Original Articles

99mTc-MDP Accumulation Mechanisms in Bone:
Basic Study on the Adsorption onto Hydroxyapatite

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The accumulation mechanisms of technetium-99m methylene diphosphonate (99mTc-MDP) were investigated using hydroxyapatite powder and various phosphates. After reaction with 99mTc-MDP, radioactivity was analyzed using a scintillation counter. The adsorption of 99mTc-MDP onto hydroxyapatite occurred within 30 sec, and was not temperature dependent at 0-95°C. There was no change in the adsorption of 99mTc-MDP onto hydroxyapatite in 5 or 50mM water-soluble organic compounds (glucose or urea). Anions had a greater effect on adsorption than cations. The only phosphate with adsorption equal to that of hydroxyapatite was calcium pyrophosphate. Adsorption onto calcium hydrogen phosphate was low at a pH of 6.0 in comparison with hydroxyapatite. These findings suggest that the adsorption of 99mTc-MDP onto hydroxyapatite is influenced by the concentration of coexisting anions and by the chemical constitution of the phosphate components.


Introduction

Bone scintigraphy using 99mTc-MDP is an essential bone function test. It is generally believed that bone loss and calcification of bone abnormalities can be detected by conventional radiography when the bone demineralization or hypermineralization is more than 30% to 50%1~3. However, since bone scintigraphy can demonstrate slight changes in bone which cannot be visualized by X-ray radiograms, 99mTc-MDP bone scanning is probably the most effective means of diagnosing early bone disease, determining the extent of bone disease, and detecting bone metastasis of malignant tumors. Although many studies have been done on the clinical use of bone scintigraphy, there have been very few basic studies on the accumulation mechanisms of 99mTc-MDP in bone tissues and lesions3~11. It is generally assumed that
99mTc-MDP is taken up at sites of active metabolic derangement of bone. Although some experimental evidence has been obtained, the mechanisms of accumulation are not completely understood. Elucidation of the mechanisms of 99mTc-MDP accumulation is important for the diagnosis and analysis of bone diseases with bone scans.

In a recent study, Kanishi proposed that the accumulation mechanisms might include both adsorption onto the surface of hydroxyapatite in bone and incorporation into the crystalline structure of hydroxyapatite. Okamoto reported that this adsorption was largely affected by the pH of the surrounding tissues, sodium ions and phosphate compounds, including ATP and GTP. In this study, the adsorption characteristics of 99mTc-MDP were investigated using hydroxyapatite powder and various phosphates to further clarify the mechanisms of accumulation.

Materials and Methods

99mTc-MDP adsorption onto hydroxyapatite

Hydroxyapatite powder (100 mg, Japan Chemical Co. Ltd., Tokyo, Japan) was placed in a test tube with 2 ml of distilled water (pH = 7), and 740 Bq of 99mTc-MDP (Nihon Medi-physics Co. Ltd., Tokyo, Japan) was added (pH = 7). After stirring with a mixer for 10 seconds, the mixture was centrifuged (3000 rpm, 5 min) to terminate the reaction at 30 sec and at 1, 2, 3 and 4 min. The supernatant was then removed, and the resultant compound was washed three times with 5 ml of distilled water. The amount of radioactivity in hydroxyapatite was determined using a well-type scintillation counter.

Effect of temperature on 99mTc-MDP adsorption onto hydroxyapatite

Hydroxyapatite powder (100 mg) was placed in a test tube, 2 ml of distilled water was added to each tube at 0, 15, 37, 60 and 95°C in water baths, and then 99mTc-MDP was added (pH = 7). After stirring with a shaker for 2 h, the mixture was centrifuged (3000 rpm, 5 min) and the supernatant was removed. The resultant compound was then washed three times with 5 ml of distilled water. The amount of radioactivity in hydroxyapatite was determined using a well-type scintillation counter.

Effect of water-soluble organic compounds on 99mTc-MDP adsorption

99mTc-MDP was reacted with hydroxyapatite powder (100 mg) in 5 and 50 mM glucose solutions as well as 5 and 50 mM urea solutions for 2 h (pH = 7), and each solution was centrifuged (3000 rpm, 5 min), then washed three times with 5 ml of distilled water. After washing, the amount of radioactivity in hydroxyapatite was determined. A mixture of 99mTc-MDP and hydroxyapatite in distilled water was used as a control.

Effect of univalent and divalent anions on 99mTc-MDP adsorption onto hydroxyapatite

Hydroxyapatite powder (100 mg) was reacted with 99mTc-MDP in 2 ml of 10, 50, 100, 150 and 200 mM of sodium chloride solution and in sodium sulfate solutions at the same concentrations (pH = 7). After stirring for 2 h, the mixture was centrifuged (3000 rpm, 5 min) and washed three times with distilled water. The amount of radioactivity in hydroxyapatite was determined. A mixture of 99mTc-MDP and hydroxyapatite in distilled water was used as a control.

99mTc-MDP adsorption onto various phosphates

Distilled water (2 ml) was added to 0.6 mmol of each of the following powders:

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