Letter to the Editors

A Study of the Internal Structure of Gallstones Based on the Differences between the Interactions to Elements of Thermal Neutrons and X-Rays[†]

Mikio TANAKA, Takashi NAGAI, Tatsuya TASAKI*, Masaru MIKI*, Keiko HIRAKAWA*,
Tokinori WATANABE*, Hisao KOBAYASHI*, Shigeto KUBOTA*⁴ and Toshio ABE*⁴

Laboratory of Chemistry, Nippon Medical School
2-297-2, Kosugi-cho, Nakahara-ku, Kawasaki-shi 211

*The Department of Surgery, Nippon Medical School Second Hospital
1-396, Kosugi-cho, Nakahara-ku, Kawasaki-shi 211

*²Department of Legal Medicine, Nippon Medical School, 1-1-15, Sendagi, Bunkyo-ku, Tokyo 113

*³Institute for Atomic Energy, Rikkyo University, 2-5-1, Nagasaka, Yokosuka-shi 240-01

*⁴Abe Sekkei Inc., 3-42-10, Yoyogi, Shibuya-ku, Tokyo 151

Key Words : neutron radiography, X-ray radiography, gallstone, internal structure

Received October 6, 1988

Many investigations at the structure of gallstones have been carried out for the purpose of elucidating the process of the gallstone's formation. Some of the investigations included the classification of the structures of the outer and cut surfaces including shapes¹⁾. Investigations by instrumental analysis including polarization microscopy, scanning electron microscopy, and magnetic resonance imaging have been reported²⁾.

Recently, a few biological applications of thermal neutron radiography have been studied³⁾. We examined the application of radiography to determine the internal structure of gallstones.

We found that appreciable information concerning the process of gallstone formation could be obtained from a comparison between neutron radiography and X-ray radiography. Much in-

formation concerning the three dimensional structure of gallstones were obtained by comparing both radiographies from the x-, y-, and z-axes of the gallstones.

Gallstones used for radiography were removed surgically in the Department of Surgery, Nippon Medical School Second Hospital. For neutron radiography, we used an intense thermal neutron flux, $3.8 \times 10^6 \text{ n}_{\text{th}} \cdot \text{cm}^{-2} \cdot \text{s}^{-1}$. Exposure time was from 40 min to 1 h. Beam uniformity was less than $\pm 7.4\%$. We performed the neutron radiography on a horizontal type NR facility of TRIGA Marck II Reactor at the Institute for Atomic Energy at Rikkyo University. The neutron radiography images were taken on Kodak mono-layer SR film with a gadolinium converter. For X-ray radiography, we used an Akoma apparatus (MX 400) operating at 27 kV, 100 mA. Exposure time was 0.6–2.0 s. The image was recorded on Kodak X-Omat TL film.

The analysis of both radiographic images was performed by drum scan densitometer (2606; Abe Sekkei Inc.) with a 50 μm aperture (square) as the reading apparatus. The signal

[†]中性子とX線の元素との相互作用の違いを利用した胆石の内部構造の研究：田中幹夫，永井 俊，田崎達也*，三樹 勝*，平川慶子*²，渡辺日章*²，小林久夫*³，久保田滋人*⁴，阿部俊雄*⁴：日本医科大学新丸子校舎化学教室，川崎市中原区小杉町 2-297-2，*日本医科大学第二病院外科，*²日本医科大学法医学教室，*³立教大学原子力研究所，*⁴(株)阿部設計。

of optical density obtained was stored on a floppy disk in a personal computer (PC-9801 VX41; NEC Corp.). The stored image was analyzed with a MICRO CIPS (Abe Sekkei Inc.) software program on the computer.

It is known that there is a large difference between the interactions for elements of thermal neutrons and X-rays. In the case of neutrons, the attenuation coefficient is very high for hydrogen. In the case of X-rays, the attenuation coefficients for calcium and phosphorous are relatively high. Consequently, substances which contain hydrogen, for example, cholesterol and water, are opaque in neutron radiography, and substances which contain calcium and phosphorous are opaque in X-ray radiography. We investigated the internal structure of gallstones with reference to the difference in the coefficients between thermal neutrons and X-rays.

Figures 1 and 2 show color-coded images from the upper side and the flank of the same gallstone. The principal component in the gallstone used was identified as cholesterol from an infrared spectrum. The neutron radiographies in Fig. 1 and Fig. 2 indicated that the difference in the permeability of the thermal neutron arose mainly from a difference in the thickness of the cholesterol layer. On the other hand, the X-ray radiographies in Fig. 1 and Fig. 2 indicated that the cholesterol layer for X-rays was transparent, but the difference in permeability was caused by a difference in the amount of substances which contained calcium.

It was found from Fig. 1 and Fig. 2 that cholesterol was surrounded by substances containing calcium in the cylinder state. It was also found that cholesterol surrounded the outside of the cylinder.

The internal structure of gallstones can not be determined from observation of their cut surfaces. However, the internal structure was revealed by a comparison of neutron and X-ray radiographies.

Substances which were contained in subdivided parts of gallstone are being analyzed at present time.

Fig. 1 Color-coded images for thermal neutron and X-ray radiographies from the upper side of the gallstone.
NRG; thermal neutron radiography,
XRG; X-ray radiography

Fig. 2 Color-coded images for thermal neutron and X-ray radiographies from the flank of the gallstone.
NRG; thermal neutron radiography,
XRG; X-ray radiography

References

- 1) Takahashi, T., Tashiro, N., Ikeuchi, J. et al.: *Jikei Medical J.*, **35**, 77-89 (1988), and the references cited therein
- 2) Moriyasu, F., Ban, N., Nishida, O. et al.: *Jpn. J. Gastroenterol.*, **83**, 2190-95 (1986)
- 3) Barton, J.P., von der Hart, P., eds.: "Neutron Radiography", Proc. the First World Conference, D. Reidel Pub. Co., (1983); Barton, J.P., Farny, G., Person, J.L. et al., eds.: "Neutron Radiography", Proc. the Second World Conference, D. Reidel Pub. Co., (1987); Kobayashi, H.: *Isotope News*, No. 394, 10-11 (1987)