Emerging Role of Phosphodiesterase 2A in Hypertension

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Phosphodiesterases cleave and, thereby, inactivate the second messengers adenosine cAMP and cGMP. Phosphodiesterases are classified according to their preference for cAMP or cGMP. Phosphodiesterase 2 belongs to a class of phosphodiesterases that hydrolyze cAMP and cGMP with similar kinetics. Several recent studies point to a hitherto underappreciated pathophysiological and therapeutic relevance of phosphodiesterase 2 in cardiovascular diseases. Specifically, phosphodiesterase 2 upregulation in heart failure desensitizes the heart toward stimulation via β-adrenergic receptors. In engineered connective tissue, phosphodiesterase 2 enhances the conversion of fibroblasts to myofibroblasts, thereby increasing tissue stiffness. Finally, phosphodiesterase 2 inhibitors induce relaxation of pulmonary arteries and inhibit proliferation of pulmonary arterial smooth muscle cells, indicating that phosphodiesterase 2 inhibitors may constitute an effective strategy for treatment of pulmonary hypertension.

On this background, published in this issue of Hypertension, a study by Li et al adds a new facet to the emerging roles of phosphodiesterase 2 in the pathophysiology of cardiovascular diseases. In sympathetic neurons, depolarization leads to calcium influx via voltage-dependent calcium channels with subsequent release of norepinephrine (Figure). Enhanced norepinephrine release can worsen hypertension, and there is evidence for defective norepinephrine reuptake into sympathetic neurons in hypertensive rats. Li et al show that brain-derived natriuretic peptide (BNP), via activation of particulate guanylyl cyclase A increases cGMP levels in sympathetic neurons, and subsequently decreases calcium influx and norepinephrine release (Figure). Ultimately, BNP reduces heart rate. These data are in accord with the notion that BNP can exert beneficial effects in cardiovascular diseases, most notably in heart failure.

The study by Li et al is important for 2 major reasons. First, because of the dual specificity of phosphodiesterase 2 for cAMP and cGMP and the allosteric stimulatory effects of cGMP on phosphodiesterase 2-catalyzed cAMP hydrolysis, phosphodiesterase 2 is, in principle, prone to mediate the cross talk between cAMP and cGMP signaling. But in the study of Li et al, there is no evidence for a cross-regulatory role of phosphodiesterase 2A between cAMP and cGMP. In agreement with the data on rat sympathetic neurons studied by Li et al in the failing rat heart, phosphodiesterase 2 is the major enzyme responsible for regulation of BNP-induced cGMP increase. An explanation for this high degree of specificity could be that all components of the BNP-particulate guanylyl cyclase A-PKG-phosphodiesterase 2 signaling pathway are localized in a defined cGMP-specific signalosome in sympathetic neurons and the failing ventricle, excluding cross talk with cAMP.

Second, in sympathetic neurons from spontaneously hypertensive rats, the expression of phosphodiesterase 2A is increased by ≈60%. Overexpression of phosphodiesterase 2A in sympathetic neurons, mimicked by adrenoviral infection, abrogates the inhibitory effects of BNP on calcium influx and norepinephrine release, and inhibition of this enhanced phosphodiesterase 2A activity with a selective phosphodiesterase 2 inhibitor restores the inhibitory effects of BNP on calcium influx and norepinephrine release. Thus, Li et al have identified a new molecular mechanism, namely enhanced phosphodiesterase 2A expression, by which beneficial cardiovascular effects of BNP are annihilated.

The study of Li et al has important implications for future research and therapeutic strategies. The genetic mechanisms underlying the upregulation of phosphodiesterase 2A in sympathetic neurons of spontaneously hypertensive rat are as yet unknown. It will be important to examine the question whether also other phosphodiesterases are dysregulated and which specific mechanisms are involved. Of course, it will be necessary to explore whether phosphodiesterase 2A expression is also altered in specific forms of human systemic hypertension. It should be kept in mind that phosphodiesterase 2 is not a single enzyme, but a family of 3 splice variants that may have slightly different functions. Moreover, in the study of Li et al on sympathetic neurons, phosphodiesterase 2A exhibited the properties of a cGMP-specific phosphodiesterase (Figure), but in other systems phosphodiesterase 2 regulates both cAMP and cGMP. This may reflect differential compartmentalization of proteins involved in cAMP and cGMP signaling.

About therapeutic interventions, 1 evident strategy based on the results of Li et al is to enhance the clinical effects of BNP derivatives such as nesiritide with phosphodiesterase 2 inhibitors. On the basis of different mechanisms of action, we may expect synergistic beneficial cardiovascular effects. A dual therapy with a particulate guanylyl cyclase A agonist and a phosphodiesterase 2 inhibitor entails, of course, the risk of increased side effects, specifically in cells that express both particulate guanylyl cyclase A and phosphodiesterase 2A. But it is certainly worthwhile to pursue this avenue of drug research.
The fact that phosphodiesterase 2A hydrolyzes both cAMP and cGMP and is stimulated by cGMP, it may be important to target just specific cell types to minimize side effects.

In conclusion, the present study of Li et al. together with other reports, most notably the study by Bubb et al on pulmonary hypertension, have placed the concept of phosphodiesterase 2 inhibition in a prominent position for future pathophysiological and pharmacological research. The study of Li et al is an excellent example how substantial progress can be obtained through wise application of pharmacological and molecular biology methods in appropriate (patho)physiological models.

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Disclosures
None.

References
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