Does endoplasmic reticulum stress mediate endothelin-1-induced renal inflammation?

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Submitted 15 April 2013; accepted in final form 8 May 2013

De Miguel C, Pollock JS. Does endoplasmic reticulum stress mediate endothelin-1-induced renal inflammation?. Am J Physiol Regul Integr Comp Physiol 305: R107–R109, 2013. First published May 15, 2013; doi:10.1152/ajpregu.00184.2013.—Endothelin-1 (ET-1) is the most potent vasoconstrictor peptide known. It exerts its actions through two pharmacologically different receptors: ET\_A and ET\_B receptors. In the renal vasculature, there is a majority of ET\_B receptors in the efferent arteriole, whereas a greater amount of ET\_A receptors are located in the afferent arteriole. The nephron is rich in ET\_B receptors, especially in the thick ascending limb and collecting ducts, while containing a smaller amount of ET\_A receptors. High levels of circulating or renal ET-1 have been described in cardiovascular diseases such as hypertension or diabetes, diseases also associated to renal inflammation. Despite extensive evidence associating high levels of ET-1 to increased renal inflammation, the molecular mechanism(s) by which ET-1 leads to renal immune infiltration and/or immune activation remains unknown. In this minireview, we propose that the ET-1/ETA pathway mediates an increase in renal endoplasmic reticulum (ER) stress, initially a survival mechanism that if prolonged, leads to the eventual death of the cell via apoptosis.

endothelin-1; endoplasmic reticulum stress; renal inflammation

RECENTLY, ENDOPLASMIC RETICULUM (ER) stress has been implicated in the development of a variety of cardiovascular and renal diseases, many of which are also associated with elevated endothelin-1 (ET-1) levels. There is also extensive evidence that links increased ET-1 levels with renal immune cell infiltration and/or immune activation. This review summarizes this evidence and proposes the working hypothesis that ET-1 induces renal inflammation and/or immune activation by stimulating renal ER stress through the ET\_A receptor (Fig. 1).

### Endothelin and Renal Inflammation

ET-1 is a very potent vasoconstrictor peptide that exerts its biological actions through the activation of two G protein-coupled receptor subtypes: ET\_A and ET\_B receptors. The affinity of ET-1 for each receptor subtype has been shown to be the same ($K_d = 0.01–0.5$ nM) (4). The vasoconstrictor effects of the ET\_A receptor are mainly mediated by a $G_{q\alpha}$ protein, whereas the vasodilatory effects of ET-1 through the ET\_B receptor are largely mediated via a $G_{s\alpha}$ protein (8).

Uprogulation of the ET-1 system is implicated in many cardiovascular diseases, such as hypertension, vascular disease, pulmonary hypertension, heart failure, renal disease, or diabetic nephropathy (14). Interestingly, many of these disorders have been reported to have an important inflammatory component to their development. The kidney, in particular the renal medulla, contains the highest concentration of ET-1 in the body, and progressive renal damage is described in transgenic animals overexpressing ET-1 (6). ET-1 stimulates renal hypertrophy, fibrosis, and inflammation predominantly through the activation of the ET\_A receptor (16, 17). Recently, our laboratory reported that chronic infusion of a nonpressor dose of ET-1 in Sprague-Dawley rats results in elevated circulating and renal levels of inflammatory mediators, such as ICAM-1 or monocyte chemoattractant protein-1 (MCP-1), as well as increased renal infiltration of macrophages and T-lymphocytes (13). Interestingly, the proinflammatory effects exerted by ET-1 in these studies were attenuated by the administration of an ET\_A receptor blocker, highlighting the involvement of this receptor in the development of the ET-1-induced proinflammatory state. We also demonstrated that ET\_A receptor activation mediates renal infiltration of T cells in a hypertensive angiotensin II-infused animal model (1). Despite a large body of evidence linking the ET-1 system with renal inflammation, the mechanism by which ET-1 leads to this inflammation remains unclear.

### ER Stress and Renal Inflammation

The ER is known to be a key cellular organelle in the modification, maturation, and folding of proteins into their active conformations. The ER is also a very sensitive sensor of stress in the cell (5). Homeostasis in the ER can be disrupted by...
ER stress is also associated with tubulointerstitial damage, diabetic nephropathy (7), or diabetic nephropathy (7). Substantial evidence also indicates that ER stress is interconnected with inflammatory signaling pathways. For instance, activation of the UPR is reported to be coupled to the production of proinflammatory cytokines like MCP-1, TNF-α, IL-6, or IL-8 (18). In addition, other studies have shown that the tree branches of the UPR can lead to activation of the central inflammatory mediator NF-κB, which induces the transcription of other inflammatory genes (21).

**ET/ETₐ Pathway and ER Stress**

Given that elevated renal levels of ET-1 and renal inflammation are highlights of renal disease, our working hypothesis is that ET-1 induces renal inflammation by elevating ER stress in the kidney (Fig. 1). The elevated ER stress levels in turn lead to the production of inflammatory mediators and renal inflammation. A recent study supports this idea by demonstrating that cultured pulmonary aortic smooth muscle cells (PASMCs) show activation of the UPR and cytokine production after exposure to ET-1 (19). Among the upregulated proinflammatory cytokines were IL-6, IL-2, and chemokine (C-C motif) ligand 5 (CCL-5). Interestingly, these effects of ET-1 were ameliorated by treatment with an ETₐ receptor blocker, whereas treatment with an ETₐ receptor antagonist did not have any effect. One of the possible mechanisms by which activation of the ETₐ receptor could lead to renal ER stress is by generation of oxidative stress. Extensive evidence indicates that ETₐ receptor activation stimulates superoxide production via NADPH oxidase (15), and that cross-talk exists between oxidative stress and ER stress (11). Moreover, stimulation of the UPR in response to oxidative stress is an adaptive mechanism to preserve cell function and survival during renal dysfunction (9). Modulation of renal ER stress through the ET system may be a novel therapeutic target against the development of renal disease in situations like hypertension or diabetes.

**GRANTS**

The authors acknowledge the grant support from the American Heart Association Postdoctoral Fellowship to C. De Miguel and a Pilot Study Research Program Grant from Georgia Regents University to J. S. Pollock.

**DISCLOSURES**

No conflicts of interest, financial or otherwise, are declared by the author(s).

**AUTHOR CONTRIBUTIONS**

Author contributions: C.D.M. and J.S.P. conception and design of research; C.D.M. performed experiments; C.D.M. analyzed data; C.D.M. and J.S.P. interpreted results of experiments; C.D.M. prepared figures; C.D.M. drafted manuscript; C.D.M. and J.S.P. edited and revised manuscript; C.D.M. and J.S.P. approved final version of manuscript.

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