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Technetium-99m in the diagnosis of left-to-right shunts

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Radio-isotope techniques for the detection of intracardiac shunts have often employed external counting over the praecordium (Prinzmetal, Corday, Spritzler, and Flieg, 1949; Huff, Parrish, and Crockett, 1957; Greenspan, Lester, Marvin, and Amplatz, 1959; Turner, Salazar, and Gorlin, 1960; Shapiro and Sharpe, 1960). However, Folse and Braunwald (1962) counted over the upper lung field and claimed to have resolved by this means those effects from blood flow through the various chambers of the heart on curves from praecordial counting. Shunts were detected by a lowered clearance rate of isotope from the lung field due to the continuous reintroduction of blood into the right heart and lesser circulation through the septal defect.

Limitations in the accuracy of external counting techniques are imposed largely by the amount of isotope which can be administered with safety to the patient, and by the degree of definition of the anatomic field viewed by the detector head. The usual detection system employed in external counting incorporates a γ-ray sensitive crystal usually made of thallium-activated sodium iodide, which is covered for most of its surface by a lead shield so that radioactivity from sites other than the desired one is excluded.

The field viewed can be further limited by fitting a lead tube or collimator to the detector head; this excludes the reception of virtually all radioactivity other than that in the body tissues directly beneath the tube (Fig. 1). With these limitations, the use of ^{131}I for shunt diagnosis is somewhat inadequate, since with the usual dose of 20 to 50 μc, and a collimation similar to that employed in the present detector head, the counting rates achieved are too low to afford precise information.

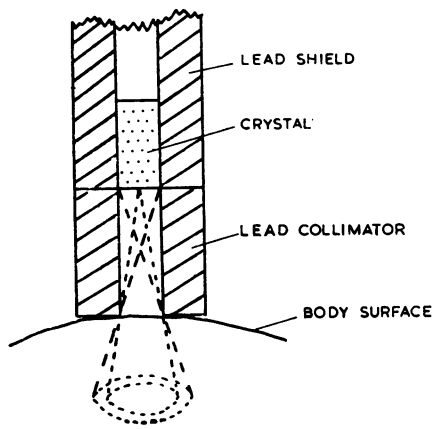

FIG. 1. *Schematic presentation of the field viewed by a crystal detector fitted with a collimator.*

The recent availability of technetium-99m (^{99m}Tc), a daughter isotope of molybdenum-99 (^{99}Mo), whose disintegration characteristics allowed for larger doses to be administered, prompted a reappraisal of the detection of intracardiac shunts by external counting.

TECHNIQUE

PREPARATION OF ISOTOPE Technetium-99m, as the pertechnetate ion $TcO4^-$, was obtained by elution from a generator column of ^{99}Mo on an alumina support (obtained from the Radiochemical Centre, Amersham, Bucks); physiological saline was used as the eluting solution. The dose, within the range 0·6 to 1·0 mc., was sterilized before use.

ADMINISTRATION Subjects were allowed to relax in the prone position for at least 15 minutes, and the

detector head was then sited over the right lung field 1 to 2 cm. lateral to the mid-clavicular line in the second intercostal space (Folse and Braunwald, 1962). The detector head incorporated a thallium-activated sodium iodide crystal, 2 in. (50 mm.) long by 1 in. (25 mm.) diameter, surrounded by a 1 in. thickness of lead, to which was fitted a lead collimator of length 3 in. (75 mm.) and diameter 1 in. (Fig. 1). Impulses were fed into a pulse tape recorder (Herbert and Hyde, 1953) and simultaneously into a suitable linear chart recorder.[1] The tape recorder provided a memory for the operation and play-back facilities for retrospective appraisal of the events.

The isotope was administered via the antecubital vein, usually opposite to the side of the body over which the detector head was placed, and the response curve was followed for two to four minutes.

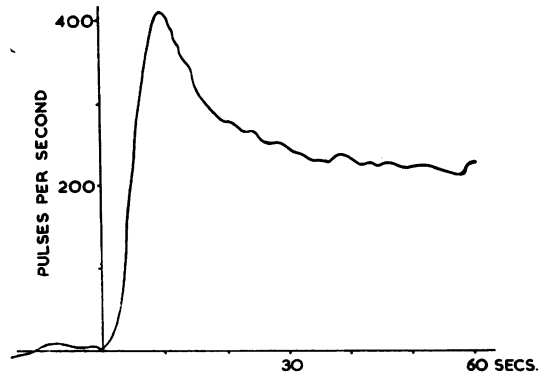

FIG. 3. *Patient with atrial septal defect.*

RESULTS

Normal subjects provided response curves similar to that in Figure 2. Maximum counting rates with doses of 1 mc. of ^{99m}Tc were within the range of 700 to 900 pulses per second, and definite secondary circulation peaks were evident. Patients with left-to-right shunts, all of which had been proved by catheterization, provided curves similar to that in Fig. 3, in which the maximum counting rate was lowered (400 to 600 pulses per second) and the clearance rate of isotope was reduced to the exclusion of a definite recirculation peak. Cases of patent ductus arteriosus, when scanned over the right and left lung fields, provided contrasting pictures of normal and abnormal curves (Figs 4 and 5), demonstrating the differential streaming

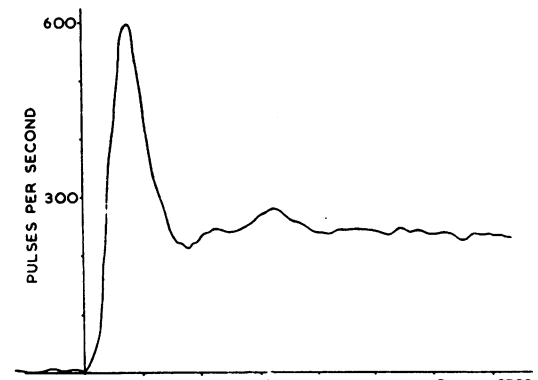

FIG. 4. *Patient with patent ductus arteriosus (right lung field).*

[1]Cambridge Instrument Company, Ltd.

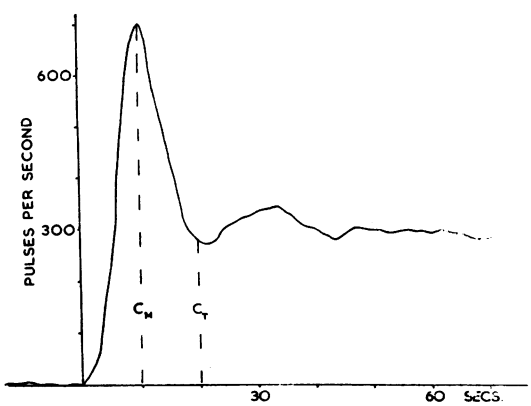

FIG. 2. *Response curve from normal subjects showing the relation between counting rate and time after injection.*

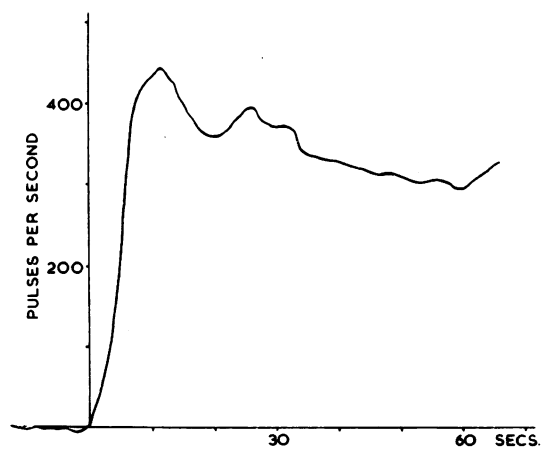

FIG. 5. *Patient with patent ductus arteriosus (left lung field).*

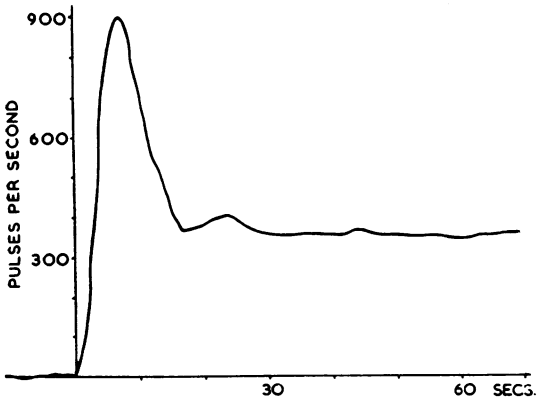

FIG. 6. *Same patient as in Fig.* 3, *after corrective surgery.*

of the arterial blood in this type of left-to-right shunt.

After surgical repair of septal defects two patients were reinvestigated, and the patient providing the abnormal pattern of Fig. 3 presented the normal characteristics of Fig. 6 after operation. The reappearance of the secondary circulation peak after surgery was impressive, as was the increase in the peak counting rate.

Folse and Braunwald (1962) differentiated between normal subjects and patients with left-to-right shunts by means of an empirical relationship similar to that employed by Carter, Bajec, Yannicelli, and Wood (1960) in dye dilution curves. An interval of time equal to that required for build-up to the maximum was marked on the time scale, and the height of the curve above the base-line at this point (C_T) was compared with the maximum height (C_M) as the simple ratio, C_T/C_M (Fig. 2). On this basis, 20 normal subjects gave a mean ratio ($C_T : C_M$) of $0{\cdot}38 \pm 0{\cdot}07$, whereas 40 patients with left-to-right shunts gave the significantly higher mean value of $0{\cdot}68 \pm 0{\cdot}12$ $P<0{\cdot}001$).

It appears, therefore, that a characteristic and diagnostic curve can be obtained with this method in the presence of a left-to-right shunt. The smallest shunt in our series had, on cardiac catheterization, a flow ratio of 1·3:1 and was easily detectable.

In order to assess the reproducibility of this technique, duplicate investigations were carried out on five patients. The results obtained are shown in Table I, and reveal that reproducibility is within the limits expected in this type of physiological investigation.

TABLE I

VALUES OF THE RATIO CT:CM IN FIVE PATIENTS: DUPLICATE ANALYSES

Patient	1st Value (V_1)	2nd Value (V_2)	Mean Value (V_M)	$\frac{V_1-V_2}{V_M}$ (%)
1	0·70	0·70	0·70	0
2	0·70	0·69	0·70	1
3	0·44	0·50	0·47	13
4	0·66	0·65	0·66	2
5	0·67	0·65	0·66	3
			Mean	4

DISCUSSION

Technetium-99m decays initially to technetium-99 with a physical half-life of six hours. This isomeric transition is associated with the emission of a single γ-ray of 0·14 MeV and, apart from a small emission of conversion electrons (8 to 11%), no β-radiation occurs. Technetium-99 itself decays with β-emission to stable ruthenium-99, but, as its half-life is 2×10^5 years, the β-radiation produced is negligible. Such disintegration characteristics enable much larger doses to be administered than in the case of ^{131}I and other similar isotopes. For example, a dose of 1 mc. ^{99m}Tc realizes only 0·01 rad as whole-body radiation, a value which is very much lower than the radiation dose (usually greater than 1 roentgen) received in the average cardiac catheterization.

Although some localization of ^{99m}Tc occurs within the body, mainly in the thyroid and stomach, total excretion from the body is rapid (Harper, Beck, Charleston, and Lathrop, 1964; Harper, Lathrop, McArdle, and Andros, 1964).

Further, as the half layer value in tissue for ^{99m}Tc is 4·5 cm., the contribution to the detected radiation arising from underlying great vessels, which has always presented a problem with ^{131}I (Conn, 1962), is correspondingly reduced. Collectively, the ability to obtain higher counting rates by the administration of larger amounts of ^{99m}Tc, together with the increased definition of the area monitored, increases the accuracy of the technique compared with the use of other isotopes.

An additional advantage of ^{99m}Tc is the small amount of screening required for detector heads. The assembly described here was a standard one, capable of use with a variety of isotopes, but sufficient screening is provided by as little as 3 mm. of lead, which decreases enormously the weight of the detector head and the strength of the support required for it.

Apart from the decreased radiation hazard of this method, as compared with techniques associated with cardiac catheterization, the

simplicity of the procedure for the patient indicates its usefulness as an out-patient screening technique, both in the detection of left-to-right shunts and in the assessment of patients who have received corrective heart surgery.

Although this technique has shown itself to be as sensitive as oximetry in recognizing left-to-right shunts qualitatively, it has not been possible to establish a reliable quantitative relationship with the calculated size of shunt as measured at cardiac catheterization. Quantitative estimations of shunts have a limited reliability both by dye dilution methods and by oximetry owing to the complex haemodynamics and streaming effects which occur within the heart in these conditions.

A comparison of the cost of using ^{99m}Tc compared with other isotopes is difficult because of its production from a generator column; but if the full capacity of the generator is realized, the cost per millicurie is less than, or comparable with, that of similar isotope preparations.

SUMMARY

Technetium-99m, as pertechnetate, has been used to demonstrate the presence of intracardiac shunts by external counting over the lung field. Definitive differences occurred in the counting-rate/time curves between 20 normal subjects and 40 patients with proved left-to-right shunts. The advantages of this isotope over ^{131}I in this type of work are discussed.

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