CIRCULATION TIMES IN CONGENITAL HEART DISEASE

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Received December 3, 1948

Since the introduction of surgical treatment for congenital heart disease, which was mainly of academic interest before, it has become important to diagnose as far as is possible the anatomical and dynamic abnormalities present in each case. This need has placed a premium upon any method, more especially if simple and safe, that may help to elucidate the problem. The purpose of this communication is to report briefly the results obtained from circulation time estimations in congenital heart disease, and to discuss what value this simple test possesses.

References to circulation times are numerous, and it is not intended to review these extensively. Blumgart, Weiss, and others first perfected a technique and studied circulation times extensively, reporting their results in 1927 and 1928. Their method involved using radium C and was an objective one, but owing to the technical complexity of the apparatus and agent it is unsuitable for clinical work. Most of the methods described subsequently for the arm-tongue time have been subjective, except those using fluorescein, histamine, and sodium cyanide. In 1933, sodium dehydrocholate was used in a series reported by Tarr, Oppenheimer, and Sager, although its first use is credited to Nebauer in 1923. Saccharin was introduced by Fishberg, Hitzig, and King in 1933. With the exception of Blumgart's radium method, measurements of the arm-lung time depend upon a subjective reaction, and ether, introduced by Hitzig in 1935 and paraldehyde first used by Caudel in 1938, were the agents commonly used. An excellent review of the methods devised was published by Baer and Slipakoff in 1938.

References to circulation times in congenital heart disease are scanty, but Tarr, Oppenheimer, and Sager (1933), report that the arm-tongue time, in a patient diagnosed as having Fallot's tetralogy, was on three occasions considerably shorter than normal. In 1937, Goldman and McGuire reported the

apparent acceleration of blood velocity as measured by the arm-tongue time in three cases of morbus cœruleus. It has been used widely at the Johns Hopkins Hospital, and Taussig (1947) states that the absence of any shortening of the time may support the diagnosis of pure pulmonary stenosis; that shortening of the time may support the diagnosis of Eisenmenger's complex even when there is no obvious cyanosis; and that a prolonged time may be found with aortic stenosis. Prinzmetal in 1941, proposed a quantitative method for the estimates of the actual amount of right to left shunt.

METHOD USED

The agents used have been 20 per cent sodium dehydrocholate in 18 estimations of the arm-tongue time, and 50 per cent saccharin in a further 22 estimations. Saccharin has been used owing to the recent difficulty in obtaining decholin, although this latter gives a sharper and more distinctive end point and has a lower threshold concentration for taste. In all 35 estimations of the arm-lung time, 5 per cent paraldehyde in saline has been used. The normal range for the arm-tongue time, using these agents, is 11 to 17 seconds, and for the arm-lung time 3 to 8 seconds.

Reports have appeared from time to time of unpleasant effects from the use of decholin, and in three cases these have resulted in the patients' death, though in all the reported cases of death, the patients showed a previous history of sensitivity, such as asthma, etc.; if patients with such a history are excluded from injections, it seems that decholin is a safe substance to use. Saccharin and paraldehyde may cause pain on injection, and the former has been reported as producing abscess formation when injected paravenously. Venous thrombosis has been reported as a frequent complication following saccharin and paraldehyde, whilst nausea and vomiting are said to follow the injection of decholin

on occasions. In this series there has been no fatality, and no evidence of venous thrombosis or any other complication except that about half the subjects complained of pain in the arm following paraldehyde, whilst one vomited after receiving decholin, and another became extremely nauseated.

All patients have been investigated while lying at rest, either in the wards or at the Cardiac Out-patients of Guy's Hospital. The injections have been made with the site of injection, in each case a vein at the bend of the elbow, approximately level with the right auricle. Four ml. of each agent are used, in all-glass syringes fitted with a wide bore intravenous needle. After venepuncture has been performed, a minute or so is allowed to pass whilst the local circulatory conditions return to normal in the previously congested area. This opportunity is taken of ensuring that the patient knows what to expect, and that he has to signal as he tastes the appropriate substance. The time taken for the actual injection has been found to be remarkably constant at 2 to 2.5 seconds, and this can be disregarded in the results. An assistant is instructed to measure the time taken from the beginning of the injection until the patient's signal. Immediately following this, the arm-lung time is estimated, using the same needle, and merely attaching the second syringe. Following the procedure, the patient is instructed to exercise his hand and arm for a few minutes to disperse any paraldehyde that might still be lying in the vein, and so cause thrombosis.

This method is used for the diagnosis of whether a right to left shunt is present or not, but in five cases Prinzmetal's suggested method has been used to assess the percentage of blood shunted from right to left. The method consists, briefly, of the measurement of the arm-tongue time using successively larger amounts of agent. It is only applicable in cases where the shunt does not exceed 50 per cent. The theory upon which the method is based postulates that any substance arriving in the right ventricle (for example) will proceed along the two alternative pathways tongue and lungs (assuming a shunt to be present), in amounts proportional to the volume of blood passing to those organs. There is also a threshold concentration necessary at the taste buds before the subject can appreciate the taste. It follows, therefore, that if less than 50 per cent of blood is shunted into the aorta, the injection of increasing amounts of agent will cause a threshold concentration to be reached first in the blood passing via the lungs to the tongue, and hence the first sensation will be noticed in a relatively long, or normal arm-tongue time. Subsequently, a concentration will be reached in the shunted blood that

will produce a taste and when this occurs the arm-tongue time measured will suddenly become shortened.

If the amount necessary to produce the initial longer time be called A, and that required to cause the sudden change, B, then it can be shown that:—

$$\text{Percentage of blood shunted} = \frac{A}{A+B} \times 100.$$

In practice the technique is similar in all respects to that previously described, except that amounts increasing by 0.2 ml. are injected until first the longer, and then the shorter time is obtained.

RESULTS

Of the 36 patients investigated, 35 were suffering from congenital heart disease. The remaining patient (always grossly cyanosed, and for 29 years thought to be a case of Fallot's tetralogy) suffered from pulmonary hæmangioma.

There were 3 patients with congenital heart disease who were not cyanosed.

The average age of patients was 15 years and the range was from 6 to 41 years.

Group I. Cyanosed Patients in whom both Circulation Times were Estimated

There were 28 patients; 20 were shown to have a right to left shunt, and in 8 the times were against a shunt. Details of these 8 are shown in Table I.

The results show failure in 3 (Cases O115, H121, and CB14), and a probable failure in a further one (Case H126) where angiocardiology confirmed the presence of a shunt. In the 4 cases at the top of the table the absence of a right to left shunt was confirmed.

Group II. Cyanosed Patients in whom only the Arm-Tongue Time was Performed

There were 5 patients in this group, and all of these were shown to have a right to left shunt.

Group III. Acyanotic Patients in whom both Times were Performed

There were 2 patients in this group and neither was suspected clinically of having a right to left shunt; in one a patent ductus arteriosus has recently been ligated (Case O122) but in the other angiocardiology very unexpectedly suggested a right to left shunt (Case C206).

Group IV. Patients in whom Prinzmetal's Method was used. (See Table II).

TABLE I
PATIENTS NOT DIAGNOSED AS HAVING A RIGHT TO LEFT SHUNT

Reference No.	Sex and age	Arm-tongue (seconds)	Arm-lung (seconds)	Diagnosis	Autopsy
(Baker 1949)	M 29	Decholin 14.0	8.5	Lung hæmangioma	Confirmed
H117	F 30	Saccharin 17.5	13.0	Valvular pulmonary stenosis	No shunt
P215*	F 20	Saccharin 33.0	22.6	Dilated pulmonary artery + aortic regurgitation	Confirmed
P212†	F 9	Saccharin 16.7	11.0	Valvular pulmonary stenosis	No shunt
H126	F 9	Saccharin 13.0	6.0	? Fallot's tetralogy	Alive
O115	M 27	Decholin 26.0	15.0	Fallot's tetralogy	No shunt
H121	F 24	Saccharin 17.2	9.2	Fallot's tetralogy	Shunt present†
CB14	F 13	Saccharin 13.8	8.4	Fallot's tetralogy	Confirmed
					Shunt present

* Cyanosis of peripheral type.

† No cyanosis at rest.

‡ Confirmed by angiocardiography.

The result was specially useful in Case P225 as he was not obviously cyanosed at rest; the final diagnosis was Eisenmenger's complex. It was rather surprising in Case O111 as she too was hardly cyanosed at rest and was thought to have valvular pulmonary stenosis with a patent foramen ovale.

Cases 0070 and 0075 were thought to have Fallot's tetralogy.

Case 0207 was thought to have valvular pulmonary stenosis and to have developed a right to left shunt later in life. This was confirmed at operation and the valve was divided by Mr. R. C. Brock.

She made an uneventful recovery, with striking improvement, already being able to walk about the hospital freely, whereas before she had been virtually bedridden. It has been possible therefore to compare her circulation times before and after operation.

	Arm-Tongue (seconds)	Arm-Lung (seconds)	Hæmo-globin%
Pre-operative ..	12.2	10.0	122
Post-operative ..	10.2	6.8	106

The first difference is the overall reduction in circulation times following operation, coupled with an increase in difference between the arm-tongue and arm-lung times. The lowering of hæmoglobin which occurred may have helped to shorten the times, but it also seems likely that the partial or complete relief of the valvular obstruction has contributed to this effect, and the reduction in pressure in the right ventricle has diminished the shunt

which had been taking place through the interauricular septum.

TABLE II

Reference No.	Sex and age	Amount producing longer time	Amount producing shorter time	Shunt
0111*	F 8	variable	results	probably 50%
0075	M 6	0.50 ml.	1.50 ml.	25%
0070	M 8	1.00 ml.	3.00 ml.	25%
0207	F 26	1.80 ml.	3.00 ml.	37%
P225 *	M 13	1.00 ml.	5.00 ml.	17%

* Cyanosis on exertion only.

DISCUSSION

The results presented above have attempted to show that the estimation of the arm-tongue time together with the arm-lung time is a simple and safe method to be used in the diagnosis of the presence of a right to left shunt. It is most important that both times be estimated together, and the only satisfactory evidence of a shunt is that they should agree within two seconds of each other. This alone can indicate that substances introduced into the right side of the heart reach a point on the great and lesser circuits simultaneously, and there must be a communication between the two before the lung capillaries are reached. Further, the blood must be passing from right to left. It is important to note that by no means every case of Fallot's

tetralogy or allied condition shows a markedly shortened arm-tongue time, as might be thought, and indeed as the scanty references in previous work report. In this series five patients had normal arm-tongue times, though in each case the arm-lung time equalled this, which demonstrates the possible error that may occur if the arm-tongue time is taken alone. The chief reason for the failure of the arm-tongue time to be shortened in every case, is probably that the compensatory polycythæmia causes the opposite effect, namely slowing of the time, as shown by Blumgart in cases of polycythæmia rubra vera. In the five cases mentioned here it is noteworthy that the hæmoglobin concentration was 140 per cent or more in each. It is appropriate to comment upon the disparity in actual values obtained for circulation times, using the methods described above and angiocardiology. The normal values stated previously will only hold good if relatively small amounts of agent are introduced into the circulation. Experience with angiocardiology performed on some of the patients used in this series shows that the opaque dye may appear in the aorta two seconds after injection, giving a grossly shortened arm-tongue time. This is to be explained by the greater quantity of dye injected, namely 50 ml. or more, which consequently causes considerable changes in venous return to the heart.

The method has certain disadvantages. It is, firstly, a subjective method and the patient's intelligent co-operation is needed. This requirement effectively rules out its use in very young children, six years being probably the youngest age at which a satisfactory result may be obtained. Since the patients attending a congenital heart clinic for advice will show a high proportion of young children, many will not be able to undergo the test. Lack of intelligence, even in older persons, apprehension, and general dislike of venepuncture are all factors that have tended to obscure results, and in this series there have been twelve failures from these particular causes.

The results show three subjects in whom a right to left shunt was not suspected upon the circulation times, but in whom autopsy had since shown this contention to be incorrect. These failures all occurred within a short time of each other, when differing amounts of saccharin to be injected were being tested, and the reason for failure seems to be that too little was used. If, as seems reasonable, these patients had a shunt of less than 50 per cent of total, then the injection of too small an amount of saccharin might cause a taste threshold to be reached only by the longer route. There is some

support for this, since in the only one of the three cases that had undergone cardiac catheterization, this investigation showed evidence of a moderate shunt only. Since these unsatisfactory results, the amount of saccharin injected has been raised, and no further trouble has been encountered.

Brief experience with Prinzmetal's method has shown this to be tolerably satisfactory, but a rather higher degree of intelligence and co-operation is required. The possible errors are great, and it has been found that repetition of the injection of similar amounts does not always produce the same response. It is unlikely that accuracy to within less than 10 per cent may be achieved, and in any case, in this context, the method is subject to the criticism that providing the presence of a shunt has been diagnosed, the clinical condition of the patient, reinforced by arterial oxygen estimations is of greater importance in indicating urgency of treatment than a doubtfully accurate estimation of the percentage of blood shunted.

SUMMARY

Results of estimating the arm-tongue and arm-lung times in a series of 36 patients suffering from suspected congenital heart disease are given. The agents used were 20 per cent sodium dehydrocholate and 50 per cent saccharin for the arm-tongue time, and 5 per cent paraldehyde for the arm-lung time.

Reference is made to the complications reported by previous workers, and in this series no reactions of any severity were observed. Prinzmetal's method of estimating the percentage of blood shunted in patients known to possess a right to left shunt was used in five cases, and a description of the method is given.

The results show that the measurement of the arm-tongue and arm-lung times together is a reliable, simple, and safe method to be used for the diagnosis of a right to left shunt, and failure was encountered in only three cases. The reasons for these failures are discussed. It is concluded that the single estimation of the arm-tongue time is not a reliable guide to the presence or absence of a shunt. The results using Prinzmetal's method show this to be of doubtful value. A discussion upon the advantages and disadvantages of the method is given.

I should like to thank Dr. Maurice Campbell and Mr. R. C. Brock for their encouragement and advice, and for permission to use their patients for this investigation.

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