite contents as well as low LDH activity. Moreover, there were remarkable increases in measured cytokines (TNF-α&IL-6). The ischemic insults were exacerbated by acute γ-irradiation in most of measured parameters except for GSH and LDH activity. In I/R treated-groups, TE could restore GSH contents and LDH (cell membrane integrity) as compared with VE with no lipid peroxidation protection. However, both supplements corrected levels of nitrite and TNF-α. Either Tur or TE could correct most of biochemical changes in irradiated rats. In general, both supplements recorded antioxidant and anti-inflammatory effects upon irradiation.

Keywords: Intestine, oxidative stress, radiotherapy, ischemia, cytokines, turmeric, tomato.

The practice use of radiotherapy was found to participate in different cardiovascular disorders. Previously, it has been suggested that radiation therapy could be a direct cause of many arterial diseases (Benoff and Schweitzer, 1995). Some studies have described post-irradiation changes of

smooth muscle cells and/ or endothelium of vessels; leading to destruction and hence ischemic effects (Hopewell *et al.*, 1986). Generation of free radicals during γ-irradiation is considered as the most important indirect mechanism of radiation injury (Dubner *et al.*, 1995). Reperfusion of the gut after an ischemic episode is accompanied with a progressive injury of mucosal structure and eventually leads to a complete loss of barrier integrity and consequently bacterial translocation (Stalliona *et al.*, 2005). Such case manifests an enhancement in production of reactive oxygen species (ROS), lipid mediators and a modification in nitric oxide levels (Eppihimer and Granger, 1997). Considerably, it has been accepted that the two methods of damage, I/R and γ-radiation up-regulate the expression of different inflammatory cytokines in intestine by activation of transcriptional factors such as nuclear factor-κB (Ichikawa *et al.*, 1997 and Linard *et al.*, 2003). Under most circumstances, the concept of pharmacologic therapy for intestinal ischemia is still tentative. Therefore, there is a great attention to function dietary supplements in balancing oxidation or even inducing cellular antioxidants. VE is available in different pharmaceutical products as a supplement and antioxidant. By regulating mitochondrial generation of superoxide and related ROS, it is not only attenuates oxidative damage but also modulates the expression and activation of related signal transduction pathways (Chow, 2003). Naturally, tomato products contain their strategic constituent lycopene in combination with other related phytochemicals, including phytoene and phytofluene (Ronen *et al.*, 1999). Lycopene as one of the most potent antioxidants; has been suggested to prevent carcinogenesis and atherogenesis by protecting critical bio molecules including proteins, lipids, low density lipoprotein and DNA (Agarwal and Rao, 1998 and Pool-Zobel *et al.*, 1997). Owing to its high number of conjugated double bonds, it exhibits high scavenging ability towards ROS (Yaping *et al.*, 2002).

This study was carried out to outline the potential use of antioxidants as adjuvant therapy; in order to overcome the morbidity resulted from ischemic risk factor which appears frequently with utilization of radiotherapy for malignant patients.

Material and Methods

Animals

Adult male Wistar rats (150-250 g) were kept under standard environments. The Study was carried out according to the guidelines of the ethical committee in Faculty of Pharmacy, Cairo University.

Drugs

VE (dl-α-tocopheryl acetate), Sigma-Alderch, USA. Tomato powder extract (containing 6% lycopene), the Arab Company for Gelatin and Pharmaceutical Products, Alexandria, Egypt.

Methods

Irradiation of animals

Irradiation was carried out at the NCRRT, Egypt. Rats were subjected to whole body (6 Gy) γ-rays using the Gamma Cell-40 biological irradiator (^{137}Caesium-source) at a dose rate of 0.72 Gy/ min.

Ileal ischemia/ reperfusion

Rats were anaesthetized and ischemia was induced by total occlusion of the superior mesenteric artery using a mini-clamp. After 30 min ischemia, reperfusion was initiated by removal of the clamp and maintained for another 30 min (Souza *et al.*, 2000).

Experimental design

Animals were randomly divided into 9 experimental groups each of eight rats. All groups, except the sham-operated were subjected to ileal I/R and four of them were exposed to γ-rays at a dose level of 6 Gy. The first group, which served as control, underwent laparatomy without I/R injury. The following two groups were served as untreated groups (I/R & irradiated I/R). The fourth group pre-treated with (100 mg/ kg/ day, per tubes), VE diluted with corn oil (Yilmaz and Yilmaz, 2006) (VE+ I/R group). The fifth group administered (67 mg/ kg/ day, per tubes), TE dissolved in corn oil (Liu *et al.*, 2003) (TE+ I/R group). The sixth group received an equivalent volume of corn oil vehicle served as control of the VE and TE-treated group (Vehicle+ I/R group). The groups (7, 8 & 9) were irradiated one h before induction of I/R protocol. They received the same treatment regimens as the three former groups (VE+ irradiated I/R, TE+ irradiated I/R and Vehicle+ irradiated I/R). All the treatments were received once daily for 14 consecutive days. Twenty-four h after the last dose administration, the rats were anaesthetized with urethane (1.2 mg/ kg, inter peritoneum (i.p.) and subjected to laparotomy.

Biochemical analysis

After 30 min of reperfusion, tissue sample from the mid portion of the ileum was excised. The tissues homogenates were used for estimation of GSH

content as described previously by (Beutler *et al.*, 1963), TBARS content according to the method of (Uchiyama and Mihara, 1978), cytosolic LDH activity (Buhl and Jackson, 1978) as well as the contents of nitrite (Green *et al.*, 1982) and pro-inflammatory cytokines (TNF-α & IL-6) by commercial kits.

Statistical analysis

All values were presented as means± S.E.M. One-way analysis of variance (ANOVA) followed by Tukey Kramer multiple comparison test was used to determine the difference between the groups in terms of all studied parameters using Graphpad Instat software (version 2). Results were considered statistically significant when $p< 0.05$.

Results

Effect of VE and tomato extract on ileal oxidative stress

Pre-treatment with VE did not buffer GSH depletion as compared to I/R group. In comparison, I/R-induced ileal GSH content reduction was markedly ameliorated by TE pre-administration (68.3 % protection), Table 1.

TABLE 1. Evaluation of oxidative stress in non irradiated rats.

Non-irradiated I/R	**Sham-operated**	**Vehicle**	**Vitamin E**	**Tomato extract**
GSH (mg/g wet tissue)	27.9± 1.2	17.6± 1.1[a]	20.3± 1.9[a]	24.8 ± 2.2[b]
TBARS (nmol/g wet tissue)	84.6± 1.7	106.4± 5.2[a]	88.6± 5.2[b]	107.30± 38[ac]
Nitrite (µmol/g wet tissue)	0.24± 0.03	0.81± 0.02[a]	0.35± 0.04[b]	0.3± 0.07[b]

[a]Significantly different from the sham-operated group. [(b,d)]significantly different from the vehicle received-groups. [(c, e)]significantly different from the VE treated-groups.

Upon irradiation, both supplements showed a significant protection against such depletion amounting 79.8 % and 113.3 %, Table 2. On other hand, oral administration of VE showed a protection (81.7 %) against I/R-induced lipid peroxidation. This was parallel to its protective effect (22 %) against I/R-induced cell membrane injury. In contrary, Pre-treatment with TE did not show marked correction in TBARS contents caused by I/R injury, Table 1. Even though, it showed around 3.1-fold increase in I/R-induced cytosolic LDH activity decrease as for VE-treated group, Fig. 1A). In comparison with VE, TE-treated group revealed about 3 times less protection against lipid

peroxidation and around 2-fold decrease in protection against enhanced LDH activity of irradiated I/R group, Table 2 & Fig. 1B).

TABLE 2. Evaluation of oxidative stress in 6Gy irradiated rats.

Irradiated I/R	**Sham-operated**	**Vehicle**	**Vitamin E**	**Tomato extract**
GSH (mg/g wet tissue)	27.9± 1.2	21.6± 1.2[a]	26.1± 1.1[d]	29.1± 1.2[d]
TBARS (nmol/g wet tissue)	84.6± 1.7	132.2± 5.2[a]	87.7± 4.4[d]	118.6± 3.5[ade]
Nitrite (µmol/g wet tissue)	0.24± 0.03	1.1± 0.08[a]	0.63± 0.04[ad]	0.60± 0.06[ad]

Legends as in Table 1.

Pre-administration of either VE or TE showed a protection against I/R-induced elevation in ileal nitrite content of non-irradiated rats recording 81 % and 60 %, respectively. For irradiated pattern, TE afforded a protection against elevated content of nitrite (amounting 88.4 %). However, VE showed just a 56.8 % protection against such elevation, Table 2.

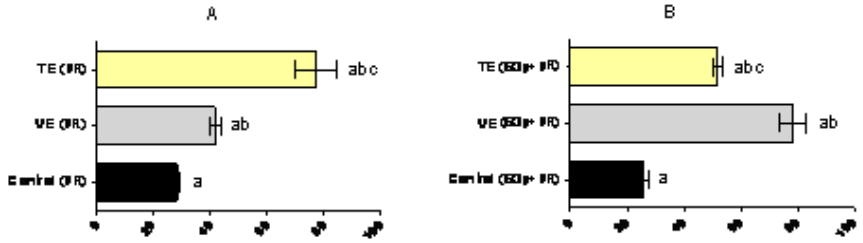

Fig. 1. Effect of VE (100 mg/kg) and tomato extract (67 mg/kg) administered orally for 14 successive days on cytosolic LDH activity (A) non-irradiated rats subjected to ileal I/R (30min/30min) or (B) irradiated rats (6 Gy) subjected afterward into I/R.

All expressed data are % of sham-operated group. Each column represents the mean of 8 experiments± SEM. [a]$p<0.05$ compared to normal group, [b]$p<0.05$ compared to I/R group, [c]$p<0.05$ compared to VE group. Tomato Extract (TE), Vitamin E (VE).

Effect of VE & TE on pro-inflammatory cytokines levels of ileal tissues

VE recorded 32.4 % and 35% protections against the increase in ileal contents of TNF-α and IL-6, respectively. On comparison with VE-treated group, TE afforded 1.5 more protection against I/R-induced elevation of TNF-α without any effect against IL-6 increase (Fig. 2 & 3A). Oral administration of either VE or TE could correct the increased TNF-α contents of irradiated

animals amounting 19.3 and 41.6%, respectively. However, both supplements did not provide any protection against the hazardous elevated ileal IL-6 contents (Fig. 2 & 3B).

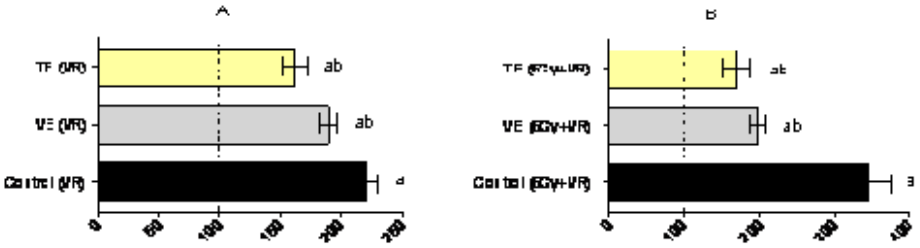

Fig. 2. Effect of VE (100 mg/kg) and tomato extract (67 mg/kg) administered orally for 14 successive days on ileal TNF-α contents (A) non-irradiated rats subjected to ileal I/R (30min/30min) or (B) irradiated rats (6 Gy) subjected afterward into I/R.

Legends as in Fig. 1.

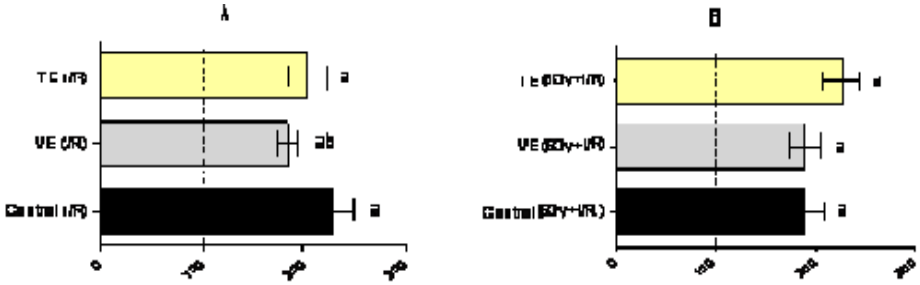

Fig. 3. Effect of VE (100 mg/kg) and tomato extract (67 mg/kg) administered orally for 14 successive days on ileal IL-6 contents (A) non-irradiated rats subjected to ileal I/R (30min/30min) or (B) irradiated rats (6 Gy) subjected afterward into I/R.

Legends as in Fig. 1.

Discussion

Under normal condition, the amount of ROS produced is under the control exerted by the antioxidant defence mechanisms. However, during oxidative stress such defence mechanisms may be overwhelmed and consequently damage may occur. The present results clearly demonstrated that I/R significantly increased the oxidative damage of intestine which worsens by γ-irradiation. Previously, it was found that reduced form of GSH (water soluble) may act as a first line of defence against oxidative stress during I/R while lipid soluble antioxidants may act later on during severe oxidative stress (Tracey *et*

al., 1999). There for VE (lipid soluble) showed no significant effect against ileal GSH content depletion of rats subjected to mild I/R (30 min/30 min). However, γ-radiation may contribute to exaggeration of the severity of oxidative stress caused by I/R. Pre-treatment with VE provided significant protection against lipid peroxidation induced by ileal I/R. This could be manifested by the observed decrease in ileal TBARS content and the increase in LDH activity as well. Also the present results showed a further protection against lipid peroxidation and restoration in cell membrane injury by VE in γ-irradiated animals. Such observations are in accordance with that reported by Yilmaz and Yilmaz (2006) on rat model. Furthermore, oral administration of VE protected against I/R-induced elevation of ileal nitrite content in either irradiated or non-irradiated animals. This effect of VE could be attributed to its antioxidant potential with a consequent protection against oxidative stress-induced iNOS activation (Guney *et al.,* 2007). In addition, VE decreased the extent of elevations in ileal cytokines (TNF-α and IL-6). Similar pattern of protection has been previously reported following myocardial I/R (Xu *et al.,* 2005). This could be explained on the basis that VE may inhibit the capacity of ROS to activate redox-sensitive signalling pathways that induce the expression of cytokine genes (Pathania *et al.,* 1999).

Pre-treatment with TE showed a remarkable protection against I/R-induced ileal GSH depletion. Similar finding has been observed in myocardial I/R model (Bansal *et al.,* 2006). This effect could be a result of the antioxidant activity of lycopene, TE component, to modulate different phase II enzymes like glutathione-S-transferase, reductase and peroxidase in different experimental models (Breinholt *et al.,* 2000). Moreover, a further increase of the GSH content attributed to daily oral administration of TE was observed in irradiated rats. This was parallel with the observation of (Saada *et al.,* 2010) on lycopene effect on small intestine of irradiated (6 Gy) rats. On other hand, no significant protection against elevation of ileal TBARS content was demonstrated with TE in I/R model. Such result might not exclude the protective effect of TE as partly manifested by the present protection against ischemic-induced decrease in LDH activity in either irradiated or non-irradiated rats. In irradiated group, lycopene reduced the rise of TBARS. Administration of TE showed a significant reduction of ileal nitrite content of either rats subjected to I/R alone or with γ-

radiation. Similar results were previously reported by Hsiao *et al.* (2004) on cerebral ischemic rats. Another effect of lycopene that could also contribute to such reduction in NO is the reduction in TNF-α production, as observed in the present study. Similar findings were previously observed by other investigators (Herzog *et al.,* 2005 and Li *et al.,* 2007). These results of TE may be attributed mainly to the antioxidant-sparing action of lycopene. It considered as the most

potent singlet oxygen quencher because of its high number of conjugated dienes (Yaping *et al.,* 2002). During such process, energy is transferred from the singlet oxygen to the lycopene molecule, which is converted into energy rich triplet state that scavenges other ROS and RNS (Atessahin *et al.,* 2006).

In conclusion, immediate γ-irradiation showed a disturbance in the measured biochemical parameters. The same dose administration of different dietary supplements revealed more protection against such hazards in irradiated models than non-irradiated ones. These findings give an attention toward further studies on cellular effects of immediate acute γ-radiation after herbal medicine administrations.

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دور الكركم و مستخلص الطماطم في الوقاية من التلف الناتج عن فقر الدم المعوي والمحدث في جرذان مشعة بأشعة جاما

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قسم البحوث الدوائية الأشعاعيه ، المركز القومي لبحوث وتكنولوجيا الإشعاع و*كلية الصيدلة ، جامعة القاهرة و **قسم الطبيعة التجريبية ، مركز البحوث النووية و**مشروع السيكلوترون ، قسم الطبيعة التجريبية ، مركز البحوث النووية مصر.

اشتملت الدراسة تأثير إصابة الأمعاء الناتجة عن فقر دم موضعي ، وما يتبعه من إعادة التروية الدموية للأمعاء؛ في ذكور الجرذان البيضاء غير المشعة. كما تم دراسة تأثير إصابة الأمعاء الناتجة عن فقر الدم ومايتبعه من إعادة التروية الدموية فى الجرذان المشعة (باستخدام جرعة واحدة مقدارها ٦ جراى). اشتملت الرسالة المقدمة أيضا على دراسة تأثير تناول بعض مضادات الأكسدة (مستخلص الطماطم بالإضافة إلى فيتامين ه) في محاولة لتحسين أو تقليل التلف الاوكسيدي المصاحب لفقر الدم المعوي وما يتبعه من إعادة التروية الدموية سواء بالنسبة لذكور الجرذان المعرضة لجرعة من الإشعاع الجامى أو الأخرى غير المعرضة.

و قد أظهرت النتائج أن إحداث فقر الدم المعوي أدى إلى التلف الاوكسيدي والذي ظهر من خلال إصابة أنسجة الأمعاء نتيجة زيادة الشدة التأكسدية بها ، و قد وضح ذلك من خلال زيادة مستوى مادة الثيوباربتيوريك النشيطة مع انخفاض مستوى الجلوتاثيون المختزل بالإضافة إلى زيادة محتوى الأنسجة من ثاني أكسيد النيتروجين، علاوة على ذلك أوضحت الدراسة وجود انخفاض في نشاط إنزيم اللاكتات دهيدروجنيز الخلوي بالأمعاء. كما أدى إلى حدوث رد فعل التهابي و الذي ظهر واضحاً من خلال إرتفاع مستوى كل من عامل الورم النخري- ألفا والإنترلوكين-٦ داخل خلايا الأمعاء. كما أظهرت نتائج الدراسة أن التعرض لأشعة جاما قد نتج عنه زيادة ملحوظة في الإصابات الناتجة عن فقر الدم المعوي. وقد أدى استعمال مستخلص الطماطم أو فيتامين ه إلى التقليل من الإصابة نتيجة زيادة الشدة التأكسدية في أنسجة الأمعاء. كما نتج عن استعمالهما تثبيط رد الفعل الالتهابي الناتج عن فقر الدم المعوي و ما يتبعه من إعادة التروية الدموية في الجرذان المشعة و غير المشعة. و أخيراً، هذه الدراسة تدعم استخدام مضادات الأكسدة في محاولة لتحسين أو تقليل الأضرار التي تنتج عن التعرض للإشعاع و خاصةً هؤلاء المعرضين للإصابة بفقر دم معوي قد يكون ناتجا عن إمراض عدة تتعلق باختلال في الدورة الدموية.