Iatrogenic Escape-capture Bigeminy*

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The primary purpose of electrical pacemakers is to stimulate the heart whenever the ventricular contractions fail for one reason or another. In addition, there has been secondary information obtained through the use of electronic equipment. Most important amongst the latter has been the analogy between natural and iatrogenic events. Artificial pacemakers have proved the importance of deductive reasoning in clinical electrocardiography. The purpose of the present communication is to present three examples of iatrogenic escape-capture bigeminy, a previously undescribed disorder of rhythm, which we believe stresses the role of electronic instruments in understanding some fundamental aspects of cardiac electrophysiology.

ESCAPE-CAPTURE BIGEMINY DURING PACEMAKING ON DEMAND

A new type of cardiac pacemaker which works only when required has been recently described (Lemberg, Castellanos, and Berkovits, 1965). This instrument will stimulate the heart after a pre-set interval without cardiac contraction has been exceeded. It will shut itself off if, and as long as, the natural beats occur at a shorter interval than that of pacemaker escapes. The function of this unit has been described elsewhere.

Figures 1 and 2 were obtained from a 66-year-old man with second degree A-V block alternating with periods of complete A-V block. The upper strip in Fig. 1 shows sinus rhythm and 3:2 A-V block with the Wenckebach phenomenon. The P waves are not well delineated in the bipolar chest leads used for cardiac monitoring. The patient was paced by means of a right ventricular catheter electrode connected to a portable demand pacemaker. In the bottom strip the artificial unit was set to escape if an interval of 1.24 sec. without effective ventricular

stimulation occurred. Initiation of pacemaking on demand produces escape-capture bigeminy. For instance, the fourth QRS complex is conducted from the atria with a prolonged P-R interval. The fifth ventricular beat is an iatrogenic escape occurring 1.24 sec. afterward. The following P waves again capture the ventricles with a long P-R. The corresponding R-R distance is only 1.18 sec., evidently shorter than the demand escape interval. Hence, it discharges the artificial pacemaker. This could not occur with fixed rate units. Thereafter, the demand pacemaker escapes again, therefore maintaining the escape-capture sequence. The same type of arrhythmia is seen in the upper strip of Fig. 2 and in the first half of the bottom strip in this same illustration. Escape-capture bigeminy ends after the 5th ventricular complex when a P wave fails to capture the ventricles at an interval shorter than that pre-set for demand escapes. Since no effective cardiac contraction occurs for 1.24 sec., the artificial pacemaker governs the heart. In consequence, bigeminy is substituted by a regular succession of artificial escapes.

ESCAPE-CAPTURE BIGEMINY DURING ATRIO-SYNCHRONIZED PACING

Various disorders of rhythm appearing after implantation of synchronized pacemaker were described in a previous communication. At that time we had not yet observed escape-capture bigeminy during the use of this effective form of cardiac pacemaking (Castellanos and Lemberg, 1964).

The upper strip in Fig. 3 was obtained after implantation of this unit in a patient with advanced A-V block. The P waves trigger the pacemaker after an atrio-pacemaker conduction time of 0.20 sec. The pacemaker in turn depolarizes the ventricles. The sino-atrial rate is 94 a minute. The same sequence of events occurs in the first complex of the bottom strip. At this moment, however, the sinus

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FIG. 1.—Escape-capture bigeminy during the operation of a demand pacemaker. Lead II. Upper strip shows sinus rhythm with 3:2 A-V block with Wenckebach phenomenon. Lower strip shows escape-capture bigeminy during pacing (see text).

FIG. 2.—Escape-capture bigeminy in upper strip changing to a succession of escapes during pacemaking on demand (lower strip). Lead II.

FIG. 3.—Escape-capture bigeminy during the operation of an atrio-synchronized pacemaker (see text). Lead II.

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rate has increased to 102 a minute. In consequence the second P wave reaches the pacemaker during the refractory period of the latter. Hence it cannot be conducted to the ventricles through the artificial bypass (conduction through the normal junction is also impossible due to the presence of apparently complete A-V block). This instrument has also a built-in escape safety mechanism. In this case it was set to escape if a pause of 1.10 sec. without a cardiac contraction occurred. This feature explains the escape taking place before the third P wave is able to activate the ventricles via the pacemaker. On the contrary, the fourth P wave occurs farther away from the QRS complex than the "blocked" one, well after the end of the refractory of the iatrogenic A-V junction. For this reason it can be conducted to the ventricles. Escape-capture bigeminy was thus initiated. In this case it persisted until the sinus rate decreased spontaneously, thus allowing for the return of 1:1 atrio-pacemaker conduction.

ESCAPE-CAPTURE BIGEMINY OCCURRING AFTER CARDIOVERSION

The term escape-capture sequence was coined by Bradley and Marriott in 1958 in order to define the electrocardiographic pattern produced by an escape beat followed by a normally conducted sinus impulse. When this sequence repeats itself resulting in a stable rhythm, it is called escape-capture bigeminy, since pairing of beats in bigeminal arrangement results. This rhythm has been called also "pseudo-reciprocal" due to its similarity to those produced by reciprocal mechanisms. The difference lies then in the latter; the P wave appears inverted in leads where it is usually upright (II-III-aVF) due to retrograde activation of

the atria, whereas in escape-capture bigeminy the P wave is generally of normal morphology since the stimulus producing it originates in the sinus node.

The arrhythmia under consideration is known to be originated by disturbances in impulse conduction. The original case reported by Bradley and Marriott (1958) was produced by 2:1 sino-atrial block. Digitalis was probably a causal factor. Escape-capture bigeminy disappeared when normal S-A conduction returned. Schamroth and Dubb (1965) published cases of escape-capture bigeminy originated by 2:1 S-A block; 3:1 A-V block; and reversed reciprocal rhythm. These authors introduced the concept of "effective intersinus interval" defined as the interval between sinus impulses at the level of the lower (escaping) pacemaker. They pointed out that this interval had to exceed the sum of the refractory period of the escape beat plus its escaping time if the escape-capture rhythm was to occur. Sinus bradycardia was not considered a fundamental cause of this arrhythmia, mainly because it is difficult to determine whether a slow sino-atrial rhythm is due to a slow rate of impulse formation or to some degree of sino-atrial block. The top strip in Fig. 4 shows widened and bizarre QRS complexes occurring at a rate of 230 a minute. In the absence of oesophageal leads the arrhythmia could be interpreted either as ventricular tachycardia, A-V nodal tachycardia with aberration, or atrial flutter with 1:1 A-V conduction and aberrant ventricular conduction. The exact nature of the disorder of rhythm is not important in relation to the events which followed a synchronized DC shock of 200 watt-second. The middle strip was recorded a few seconds after cardioversion. The first P wave is conducted with a normal P-R interval. It is followed by an A-V nodal escape which depolarizes

FIG. 4.—Escape-capture bigeminy appearing during a period of post-cardioversion sinus bradycardia. Top strip shows widened and bizarre QRS complexes at 230 a minute, the interpretation being tachycardia of indeterminate origin. Middle and lower leads recorded after conversion by DC counter-shock, showing bradycardia followed by escape-capture bigeminy.

the ventricles after a long pause without detectable atrial activity. The second P wave stimulates the ventricles soon after the escape, and establishes the sequence of escape-capture bigeminy initiated apparently by a sinus node effectively discharging at a rate of around 35 a minute (sinus bradycardia). The fourth P wave falls in the refractory period of the preceding escape (due to sinus arrhythmia), therefore being ineffective in stimulating the ventricles. It is thus followed by another escape. Finally, the last P wave again captures the ventricles in the escape-capture fashion.

The main problem in this case is whether the arrhythmia under consideration is triggered by sinus bradycardia or some form of S-A conduction disturbance. The lower strip, obtained a few seconds later, shows a gradual speeding up of the sinus pacemaker so that A-V dissociation and escape-capture bigeminy are replaced by sinus rhythm at a rate of 60.

It is not unusual to have a gradual increase in rate of a previously depressed sino-atrial node after progressive cessation of inhibition of impulse formation (Gaskell's rhythm of development) (Pick, Langendorf, and Katz, 1951). This phenomenon represents a disturbance of automaticity and can be an after-effect either of the rapid atrial contractions or of digitalis on the sino-atrial node rhythmicity. The electric shock could have contributed to the sinus bradycardia, but in the absence of drugs or of a chronic atrial arrhythmia, cardioversion produces very little depression of impulse formation in the sinus node (Castellanos *et al.*, 1965). The interpretation of escape-capture bigeminy due to marked sinus bradycardia appearing after cardioversion (but not necessarily produced exclusively by this procedure) is thus justified. The arrhythmia persisted until the sinus rate increased spontaneously, thus allowing for the return of 1:1 A-V conduction.

DISCUSSION

The diagnosis of the heretofore undescribed arrhythmias presented in this communication was made possible through the knowledge obtained by the analysis of clinical electrocardiograms. Understanding of the function of artificial pacemakers and equipment for electrical conversion under normal and abnormal conditions is facilitated when the

behaviour of naturally occurring disturbances in impulse formation and impulse conduction is fully comprehended (Castellanos and Lemberg, 1964). Advances in the recently introduced field of iatrogenic electrical arrhythmias have corroborated the importance of the deductive reasoning made for more than 40 years by clinical investigations of the arrhythmias. Disorders of rhythm appearing after the use of the more sophisticated electronic equipment should not be taken as evidence against their effectiveness. On the contrary, a thorough knowledge of the normal and abnormal behaviour of these instruments has increased the safety with which they can be used in the management of patients.

SUMMARY

The heretofore undescribed mechanisms of escape-capture bigeminy have been presented. In addition to S-A block, A-V block, and reversed reciprocal rhythm, this arrhythmia was seen to occur during the operation of certain artificial pacemakers (such as the demand and atrio-synchronized units) which function on an "escape" basis. In one case escape-capture bigeminy occurred during a period of post-cardioversion sinus bradycardia. The analysis of iatrogenic electrical arrhythmias has proved the importance of deductive reasoning in clinical electrocardiography.

REFERENCES

- Bradley, S. M., and Marriott, H. J. L. (1958). Escape-capture bigeminy. Report of a case of A-V dissociation initiated by 2:1 S-A block with resulting bigeminal rhythm. *Amer. J. Cardiol.*, **1**, 640.
- Castellanos, A., Jr., and Lemberg, L. (1964). Disorders of rhythm appearing after implantation of synchronized pacemakers. *Brit. Heart J.*, **26**, 747.
- , —, Gosselin, A., and Fonseca, E. J. (1965). Evaluation of countershock treatment of atrial flutter. With special reference to arrhythmias related to this procedure. *Arch. intern. Med.*, **115**, 426.
- Lemberg, L., Castellanos, A., Jr., and Berkovits, B. V. (1965). Pacemaking on demand in AV block. *J. Amer. med. Ass.*, **191**, 12.
- Pick, A., Langendorf, R., and Katz, L. N. (1951). Depression of cardiac pacemakers by premature impulses. *Amer. Heart J.*, **41**, 49.
- Schamroth, L., and Dubb, A. (1965). Escape-capture bigeminy. Mechanisms in S-A block, A-V block, and reversed reciprocal rhythm. *Brit. Heart J.*, **27**, 667.