Cardioprotective Brain Mechanisms

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Progressive cardiac dysfunction after a myocardial infarction (MI) is a major contributor to the high incidence of heart failure in many parts of the world. The initial myocardial injury and the resulting decrease in left ventricular (LV) function activate a variety of systems to sustain the cardiovascular homeostasis. However, in the long-term their activation contributes to adverse cardiac remodeling and a further decrease in LV function. In recent years it has become apparent that the central nervous system (CNS) plays a pivotal role in this regard. Post-MI, several stimuli can activate CNS-angiotensinergic sympathoexcitatory pathways and as a result not only cause sympathetic hyperactivity but also activate the circulating and cardiac renin-angiotensin-aldosterone system, cytokines, and vasopressin, all contributing to further myocyte loss and decreased myocyte function.1 No braking, that is, balancing mechanisms are apparently being activated, and this is considered the main reason for progressive cardiac dysfunction leading to clinical heart failure and death. Drug therapy involving β-blockers, angiotensin-converting enzyme inhibitors/angiotensin II type 1-receptor blockers, and mineralocorticoid receptor blockers has a marked impact, but heart failure remains a major problem. The study by Okada et al² in the current issue of Arteriosclerosis, Thrombosis, and Vascular Biology provides a new perspective and suggests that cardioprotective mechanisms are actually being activated and can attenuate heart failure post-MI, at least in mice.

See accompanying article on page 1902

Brain-derived neurotrophic factor (Bdnf) and its receptor, tropomyosin-related kinase receptor B (TrkB), are present both in the CNS and in the heart. Okada et al² showed that in mice with a marked decrease in LV ejection fraction (<20%) at 2 weeks post-MI, brain and plasma Bdnf, as well as cardiac TrkB expression are clearly increased, but cardiac Bdnf expression markedly decreased. Destruction of the cardiac terminals of sensory afferent neurons from the heart by local treatment with capsaicin prevented the increase in neuronal expression of Bdnf, as well as the increase in plasma Bdnf, after MI. Interestingly, despite possibly lower sympathetic activity,¹ these mice exhibited a further decrease in ejection fraction, a larger area of myocardial fibrosis, and impaired vascularization of the peri-infarct zone. Using state-of-the-art genetic targeting technology, Okada et al further dissected the role of specific components of the CNS-blood-heart Bdnf-TrkB axis. Mice with systemic deletion of the Bdnf gene at 2 weeks post-MI exhibited a further decrease in LV ejection fraction, as well as more fibrosis, and terminal deoxynucleotidyl transferase dUTP nick-end labeling–positive cardiomyocytes associated with increased expression of the proapoptotic B-cell lymphoma 2–associated X protein and decreased expression of the prosurvival molecule B-cell lymphoma protein 2. Impaired vascularization and decreased vascular endothelial growth factor expression were also apparent. Cardiac-specific deletion of the Bdnf gene did not affect cardiac remodeling and dysfunction post-MI. In contrast, after genetic disruption of neuronal Bdnf expression, plasma Bdnf levels did not increase post-MI and adverse cardiac remodeling and dysfunction were again apparent. Specific disruption of the TrkB gene in the myocardium was also associated with adverse cardiac remodeling and dysfunction. Finally, intra-peritoneal injection of Bdnf recombinant protein on day 0 and day 1 increased plasma Bdnf levels 4- to 5-fold above those in control MI mice and restored the cardiac phenotype in either mice treated with capsaicin or those with neuronal-specific deletion of the Bdnf gene. The authors conclude that Bdnf via the cardiac TrkB receptor plays a protective role in the heart post-MI by inducing angiogenesis and upregulating expression of prosurvival factors. In addition, the findings suggest that post-MI cardiac afferent nerve fibers relay mechanosensitive or chemosensitive information to the CNS, possibly the paraventricular nucleus,³ and thereby increase neuronal Bdnf expression, which in turn causes an increase in plasma Bdnf levels. The authors state—Bdnf release from the brain—do not speculate on possible mechanisms through which release of this protein into the circulation may occur.

The study has some limitations. MI sizes are presumably large considering the low ejection fraction. However, the actual MI sizes were, surprisingly, not reported; effects of Bdnf deficiency on MI size can, therefore, not be excluded. Cardiac function was only assessed by echocardiography. This provides limited information and assessment of LV function by, for example, Millar Catheter, in at least some of the experiments would have been much more informative. Finally, some of the mice groups exhibited very low ejection fraction (≈10%), and presumably increased mortality. This is a critical end point, but unfortunately no data on mortality were provided.

Irrespective of these limitations, the present study by Okada et al² clearly demonstrates that the ischemic myocardium sends signals to the CNS not only to increase sympathetic activity and other mechanisms to maintain cardiovascular homeostasis but also to activate cardioprotective mechanisms, such as the Bdnf-TrkB axis. The latter may serve to dampen the adverse effects of, for example, the sympathetic tone on the heart (see

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1749
schematic outline in Figure). If this concept also applies to humans, decreased activity of the Bdnf-TrkB axis in humans with neurodegenerative diseases, depression, or metabolic disorders may contribute to increased risk for heart failure post-MI. If so, plasma Bdnf levels may become another risk factor/marker and drugs to stimulate cardiac TrkB receptors may become a novel strategy to inhibit progressive cardiac dysfunction post-MI.

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References

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