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KIDNEYS ADAPTATION OF KID AND CALF NEWBORNS TO NATREMIA REGULATION

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ABSTRACT

The experiment was carried out by means of clearance methods on 8 kids of Biała Szlachetna breed and 10 calves of black–white breed in the period of the first 14 days of their life. The goal of the examination was to specify the kidneys ability to regulate natremia. It was proved that goats' and calves' kidneys have the ability to keep natremia as early as from the moment of birth, yet the dynamics of kidneys functional changes in this period differs depending on the species of animal. The stabilisation of glomerular filtration rate and tubular sodium resorption in kids` kidneys take place in the first week of their life. It is the most difficult period to keep water-electrolyte homeostasis of organisms of these animals. Low effectiveness of sodium saving in calves kidneys was found, which may be the reason for limited adaptative abilities of these animals in their neonatal period.

Key words: kidneys, neonatal period, adaptation, glomerular filtration rate, tubule resorption, excretion, sodium, natremia

INTRODUCTION

The postnatal period is, from the physiological point of view, one of the most difficult ones in the life of an organism, because of the necessity for fast adaptation of an organism to an entirely different and aggressive external environment. After birth, the organism of a majority of animals is not fully mature yet. Newborns show a number of distinctions, both morphological and functional in comparison to an adult individual.

The examination of kidneys activity in newborns of numerous species prove that kidneys are efficient as early as after birth. Yet, kidneys activity in the neonatal period, in comparison to the period of full somatic maturity, demonstrates considerable differences: the renal blood flow is lower, the plasma filtration in glomerules is decreased, and the processes of resorption and secretion in kidney tubules are less efficient – especially of water and electrolytes. It is confirmed by examination carried out in children [7,23], piglets [1,8], lambs [3,13] and puppies [15,19] in their neonatal period.

Osmotic equilibrium of systemic fluids depends mainly on the kidneys ability to save or (and) excrete sodium, the main electrolyte of extracellular fluid. It was proved, in different animal species, that in the early postnatal period the secretory-resorptive efficiency of kidney tubules is lowered. The functional immaturity of kidneys in the neonatal period makes their functional reserve very narrow. It results in limited adaptative possibilities, and keeping the water-electrolyte homeostasis in the first days after birth is one of the conditions of the organism survival.

Calves and kids are rated among animals of high postnatal somatic maturity. Yet, even in these animals kidneys show lower efficiency in keeping stability of water-electrolyte environment in comparison to adult animals. Taking the above into consideration and the fact that the dynamics of adaptative changes closely depends on time (postnatal development rate), a decision was made to observe the kidneys ability of two species of ruminants (calves and kids) to regulate natremia in the first 14 days of their life.

MATERIAL AND METHODS

The experiment was carried out by means of clearance methods on 8 kids of Biała Szlachetna breed (Phot. 1) and 10 calves of black-white breed from the moment of birth till the 14^{th} day of their life. The kids were kept in coops together with their mothers, and during the time of urine collection they stayed in cages. As for calves, they stayed in individual cages. The animals were fed with colostrum and mother's milk; they had free access to fodder (hay, straw) and water. The examination was always commenced in the morning hours (8.00 – 9.00). The animals were weighed each day. The blood for examination was taken from external cervical vein, was protected against clotting with heparin, and then centrifuged. The obtained plasma and urine (collected in order to determine minute diuresis) was frozen (-20°C) until the time of conducting analysis. The examination was carried out each day till the 8^{th} day of life, and then on the 10^{th}, 12^{th} and 14^{th} day. The following were determined in the blood and urine:

- sodium concentration (by means of flame photometry method – Flapho 4)
- endogenic creatinine concentration (by means of Folina-Wu method).

The value of tubular sodium resorption and a load of sodium excreted with urine were calculated. On the basis of detailed results the mean values and standard deviations were calculated. The results were standardised for 1 kg of body weight. For the purpose of observing the significance of differences, the obtained results were subject to statistic calculations by means of the analysis of variance method.

Phot. 1. Kids of Biała Szlachetna breed

RESULTS AND DISCUSSION

Glomerular Filtration Rate (GFR) in kids on the first day after birth was low and amounted to 1.69 ml/min./kg b.w. and significantly increased to the 5th day of life, to the value of 2.68 ml/min./kg b.w. These differences were statistically confirmed ($p<0.01$) (Table 1). GFR of newborn calves was at a similar level (1.75 ml/min./kg b.w. on the 1st day of life) and increased as the animals grew (3.32 ml/min./kg b.w. on the 12th day of life). The observed changes of glomerular filtration were statistically significant ($p<0.01$ i $p<0.05$).

An increasing tendency of glomerular filtration rate in the first days of life was also observed in piglets [1,10] and lambs [3]. Low glomerular filtration in the first period of life is a result of lower morphological maturity of cells forming the filtration barrier. It was demonstrated that pores in piglets in endothelium of glomerulus capillary vessels are “closed” by a thick basement membrane [9,26]. The increase of filtration after birth is considered to take place also thanks to the increase of renal bodies diameter and the size of pores in the filtration membrane. Many authors believe that low filtration in the early postnatal period is conditioned by low filtration pressure, particularly on the first 2-3 days of life.

As results from the above, the increasing tendency of plasma filtration in renal glomerules always takes place, while the dynamics of these changes is diversified and depends on the animal species.

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Table 1. Endogenic creatinine clearance (GFR – ml/min./kg b.w.)

Specification		Days of life										
		1	2	3	4	5	6	7	8	10	12	14
		A	B	C	D	E	F	G	H	I	J	K
KIDS	$\bar{x}$	**1.69**	**1.94**	**2.12**	**2.38**	**A 2.68**	**2.53**	**2.29**	**1.93**	**2.23**	**1.83**	**2.52**
	SD	0.47	0.40	0.27	0.54	1.22	0.79	0.90	0.95	0.93	0.49	1.06
CALVES	$\bar{x}$	**1.75**	**1.87**	**a 2.07**	**aB 2.12**	**ab 2.24**	**abC 2.33**	**a-d.E 2.50**	**a-f.G 2.70**	**a-h 3.12**	**a-h.J 3.32**	**a-h 3.21**
	SD	0.24	0.25	0.24	0.23	0.24	0.26	0.25	0.31	0.38	0.35	0.29

Significance level: p<0.01 – A, B ... and p<0.05 – a, b.....

Tubular sodium resorption (TR_{Na}) in examined kids demonstrated highly significant increase ($p<0.01$) in the period from birth (97.31 %) to 4^{th} –5^{th} day of life (99.48 %), and then remained at a stabile level, in the range from 99.14 to 99.55 % (Table 2). An opposite tendency of TR_{Na} changes was observed in calves. Sodium resorption in the first 3-4 days of life of these newborns was high, like in adult individuals (99.69% - 99.87%) and decreased with age to the value of 97.78% in the 14^{th} day of life. These results show that the time needed for the stabilisation of renal sodium resorption, an electrolyte determining the molality of extracellular fluid, at a level observed in adult animals, is very short in kids (the first week of life). On the other hand, the resorption efficiency of this electrolyte in calves` kidneys is significantly lower.

It seems that the relatively high Na^+ sparing found in the experiment in the first days of calves' life might have been regulated by mother's mineralocorticoids. This thesis is confirmed by Hansen and Smith's observations [14], who proved in experiments on human newborns that the reserve of mineralocorticoids obtained during the fetal development from mother's organism provides the electrolyte equilibrium in the early postnatal period. Also other authors conclude that the increased aldosterone concentration in the blood of newborns may be connected with aldosterone "passing" from mother's circulation directly before labour [7,11]. Sodium resorption efficiency decreasing as calves grew might have been related to the immaturity of transport systems in renal tubular cells. The leading molecular mechanism protecting the active sodium transport is Na,K–ATP-ase [25]. It was proved that during ontogenesis the activity of this enzyme increases. As animals grow, the surface of cell membranes also gets enlarged, while keeping a standard number of enzymatic units falling per unit of membrane surface [24]. The regulation of sodium balance also depends on the balanced activity of natriuretic (e.g. ANP) and anti-natriuretic (e.g. of renin-angiotensin-aldosterone system) "factors" on kidneys. The changes of renal hemodynamics also play a significant role.

Table 2.Tubular sodium resorption (TR_{Na} - %)

Specification		Days of life										
		1	2	3	4	5	6	7	8	10	12	14
		A	B	C	D	E	F	G	H	I	J	K
KIDS	$\bar{x}$	**97.31**	**A 98.64**	**A 99.03**	**AB 99.43**	**ABC 99.48**	**ABC 99.53**	**AB 99.39**	**ABC 99.55**	**ABC 99.46**	**AB 99.33**	**AB 99.14**
	SD	1.74	0.58	0.52	0.20	0.43	0.19	0.26	0.16	0.40	0.46	0.65
CALVES	$\bar{x}$	**99.87**	**99.56**	**99.66**	**99.69**	**99.34**	**99.14**	**98.86**	**J.K 99.50**	**A-H 97.37**	**c.d 98.52**	**A-F.g.h 97.78**
	SD	0.04	0.17	0.19	0.25	0.33	0.57	0.42	0.38	0.30	0.30	0.29

Significance level: p<0.01 – A, B ... and p<0.05 – a, b.....

The changes of sodium charge volume excreted with urine were an effect of filtration changes in renal glomerulus and resorption in tubules. The highest volume of sodium was excreted by kids in the first 24 hours of their life (5.68 µmol/min./kg b.w.). On the following days the decrease of Na^+ excretion with urine was observed, and from the 4^{th}-5^{th} day of life the sodium charge excreted with urine stabilised and ranged from 1.19 to 2.41 µmol/min./kg b.w. (Table 3). The observed differences were statistically significant (p<0.01). An opposite direction of changes was observed in calves, i.e. the increase of sodium excretion with urine. The lowest value was noted in the first 24 hours after birth (0.22 µmol/min./kg b.w.), and the highest in the 10^{th} day of life (4.30 µmol/min./kg b.w.). The observed differences were confirmed statistically (p<0.01 and p<0.05).

Table 3. Sodium excretion with urine (UV_{Na} - µmol/min./kg b.w.).

Specification		Days of life										
		1	2	3	4	5	6	7	8	10	12	14
		A	B	C	D	E	F	G	H	I	J	K
KIDS	$\bar{x}$	**5.68**	**A 3.68**	**A 2.91**	**AB 1.91**	**ABC 1.65**	**ABC 1.59**	**AB 1.92**	**ABC 1.19**	**ABC 1.59**	**AB 1.78**	**ABH 2.41**
	SD	1.05	1.56	1.30	0.59	0.73	0.75	1.05	0.58	1.15	1.31	1.53
CALVES	$\bar{x}$	**0.22**	**a >0.79**	**a 0.66**	**aB 0.60**	**a-d 1.22**	**a-e 1.48**	**a-f 1.92**	**0.91**	**a-g.k 4.30**	**a-i.k 2.57**	**a-j 3.44**
	SD	0.07	0.19	0.15	0.12	0.25	0.23	0.28	0.21	0.28	0.34	0.29

Significance level: p<0.01 – A, B ... and p<0.05 – a, b.....

The indicator of efficiency of renal homeostatic mechanisms is the electrolyte concentration in blood and plasma molality, dependent mainly on sodium concentration. The concentration of Na^+ in the blood of examined kids was stabile, and ranged from 142.62 to 148.37 mmol/l. The observed changes were not statistically significant (p<0.05) (Table 4). Neither were any statistically significant changes (p<0.05) observed in concentration of this electrolyte in blood plasma in calves, yet sodium concentration in calves' blood was considerably lower than in kids'. The majority of authors, when examining the mineral profile of newborns' blood of other animal species in the postnatal period, did not observe any rapid changes in sodium contents in plasma [4,17], either. Other works [20,21,22], [5,6], [12], [17,18], [2], [16] indicate the oscillations of the main electrolytes and blood osmotic pressure in the postnatal

period. However, according to these authors, they are within the ranges accepted as physiological norms, and indirectly indicate efficient functioning of mechanisms protecting electrolyte homeostasis of the organism in the neonatal period.

Table 4. Sodium concentration in blood plasma (P_{Na} – mmol/l)

Specification		Days of life										
		1	2	3	4	5	6	7	8	10	12	14
		A	B	C	D	E	F	G	H	I	J	K
KIDS	$\bar{x}$	**144.40**	**146.06**	**145.50**	**146.00**	**142.62**	**143.37**	**143.78**	**146.00**	**143.25**	**147.94**	**148.37**
	SD	13.14	15.03	17.74	14.48	15.80	17.09	17.13	13.58	8.10	14.40	8.78
CALVES	$\bar{x}$	**128.50**	**129.10**	**128.60**	**127.00**	**127.80**	**127.70**	**128.00**	**119.60**	**127.80**	**134.67**	**127.50**
	SD	1.60	2.10	2.30	3.20	2.50	2.10	2.40	2.72	2.49	2.50	3.00

Significance level: p<0.01 – A, B ... and p<0.05 – a, b.....

The presented results suggest that the kidneys of newborns, of both kids and calves, regulate natremia efficiently in the first two weeks of life and can adjust their activity to the current needs of the organism. It is an indirect proof of adaptative possibilities of these animals. The results of the presented experiment indicate, however, considerable species differences in the dynamics of kidneys' functional changes. The kidneys of kids at the moment of birth seem to be more functionally mature in comparison to the kidneys of calves.

CONCLUSIONS

1. The kidneys of kids and calves have the ability to keep natremia as early as in the neonatal period.
2. The dynamics of kidneys' functional changes in the neonatal period varies depending on the animal species.
3. The stabilisation of glomerular filtration rate and sodium tubular resorption in the kidneys of kids takes place in the first week of life. It is the most difficult period for keeping the water-electrolyte homeostasis of the organism of these animals.
4. Low efficiency of sodium saving in the kidneys of calves in the early postnatal period may constitute a reason for limited adaptative possibilities of these animals.

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