A NEW METHOD OF BLOOD FLOW MEASUREMENT BY MEANS OF DIGITALLY CONTROLLED DYNAMIC RADIOGRAPHY

A Preliminary Report

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Among various techniques of blood flow measurement, the clearance methods using radioactive inert gas or heat and the tracer methods such as serial angiography or radiorheography, are currently being developed for use in neurosurgical diagnosis. These methods for practical reasons, however, can be applied only to estimating the transit time between the neck and the head. In serial angiography,[1] the circulation time is estimated by vague images of the bolus of the contrast medium. Radiorheography, using nondiffusible radioactive tracers such as I^{131} or I^{125}PAHA and RISA[2),3)] can not be sharply collimated in small enough areas. Thus, the regional blood flow in small branches of the cerebral arteries can not be measured by these methods.

In order to make more accurate measurements of the regional blood flow, we have devised a new method employing digitally controlled dynamic radiography, and some preliminary experiments have been conducted for testing the method with the aid of currently available x-ray devices. The experimental scheme of the dynamic radiography to be employed in the observation of articulatory movements has been reported elsewhere.[4),5),6)] The characteristics of the present system for preliminary experiments also have been described in some detail in previous reports.[5),6)] In the case of blood flow measurements, selected portions of the target vessel are exposed to a computer-directed x-ray microbeam, the diameter of which may be from

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0. 5 mm to 1. 0 mm. The intensity of the transmitted x-ray through each selected point in the organ is measured as a function of time and stored in the computer memory. When a contrast medium is injected into an arterial vessel at its proximal portion, the arrival of the contrast medium at a distal portion of the same vessel can be detected by observing the variation in the radiopacity. By simultaneously measuring the arrival times at two different cross sections along the vessel, the transit time of the contrast medium is estimated, and the speed of flow can be calculated if the geometry of the arterial structure is known.

In the preliminary experiment reported here, the common carotid artery of a dog was selected as the target vessel. The contrast medium (Conray, 60 %) was injected through a thin polyethylene tube which was inserted into the carotid artery, about 4 cm upstream from the more proximal point selected for the opacity measurement. First, a selected portion of the x-ray image field was scanned by the microbeam with the contrast medium injected in the vessel. Figure 1-a illustrates an oscilloscope display of the image. The diameter of the x-ray microbeam was about 1 mm. (Each point in the display represents the center of a exposed spot in the object). The experimenter selected two sections (A) and (B), along the artery displayed on the oscilloscope, using a computer-generated pointer which indicated each specified position in the display with a cross for visual monitoring (see Figure 1-a). The contrast medium was then injected again. Time variations of the x-ray intensity were then automatically obtained simultaneously at six different points, three at each of the two specified sections. The sampled points at each cross section were selected at a spacing of 0. 5 mm. All six sample points were cyclically exposed on a time-shared multiple measurement basis. The x-ray intensity was measured for a 1-msec time interval for each space-time sample. Thus, the x-ray intensity at each of six points was estimated and stored in the computer memory every 6-msec. An example of a set of the intensity values as time functions is given in Figure 1-b.

At each section, (A) or (B), a sudden decrease in x-ray transmission can be observed reflecting the arrival of the contrast medium. The temporal patterns are different for these sections at different distances from the

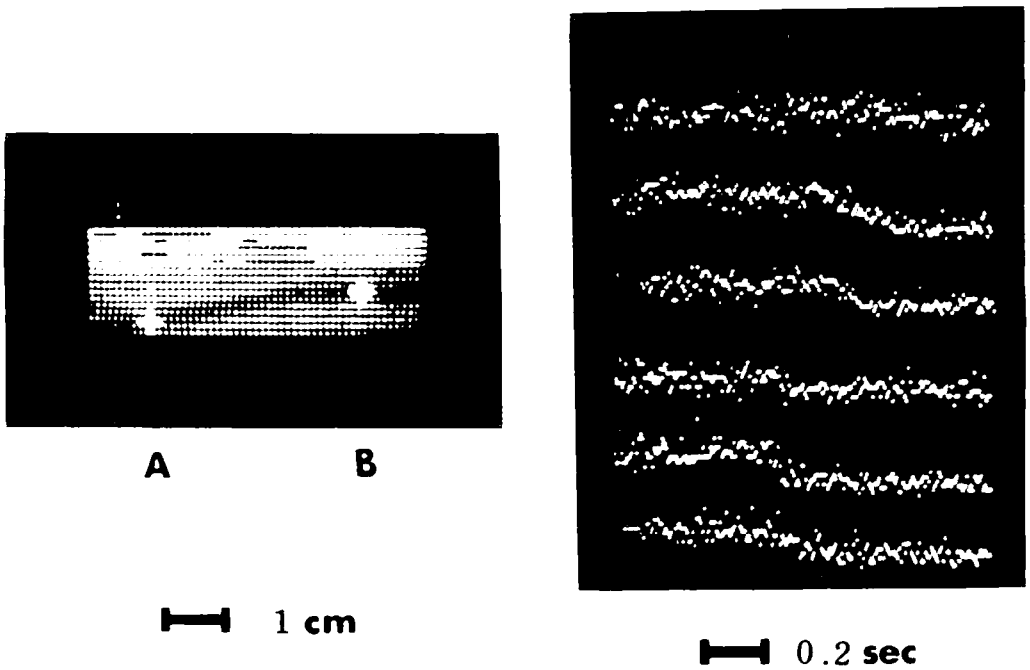

Figure 1. (a) x-ray image of the common carotid artery of the dog. (b) Time vatiations in the x-ray intensity observed at six sample points, three at each of the two specified sections indicated in (a) by the crosses.

injection point, and they also vary depending on the position within a cross-section of the artery. By using a curve exhibiting the most apparent decrease in the x-ray transmission in determining the arrival time at each of the sections (A) and (B), the transit time of the contrast medium was estimated at 0.23 sec. The distance between these points was estimated at 3.3 cm, assuming that the object vessel lay in a plane perpendicular to the x-ray beam. The velocity of the blood flow was thus estimated at 14 cm/sec.

As another example of the many possible applications of the same technique, the pulsative movement of the arterial wall was observed by using a finer x-ray beam (approximately, 0.5 mm in diameter). Figure 2 shows the time vatiations in the x-ray intensity observed at seven sample points on a line transversing the arterial wall. The sample points were set 0.25 mm apart. In the figure it is seen that at point G, no significant variation over time was found to be caused by the injection, and it can be judged that this point lay outside the blood stream. At point A which was presumably located in the mid-stream of the artery, the x-ray transmission decreased upon the arrival of the contrast medium and then remained at a constant low level. At other sample points between A and G, in Figure 2, various degrees

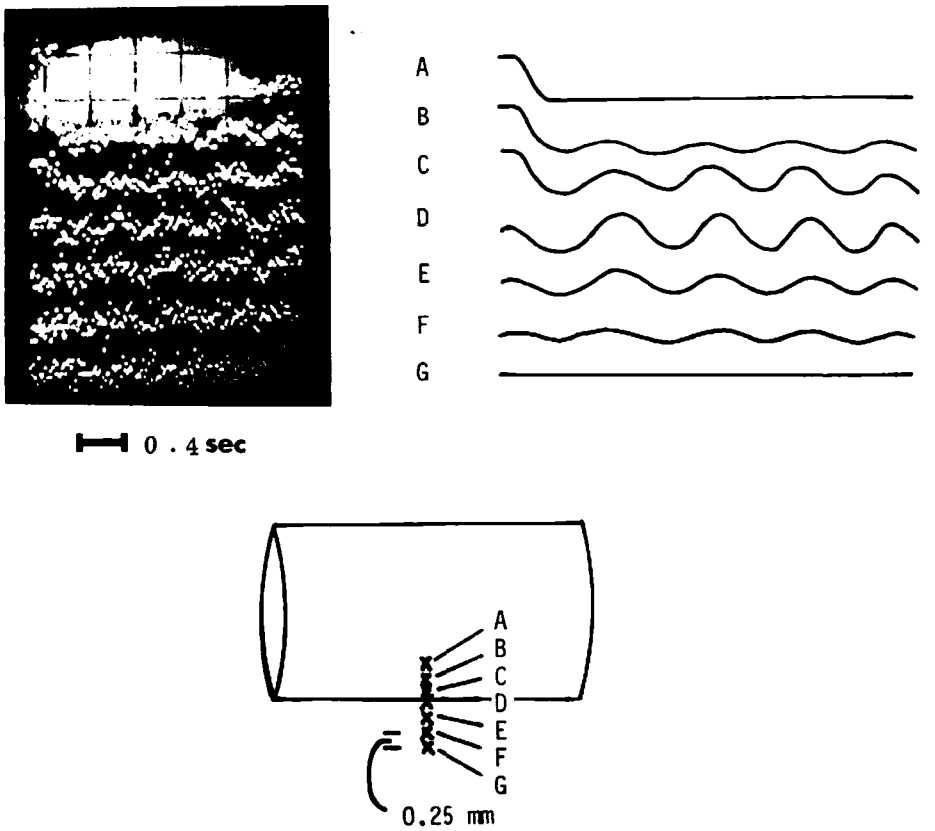

Figure 2. Time variations in the x-ray intensity observed at seven sample points across the vessel wall.

of periodic modulations are observed in the radiopacity. This reveals the pulsative movement of the arterial wall. The width of the pulsative movement of the arterial wall can be aclculated by comparisons of this radiopacity at adjacent points as functions of time. In this case, it was estimated to be close to 1 mm. The inner diameter of the arterial wall in this portion of the artery was approximately 7mm.

In the experiment described above, the blood flow was measured at only one selected segment of an artery, but this technique has potentiality for measuring the blood flow of many portions of the cerebral vessels simultaneously. The volume velocity of blood also can be estimated by a calculation considering the cross-sectional area of the vessel and the speed distribution

within the cross-section. The measurement of the pulsative movements of the vessel wall also may be applied to detecting abnormalities in elastic properties of the cerebral vessels, e. g. in the case of aneurysm.

In order to achieve these goals in neurosurgical practice, however, a new x-ray microbeam generator with a higher acceleration voltage will have to be employed.

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