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Calcium-47 Kinetics in Cattle as a Function of Age^{1,2}

by

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ABSTRACT

Eleven non-pregnant, non-lactating cattle ranging in age from 6 months to 9 years were used in a ^{47}Ca kinetic study of the readily exchangeable calcium pool as a function of age. After analysis of the plasma specific activity curves with increasing time, the kinetic parameters of this pool were shown to change as follows: pool size increased from 40-60 gm at 6 months to 90 at 12 months and then decreased to a value of about 35 gm in older cows; pool biological half-life fell slightly from 6 months to about 20 hr at 12 months and subsequently rose to a maximum of 35 to 40 hr in mature animals; and pool transfer rate, an index of turnover, increased from 6 to 12 months to a high of about 2.5 gm/hr and gradually declined to a low of approximately 0.75 gm/hr in mature cows. These results confirmed earlier findings in goats. When pool size was considered on a per Kg body weight basis, a maximum of 10 gm/Kg was observed in cattle at 6 months and was followed by an exponential decline to a minimum of 0.2 gm/Kg in older animals. The same effect was observed when the pool transfer rate was considered with respect to body weight. The transfer rate in gms Ca/hr./100Kg body weight ranged from 1.2 to 0.2 in cattle 6-12 months to 9 years of age, respectively. Blood calcium concentrations fell only slightly but significantly with increasing age. A brief discussion of the possible effects of growth and the onset of puberty on the readily exchangeable calcium pool is made.

INTRODUCTION

The percentage of exchangeable bone calcium has been estimated by a combined balance and ^{45}Ca tracer experiment to decrease four to twelve fold in cows between six months and about fifteen years of age (2). Since the age-related changes in the calcium metabolism of dairy cows is so important, especially with respect to parturient hypocalcemia, it was considered that more precise measurements of the readily exchangeable calcium pool (RECaP) would be of value, particularly its turnover. This pool consists of calcium in extracellular fluids, soft tissues and a small portion of bone. A theoretical discussion of this pool is available in the literature (5).

Because of some limitations in the use of the beta-particle emitting ^{45}Ca and the relative ease in handling the gamma photon emitting ^{47}Ca , the latter radionuclide was chosen to investigate the size in gm, biological half-life in hr and transferrate, an index of turnover in gm per hr of the RECaP in normocalcemic, non-pregnant, non-lactating cattle as a function of age.

METHODS

The eleven non-pregnant, non-lactating cattle which were used in this experiment ranged from six months to nine years of age. Of the group, three were male and eight were female, and the breeds represented were: Holstein, Hereford, Jersey, Guernsey, and Brown Swiss Cross (Table I).

Before and during the experiment the animals were fed a loose hay and grain ration and were provided water ad libitum. The health of the animals was unremarkable and housing was adequate.

Each animal was intravenously injected with a 60 to 125 μCi dose of ^{47}Ca which contained less than one-half mg total calcium. Blood samples (50 ml) were withdrawn within an hour post-injection and at several other times up to 192 hr

post-injection. Determinations of stable calcium and radio-calcium were made as reported in a previous paper (1). The specific activity of each sample, expressed as % of injected dose per gm Ca, was plotted, as illustrated by the example in Figure 1, as a function of time post-injection. Pool size (E) in gm, biological half-life ($T_{1/2}$) in hr and transfer rate (TR) in gm/hr of the RECaP were calculated for each animal from three plots (see references 1 and 5 for further details). TR is calculated by multiplying E by $0.693/T_{1/2}$ and it serves as an index of turnover of the RECaP.

RESULTS

In Table I are listed the E, $T_{1/2}$ and TR values of the RECaP of the different experimental cattle. Also included in the table are the values of these kinetic parameters of a heifer injected first at eight months and subsequently followed to a year of age. These values are no different from similarly aged animals. The changes in E, $T_{1/2}$ and TR as a function of age are plotted in Figures 2 to 4.

Figure 2 shows that E increased from 40 to 60 gm at about six months to a value of 90 gm by one year of age and then fell somewhat gradually to a value of approximately 35 gm in mature cows. There appeared to be no sex difference in animals up to a year and a half in age.

In Figure 3 are illustrated the inverse changes of $T_{1/2}$ as a function of age compared to those observed for E. $T_{1/2}$ fell from 25 to 30 hr. at six months of age to about 20 hr at a year and then rose to values ranging from 30 to 40 hr in mature animals. Again sex appeared to have no effect on this value up to one and a half years of age.

The increase in TR from six to 12 months of age to a maximum of about 2.5 gm/hr and its gradual decline to a minimum of about 0.5 gm/hr by seven

years is graphically presented in Figure 4. Some variation observed in TR is attributed to individual animal variations, in particular $T_{1/2}$, but the pattern of a rising TR to a maximum at one year and then its four-fold slow decay with time is clearly evident.

The changes in all three kinetic parameters, an increase in E, $T_{1/2}$, a slight decrease in $T_{1/2}$ and an increase in TR, in calves from six months to a year of age (Figs. 2-4) are of interest. It should be emphasized that the onset of puberty in cows occurs between six and 10 months, which may explain the maxima in E and TR at a year of age. However, a large increment in body weight, and hence bone mineral mass, occurs during this period, which might also explain the maximal values of E and TR. E is related to body weight in the following way: younger, lighter animals have about 0.5 gm Ca in the RECaP per kg body weight, whereas heavier mature cows have only about 0.2 gm Ca/Kg body weight. These data from mature cows corroborates the findings of mature goats on a per body weight basis (1). When E is plotted as gm Ca in the RECaP per Kg body weight against age, a maximum was observed in cattle at six months and decreased in an exponential manner to a minimum in older animals. With respect to body weight then, E decreases as a function of age. This pattern is also shown when TR is plotted on a per 100 kg body weight basis as a function of age (Fig. 5). A maximum of about 1.2 gm Ca/hr/100 kg body weight is observed in calves 6 to 12 months of age and the value falls to about 0.2 gm Ca/hr/100 kg body weight in mature cattle. The pattern of this plot is mainly a reflection of the changes of E with time.

Total plasma calcium concentration of all animals was approximately 10 mg % (range: 8.9 to 10.4). However, a significant fall ($p < .05$) in mean calcium values was found between 7 animals one and a half years and under (mean 9.8) and 6 animals over one and a half years of age (mean 9.2) by the student-t test.

DISCUSSION

Age of cattle has been shown to have a great influence on the values of the parameters of the RECaP, namely E, $T_{1/2}$ and TR. Animals younger than a year have smaller E, longer $T_{1/2}$ and smaller TR values than animals of a year old, but these differences disappeared when comparison was made on the basis of body weight. Older mature cows have smaller E, longer $T_{1/2}$ and smaller TR values than younger animals. Our findings of changes in E from 90 to 30 gm from one to seven years of age are in close agreement with the age-dependent change in the percent of exchangeable bone calcium found using ^{45}Ca by Hansard et al. (2) who estimated that calves six months of age had two to three times more exchangeable calcium than cows three years of age and older cows had even less exchangeable calcium. However, these authors presented no evidence on the turnover of exchangeable bone Ca.

In addition to a reduction in the amount of exchangeable calcium in cows as a function of age, cows have been shown to have a lowered efficiency of gastrointestinal absorption of calcium with increasing age (3). Diminution of these two major flows of calcium into blood as a function of age may impose a severe challenge to calcium homeostatic regulatory mechanisms in older parturient cows. The amount of readily exchangeable calcium may not be able to meet the rapid demands for calcium during the stressful times of parturition and the initiation of lactation. Parturient hypocalcemia occurs in almost all cows (4) but it is not known yet how the RECaP is affected by the lowered blood calcium concentration. Neither is it known whether bone cells are unresponsive to parathyroid hormone in late pregnancy and early lactation when incipient paretic

cows have been demonstrated to be in negative calcium balance (6). Experiments are in progress to investigate these questions in cows for we know from our studies (1) of goats that dramatic changes in the turnover of the RECaP occur in the peri-parturient goat even though this animal very infrequently undergoes parturient paresis.

The age-related findings of E, $T_{1/2}$ and TR in cows are in good agreement with those observed in goats (1). With respect to changes in the kinetic parameters of the RECaP as a function of age, then, the goat appears to be a good model for the cow. For example, in both the cow and goat, the decline in pool size after one year of age could be due to the rapidly decreasing rate of growth of the skeleton, which probably results in a reduction of the amount of skeletal calcium that is included in the RECaP. In particular, active bone surfaces decrease as a result of decreased remodeling activity prerequisite to growth.

The information on age-related changes in the RECaP of non-pregnant, non-lactating cows should be useful in evaluating the dynamic changes in E, $T_{1/2}$ and TR as a function of gestation, parturition and lactation in bovine animals.

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Table I

Schedule of Experimental Cattle and Kinetic Parameters
- of the Readily Exchangeable Calcium Pool

<u>Cow No.</u>	<u>Breed</u>	<u>Age</u>	<u>Sex</u>	<u>E (gm)</u>	<u>T 1/2 (hr)</u>	<u>TR (gm/hr)</u>	<u>TR (gm/hr/ 100 kg body weight)</u>
1	Holstein	7 yrs	F	30.74	36.34	0.586	0.129
2	Holstein	1 1/2 yrs	M	62.45	25.66	1.687	0.465
3	Hereford	5 yrs	M	47.38	29.83	1.101	0.608
4	Hereford	5 yrs	F	36.06	29.55	0.846	0.170
5	Jersey	7 yrs	F	27.43	39.37	0.483	0.152
6	Jersey	7 yrs	F	35.51	29.43	0.836	0.263
7	Guernsey	1 yr	M	87.08	23.27	2.594	1.433
8	Hereford	6 mon	M	66.88	29.95	1.548	1.138
9	Jersey	9 yrs	F	38.98	27.25	0.991	0.273
10	Jersey	8 yrs	F	25.57	28.47	0.622	0.172
11 ^a	*Gu-Ho x Brn Swiss	8 mos	F	60.64	20.49	2.051	1.063
11 ^b	*	10 mos	F	79.43	22.06	2.496	1.067
11 ^c	*	12 mos	F	53.26	18.44	2.002	0.723

^{a,b,c} Repeated measurements in same animal at different ages.

*Guernsey-Holstein x Brown Swiss

Figure Legends

1. Blood ^{47}Ca specific activity curve as a function of time in a cow. Note the relatively linear portion of the curve between roughly 24 and 80 hours.
E, $T_{1/2}$ and TR of the RECaP are calculated from this portion of the curve by extrapolation to time (see text).
2. Plot of E as a function of age of cattle.
3. Plot of $T_{1/2}$ as a function of age of cattle.
4. Plot of TR as a function of age of cattle.
5. Plot of $\text{TR}/100$ kg body weight as a function of age of cattle.

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Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5