Review Article

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Acid-Base Control and Osteoporosis: A Review

Barzel US*

Albert Einstein College of Medicine, Bronx, New York, USA

***Correspondence:** Uriel S Barzel, Medicine (Endocrinology), Albert Einstein College of Medicine, Bronx, New York, USA, E-mail: uri@barzel.org

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Abstract

Bone functions as a store of alkali buffer, and is consumed over time if the organism is continually exposed to an acid-producing diet. This may result in osteoporosis. Alkali therapy may protect the bone, and may prevent the development of osteoporosis.

Keywords: Acid-base, Bone, Osteoporosis, Alkalinization

Introduction

The purpose of this brief review is to revisit the proposition that osteoporosis is the result of the significant role that bone plays in the control of acid-base regulation of the organism, primarily as a source of buffer. The implication of this theory for the development of osteoporosis, the potential of osteoporosis treatment, and its prevention will be examined.

Bone is a large reservoir of calcium salt. It responds dynamically to changes in acid-base of the internal milieu. When calcium or other alkali salts are absorbed from the diet, they are stored as bone tissue. When the body is challenged by a diet providing excess of acid, bone resorption contributes to the maintenance of blood pH.

I will first describe animal studies that provide a proof of concept. I will follow with selected human studies that examine this proposition.

Animal studies

Adult male rats were fed a regular or low calcium diet and distilled water or 2% ammonium chloride for one year [1]. Femoral bone length, volume, fat free solid, density, and total bone calcium were recorded (Figure 1). Bone length

and volume increased equally in all group, as compared with initial, control values. Bones of animals on a regular diet gained fat free solid and calcium. Those receiving 2% ammonium chloride failed to increase either volume or total calcium content. Their bone density was lower as well. Animals receiving a low calcium diet had lower femoral calcium content and lower density. Those receiving low calcium diets and 2% ammonium chloride had significantly lower femoral fat free solid, calcium, and bone density. Figure 2 provides a histological picture of the effect on rat bone of low calcium diet plus acid in comparison with bone of an animal on regular diet and water.

This study was repeated (Figure 3) but extended to include two additional groups: one on 0.5% NaOH and the other on a combination of 0.25% NaHCO₃ and 0.3% KHCO₃ [2]. The effect of ammonium chloride and of low calcium diet was reproduced. Animals on a low calcium diet receiving the alkali in their liquids had higher fat free weight and calcium. In fact, the animals receiving the combination of potassium and sodium salts had bone fat free weight and bone calcium that were not statistically different from those of animals on a regular diet and distilled water.

Thus, it is clear that long term exposure to an acid intake can negatively affect bone. Alkali administration

can protect bone even when the diet is deficient in calcium.

Figure 1: Effect of ad lib ingestion of regular or low calcium diet, and water or ammonium chloride on the following characteristics of the femur: length, fat free solid, density, volume, **calcium**.

Figure 2: Histologic section of a long bone from an animal receiving regular diet(left) and low calcium diet with 2% ammonium chloride (right).

Human studies

Tabatabai et al. [3] ran a three-year study in which 2267 elderly persons, female and male aged 74 ± 3 years, had bone density measurements three years apart. There was no intervention otherwise. When the bone density examination was repeated, each person had an examination of arterialized venous bicarbonate.

The investigators were able to demonstrate (Figure 4) that those with lower bicarbonate blood level lost bone density, while those with the highest blood bicarbonate

had an increase in their bone density. Thus, they demonstrated that acid-base state influences spontaneous bone resorption and bone formation.

Figure 3: Effect of ad lib ingestion of regular or low calcium diet, and water, acid, or alkali on fat free weight and calcium content of the femur.

Figure 4: Annualized rate of change in BMD (percent per year) by quartile of arterialized venous bicarbonate adjusted for age, sex, race, clinic site, smoking, and eGFR.

The laboratory of A. Sebastian [4] reported in placebo-controlled study of potassium bicarbonate ingestion that 170 post-menopausal women, over a three-year period, maintained a persistent alkalinization of the urine, and lower urinary calcium (Figures 5,6,7).

Figure 5: Effect of KHCO_3 ingestion on urine pH.

Placebo vs.	ΔUCaV mg/1000 mg Cr	P value
KHCO_3 , 90 mmol/d	-27.6	<0.001
KHCO_3 , 60 mmol/d	-25.4	0.001
KHCO_3 , 30 mmol/d	-17.4	0.017

Figure 6: Effect of KHCO_3 ingestion on urinary calcium vs placebo.

Figure 7: KHCO_3 dose-dependent urine Ca-lowering.

In a study from the laboratory of C. Sakhaee et al. [5], 18 women with mean age of 58, alkali administration resulted in reduction of bone resorption markers (Figure 8).

In a placebo-controlled study of 52 subjects, age 55 years or older, of ingestion of potassium citrate over 6 J Bone Biol Osteoporosis, 4(1): 99-102 (2018)

months, Moseley et al. [6] demonstrate a significant reduction in urinary calcium, significant improvement of calcium balance, and reduction of N-telopeptide (bone resorption marker).

Figure 8: Urinary calcium and bone resorption markers in response to alkali therapy.

*Denotes statistical significance at $P < 0.0083$.

Similarly, Dawson-Hughes, in a placebo-controlled study of 171 women 50 years old or older [7], bicarbonate ingestion reduced urinary calcium and significantly lowered bone resorption markers.

Discussion

According to our postulate, persons with acid producing diets resorb bone for its buffering capacity. If the acid loading and the resorption of bone is chronic, the amount resorbed daily may not be large, but, if continued for many years, may cause significant bone loss: Assuming an excess of 40 mg calcium resorbed from bone and excreted in the urine daily, over 40 years the amount of calcium lost will be greater than half the total calcium in a skeleton of an average healthy young adult. This undetectable loss of bone and inapparent excess urinary calcium are not clinically recognizable. In fact, a person who has been losing minimal amount of bone chronically, may have microscopically normal bone, but the total bone tissue is so low that a fracture may occur with little or no trauma. By definition, this is osteoporosis.

Summary

These studies support our theory that maintenance of acid-base balance has a significant and lasting effect on calcium and bone metabolism and may play a significant role in the development of osteoporosis. We believe that alkali therapy may be useful in the treatment of

osteoporosis. No less important, alkali ingestion may be useful in the prevention of osteoporosis.

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