

REDUCTION OF THE TONIC EFFECT OF $BaCl_2$ BY DIFFERENT CATIONS IN ISOLATED HEARTS AND SMOOTH-MUSCLE ORGANS OF THE EDIBLE SNAIL (*HELIX POMATIA* L.)

L. ERDÉLYI

Institute of General Zoology and Biology, Attila József University, Szeged

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Introduction

In earlier publications (Erdélyi, 1965) I dealt with the effect of different cations on the functioning of isolated heart of edible snail. Among them I have examined in details, on qualitative and quantitative bases, the effect of $BaCl_2$ on the functioning of heart. (Diagr. 1 and 2 belong to the above mentioned article. See Figs. 2, 3 there, too.) As a result of the performed examinations I have ascertained that the influence exerted by $BaCl_2$ is manifested in an increase of tonicity in direct proportion to the applied dose, till getting to the saturation value. This effect of $BaCl_2$ can be observed, in a way, analogous to the investigation on *Mammalia*, on intestine and fragments of organs of the reproductive system of snail (Minker and Koltai, 1961). It became clear by my further examinations that the antagonists of the effect of $BaCl_2$ in the heart, intestine and penis with flagellum is $CaCl_2$ (Erdélyi, 1968).

Of late, I have examined the efficiency of mono-, di-, and trivalent cations in respect of antagonism. I want to treat of the results obtained, in details, in my present publication.

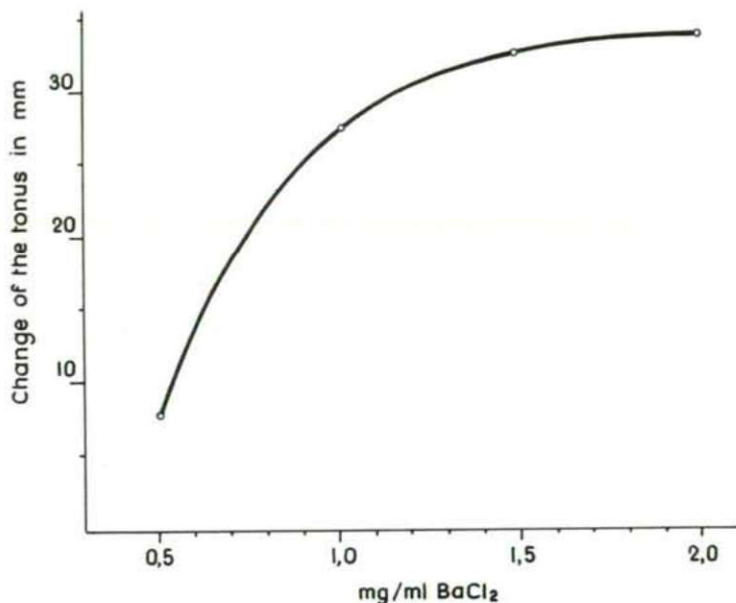
Material and methods

I have examined in a lot of experiments on isolated hearts and fragments of intestine and penis with flagellum of edible snail (*Helix pomatia* L.) how effective the following mono-, di-, and trivalent cations are: Cs^+ , Li^+ , NH_4^{++} , Be^{++} , Ca^{++} , Cd^{++} , Co^{++} , Fe^{++} , Mg^{++} , Mn^{++} , Sn^{++} , Sr^{++} , Zn^{++} , Al^{+++} , Bi^{+++} , Fe^{+++} , after the administration of $BaCl_2$. The isolated organs were expanded, at the experiments, in a ten ml. organ-vesel, in Jullien's *Helix-Ringer*. During the experiments I have taken care of airing the organs and the experiments were carried out at a standing temperature of $27^\circ C$, in summer, resp. in early autumn.

Results and Discussion

The effect of $BaCl_2$ both on heart and intestine, resp. on fragments of organs of the reproductive system is modified in a very various way

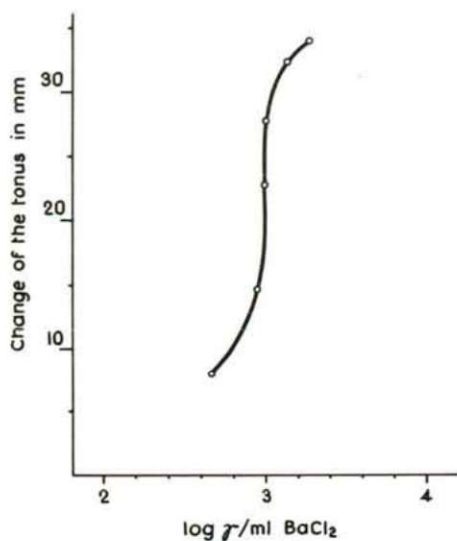
by the examined different mono-, di-, and trivalent cations. The changes of effect are summarized in Table 1. At reading the data of the published Table, it is to be considered that the change of cation effects is defined in relation to the change of function caused by the influence of BaCl_2



Diagr. 1. Curve of tonus increasing effect of BaCl_2

in a concentration of 1 mg/ml. Anyway, only the tonic effect of BaCl_2 in a concentration of 1 mg/ml is common in every case of the three organs examined. Other parameters of the organs functioning automatically are modified by BaCl_2 in the tonic area in a highly different form. At the heart and penis with flagellum the amplitude of automatic functioning mostly decreases while in case of intestine it rather grows. At heart the frequency is unchanged or a little decreased, at intestine and the fragments of organs of the reproductive system it decreases somewhat, as well. In the Table, the change of effect of the different cations is demonstrated on the basis of the summarized result of an examination of more kinds of doses, and a mean change of tendency, obtained from several experiments, was taken into consideration. In the single experiments, the detailed course of the changes of effects may be valued by the kymogramm.

Considering the above-mentioned facts, it can be read from the data of Table that from the cations examined the most perfect antagonists of BaCl_2 is CaCl_2 . The increased tonicity caused by BaCl_2 is compensated completely by CaCl_2 both in intestine and in the heart, and in the penis with flagellum, too, it is considerably decreased. Similarly, the change of amplitude and



Diagr. 2. Barium dose effect curve.

TABLE 1. The marks of Table concern the changes following the effect of 1 mg/ml BaCl₂ concentration, taking place under the influence of the doses of ions, given in the Table, and being the most optimal in respect of the phenomenon. Cf. the physiological effect of BaCl₂ in the text. +: indicates an increasing effect, -: a decreasing one, +-: a changing one, and \emptyset : an unchanged effect.

Ions	Heart			Intestine			Penis with flagellum		
	tonus	fre- quency	ampli- tude	tonus	fre- quency	ampli- tude	tonus	fre- quency	ampli- tude
Cs+	+	-	+-	+	\emptyset	+	-	-	+
Li+	+-	\emptyset	-	+	+-	+-	-	-	+
NH ₄ ⁺	+-	-	+-	+-	-	+-	-	+	+-
Be ⁺⁺	-	-	-	-	+	+-	-	+	+
Ca ⁺⁺	-	+	+	-	+-	+	-	+-	+
Cd ⁺⁺	-	-	+-	-	+	-	+-	-	-
Co ⁺⁺	-	-	+	+-	+-	-	-	+	+
Fe ⁺⁺	+-	-	+-	-	-	-	+-	+-	+
Mg ⁺⁺	+	-	\emptyset	+	\emptyset	+	+	\emptyset	+
Mn ⁺⁺	-	-	+	-	-	+	-	-	+
Sn ⁺⁺	-	-	+-	-	-	+	-	-	+
Sr ⁺⁺	+	-	+-	+	\emptyset	+-	+	\emptyset	+-
Zn ⁺⁺	+	-	+	-	+-	+-	-	-	+
Al ⁺⁺⁺	-	-	+	-	+	\emptyset	-	-	+
Bi ⁺⁺⁺	+	-	-	-	-	-	-	+	+
Fe ⁺⁺⁺	+-	-	+-	-	-	-	+-	+-	+

frequency caused by BaCl_2 is antagonized in the intestine, heart and penis with flagellum by CaCl_2 , even if after the formation of a compensatory area, secondarily, an increase of amplitude occurs in case of all the three organs examined, as a result of a joint effect of both ions. The effect of the other cations is characterized by compensating some characteristics of the parameter changes caused by BaCl_2 in a form agreeing or disagreeing, in any organs. There are, however, quite a lot of cations which, as to their effects, cannot be considered at all as antagonists of any parameter change of BaCl_2 . Further on, I will separately deal in details with the effect of the cations examined.

CsCl. CsCl doesn't prevent the development of an increased tonicity caused by BaCl_2 , either in intestine or in the heart (Plate I. Fig. 1). Opposite to the two organs mentioned above, however, the barium spasm of fragments of organs of the reproductive system is slightly counteracted by it, meanwhile the amplitude of automatic functioning is growing and the frequency decreasing a little. CsCl promotes in the intestine a further increase of the amplitude produced by barium ions the frequency is, however, not essentially influenced by it. In the heart a decrease of frequency takes place as a result of the joint effect of both ions while the amplitudes become unstable in consequence of the periodic change of the force of retractions.

LiCl. LiCl decreases the tonic effect of BaCl_2 both in the heart and in penis with flagellum examined, while in the heart a decrease of amplitude appears without any essential change of frequency (negative inotropic effect). The effect on the fragments of organs of the reproductive system exactly antagonistic, accompanied by a strong increase of amplitude and decrease of frequency. In the intestine, the tonic effect of BaCl_2 is increased by LiCl while instabil changes of amplitude and frequency occur.

NH_4Cl . The barium spasm of organs of the reproductive system is somewhat decreased by NH_4Cl while frequency is increased and the amplitude of the automatic functioning along the line of the tonus decrease is unchanged: however, later on major changes occur with infrequent, and minor ones with frequent, amplitudes. The tonus of BaCl_2 is decreased by NH_4Cl in the heart, resp. in intestine but in lesser degree and only transitorily (Plate I. Fig. 2). After the part of decreased tonicity, an increase of tonus appears in the heart faster and is the intestine more slowly. At the line of the decreased tonus the amplitude is decreasing, too, both in case of heart and of intestine while the frequency is not changing essentially. In the domain of the increased tonus, similarly, a decrease of frequency ensues analogously in both organs while the amplitude of the automatic functioning is composed of major components of rare waves and of minor ones of dense waves.

BeCl_2 . The tonic effect of BaCl_2 in an isolated heart is fully antagonized by BeCl_2 (Plate I. Fig. 3). Simultaneously with the decrease of tonus, however, a decrease of amplitude and a minor decrease of frequency take place, demonstrating that the $\text{Ba}^{++}\text{-Be}^{++}$ antagonism concerns only the tonic change of heart functioning. The tonus decreasing effect of BeCl_2 appears also in case of penis and of intestine. At both latter organs, however, besides the periodical fluctuation of tonus, finally a

decrease of tonicity prevails. Frequency and amplitude of the automatic function of penis is strongly increasing, as a result of the joint influence of both ions, while at intestines both frequency and amplitude get a changing value and, finally, the effect is stabilized on the level of decrease (Plate II. Fig. 1).

CdCl_2 . CdCl_2 decreases strongly the tonus of isolated heart and fragments of intestine, at the same time increasing that of the penis. Simultaneously with the tonic change, its strongly retarding effect prevails besides the barium ions, as well. In case of the fragments of intestine, it immediately suspends the automatic functioning while in the penis and in the heart the standstill of motion takes place but gradually. In case of the penis the cadmium checking continues decreasing the parameters till the automatic functioning being suspended, while in case of the heart only the frequency decreases strongly at the line of the tonic decrease, the amplitude is initially increasing and the full heart block follows later.

CoCl_2 . The tonicity of heart and penis with flagellum is strongly decreased by CoCl_2 , while at intestine there occurs but a decrease of transitory character and the tonus increases, with some rupture, even after CoCl_2 having been administered. As a result of the joint effect of both ions, the amplitude of the cardiac functioning is increasing, its frequency, however, decreasing. The amplitude of the automatic functioning of the isolated fragments of intestine and penis with flagellum is changing, major strong and minor weaker contraction groups follow one another. Frequency is changing, too, in case of both latter organs.

FeCl_2 . In case of all the three organs examined FeCl_2 and FeCl_3 have a thoroughly analogous influence. Affected by ferric ions, the barium spasm ceases to some extent. At intestine the solution of tonus is undiminished, at the heart and the penis the initial decreasing tendency rises after some rupture. Influenced by ferric ions, the motion of intestine ceases to function; at the heart, too, the short blocking period appears, followed by returning of the automatic functioning. Then the frequency decreases followed by a weak decrease of amplitude in changing periods. At penis with flagellum a strong increase of amplitude can be observed, as a consequence of ferric ions, followed by a changing frequency.

MgCl_2 . The tonic effect of barium ions cannot be defended, in case of any organs examined, by MgCl_2 . The line of the increased tonus continues rising even after the administration of MgCl_2 . As a result of the joint effect of both ions, the amplitude of cardiac function does not change essentially; the frequency, on the other hand, is decreasing somewhat. In the intestine a strong increase of amplitude is brought about by the magnesium ions; later on, however, it decreases in the state of a rising tonus. The motion of the penis is stimulated by the magnesium ions. Influenced by MgCl_2 , strong contractions of big waves and those of dense small amplitude follow one another.

MnCl_2 . The tonicity of the isolated heart of snail is diminished extremely strongly by MnCl_2 , until reaching the full compensatory level, that of the isolated fragments of intestine and organs of the reproductive system even beyond that (Plate II. Fig. 2). At the line of the

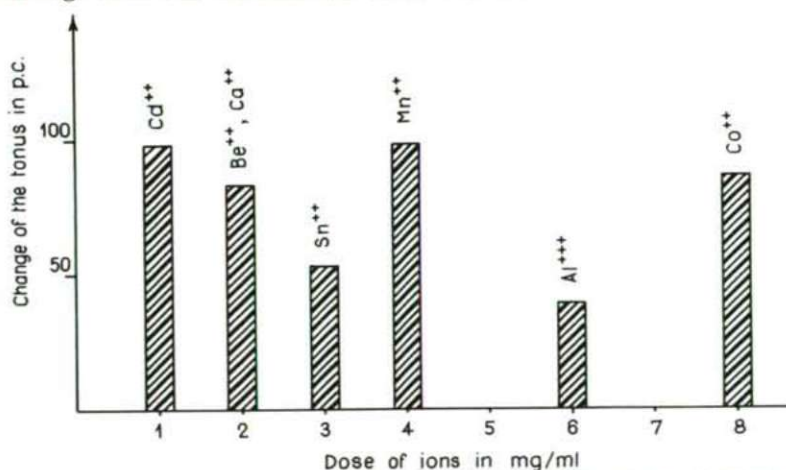
decreased tonicity in case of heart an intensive increase of the amplitude appears and meanwhile the frequency is decreasing in a high degree (positive inotrope and negative chronotrope effect). In the intestine lesser dense and major more rarely repeated waves follow one another with somewhat smaller frequency, compared with the effects of barium ions (Plate II. Fig. 3). On the fragments of organs of the reproductive system, similarly to the heart, a strong increase of amplitude takes place followed by a very intensive increase of frequency. Later on, the frequency becomes also here slower at the line of the tonic decrease.

SnCl_2 . Influenced by SnCl_2 , the tonicity of all the three isolated organs is decreasing a little while other parameters of the automatic functioning gradually decrease.

$\text{Sr}(\text{NO}_3)_2$. Stroncium ions, similarly to the magnesium ions, result in a further increase of tonus. The amplitude of the automatic functioning is, in case of all the three organs, of changing strength, the frequency at heart is decreasing a little, in case of the two other organs it is, however, unchanged.

ZnCl_2 . The tonicity of intestine and of the penis are decreased while that of heart is raised by ZnCl_2 . Influenced by zinc ions, the amplitude of cardiac functioning is growing (positive inotrop effect), while its frequency decreasing (negative chronotrope effect). In the intestines there can initially be observed strong changes of large amplitude and of decreasing frequency, later continued by motions of quick frequency and small amplitude. The amplitude of penis is increasing under the influence of ZnCl_2 while its frequency is decreasing.

AlCl_3 . Under the influence of AlCl_3 the tonicity of all the three isolated organs (heart, intestine, penis) decreases a little. The degree of tonic change and the connection with the dose are shown related to the



Diagr. 3. *Helix*: heart. The tonus of the isolated heart is decreased by the different doses of the different cations in a changing degree. The tonus-increasing effect of 1 mg/ml BaCl_2 concentration is 100 per cent.

heart at the most important tonus-reducing ions in Diagr. 3. Simultaneously with the decrease of tonicity a decrease of amplitude and frequency takes place in the heart. In case of intestine there is no major change in amplitude; the frequency, however, is decreasing a little.

BiCl_3 . Affected by bismuth ions, the tonus of heart continues rising; on the other hand, that of intestine and of penis is somewhat decreasing. BiCl_3 has a strongly retarding effect on the functioning of heart and intestine while the motion of the penis is strongly stimulated by it.

Summary

The effect of the examined cations against BaCl_2 can be summarized as follows:

1. In case of the heart, the tonus-increasing effect of BaCl_2 is influenced by the different cations examined in different ways which can be divided into three main groups.

a) In very different doses (in concentration of 1—8 mg/ml after 1 mg/ml BaCl_2) the tonus is decreased by cations: Ca^{**} , Be^{**} , Cd^{**} , Co^{**} , Mn^{**} , Sn^{**} , Al^{***} .

b) The tonus is unchanged or increasing under the influence of cations Cs^+ , Mg^{**} , Sr^{**} , Zn^{**} , Bi^{***} .

c) Finally, the tonus is showing a significant variation, initially it is decreasing, later on, however, increasing under the influence of cations Li^+ , NH_4^+ , Fe^{**} , Fe^{***} .

2. The barium spasm of smooth-muscles of the intestine and penis is decreased, just as in case of heart, by Ca^{**} , Be^{**} , Mn^{**} , Sn^{**} , and Al^{***} .

On the other hand, Sr^{**} , and Mg^{**} are, in the latter case too, synergists of BaCl_2 .

3. Amplitude and frequency change in case of all the three organs in a highly different form, both in the direction of increase and decrease, but they cannot be connected with the influence of the given ion on tonicity.

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Address of the author:

Dr. Erdélyi
Institute of General Zoology of the
A. J. University Szeged, Hungary

Plate I. *Helix*: heart. Under the influence of cesium ions, the tonus-increase elicited by BaCl_2 has remained, the frequency decreased, and the amplitude increased a little.

Helix: heart. Under the influence of NH_4Cl , the tonus initially shows a decreasing tendency then it again rises. Meanwhile the amplitude of automatic functioning is increasing and its frequency decreasing.

Helix: heart. Under the influence of berillium, the barium spasm is thoroughly counteracted. This change, however, leads to a strong decrease of amplitude.

Plate II. *Helix*: penis with flagellum. The berillium and barium ions, acting together, stimulate strongly the automatism of penis.

Helix: heart. Under the influence of Mn^{++} , the barium spasm is counteracted, but the joint effect of both ions is accompanied by a strong decrease of frequency and an increase of amplitude.

Helix: intestine. The strong decrease of tonicity, influenced by Mn^{++} is obvious, as well as the stimulation of automatic peristalses.

PLATE I

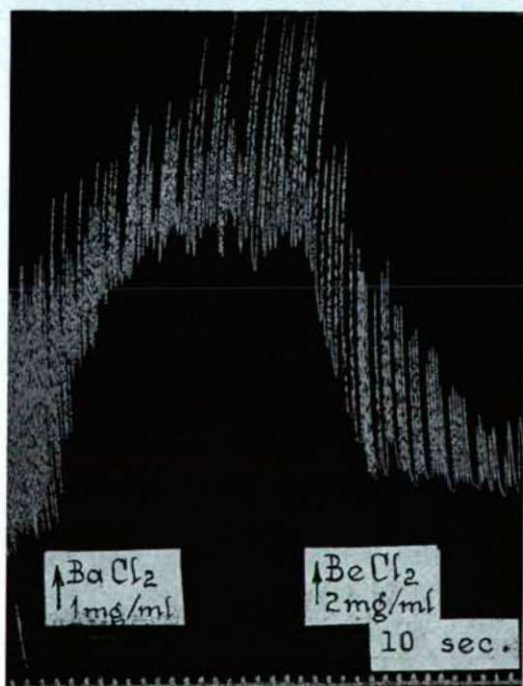
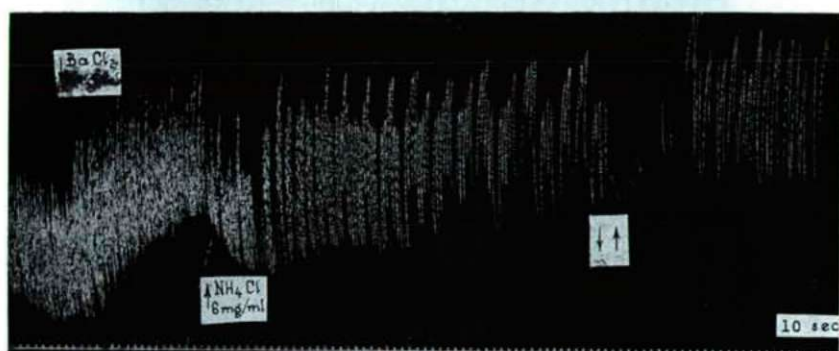
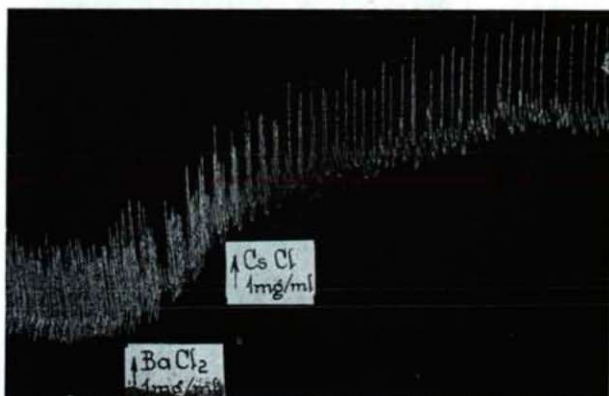


PLATE II

