DOE/ER/60200--T1

FINAL TECHNICAL REPORT

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K-Edge Subtraction Angiography With Synchrotron X-Rays

The following material represents a summary of the accomplishments of the project DE-AT03-84ER60200 over a period of 02/01/84 to 01/31/87. The ultimate aim was the development of an angiographic method and appropriate equipment for imaging with x-rays the coronary arteries in a non-invasive manner. Successive steps involved studies with phantoms, live animals and finally with human subjects. Clinical evaluation of human coronary arteries remains a goal of this and a continuing project, and steps along the way to such an achievement are in process. Transvenous injection of a dye using the method of iodine dichromography near 33.2 KeV, the K-edge of iodine, forms the basis of the method.

The studies have been carried out with synchrotron radiation obtained from the SSRL storage ring, SPEAR. Some results are listed below:

1. Two studies, using five human subjects in all, were carried out on the coronary system with a resolution of 0.5 mm.

2. A rotating shutter scheme was developed which eclipsed successively each of the two monoenergetic x-ray beams, and contained two drums each bearing 10 lobes. The two monoenergetic beams were selected by Si crystal diffraction means just below and just above the K-edge of iodine, and appropriate logarithmic subtraction was employed to construct the final images. Typical energy bands selected were 25 eV wide and were separated by approximately ten times this amount. Typical exposure times for each line image were 1.7-3.3 msec. The final scanned image is developed from 256 scan lines in vertical sequence. Each line of the scan was measured by a special lithium drifted silicon detector containing 300 elements, producing pixel elements of 0.5 x 0.5 mm.

3. A moving chair was built and operated which allowed vertical scanning of the patient through the x-ray beam. Typical chair speeds were 6-12 cm/sec.

4. A safety system was developed which protected patients and operating personnel against possible accidental exposures to the x-ray beams and also allowed measurement of the ionization dose to each patient.

5. Image enhancement techniques were initiated and were used to provide representations of coronary arteries with greater

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clarity and contrast than in the original image. These techniques are very valuable when imaging arteries in the presence of overlying structures containing the dye.

6. The human studies employed transvenous injections of a standard contrast agent containing iodine. While the images were very good, the resulting angiographic images of humans do not have the quality of previous studies carried out on anaesthetized dogs. The latter studies would be clinically acceptable. Because of the additional absorption in the anatomically thicker human body, the transmitted intensities at the detector are smaller than in dogs and the signal-to-noise ratios suffer accordingly. Nevertheless, the images obtained are sufficient to observe arteries such as the left anterior descending artery, the right coronary artery, and the left and right internal mammary arteries, and vein and internal mammary grafts. With improvements in beam intensities by a factor of 5-10, it is expected that the resulting images will be as good as, or better than, the dog images.

In order to obtain improved clinically acceptable images for humans, the following developments are in process: Increase of beam intensity at SSRL, replacement of the rotating shutter with a dual detector strip of 600 elements and a corresponding dual monochromator, and production of a 1200 element dual detector that will provide improved spatial resolution of 0.25 mm. Future studies are also planned at the National Light Source at Brookhaven.

Publications describing the work carried out for this project are appended. The second set of observations in human subjects is being prepared for publication. The first set is included in the present publications (reference 11).

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Robert Hofstadter

Robert Hofstadter
Principal Investigator

attachments: (removed and cycled separately) -

1. "Evaluation of Synchrotron X-Rays for Transvenous Coronary Angiography", Nuclear Instruments and Methods, 222, 308 (1984).

(continued on page 3)

2. "Evaluation of Synchrotron X-Rays for Digital Subtraction Coronary Angiography", Proceedings, IEEE Science Symposium, October 19-24, 1984.
3. "Medical Imaging with Synchrotron Radiation", Nuclear Instruments and Methods, 222, 302 (1984).
4. "Rotating X-Ray Collimating Slit for Line-Scan Dual-Energy Medical Imaging", IEEE Trans. on Nuclear Science, NS-31, 548 (1984).
5. "Prospects for Non-Invasive Angiography with Tunable X-Rays", Nuclear Instruments and Methods, B10/11, 323 (1985).
6. "The Angiography Program at Stanford", Nuclear Instruments and Methods, A246, 719 (1986).
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9. "Veiling Glare of a Linear Multichannel Si(Li) Detector", Optical Engineering, 25/4, 532 (1986).
10. "Transvenous Coronary Angiography in Dogs Using Synchrotron Radiation", International J. Cardiac Imaging, in press.
11. "Transvenous Coronary Angiography in Humans Using Synchrotron Radiation", Proc. Natl. Acad. Sci. USA, 83, 9724 (1986).

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