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Relationship between the incidence infection stones and the magnesium-calcium ratio of tap water

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Summary. In a previous study we showed that the magnesium–calcium ratio of tap water is negatively correlated with the incidence of calcium-containing urinary stones. In this study we examined the relationship between the incidence of struvite stones, water hardness and the regional geological features on the basis of our previous study and an epidemiological study of urolithiasis performed in Japan. The magnesium–calcium ratio of tap water was found to correlate positively with the incidence of struvite stones. The tap water magnesium–calcium ratio was high in regions of basalt and sedimentary rock and was low in granite and limestone areas. The incidence of struvite stones in the regions of basalt and sedimentary rock was higher than that in the granite and limestone areas. Thus, this study suggested that the incidence of struvite stones is related to the magnesium–calcium ratio of tap water and to the regional geology, as is the case for calcium-containing stones.

Key words: Geological features – Magnesium – calcium ratio – Struvite – Tap water – Urinary stones

There is controversy regarding the relationship between urinary stones and the hardness of drinking water. Some investigators have reported a higher incidence of urinary stones in soft-water areas [1, 8], while others have failed to find any significant correlation between water hardness and urinary stones [2, 7]. One possible reason is that most studies assessed only the calcium concentration of tap water as a measure of water hardness, while our previous study showed that there was little relationship between the incidence of urinary stones and the calcium concentration of tap water [5]. However, there was a negative correlation between the incidence of urolithiasis and the magnesium–calcium ratio of tap water. Furthermore, the incidence of urolithiasis was high in granite and limestone geological regions with a low tap water magnesium–calcium ratio, but was low in sedimentary rock and basalt areas with a high magnesium–calcium ratio.

Most previous investigations have addressed the relationship between water hardness and the incidence of calcium-containing stones such as calcium oxalate and calcium phosphate. However, urinary stones consist not only of calcium-containing stones but also of other components such as struvite and uric acid, even though these only account for 20–25% of stones in industrialized countries including Japan [6, 11]. There is no literature available concerning the relationship between the components in tap water and the incidence of non-calcium-containing urinary stones. Our previous study showed that the incidence of urinary stones was related to the magnesium–calcium ratio of tap water, and a high magnesium–calcium ratio is also suspected to affect the formation of magnesium-containing stones such as magnesium ammonium phosphate (struvite). Accordingly, we examined the relationship between the incidence of struvite stones and water hardness on the basis of our previous study and a recent epidemiological survey of urolithiasis in Japan [11].

Materials and methods

Tap water was collected at 85 major cities throughout Japan using special containers for metal assay. The calcium and magnesium concentrations were determined by atomic absorption spectrometry. The nature of the soil at the water sources and their feeding rivers was determined using a map issued by the Japanese Ministry of International Trade and Industry (Geological Survey of Japan). The above methods were the same as those used previously [5]. The incidence of upper urinary tract stones in japan was calculated on the basis of the results of a survey carried out in 1988 by Yoshida and Okada with the cooperation of the Japanese Urological Association [11]. The relationship between the incidence of urolithiasis and the nature of the water and soil was examined by classifying Japan into 17 geological districts.

Spearman's correlation coefficient was used for statistical analysis.

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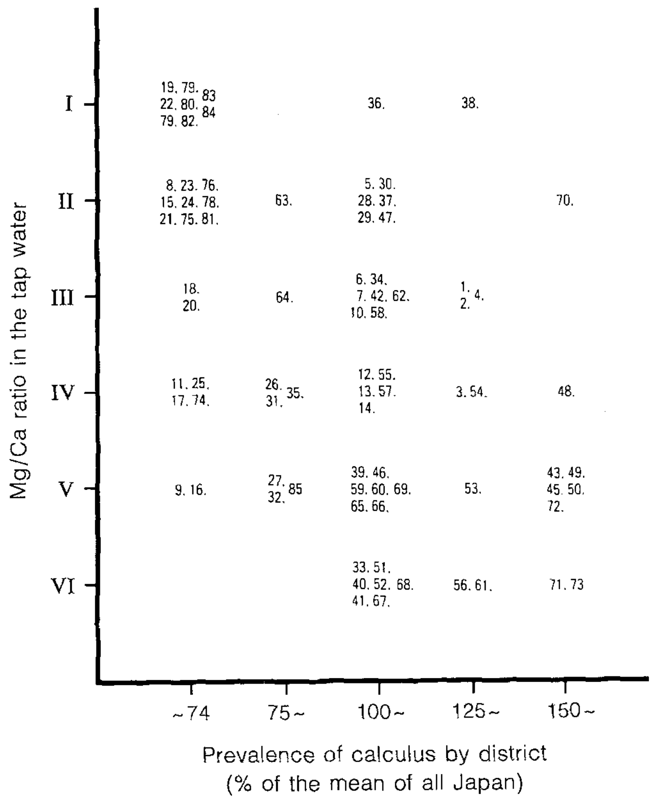

Fig. 1. Negative correlation between the incidence of upper urinary tract stones and the magnesium–calcium ratio of tap water ($P<0.01$); $r=-0.470$; $P<0.01$. *Numbers* indicate the cities where tap water was measured and are the same as in the previous survey [5]

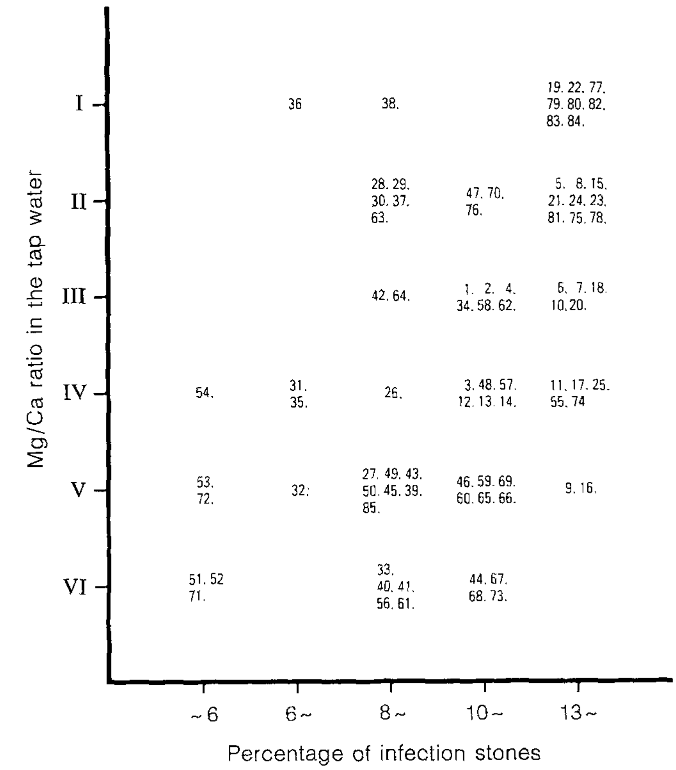

Fig. 3. Positive correlation between the incidence of infection stones and the magnesium–calcium ratio of tap water ($P<0.01$)

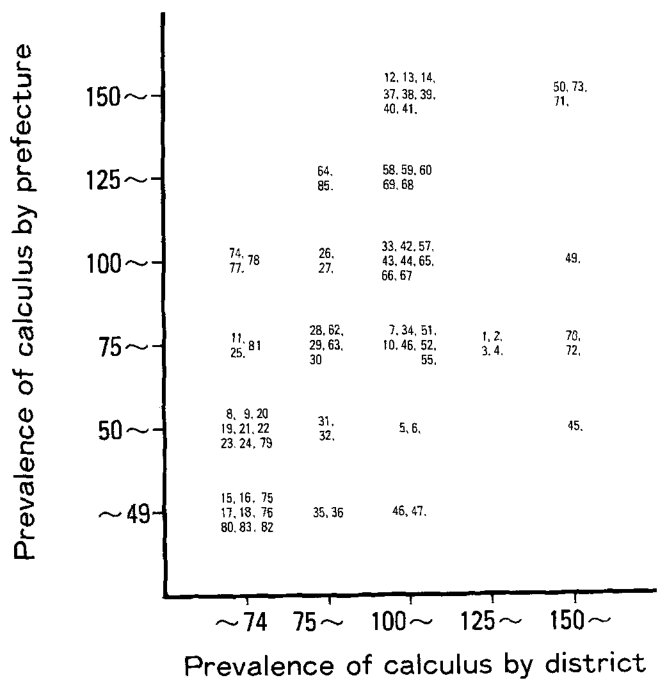

Fig. 4. The prevalence of urolithiasis in Japan by prefecture in 1977 [10]; $r=0.541$ was similar to that of urolithiasis by district in 1988 [11]

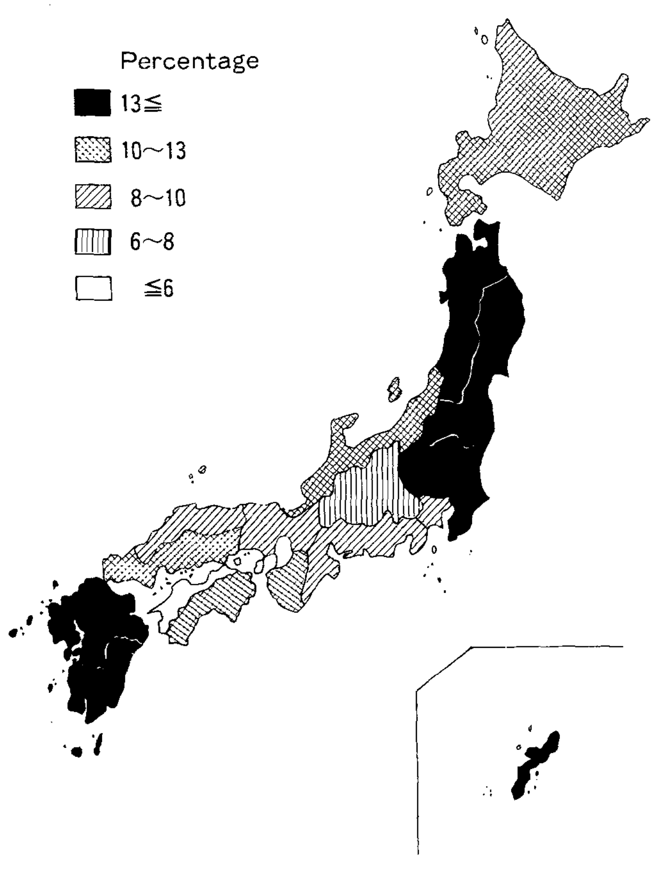

Fig. 2. Seventeen geological districts were divided into five groups according to the incidence of infection stones [7] $r=0.481$; $P<0.01$

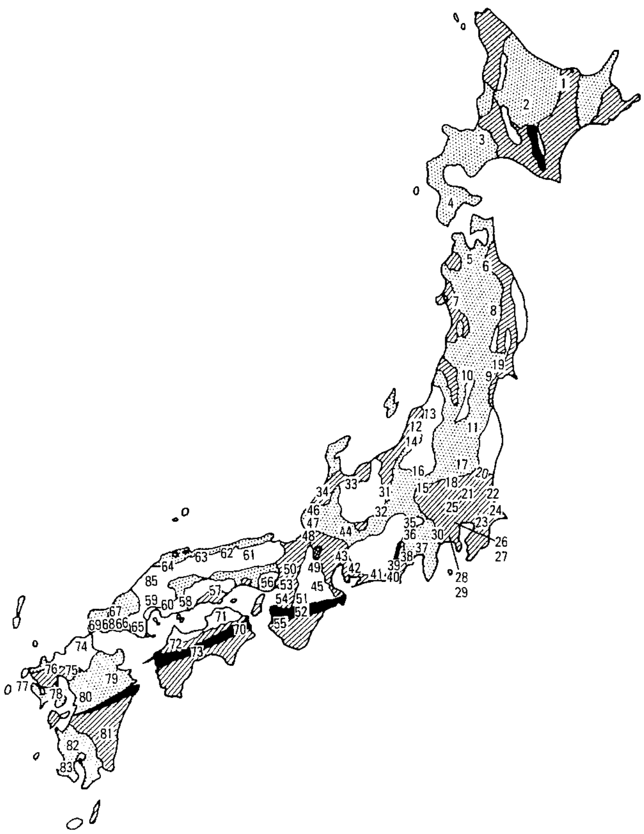

Fig. 5. Geological features of Japan. *Numbers* indicate the cities where tap water surveyed. ▨ Sedimentary rock areas; ▩ basalt areas, ▬ metamorphic rock areas; ▭ granite areas; ▦ limestone areas

Results

The range of calcium and magnesium concentrations in tap water was 0.22–0.86 mg/dl and 0.08–1.28 mg/dl, respectively. Calcium or magnesium alone were not correlated with the incidence of urolithiasis. The 85 cities were classified into six groups according to magnesium-calcium ratio of their tap water. The incidence of all kinds of upper urinary tract stones was low in the areas where the magnesium-calcium ratio of tap water high ($P<0.01$) (Fig. 1). Figure 2 shows the percentage of infection stones classified into five groups in the 17 districts. There was a significant positive correlation between the percentage of infection stones and the magnesium-calcium ratio of tap water in each city ($P<0.01$) (Fig. 3), although there was no relationship between infection stones and calcium or magnesium levels per se.

In the epidemiological study performed in 1988 [11], data were collected from 81% of the urological departments in Japan. The 1988 survery data on the mean incidence of urolithiasis in Japan were almost the same as the results of a previous survey performed in 1979 [10] (Fig. 4).

The geological features were classified into five categories (granite, basalt, sedimentary rock, metamorphic rock and limestone) in accordance with the geological survey map of Japan (Fig. 5). The incidence of infection stones was generally high in regions of basalt and sedimentary rock and low in granite and limestone areas (Fig. 6).

Discussion

In this study, the major findings were as follows: As in our previous study, there was a negative correlation between the incidence of all kinds of upper urinary tract stones and

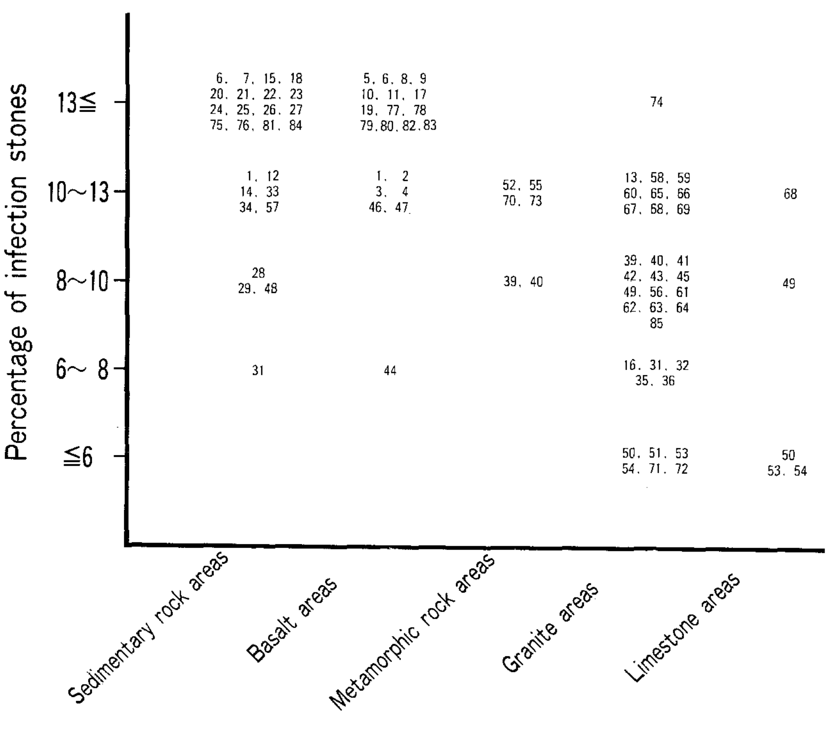

Fig. 6. Relationship between geological features and the incidence of infection stones. *Numbers* indicate the cities surveyed. Ten cities are marked twice because the tap water was obtained from two or more geological regions

the magnesium–calcium ratio of tap water. In addition, there was a positive correlation between the incidence of infection stones and the tap water magnesium–calcium ratio.

In industrialized countries, about 75–80% of upper urinary tract stones contain calcium [6]. In the country-wide epidemiological study by Yoshida and Okada [11] 79.4% of the patients with urolithiasis in Japan had calcium oxalate and/or calcium phosphate stones. 7.4% had magnesium ammonium phosphate stones. 5.2% had uric acid stones, and 1% had cystine stones. It is known that magnesium present in urine as a bivalent cation that competes with calcium for binding and has an inhibitory effect on the formation of calcium stones. Thus, the magnesium in tap water is considered to prevent the formation of calcium-containing stoned [9]. In fact, our previous and present studies showed that the incidence of upper urinary tract stones was closely correlated with the magnesium–calcium ratio of tap water and with the geology of each of the areas studies. On the other hand, the high concentration of magnesium in tap water is assumed to promote the formation of magnesium-containing stones such as magnesium ammonium phosphate stone. For this reason, we investigated the relationship between the magnesium concentration of tap water and the incidence of magnesium ammonium phosphate stones. The incidence of magnesium ammonium phosphate stones in this study was determined by a survey done by the Japanese Urological Association [11] and the majority of infection stones were found to be magnesium ammonium phosphate stones.

Our previous study indicated that the magnesium–calcium ratio of tap water was related closely to the geological features of a region. This study showed that the incidence of magnesium ammonium phosphate stones was high in regions of basalt and sedimentary rock, and was low in granite and limestone areas. The mean magnesium–calcium ratios of tap water in the basalt and sedimentary rock regions were high (0.7 and 1.3, respectively), while the ratios for granite and limestone areas were low (0.3 and 0.1, respectively) [5]. These data suggest that the incidence of magnesium ammonium phosphate stones was also related to the regional geology, as is the incidence of calcium-containing stones.

Is it well known that many factors such as diet, sex, age and climate influence the formation of calcium-containing or magnesium ammonium phosphate stones. The main factor contributing to the formation of magnesium ammonium phosphate stones is infection of the urine and renal parenchyma by urease-producing bacteria which hydrolyse urea to ammonia [3]. Both urinary tract infection and magnesium ammonium phosphate stones are more common in females than in males [10, 11]. The high incidence of calcium stones in industrialized countries is ascribed to a diet containing large amounts of animal protein, while the incidence of magnesium ammonium phosphate stones is high in developing countries [4]. According to the epidemiological study of Yoshida and Okada [1] the incidence of magnesium ammonium phosphate stones was lower in Tokyo than in its surroundings, although both regions were sedimentary rock areas and had a high magnesium–calcium ratio of tap water. One possible reason is that the inhabitants of Tokyo are younger and favour European-style meals over typical Japanes food.

The intake of magnesium and calcium from tap water and that used in cooking is only 10–20% of the total dietary intake for the Japanese population. However, the adverse effect of an imbalance of calcium and magnesium intake may only become noticeable after many years of drinking the tap water of a particular region. Although magnesium has an inhibitory effect on the formation of calcium-containing stones, patients with urinary tract infection or an indwelling catheter should probably be encouraged to drink water containing low levels of magnesium.

In this study we examined the relationship between water hardness and the incidence of struvite stones in upper urinary stone. We ignored lower urinary stones because these account for only 5% for stones in Japan, and the main phatogenesis of lower urinary stone is urinary obstruction and infection.

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