

INTERPOLATED CONTRACTIONS OF THE HEART WITH ESPECIAL REFERENCE TO THEIR EFFECT ON THE RADIAL PULSE *

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INTRODUCTION

Attention should be directed to some of the characteristics of interpolated contractions of the heart, particularly as they affect the radial pulse, since at times this type of cardiac irregularity is confusing.

An interpolated beat is a premature contraction of the ventricles which is not followed by a compensatory pause and does not disturb the dominant rhythm of the heart. It is impossible for auricular beats to be interpolated, because auricular premature beats are bound to disturb the dominant rhythm. It is also impossible to have interpolated beats in a case of complete auriculoventricular heart block, because here the dominant rhythm is ventricular, and so it, too, would be disturbed. Dresbach and Munford¹ state that interpolation in a case of Stokes-Adams' disease was reported by Lichtheim in 1905, but such a phenomenon is very unlikely. Inasmuch as interpolated beats can be no other than ventricular and must be premature, the cumbersome expression "interpolated premature ventricular contractions" can be discarded. In this paper we shall restrict ourselves to the term "interpolated beats." This form of premature beat is the only true "extrasystole," the term as it has been applied to the usual premature beat being unsatisfactory, since the heart rate in such a case is unchanged. Interpolated beats are relatively infrequent but not so rare as has been stated by some authors. The A-V conduction is usually delayed following the interpolated beat, causing a delay in the appearance of the next normal pulse wave (Figures 1, 2, 3 and 4).

The mistake most frequently made, in the instances where wrong interpretations of the arterial pulse occur, is in stating that two premature beats appear, one immediately following the other; the first beat, the interpolated one, being designated as the first premature beat, while the next, which is the normal, is called the second premature beat. Again, a confusing picture may be presented where the regular occurrence of interpolated contractions every third beat, failing to reach the

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1. Dresbach, M., and Munford, S. A.: Interpolated Extrasystoles in an Apparently Normal Human Heart, Illustrated by Electrocardiograms and Polygrams, *Heart* 5:197, 1913.

wrist, gives rise to pseudo-alternation. Three other very rare sources of error will be discussed later. This communication is presented in an effort to show wherein errors have been made and to simplify the diagnosis of this form of arrhythmia.

HISTORICAL

A résumé of the literature on this subject, up to 1914, appears in an article by Dresbach and Munford.¹ Busquet² stated that the first published tracing of interpolated beats was in the work of Marey,³ in 1881. However, on examination no definite example was found by us among the 375 tracings in this book. It is possible that in Figure 355, page 723, such an irregularity appears, but it is more likely a bigeminal pulse due to very late premature beats. In an earlier publication by Marcy⁴ a questionable interpolated beat appears in Figure 89, page 292. Uncertainty in diagnosis here is due to the fact that hiccup occurred at this moment, so that the picture is more likely the result of artefact. His Figure 202, page 524, may possibly contain interpolated beats.

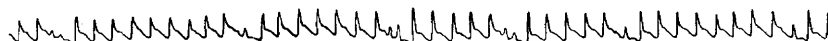


Fig. 1.—An arteriogram of T. O. showing clearly a typical curve of interpolated beats. Most of them can be easily seen; their amplitude varies and they are followed by normal beats of small size and delayed appearance. There is not always close relationship between the size of the interpolated beats and the size of the succeeding normal beats.

Wenckebach,⁵ while correcting Mackenzie's error of interpreting an interpolated beat and its succeeding normal beat as two premature beats (Fig. 83, p. 99 of Mackenzie's "Study of the Pulse, Arterial, Venous, and Hepatic, and of the Movements of the Heart") fell into the same error in his interpretation of his own Figure 10. Here the great delay in the appearance of the normal beat undoubtedly misled him. He republished in his book on the arrhyth-

2. Busquet, H.: Les Extra-systoles sans Repos Compensateur, Arch. d. Mal du Cœur, Paris 5:187, 1912.

3. Marey, E. J.: Irregularités Périodiques du Pouls chez le Vieillard, Circulation du Sang, 1881.

4. Marey, E. J.: Physiologie médicale de la Circulation du Sang, Paris, 1863, Adrien Delahaye, Libraire-Editeur.

5. Wenckebach, K. F.: Zur Analyse des Unregelmässigen Pulses, Ztschr. f. klin. Med. 36:181, 1898.

6. Mackenzie, J.: The Study of the Pulse, Arterial, Venous, and Hepatic, and of the Movements of the Heart, 1902.

mias⁷ this same tracing with the same interpretation. Figure 9 of his book is correctly interpreted. Mackenzie's⁶ Figures 53 and 54 probably contain examples of this condition. Trendelenberg⁸ published tracings demonstrating interpolated beats as they were produced experimentally in frogs' hearts. One year later, in Hoffman's⁹ writings, a good example appears in a poor tracing (his Fig. 5). Here the picture of pseudo-alternation is produced by the occurrence of interpolated beats, every third beat failing to reach the wrist. The true condition was unrecognized by the author. Also in 1904 Volhard,¹⁰ in a paper on "Ventricular Bigeminy without Compensatory Pause, Resulting

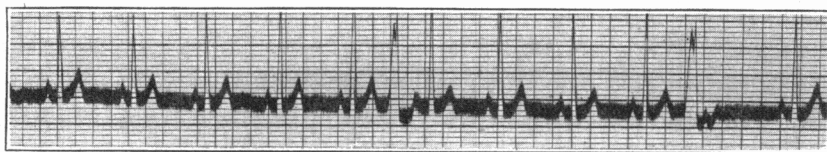


Fig. 2.—Electrocardiogram of T. O., Lead II. Here are shown premature beats of two types: the first interpolated; and the second a premature ventricular contraction with compensatory pause. The stimuli which provoke each contraction arise from the same point of the right ventricle in each instance. The *P-R* interval after the premature beat is greater than the *P-R* interval which precedes it.

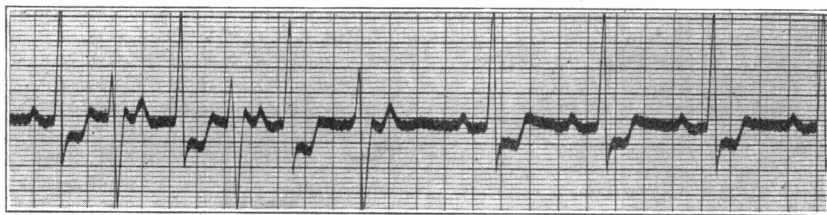


Fig. 3.—Electrocardiogram of Y (Lead II), a case of prolonged A-V conduction. The second and fourth contractions of the series are interpolated. The A-V conduction time is lengthened after the first, but practically no lengthening occurs after the second. The sixth beat is a premature contraction of the ventricle with full pause following. The remaining part of the curve is of normal rhythm, the prolonged conduction time being evident. All the premature beats arise from the same focus of left ventricle whether they are interpolated or not. The T wave shows evidence of digitalization.

7. Wenckebach, K. F.: *Die Arrhythmie als Ausdruck Bestimmter Functionsstörungen*, Leipzig, Verlag von Wilhelm Englemann, 1903.

8. Trendelenberg, W.: *Ueber ein Wegfall der Compensatorische Ruhe am Spontan Schlagenden Froschherzen*, Arch. f. Anat. u. Physiol., Physiol. Abt., 1903.

9. Hoffman, A.: *Ueber Verdoppelung der Herzfrequenz nebst Bemerkungen zur Analyse des Unregelmässigen Pulses*, Ztschr. f. klin. Med. **53**: 1904.

10. Volhard, F.: *Ueber Ventriculare Bigeminie ohne Compensatorische Pause Durch Rückläufigen Herzkontraktionen*, Ztschr. f. klin. Med. **53**: 475, 1904.

from Retrograde Ventriculo-Auricular Contraction," in his Figure 8 interprets the tracing as an interpolated contraction. By accurate measurements of the radial curve in this figure it is obvious that a pairing of premature beats occurs, no interpolation taking place. Pan¹¹ shows two striking demonstrations of the irregularity. In his Figure 15, a tracing from the cubital artery, interpolation occurs, the beat failing to appear in the sphygmographic curve. The succeeding normal beat is delayed and decreased in amplitude. There is also shown very clearly in Figure 23 the failure of an interpolated beat to reach the wrist, with marked delay and decrease in size of the next normal wave. Hay's little volume¹² contains three curves with all the interpolated beats coming through, the next normal beats being only slightly smaller



Fig. 4.—A radial curve of A illustrating what at first glance might be called a short paroxysm of tachycardia. On closer inspection it proves not to be. The first beat of the run of four is normal, the second interpolated, the third normal (slightly retarded) and the fourth a ventricular premature contraction with compensatory pause.



Fig. 5.—Radial tracing of E. D. showing an arrhythmia due to numerous interpolated contractions, in the last half of the tracing occurring every third beat and giving rise to a well-marked pseudo-alternation. There is delay in the small beats with non-appearance of the interpolated beats. In the middle of the tracing two of the interpolated contractions are clearly seen. At the beginning of the tracing there is an ordinary bigeminal pulse due to ventricular premature contractions every second beat, followed by compensatory pauses.

than the preceding normal pulse waves. Prolongation of the As-Vs interval following the interpolated beat is discussed by this author. Laslett,¹³ in discussing a case showing the "Regular Occurrence of

11. Pan, O.: Ueber das Verhalten des Venen Pulses bei den durch Extrasystolen verursachten Unregelmässigkeiten des menschlichen Herzens, *Ztschr. f. Exp. Path. u. Therap.* 1:57, 1905.

12. Hay, J.: *Graphic Methods in Heart Disease*, 1907.

13. Laslett, E. E.: The Regular Occurrence of Interpolated Extrasystoles, *Heart* 1:83, 1909-10.

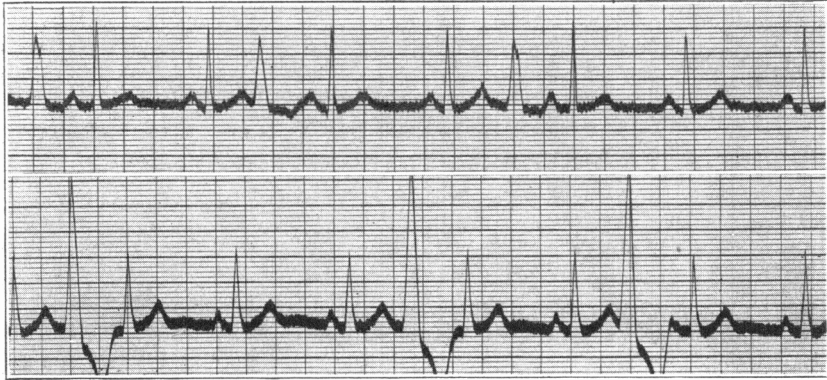


Fig. 6.—An electrocardiogram, Leads I and III, of E. D. Three interpolated contractions appear in Lead I and following each the *P-R* interval is slightly lengthened. Three interpolations are seen also in Lead III. This electrocardiogram confirms the interpretation of the radial tracing of Figure 5. Abscissa = 0.2 sec., ordinate = 10-4 volt. These same measurements apply to the electrocardiograms following.

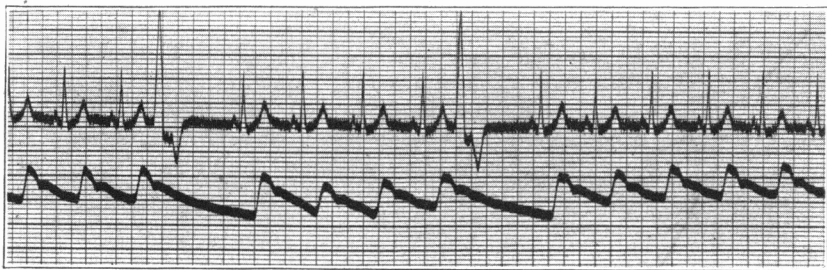


Fig. 7.—Simultaneous electrocardiogram (Lead II) and sphygmogram from radial artery (E. D.). This and the three following figures are from the same patient, all taken on the same occasion. Here is seen the appearance of premature ventricular contractions at two points; in neither instance does the beat show in the radial curve.

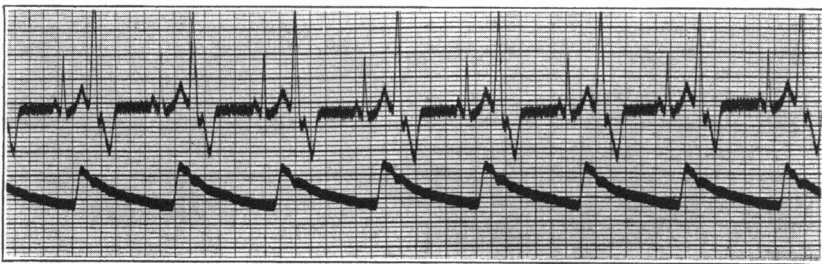


Fig. 8.—Simultaneous electrocardiogram (Lead II) and arteriogram (radial) (E. D.) which shows a perfectly regular radial pulse with a rate between 40 and 50 per min., the result of the regular occurrence of premature ventricular contractions every second beat, failing to reach the wrist.

Interpolated Extra-Systoles," states that the marked prolongation of the As-Vs interval following the interpolated beat does not seem to be the rule, the exact significance of this factor with regard to the origin of the compensatory pause not being clear. An excellent illustration of pseudo-alternation due to interpolated beats every third beat, not reaching the radial curve, is given by Gallavardin and Gravier.¹⁴ The small normal contractions are considerably delayed. An incorrect interpretation by Mackenzie in his "Diseases of the Heart"¹⁵ (p. 208, Fig. 118), is indicated by analysis of the jugular pulse tracing. Undoubtedly, the delay in the appearance of the normal beat, marked by Mackenzie as

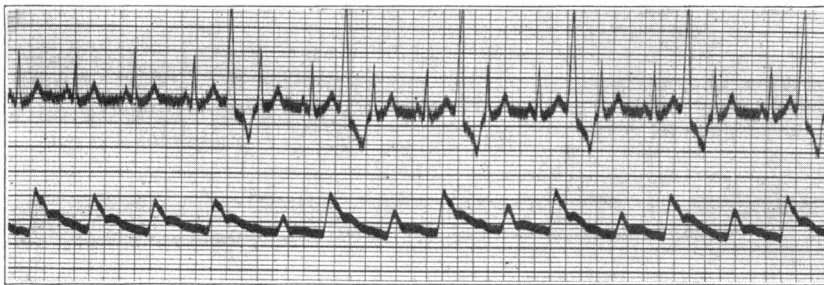


Fig. 9.—Simultaneous electrocardiogram (Lead II) and radial curve (E. D.). A short phase of normal rhythm is interrupted by an interpolated contraction, which irregularity persists throughout the remainder of the tracing. The occurrence of the interpolated beats every third beat and their failure to come through to the radial artery gives a characteristic picture in the sphygmogram.

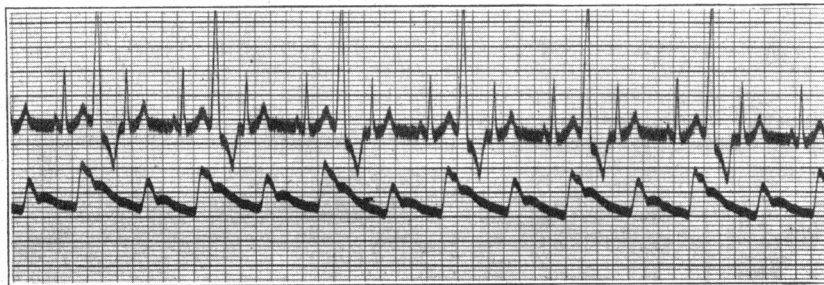


Fig. 10.—Simultaneous electrocardiogram (Lead II) and radial tracing (E. D.). Interpolated contractions occur regularly every third beat producing very prettily a picture of constant alternation in the sphygmogram. With the electrocardiographic curve as a guide in this case, the interpretation of the arteriogram is very simple.

14. Gallavardin, L., and Gravier, L.: Quelques Particularités de l'Alternance du Pouls: Variété du Pouls Pseudoalternant; Couples Extra-systoliques et Alternances; Changements de Sens Spontanés de l'Alternance, *Arch. d. mal. du Cœur* 7:497, 1914.

15. Mackenzie, J.: *Diseases of the Heart*, Ed. 3, 1913.

the second r' , misled him. The high wave in the jugular pulse during the long radial intermission is made up of a and c and not a alone or a and v . There occurred here an alternation of the normal and premature beats, the first premature beat interpolated and the second following by a compensatory pause but failing to reach the wrist. In "Clinical Cardiology"¹⁶ Neuhof published a radial tracing (Fig. 153, p. 71) the small beat of which he refers to as "an extrasystole which is not premature"; the disorder is almost certainly due, however, to the interpolation of a contraction which failed to reach the wrist, but which reduced in size and delayed the next normal beat. Lewis¹⁷ gives a few curves showing interpolation. Figure 165, page 208, in his new edition, is an electrocardiogram in which there are two interpolated contractions, with very slight As-Vs lengthening following them. Also, Figure 164, page 208, a simultaneous record of electrocardiogram, phlebogram and sphygmogram, contains a single interpolated beat. This fails to change the sphygmogram, except to delay the next normal wave about one-tenth second. Length-

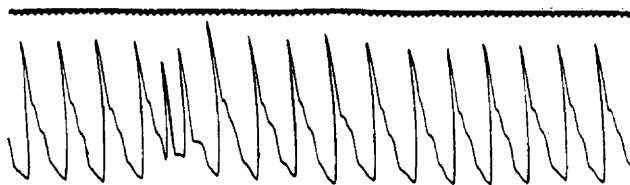


Fig. 11.—A sphygmogram of S. showing four beats of the normal rhythm followed by an interpolated contraction. The succeeding beat, the normal, is slightly delayed and decreased in amplitude. Time intervals 0.2 sec. In all further arteriograms the same time interval is recorded.

ening of the P-R interval occurs. Lewis states that the reason for the prolongation is obscure since the extra beat has not been propagated through the A-V bundle. However, it may have traversed the A-V bundle and been stopped at the auriculo-nodal junction which is the point of greatest retardation in the A-V conduction. Lewis' statement that the larger the pulse wave of the interpolated beat, the smaller is the succeeding pulse, is not always borne out (see our own Figure 1). Figure 98, page 150, of Lewis' new edition,¹⁷ an experimental curve from the dog's carotid simulates very closely the picture produced in man by an interpolated beat failing to reach the wrist followed by a weak normal wave. A simultaneous curve taken directly from the ventricle proves that the weak beats are much delayed premature ven-

16. Neuhof, S.: Clinical Cardiology, 1917.

17. Lewis, T.: Mechanism and Graphic Registration of the Heart Beat, 1920.

tricular contractions, and not due to normal beats delayed as the result of interpolated contractions which failed to reach the carotid. This possibility must be kept in mind in the arterial tracings from man, although, as Lewis states, "it is but rarely responsible for an inaccurate interpretation."

OCCURRENCE

Among 5,000 electrocardiographic plates taken of 2,392 subjects in the Cardiographic Laboratory of the Massachusetts General Hospital from 1914 to 1920, ventricular premature beats occurred in 284 plates of 200 patients, not including the ectopic beats of auricular fibrillation or of complete heart block. They were interpolated in twenty-four of these plates (8 per cent.), and in fourteen patients (0.6 per cent. of total patients, and 7 per cent. of cases showing premature beats). After for-

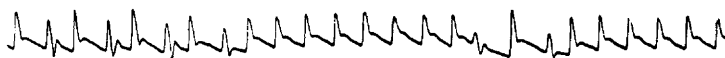


Fig. 12.—Radial curve beginning as bigeminy due to interpolated contractions every third beat, failing to reach the wrist. Then follows a phase of normal rhythm, a premature ventricular contraction with compensatory pause, and an interpolated beat, which does not come through.

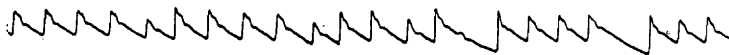


Fig. 13.—A sphygmogram in which an interpolated contraction occurs immediately after the fourth beat of the normal series and fails to show in the curve. A delayed small normal beat follows; then a run of four normal waves and the process is repeated. Two more normal beats come through and we see the same anomaly again. The last two interruptions are the result of premature contractions of the ventricle with compensatory pauses.

ty-two interpolated beats of these fourteen patients, there was definite prolongation of the P-R interval; in three instances there was no prolongation; and in thirty-four the prolongation was questionable. In one case it was observed that in the presence of sinus arrhythmia associated with interpolated beats, during the rapid rates of the auricular pacemaker, the P-R interval was much delayed, but that it was normal or only slightly delayed during the slower intervals.

The significance of the interpolated beat is just that of the premature ventricular beat generally—that is, the interpolated beat is evidence of an irritated heart, but not necessarily of heart disease. Its

presence adds nothing to the prognosis of a given case. Of our fourteen patients, six showed evidence of heart disease; four were questionable, and the other four showed merely an irritated heart. One of the last four, (Figs. 5, 6, 7, 8, 9 and 10) has had an intermittent pulse for fifteen years, but has had no other cardiac symptoms than the occasional palpitation. The interpolated beat is merely a rare variety of premature ventricular contraction. Nearly every case showing it also shows at other times the usual ventricular premature beat with compensatory pause. The slower the pulse the more apt is the ventricular premature contraction to be interpolated, for in such an instance the ventricle will have recovered from its refractory phase following its interpolated contraction when the next normal auricular impulse reaches it.

DIFFERENTIAL DIAGNOSIS

The interpolated beat in the arteriogram must be differentiated especially from two other conditions with which it is apt to be confused. These are: (1) the occurrence of successive ventricular premature contractions; and (2) *pulsus alternans*. In the historical résumé we have already mentioned this possibility of confusion. Without venous pulse tracings or electrocardiograms the diagnosis may at times be difficult.

Often the analysis of the radial tracings where interpolation occurs is simple, the interpolated beat fitting in between two normal beats with very little delay in the time or decrease in the amplitude of the second normal beat (Fig. 11). The occurrence of two successive ventricular beats is uncommon. In the Cardiographic Laboratory of the Massachusetts General Hospital, among 260 electrocardiograms of 186 patients showing premature ventricular contractions (not including those showing interpolated beats together with premature ventricular contractions with pauses) pairing of these premature beats was found in twenty-one plates. There was a total of ninety-eight instances of pairing, seventy-four of these having occurred in nine plates of one patient. Therefore, leaving out of consideration this one case in which they occurred so frequently, we have the appearance of consecutive premature contractions twenty-four times in only twelve out of the 251 different plates of 185 patients. Among these ninety-eight instances where pairing occurred, accurate measurement was possible in only sixty-five, and in only six of these did the interval during the pairing equal the space between two normal beats. In three instances the interval was equal to the space between three normal beats, which condition cannot occur in the case of interpolated beats. In the other fifty-six instances the space over the pair was unequal to either two or three normal beats but fell between these two measurements or between

the measurements of three and four normal beats.¹⁸ When in doubt, an electrocardiogram is necessary to distinguish between the interpolated beat disorder and the occurrence of a pair of ventricular premature beats.

The second condition which may be confused with interpolated contractions is constant alternation of the pulse, in which the weak beats are considerably delayed (Figs. 5, 10 and 12). This difficulty occurs rarely, because it necessitates the absence in the radial pulse of all evidence of the interpolated beats themselves. In such a case an electrocardiogram or jugular pulse tracing clears up the situation at once. We have found constant alternation much more common than constant pseudo-alternation due to interpolated beats. In only two cases have we discovered this type of pseudo-alternation, a possibility rarely recognized.



Fig. 14.—Tracing from radial artery. Near each end of the curve two very small waves are seen. These are the normal contractions which have been preceded by interpolated beats failing to show in the tracing. Near the center the two long intermissions are produced by ventricular premature contractions, failing to reach the artery, and followed by full pauses.

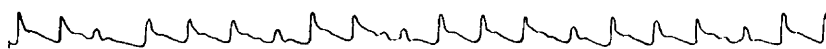


Fig. 15.—A sphygmogram of T. O. illustrating a premature ventricular beat of the usual type, it being at the first point of interruption of the regular rhythm in the tracing. Then follow three normal beats. In the remainder of the curve four interpolated beats varying in amplitude occur, and in each instance a small delayed normal contraction follows.

A third possible source of error in the analysis of radial tracings in arrhythmia due to interpolation is the infrequent return to one-to-one rhythm for three beats in long stretches of two-to-one auriculoventricular heart block. In both instances the time of the two short intervals is greater than that of one long space because of the increase in the P-R interval. In such rare instances electrocardiograms or jugular pulse tracings are necessary for differentiation. We have seen one

18. This break in the dominant rhythm is due to retrograde contraction of the auricle following one or the other or both of the ventricular premature beats.

such case of heart block which might be confused with the interpolated contraction, but the radial pulse was not of characteristic form.

A fourth arrhythmia to be differentiated from the interpolated beat in the arteriogram is the premature ventricular contraction occurring at every fourth beat and failing to reach the wrist. Here, also, venous pulse tracings or electrocardiograms' quickly differentiate, but the arteriogram itself is usually quite different in form from that of the interpolated beat arrhythmia in that the beats of the normal rhythm are evenly spaced and uniform in amplitude, which is not the case in interpolation.

A fifth condition to be considered in the differential diagnosis are short runs of paroxysmal tachycardia. Occasionally, one finds interpolated beats occurring every other beat, as in Dresbach and Munford's¹ case, and for a few beats in our Figure 3. In this figure two such interpolated beats are shown, and the third beat is followed by a compensatory pause. The pulse, upon palpation or auscultation of the heart, would have shown in this case six beats in rapid succession and might have simulated a short paroxysm of tachycardia. In

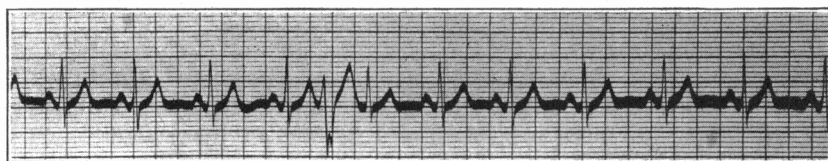


Fig. 16.—An electrocardiogram of S. T. in which one interpolated contraction occurs after the fourth beat of the normal rhythm. The large wave succeeding results from the falling together of the T and P waves. Note the lengthening of the P-R interval after this contraction.

Figure 4 there is shown a short phase of four beats in rapid succession. Here the interpretation undoubtedly is as follows: the first of the four is normal, the second is an interpolated contraction, the third is normal, and the fourth a premature ventricular contraction followed by a compensatory pause.

Figures 13 and 14 illustrate two radial pulses difficult at first glance to interpret. In Figure 13 two long pauses appear in the tracing, one with a poorly marked premature beat in evidence, while in the other a premature beat takes place but is not forcible enough to come through and appear in the curve. At the beginning and middle of the tracing are three delayed and diminished beats which follow interpolated contractions too weak to reach the radial artery. It is this abnormality in the arteriogram which has puzzled a good many students but which is perfectly typical and easily recognized as soon as one is familiar with it. Figure 14 shows likewise two small beats which are the normal

contractions following interpolated beats, not reaching the wrist. Two long intermissions are also seen due to premature ventricular beats with compensatory pauses. These also do not appear.

Figures 7, 8, 9, and 10 are tracings from a single patient who has shown various forms of arrhythmia of the pulse as a result of premature ventricular and interpolated beats. In Figure 7 are shown simple premature beats with pauses, the beats not coming through to the wrist. Figure 8 shows the regular occurrence of premature contractions every second beat, none of them being forcible enough to produce a wave. It illustrates a slow, dead regular pulse the palpation of which, alone, at this particular time would not suggest the presence of premature beats. In Figure 9 we note the onset of a phase of arrhythmia due to interpolated beats, every third beat not coming through. And Figure 10 shows a continuation of this same rhythm. These last two illustrations show in a very clear manner the mechanism of the usual effect on the radial pulse of interpolated beats and illustrate one type of pseudo-alternation. If the reader will familiarize himself with the arrhythmia found in these figures he will save a good deal of effort in the future in analyzing such curves.

SUMMARY

There is here given a brief historical review of the subject of interpolated beats. Figures are given stating the frequency with which interpolated beats and premature ventricular contractions have been found in the graphic records of the Cardiographic Laboratory of the Massachusetts General Hospital. Points in regard to the differential diagnosis of this form of arrhythmia are discussed; the five conditions from which it must be differentiated in the arterial pulse being: first, the occurrence of two premature ventricular beats in succession; second, constant alternation of the pulse in which there is a delay in the weaker beats; third, auriculoventricular heart block associated with an occasional return to one-to-one rhythm for three beats in long stretches of two-to-one rhythm; fourth, arrhythmia due to the premature beats every fourth beat which fail to appear in the arteriogram; and fifth, short paroxysms of tachycardia. Emphasis is laid upon that type of tracing which is most frequently misinterpreted, namely, where in the course of a phase of regular rhythm there occurs an interpolated beat which, not showing in the curve, causes a delay and diminution in the size of the next normal wave. Insufficient emphasis has been put in the past on this abnormality in the arteriogram, and it is on this that we lay special stress.