Microangiography in Isolated Perfused Rat Heart to Evaluate Vascular Response

Organs within the body have the ability to regulate their own blood supply. Vasoconstriction decreases blood flow, while vasodilatation increases blood flow. Visualization of constriction and dilation of blood vessels with drags (vasoactive agents) is a useful research tool for evaluating vascular response. Microangiography with spatial resolution in the micrometer range was carried out to depict vascular response in an isolated perfused rat heart [1]. In imaging experiments, the rat was anesthetized, then the heart was excised. The isolated heart was mounted on a steel tube and perfused with perfusion fluid to supply nutrients and oxygen (Fig. 1); perfusion fluid was used as a substitute for blood and directed into blood vessels. The contractile function and regular heart rhythm returned to the isolated heart within a few seconds. The isolated perfused heart provides an excellent test-bed for undertaking carefully controlled dose-response studies. After administering an iodine contrast agent injection, the vascular response in small blood vessels could be visualized during the perfusion of vasoactive agents.

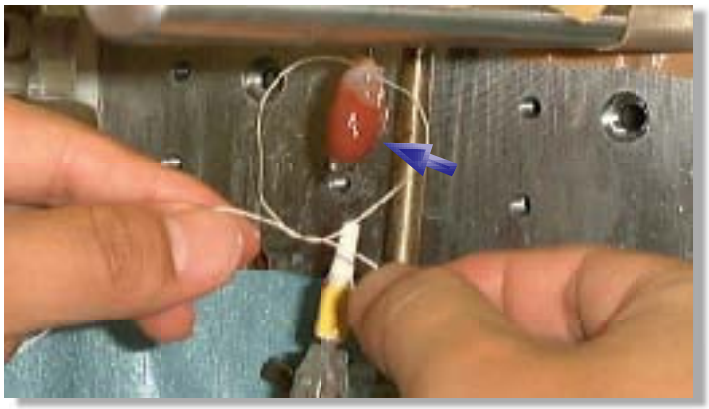

Fig. 1. Isolated perfused rat heart indicated by a blue arrow.

Coronary microangiographic imaging was carried out at the **BL28B2** bending-magnet beamline, employing a single crystal monochromator, with the monochromatic X-ray energy adjusted to 33.2 keV just above the iodine *K*-edge energy. An X-ray imaging system requires a high shutter speed (short exposure time) to produce sharp and blur-free images of fast-moving hearts, and for this purpose we developed a shutter system using a moving-coil galvanometer-based scanner. The shortest shutter open time was 3 ms.

X-rays transmitted through the object are detected by the X-ray direct-conversion type detector incorporating the X-ray SATICON pickup tube [2-4]. The X-ray camera has a resolution of 1,050 scanning lines and can record images at a maximum speed of 30 frames/s. Sequential images were obtained with an input field of view of 6.9 mm × 6.9 mm, and the equivalent pixel size projected onto the input window was 6.9 μm. Image signals are converted into a digital format and stored in a frame memory with a 1024 × 1024 pixels format and 10-bit resolution.

Acetylcholine and sodium nitroprusside were vasoactive agents used in this experiment, and with them a study to evaluate vascular responses by measuring internal diameters of small blood vessels on the baseline and under the stress of induced vasoactive agents (perfusion of agents). Sequential images of the left coronary arteries were taken at heart rates of 300 - 400 per minute. Small blood vessels of less than 50 μm in diameter were displayed in images (Fig. 2). The images show an area of 5.6 mm wide by 4.4 mm high.

Figure 2(a) shows a frame from a baseline angiographic sequence, Fig. 2(b) an acetylcholine stress sequence, and Fig. 2(c) a sodium nitroprusside stress sequence. All of these images show typical diameter changes in small coronary arteries in response to agents.

In the arterial tree, vasodilatation (white arrows) was observed in small arteries less than approximately 100 μm in diameter, whereas large arteries (yellow arrows) underwent almost no change in internal diameter due to the vasoactive agents. These agents only change the diameters of small blood vessels. Furthermore, new arterial branches of coronary arteries with diameters of 20 - 30 μm became visible in Fig. 2(c). The present imaging system enables the direct evaluation of vasodilatation in small coronary arteries of less than 50 μm diameter for this time.

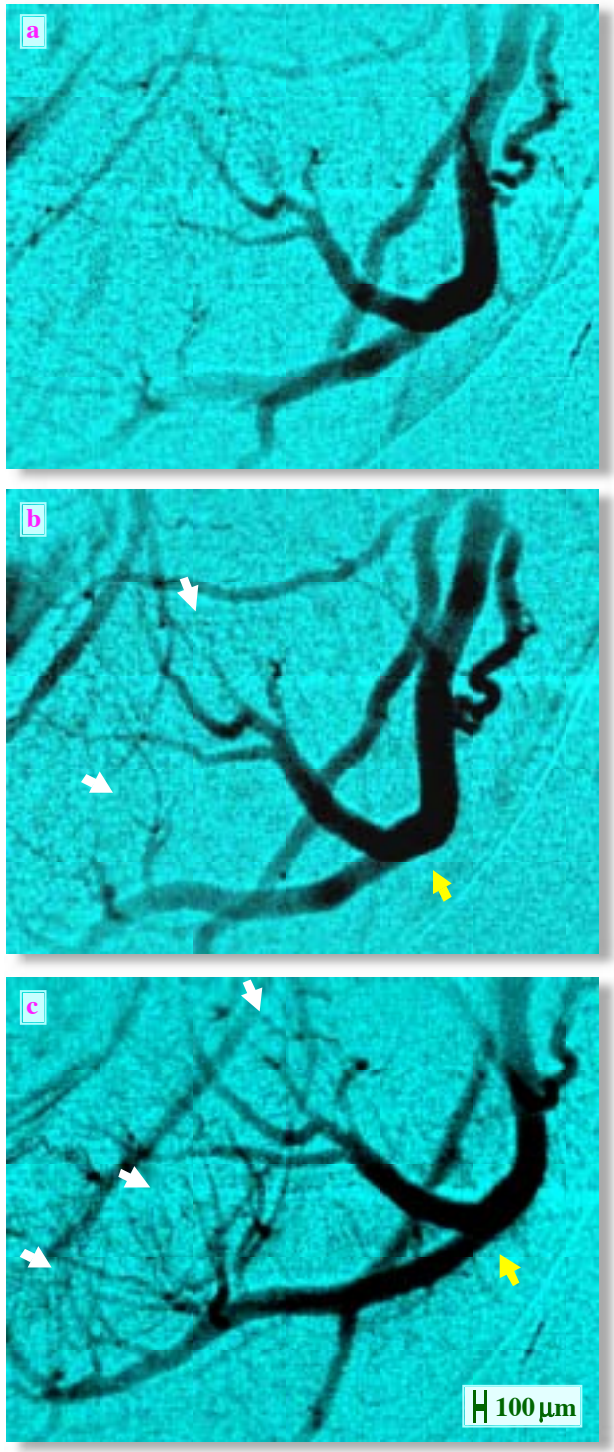

*Fig. 2. Microangiographic images **(a)** at baseline, **(b)** with acetylcholine stress and **(c)** with sodium nitroprusside stress. White arrows in **(b)** and **(c)** indicate apparent vasodilatation and new arterial branches in response to vasoactive agents, whereas large arteries (yellow arrows) underwent almost no change of internal diameter.*

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