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III. 21 Monochromatic Medical Radiography by Particle Bombardment II

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Introduction

On account of their probable analytic applicability, monochromatic x ray radiography has attracted considerable interest. For instance, mapping of selected elements can be attained if we obtain 2 radiographs with different monochromatic x rays, one above the K-edge and the other below that, and carry out subtraction. Similar elemental imaging can be carried out by absorption edge fluoroscopy. When the objects are large enough, especially when medical objects are considered, intensity of the monochromatic x rays offers a serious problem. From physical limitations, most of the radioisotopic sources are of limited use but for experimental small object analysis. Simulations have been attempted by elaborate filtration of polychromatic x rays<sup>1)</sup>.

Monochromatic radiography using Particle Induced Monochromatic X rays (PIMX) may possess the following positive advantages.

(i) Acquisition of strictly monochromatic K-x rays with very small bremsstrahlung;

(ii) A rather broad range of PIMX by selecting appropriate target metals. Using an experimental system with devoted target chamber as reported previously<sup>2)</sup>, experiments were expanded to larger objects of a thyroid phantom and human limb phantoms with real human bones. Monochromatic radiograms were taken with photons of several monochromatic energies. The results were compared with the conventional polychromatic medical x ray radiograms. The data appeared to be encouraging enough.

Materials and Methods

A Picker-type thyroid phantom for nuclear medicine was filled with Angiographin that contained 1 % of iodine. The absorption edge of iodine is 33.16 KeV, and  $K_{\alpha}$ -x rays from La (33.4 KeV) was employed. The La metal target  $20 \times 20 \times 0.5$  mm was mounted in place in a chamber that had been described previously<sup>2)</sup>, and was irradiated by 6 MeV protons. The resultant  $K_{\alpha}$ -x rays were monochromatic as monitored by pulse height analysis with Si(Li) detector (see Fig. 1). In order to remove as much as possible  $K_{\beta}$ -x ray contaminations, Ba absorber was attempted by inserting between the target and radiographic phantoms. A similar Ce target was also prepared. A graded staircase phantom (Fig. 4) was constructed with acrylite plates of 1 mm thickness and was filled with 2 % Angiographin.

Upper and lower limb phantoms were also used. They contained dried human bones. Ta  $K_{\alpha}$ -x rays of 57.5 KeV was employed, too, on these phantoms to compare with the results for La  $K_{\alpha}$ . A conventional radiography of the limb phantoms was carried out by a medical x ray machine, and the exposure data were shown in Fig. 2 (b).

## Results

Filtration of La K-x rays. Figure 1 shows that the  $K_{\beta}/K_{\alpha}$  ratio was reduced to 1/20 of the original ratio.

Monochromatic radiographs of the limb phantom. A uniform exposure of the hand bones was achieved with PIMX while inhomogeneous exposure was seen with the conventional 35 KVp radiogram (Fig. 2).

Monochromatic radiographs with La  $K_{\alpha}$ -x rays (33.4 KeV) and Ta  $K_{\alpha}$ -x rays (57.5 KeV). In order to obtain a rough estimate of appropriate x ray energy range, lower limb phantom was radiographed with an equal Coulomb number but 2 different x ray energies, one 33.4 KeV from La  $K_{\alpha}$  and the other 57.5 KeV from Ta  $K_{\alpha}$ . The lower energy radiogram was greatly more legible than the other (Fig. 3).

Monochromatic radiographs of the thyroid and graded phantoms. Clean radiographs were obtained with either La  $K_{\alpha}$ - or Ce  $K_{\alpha}$ -x rays (Fig. 4).

## Comments

When there should be any unnegligible amounts of contamination from  $K_{\beta}$ -x rays, attenuation should be undertaken by use of appropriate filters, the La  $K_{\beta}/K_{\alpha}$  ratio was greatly reduced, and nearly complete monochromatism seemed to have been attained.

The results from the thyroid and graded phantoms seem to suggest that quantitative analysis of iodine content of the thyroid can be achieved in vivo. It is possible that iodine content of the thyroid may increase or decrease before any clinical symptoms become apparent; Graves' disease can be hinted at as soon as an appreciable increment in iodine content is suggested. Diagnosis of untoward development of hypothyroidism can well be antedated to clinical and radioiodine detection by such measurement.

The comparison of monochromatic radiography with PIMX and conventional radiogram of the bones (Fig. 2) indicated; (1) homogeneous exposure is feasible with the former; (2) inhomogeneous exposure in the conventional radiogram may represent underexposure due to excessive absorption of the low-energy x rays in the conventional polychromatic x rays; (3) the radiography with PIMX may be best suited to an in vivo bone densitometry because of its absolute monochromatism.

## References

- 1) Mistretta C. A., Kelcz F., Ort M. G. et al., Investigative Radiology, November 1973.
- 2) Okuyama S., Sera K., Mishina H., Ishii K., Yamadera A. and Matsuzawa T., CYRIC Annual Report 1980.

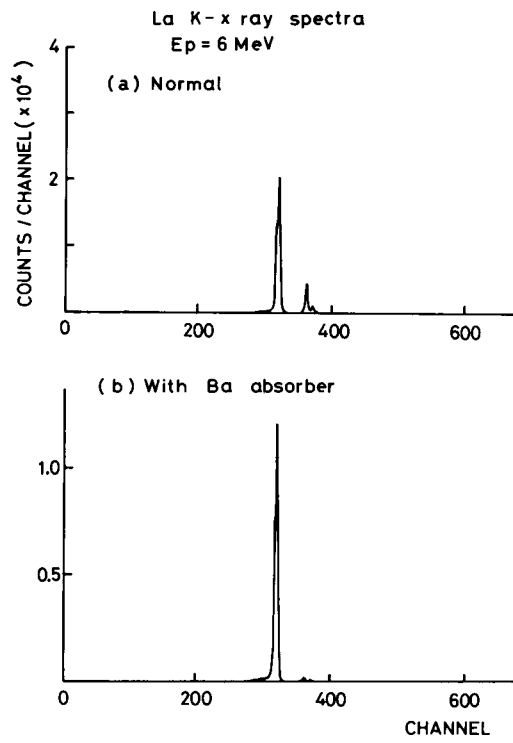


Fig. 1. Normal (a) and filtered (b) K-x ray spectra detected with Si(Li) detector.



(a)

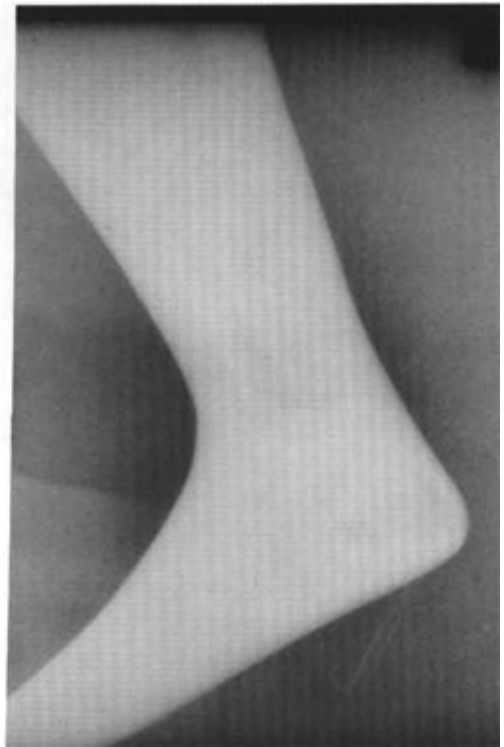


(b)

Fig. 2. (a) Monochromatic radiograph of the upper limb phantom with La K-x rays.  
(b) Conventional polychromatic radiograph of the same phantom by the  
medical x ray machine ( $V_p=35$  KV).

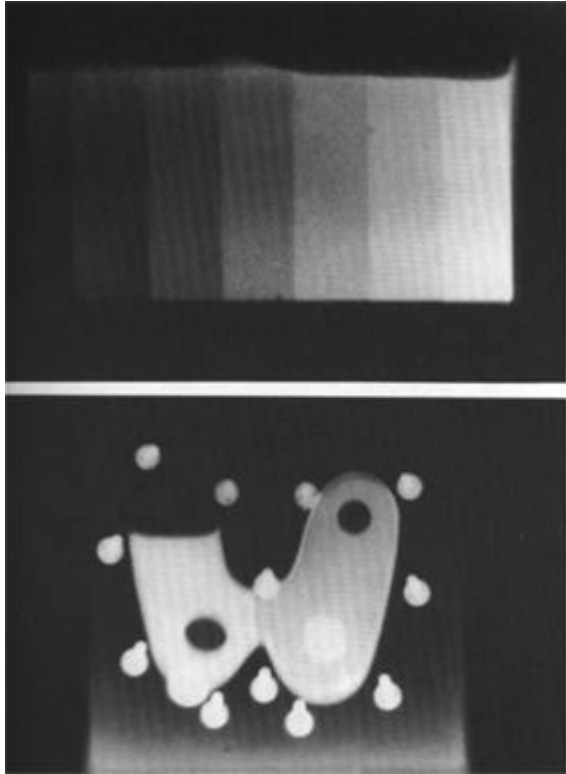


(a)

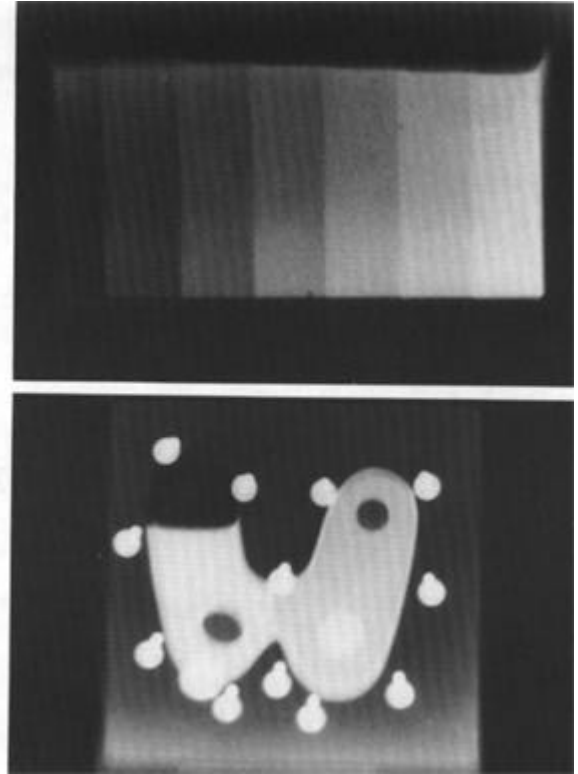


(b)

Fig. 3. Monochromatic radiographs of the lower limb phantom with La K-x rays (a) and with Ta K-x rays (b).



(a)



(b)

Fig. 4. Monochromatic radiographs of the graded staircase phantom (upper) and the thyroid phantom (lower) with La K-x rays (a) and Ce K-x rays (b).