A Saline Conductivity Method for Detection of Cardiac Shunts by Indicator-Dilution Technic

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A new method for cardiovascular shunt detection is described using the indicator-dilution principle applied to blood conductivity changes produced by 5 per cent saline. It possesses these distinct advantages over the Evans blue technic: (1) an unlimited number of determinations can be made without an increasing blood dye background or bluish discoloration of the patient, (2) oximetric determination of blood oxygen saturation is not interfered with, and (3) a simple modification of the carrier amplifiers of commonly used recording systems supplies most of the necessary instrumentation.

Although indicator dilution technics, using chiefly T-1824 (Evans blue dye), have been of value in the determination of the site and type of cardiovascular shunts, the methods suffer certain major limitations despite refinements in the recording of the dye curves. With regard to Evans blue, repeated determinations result in an increasing blood background of this protein-bound dye, which restricts both the number and frequency of accurate measurements; frequently it is advantageous to have repeated curves from both the same and multiple sites. In addition, following its use the photometric determination of blood oxygen saturation is no longer possible. One of the lesser objections is the bluish discoloration of the patient that may result after multiple determinations.

The use of hypertonic saline as the indicator in the determination of cardiac output by the indicator-dilution technic has been described by several authors. It occurred to us that this conductivity method was applicable to cardiovascular shunt detection and during the past year a modification of the method has been successfully applied to the detection of such shunts.

**METHOD**

Twenty-one patients with congenital heart disease, 12 of whom had intracardiac shunts, have been studied. Representative curves are shown on 4 patients as follows: (1) A 21-year-old white female with isolated valvular pulmonic stenosis, (2) a 21-year-old white male with Eisenmenger's syndrome, (3) a 30-year-old white male with a ventricular septal defect and a predominant left-to-right but small right-to-left shunt, and (4) a 3-year-old Negro female with tetralogy of Fallot.

Injection of 5 per cent saline, 2 to 5 ml. depending upon patient size, was accomplished through a standard cardiac catheter into various sites in the right heart and pulmonary artery. In the case of the Eisenmenger's syndrome, 75 mg. of Bromsulphalein (BSP) was injected with the 5 per cent saline and simultaneous BSP and conductivity curves were obtained. Recording in all cases was done on blood drawn from an indwelling arterial needle. Blood was drawn through the conductivity cell by a constant withdrawal pump at rates of 5 or 10 ml./min.

**Conductivity Cell.** The conductivity cell consisted of 2 platinum electrodes imbedded in a plastic cylinder. The electrodes were constructed from a platinum cylinder 15 mm. long and 1.3 mm. in internal diameter. This was separated into two longitudinal halves by the removal of two 0.3 mm. sectors at opposite ends of a diameter. The two sections, still separated by 0.3 mm. at each edge, were mounted flush, midway along the 1.3 mm. bore of a hollow plastic cylinder 60 mm. in length and 15 mm. in outside diameter. Both ends of the cylinder were fitted with standard male slip fittings for hypodermic needles. The electrodes were platinized with platinum chloride containing 0.025 per cent lead acetate and during

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*Obtainable from the W A M Manufacturing Company, Columbus, Ohio.
†Similar cells can be obtained from Mr. Elmer Lusk, Columbus, Ohio.
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FIG. 1. A saline dilution curve with no evidence of shunting obtained from a 21-year-old white female with isolated valvular pulmonic stenosis. Injection site, right atrium; sampling site, brachial artery. Small black bar above baseline represents onset and duration of injection; time lines represent 1 sec. intervals. Appearance time (A.T.), measured from the onset of injection to the onset of the curve, is 8 sec., which is normal. The ascending and descending limbs of the curve are smoothly inscribed. Fine saw tooth oscillations in this and subsequent curves represent impedance changes produced by arterial pulse. Recording made with an Electronics for Medicine 55-2 oscillograph.

The cell was found to have a resistance of 48 ohms with 0.85 per cent saline at 40°C, and a temperature characteristic of 2.1 per cent per degree.

Bridge. The bridge used was essentially similar to that used by Holt. Five hundred ohm resistances replaced 1500 ohm resistances in the fixed arms. The variable resistance was a 500 ohm ten turn Helipot.

Oscillator and Detector. A commercial carrier amplifier (Electronics For Medicine 55-2 or Sanborn) was used as the oscillator and detector. Most commercial carrier amplifiers can be modified for this purpose. The galvanometer was used for nulling. Since the compensating resistance and capacitor balances of the amplifier-detector introduce an unknown element into the bridge, they were removed entirely from the circuit with double-pole single-throw switches.

Recording. This was done either by oscillographic photography (Electronics For Medicine) or directly (Sanborn Polyviso).

RESULTS

A curve without shunts is shown in figure 1. The identical form and time course of the simultaneous BSP and saline dilution curves obtained following injection into the superior vena cava of the patient with Eisenmenger's syndrome is shown in figure 2. Four curves obtained from the sites as indicated in a patient with a ventricular septal defect and a bidirectional shunt are shown in figure 3. Two curves obtained from two different sites in a patient with tetralogy of Fallot are shown in figure 4. Of the 12 patients with intracardiac shunts, 5 were of the isolated right-to-left type. In these cases accurate localization of the shunt site was accomplished by the use of conductivity curves. Such localization could only be inferred by routine right heart catheterization without the use of indicator dilution technics.

DISCUSSION

That saline-induced impedance changes could be used as an indicator for the determination of cardiac output by the indicator-dilution technic was first described by Stewart and was later substantiated by a number of other observers. The procedure has not been used for shunt detection to our knowledge. The conductivity method here described has the same advantages as the photometric Evans blue technic in that a perma-
FIG. 3. Four curves obtained in a 21-year-old white male with ventricular septal defect. Sampling site was the brachial artery. A obtained by injection into main pulmonary artery revealing only a left-to-right shunt as evidenced by a prolonged disappearance time, B to D obtained by injection into right ventricle at sites noted. As the catheter is withdrawn toward the tricuspid valve it can be noted that an earlier and a progressively larger first peak occurs, indicating the presence of a small right-to-left shunt. The brachial arterial oxygen saturation at this time was 92 per cent. Injection bars, time lines and recording as in fig. 1.

It would appear, therefore, that wherever the indicator-dilution technic is applicable for the detection and localization of cardiovascular shunting, especially right-to-left, the conductivity method can be used. The polycythemia present in many patients with right-to-left shunts works to the advantage of the method in that there is a greater impedance change per volume of saline injected. Thus the method is most sensitive when dilution curves are the most useful. The method suf-
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fers the same limitations in permitting recognition of left-to-right shunting as any indicator dilution technic, in that only the presence but not the location of such a shunt can be detected. The blood oxygen studies fortunately are far more efficient in this regard.

SUMMARY

A conductivity method using 5 per cent saline has been described for the detection of cardiovascular shunting by the indicator-dilution technic. The advantages of this method over Evans blue dye are (1) frequent determinations are possible without increasing indicator background in the blood, (2) it does not interfere with cuvette oximetry, (3) it does not discolor the patient, and (4) most of the instrumentation is accomplished by a simple modification of the commonly used carrier amplifiers.

SUMMARIO IN INTERLINGUA

Un methodo de conductivitate que utilisa un solution salin de 5 pro cento es describite pro le detection de shunts cardiovascular per medio del technica a dilution del indicator. Le avantages del metodo in comparation con le uso de blau de Evans es le sequente: (1) Frecuentes determinationes es possible sin augmentar le residuo del indicator in le sanguine; (2) illo non disrangia le uso de oxymetria a cuvette: (3) illo non discolora le pa-tiente; e (4) le plus grande parte del instrumentation es effectuate per un simple modi-fication del amplificatores de portator que es in uso commun.

REFERENCES

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