TRIPLE HEART RHYTHM *

BY

WILLIAM EVANS

From the Cardiac Department of The London Hospital

Received August 28, 1943

Triple heart rhythm stands for the cadence produced when three sounds recur in successive cardiac cycles, just as two sounds compose the familiar dual rhythm of cardiac auscultation, and more rarely, four sounds a quadruple rhythm.

The conflicting views on the subject have long served to discourage attempts at a clinical perception of the problem. Disagreement is perhaps best illustrated by recounting the varied terminology employed to describe it. Thus we have gallop rhythm, canter rhythm, and trot rhythm; presystolic gallop, systolic gallop, protodiastolic gallop, and mesodiastolic gallop; complete summation gallop and incomplete summation gallop; auricular gallop, ventricular gallop, and auriculo-ventricular gallop; true gallop; left-sided gallop and right-sided gallop; rapid-filling gallop; diastolic echo; mitral opening snap; reduplication of first sound and reduplication of second sound; Potain's murmur; third heart sound and fourth heart sound. Others may have escaped my notice. This muddled nomenclature, as long as it stands, will frustrate any attempt to unify the many views held on triple rhythm. There is need of a simplified terminology based on clinical findings. It is indeed clear that a neglect of the clinical aspect on the one hand, and a persistence on the part of many to explain the *mechanism* of the supernumerary sound on the other hand, and to classify triple rhythm in accordance with sound records, have been largely responsible for obscuring this common form of cardiac rhythm. Phonocardiography need not become a routine test in clinical cardiology; when it has helped to establish a classification of triple rhythm it will have achieved its main purpose, though it will still serve in other auscultatory problems. In the present investigation it has been a condition that the supernumerary heart sound should be elicited first by clinical auscultation. No phonocardiogram was taken as a preliminary test, and it was only recorded later in order to confirm or correct the clinical impression that had already been gained.

Among patients attending the Cardiac Department of the London Hospital during a recent period, and known to have heart disease or referred for an opinion on the heart, there were 270 who presented triple rhythm. These were placed in a special series for which a set method of inquiry had been prepared. A regularized history was taken and a general examination was made. A special record was taken of the heart rate at rest and after exercise, the presence of cardiac enlargement, the symptoms and signs of heart failure, and the blood pressure. As to the supernumerary sound, its site, distribution, and character, were separately noted, as well as the effects upon it of respiration, change of posture, and induced tachycardia. The apical impulse was examined by palpation and direct auscultation. Cardioscopy was a routine method of examination by which the size of the separate heart chambers was assessed. At the start certain measurements were taken; these included the width of the heart and thorax, and the height of the right auricle and diaphragm, but they were discontinued when it was realized that they brought no valuable information. Sometimes, however, use was made of

* The third Strickland Goodall Memorial Lecture delivered before the Worshipful Society of Apothecaries in London, June 24, 1942.

the distance between the junction of the right auricle and superior vena cava and the summit of the pulmonary arc, for it partly expressed the degree of pulmonary artery distension when present. In certain patients a limb lead electrocardiogram was always taken. A phonocardiogram by a Cambridge string galvanometer and the electrocardiogram were taken simultaneously on the same plate.

In addition to the series of patients with triple rhythm, 200 subjects were added in due course to serve as control cases for this investigation of certain types of triple rhythm.

CLASSIFICATION

I do not intend to deal here with a complete bibliography of the subject because a faithful account of it was recorded by Holt (1927). Of course I shall refer to the work of many of those who before and since have described their clinical and graphic findings in patients with triple rhythm, and have thus contributed much to our knowledge of the problem. Particularly do I want to mention the astute observations of Potain (1856, 1866, 1876, 1880, 1894, and 1900) in pre-phonocardiographic days more than half a century ago. He differentiated between gallop and split sounds. A reduplicated or split sound, he said, was one where the two components had the same quality and pitch and were separated one from the other by a very short interval, while a gallop rhythm had a sound added to the normal sounds, and separated from them by an appreciable interval. The added sound was usually short and dull, a sort of thud, often better felt than heard, and frequently missed if auscultation was carried out with a stethoscope alone, monaural though it was. Usually it was detected in the region between the apex, the left border of the sternum, and the second rib, and it was sometimes heard over a limited area. The added sound was always diastolic and according to its position it could be described as protodiastolic, mesodiastolic, or presystolic. The typical gallop was presystolic; the protodiastolic gallop presented a diastolic echo and could be likened to the recall on the drum or a rebound of a hammer on the anvil.

The term gallop rhythm has become rooted in the history of triple heart sounds and most writers have adopted it. But since the qualifying terms gallop and canter only imply that the rhythm initiated by three sounds in the cardiac cycle is simulated by the sounds produced by a moving horse, and since adherence to such terms prevents a modern understanding of this form of cardiac rhythm, I mean to discard them. Instead it is only necessary to appreciate that when a supernumerary sound in the cardiac cycle gives rise to triple rhythm, three types may be recognized according to the position of the adventitious sound.

In the *first type* the added sound is found early in cardiac diastole; it follows the second sound immediately and is the third sound in the cardiac cycle. In the *second type* the added sound occurs late in ventricular diastole; it succeeds the period which the third sound customarily occupies, immediately precedes the first heart sound, and therefore may be styled the fourth sound. Thus the third sound disturbs the early part of the silent diastolic period, and the fourth sound disturbs the end part. In the *third type* the added sound is situated towards the end of systole just before the second heart sound. The position of the adventitious sound in the respective types is usually determined readily by auscultation even in the presence of moderate tachycardia. Severe tachycardia may be a distinct handicap although even then a classification of triple rhythm can usually be determined, and especially when aided by ancillary clinical data, but short of phonocardiography. A scheme setting out the positions occupied by these supernumerary sounds in the cardiac cycle is shown in Fig. 1.

The clinical conditions which give rise to the supernumerary sounds have been arranged according to the type of triple rhythm which they constitute, and this arrangement suggests a classification of triple rhythm.

	Systole	DIASTOLE	Systole	
DUAL RHYTHM	... lup ----- dup 1 2		lup ----- dup 1 2	... Normal Heart Sounds
	... lup ----- dup 1 2	dub 3	lup ----- dup 1 2	dub Third Heart Sound present (TYPE I)
TRIPLE RHYTHM	lub 4 lup ----- dup 1 2	 lub 4	lub 4 lup ----- dup 1 2	... Fourth Heart Sound present (TYPE II)
	... lup - dub 1 S dup 2		lup - dub 1 S dup 2	... Systolic Extra Sound (TYPE III)
QUADRUPLE RHYTHM	lub 4 lup ----- dup 1 2	dub 3	lub 4 lup ----- dup 1 2	dub 3 Third and Fourth Sounds present (TYPES I and II)

FIG. 1.—Scheme showing position of heart sounds in cardiac cycle in different types of triple rhythm. S—systolic extra sound. Fourth heart sound occurs in *ventricular* diastole, but in *auricular* systole.

TABLE I
THE CLASSIFICATION OF TRIPLE HEART RHYTHM

	No. of cases	
Type I.—Addition of the third heart sound	205	
(a) In health	125	
(b) In right ventricular failure	80	
Mitral stenosis	44	
Hypertension	16	
Thyroid toxæmia	8	
Congenital heart disease	7	
Emphysema	5	
Type II.—Addition of the fourth heart sound	60	
(a) In delayed A-V conduction	14	
(b) In left ventricular failure	46	
Hypertension	41	
Aortic incompetence	5	
Type III.—An extra heart sound in late systole	5	
	Total 270 cases	

The special clinical and graphic features of the three types of triple rhythm will now be described.

TYPE I.—ADDITION OF THE THIRD HEART SOUND

When the third heart sound becomes audible in successive cardiac cycles, a form of triple rhythm designated here Type I, is established. As long ago as 1855 Stokes reported a case in which an early diastolic sound was heard, but it was A. G. Gibson (1907) and Hirschfelder (1907) who independently discovered that a wave in the venous tracing was associated with a sound in early diastole. Gibson found that this “b” wave, placed between the “v” and “a” waves, was seen at its best in healthy young adults, and in two of these he detected a sound between the second and the succeeding first sound. He said that it was not easy to hear, but was most distinct in the short interval between expiration and inspiration, and when pressure was applied to the abdomen. Gibson informed Einthoven of his discovery and the latter (1907) recorded a sound which corresponded in position with Gibson’s “b” wave and Hirschfelder’s “h” wave.

I have assembled 205 cases that on clinical examination showed triple rhythm due to the appearance of the third heart sound. Of these 125 were healthy subjects, while the remaining 80 had some form of heart disease.

Before defining the precise position of the third sound in the cardiac cycle it is necessary to describe the normal phonocardiogram of dual rhythm and the relation of the separate phases of the tracing to the electrocardiogram. Thus, the auricular sound in health starts, as a rule, at the end of the P wave and merges into the ventricular part of the first sound which

starts near the S wave and never in front of the R wave. The second sound begins at the end of the T wave (Fig. 2).

TYPE Ia.—THE THIRD HEART SOUND IN HEALTH

Einthoven (1907) found that the third heart sound in healthy subjects commenced 0.10 to 0.15 sec. after the onset of the second sound, and Lewis (1912) confirmed this. The average in my series was 0.19 sec. (Fig. 3). I have found no value in the measurements which express

FIG. 2.—Dual rhythm. Healthy man, aged 25. In this and subsequent figures, SR is sound record, and a and v are auricular and ventricular parts of first heart sound respectively.

FIG. 3.—Triple rhythm, Type Ia. From a healthy man, aged 21.

the duration of the supernumerary heart sounds, but the measure of the interval between them has great value. Thus it is not unusual for this interval to become annulled and cause the third and fourth sounds to fuse from shortening of the diastolic phase by tachycardia and/or lengthening of the auriculo-ventricular period.

Mechanism. As it is of no consequence here to know the actual mechanism producing the third heart sound, little time will be spent in debating the many theories advanced to explain it, for our closest attention needs to be directed to the clinical data presented by subjects with this form of triple rhythm. It is sufficient, therefore, to recount the common views. Gibson (1907) thought that sudden distension of the ventricle by blood from the auricle accounted for the sound, implying vibration of a taut ventricular wall. Einthoven (1907) believed that it was caused by vibration of the semilunar valves. According to Thayer (1908) and Sewall (1909) the sound is produced by vibration of the auriculo-ventricular valves after they have been floated into a position of closure by blood distending the ventricles. Thus, it is not known for certain which part of the heart vibrates, but this is immaterial for a clear understanding of the more noteworthy clinical aspects.

Incidence. The incidence of this type of triple rhythm is commonly regarded as uncertain, for while many writers speak of it as a common clinical finding, others have said it is rare and some have disputed its existence. Obrastzow (1905) heard it in 90 per cent of healthy subjects, Thayer (1909) in 65 per cent of healthy young adults, Gubergritz (1925) in 93 per cent, and Steinberg (1925) in 95 per cent of healthy children. Bridgman (1915) heard the sound in 13 out of 15 healthy boys, aged 12 to 15 years, and recorded it phonocardiographically in all of them. The third heart sound was recorded in 60 out of 100 medical students in whom sound tracings were taken by Braun-Menendez and Orias (1934).

When 50 control cases with dual rhythm were collected alongside 50 subjects showing a third sound, triple rhythm was commoner than dual rhythm in subjects of 15 to 18 years of age, and only a little less common between the ages of 18 and 20. A general acceptance of the fact that this form of triple rhythm is so common in young subjects is overdue. This realization will come to us as soon as we regularize auscultation to include self-catechism having as one of its questions: "Do I hear more than two heart sounds?" Reference to the incidence of this type of triple rhythm in older subjects is scarce. Since this has an important

bearing on differential diagnosis from other forms of triple rhythm, I sought it at all ages. Its rare appearance in older subjects became apparent. In a series of 125 where this form of triple rhythm was heard, which excluded children under 9, 115 were under 25 years. The actual incidence among the older group was as follows: 1 aged 25, 1 aged 26, 1 aged 27, 1 aged 28, 2 aged 30, 1 aged 34, 1 aged 35, 1 aged 38, and 1 aged 39. Thus triple rhythm, Type Ia, was never heard in subjects of 40 or over; it was rare over 30 (4 out of 125) and uncommon at 25 or over (10 out of 125).

Site. The third heart sound was best heard in the fourth intercostal space at a point half-way between the nipple line and the lateral border of the sternum and, therefore, a little way internal to the mitral area (Fig. 4). In two patients in whom the sound was more distinct

FIG. 4.—Localization of supernumerary sounds in triple rhythm. Dots and discontinuous lines indicate places of maximum intensity and distribution. (A) Type Ia, Type IIa, and Type III. (B) Type Ib. (C) Type IIb.

just outside the mitral area, the heart was found to be displaced outwards by scoliosis. The location of the sound is important because it may by itself decide the diagnosis of triple rhythm Type Ia (third heart sound in health) from Type Ib (third heart sound in disease), for in the physiological variety it is most distinct inside, and in the pathological type usually outside, the mitral area. In part, perhaps wholly, this variation in the site of maximum intensity of the sound in the two groups depends on the size of the heart, so that in the pathological states which may show a third heart sound, the apex beat is moved outwards from cardiac enlargement.

Conditions influencing the intensity of the sound. In order to bring out the third heart sound or to increase its intensity, Thayer (1909) adopted certain manœuvres which moved the apex nearer to the chest wall and accelerated the venous return to the heart. Thus he listened with the subject in the reclining posture after exercise, or inclined on his left side, or while an assistant elevated the arms and legs; he also applied abdominal pressure. I have tested all these means and found that only two consistently accentuated the third heart sound, namely the induction of moderate tachycardia, and the adoption of the reclining posture. In all 125 subjects with triple rhythm, Type Ia, the sound was best heard in the reclining posture, and in 90 the sound actually disappeared as the subject assumed the upright position. In 22 of the 35 cases in which the sound persisted in the upright posture, its audibility only lasted as long as the tachycardia induced by the change of posture lasted.

The influence of posture on this triple rhythm also helps materially to decide which variety is present, whether Type Ia or Type Ib. This in Type Ib the third sound is heard in both upright and reclining postures, whereas in Type Ia the sound usually disappears in the upright posture unless tachycardia is present (Fig. 5). Presumably this characteristic influence of posture is related to pressure within the right heart so that in the pathological type of triple rhythm the increased pressure does not fall below the threshold at which the third sound appears, even when the upright posture is adopted.

FIG. 5.—Triple rhythm, Type Ia. The third heart sound recorded in the reclining posture (A) disappeared in the erect posture (B). From a healthy girl, aged 15.

The Heart in Triple Rhythm, Type Ia

From routine cardioscopy in healthy subjects with a third heart sound, I found that the heart showed a characteristic outline. My early impression was that its most distinctive feature was enlargement of the pulmonary artery seen as a prominent pulmonary arc. Thinking that this might be part of a more general distension of the right heart I sought other signs, so that the height of the venous column in the neck was measured, and at cardioscopy a record was made of the size of the right auricle and ventricle, and prominence of the superior vena cava and hilar shadows; the height of the diaphragm and of the right auricle was measured as well as the width of the heart and thorax. Although these changes were not found consistently, yet some characteristic of the average radiological appearance of the heart in young subjects was very often preserved. Thus, there might be a squat-like appearance of the cardiac shadow, high diaphragm and shallow thoracic cage, prominence of the right auricle and sometimes of the superior vena cava, prominence of the pulmonary artery which filled the pulmonary bay, and increased density of the hilar shadows (Fig. 6). As enlargement

FIG. 6.—Characteristic heart outline in healthy child, aged 12. Pulmonary artery index (hereafter designated P.A. index), 6.0. This and subsequent X-rays are teleradiograms.

of the pulmonary arc was the most constant feature of the cardiac silhouette, a search was made for a means of recording the impression of the size of the pulmonary artery obtained by cardioscopy. For this purpose the distance was measured between the junction of superior vena cava and right auricle, and the summit of the pulmonary arc. This distance, measured in centimetres, is a rough estimate of the degree of pulmonary artery distension and I have named it the *pulmonary artery (P.A.) index* (Fig. 7). This value, representing as it does the width of the vascular pedicle at its base, is not an actual measure of the pulmonary artery, and two facts lessen its usefulness; the distance is increased by elevation of the diaphragm and diminished when the diaphragm is low, and the measurement is increased to the right when the ascending aorta is displaced from unfolding of its arch. Yet I have found the measurement useful as a means of recording the visual impression of the size of the pulmonary artery, although the numerical value does not always tally precisely with the judgement formed on cardioscopy which must remain as the most dependable guide in this matter.

FIG. 7.—Measure of pulmonary artery distension. A, junction of superior vena cava and right auricle. B, summit of pulmonary arc. Distance AB in centimetres is *pulmonary artery (P.A.) index*.

In 50 consecutive cases over the age of 15 the size of the pulmonary artery was estimated in terms of the pulmonary artery index as well as by visual impression, and was compared with the same findings in 50 subjects of corresponding age presenting dual rhythm. In the triple rhythm series the artery was prominent in 47 as against 8 in the control group with dual rhythm (Fig. 8). In 2 cases showing prominence of the pulmonary artery (moderate in one, and conspicuous in another) in which the third heart sound was not heard by clinical auscultation, the phonocardiograph recorded the sound. Although some degree of pulmonary artery enlargement was found in a few cases (8 out of 50) in which no third heart sound was heard,

FIG. 8.—Triple rhythm, Type Ia. Teleradiograms in two healthy subjects, aged 23. (A) with a P.A. index of 6.8 showed triple rhythm and (B) with a P.A. index of 6.1, dual rhythm. Other similar contrasted pairs were submitted but had to be omitted from consideration of space.

and no enlargement in 3 of the 50 cases in which the third heart sound was present, the incidence of this radiological finding was so common in the triple rhythm group compared with the control group with dual rhythm, that the association between pulmonary artery enlargement and triple rhythm, Type Ia, is strongly supported. I have been at some pains to

control the observation, and it is significant that 40 out of 50 cases with triple rhythm showed a pulmonary artery index of 6.5 or over, whereas the index was less than 6.5 in 41 out of 50 cases of the same age that showed dual rhythm (Tables II and III). The limb lead electrocardiogram in subjects in this group was in no way distinctive, but changes in the chest leads are being further examined.

TABLE II
THE SIZE OF THE PULMONARY ARTERY IN 100 HEALTHY SUBJECTS HALF WITH TRIPLE RHYTHM (TYPE Ia) AND HALF WITH DUAL RHYTHM

Age	Estimate of pulmonary artery distension at cardioscopy		Pulmonary artery index	
	Subjects with triple rhythm	Control cases	Subjects with triple rhythm	Control cases
16	++*	—*	7.0	5.5
16	+++	—	7.0	5.9
16	+++	—	7.0	5.5
17	+++	—	6.5	5.0
17	++	—	7.0	6.0
17	++	—	6.5	5.7
17	++	—	7.0	5.2
17	++	—	6.0	5.0
18	++	—	7.0	6.0
18	++	—	6.5	6.5
18	++	—	7.0	6.4
18	++	—	6.5	6.0
18	++	—	6.4	6.4
18	++	—	7.0	5.9
18	++	—	6.5	5.0
18	++	—	7.0	5.6
18	++	—	7.0	5.7
18	+	—	6.5	5.5
18	+	—	5.5	6.2
18	+++	—	8.0	6.4
18	++	—	6.5	5.4
18	++	+	6.0	6.1
18	++	+	6.8	5.3
18	++	+	7.2	5.5
18	+	—	6.2	5.5
19	++	—	7.0	5.8
19	++	+	6.0	6.5
19	++	—	7.0	5.5
19	++	—	7.0	4.5
19	++	—	6.5	6.2
19	++	—	7.0	5.2
20	++	—	7.6	6.5
20	++	—	8.0	4.5
20	+	—	7.0	6.0
20	+	—	6.0	5.5
21	+	+++	6.7	7.4
21	+	—	7.2	6.3
21	+	—	6.6	5.4
21	+	—	6.0	6.0
21	+	+	6.0	6.5
22	+	—	6.7	4.5
22	+	—	6.8	6.5
22	+	—	6.8	5.5
23	++	+	6.8	5.9
23	+++	++	7.0	7.0
24	++	—	7.4	6.2
24	++	—	5.8	5.5
25	++	—	6.8	6.0
27	++	+	6.8	5.8
30	++	—	6.7	5.2

* + + +, indicate, great distension; + +, moderate distension; +, slight distension; —, no distension.

TABLE III
COMPARING THE SIZE OF THE PULMONARY ARTERY IN 50 SUBJECTS WITH TRIPLE RHYTHM (TYPE Ia) AND IN 50 SUBJECTS WITH DUAL RHYTHM

Measure of pulmonary artery enlargement		Cases with triple rhythm	Control cases with dual rhythm
Estimate at cardioscopy	Great	3	1
	Moderate	22	1
	Slight	22	6
	No enlargement	3	42
Pulmonary artery index	Average	6.7	5.7
	Less than 5.0	0	3
	5.0 to 5.9	2	26
	6.0 to 6.4	8	14
	6.5 to 6.9	18	5
	7.0 or over	22	2

TYPE Ib.—THE THIRD HEART SOUND IN RIGHT VENTRICULAR FAILURE

Potain (1900) considered that protodiastolic gallop was not a state where the third heart sound was accentuated, but that it was actually a presystolic gallop in the presence of tachycardia. Although admitting the similarity between the physiological third heart sound and the protodiastolic sound, Gubergitz (1925) believed that there was a difference in the quality and intensity of the sounds. Wolferth and Margolies (1933) observed no essential difference in quality, location, time relation, or influence of posture and various manœuvres on the sounds. They considered that apart from the fact that the physiological third heart sound became increasingly rare with advancing age, the only criterion available for differentiation was the state of the cardiac function; when this was abnormal the sound could be arbitrarily classed as a gallop sound, but if no abnormality was detected the sound could be regarded as a physiological third sound. Lian (1934) believed that the protodiastolic gallop was produced by an accentuation of the physiological phenomenon connected with the third heart sound. I found that this form of triple rhythm can be distinguished from the physiological type by regarding its position of maximum audibility, the effect upon it of posture, its age incidence, and the state of the heart. Thus, it was best heard in the mitral area or beyond according to the degree of cardiac enlargement (Fig. 4); although better heard in the reclining posture it was usually audible in the upright posture; it was found even in elderly patients; it was associated with disease which produces enlargement and failure of the right side of the heart, namely mitral stenosis, hypertension, thyroid toxæmia, congenital heart disease, emphysema, pulmonary embolism, and pulmonary hypertension. Not all cases with these clinical conditions have triple rhythm, and the circumstances deciding its presence will be mentioned as each condition is discussed.

As in triple rhythm of Type Ia, so in Type Ib, the limb lead electrocardiogram was not in any way distinctive, except that it sometimes showed auricular fibrillation or right axis deviation.

The Third Heart Sound in Mitral Stenosis

In no other section of triple rhythm is opinion more confused than in the one dealing with the supernumerary heart sound in mitral stenosis. Lewis (1915 and 1934) stated that a wide duplication of the second sound initiating a sort of gallop rhythm occurred especially in cases of mitral stenosis with a slow heart rate. The extra sound in the early part of a long diastole was unrelated to auricular systole because it persisted when the auricles fibrillated; it was probably due to an unusual intensification of the normal third heart sound and tended to be confined to the region of the apical impulse. Conner (1927) described 10 patients, 4 with severe mitral stenosis, in whom he found an unusual variety of gallop rhythm; the supernumerary sound in early diastole was so exaggerated as to dominate the auscultatory findings resulting in a sound much louder than the two heart sounds which preceded it. White (1931) said that the protodiastolic gallop produced by accentuation of the third sound of the heart was relatively rare in mitral stenosis since it was masked by the diastolic murmur. Wolferth and Margolies (1933) differentiated between the opening snap of mitral stenosis and the physiological third heart sound or protodiastolic gallop, in that the snap was short and sharp, closer to the second sound, heard only in mitral stenosis, and in the third and fourth interspace over the body of the heart and not at the apex. Bramwell (1935) and Braun-Menendez (1938) regarded the gallop rhythm in mitral stenosis as the result of an exaggerated third heart sound.

Triple rhythm was specially sought in 70 patients with mitral stenosis, 25 of whom also had auricular fibrillation, and it was found in 44 (63 per cent). The added sound was heard in 21 of the 25 cases with fibrillation, and in 23 of the 45 with sinus rhythm. Thus triple rhythm was a much commoner finding with fibrillation present. Usually it was heard best towards the anterior axillary line over the displaced apex beat, but sometimes equally well in

the mitral area. The triple rhythm of mitral stenosis was always heard in the erect as well as in the reclining position. Although moderate tachycardia was found to accentuate most forms of triple rhythm, it had a deterrent effect on that of mitral stenosis with auricular fibrillation. In 14 of the 44 cases with triple rhythm the third sound was short and clear like the second sound, although generally less loud. The distance between the second and third sounds was compared with the same measurement obtained in cases of triple rhythm in health, i.e. Type Ia; in the healthy group the distance varied between 0.16 and 0.23 with an average of 0.19 sec. while in the presence of heart disease (Type Ib) it varied from 0.13 to 0.20 with an average of 0.18 sec., so the position of the third sound was the same in both the healthy and pathological groups (Fig. 9 and 10). In the remaining 30 cases the third sound was

FIG. 9.—Triple rhythm, Type Ib, in a woman aged 28 with mitral stenosis. Diastolic murmur preceded first sound, and mid-diastolic murmur started at site of third heart sound.

FIG. 10.—Triple rhythm, Type Ib, in a woman aged 46 with mitral stenosis and auricular fibrillation. Third heart sound was clear and not associated with murmur.

associated with the characteristic rumbling diastolic murmur of varying duration. This study of the relationship between the third sound and the mid-diastolic murmur in mitral stenosis has shown that they always coincide. I never found the diastolic murmur of mitral stenosis situated in the cardiac cycle in front of the third heart sound. It follows then that a diastolic murmur in mitral stenosis may occupy the late- or mid-diastolic period, but never the early part, so that an early diastolic murmur in the mitral area immediately following the second sound is evidence of aortic incompetence. Although the audibility of the supernumerary sound in mitral stenosis was sometimes disturbed in the mitral area by the diastolic murmur of aortic incompetence, it was never wholly obscured by it especially if auscultation was carried out towards the axilla.

An estimate of the size of the heart was made at cardioscopy in all cases of mitral stenosis that were specially examined for triple rhythm. The size of individual cavities was assessed and the presence and extent of pulmonary congestion. The pulmonary artery index was also recorded, and the results are given in Table IV. These appear to establish that in patients with mitral stenosis the finding of a triple rhythm gives some indication of the degree of cardiac enlargement. The size of the heart as a rule was least in those patients without (Fig. 11), and greatest in those with, triple rhythm (Fig. 12). When the heart was very large

TABLE IV
PULMONARY ARTERY INDEX IN 70 PATIENTS WITH MITRAL STENOSIS

Pulmonary artery index	44 patients with triple rhythm (Type Ib)	26 patients with dual rhythm
Average	8.4	6.3
Less than 7.0	5 patients	16 patients
7.0 to 7.5	10 "	8 "
7.6 to 8.9	14 "	2 "
9.0 or over	15 "	0 "

the supernumerary sound was commonly associated with the characteristic rumbling diastolic murmur. In view of this association between triple rhythm and the size of the heart it follows that this auscultatory sign does not always aid in the recognition of *early* mitral stenosis, but

FIG. 11.—Dual rhythm in a woman, aged 24, with mitral stenosis. Teleradiogram shows slight cardiac enlargement and P.A. index of 7.6.

it can tell something of the size of the right heart and it may often provide a valuable clue in differential diagnosis. Thus, in a case with auricular fibrillation where auscultation in the mitral area finds only a systolic murmur and no certain evidence of mitral disease, the presence of this type of triple rhythm will help to establish the diagnosis of mitral stenosis. This

FIG. 12. Triple rhythm, Type Ib, in a man, aged 52, with mitral stenosis. Teleradiogram shows considerable cardiac enlargement and high P.A. index of 9.4.

FIG. 13.—Triple rhythm, Type Ib, in a woman, aged 18, with thyroid toxæmia. Teleradiogram shows cardiac enlargement and high P.A. index value of 8.0.

triple rhythm is also expected in the fibrillation of thyroid toxæmia, and is not uncommon in prolonged hypertensive failure with fibrillation, but I have never met it in *senile* or *lone* fibrillation, where the heart was of normal size or thereabouts.

The Third Heart Sound in Hypertension

When heart failure makes its appearance in hypertension, triple rhythm is commonplace, but it is usually due to the presence of the fourth heart sound and not the third. Such patients are subject to paroxysmal nocturnal breathlessness and show pulmonary congestion on radiological examination. The familiar signs of right heart failure, namely, cyanosis, distension of veins in the neck, enlargement of the liver, ascites, and œdema of the ankles, are missing. When, however, left ventricular failure has been present for some time these signs often appear, and triple rhythm due to the third heart sound may then be elicited especially if tachycardia has not shortened diastole to such an extent as to cause fusion of the third and fourth sounds. This latter event has been described in a valuable paper by Wolferth and Margolies (1933) as summation gallop. Although the term is a useful one, it has limited clinical value by itself, depending as it does on findings in the phonocardiogram, and it is necessary to decide which supernumerary sound preponderates in the sound record after tachycardia has subsided. Many patients presenting triple rhythm, Type IIb, show this fusion of the two sounds; but when the effects of failure have been reduced by rest and the use of mercurial diuretics, and tachycardia has subsided with lengthening of the diastolic period

FIG. 14.—Triple rhythm, Type IIb (shown in A), changed to Type Ib (shown in B), after treatment with rest and mercurial diuretics. Male, aged 40, with hypertensive heart failure.

causing separation of the third and fourth heart sounds, the triple rhythm often changes from Type IIb to Type Ib (Fig. 14).

So far, I have found triple rhythm due to the third heart sound in 16 patients, but this does not mean that it is uncommon. Indeed, if we continue to search for this auscultatory sign in patients with hypertensive heart failure during the later phase of their illness, we shall often find it. The sound was heard best over the displaced apex beat near the anterior axilla, and although more distinct in the reclining posture it was also audible in the upright position. On cardioscopy these patients showed enlargement of the right auricle and ventricle, as well as the distension of the left ventricle and hilar congestion that constitute the earlier changes in hypertensive heart failure (Fig. 15).

Indicating, as I believe it does in hypertension, failure of the right heart as well as the left, this form of triple rhythm (Fig. 16) is a valuable sign. Of the fourth heart sound in hypertension it has been said that it is the cry of the heart for help (Obrastzow, 1905): if this metaphor is acceptable then we should recognize in the third heart sound in hypertension a more desperate appeal for assistance.

FIG. 15.—Triple rhythm, Type Ib, in a man aged 60, with hypertensive heart failure. Teleradiogram in anterior and oblique views show enlargement of right heart in addition to left ventricle, providing evidence of biventricular failure.

The Third Heart Sound in Thyroid Toxæmia

Triple rhythm due to the presence of the third heart sound was audible in the mitral area in the reclining and erect posture in 8 patients with toxic goitre. In all, tachycardia was moderate and was not regarded as a contributory factor. Hypertension was present in 2 of them. On cardioscopy some degree of cardiac enlargement and prominence of the pulmonary artery was present in 7: in 1 case there was enlargement of the left ventricle. As a rule then, when this form of triple rhythm was found in thyroid toxæmia, the heart on cardioscopy showed changes described by Parkinson and Cookson (1931). The special form characteristic of the goitre heart is based upon a combination of prominence of the pulmonary arc, the right heart, and the left ventricle. These changes are shown in a radiogram from a patient in this series exhibiting this type of triple rhythm (Fig. 13). No cardiac enlargement was found in a control series of cases with thyroid toxæmia who showed dual rhythm.

The Third Heart Sound in Congenital Heart Disease

I have never met with this form of triple rhythm in patients with congenital heart disease in the absence of right-sided cardiac enlargement. On the other hand, it has been absent in some cases showing considerable enlargement. The relationship between the actual congenital lesion, the size of the separate cavities of the heart, and the presence or absence of triple rhythm is being studied. In the meantime it may be said that triple rhythm, Type Ib, is only found in subjects with congenital heart disease that has caused enlargement of the right side of the heart.

The Third Heart Sound in Emphysema

Clinical signs of cardiovascular changes are reported to be uncommon in emphysema. Parkinson and Hoyle (1937) said that simple clinical evidence that the heart was involved by the lung affection was usually wanting. Heart failure, although carefully sought with the aid of radioscopy in their series, was not common, and when it occurred it was a late event and almost invariably terminal.

I have looked for triple rhythm in patients with long standing emphysema and only discovered it in 5 (Fig. 17): in each case breathlessness from emphysema had been present for many years, but more recently heart failure with normal rhythm had set in, and with hepatic distension, ascites, and œdema in 3 of them. On auscultation in the mitral area triple rhythm,

Type Ib, was found, and the supernumerary sound was heard in the erect as well as in the reclining posture. Cardioscopy in these 5 patients showed cardiac enlargement and pulmonary congestion; the enlargement involved the right heart and pulmonary artery, and there was slight distension of the left ventricle although none had hypertension. The pulmonary artery index was 7.2, 8.0, 8.0, 8.2, and 9.5 in these five patients compared with an average of 6.2 in a control series of ten patients who had much emphysema without heart failure and presented a dual heart rhythm. In 80 patients with emphysema examined radiologically by

FIG. 16.—Triple rhythm, Type Ib, in a man, aged 71, with hypertensive heart failure.

FIG. 17.—Triple rhythm, Type Ib, in a man, aged 58, with heart failure from emphysema.

Parkinson and Hoyle (1937), slight or moderate enlargement of the right auricle was present in 11, of the conus of the right ventricle in 33, and of the pulmonary artery in 22; a similar degree of enlargement of the right ventricle showed in 14 cases, but great enlargement was only met with in 4 patients, 3 of whom had heart failure.

Clinical and radiological examination of patients with emphysema permits me to say that triple rhythm, Type Ib, in these cases signifies prominent enlargement of the right heart and heart failure, and that it connotes the changes shown in Fig. 18. These changes were absent in patients with emphysema in whom a dual heart rhythm was heard (Fig. 19). This auscul-

FIG. 18.—Triple rhythm, Type Ib, in a man, aged 53, with heart failure from emphysema. Teleradiogram shows considerable cardiac enlargement and pulmonary congestion; pulmonary artery is distended with a P.A. index of 9.5.

FIG 19.—Dual rhythm in a woman, aged 42, with emphysema and bronchitis and without heart failure. Teleradiogram shows no cardiac enlargement and a P.A. index is 6.3.

tatory finding of triple rhythm in emphysema is, therefore, a sign of prognostic significance for it signifies that any patient presenting it is unlikely to survive many months. Four patients reported here died within five months of finding this form of triple rhythm, and the other is precariously ill. The same triple rhythm has since been found in patients with pulmonary embolism and pulmonary hypertension.

A triple rhythm was found in 5 patients with constricting pericarditis but it was absent in 13 others. As the cases showing triple rhythm were young subjects, a further study of this group is being made to try to discover any factor which might determine the presence of the third heart sound.

TYPE II.—ADDITION OF THE FOURTH HEART SOUND

Triple rhythm caused by an added sound in late diastole is not less important in diagnosis and prognosis than triple rhythm resulting from an extra sound in early diastole. Since the adventitious sound in this form occupies a place that is later than the point at which the third sound occurs it may be called the fourth sound, and it immediately precedes the first heart sound. Actually it occurs during auricular systole so that it only precedes the ventricular moiety of the first heart sound (Fig. 1). As in the case of triple rhythm of Type I, so also in this variety designated Type II, there are two classes; in the first the supernumerary sound is produced by auricular systole and appears only when auriculo-ventricular conduction is delayed; in the second, although the sound is produced in or by the left ventricle affected by failure, regulated contraction of the auricle is again necessary for its production, and it is never heard in auricular fibrillation. Among 60 patients with triple rhythm due to the presence of the fourth heart sound, 14 belonged to the first group and 46 to the second. These two varieties will now be described.

TYPE IIa.—THE FOURTH HEART SOUND IN DELAYED A-V CONDUCTION

A sound produced by auricular systole is easily recorded, but the circumstances deciding its audibility are not altogether understood. In sound tracings from 16 healthy schoolboys, Bridgman (1914) recorded a presystolic sound in 11 of them. Since it was represented by a wave that usually showed displacement in only one direction, he concluded that it was subject to marked damping at the source. The wave occurred 0.02 sec. after the beginning of the auricular wave of the apex cardiogram, 0.07 sec. before the beginning of the first sound, and lasted 0.04 sec. Bridgman suggested that the sound was produced by tension of the ventricular walls caused by the onset of auricular contraction, and that there was a possible relationship between this sound and presystolic gallop. Lewis (1915) explained that the auricular sounds were not heard in the normal heart because the auricular and ventricular systoles occurred too close together. He also said that when contraction of the auricle was audible in certain cases of heart block, the human ear could sometimes detect a double sound and that sound records illustrated its dual nature. Reid (1921) also observed two components in the auricular sound itself where the second promptly followed the first and the vibrations of the second filled the interval of 0.05 sec. before the onset of the sound due to ventricular systole. After introducing a sound recording device into the œsophagus in 50 normal subjects, Taquini and Braun-Menendez (1935) were able to see the auricular sound clearly in every tracing. In 100 healthy students Braun-Menendez and Orias (1934) recorded the auricular sound on the surface of the chest in 20, while Caeiro and Orias (1937) using a more sensitive device recorded auricular vibration in 17 out of 20 healthy young adults. Braun-Menendez (1938) said that although it was difficult to recognize the auricular sound by auscultation this did not mean that it was inaudible; the impression gained by auscultation was that of an impurity of the first sound, or when the auricular sound was louder, a splitting of the first sound.

In the interpretation of sound records taken simultaneously with the electrocardiogram it is an accepted fact that the first sound is never recorded earlier than the R wave. Any sound wave visible immediately in front of the R wave must be the direct or indirect result of auricular contraction. In 32 sound records from cases in which a clear first sound was elicited on clinical auscultation, an auricular sound was recorded graphically in 30. In 20 of these the sound commenced at the end of the P wave in the electrocardiogram and just after in 4, but in 6 it started earlier and coincided with the descending limb of P. In some instances of isolated auricular contraction as in complete heart block the auricular sound also commenced early and once coincided with the summit of the P wave when it showed two separate groups of vibrations which were appreciated by clinical auscultation, giving to the auricular sound a dual character (Fig. 20 and 21). Since the supernumerary sound in delayed auriculo-ventricular

FIG. 20.—Auricular sounds recorded in complete heart block. Auricular wave immediately following the first heart sound (a) is suppressed.

conduction shows the same time relationship to the P wave as the auricular sound in records from subjects with dual rhythm, the sound is clearly caused by auricular contraction; it was never heard or recorded in auricular fibrillation. As in patients with complete heart block so also in subjects showing delayed A-V conduction the auricular sound is not always audible. In children and young adults the auricular sound was heard whenever the P-R interval in the electrocardiogram was prolonged, but not so in older subjects in whom it was often inaudible.

In the 14 subjects in this series where triple rhythm resulted from delayed A-V conduction (Fig. 22), the P-R interval measured from 0.20 to 0.33 with an average of 0.25 sec. Six of them were considered healthy after an examination that included cardioscopy, and the remaining 8 showed disease, this including mitral stenosis, coronary atheroma, and bundle branch block. Although a prolonged P-R interval was found in 7 patients presenting

FIG. 21.—Isolated auricular sound in complete heart block showing early and late components; commencement coincides with summit of P wave. Tracings from a man, aged 60, with Stokes-Adams attacks. Auricular sound occasionally audible.

FIG. 22.—Triple rhythm. Type IIa, in a woman, aged 25, who showed no evidence of heart disease apart from delayed auriculo-ventricular conduction.

a fourth heart sound in left ventricular failure, it was not here regarded as having by itself initiated the supernumerary sound. Besides, the area over which the sound was heard was characteristic of the form of triple rhythm found in failure (Type IIb). Triple rhythm (Type IIa) was best heard a little internal to the mitral area and for a little distance around (Fig. 4). Although best heard with the subject reclining, it persisted in the erect posture. The rhythm was often made more obvious by induced tachycardia.

Sometimes four sounds could be heard in each cardiac cycle and the circumstances favouring this *quadruple rhythm* were found in the association of a delayed A-V conduction with a

FIG. 23.—Quadruple rhythm caused by presence of fourth heart sound in delayed auriculo-ventricular conduction, and third heart sound in mitral stenosis, from a girl, aged 19.

FIG. 24.—Quadruple rhythm caused by presence of fourth heart sound in delayed A-V conduction, and third heart sound in hypertensive failure, from a man, aged 44.

physiological third heart sound, or with a third heart sound in mitral stenosis (Fig. 23) or in prolonged hypertension (Fig. 24).

TYPE IIb.—THE FOURTH HEART SOUND IN LEFT VENTRICULAR FAILURE

For more than half a century this form of triple rhythm has been a physical sign familiar to many clinicians. There has been almost general agreement on its significance in diagnosis and in prognosis, and fair agreement on the mechanism of its production. Whenever opinion has been confused about its recognition it has usually meant that other varieties of triple rhythm have been included erroneously in this group rather than that a patient with this sound has been wrongly allocated to another group. Indeed, when a triple rhythm is alluded to as “gallop” without specific reference to its kind, it is understood as a rule to imply the type that is now to be described.

Among 60 patients with triple rhythm due to the presence of the fourth heart sound, left ventricular failure was the cause in 46, and the characteristics of this form have been determined from a clinical and graphic study of them. Hypertension had caused left ventricular failure in 41, and aortic incompetence, in 5. There were no cases of aortic stenosis.

The Fourth Heart Sound in Hypertension

As to the mechanism of this type of triple rhythm it is clear that two conditions are necessary for its production—left ventricular failure and a normally contracting auricle. Raised diastolic tension within the ventricle and increased intra-auricular pressure were mentioned by Mond and Oppenheimer (1929) as the cause of the supernumerary sound. Duchosal (1932) wrote that it was generally admitted that hypotonicity of the failing myocardium caused the ventricle to dilate suddenly and audibly under the influence of the auricular blood wave, so that auricular contraction on the one hand and ventricular hypotonicity on the other, were the two principal factors in the production of gallop rhythm. From his study of phonocardiograms Duchosal maintained that hypotonicity of the ventricle, which regulated the production and quality of the sound, could not by itself explain all the phenomena connected with gallop rhythm, and that it was necessary to consider the variation in the force and volume of the

auricular wave judged by changes in the interval between the P wave of the electrocardiogram and the supernumerary sound (the P-G interval). Since the sound appeared to come from the shock of the auricular blood wave on a hypotonic ventricle, he described it as auricular gallop, but Wolferth and Margolies (1933) considered the term misleading because there was no proof that the sound originated in the auricle.

Clinical features. The average age was 55 and only 3 were under the age of 40; this agrees with Bramwell's (1935) finding of 8 under 40 among 62 patients. Dyspnoea was always the outstanding symptom and in 30 this included cardiac asthma. Œdema of the ankles was found in 5 patients only and crepitations in the lungs or pleural effusion were present in less than half. In 38 the diastolic blood pressure was above 100, and the systolic was above 200 except in 6. In 3 patients a low blood pressure reading was ascribed to cardiac infarction. The cardiogram was usually abnormal and characteristic of hypertensive heart disease in that it showed left axis deviation, inversion of the T wave in lead I, and sometimes bundle branch block. Enlargement of the left ventricle, and sometimes of the other chambers in varying degree, was seen on cardioscopy. Pulmonary congestion, best seen at the hila, was also present in varying degree.

The supernumerary sound. The sound had a duller quality than the first heart sound which succeeded it. The interval separating the two sounds was brief, yet it was sometimes better appreciated by clinical auscultation than in the phonocardiogram where the sounds were often almost conjoined. It was usually heard along a line running from the displaced apex beat near the anterior axilla to the left border of the xiphisternum and was most intense at these two stations (Fig. 4). Thus among 41 patients it was heard at both places in 28, but better at the xiphisternum in 17 and at the apex in 11: in 8 it was heard at the apex only and in 5 at the xiphisternum only. I found no constant changes in the cardiac outline to correspond with the site of maximum intensity of the sound. These findings differ from those of Wolferth and Margolies (1933) who stated that in most cases the gallop sound was heard best in the neighbourhood of the apex impulse and only occasionally over or just to the left of the lower end of the sternum. They also said that such right-sided gallop occurred with dilatation of the right side of the heart and tricuspid insufficiency. The characteristic dual impulse associated with this type of triple rhythm was felt in most cases and was invariably present whenever the supernumerary sound was heard well. This was best appreciated by placing the naked ear to the chest when the impulse could be felt and the sound heard at the same time. As with other forms of triple rhythm this sound was better heard with the patient in the reclining position although it persisted in the erect. French writers have written on the association of tachycardia with this type of triple rhythm, and Bramwell (1935) has emphasized it as a constant finding. Naturally, tachycardia is common in patients with hypertensive heart failure, but I found this rhythm in five patients with a normal heart rate, and failed to produce it in seven with hypertension and heart failure by inducing tachycardia by exercise or ingestion of trinitrin (1/50 grain). None the less, whenever the triple rhythm is heard faintly, tachycardia usually accentuates it, and this accentuation is sometimes due to the superimposing of the third on the fourth heart sound, the summation gallop of Wolferth and Margolies (1933), as a result of shortening of the diastolic period (Fig. 25). Lewis in 1915 spoke of the effects of auricular fibrillation on this type of gallop rhythm. He said that if the rhythm was the result of a sudden rush of blood into the ventricle at the time of auricular systole one would not expect to meet with it in cases of fibrillation, and he had never found it.

The sound record. That the interval between the fourth and first heart sounds in this form of triple rhythm may often be better appreciated on clinical auscultation than in a sound record, has already been mentioned. The clear presentation of this triple rhythm appears to depend more on the intensity of the fourth heart sound and less on the length of the interval between the fourth and first sounds, although this plays a part whenever it is obviously pro-

FIG. 25.—Triple rhythm, Type IIb (shown in A), changed to dual rhythm with splitting of first sound (shown in B), in a man, aged 69, with hypertensive heart failure, after treatment with rest and mercurial diuretics. The slower heart rate has caused separation of the third and fourth heart sounds. Third sound recorded but not audible.

longed. The intensity of the fourth sound probably depends on the degree of left ventricular failure; it is certainly increased by the frequent coincidence of the third sound which reinforces it. Duchosal (1932) has stressed the importance of the duration of the interval between the P wave in the electrocardiogram and the gallop sound in the sound record (the P-G interval). In connection with it he formulated two laws. The first law was that the P-G interval was an index of the seriousness of the affection; if the P-G was less than 0.05 sec. the prognosis was bad, but if greater the outlook was better. The second law was that the P-G interval varied in proportion to the improvement or aggravation of the case during the course of the illness. In cases presenting this triple rhythm, I have not found the start of the auricular sound in the phonocardiogram any nearer to the P wave of the electrocardiogram than in healthy subjects; it usually started at the end of the P wave as in the normal. Often when the start of the auricular sound wave appeared to coincide with the descending limb of the P wave or even with its summit—and such examples were common—it was found that the first part of the sound wave was the third heart sound which was continued into the fourth. When tachycardia subsided the third sound separated from the auricular sound which began at the end of the P wave. Although this summation effect of the third and fourth heart sounds is common in patients with left ventricular failure and tachycardia, I believe that the audibility of this type of triple rhythm depends a little on the summation effect but much more on the accentuation of the supernumerary sound itself from the ventricular failure.

The Fourth Heart sound in Aortic Incompetence

There were 5 examples of this, and left ventricular failure with normal heart rhythm was common to all of them. Hypertension was present in four and in one this was the result of coarctation of the aorta. Hypertension was absent in one case where the aortic leak developed quickly from bacterial endocarditis. With the progress of cardiac enlargement and failure in this patient, dual rhythm gave way to triple rhythm (Fig. 26). The clinical and graphic character of this supernumerary sound did not differ from that in hypertensive heart failure. It is likely that the fourth heart sound occurs as well in aortic stenosis and heart failure, but I have not yet met with a case.

Two conditions in particular have to be described in connection with triple rhythm, Type II: they are splitting of the first heart sound due to an accentuated but not displaced auricular sound, and splitting of the first sound in bundle branch block.

Splitting of the First Heart Sound

A splitting of the first sound results from a separation of its two natural sound components, the auricular and the ventricular. Although the designation of duplication may well convey

FIG. 26.—Triple rhythm, Type IIb, in a man, aged 62, with heart failure from aortic incompetence.

the impression gained by clinical auscultation, the term is a misnomer since the combined sound is never in fact repeated as a whole, but it often divides. It has been known for years that a “double first sound”, i.e. splitting of the first sound, was found in healthy subjects as well as in patients with heart disease. By itself this auscultatory finding has no special significance, except in bundle branch block which is to be considered separately, for it is only an exaggeration of the separation (and often in health) of these two constituent groups of vibrations. Cossio and Braun-Menendez (1935) found that in many cases where a diagnosis of splitting of the first sound had been made on clinical auscultation, the real cause of the auscultatory impression was the presence of an auricular sound. The frequency with which the auricular sound can be recorded phonocardiographically has already been mentioned, and it was found commonly in cases which showed neither splitting of the first sound nor the presence of a fourth heart sound. Usually only the second part of the auricular sound was evident and this was fused with the ventricular component of the first heart sound. A delay in auriculo-ventricular conduction (prolonged P-R interval), or bundle branch block, can each determine a splitting of the first sound, but a third variety of splitting is often heard in health and in the presence of a normal electrocardiogram, and the recognition of this is of great importance in clinical diagnosis. For this reason it is to be the subject of further cardiographic investigation.

Triple Rhythm in Bundle Branch Block

Lewis (1912 b) recorded the heart sounds in 4 patients with bundle branch block in whom a “duplication” of the first heart sound was heard on clinical auscultation. He said that the two sound elements could be dissimilar, in which case the first element was of smaller amplitude than the second and different from it in character. The first part commenced before, though the greater part of it coincided with, the ventricular complex. The second stood in much the same position as the normal first sound, but as a rule a little later, coming either 0.05 to 0.07 sec. after the opening of the electric deflections of the ventricle. The first element was properly speaking presystolic and occurred in part at least coincidentally with the auricular contraction; from its time relations it was clearly independent of ventricular systole. Lewis concluded that the double sound was not due to asynchronous action of the two ventricles resulting from the abnormal path taken by the contraction wave and leading to asynchronous closure of the valves. The P-R interval was prolonged in each of the two records that he published. From a clinical investigation of 41 cases of bundle branch block, Hill (1931) concluded that a duplicated mitral first sound was of little diagnostic value, because it occurred in cases other than bundle branch block and disappeared even while the block persisted. Campbell and Suzman (1932) reported an interesting case in which triple rhythm and bundle branch block disappeared simultaneously. Graybiel and Sprague (1933) described their

findings in 395 cases of bundle branch block; they said that diagnosis could only be made with certainty by the electrocardiograph. J. K. Lewis (1934) took sound records in 20 patients with bundle branch block; presystolic gallop was present in 9 and in 3 of these a presystolic impulse was felt; in 5 a duplicated first sound was heard. He came to the conclusion that the presence of triple rhythm in bundle branch block could be accounted for by the fact that both conditions occurred in the same general type of heart disease and under the same circumstances, and it was not related to the bundle branch block itself nor to asynchronism of the ventricles.

A triple rhythm was sought in 30 patients in whom a bundle branch block was shown in the electrocardiogram and it was found in 13. In 6 of these the triple rhythm was caused by the appearance of the fourth heart sound in delayed auriculo-ventricular conduction (Type IIa), and in the other 7 by the fourth heart sound in left ventricular failure (Type IIb). In only 2 of the remaining 17 cases with dual rhythm was the first sound clear in the mitral area; in 15 there was either a roughish systolic murmur with slurring of the sound sometimes simulating a presystolic murmur, or a splitting of the first sound. The relationship between a delayed auriculo-ventricular conduction time as shown by a prolonged P-R interval, and the incidence of triple rhythm in bundle branch block, was specially examined. A delay was present in 14 but not in the remaining 16. Out of the 14 cases with a P-R interval longer than 0.22 sec., 11 showed triple rhythm and 3 had dual rhythm. Among the 16 cases in which the P-R interval was less than 0.2 sec. there were 14 with dual rhythm. The remaining 2 showed triple rhythm (Type IIb) from left ventricular failure. These findings are summarized in Table V.

TABLE V
AUSCULTATORY FINDINGS IN 30 PATIENTS WITH BUNDLE BRANCH BLOCK

<i>Incidence of triple rhythm</i>			
Dual rhythm in 17	..	..	{ 2—Clear first sound 15—Rough systolic murmur; slurred first sound; splitting of first sound 6—Type IIa 7—Type IIb
Triple rhythm in 13	..	..	
<i>Triple rhythm in relation to A-V period</i>			
Prolonged P-R in 14	..	..	{ 3—Dual rhythm 11—Triple rhythm 14—Dual rhythm 2—Triple rhythm (Type IIb)
Normal P-R in 16	..	..	
			{ 6—Type IIa 5—Type IIb

The ventricular part of the first sound in the phonocardiogram of bundle branch block appears in relation to an S wave that is delayed because of a lengthening of the R-S interval. When this is considered alongside the fact that the P-R interval is also full and often prolonged in this condition, it is not difficult to understand why splitting of the first sound is common in patients presenting bundle branch block (Fig. 27).

Thus in the series reported here a pure first heart sound was uncommon (only 2 out of 30).

FIG. 27.—Splitting of first heart sound in bundle branch block in a man, aged 62. Auricular part of first heart sound is accentuated and ventricular part commences opposite delayed S wave of electrocardiogram.

In half the cases the sound was either obscured by a murmur or showed splitting. Triple rhythm in bundle branch block was never present unless there was delay in A-V conduction or left ventricular failure, and often both conditions existed together. It is because of this separation of the auricular and ventricular components of the first heart sound in bundle branch block that the condition may be referred to as one of "potential triple rhythm." The ease with which this rhythm becomes established either by a further slight increase in the P-R interval or at the first sign of left ventricular failure, is dependent on the already lengthened P-S interval which characterises bundle branch block.

TYPE III.—AN EXTRA HEART SOUND IN LATE SYSTOLE

Under the title systolic gallop, Johnston (1938) reported 21 patients in whom the systolic position of the supernumerary sound was shown in phonocardiograms. He pointed out that it usually happened in healthy hearts and that its importance lay in the fact that it was sometimes mistaken for a diastolic gallop. Laubry (1930) defined gallop rhythm as the result of the interposition of a third independent sound between the two heart sounds; it might occur during the short silence (systolic gallop) which was rare, or during the long silence (diastolic gallop) which was common and the only form which needed study. Among my 270 cases of triple rhythm there were 5 in which the supernumerary sound was situated in the systolic period. In all five a correct clinical interpretation was made before undertaking the phonocardiographic test which confirmed it (Fig. 28). Although casual auscultation may regard

FIG. 28.—Triple rhythm, Type III, in a healthy man, aged 37. Added sounds are recorded in late systole and precede the second sound.

this as triple rhythm (Type I) a more careful examination will localize the supernumerary sound in front of and not after the second heart sound. It is possible to recognize the second of the three heart sounds as the supernumerary sound by paying attention to its character as well as its timing. Thus it can be made out that it is dull or muffled or like a click, compared with the clear second heart sound which immediately follows it. These characteristics were more readily appreciated when the stethoscope was moved away a little distance from the point of maximum intensity in the mitral area. In none of the five patients was there heart disease; in one the left ventricle was slightly enlarged from moderate hypertension. It is of interest that all five subjects had been informed after previous clinical examinations that they had "heart trouble," which shows that the importance of this innocent rhythm lies in its recognition.

SUMMARY AND CONCLUSIONS

Triple rhythm is the cadence produced by the recurrence in successive cardiac cycles of three separate sounds. The chief purpose of this work has been to classify triple rhythm in accord with findings on clinical, radiological, cardiographic, and sometimes pathological examination of the heart, in patients presenting this auscultatory sign. Splitting of the first

sound at the apex or of the second sound at the base of the heart are not included in its scope. The investigation has shown the need for discarding the terminology hitherto in use for triple rhythm and adopting one that is based on the clinical condition and avoids any preoccupation with the mechanism of the extra sound. As soon as it becomes the custom to listen specifically for a sound in addition to the more familiar first and second heart sounds, triple rhythm will be found to be common, perhaps as common as dual rhythm in patients sent for examination of the heart.

When the position of the adventitious sound in the cardiac cycle was considered alongside the clinical state of the patient in 270 cases with triple rhythm, it was possible to place them in three groups. As a rule, even under the handicap of fairly severe tachycardia, the position of the extra sound could be told by auscultation, aided by the clinical data, and before phonocardiography was used for scientific support.

In the first group (Type I), consisting of 205 cases, the added sound was the third heart sound occurring in early cardiac diastole. This group comprised of 125 healthy subjects, and 80 patients with right ventricular heart failure. The innocent triple rhythm (Type Ia) is distinguished from that due to right heart failure (Type Ib) by regarding the site of maximum audibility of the sound, the effect of posture upon the sound, and the health or disease of the heart. In Type Ia the sound is best heard a little internal to the normal apex in the mitral area, it is usually audible only in recumbency, and it is found in young healthy persons. It is uncommon after 24 (20 out of 125 in this series) and after 40 it is seldom if ever heard. On cardioscopy some degree of prominence of the pulmonary artery is a characteristic finding—an association in keeping with the common incidence of this auscultatory sign in children where a prominence of the pulmonary arc is a recognized feature of the normal radiogram. In Type Ib the sound is loudest at the apex, which is displaced according to the degree of cardiac enlargement; it persists in the upright as well as in the recumbent posture, and it is associated with disease that causes right ventricular enlargement and failure, such as mitral stenosis, hypertension, thyroid toxæmia, congenital heart disease, emphysema, pulmonary embolism, and pulmonary hypertension. Triple rhythm was present in half the cases of mitral stenosis and in four-fifths of those with auricular fibrillation. More often than not the third heart sound in mitral stenosis was joined with the characteristic diastolic murmur. When the third heart sound was present in hypertensive failure there was clinical evidence of failure of the right as well as of the left ventricle (biventricular failure), and cardioscopy showed enlargement of the right heart in addition to that of the left, and pulmonary congestion characteristic of the early phase of this failure. Patients with thyroid toxæmia showing a third heart sound had general enlargement of the heart and a prominent pulmonary artery; indeed the finding of this triple rhythm in each case predicted such changes while a series in which there was dual rhythm were without cardiac enlargement. Not all cases of congenital heart disease showed the third heart sound; but, when they did, enlargement of the right side of the heart, although probably not the only criterion, seemed essential to its appearance. The few patients with heart failure from emphysema, in whom considerable enlargement of the heart was seen at cardioscopy, showed this triple rhythm. A series of cases of emphysema with dual rhythm showed slight or no cardiac enlargement and no failure, so that the finding of the third heart sound in emphysema implies the presence of cardiac enlargement and failure and predicts a serious prognosis.

In the second group (Type II) the fourth heart sound is added during auricular systole and at the end of ventricular diastole. There were 60 patients with this variety of triple rhythm. In 14 of them it was the outcome of delayed A-V conduction (Type IIa). Not all cases whose P-R interval exceeds 0.2 sec. will show triple rhythm, although in young subjects, few will fail to present it. In 46 patients the extra sound appeared during left ventricular failure (Type IIb), where auricular action, although probably not the direct cause of the sound, is essential for its production, because it disappears with the onset of auricular fibrillation. Hypertension

is the usual cause of the left ventricular failure initiating this variety of triple rhythm, but occasionally it is the result of aortic incompetence. The added sound in these cases, although audible as a rule over the displaced apex beat, is usually best heard near the xiphisternum, and since it is accompanied by a palpable impulse, the rhythm is well appreciated by direct auscultation whereby the impulse is felt and the triple rhythm is heard simultaneously. This rhythm is often annulled when failure symptoms abate after the use of mercurial diuretics, but later it may give way to triple rhythm (Type Ib) when failure of the right heart has become added.

Bundle branch block with its wide P-R and QRS periods is a potential source of triple rhythm on this account for the fourth heart sound will appear when the P-R interval lengthens further or when the left ventricle begins to fail.

In the third, and least important group (Type III), an extra sound is added in late systole. It occurs in health, and almost its only importance lies in distinguishing it from the third heart sound. Since tachycardia is usually absent, its recognition on clinical auscultation is not difficult.

Triple rhythm is a common auscultatory sign, and it can be of great aid in the diagnosis of cardiovascular disorder. It should be sought specifically in every case, and when found, the position of the supernumerary sound in the cardiac cycle should be traced, and its significance determined in the light of clinical findings and in accordance with some classification such as that here proposed.

I wish to thank Dr. John Parkinson, Physician to the Cardiac Department, for his helpful criticism of this work. Mr. William Dicks, Technician to the Department has collaborated in producing the sound records.

REFERENCES

- Bramwell, C. (1935). *Quart. J. Med.*, **4**, 149.
 Braun-Menendez, E. (1938). *Lancet*, **2**, 761.
 — and Orias, O. (1934). *Rev. Argent. Cardiol.*, **1**, 101.
 Bridgman, E. W. (1915). *Heart*, **6**, 41.
 Cairo, A., and Orias, O. (1937). *Rev. Argent. Cardiol.*, **4**, 71.
 Campbell, M., and Suzman, S. S. (1932). *Lancet*, **1**, 985.
 Conner, L. A. (1927). *Amer. Heart J.*, **2**, 514.
 Cossio, P., and Braun-Menendez, E. (1935), *ibid.*, **2**, 149.
 Duchosal, P. (1932), *ibid.*, **7**, 613.
 Einthoven, W. (1907). *Arch. ges. Physiol.*, **120**, 31.
 Gibson, A. G. (1907). *Lancet*, **2**, 1380.
 Graybiel, A., and Sprague, H. B. (1933). *Amer. J. Med. Sci.*, **185**, 395.
 Gubergitz, M. (1925). *Ztsch. Klin. Med.*, **102**, 109.
 Hill, I. G. W. (1931). *Quart. J. Med.*, **24**, 15.
 Holt, E. (1927). *Amer. Heart J.*, **2**, 453.
 Hirschfelder, A. D. (1907). *Bull. Johns Hopkins Hosp.*, **18**, 265.
 Johnston, F. D. (1938). *Amer. Heart J.*, **15**, 221.
 Laubry, C. (1930). *Nouveau Traité de Path. Int.*, Paris.
 Lewis, J. K. (1934). *Arch. intern. Med.*, **53**, 741.
 Lewis, T. (1912). *Heart*, **4**, 241.
 — (1912). *Quart. J. Med.*, **6**, 441.
 — (1915). *Lectures on the Heart*, N. York.
 — (1934). *Diseases of the Heart*, London.
 Lian, C. (1934). *Problèmes Actuels Path. Méd.*, **3**, 257.
 Mond, H., and Oppenheimer, E. T. (1929). *Arch. intern. Med.*, **43**, 166.
 Obrastzow, W. P. (1905). *Ztsch. Klin. Med.*, **57**, 70.
 Parkinson, J., and Cookson, H. (1931). *Quar. J. Méd.*, **24**, 499.
 — and Hoyle, C. (1937). *Quar. J. Med.*, **30**, 59.
 Potain, C. (1856). *Bull. Soc. Anat. de Paris*, **31**, 378.
 — (1866). *Bull. et Mem. Soc. Méd. des hôp. de Paris*, **3**, 138.
 — (1876). *Ibid.*, **12**, 137.
 — (1880). *Gaz. de hôp.*, **53**, 529.
 — (1894). *Clin. méd. de la Charité*, Paris, **29**.
 — (1900). *Semaine Méd.*, **20**, 175.
 Reid, W. B. (1921). *J. Amer. Med. Assc.*, **76**, 928.
 Sewall, H. (1909). *Amer. J. Med. Sci.*, **138**, 10.
 Steinberg, L. D. (1925). *Z. Kinderheilk.*, **40**, 620.
 Stokes, W. E. (1855). *Diseases of Heart and Aorta*, Philadelphia.
 Taquini, A. C., and Braun-Menendez, E. (1935). *C. R. Soc. Biol.*, Paris, **120**, 728.
 Thayer, W. S. (1908). *Boston Med. Surg. Jour.*, **158**, 713.
 — (1909). *Arch. intern. Med.*, **6**, 297.
 White, P. D. (1931). *Heart Disease*, N. York.
 Wolfert, C. C., and Margolies, A. (1933). *Amer. Heart J.*, **8**, 441.