ANALYSIS OF PRECORDIAL ISOTOPE DILUTION CURVES OBTAINED AFTER ANTECUBITAL AND INTRACARDIAC INJECTION

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Conventional techniques using external precordial isotope counting to measure cardiac output are based on injecting ^{131}I-labeled human serum albumin into an antecubital vein and then recording the precordial primary passage curve (radiocardiogram) with a NaI(Tl) detector probe. The precordial tracings are analyzed, and using the blood volume calculated by isotope dilution an estimate of cardiac output is derived.

Huff has reported good correlation between precordial outputs with simultaneous direct Fick determinations in dogs and humans (*1*). His original emphasis was on viewing the passage of the radioisotope bolus over the aorta. Subsequent work with wide-angle collimation has apparently resulted in reliable output determinations even though multiple heart chambers are viewed simultaneously (*2*). Recently, a compilation (*3*) of the results of several investigations showed good agreement between cardiac output obtained by external counting and by other methods. External detection techniques using intracardiac injections have been reported and appear to be useful for detecting and localizing left-to-right and right-to-left shunts in congenital heart disease (*4,5*). Johnson *et al* (*6*) have suggested analyzing the precordial curve to measure central transit time which they subdivided further into arterial and venous segments.

In the present paper cardiac outputs obtained by precordial detection of isotope injected into an antecubital vein are compared with simultaneous direct Fick outputs. The curve of the primary passage after antecubital injection is analyzed to determine the transit time from the right heart peak to the left heart peak which has been suggested by Johnson *et al* to be an estimate of the pulmonary transit time. This time is compared to pulmonary artery pressure. Circulation times measured from the time the isotope appears in the heart to the time it appears in the head are analyzed after antecubital and left ventricular injections. The difference between these two circulation times is an estimate of true transit time from the right heart to the left heart and is compared with mean pulmonary artery pressure in five patients with rheumatic heart disease, one patient with intraatrial septal defect, one with primary myocardial disease and one patient suspected of—but found to have no evidence of—organic heart disease.

MATERIALS AND METHODS

A precordial detector probe containing a 2-in. NaI(Tl) crystal detector, collimated to 2½ in. in diameter and recessed 3½ in., was placed over the third interspace in the midsternal line. A second unshielded probe was directed at the midfrontal region

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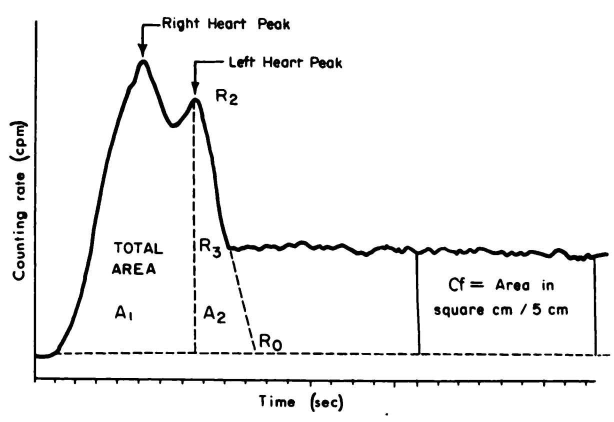

$$\text{TOTAL AREA} = A_1 + \frac{R_2 - R_0}{R_2 - R_3} A_2$$

FIG. 1. Stylized primary passage curve obtained by external detection shows area measurements used to calculate cardiac index.

of the head with the detector crystal flush to the surface. The probes (Picker Model 2801D) were connected through ratemeters (Picker Model 5846; time constant 0.3 sec and counting range 0–30 K) to a rectilinear galvanometric recorder with full-scale pen travel time of 0.25 sec (graph speed 15.2 cm/min).

Fifteen to 20 μCi of ^{131}I-labeled human serum albumin in 1 ml was injected rapidly with a tuberculin syringe as a bolus into an antecubital vein during oxygen collection for a simultaneous Fick cardiac output determination.

Blood volume was obtained by extrapolating back to injection time from specimens taken 10 and 20 min after injection.

Subsequent injections of 10–15 μCi ^{131}I-labeled hippuran were made through the catheter at progressive downstream sites, including the pulmonary artery and the left ventricle. Ten milliliters of saline were used to flush the catheter immediately after each isotope injection.

Cardiac output was calculated from the curve (Fig. 1) by the usual techniques (7) and is expressed as liters/min/square meter of body surface. The precordial dilution curves were analyzed for right-heart-peak to left-heart-peak transit times.

Circulation time from the first appearance of radioisotope tracer into the heart to its appearance in the head was calculated for both antecubital and left ventricular injection. The difference in circulation time was considered to reflect the mean time required for the isotope to traverse the pulmonary circuit after antecubital injection (pulmonary transit time) but it corresponds more nearly to right atrial to left ventricular transit time.

Linear correlation and regression analyses were performed on measurements of cardiac index by Fick and precordial dilution methods, peak-to-peak transit times compared to pulmonary artery pressure, central transit time compared to pulmonary artery pressure and Fick indices compared to indices obtained by progressive downstream tracer injection. The Student "t" test was performed on all correlation coefficients. Significance was established at the 95% confidence level.

RESULTS

Cardiac index obtained by radioisotope and Fick techniques (Fig. 2). There was good correlation ($r = +0.82$, $p < 0.05$) between cardiac indices obtained simultaneously from the Fick principle determinations and radioisotope precordial curves made after antecubital injections.

Right-heart-peak to left-heart-peak circulation time compared to mean pulmonary artery pressure (Fig. 3). The primary passage curve obtained by precordial counting shows a rapid increase in counting rate to a so-called right heart peak—a slight fall in the peak thought to be due to radioisotope diffusion after it is washed out of the heart—and the appearance of a second peak thought to be due to return of the tracer to the left side of the heart. This is followed by a steep decrease indicating tracer disappearance into the aorta (Fig. 1). The normal right and left heart peaks are relatively sharp, and the over-all appearance of the normal primary passage curve is slim. However, the correlation between the right-heart-peak to left-heart-peak time and the mean pulmonary artery pressure was poor ($r = +0.32$, $p > 0.05$).

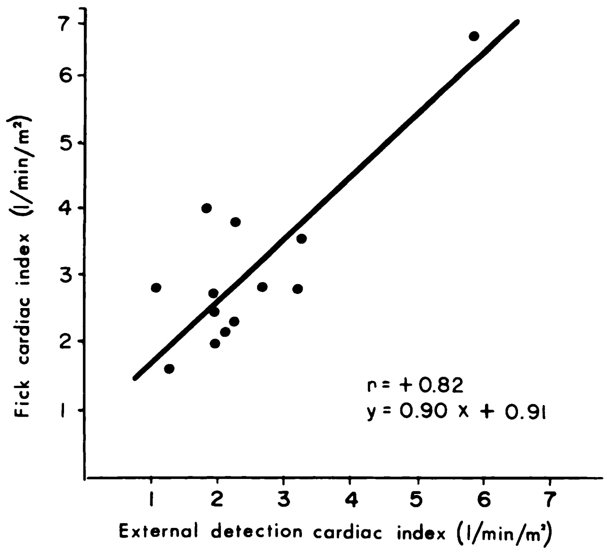

FIG. 2. Comparison of cardiac indices obtained by simultaneous determinations using Fick principle and external detection.

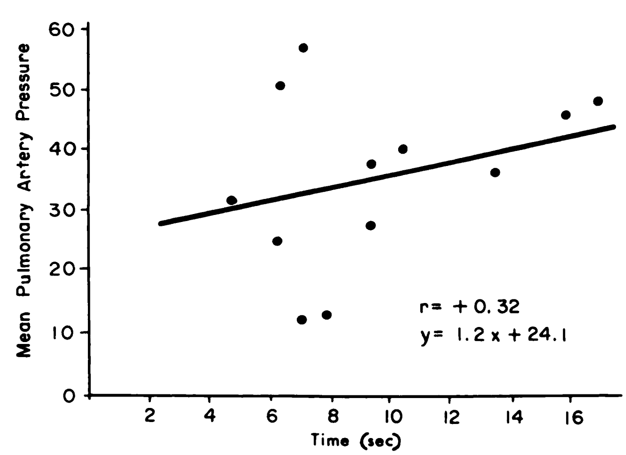

FIG. 3. Gross time interval from peak concentration of radioisotope in right heart to its peak concentration in left heart is compared to mean pulmonary artery pressure.

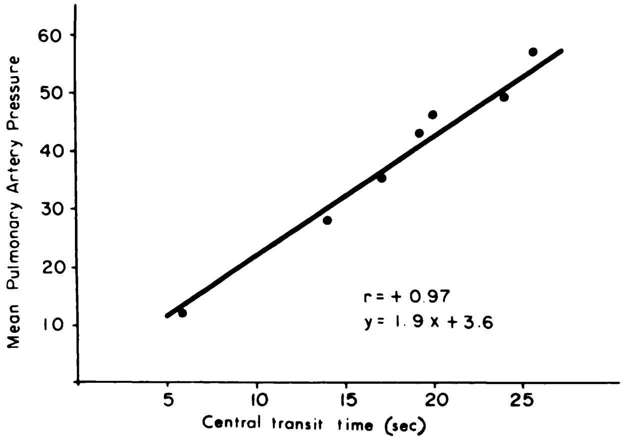

FIG. 4. Heart-to-head circulation time is defined as time interval in seconds between first appearance of radioactivity in heart and its first appearance in head. Arithmetic difference in heart-to-head circulation time after antecubital compared to left ventricular injection reflects primarily transit time through pulmonary circuit.

Correlation of central transit time with pulmonary artery pressure (Fig. 4). The heart-to-head circulation time based on the time between the first appearance of isotope in the heart and its appearance in the frontal region of the head was obtained after antecubital vein and left ventricular injection. The difference in heart-to-head transit time following antecubital and left ventricular injection is a measure of transit time from the appearance of the isotope in the right heart to its arrival in the left ventricle. These data correlated well with the mean pulmonary artery pressure ($r = +0.97$, $p < 0.05$).

Cardiac index determined from precordial dilution curves after progressive downstream injection (Fig. 5). Cardiac index was calculated from the precordial dilution curves after antecubital injections and progressive downstream intracardiac injections. A progressive increase in the calculated index was noted from precordial dilution curves obtained from serial antecubital, pulmonary artery and left ventricular injections. Cardiac indices correlated with Fick principle indices only when calculated from curves obtained after antecubital injections. Cardiac indices calculated from curves obtained after intracardiac injections did not correlate with Fick cardiac index values ($p > 0.05$).

DISCUSSION

The reliability of the precordial method for measuring cardiac index after antecubital injection of ^{131}I-labeled human serum albumin is confirmed by comparing it with measurements based on the Fick principle. Injection of the isotope elsewhere yields cardiac indices greater than those calculated by the Fick principle. The reasons for this are not known. However, the empirical correlation of the precordial technique after antecubital injection with the Fick method is sufficiently good, and the method can be used reliably.

Previous observations suggested that the time between the precordial right and left heart peaks might be useful as a measure of pulmonary transit time (*6*). However, congestive heart failure makes it difficult to evaluate the relationship of the right-to-left heart peak to pulmonary transit time (*8*). Moreover the right-to-left heart-peak transit time does not correlate with pulmonary artery pressure in the present investigation. However, excellent correlation with pulmonary artery pressure was obtained when the central transit time was estimated from the difference in the right heart-to-head and left heart-to-head appearance times. This reflects the time of tracer transit from its first appearance in the right atrium and ventricle to the left ventricle and approximates the pulmonary or central transit time.

A variety of unknown interrelationships must limit the accuracy of the peak-to-peak transit time as a reflection of pulmonary transit time. In the anterior-posterior projection the chambers of the right side almost completely overlap the left, and collimation for separation is not possible. The volumes of blood are not equal, and washout from each chamber is an exponential function requiring the assumption of at least two in-series mixing chambers separated by a parallel flow net of different path lengths and transit times (*9*). Also recirculation to the heart from short rapidly cleared peripheral beds such as brain and kidney occurs before the right ventricle is cleared

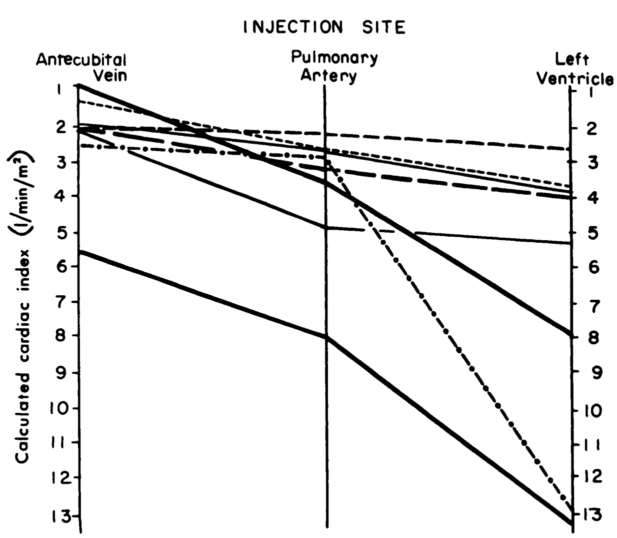

FIG. 5. Cardiac indices calculated from serially obtained primary passage curves after antecubital, pulmonary artery and left ventricular injections. Same blood volume was used for each calculation.

(*10*). It is likely that all these factors contribute in part to the distortion of the true mean pulmonary transit time from the observed peak-to-peak time.

SUMMARY

The external precordial isotope detection method with antecubital injection of ^{131}I-labeled albumin for calculating cardiac index compares favorably with the results of the Fick method in 13 patients with a variety of cardiac lesions. The external detection method requires injection into the peripheral venous system to measure cardiac output. When injections are made downstream into cardiac chambers and one or more cardiac chambers or the pulmonary circulation is bypassed, the method does not correlate well with cardiac output obtained by the Fick principle.

Analysis of primary-passage curves obtained by precordial detection after antecubital injections showed that the right-to-left heart transit time—the time from peak count of the radioisotope into the right heart to the time of peak count into the left heart—did not correlate well with mean pulmonary artery pressure. The difference between the heart-to-head circulation time after antecubital and left ventricular injection, which is a measure of right heart to left ventricular transit time, correlated well with the mean pulmonary artery pressure.

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