THE DETERMINATION OF CARDIAC OUTPUT DURING ANAESTHESIA.*


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The problems facing the investigator concerned with the measurement of cardiac output during anaesthesia are formidable. Of the methods and modifications available in the cardiological laboratory, few lend themselves to ready adaptation to meet the needs of the operating theatre, and in practice only two, the direct Fick method and the dye dilution technique, have had wide use. Of these, the direct Fick is of doubtful value, and indeed, Prime and Gray concluded that it could do little more than indicate trends.

Before the Fick principle can be applied the oxygen content of both arterial and mixed venous blood, and the oxygen consumption, must be known. The oxygen content of arterial blood may be obtained by direct analysis, but this may be difficult in the presence of anaesthetic gases. Alternatively, if the haemoglobin concentration is known and 95 per cent. oxygen saturation is assumed, the oxygen content can be calculated. The assumption, however, is not always valid under certain anaesthetic conditions. The mixed venous sample presents a bigger problem, not only because of the difficulty of analysis but also because it is not easy to justify catheterisation of the pulmonary artery during routine surgery. Furthermore, the measurement of oxygen consumption itself is complicated and tedious in the presence of anaesthetic gases and the almost invariable retention of carbon dioxide during anaesthesia adds an error which is difficult to assess.

The use of the dye dilution technique avoids these hazards and, though controversy still exists about the validity of certain forms of recording, it is generally agreed that the method offers the most promising means yet of studying the haemodynamic changes associated with anaesthesia. It is based on the principle first propounded by Hering (1829), that if an indicator is injected into the circulation at a constant rate and its dilution estimated from a site distal to that of the injection, then the velocity of flow can be calculated. On the basis of Hering's work, Stewart measured cardiac output, using a salt solution as an indicator. The electrical resistance of such a solution varies with its concentration in blood, and by measuring the change in resistance he was able to calculate the output. Despite a considerable amount of research during the intervening years, the method had little more than curiosity value until 1928 when Hamilton and his associates placed it on a firm clinical basis. Their method was to inject a known quantity of dye into a vein and immediately afterwards to obtain blood samples from a peripheral artery at 1–2 second intervals. The sampling system consisted of a rotating drum on which were mounted 20 to 30 glass collecting tubes into which blood from an arterial needle was allowed to flow for a 1–2 second period. The concentration of dye in each test tube was estimated and the results plotted. The curve obtained was the record of

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the changing concentration with time of the dye injected into the circulation. From such a curve can be derived the fastest and mean circulation time, the rate of blood flow between the site of injection and that of sampling, i.e., the cardiac output, the volume of the system between these sites, i.e., the intrathoracic blood volume, the total blood volume and the presence of abnormal circulating pathways.

Since Hamilton's early work, research has been concentrated mainly on finding a suitable indicator and a convenient means of recording the changing concentration of that indicator in blood. Much of this research has revolved round the development of the cuvette and the ear-piece oximeter, (Millikan\textsuperscript{6}; Wood and Geraci\textsuperscript{12}), both of which utilise the properties of photo-electric cells to measure the concentration of dye used as indicator in blood. It