Factors Influencing Retrograde Conduction

Study of 30 Patients During Cardiac Catheterization*

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Retrograde conduction from ventricle to atrium is a well-recognized occurrence in the human heart. The phenomenon has been observed repeatedly during ventricular tachycardia (Kistin, 1961), with ventricular premature and interpolated beats (Kistin, 1959, 1963; Kistin and Landowne, 1951), in patients with ventricular pacemakers (Kastor and De Sanctis, 1967; Barold, Linhart, and Samet, 1968), and occasionally in the presence of high-grade antegrade atrioventricular (AV) block (Cohn and Fraser, 1914; Winternitz and Langendorf, 1944; Scherf and Cohen, 1964; Castillo and Samet, 1967; Kastor *et al.*, 1967; Fletcher and Morton, 1968). Study of such events has been useful in elucidating the functional characteristics of the cardiac conduction system, and in explaining the electrophysiology of arrhythmias with bidirectional conduction.

The incidence of retrograde conduction, however, as reported, has shown considerable variation. This paper reports the result of a study designed to examine those factors which potentially might influence the frequency of ventriculo-atrial conduction in man. Particular attention was paid to the relation of the incidence and velocity of retrograde conduction to heart rate, the status of antegrade conduction, the nature of the underlying heart disease, and the presence of cardiac drugs.

METHODS

Attempts were made to induce ventriculo-atrial conduction in 30 patients admitted for diagnostic right and retrograde left heart catheterization. Bipolar electrode catheters were passed pervenously into the right atrium, and simultaneous bipolar intra-atrial and single limb

lead electrocardiograms were then recorded during mechanical stimulation of the left ventricle.

Retrograde conduction was identified by the finding in the intra-atrial recording of P waves that were different in form and premature in timing with respect to the sinus P waves. Bipolar intra-atrial leads were always used, since unipolar leads did not show as faithfully the changes in form with different impulse sources. Kistin (1963) has made similar observations in his studies with oesophageal leads.

RESULTS

Specific information about each of the patients is listed in Tables I and II. Retrograde conduction was observed in 14 of the 30 patients studied. The P-R intervals of conducted sinus beats were significantly shorter ($p < 0.01$) in those patients who showed retrograde conduction than in those who did not (Fig. 1). The time intervals from the beginning of QRS to the start of the retrograde atrial activation (R-P' intervals) were less than P-R intervals in 7 patients, equal in 1, and longer in 6 (Table I). The incidence of ventriculo-atrial conduction was not clearly related to the sinus rate (Fig. 2), to use of digitalis or other cardiac medication, or to the type of cardiac lesion present (Tables I and II).

Examples of the observed rhythms are displayed in Fig. 3-7. The tracings were prepared by direct copy of the original strips in order to increase clarity. Ladder diagrams have been constructed to illustrate our interpretations of the electrocardiographic events.

DISCUSSION

The results obtained in this study demonstrate the high frequency with which ventriculo-atrial conduction can occur under a variety of circumstances. Despite the use of *random* stimulation of

Received January 23, 1969.

* Supported in part by Grants from the United States Public Health Service.

TABLE I

14 PATIENTS WITH RETROGRADE CONDUCTION STUDIED WITH INTRA-ATRIAL ELECTROCARDIOGRAMS

Case No.	Age and sex	P-R interval (sec.)	R-P' interval (sec.)	Sinus rate	Digitalis	Cardiac lesion(s)
1	58 F	0.12	0.10	100	Yes	Mitral regurgitation; ruptured chordae tendineae
2	28 F	0.14	0.14	75	Yes	Aortic and mitral stenosis; aortic regurgitation
3	47 F	0.14	0.10	85	No	Idiopathic hypertrophic subaortic stenosis
4	63 M	0.14	0.20	88	Yes	Mitral stenosis
5	42 M	0.14	0.22	115	Yes	Idiopathic hypertrophic subaortic stenosis
6	45 F	0.14	0.12	85	Yes	Arteriosclerotic heart disease
7	54 M	0.14	0.16	88	Yes	Arteriosclerotic heart disease
8	36 M	0.16	0.14	88	Yes	Aortic regurgitation and stenosis
9	2 M	0.16	0.20	115	—	Primum atrial septal defect
10	54 F	0.16	0.12	65	No	No heart disease
11	54 F	0.16	0.20	115	Yes	Mitral regurgitation; ruptured chordae tendineae
12	55 M	0.16	0.28	95	Yes	Aortic stenosis
13	42 M	0.18	0.16	90	No	Idiopathic hypertrophic subaortic stenosis
14	67 M	0.22	0.16	55	Yes	Mitral regurgitation; aortic stenosis

TABLE II

16 PATIENTS WITHOUT DEMONSTRABLE RETROGRADE CONDUCTION

Case No.	Age and sex	P-R interval (sec.)	Sinus rate	Digitalis	Cardiac lesion(s)
15	58 M	0.14	95	No	Aortic stenosis and regurgitation
16	57 M	0.16	90	Yes	Aortic stenosis and regurgitation
17	43 F	0.16	88	Yes	Aortic stenosis; arteriosclerotic heart disease
18	57 M	0.18	110	—	Mitral regurgitation
19	65 M	0.20	70	No	Aortic stenosis; arteriosclerotic heart disease
20	39 M	0.20	78	Yes	Mitral stenosis, aortic regurgitation
21	45 M	0.20	80	No	Aortic regurgitation
22	50 F	0.20	90	No	Mitral stenosis
23	62 M	0.20	70	No	Aortic stenosis
24	70 M	0.20	88	Yes	Aortic regurgitation and stenosis
25	53 F	0.20	75	Yes	Mitral stenosis
26	47 M	0.20	85	Yes	Aortic regurgitation
27	58 M	0.20	75	Yes	Mitral regurgitation; arteriosclerotic heart disease
28	57 F	0.20	95	Yes	Aortic stenosis and regurgitation
29	54 M	0.22	90	Yes	Aortic regurgitation
30	67 M	0.48	92	Yes	Aortic regurgitation

the left ventricle, the incidence of retrograde conduction in our patients approached 50 per cent. Samet, Castillo, and Bernstein (1967), by selectively inducing the ventricular ectopic beat at a time when the ventricles and atria were least likely to be refractory, showed retrograde conduction in 29 of 31 subjects, some with normal and others with abnormal hearts. Thus, it is likely that the incidence of ventriculo-atrial conduction in the present series could have been increased if such specialized pacing techniques had been employed.

The existence of a relation between the speed of forward conduction and the incidence of retrograde conduction found in our patients has not, to our knowledge, been previously documented in man. Though there was some overlap, the P-R intervals in those patients showing retrograde conduction were significantly shorter than in those who did not. Such a relation might be anticipated, since with the

RETROGRADE CONDUCTION

FIG. 1.—Relation of P-R interval to occurrence of retrograde (VA) conduction shown by intra-atrial leads during left ventricular catheter stimulation. The likelihood of finding VA conduction is directly related to the speed of AV conduction.

FIG. 2.—Relation of sinus rate to occurrence of retrograde conduction. The likelihood of finding VA conduction does not appear to be related to the sinus rates observed in this study.

FIG. 3.—Left ventricular stimulation without retrograde conduction (Case 28, P-R=0.20 sec., sinus rate 95 beats/min.). Abbreviations in this and subsequent figures: P=sinus beat; P'=retrograde atrial beat; QRS=supraventricular depolarization of ventricle, QRS'=ventricular beats induced by catheter. Time lines 0-20 sec. Ladder diagram: AM=atrial musculature; SP=sinus pacemaker; A-VJ=atrioventricular junction (node); VP=ventricular pacemaker; VM=ventricular musculature. Retrograde conduction is shown with broken lines.

The atria are continuously discharged by the sinus pacemaker which stimulates the ventricles for three beats (A_1 , A_4 , A_8). Most of the ventricular beats, however, are produced by mechanical stimulation of the left ventricle and none are conducted in retrograde fashion to the atria (V_2 - V_5 , V_7 - V_{11}). The retrograde pathways are never able to conduct the ventricular beats to the atrium; the exact locus of the VA block is not known.

FIG. 4.—Left ventricular stimulation with retrograde conduction (Case 4, P-R=0.14 sec.; sinus rate=88 beats/min.). Beats A₁ and A₂ are normal sinus beats. A₃ does not reach the ventricles because of the discharge of ventricular beat V₃ at about the same instant. Then ventricular beats V₄-V₆ capture the atria with 1:1 retrograde conduction; the sinus pacemaker is suppressed (Pick, Langendorf, and Katz, 1951). With cessation of ventricular stimulation, the sinus impulse reappears after a pause (A₇) and is conducted in usual fashion to the ventricles (V₇).

longer P-R intervals the refractory period of the conduction system would probably be longer, thus more often precluding retrograde penetration into the atrium by a randomly induced ventricular ectopic beat.

Similarly, in those patients with ventriculo-atrial conduction the P-R and R-P' intervals usually approximated one another within a few hundredths of a second, suggesting that the factors influencing the speed of antegrade conduction affect retrograde conduction in an equal manner. Kistin, Tawakkol, and Massumi (1967) also noted a similar relation between antegrade and retrograde conduction times. In some instances, however, measurement of the total time for retrograde conduction may be subject to error due to the inability to recognize the isoelectric portion of the QRS complex if single leads are used. This difficulty may be overcome through the simultaneous recording of multiple external leads in addition to the oesophageal or intra-atrial leads (Kistin, 1966).

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The data further indicate that within the range of sinus rates encountered (65 to 115 beats/min.), there is no correlation between rate and the incidence of retrograde conduction. At faster heart rates, a correlation might have appeared, since less time would be available for a properly timed retrograde impulse to capture the atria, despite the absolute shortening of atrial refractoriness which occurs as heart rate increases (Mendez, Gruhzit, and Moe, 1956).

Similarly, there was no relation between the incidence of ventriculo-atrial conduction and the use of digitalis or the type of heart disease. It is possible, of course, that in a larger series of patients, or in patients with faster heart rates or with selectively (as opposed to randomly) induced ventricular ectopic beats some difference might have emerged. The implication, however, is that whatever influence was exerted by glycosides or myocardial disease similarly affected conduction in both directions.

FIG. 5.—Left ventricular stimulation with retrograde conduction and interference between atrial and ventricular impulses (same patient as in Fig. 4). The sinus pacemaker drives the heart in normal fashion for beat A_1 . Then ventricular beats begin (V_2 – V_6), the first of which (V_2) is blocked in the AV junction by the antegrade impulse from the sinus (A_2). The next three beats, however, capture the atrium with 1:1 retrograde conduction (V_3 , V_4 , V_5). Ventricular beat V_6 is blocked before reaching the atria somewhere in the retrograde pathways which are still refractory from the effects of the previous ventricular beats. A sinus beat (A_6) concludes the record. This tracing shows that either atrial or ventricular activity can block retrograde conduction.

Animal Studies. In the present work and in the clinical studies mentioned previously, attempts to correlate the presence of retrograde conduction with such factors as speed of forward conduction, drugs, type of heart disease, and coupling intervals have produced variable results. In experimental models such influences have been applied more predictably. Hypothermia has, for example, been shown to speed ventriculo-atrial conduction, which may account for the finding at low temperatures of a reversed form of the usual irregular ventricular response to atrial fibrillation (Francis, Campbell, and Hoff, 1960). When the ventricles fibrillated, an irregular atrial tachycardia developed presumably brought about by retrograde conduction.

The role of vagal stimulation has also been investigated and found to have a greater inhibitory effect on retrograde than on antegrade conduction (Francis and Hoff, 1965). Paradoxically, however, carotid sinus pressure has occasionally facilitated retrograde conduction as observed in human electrocardiograms (Scherf, Cohen, and Rafailzadeh, 1966).

Clinical Significance of Ventriculo-atrial Conduction. The influence of retrograde conduction in clinical situations has been emphasized by several investigators. *Suppression* of forward conduction by retrograde penetration of the AV tissues is revealed by the presence of “compensatory-like” pauses after ventricular ectopic beats, which occur in patients with atrial fibrillation (Langendorf, Pick, and Katz, 1965b; Langendorf *et al.*, 1965a), and by the prolongation of AV junctional escape intervals after ventricular premature beats (Fig. 7) (Hwang and Langendorf, 1950). The P-R interval can be prolonged through a similar mechanism by an interpolated ventricular beat in sinus rhythm (Katz and Pick, 1956), or by the junctional pacemaker during AV dissociation with ventricular capture beats (Schamroth and Friedberg, 1965; Lister *et al.*, 1967). An inverted P wave need not necessarily be seen in order to infer the presence of retrograde penetration, at least as far as the AV junction (Schamroth and Rosenzweig, 1962; Moe, Abildskov, and Mendez, 1964). Concealed retrograde conduction

FIG. 6.—Left ventricular stimulation producing retrograde conduction and a reciprocal beat (Case 12, PR=0.16 sec.; sinus rate=95 beats/min.). Top tracing of bipolar intra-atrial electrocardiogram; lower tracing of lead III (diagram identified with Fig. 3).

After two sinus beats (V_1 , V_2) the ventricle is discharged by catheter stimulation three times. Retrograde conduction from V_3 and V_4 is blocked before reaching the atria which remain under control of the sinus node. V_5 , however, occurs sufficiently late to find the retrograde pathways intact, though A_5 has been prevented from reaching the ventricles by the AV junctional penetration of V_5 . The atria are depolarized (A_6) by V_5 which also returns in reciprocal fashion to discharge the ventricles again (V_6). (A possible alternative explanation is that A_6 is an atrial reciprocal beat from A_5 which also discharged (V_6). Under such circumstances V_6 would be blocked in the AV junction, and by way of concealed retrograde penetration lengthen the A_5 - A_6 interval.) Sinus rhythm is re-established by A_7 and A_8 .

Interpolated ventricular beats may occur in similar sequence as in V_5 , A_6 , V_6 , with the ventricular beat discharging the following "sinus" beat by means of retrograde conduction (Kistin, 1963).

has also been invoked to explain some instances of parasystole with fixed coupling (Langendorf and Pick, 1967).

Conversely, retrograde penetration, it is thought, may facilitate forward conduction through the property of supernormal conductivity. Examples of this phenomenon are found clinically in AV block when relatively normal atrioventricular conduction unexpectedly occurs, apparently produced by effects of the preceding ventricular beat on the AV junction (Lewis and Master, 1924; Pick, Langendorf, and Katz, 1962; Burchell, 1963).

SUMMARY

The characteristics of ventriculo-atrial conduc-

tion induced by random left ventricular stimulation during cardiac catheterization have been studied by measured intra-atrial electrocardiograms. Retrograde conduction was detected in 14 of 30 patients studied. Ventriculo-atrial conduction was more frequently seen when shorter P-R intervals were present. In those patients with ventriculo-atrial conduction R-P' intervals were less than P-R intervals in 7, equal in 1, and longer in 6 patients. The sinus rate, use of digitalis, or the type of heart pathology did not appear to influence the likelihood of recording ventriculo-atrial transmission.

Ventriculo-atrial conduction in man is clearly not an uncommon event, and techniques are now available for its study. The possible clinical significance of its occurrence has been reviewed.

FIG. 7.—Left ventricular stimulation producing retrograde conduction with accelerated AV junctional escapes (same patient as in Fig. 6). VA conduction is present for the first three beats. Ventricular stimulation then stops and the sinus fires (A_4 , A_5) but not soon enough to capture the ventricles which are discharged by an accelerated AV junctional pacemaker at a rate of 73 (V_4 , V_5). V_6 which follows is another ventricular beat and reaches the atria at about the time the sinus would be expected to discharge. A_6 , therefore, may be a fusion of the sinus beat with the retrograde beat. (In the ladder diagram the beat is illustrated as if it were wholly retrograde.) Concealed retrograde penetration of the AV junction by V_6 discharges the junctional pacemaker and causes V_7 to appear after a slightly longer escape interval than expected. A sinus beat (A_8) concludes the record.

This tracing shows how retrograde atrial activation can sufficiently slow sinus rhythm to allow the escape of lower pacemakers.

The authors would like to thank Drs. Charles L. Schulman and Yolando Q. M. Sulit who participated in the collection of the data. The diagrams were prepared by the Medical Art Department of the Massachusetts General Hospital.

REFERENCES

- Barold, S. S., Linhart, J. W., and Samet, P. (1968). Reciprocal beating induced by ventricular pacing. *Circulation*, **38**, 330.
- Burchell, H. B. (1963). Analogy of electronic pacemaker and ventricular parasystole with observations on refractory period, supernormal phase, and synchronization. *Circulation*, **27**, 878.
- Castillo, C., and Samet, P. (1967). Retrograde conduction in complete heart block. *Brit. Heart J.*, **29**, 553.
- Cohn, A. E., and Fraser, F. R. (1914). The occurrence of auricular contractions in a case of incomplete and complete heart-block due to stimuli received from the contracting ventricles. *Heart*, **5**, 141.
- Fletcher, E., and Morton, P. (1968). Atrioventricular dissociation with intact retrograde conduction. *Brit. Heart J.*, **30**, 458.
- Francis, C. K., Campbell, C. A., and Hoff, H. E. (1960). Hypothermic facilitation of retrograde V-A conduction. *J. appl. Physiol.*, **15**, 1035.
- , and Hoff, H. E. (1965). The influence of local atropinization of the A-V node on retrograde V-A conduction. *Cardiovasc. Res. Center Bull.*, **4**, 5.
- Hwang, W., and Langendorf, R. (1950). Auriculoventricular nodal escape in the presence of auricular fibrillation. *Circulation*, **1**, 930.
- Kastor, J. A., and DeSanctis, R. W. (1967). Reciprocal beating from artificial ventricular pacemaker. *Circulation*, **35**, 1170.
- , Sanders, C. A., Harthorne, J. W., Sulit, Y. Q. M., Leinbach, R. C., and Schulman, C. L. (1967). Retrograde conduction during cardiac catheterization and in patients with heart block. *Circulation*, **35-36**, Suppl. II, p. 156 (Abstract).
- Katz, L. N., and Pick, A. (1956). *Clinical Electrocardiography. Part I. The Arrhythmias*, p. 185. Lea and Febiger, Philadelphia.
- Kistin, A. D. (1959). Mechanisms determining reciprocal rhythm initiated by ventricular premature systoles. Multiple pathways of conduction. *Amer. J. Cardiol.*, **3**, 365.

- (1961). Retrograde conduction to the atria in ventricular tachycardia. *Circulation*, **24**, 236.
- (1963). Multiple pathways of conduction and reciprocal rhythm with interpolated ventricular premature systoles. *Amer. Heart J.*, **65**, 162.
- (1966). Atrioventricular junctional premature and escape beats with altered QRS and fusion. *Circulation*, **34**, 740.
- , and Landowne, M. (1951). Retrograde conduction from premature ventricular contractions, a common occurrence in the human heart. *Circulation*, **3**, 738.
- , Tawakkol, A., and Massumi, R. A. (1967). Atrial rhythm in ventricular tachycardia occurring during cardiac catheterization. *Circulation*, **35**, 10.
- Langendorf, R., and Pick, A. (1967). Parasystole with fixed coupling. *Circulation*, **35**, 304.
- , —, Edelist, A., and Katz, L. N. (1965a). Experimental demonstration of concealed AV conduction in the human heart. *Circulation*, **32**, 386.
- , —, and Katz, L. N. (1965b). Ventricular response in atrial fibrillation. Role of concealed conduction in the AV junction. *Circulation*, **32**, 69.
- Lewis, T., and Master, A. M. (1924). Supernormal recovery phase, illustrated by two clinical cases of heart-block. *Heart*, **11**, 371.
- Lister, J. W., Delman, A. J., Stein, E., Grunwald, R., and Robinson, G. (1967). The dominant pacemaker of the human heart. Antegrade and retrograde activation of the heart. *Circulation*, **35**, 22.
- Mendez, C., Gruhzit, C. C., and Moe, G. K. (1956). Influence of cycle length upon refractory period of auricles, ventricles, and A-V node in the dog. *Amer. J. Physiol.*, **184**, 287.
- Moe, G. K., Abildskov, J. A., and Mendez, C. (1964). An experimental study of concealed conduction. *Amer. Heart J.*, **67**, 338.
- Pick, A., Langendorf, R., and Katz, L. N. (1951). Depression of cardiac pacemakers by premature impulses. *Amer. Heart J.*, **41**, 49.
- , —, and — (1962). The supernormal phase of atrioventricular conduction. I. Fundamental mechanisms. *Circulation*, **26**, 388.
- Samet, P., Castillo, C., and Bernstein, W. H. (1967). Studies in P wave synchronization. *Amer. J. Cardiol.*, **19**, 207.
- Schamroth, L., and Friedberg, H. D. (1965). Significance of retrograde conduction in A-V dissociation. *Brit. Heart J.*, **27**, 896.
- , and Rosenzweig, D. (1962). Reciprocal ventricular extrasystoles. *Brit. Heart J.*, **24**, 805.
- Scherf, D., and Cohen, J. (1964). *The Atrioventricular Node and Selected Cardiac Arrhythmias*, p. 208. Grune and Stratton, New York and London.
- , —, and Rafailzadeh, M. (1966). Excitatory effects of carotid sinus pressure. *Amer. J. Cardiol.*, **17**, 240.
- Winternitz, M., and Langendorf, R. (1944). Auriculo-ventricular block with ventriculoauricular response. *Amer. Heart J.*, **27**, 301.