Effects of removal of external Na^+ ions on vascular smooth muscles

Tadao Tomita and Hiroyuki Tokuno
Department of Physiology,
School of Medicine, Nagoya University

Summary

Contractions produced by Na^+ removal were studied in muscle strips isolated from canine coronary artery. The contraction in the absence of Na^+ (0-Na, Na^+ being substituted by choline, sucrose or N-methyl-D-glucamine) was not affected by phentolamine but was strongly inhibited by verapamil. Ouabain slowly potentiated the 0-Na contraction and markedly reduced the inhibition due to verapamil. Amiloride and excess Mg^{2+} reduced the 0-Na contraction and the degree of their inhibition was similar after ouabain treatment. The decrease in verapamil susceptibility could syggest that the 0-Na contraction has verapamil-sensitive and -insensitive components. The former is probably due to Ca^{2+} influx through voltage-dependent channels and the latter to Ca^{2+} influx through Na^+-Ca^{2+} exchange process.

In single cells dispersed enzymatically from the rabbit portal vein, Na^+-Ca^{2+} exchange current could be recorded with the whole-cell voltage clamp method. The experiments were carried out under conditions in which Ca^{2+} and K^+ channels as well as a sodium pump were blocked. The direction of the current was depending on the concentration gradient of Na^+ and their property was very similar to that observed in cardiac cells. The exchange current was not much affected by amiloride (0.5 mM) and verapamil (0.01 mM), but strongly inhibited by excess Mg^{2+} (6-12 mM).

Intracellular pH was measured in the guinea-pig aorta, after loading a pH-sensitive dye, dimethyl-carboxyfluorescein (Me_2CF). 20 mM ammonium chloride (NH_4Cl) produced intracellular alkalinization on application and transient acidification on removal. Removal of external Na^+ produced acidification and retarded recovery from NH_4Cl-induced acidification until readmission of Na^+.

From these results, a possiblity was considered that removal of external Na^+ blocks Na^+-H^+ exchange, resulting in acidification and that this blcoks K^+ channels, leading to membrane depolarization. The depolarization activates Ca^{2+} channels and produces contraction due to Ca^{2+} influx. This explains the susceptibility of the 0-Na contraction to verapamil. Ouabain treatment probably increases a contribution of Na^+-Ca^{2+} exchange process to the 0-Na contraction, by increasing intracellular Na^+ concentration and reduces susceptibility to verapamil.