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Phasic Blood Flow in Coronary Arteries Obtained by a New Differential Manometric Method.

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An optically recording flow meter has been devised which accurately registers the phasic blood flow in the various vessels of the heart.

The rate of flow is measured by directing the blood through a thin orifice plate (or Pitot tube arrangement). The momentary acceleration of the blood so produced causes a lowering of the lateral pressure (for a short distance downstream) which is proportional to the square of the acceleration. The moment to moment differences between the lateral pressures above and below the orifice, recorded by a differential manometer, give the phasic changes in the rate of blood flow.

The upstream lateral pressure is led to a manometer tip with a 4 mm opening covered with a special rubber membrane 0.003 to 0.006 inch thick stretched 3 to 5 times. A waterproofed plano mirror (chip from a Bureau of Standards certified counting chamber cover slip) is mounted on the membrane by a peg or splint with special cement (to prevent hysteresis). The downstream lateral pressure is led directly to a water tight chamber (made of transparent Lucite) which surrounds the membrane. The light beam enters this chamber through a low diopter plano-convex lens (0.5 to 0.7). This lens should be at least 1.5 mm thick to prevent distortion under pressure. A small angle prism, capable of rotation through 360 degrees, mounted in front of the lens, corrects the prismatic effect of the Locke's solution with which the chamber and unit are filled. The whole assembly is mounted in the carriage of a Gregg manometer.

When filled with Locke's solution by means of a flexible tube the meter, as used in small vessels such as the coronary arteries, has a frequency of 80 to 120 double vibrations per second and for a differential pressure of 10 mm Hg gives a deflection of 40 to 60 mm at 4 meters camera projection distance. This sensitivity, which can be easily increased or decreased either by changing the orifice plate or the meter tip during the experiment, is sufficient to detect flows as small as 10 cc per minute. At flows of 60 to 80 cc per minute the net loss of head in the stream is not more than 3 to 4 mm Hg. The meter has no appreciable lag (less than 0.001 second) and faithfully follows the sudden starting and stopping of flow produced by rotation of a stopcock. It gives correct flow figures for when alternating flow is produced through the meter by a reciprocating plunger the flow calculated from the flow meter curves varies from 2 to occasionally as high as 10% from the flows directly and simultaneously measured in a graduate.

The meter has been used to measure the phasic coronary flow in the *ramus descendens* of the dog under a variety of circulatory conditions. The loss of pressure head in the blood stream approximates 4 mm Hg. This is, however, insufficient to affect the vascular bed since continuous use of the meter over long periods of time causes no alteration of the blood flow. With good dynamic conditions prevailing the meter records show that the systolic coronary flow may be as large as that during diastole (for an equivalent time interval). The systolic and diastolic flows are separated by abrupt flow reductions during the isometric contraction period and late systole.

Such flows have been compared with the flow curves reconstructed from differential pressure curves taken at essentially the same time.[1] Such comparison of the flows obtained by the two methods confirms the conclusions drawn from constant pressure flow meter studies[2] that the differential pressure curves faithfully record the proper time relations and directional changes in flow but may underestimate the phasic changes in velocity. In addition the isometric retardation and the inflow during rapid ejection and isometric relaxation may be relatively greater than indicated by the differential pressures.

During elevation of systemic pressure (compression of the aorta or blood transfusion) or temporary reduction of the coronary blood supply (the flow being measured just after restoration of the normal blood supply) the flows increase markedly during both systole and diastole. Such flow increases are generally greater than indicated by the differential pressures. The reasons for these differences in coronary flow as measured by the two methods are now being studied.

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1 Green, H. D., Gregg, D. E., and Wiggers, C. J., *Am. J. Physiol.*, 1935, **112**, 362.

2 Green, H. D., and Gregg, D. E., unpublished experiments.