THE CONTRIBUTION OF VENOUS CATHETERIZATION AND OTHER CIRCULATORY TECHNIQUES TO CARDIOLOGY

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In the years between the wars the emphasis in cardiology was placed on anatomical diagnosis of heart lesions, and comparatively little attention was directed to the action of the heart as a pump or to the part played by the peripheral circulation. The cardiologist was considered adequately equipped when he possessed an electrocardiogram and an X-ray screen. In recent years, however, the functional aspect has come into increasing prominence. Many workers have found that the study of the heart alone may be inadequate and that much valuable information can be obtained from simultaneous or parallel observations on the peripheral circulation.

Results obtained from experimental observations on animals must always be subjected to critical consideration before they can be applied to the intact circulation of unanaesthetized man. The erect posture, for instance, has produced modifications and reactions which may not be present in species which run on all fours. Man as a subject for circulatory observation has, moreover, some special advantages; he does not require an anaesthetic and will co-operate when asked; his vessels are a reasonable size; in older adults at any rate the circulation is not unduly labile, thus enabling some assessment to be made of the effects

of various stimuli. Disease or congenital abnormalities create, spontaneously, conditions which may be difficult to reproduce in the experimental animal. On the other hand, it is not possible in man at present to cut off certain parts of the circulation from nervous or endocrine influences, to obtain in the normal subject pressure records from such chambers as the left auricle or to measure directly the blood-flow in a peripheral artery.

Some of the techniques at present available for the physiological study of the circulation in man will be briefly surveyed in this paper.

Venous Catheterization

Measurement of Cardiac Output. The introduction of a long flexible tube into the veins of man was initiated by Bleichröder (1912) and was developed by Cournand and Ranges (1941) for measuring the A-V oxygen difference of the Fick equation:—

$$\text{Cardiac output L/min.} = \frac{\text{Oxygen consumption cc./min.}}{\text{A-V O}_2 \text{ diff. cc./L}}$$

Regarded by many with concern when first used

FIG. 1.—Right auricular pressure record in a subject without cardiovascular disease. At the vertical white line 2 mg. atropine were injected intravenously. With acceleration of the heart rate auricular pressure falls. Respiratory variations also appear on the tracing.

FIG. 2.—Blood pressure records from small arteries. Right hand curve shows the blood pressure in the umbilical artery of the foetal rabbit. Left hand curve shows the maternal blood pressure in the ear artery.

in this country, the procedure seems to have achieved some popularity in the relatively minor static role of an accessory laboratory aid to diagnosis in congenital heart lesions. No intravascular procedure is without some risk and in non-expert hands may prove dangerous. Although over 1,000 catheterizations may be performed without untoward incident, the following accidents are known to have occurred in addition to the localized thrombosis frequently reported; fatal packed pulmonary embolism from axillary or subclavian thrombosis; haemopericardium from penetration of the heart wall; sudden stoppage of the heart with the catheter in the ventricle, pulmonary artery or coronary sinus; and systemic embolism in right to left intracardiac shunts. Immediate air embolism or later clot embolism in congenital heart disease and the use of rigorgenic catheters in severe heart failure are perhaps the main risks, but they can be avoided.

The optimum position for the tip of the catheter depends on the observations in progress. Many workers prefer the outflow tract of the right ventricle or the pulmonary artery for sampling since errors of mixing are less in these sites; extra systoles or abnormal rhythms may however result with the catheter in these situations. If right auricular pressure tracings are desired, samples for gas analysis may have to be obtained from above the tricuspid valves. The catheter may be passed to the desired position either under an X-ray screen or without visualization by observation of

the intracardiac pressure and electrocardiographic changes.

Measurement of oxygen content of arterial and venous blood. For most purposes oxygen content is calculated from Van Slyke or Haldane determinations. Rather less accurate photometric methods allow relative changes in the haemoglobin-combined oxygen to be followed rapidly (Groom, *et al.*, 1948). Work in progress indicates that special difficulties in determining oxygen content may be associated with blood from anaesthetized patients, as well as from cases of polycythaemia and congenital heart disease.

Pressure Measuring Devices

Manometers with optical recording (Hamilton, *et al.*, 1934), condenser manometers (Buchthal, 1943; Hansen, 1947; Lilly, 1942) and strain gauges (Groom, *et al.*, 1948) are among the types in use. All have defects; indeed any pressure measuring instrument at the distal end of a long flexible tube will necessarily record some artefacts. At the present time condenser manometers are probably the most satisfactory instruments and Figs. 1 and 2 show some records obtained by their aid.

Continuous improvements are to be expected in these instruments and it seems probable that they will form part of basic equipment for measuring arterial, intracardiac, and venous blood pressures.

Measurement of Peripheral Blood-Flow

The value of the venous occlusion plethysmograph (Hewlett and Zwaluwenberg, 1909; Lewis and Grant, 1925; Barcroft and Edholm, 1943) for the measurement of blood-flow through the hand, foot, forearm and calf is well established. The beginner may find this technique rather more difficult than venous catheterization.

Apart from local studies on the circulation, simultaneous measurement of forearm flow and cardiac output has thrown some light on problems such as vasovagal fainting (Barcroft *et al.*, 1944) and heart failure (Howarth and Sharpey-Schafer, 1947).

The shorter the period over which blood-flow is measured the more physiological variations become apparent. Methods, therefore, such as the Stewart calorimeter method (Stewart, 1911) which require many minutes can only indicate average flow changes. Clearance methods must necessarily suffer from this defect. Catheterization of the hepatic veins for measurement of hepatic blood flow (Bradley *et al.*, 1945) and of the renal veins in renal blood flow estimations are among recently developed techniques. The nitrous oxide method provides a new technique for measuring blood flow; it has been used to measure blood flow through organs such as the heart (Goodale *et al.*, 1948; Eckenhoff *et al.*, 1948), and through the brain (Kety and Schmidt, 1945). Calculation of coronary blood flow, however, needs certain assumptions which may or may not prove to be justifiable. This technique does not appear to be easy.

Conclusion

The static anatomical ideas of the older cardiologists still linger on, and the present concern with minute diagnosis of congenital hearts would seem to be a direct descendant of this attitude. Some beginning has however been made towards the functional aspect of circulatory disorders and there is every hope that with the continuous development of new techniques our knowledge of function will slowly increase. Thus recently the detailed physiological studies of Bing and his colleagues (1947 to 1949) have already added considerably to our understanding of congenital heart disease.

It is easy to become narrow and to forget that the circulation must be considered as a whole. The attempted elucidation of the action of drugs both old and new, for instance, requires the use of all known methods; for drugs, unfortunately, frequently do not affect the heart alone, but also other parts of the circulation. Similarly, those investigating the peripheral circulation must need be aware not only of alterations in cardiac filling pressures and output, but also of changes in respiratory function. In the past, much attention has been paid by physiologists to the arterial and capillary systems, but relatively little to the veins. Recent work on man would suggest that the function of the latter is of considerable importance; studies being carried on in this field involve the complicated mathematics of the potentially slack elastic tube.

In 1935, Sir Thomas Lewis was heard to remark that cardiology was static and likely to remain so. For once he appears to have been wrong.

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