

**PHARMACODYNAMIC INTERACTION OF GARLIC WITH CAPTOPRIL IN ISCHEMIA-REPERFUSION INDUCED MYOCARDIAL DAMAGE IN RATS**

**Syed Mohammed Basheeruddin Asdaq<sup>1\*</sup> and  
Mohammed Naseeruddin Inamdar<sup>2</sup>**

<sup>\*1</sup>Department of Pharmacology, Krupanidhi College of Pharmacy,  
# 5, Sarjapur Road, Koramangala, Bangalore-560 034, INDIA;  
E-mail: [basheer\\_1@rediffmail.com](mailto:basheer_1@rediffmail.com)/[sasdaq@gmail.com](mailto:sasdaq@gmail.com)  
Phone: +91-80-25535751; Fax: +91-80-51309161

<sup>2</sup>Department of Pharmacology, Al-Ameen College of Pharmacy,  
Bangalore-560 027

**Summary**

It is known that various preparations of garlic and ACE inhibitor such as captopril (CAP) have beneficial effects on the left ventricular function and cardiovascular events after myocardial infarction (MI) when used individually. There is no reported interaction between garlic homogenate (GH) and CAP during and after acute MI. Thus the purpose of the present study was to explore the interaction of GH with CAP on ischemia-reperfusion injury (IRI) in isolated rat heart preparation. Albino rats were treated with GH at three different doses of 125 mg/kg, (GH-125), 250 mg/kg (GH-250) and 500 mg/kg (GH-500) for 30 days orally. The hearts were excised and mounted on modified Langendorff setup and subjected to 15 min global no flow ischemia. Perfusates were collected both during pre and post-ischemic period. At the end of reperfusion, ischemic heart was either made into heart tissue homogenate (HTH) or histological slides were prepared using hematoxylin and eosin stains. Pretreatment of animals with CAP and GH-250 (either alone or in combination) provided significant protection to myocardium from IRI damage as indicated by significant decrease in LDH and CK-MB activities in perfusate and vice versa in HTH. Similarly, the recovery (%) in developed tension and heart rate were significantly more in treated groups during post-ischemia when compared to control. Moreover, GH-250 in presence or absence of CAP showed significant increase in activities of antioxidant enzymes such as superoxide dismutase and catalase in HTH. However, GH-500 failed to show cardioprotective effect when given alone or along with CAP. These biochemical findings were supported by changes in histopathological studies.

**Key words:** Garlic; interaction; ischemia-reperfusion; isolated heart; captopril.

### **Introduction**

Simultaneous administration of herbs and drugs may mimic, magnify or oppose the pharmacological effects of each other (1). It is widely believed that although herbs hold promise as therapeutically effective medicaments, in-depth and appropriate studies should be carried out to confirm their efficacy in the presence of modern medicines.

Epidemiologic studies show an inverse correlation between garlic consumption and progression of cardiovascular diseases (2). Garlic and its preparations have been widely recognized as agents for prevention and treatment of cardiovascular and other metabolic diseases such as atherosclerosis, arrhythmia, hyperlipidemia, thrombosis, hypertension and diabetes (3). Garlic is also reported to possess cardioprotective (4), antioxidant (5), antineoplastic and antimicrobial properties (6). Further, garlic has significant antiarrhythmic effect in both ventricular and supraventricular arrhythmias (7). It is reported that garlic in moderate doses for long period augments the endogenous antioxidants activities and depletes the oxidative damaging effects by either increasing the synthesis of endogenous antioxidants or decreasing the generation of oxidants like oxygen free radicals (8). Furthermore, it also exerts anti-oxidant effect in isoprenaline-induced myocardial infarction in rat (9). Garlic juice inhibits norepinephrine-induced contractions of rabbit and guinea pig aortic rings. It is also reported to inhibit the force of contraction of isolated rabbit heart in a concentration-dependent manner (10).

It is well known that captopril (CAP) can ameliorate the deleterious effects of elevated renin and angiotensin II levels in patients with acute myocardial infarction. The results of several important clinical trials have shown that ACE inhibitors significantly reduce cardiovascular morbidity and mortality by attenuation of the left ventricular enlargement and heart failure, and also by reductions in the occurrence of acute coronary artery disease-related events (11).

Earlier reports on the drug interaction studies of garlic with calcium channel blockers indicate that it produces concentration dependent synergistic effect due to its own calcium channel blocking effect (12). Moreover, it was demonstrated in our recent study that garlic mimics beta blocking property at moderate doses and together they show synergistic activity (13). However, no scientific observations are available regarding the interaction of garlic with CAP during conventional cardioprotective therapy. Hence, the present investigation was undertaken to demonstrate the protective effect of different doses of garlic and to determine its interaction with CAP, during IRI damage to myocardium using isolated perfused rat heart preparation.

## **Methods**

### *Chemicals*

All chemicals used were of analytical grade and purchased from standard companies. Biochemical kits like LDH and CK-MB were procured from Crest Biosystems (Goa, India).

### *Preparation of Plant extract*

Garlic (*Allium sativum*) bulbs were purchased from the local market. The cloves were peeled, sliced, ground into a paste and suspended in distilled water. Three different doses of the garlic homogenate corresponding to 125 mg/kg, 250 mg/kg and 500 mg/kg were used (8). The garlic homogenate (GH) was administered within 30 min of preparation.

### *Experimental animals*

Laboratory bred female Wistar albino rats weighing between 200-250 g were housed at  $25^{\circ} \pm 5^{\circ}\text{C}$  in a well-ventilated animal house under 12:12 hour light and dark cycle. The rats had free access to standard rat chow (Amrut Laboratory Animal feed, Maharashtra, India) containing protein 22.10%, oil 4.13%, fibre 3.15%, ash 5.15%, sand (silica) 1.12% w/w) and water *ad libitum*. There was no significant difference in the body weight of the treated rats when compared with control, either at the beginning or at the end of the study period. Institutional Animal Ethics Committee approved the experimental protocol; animals were maintained under standard conditions in an animal house approved by Committee for the Purpose of Control and Supervision on Experiments on Animals (CPCSEA).

### *Experimental Protocol*

The animals were divided into different treatment groups. The first group served as control and the animals of group II received captopril orally at a dose of 30 mg/kg (14). The animals of III, IV and V were treated orally for 30 days with three different dose of GH at 125 mg/kg, 250 mg/kg and 500 mg/kg respectively. The animals of group VI, VII and VIII received three different doses of GH for 30 days at 125 mg/kg, 250 mg/kg and 500 mg/kg respectively along with CAP (30 mg/kg) during the last seven days of GH treatment.

### *Experimental Procedure*

A modified Langendorff apparatus for the isolated perfused heart was set up as mentioned elsewhere (15). The heart was isolated from each animal 2 hrs after the last dose of the drug(s) under ketamine (70 mg/kg, i.p) and xylazine (10 mg/kg, i.p) anesthesia. The isolated heart was perfused with Krebs-Henseleit (K-H) solution

gassed with carbogen (95% O<sub>2</sub> and 5% CO<sub>2</sub>) at 37 °C at a constant flow rate of 5 ml/min. The composition of K-H solution was (mM) NaCl 118, KCl 4.7, NaHCO<sub>3</sub> 25, NaHPO<sub>4</sub> 1.0, MgSO<sub>4</sub>.7H<sub>2</sub>O 0.57, CaCl<sub>2</sub> 2.5 and glucose 11). The pH of K-H solution was adjusted to 7.4 to avoid K-H buffer acidosis that may occur after prolonged gassing with carbogen. The heart was allowed to equilibrate for 10 min and then regular recordings were taken for a perfusion period of 15 min. Measurement of contractile force was done using force displacement transducer and recorded on a Student Physiograph (INCO, Mumbai, India). After the initial preischemic perfusion, heart was subjected to 15 min of global no-flow ischemia (16) by blocking the flow of K-H solution & carbogen supply followed by 15 min of reperfusion. The heart rate and developed tension were measured during pre-ischemic and post-ischemic period and recovery (%) was calculated. Lactate dehydrogenase (LDH) and creatine kinase-MB (CK-MB) activity were measured in the perfusate during pre-ischemic and post-ischemic period. The heart was then homogenized to prepare heart tissue homogenate (HTH) using sucrose (0.25 M) (17) and the activity of LDH, CK-MB, superoxide dismutase (SOD) (18) and catalase (19) was determined. Microscopic slides of myocardium were prepared for histopathological studies after post-ischemia (20). Volume fraction of interstitial space (VFITS) in myocardial tissue was determined from hematoxylin and eosin (H &E) stained transverse sections by using the equation (21).

$$\text{VFITS} = \frac{(100\% \times \text{Area of interstitial space})}{\text{Total tissue area.}}$$

The myocardial damage was determined by giving scores depending on the intensity as follows (20); no changes – score 00; mild – score 01 (focal myocytes damage or small multifocal degeneration with slight degree of inflammatory process); moderate – score 02 (extensive myofibrillar degeneration and/or diffuse inflammatory process); marked – score 03 (necrosis with diffuse inflammatory process).

#### *Statistical analysis*

Results are expressed as mean ± SEM. Statistical significance was assessed using One-way Analysis of variance (ANOVA) followed by Tukey multiple comparison tests. p<0.05 was considered significant.

### **Results**

#### *Effect on LDH & CK-MB activities:*

The biological activities of endogenous enzymes like LDH and CK-MB were evaluated in coronary effluent (perfusate) during pre and post-ischemic periods as

well as in heart tissue homogenate (HTH). There was significant ( $p < 0.001$ ) rise in enzyme activities in heart perfusate of animals pretreated with GH-500 and depletion in enzyme activities were observed after treatment with GH-125 and GH-250 alone or in combination with CAP when compared to IRI control. During post-ischemia, there was significant ( $p < 0.001$ ) decline in enzyme activities in the perfusate of GH pretreated groups and GH with CAP treated groups when compared to control (Table 1). Further, high dose of GH-500 was found to significantly ( $p < 0.001$ ) reduce the activities of these enzymes in HTH when compared to control and addition of CAP in GH-500 therapy failed to protect the myocardium from ischemic damage. Furthermore, there was significant elevation ( $p < 0.001$ ) in activities of enzymes in HTH of animals pretreated with GH 250 and GH-250 + CAP when compared to control (Table 2). Moreover, it was also noted that the pretreatment of animals with CAP significantly ( $p < 0.001$ ) imparted protection to myocardium by declining the endogenous enzyme activities in perfusate both during pre and post-ischemia and vice versa in HTH (Table 1 & 2).

#### *Effect on SOD and catalase activity*

The SOD and catalase activity in the HTH were significantly ( $p < 0.001$ ) increased after treatment with GH-250. However, incorporation of CAP during regimen with either GH-125 or GH-500 did not produce any significant increase in activities of these enzymes in HTH (Table 2).

#### *Developed Tension and Heart rate*

Pretreatment of CAP significantly ( $p < 0.001$ ) imparts recovery to ischemic heart in terms of developed tension and heart rate. There was also significant ( $p < 0.001$ ) recovery from global ischemia in groups treated with GH-250 either alone or with CAP ((Table 3). On the contrary, addition of CAP significantly provides protection to ischemic heart in GH-125 pretreated animals.

#### *VFITS and histological scores (Figure 1- Figure 3):*

IRI induced elevation in VFITS values and histological scores. They showed patchy areas of necrosis, hyalinization of muscle fibers with focal cellular infiltrations. The muscle fibers showed vacuolar changes with fragmentation suggestive of necrosis (Figure: 1). These damages were reversed significantly ( $p < 0.001$ ) in microscopic section of myocardial slides of GH-250 and GH-250+CAP groups (Figure: 2). As expected, GH-500 as well as GH-500+CAP did not show any improvement from myocardial damage occurring due to IRI (Table 3).

**Table-1**  
Effect on LDH and CK-MB activities in rat heart perfusate

Treatment	LDH Activity (U/L)		CK-MB (U/L)	
	Pre-ischemia	Post-ischemia	Pre-ischemia	Post-ischemia
IRI CONTROL	201.27±4.42	546.75±11.89	21.21±0.59	41.16±1.05
CAP	178.11±1.44 <sup>***</sup>	293.34±5.15 <sup>***</sup>	13.61±0.24 <sup>***</sup>	26.40±0.78 <sup>***</sup>
GH-125	192.99±2.15	485.66±5.68 <sup>*</sup>	19.10±0.61 <sup>*</sup>	34.81±0.35 <sup>*</sup>
GH-250	162.51±1.63 <sup>***</sup>	388.49 ± 3.32 <sup>***</sup>	13.85±0.42 <sup>***</sup>	26.58± 0.83 <sup>***</sup>
GH-500	406.81±9.55 <sup>***</sup>	576.70±9.57 <sup>*</sup>	29.06±0.55 <sup>***</sup>	46.48±0.80 <sup>***</sup>
GH-125 + CAP	173.52±1.27 <sup>***</sup>	280.75±7.86 <sup>***</sup>	14.64±0.20 <sup>***</sup>	31.40±0.52 <sup>***</sup>
GH-250 + CAP	152.46±1.35 <sup>***</sup>	235.33±5.13 <sup>***</sup>	12.48±0.18 <sup>***</sup>	21.64±0.25 <sup>***</sup>
GH-500 + CAP	243.56±3.41	482.16 ± 3.60	22.45±0.19	43.93 ± 0.65

Values are expressed as mean ± SEM for eight rats in each group.

<sup>\*\*\*</sup>Significantly different from IRI control  $P < 0.001$ .

Garlic Homogenate (GH)- 125 mg/kg, 250 mg/kg & 500 mg/kg  
(30 days treatment, *p.o.*)

Captopril (CAP)-30 mg/kg (7 days treatment, *p.o.*)

Table-2

Effect on LDH, CK-MB, SOD and Catalase activities in heart tissue homogenate of isolated rat heart preparation

Treatment	LDH (U/g wet tissue)	CK-MB (U/g wet tissue)	SOD (Units/mg protein)	Catalase (Units/mg protein)
IRI CONTROL	761.95±35.18	49.76±0.97	1.44±0.00	2.08±0.05
CAP	889.80±34.03 <sup>***</sup>	44.33±1.21 <sup>***</sup>	1.99±0.12 <sup>*</sup>	2.24±0.28 <sup>*</sup>
GH-125	739.46±26.13	51.82±0.44	2.72±0.04 <sup>***</sup>	3.32±0.10 <sup>***</sup>
GH-250	979.35±4.62 <sup>***</sup>	63.83±0.85 <sup>***</sup>	5.31±0.04 <sup>***</sup>	6.69±0.17 <sup>***</sup>
GH-500	431.30±14.19 <sup>***</sup>	46.55±1.11 <sup>*</sup>	1.95±0.00	2.35±0.06
GH-125 + CAP	855.67±9.61 <sup>*</sup>	46.99±3.54 <sup>*</sup>	2.11±0.05 <sup>*</sup>	2.77±0.22 <sup>*</sup>
GH-250 + CAP	1121.83±24.66 <sup>***</sup>	67.25±0.97 <sup>***</sup>	6.96±0.27 <sup>***</sup>	7.55±0.18 <sup>***</sup>
GH-500 + CAP	786.40±12.64	43.77±0.20	1.98±0.06	2.37±0.09

Values are expressed as mean ± SEM for eight rats in each group.

<sup>\*\*\*</sup>Significantly different from IRI group  $P < 0.001$ .

Garlic Homogenate (GH)- 125 mg/kg, 250 mg/kg & 500 mg/kg  
(30 days treatment, *p.o.*)

Captopril (CAP)-30 mg/kg (7 days treatment, *p.o.*)

**SOD Units:** One enzymatic unit of SOD is the amount in the form of proteins present in 100 µl of 10 % heart tissue required to inhibit the reduction of 24 mM NBT by 50%.

**Catalase Units:** One international unit of catalase is the amount, which catalyzes the decomposition of 1 mM hydrogen peroxide per minute at 37°C.

**Table-3**

Effect on percentage recovery of developed tension & heart rate, volume fraction of interstitial space (VFITS) and histological scores

Treatment	<u>Percentage Recovery</u>		VFITS <sup>1</sup>	Histological scores <sup>2</sup>
	Developed Tension	Heart Rate		
Vehicle	22.27±4.17	33.72±2.23	39.03±1.71	3.33±0.33
CAP	68.98±4.70 <sup>***</sup>	64.66±3.63 <sup>***</sup>	29.79±1.63 <sup>***</sup>	1.55±0.21 <sup>***</sup>
GH-125	51.06±8.87	57.29±2.16 <sup>***</sup>	28.09±0.69 <sup>***</sup>	2.52±0.42
GH-250	75.02±9.23 <sup>***</sup>	79.04±3.14 <sup>***</sup>	25.24±0.93 <sup>***</sup>	1.5±0.22 <sup>**</sup>
GH-500	13.68±6.22	32.04±1.71	35.49±0.54	3.66±0.33
GH-125 + CAP	46.44±5.94 <sup>**</sup>	56.46±1.37 <sup>**</sup>	28.39±0.60 <sup>***</sup>	2.63±0.30 <sup>*</sup>
GH-250 + CAP	91.44±1.25 <sup>***</sup>	90.42±1.32 <sup>***</sup>	22.44±1.30 <sup>***</sup>	1.10±0.16 <sup>***</sup>
GH-500 + CAP	23.72±4.78	36.89±1.92	33.49±0.50	3.25±0.51

Values are expressed as mean ± SEM for eight rats in each group.

<sup>\*\*\*</sup>Significantly different from IRI group  $P < 0.001$ .

Garlic Homogenate (GH)- 125 mg/kg, 250 mg/kg & 500 mg/kg  
(30 days treatment, *p.o.*)

Captopril (CAP)-30 mg/kg (7 days treatment, *p.o.*)



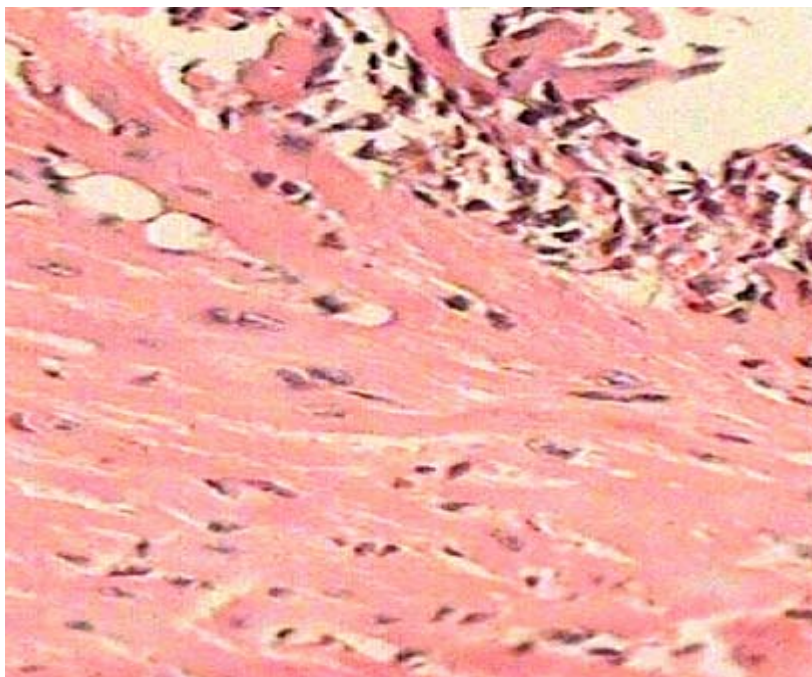


Figure:1 IRI control- Patchy areas of necrosis, hyalinization of muscle fibers with focal cellular infiltrations. Muscle fibers showed vacuolar changes with fragmentation suggestive of necrosis.

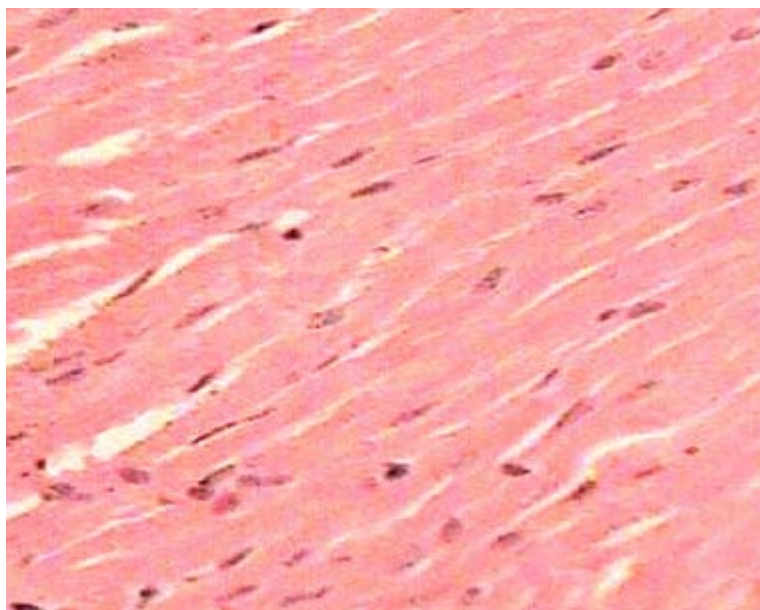


Figure:2 GH-250+CAP- Normal cellular structure with decreased interstitial space.

### Discussion

The research envisaged was carried out to determine the effect of different doses of GH and its interaction with CAP during IRI induced myocardial infarction (MI) in isolated rat heart preparation. The results show that high dose of GH (500 mg/kg) aggravates the IRI whereas moderate dose of GH (250 mg/kg) protect the myocardium against IRI damage. It was also demonstrated in the present study that the incorporation of CAP during IRI in presence of GH-250 produces synergistic cardioprotective effect.

GH was administered at three different doses, which were reported to be safe (125 mg/kg, 250 mg/kg & 500 mg/kg) (8). An earlier study on the effect of GH on cardiovascular system suggests that GH induced cardioprotection is due to its active organosulfur metabolites; S-allylcysteine (SAC) and S-allylmercaptocysteine (SAMC), which have potent antioxidant activity (22-24). Allicin (allyl 2-propenethiosulfinate) was earlier thought to be the principle bioactive compound responsible for the cardioprotective effect. However, recent studies suggest that allicin is an unstable and transient compound with oxidant activity (25) that is virtually undetectable in blood circulation after garlic ingestion and decomposes to form the SAC and SAMC (26). GH was administered orally instead of introducing it into the perfusion fluid to avail the activity of SAC and SAMC, which are effective metabolites of garlic formed only in circulation from allicin.

Myocardial damage was induced using ischemia-reperfusion injury (IRI) model. Ischemia is an acute or chronic form of cardiac disability arising due to the imbalance between the myocardial supply and demand for oxygenated blood. The IRI was induced following no-flow global ischemia (16), where sudden occlusion of physiological salt solution (PSS) results in immediate biochemical alterations (27). The increase in intracellular  $\text{Na}^+$  serves to drive  $\text{Ca}^{2+}$  intracellularly via  $\text{Na}^+/\text{Ca}^{2+}$  exchange that results in irreversible damage to myocardium at the end of 15 min global ischemia (28).

It is well established that the biological markers like endogenous enzyme are organ specific and leak from the damaged organ during necrosis (29). Damaged to the cardiac musculature due to IRI results in leakage of cardiac biomarkers such as LDH and CK-MB into the perfusate with resultant decrease in their activities in HTH (29-31). Prophylactic administration of GH-250 (30 days *p.o*) and CAP, a good cardioprotective agent (11), either alone or together restored the enzyme activity to normal in heart tissue homogenate (HTH) and perfusate to substantial extent.

The IRI damage to myocardium is also due to release of oxygen free radicals (OFRs), that causes destruction of myocardial membrane and leakage of bioenzymes in perfusate. Among number of OFRs associated with myocardial contractile and rhythmic disturbances (32), contribution of superoxide to myocardial damage is believed to be the highest and this radical is combated by elevated activities of endogenous antioxidant enzyme - the superoxide dismutase (SOD) (33). In addition to this, measurement of catalase activity was carried out as elevation in SOD dismutates superoxide but results in accumulation of H<sub>2</sub>O<sub>2</sub> which could further precipitate the MI (34). Pretreatment of animals with GH (250 mg/kg) alone or along with CAP produced remarkable elevation in SOD and catalase activities when compared to control indicating cardioprotective effect. However, pretreatment of animals with high GH (500 mg/kg) did not produce any significant incline in antioxidant enzyme activities and CAP failed to reverse these conditions. The result clearly demonstrates that GH in moderate dose reduces oxidative damage and in high doses aggravates oxidative stress. It is also interesting to find that eventhough CAP provides protection in terms of substantial recovery from ischemic damage, there was no inclination of endogenous antioxidant activities suggesting an alternate pathway for its protective ability.

It is well established that angiotensin-converting enzyme inhibitor such as CAP can ameliorate the deleterious effects of elevated renin and angiotensin II levels in patients with acute myocardial infarction. The results of several important clinical trials have shown that ACE inhibitors significantly reduce cardiovascular morbidity and mortality by attenuation of the left ventricular enlargement and heart failure, and also by reductions in the occurrence of acute coronary artery disease-related events (11). The above stated CAP protective activity at times of stress such as IRI was demonstrated in our study, which was evident from good recovery in functional parameters in CAP incorporated groups. Maximum recovery was seen in groups with GH (250 mg/kg) alone or along with CAP and remarkable recovery was seen even at low dose GH (125mg/kg) in presence of CAP. GH (500 mg/kg) showed toxic effect which is indicated by poor recovery from IRI.

Histopathological studies were carried out for confirmation of biochemical findings. The parameters - VFITS and histological scores were used to determine the myocardial damage. Pretreatment with GH at doses of 250 mg/kg alone or with CAP substantially decreased the interstitial cavity and kept the myocardial integrity during IRI damage. This effect might be due to augmentation of endogenous antioxidant enzyme synthesis. There was also remarkable reduction in the pathological scores with GH (250 mg/kg) in presence of CAP. These results suggest the enhancement of CAP mediated protection to myocardium by moderate dose of GH during MI.

In conclusion, pretreatment of GH (250 mg/kg) offers protection from myocardial injury in IRI myocardial damage. Incorporation of CAP augments myocardial protection. However, high dose of GH (GH-500) was found to increase the oxidative stress that could aggravate the pathological complications. Therefore, diet containing moderate doses of garlic could prove beneficial to the heart and administration of garlic with CAP produces additive effect.

### References

1. Fugh-Berman A. Herb-drug interaction. *The Lancet* 2000; 355:134-138.
2. Rahman K, Lowe GM. Garlic and cardiovascular diseases: a critical review. *J Nutr* 2006; 136:736S-740S.
3. Banerjee KS, Moulik SK. Effect of garlic on cardiovascular disorders: a review. *Nutr J* 2002; 1:1-14.
4. Isensee H, Rietz B, Jacob R. Cardioprotective actions of garlic (*Allium sativum*). *Arzneimittelforschung* 1993; 43: 94-98.
5. Banerjee SK, Dinda AK, Manchanda SC, Maulik SK. Chronic garlic administration protects rat heart against oxidative stress induced by ischemic reperfusion injury. *BMC Pharmacol* 2002; 2: 16-21
6. Tattelman E. Health effects of garlic. *Am Fam Physician* 2005; 72: 103-106.
7. Rietz B, Isensee H, Strobach H, Makdessi S, Jacob R. Cardioprotective actions of wild garlic (*Allium ursinum*) in ischemia and reperfusion. *Mol Cell Biochem* 1993; 119: 143-50.
8. Banerjee SK, Maulik M, Mancahanda SC, Dinda AK, Gupta SK, Maulik SK. Dose- dependent induction of endogenous antioxidants in rat heart by chronic administration of garlic. *Life Sci* 2002; 70: 1509-1518.
9. Ciplea AG, Richter KD. The protective effect of *Allium sativum* and *crataegus* on isoprenaline-induced tissue necroses in rats. *Arzneimittelforschung* 1988; 38: 1583-92.
10. Aqel MB, Gharaibah MN, Salhab AS. Direct relaxant effects of garlic juice on smooth and cardiac muscles. *J Ethnopharmacol* 1991; 33: 13-19.
11. Vasiljevic Z, Boskovic A, Ostojic M, Prostran M, Kocev N. Long-term effect of captopril on plasma lipids in acute myocardial infarction: possible mechanism. *Medicine Biol* 1999; 06: 69 – 72
12. Martin N, Bardisa L, Pantoja C, Barra E, Demetrio C, Valenzuela J. Involvement of calcium in the cardiac depressant actions of a garlic dialysate. *J Ethnopharmacol* 1997; 55: 13-118.

13. Asdaq SMB, Inamdar MN, Asad M, Nanjundan PK, Interaction of propranolol with garlic in isoproterenol induced myocardial infarction in rat. *J Pharmacol Toxicol* 2008; 496: 1816.
14. Kosmala M, Oledzka K, Lewandowski K, Filczewski M, Miłobedzka J. A comparison of antihypertensive properties of captopril and enalapril after single and multiple oral administration in spontaneously hypertensive rats. *Pol J Pharmacol Pharm* 1992; 44: 437-42.
15. Inamdar MN, Venkataraman BV, Aleem MA. A simple and improved perfusion apparatus for isolated hearts. *Ind J Pharmacol* 1994; 26: 262-265.
16. Mouhieddine S, Tresallet N, Boucher F, Leiris JD. Ultrastructural basis of the free-radical scavenging effect of indapamide in experimental myocardial ischemia and reperfusion. *J Cardiovasc Pharmacol* 1993; 22: S47-52.
17. Buerke I, Prufer D, Dahm M, Oelert H, Meyer J, Darius H. Blocking of Classical Complement Pathway Inhibits Endothelial Adhesion Molecule Expression and Preserves Ischemic Myocardium from Reperfusion Injury. *J Pharmacol Exp Ther* 1998; 286: 429-438.
18. Erich F, Elastner M. Inhibition of nitrite formation from hydroxyl ammonium chloride. A simple assay of super oxide dismutase. *Anal Chem* 1976; 70: 616-20.
19. Eva ML. Mechanism of pH dependent hydrogen peroxide cytotoxicity in-vitro. *Arch Biochem Biophys* 1988; 365: 362-72.
20. Karthikeyan K, SaralaBai BR, Devaraj N. Cardioprotective effect of grape seed proanthocyanidins on isoproterenol-induced myocardial injury in rats. *Int J Cardiol* 2007; 115: 326-33.
21. Zhai P, Eurell TE, Cotthaus R, Jeffery EH, Bahr JM, Gross DR. Effect of estrogen on global myocardial ischemia reperfusion injury in female rats. *Am J Physiol Heart Circ* 2000; 279: H2766-H2775.
22. Ide, N and Lau BHS. Garlic compounds protect vascular endothelial cells from oxidized low density lipoprotein-induced injury. *J Pharm Pharmacol* 1997; 49: 908-911.
23. Imai J, Ide N, Nagae S, Moriguchi T, Matsuura H, Itakura Y. Antioxidants and free radical scavenging effects of aged garlic extract and its constituents. *Planta Med* 1994; 60: 417-420.
24. Wei Z, Lau BHS. Garlic inhibits free radical generation and aug-ments antioxidant enzyme activity in vascular endothelial cells. *Nutr Res* 1998; 18: 61-70.
25. Freeman F, Koder Y. Garlic chemistry: stability of S-(2-propenyl) 2-propene-1-sulfinothioate (allicin) in blood, solvents and simulated physio-logical fluids. *J Agric Food Chem* 1995; 43: 2332-2338.

26. Lawson LD, Ransom DK, Hughs BG. Inhibition of whole blood platelet aggregation by compounds in garlic clove extracts and commercial garlic products. *Thromb Res* 1992; 65:141–156.
27. Jennings RB, Murry CE, Steenbergen CJ. Development of cell injury in sustained acute ischemia. *Circulation* 1990; 82: II-2.
28. Jennings RB, Schaper J, Hill ML. Effect of reperfusion late in the phase of reversible ischemic injury: changes in cell volume, electrolytes, metabolites, and ultrastructure. *Circul Res* 1985; 56: 262–278.
29. Hearse D. Cellular damage during myocardial ischaemia: metabolic changes leading to enzyme leakage. In: Hearse DJ, De LJ, Loisance D, eds. *Enzymes in Cardiology*, New York, PA: John Wiley and sons ltd, 1979; 1-21.
30. Dumoulin MJ, Adam A, Burnett J, Heublein D, Yamaguchi N, Lamontagne D. The cardioprotective effect of dual metallopeptidase inhibition: respective roles of endogenous kinins and natriuretic peptides. *Can J Physiol Pharmacol* 2005; 83: 166-173.
31. Lee BH, Seo H, Yi KY, Lee S, Lee S, Yoo SE. Effects of KR-32570, a new Na<sup>+</sup>/H<sup>+</sup> exchanger inhibitor, on functional and metabolic impairments produced by global ischemia and reperfusion in the perfused rat heart. *Eur J Pharmacol* 2005; 511: 175-82.
32. Mc Cord JM. Free radicals and myocardial ischemia. *Free Rad Biol & Med* 1988; 4: 9-13.
33. Guarnieri C, Flamigni F, Calderera CM. Role of oxygen in cellular damage induced by reoxygenation of hypoxic heart. *J Mol Cell Cardiol* 1980; 12: 797–808.
34. Yim MB, Chock PB, Stadtman ER. Copper, zinc superoxide dismutase, catalyzes hydroxyl radical production from hydrogen peroxide. *Proceeding of the Academy of National Science USA* 87, 1990; 5006-5010.