Cardiac and Renal Energy Metabolism following Intestinal Ischemia-Reperfusion: in vitro ^{1}H and ^{31}P Magnetic Resonance Spectroscopy Study

P. Vejchapipat[1,2], H. G. Parkes[2], D. G. Gadian[2], S. Vinardi[3], S. Chittmittrapap[1], A. Pierro[3]

[1]Department of Surgery, Chulalongkorn University, Patumwan, Bangkok, Thailand, [2]Radiology and Physics Unit, Institute of Child Health, 30 Guilford street, London, United Kingdom, [3]Paediatric Surgery Unit, Institute of Child Health, 30 Guilford street, London, United Kingdom

Introduction: Intestinal ischemia-reperfusion (IR) is a devastating surgical condition.[1] Patients with this disease usually suffer from multiple organ dysfunction. Hepatic impairment[2] and respiratory insufficiency[3] have been reported as a consequence of intestinal IR. However, the effects of intestinal IR towards other organs such as heart and kidneys receive little attention. Cardiac and renal dysfunction following major stress can be life threatening. This study was designed to investigate cardiac and renal energy metabolism following intestinal IR using in vitro ^{1}H and ^{31}P MRS of tissue extracts.

Materials and Methods: Two groups of male adult rats were studied (n= 6 per group); (A) sham operation for 180 min and (B) 60 min intestinal ischemia + 120 min reperfusion. *Surgical procedure*: Animals were anesthetized with oxygen and halothane. Rectal temperature was maintained at normothermia (36-38 C). Intestinal IR was performed by clamping and unclamping the superior mesenteric artery for the assigned duration. At the end of the experiment, small intestine, heart, and kidney were quickly removed and freeze-clamped for biochemical study. *In vitro ^{1}H and ^{31}P MRS measurement:* The intestine, heart, and kidneys were extracted into methanol/water/chloroform (2:1:2). The water-soluble extracts were dried using nitrogen gas and reconstituted in D_2O. ^{1}H and ^{1}H-decoupled ^{31}P spectra were acquired on an 11.7T Varian Unity-plus spectrometer (^{1}H MRS-128 acquisitions, 45^{o} pulse angle, TR= 16 sec; ^{31}P MRS-2000 acquisitions, 45^{o} pulse angle, TR=6 sec). Resonance intensities were determined using the Varian deconvolution routine and converted to concentration by reference to an added standard.[4] Tissue phosphocreatine (PCr), ATP, inorganic phosphate (Pi), glucose, alanine and lactate were analyzed. *Statistical analysis:* Unpaired t-tests were used. Significant differences were established at $^{*}P < 0.05$.

Results: *Small intestine* Intestinal IR caused marked drops in tissue glucose, PCr and ATP together with increases in Pi and lactate (Fig. 1). *Heart* There were no significant differences in tissue glucose, PCr, ATP, Pi or lactate between sham and intestinal IR animals (Fig. 2). *Kidneys* Intestinal IR did not affect renal ATP or Pi levels. However, the significant increases in renal glucose, alanine, and lactate levels after intestinal IR were observed (Fig. 3).

Conclusion: Intestinal ischemia for 60 min followed by reperfusion for 120 min caused intestinal energy failure. Metabolically, heart and kidneys respond to intestinal IR differently. Although there were no changes in renal ATP and Pi, increases in renal alanine and lactate, markers for tissue hypoxia, were revealed. These indicate that there might be some degree of inadequate renal perfusion after intestinal IR. However, the intestinal and renal metabolic changes observed after intestinal IR are unlikely to be due to cardiac energy failure. Our observation increases the understandings in the pathophysiology of multiple organ failure following intestinal IR. More studies are needed to elucidate the detailed mechanisms.

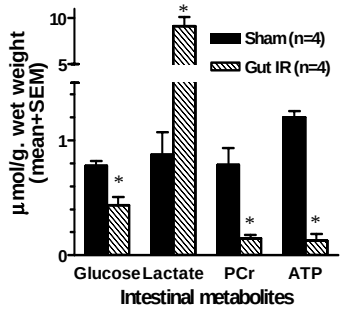

Figure 1.

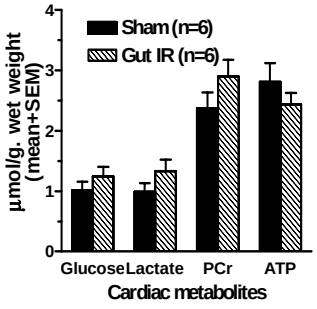

Figure 2.

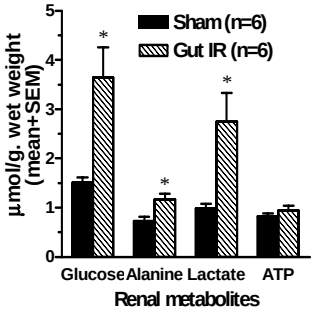

Figure 3.

References

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