# METHOD OF CALIBRATING INDICATOR DILUTION CURVES

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A calibration system consisting of a calibration loop, sensor, and continuous-flow pump, creating a constant velocity of blood flow in this system, can be used to carry out calibration without further removal of blood, and subsequently to caluclate dilution curves of indicators, in this case dye-dilution and thermodilution curves.

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Careful testing of the method of dynamic calibration of indicator dilution curves [2, 3] and comparison with direct measurements in vitro and also with the classical method of calculation as described by Hamilton et al. [1] in vivo have demonstrated the close agreement between the results obtained. The method of dynamic calibration is finding an increasing number of supporters [4-6].

A calibration system for dynamic calibration of dye-dilution curves or thermodilution curves is described below.

The calibration system is shown schematically in Fig. 1. It consists of a calibration loop (4) with a magnetic mixer joined by two three-way cocks (3) on one side with a needle or catheter for insertion into an artery or vein, and on the other side with a photosensor (5) (or with a sensor of another type, such as a thermistor), the photosensitive element of which (8) is illuminated with a small lamp, and the optimal intensity of illumination is controlled by a diaphragm (7). As Fig. 1 shows, this system is connected with a suction pump (6) creating a flow of blood or other liquid at constant velocity.

The cannula (1) is connected to the three-way cock by means of a thick rubber tube with internal diameter 3-5 mm, which can easily be pierced by the needle of an accurately calibrated 1-ml syringe (2) for introduction of the standard dose of indicator. The calibration loop is made from a Mohr's pipet and has a capacity of 10 ml. Another calibration loop which is used consists of a vinyl chloride tube 16 cm long and 6 mm in its internal diameter, filled with nonsiliconized spherical glass beads 5 mm in diameter [2, 6]. In this case there is no need for a magnetic mixer.

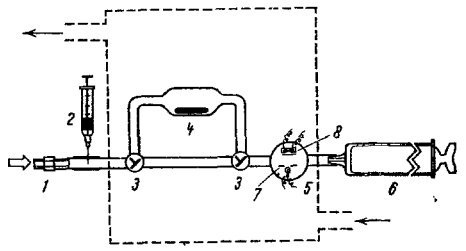


Fig. 1. Scheme of calibration system (description in text). Broken line encloses that part of the calibration loop which can be thermostatically controlled.

The quantity of dye (Evans' or Coomassie blue) required to record the calibration curve is 5-50 μg. After the calibration curve has been recorded the three-way cocks are turned so as to shut off the calibration loop, after which the indicator is injected into a peripheral vein or into the right heart of dogs, and the dilution curve is recorded by means of the calibration system from the carotid or femoral artery. After each recording of the dilution curve the blood can be returned into the blood stream of the tested animal by switching the suction pump into reverse.

An example of a thermodilution curve recorded during aspiration of blood from the carotid artery of a dog after injection of cold polyglucin into the superior vena cava is given

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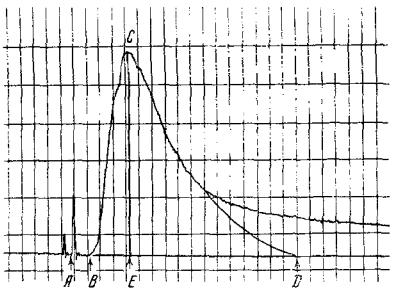


Fig. 2

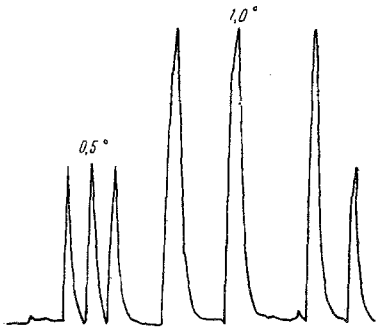


Fig. 3

Fig. 2. Thermodilution curve recorded on an EZ-2 linear automatic writer (Czechoslovakia). Blood was aspirated from the carotid artery of the dog through the calibration system. A) Time of injection of indicator B) point where thermodilution curve begins to rise; CE) peak of thermodilution curve; D) point of intersection of extrapolated part of descending section of thermodilution curve with reference line.

Fig. 3. Series of calibration curves after injection of standard dose of cold polyglucin into calibration loop, recorded on EZ-2 automatic writer at slow winding speed.

in Fig. 2. A type MT-54 thermister from a type 055 (TSM-2) electrical thermometer, slightly modified for recording thermodilution, is used.

The suction pump consists of a 100-ml glass syringe the plunger of which is connected rigidly to a nut. A threaded metal rod, connected to the shaft of a type RD-09 reversing motor, is screwed into this nut. To prevent the blood from entering the syring of the pump, a hermetically sealed vessel with a capacity of about 70 ml is included between it and the sensor. Recently we have used a 24 V dc microcompressor as the suction pump.

Before the investigation the whole system is filled with physiological saline with heparin, and heparin is injected intravenously into the animal in the usual dose.

The principle of the dynamic calibration method is thus that standard calibration indicator-dilution curves are recorded initially, and then, after disconnection of the calibration loop, the experimental dilution curve is recorded when the indicator is injected into one part of the venous system. Next the areas of the calibration and experimental curves are determined and the minute blood volume and other hemodynamic indices calculated.

The volume blood flow in the calibration system and the volume of injected indicator determine the area of the dilution curve. On the assumption that the areas of the dilution curves of the tested animal and in the calibration system are determined by the same factors, the volume velocity of blood flow of the tested animal (Q) bears the same ratio to the velocity of blood flow in the calibration system ($Q_c$) as the volume of dye injected into the animal (i) to the volume of dye injected into the calibration system ($i_c$):

$$Q : Q_c = i : i_c, \text{ whence } Q = \frac{i \cdot Q_c}{i_c}.$$

Bearing in mind that the areas of dilution curves recorded from the calibration system and from the animal's vascular system are not always identical, a correction factor must be introduced, i.e., if A represents the area of the indicator-dilution curve in the animal's vascular system and $A_c$ the area of the dilution curve in the calibration system, then

$$Q = \frac{i \cdot Q_c}{i_c} \cdot \frac{A_c}{A}, \text{ or } Q = \frac{i \cdot Q_c \cdot A_c}{i_c \cdot A}.$$

This formula was deduced by Emanuel and Norman [2]. Since the blood flow in the calibration system is known (to begin with the calibration system was calibrated from a buret filled with heparinized blood), and since the volumes of injected indicator and the area of the calibration curve also are known, this formula can be simplified by introducing a factor $C_c$ (the calibration constant): $C_c = Q_c\ A_c/i_c$, where Q, or MVC (minute volume of the circulation) is equal to $C_c \cdot i/A$.

The reproducibility of the curve and linearity of the response of the calibration system are illustrated in Fig. 3, which shows a series of thermodilution curves recorded in a continuous-flow cuvette by means of a calibration system immersed in a type TS-15M thermostat at a temperature of 38°.

## LITERATURE CITED


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