Studies in Intracardiac Electrography in Man

IV. The Potential Variations in the Coronary Venous System

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with the technical assistance of Eunice Gilman

Two parallel researches in progress at the Brigham Hospital, one an investigation of intracardiac electrography in general, the other a long-term study of heart muscle metabolism with the aid of the venous catheter, converge, resulting in the interesting practical and theoretical findings reported here. The authors show how the electrogram may help establish the position of the catheter in the coronary venous system and indicate the type of potential variations recorded in the coronary sinus, in its continuation, the great cardiac vein, and in its tributary, the middle cardiac vein.

UNTIL recently our concepts of the mode of electrical activation of the human heart have been derived largely from studies of the canine heart. With the advent of venous catheterization technic, and the possibility of recording the potentials within the right side of the heart, the similarity of right sided potentials in man to those in the dog has been demonstrated.1–10 Left ventricular cavity potentials have also been recorded in man, once by the hazardous procedure of passing a catheter through the arterial system and the aortic valve into a normally activated left ventricle,11 and once by passing the catheter through an interatrial septal defect and the mitral valve into the left ventricle of a patient with right bundle branch block.12 In both of these studies, the QRS complex within the left ventricle was directed downward. Since in both instances the septum is presumed to be activated in a normal direction from its left to its right side, these studies apparently confirm the similarity of left as well as right ventricular cavity potentials in man to those in the dog. In two other studies,7,9 the recording of left-sided potentials was not clearly documented.

Coronary venous catheterization technic3 has offered still another feasible approach to the study of the electrical activation of the human heart, as we have already reported in preliminary form.14 This procedure has been used chiefly for studies on coronary blood flow and myocardial metabolism in dogs and man, in collaboration with Bing, Eckenhoff and their associates.15–18 One observation of the electrical potentials recorded through a catheter fortuitously inserted into the coronary sinus of a patient with hypertensive cardiovascular disease was reported recently by Kert and Hoobler.10 The present report is an analysis of the potentials recorded through a catheter systematically inserted into the various accessible branches of the coronary venous system, including the coronary sinus, great cardiac vein and middle cardiac vein, among six subjects with essentially normal hearts.

METHOD

The coronary sinus, great cardiac vein or middle cardiac vein were catheterized using a No. 7 or 8F “bird’s eye” venous catheter provided with multiple openings near the tip, as described elsewhere.19

A systematic technic of intubating the coronary sinus and its branches, following the essential principles formulated for the same procedure in intact

* Available from the U. S. Catheter and Instrument Co., 334 Bay St., Glens Falls, N. Y.
dogs, was applied to the present studies in man. The regional anatomy pertinent to coronary sinus catheterization was recently described by Bing and associates, and will therefore not be reviewed here. The catheter was introduced into the right atrium by the technic of Courand and Ranges. The tip was then passed into the inferior vena cava. This maneuver was often aided by having the patient take a deep breath just as the catheter was advanced downward from a position low and posterior in the right atrium. Often the right anterior oblique position gave a better view of the posteriorly oriented inferior vena cava, so that the catheter could be directed into it more deliberately.

Once inside the inferior vena cava, with the subject now returned to the posteroanterior position, the slightly curved tip was turned to point medially (toward the patient’s left), and cautiously withdrawn into the atrium. At the instant at which the catheter tip flicked free from the vena cava into the atrium proper, a slight medial shift of the tip occurred, aided by the fact that the curved tip had already been directed medially. This slight shift carried the tip to a point directly opposite the coronary sinus ostium, which lies immediately adjacent to the inferior vena cava, on the posteroinferior medi- al surface of the right atrium, with only the Eustachian ridge separating the ostia of the two vessels. After several thrusts of the catheter at this point, the tip would usually enter the coronary sinus ostium. Again, alternating posteroanterior and right anterior oblique fluoroscopic views often helped to make sure that the catheter remained properly oriented along the posterior atrial surface. If the tip was allowed to drift anteriorly, it would almost invariably pass through the tricuspid valve into the right ventricle.

As the catheter now passed into the coronary sinus and on into the great cardiac vein, it appeared to turn sharply across the cardiac shadow, slightly cephalad, across the posterior surface along the atrioventricular groove, often reaching the left border of the heart. Occasionally the catheter entered the middle cardiac vein, passing from its ostium, just inside the coronary sinus ostium, out along the postero- inferior septal surface toward the apex.

Difficulty in intubating the coronary sinus because of deflection of the catheter by a prominent Eustachian ridge has been reported. This has not been apparent during the present study, possibly because of selection of a catheter with only a slightly curved tip. The optimal curve in the tip for this procedure has appeared to be much less than the optimal curve for entering the right ventricle and pulmonary artery. Likewise the remnant of the valve of the coronary sinus (thebesian valve) has never appeared to interfere with coronary sinus intubation in the adults studied. Insertion into the coronary sinus has been found to be distinctly easier from the left arm, because of the natural tendency for the curve to be oriented medially in the right atrium when approached from this direction. It has sometimes been difficult or impossible to keep the tip pointed in the proper direction on withdrawal from the inferior vena cava, when the heart has been approached from the right arm. It has also been very difficult to approach the coronary sinus with any degree of consistency by first going through the tricuspid valve and using this as a point of reference rather than the inferior vena cava. It has usually been obvious within two or three minutes of fluoroscopy time whether or not the catheter has been properly curved to enter the coronary sinus. If not, a second, third or even a fourth catheter has been tried in succession, often with success as one with the proper curve and orientation has been obtained. Seventeen out of 30 such procedures have been technically successful over the past year, with most of the failures occurring in heavy or emphysematous patients where fluoroscopic visualization has been poor. Patients with dilated or hypertrophied left ventricles have presented no special difficulty by the technic described, possibly because such patients also tend to have a dilated coronary sinus. Once the catheter has been passed successfully into the inferior vena cava, the technic of coronary sinus catheterization has been successful in 7 of the last 11 procedures.

The localization of the catheter within the coronary venous system was determined first by the characteristic course of the catheter under fluoroscopic control. Distinction between a position within the right ventricle and the coronary sinus was easier in the right anterior oblique than in the posteroanterior view, as illustrated elsewhere in dogs. Successful coronary venous catherization was then confirmed by the pressures recorded through the catheter by means of a Sanborn electromanometer. Unless there was some element of coronary venous obstruction by the catheter, there was never more than 1 or 2 mm. pressure gradient between the mean levels in the coronary venous system and the right atrium (see table 1), and a characteristic short systolic pulse pressure wave was clearly distinguishable from pressures in the right ventricle or right atrium. Absence of extrasystoles did not prove to be a completely reliable indication that the catheter was in the coronary venous system rather than the right ventricle, as discussed below, but it was none the less true that rapid runs of multiple ventricular extrasystoles were seen only when the catheter was in the right ventricle. Finally, coronary venous blood samples were much darker than mixed venous blood, as emphasized in previous reports, reflecting a very low coronary venous oxygen saturation. Significantly lower levels of pyruvate, lactate and glucose were also characteristic of coronary venous blood compared to arterial blood, measured
by methods discussed in detail in connection with similar findings in dogs.\(^a\) (See table 1.)

A stainless steel wire of 1/64-inch diameter was passed to within four centimeters of the tip of the catheter. The proximal few centimeters of the wire were incorporated in and passed through a three-way stopcock whose distal end fitted into the proximal end of the catheter and whose lateral arm received the tube leading to a saline drip apparatus or a Sanborn electromanometer (condenser microphone type). The proximal end of the wire was coupled to a central terminal of the Wilson type. A continuous saline drip was run through the side arm of the adapter except when pressure measurements were being made or samples of blood were being drawn for chemical analysis. To prevent the development of artefacts and wandering of the baseline of the electrogram, it was necessary to eliminate any leakage about the adapter. Tracings of the intracardiac potentials were recorded simultaneously with the unipolar left leg lead (V\(_L\)) with a Sanborn Tri-Beam Electrocardiograph. In one instance a Cournand double-lumen catheter,\(^2\) whose proximal lateral opening was 10 cm. from its distal terminal opening, was used. In this way it was possible to record the potentials simultaneously at two points within the heart, e.g., coronary sinus and right atrium, pulmonary artery and right ventricle, or right ventricle and right atrium. In all cases additional recordings were made at one or more points in the right ventricle and atrium, as well as conventional and unipolar limb leads and unipolar chest leads for comparison with the potentials in the coronary venous system.

**TABLE 1.—The Chemical and Manometric Findings in Coronary Venous Blood**

<table>
<thead>
<tr>
<th>Name</th>
<th>G. L.</th>
<th>B. C.</th>
<th>G. C.</th>
<th>T. D.</th>
<th>A. B.</th>
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<td>Pressures, mm. Hg</td>
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<tr>
<td>Coronary venous:</td>
<td>7</td>
<td>(8(^a))</td>
<td>5</td>
<td>2</td>
<td>(12(^a))</td>
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<td>5</td>
<td>3</td>
<td>4</td>
<td>1</td>
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<tr>
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<td>28/5</td>
<td>30/0</td>
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<td>17.2</td>
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<td>16.9</td>
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<td>0.9</td>
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<tr>
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<td>7.1</td>
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<td>98</td>
<td>81</td>
<td>97</td>
<td>74</td>
<td>—</td>
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\(^a\) Values in parenthesis were apparently obtained with the catheter partially obstructing the coronary venous system, with lower subsequent values obtained after withdrawing the catheter slightly.

Seven successful coronary venous catheterizations were carried out in 6 individuals with normal hearts, among 12 deliberate attempts in 10 subjects. In 5 of these subjects the potentials of the coronary sinus and great cardiac vein were recorded. In 2 subjects records were obtained with the catheter at several different points within the middle cardiac vein.

**Results**

Seven successful coronary venous catheterizations were carried out in 6 individuals with normal hearts, among 12 deliberate attempts in 10 subjects. In 5 of these subjects the potentials of the coronary sinus and great cardiac vein were recorded. In 2 subjects records were obtained with the catheter at several different points within the middle cardiac vein.

**The Potentials in the Coronary Sinus and Great Cardiac Vein**

In subject G.L., when the catheter was in the great cardiac vein the auricular complex was directed entirely upward (fig. 1A) with the intrinsic deflection at 0.08 second. The descending limb did not quite return to the isoelectric line but was followed by a secondary upward deflection (R'a) with a slightly more gradual slope, measuring about half as tall as Ra. The returning limb of the secondary R wave descended slowly and flattened out to form an upward deviation of the auriculoventricular segment (R’a-Q) in the manner described elsewhere.\(^3\)\(^,\)\(^8\) This gave way to a deep broad (0.06 second) ventricular Q wave, a less prominent R wave, and an inverted T wave. When the catheter was now withdrawn about 2 cm. into the coronary sinus proper, the auricular deflection (fig. 1B) consisted initially of a slow upward component beginning about 0.04 sec-
ond after the beginning of the P wave recorded simultaneously in Lead V_F. This was superseded by a rapid equi- and bi-phasic deflection (RSa) whose apex (intrinsic deflection time, recorded at the apex of this rapid auricular deflection) occurred 0.07 second after the beginning of the P wave. The Sa wave returned not quite to the isoelectric line and was superseded by a small downward deflection which

followed immediately after the completion of the P wave in Lead V_F. This in turn was followed by a biphasic ventricular complex consisting of a prominent Q wave 0.06 second in duration and exceeding the following ventricular R wave in both magnitude and duration. This was followed by an inverted T wave.

In this individual, electrograms were also obtained at high and low levels in the right atrium. It will be noted that at low levels (fig. 1C) the intrinsic deflection occurred at 0.03 second and at high levels (fig. 1D) at 0.02 second. The ventricular complex at each level consisted of a broad QS followed by an inverted T wave. It was also observed that whereas deep inspiration moved the catheter a considerable distance and produced corresponding changes in the appearance of the auricular complex while the catheter was in the right atrium, a similar deep inspiration while the catheter was in the great cardiac vein pro-

Fig. 1.—Subject G. L.: Potentials in great cardiac vein (A) and coronary sinus (B) compared with potentials low (C) and high (D) in the right atrium. Note the lateness of the intrinsic auricular deflection in the coronary venous system as compared with the right atrium, and the prominent ventricular Q and R in the coronary veins compared with the QS type of deflection in the right atrium.

duced no change in electrographic appearance or in the position of the catheter as determined by fluoroscopic observation in posteroanterior and oblique projection. This is interpreted as evidence of the absolute or relative immobility of the catheter while in the great cardiac vein, the force developed by inspiration apparently merely taking up the slack in the intra-atrial portion of the catheter.

In subject G.C. electrograms were recorded at only one point in the coronary sinus. At this location the auricular complex (fig. 2) con-
sisted of an upward deflection (Ra) with an intrinsic deflection at 0.07 second. The returning limb of this Ra was interrupted by a sudden break with a slower return toward the isoelectric line. This constitutes an upward deviation of the Ra-Q segment. This in turn was superseded at a level still above the isoelectric line by a prominent Q wave which began shortly before the beginning of Q of simultaneously recorded Lead Vf. The broad Q was followed by a large Ra wave, which in turn was followed by a small Sa wave. The intrinsic deflection of the auricular complex occurred at 0.05 second. After an isoelectric interval, this was followed by a broad Q wave (0.05 second in duration) and this, in turn, by a slightly smaller and narrower R wave. The T wave was notched and slightly inverted.

In subject T.D., the coronary sinus tracings were somewhat atypical (fig. 4). The Ra deflection was much less conspicuous. The intrinsic deflection was inscribed at 0.07 second. The Q wave was less prominent and narrower (0.03 second) and R more prominent than in the coronary sinus tracings described above.

![Fig. 2](https://example.com/fig2.png)

**Fig. 2.**—Subject G. C.: Characteristic coronary sinus potentials (upper curve) with a very tall upright P wave, late intrinsic auricular deflection (0.07 sec.), prominent Q and R waves. Simultaneous Lead Vf (lower curve).

![Fig. 3](https://example.com/fig3.png)

**Fig. 3.**—Subject C. M.: Coronary sinus potentials (upper) with simultaneous Vf lead (lower curve). Intrinsic auricular deflection at 0.05 sec.; deep Q wave, prominent R wave.

The T wave was biphasic but predominantly inverted.

In subject M.C., tracings obtained in the great cardiac vein (fig. 5A) showed a very large auricular deflection with the apex of Ra at 0.06 second. A definite Sa wave followed. This was followed by large ventricular Q and R waves and a biphasic T wave.

On withdrawing the catheter from the great cardiac vein to the coronary sinus proper numerous supraventricular premature beats developed and the Sa wave disappeared (fig. 5B). The intrinsic deflection was now inscribed at 0.07 second. Meanwhile, although ventricular Q and R waves were retained, an auricular S wave reappeared (fig. 5C, beginning of strip). Continuous tracings (fig. 5C) were then recorded as the catheter was withdrawn from the coronary sinus into the right atrium. Reference to this figure shows how the complexes were characteristic successively of the coronary
sinus, then of the right atrium and finally of the right ventricle.

sec.) electrograms from the first 4 subjects described above are reproduced in figure 6. The

![Figure 5](image)

**Fig. 5.**—Subject M. C.: Excerpts from a continuous tracing during withdrawal of the catheter from the great cardiac vein. An Sa wave is present deep in the great cardiac vein (A), disappearing at a point (B) in the coronary sinus, only to reappear in the proximal coronary sinus (C). The final strip (C) was recorded as the tip of the catheter was withdrawn from the coronary sinus into the right atrium and passed into the right ventricle, and shows in turn the characteristic potentials of each region. Note the supraventricular premature beats (x) in strip B, during withdrawal of the catheter through the coronary venous system.

![Figure 6](image)

**Fig. 6.**—Low speed electrograms (25 mm. per sec.) from the coronary venous system (upper) with simultaneous VF potentials (lower curves) in 4 normal subjects. Note the family resemblance of these tracings.

To demonstrate the family resemblance of potentials recorded in the coronary sinus or great cardiac vein, the low speed (25 mm. per existence of auricular intrinsic deflections, usually of considerable magnitude, their inscription at the height of or during the latter half
of the P wave of simultaneously recorded Lead V_f and the existence of prominent ventricular Q and R waves and of inverted ventricular T waves are at once apparent.

The Potentials in the Middle Cardiac Vein

In 2 of the 6 individuals studied, the catheter was passed into the middle cardiac vein as determined by fluoroscopic examination and roentgenograms made with the subject rotated in various positions as well as by chemical and manometric determinations (table 1). In patient A.B., with the catheter a considerable distance into the vein, a flat P wave (fig. 7A), followed by an R wave, was recorded. No Q wave was present. The T wave was upright. These tracings correspond to left ventricular epicardial potentials. When the catheter was drawn a few centimeters more proximal, the electrogram (fig. 7B) changed abruptly from a predominantly upright to a downward (QS) complex followed by a flat T wave. A ventricular R wave was not recorded. This tracing probably represented right ventricular epicardial potentials.

The absence of a Q wave when the catheter was over the left ventricular epicardium and the absence of an R wave over the right ventricular epicardium suggests that the catheter tip may have been very close to the septum in each instance.

Subject T.D. showed a similar left ventricular epicardial potential when the catheter was passed for 4 to 5 cm. into the middle cardiac vein, although here there was a small Q wave (fig. 7C, lower curve). On withdrawing the catheter more proximal again an abrupt shift to a right ventricular epicardial pattern was noted, this time with a small R wave (fig. 7D, lower curve). Since this R wave of the right ventricular epicardial potential coincided with the Q wave of the left ventricular epicardial potential, it seems reasonable that they represent two aspects of the same electrical event,
namely, septal activation. Furthermore, unlike the tracings in subject A.B., each of the electrode positions must have been far enough from the plane of the interventricular septum to face respectively the approaching wave of septal activation at the proximal position and the retreating wave at the distal position.

Isolated ventricular premature beats were noted when the catheter was passed into the middle cardiac vein in each instance as illustrated in figures 7B and 7D.

When figure 7D was recorded, the proximal opening of a double lumen catheter was in the right atrium near the superior vena cava (upper curve) and the distal opening in the middle cardiac vein (lower curve). The third QRS complex is premature and of greater duration and magnitude than the preceding or following QRS complexes. As recorded at the superior caval electrode, the auricular complex follows the premature ventricular complex, interrupting the ventricular T wave. This auricular complex, in contrast to all other auricular complexes in this strip, which were directed entirely downward, was biphasic with an initial upward and final downward deflection. This indicates that whereas the impulse in the normal beats proceeded away from the superior vena cava, in the premature beat atrial depolarization first approached then reeded from the superior vena cava. The postextrasystolic pause was quite compensatory but the changed direction of atrial depolarization suggests retrograde depolarization of the atrium if not of the sinoatrial node.

**Discussion**

*Left Atrial Potentials*

Previous studies have demonstrated the presence of large auricular deflections within the right atrium, being inscribed early at high atrial levels and later at low atrial levels, but in general occurring during the first half of the P wave of a simultaneously recorded limb lead. By the use of simultaneously recorded intracardiac and esophageal leads, it was shown that the right atrium was activated some 0.05 to 0.08 second earlier than the left atrium as recorded in the esophageal lead at approximately the same horizontal plane. It appeared then that, in general, the right atrium is stimulated before the left and that the auricular intrinsic deflection occurs during the first half of the auricular complex in the right atrium and during the second half of the auricular complex in the left atrium.

When the catheter is introduced into the orifice of the coronary sinus in the lower part of the right atrium, it must take a leftward course. Unless the tip happens to enter the tributary middle cardiac vein, the catheter, on further insertion, tends to follow the course of the coronary sinus and its continuation, the great cardiac vein. This circles around the left side of the atrioventricular groove, then the left anterior aspect of this groove to the anterior longitudinal sulcus where it turns toward the cardiac apex, paralleling in a general way the course of the descending branch of the left coronary artery. After passing through the heart wall at the inferior angle of the right atrium, the catheter very promptly enters the atrioventricular groove. At this point the electrode is at the brim of the left atrium and of the left ventricle, and capable of recording the potentials of both of these cavities. This is illustrated in figure 8, which shows the heart in sagittal section. It will be obvious that an electrode in the coronary sinus would reflect the potentials not only of the left atrial and ventricular cavities, but also of a portion of the epicardial surface of the left ventricle.

One would predict then that the electrode in the coronary sinus must record the potentials of the lower part of the left atrium. The auricular intrinsic deflection should therefore occur at the height of or during the latter half of the P wave of simultaneously recorded Lead V6. The further the electrode lies from the atrial pacemaker, the later should this intrinsic deflection be inscribed. Assuming uniform conduction of the impulse over the atrial surfaces, the electrode must eventually reach a point on the anterolateral aspect of the atrioventricular groove 180 degrees from the projection of the sinoatrial node upon this groove, toward which point the wave of atrial depolarization must converge from all angles. At this point the rapid auricular deflection should be entirely upright, for no atrial muscle is stimulated after this point. Figures 1A, 2 and 5B are actual examples of the type of electrogram predicted. At points nearer the cardiac pacemaker the rapid deflection should be largely upward (Ra) but this might be followed by a downward (Sa) deflection because some atrial
muscle, further from the pacemaker, is stimulated later. Actual examples of this theoretic potential are illustrated in figures 1B, 3, and 5C. If the catheter is now passed to a point beyond the meridian intercepting the pacemaker, the intrinsic deflection may again appear earlier and an Sa wave may reappear because atrial muscle is now activated later than this new point. This is borne out by figures 5A–C showing an Sa wave in the great broad Q wave followed by an R wave. This Q wave corresponds to the initial ventricular deflection recorded directly in the chamber of the dog’s left ventricle. It corresponds also to the initial part of the human left ventricular cavity electrogram described by Zimmerman and co-workers in aortic insufficiency, and by Sodi-Pallares. The evidence of the present study of normally activated hearts establishes this broad Q wave recorded in the coronary sinus and great cardiac vein as representing the left ventricular cavity potential. The succeeding R wave probably represents the accessible left ventricular epicardial potential. By contrast the initial ventricular complex in the right ventricular cavity shows a small initial R wave followed by a deep S wave. The initial ventricular complex recorded in the right atrium generally consists of a QS deflection.

Ventricular repolarization is normally represented as an upright T wave on the precordium overlying the left ventricle. In our experience and in that of most observers it

Fig. 8.—Relationship of the coronary sinus to the left atrium and left ventricle, in sagittal section (after Piersol).
is usually recorded as an inverted T wave in the right ventricular cavity but occasionally has been reported as upright in that location. Since the coronary sinus is normally in an anatomical relationship with the left ventricular cavity and only to a slight extent with the left ventricular epicardium, the potentials recorded there must represent the composite effect of left ventricular cavity and epicardial potentials. Since the T wave is inverted in the coronary sinus, the cavity effect must be predominant. This relationship primarily to endocardium is emphasized in figure 8.

Generalizations are hardly warranted on the basis of the observations of the potentials in the middle cardiac veins of only two individuals. They do suggest some variability in the curves registered in that vessel depending possibly upon a variation in the course of this vessel in relation to the posterior interventricular sulcus. As the catheter in this vessel crosses the interventricular septum toward the apex, an abrupt change from predominantly downward (right ventricular) to predominantly upward (left ventricular) potentials may be detected as illustrated in figure 7.

Kert and Hoobler18 published electrograms obtained from three positions in the coronary sinus of a patient with essential hypertension. Each electrogram showed auricular intrinsic deflections occurring during the latter half of the P wave recorded simultaneously in Lead Vr. The first of the three tracings showed a broad ventricular Q wave followed by a broad R wave; the other two showed very inconspicuous ventricular Q waves but very prominent R waves. These R waves differed in time from one position to another in the coronary sinus. The authors suggest that they reflect the activation of different portions of the base of the left ventricle. The discrepancy between these observations and ours, in which a broad Q wave was always recorded with the electrode in the coronary sinus, may be related to the fact that all of our subjects had normal hearts, whereas the patient of Kert and Hoobler had left ventricular enlargement. It is conceivable that under the latter circumstance the coronary sinus may lie in a more intimate relationship with the epicardial than the endocardial aspect of the left ventricle.

**Accidental Catheterization of the Coronary Sinus**

In a previous communication from this laboratory, an initial ventricular R wave was noted in what was at first sight considered to be the right ventricle in all but 3 of 27 individuals. In 2 of these exceptions (subjects 6 and 26, figures 7F and 8 of that paper) it was impossible to confirm the intraventricular location of the electrode by passing the catheter on into the right pulmonary artery. The course of the catheter as determined in posteroanterior projection by fluoroscopy and roentgenography was consistent with the location of the catheter in the right ventricle of these individuals but roentgen-ray observations with the subjects in the right anterior oblique position were not carried out. In the third subject (subject 8, figures 7A–E in the paper referred to) the catheter was successfully passed into the pulmonary artery. In these three individuals upright or predominantly upright rapid auricular deflections and prominent ventricular Q waves were recorded. Simultaneous electrocardiograms showed the auricular intrinsic deflection to be inscribed during the latter one-half of the P wave. It seemed clear that these potentials were developed in the left side of the heart and the possibility of accidental catheterization of the left atrium through an interatrial septal defect was suggested but not proved.

It has been pointed out, however, that the anteroposterior projection of the catheter in the coronary sinus may be quite similar to that of the catheter in the right ventricle. The differentiation between these two possible courses of the catheter requires roentgen-ray examination in the right oblique position. Furthermore, the potentials recorded in the three subjects described above are identical with those recorded in the present study when the coronary sinus was deliberately catheterized. Accidental catheterization of the coronary sinus, therefore, seems the most likely explanation for the electrographic findings in at least two (subjects 6 and 26) of the three instances described. The explanation for the findings in the third (subject 8) individual is not clear.
This digression has been deliberately pursued in some detail to emphasize the possibility of confusion in electrographic studies of the human heart by accidental catheterization of the coronary sinus.

Arrhythmias

The problem of arrhythmias during coronary venous catheterization should be evaluated as a possible hazard of the procedure. Nodal and auricular premature beats have been reported in dogs during insertion of the catheter into the coronary venous system, but they have not been reported to occur once the catheter had been left in position. No ventricular premature beats were observed. Similar supraventricular beats are here reported in man, again found only during actual manipulation of the catheter within the coronary sinus or great cardiac vein. In the distal part of the middle cardiac vein, however, ventricular premature beats occurred even after the catheter had been left in place. Myocardial irritation here may have corresponded to the intimate relationship of the middle cardiac vein to the subepicardial myocardium. By contrast, the coronary sinus and proximal part of the great cardiac vein are embedded in a relatively appreciable amount of fatty tissue which may shield the myocardium from contact with the tip of the catheter.

Significant ventricular arrhythmias are commonly noted if the catheter tip is passed beyond the tricuspid valve into the right ventricle, and constitute a conceivable hazard to the usual cardiac catheterization procedures. The absence of anything but transient supraventricular premature beats during catheterization of the coronary sinus and great cardiac vein contributes to the relative safety of this procedure.

Summary and Conclusions

Catheterization of the coronary venous system in 6 individuals with normal hearts appeared to be a relatively safe procedure. Supraventricular premature beats developed during manipulation of the catheter within the great cardiac vein or coronary sinus. Ventricular premature beats were recorded with the catheter in the middle cardiac vein.

As confirmatory evidence of successful coronary venous catheterization, coronary venous blood may be identified grossly by its dark color, and chemically by its reduced content of oxygen, pyruvate, lactate and glucose, when compared with arterial or mixed venous blood. However, as an immediate aid to fluoroscopic and manometric control of the catheterization procedure, electrograms recorded from the catheter tip may serve to determine its location within the chambers of the heart and the various regions of the coronary venous system.

The electrogram in the distal portions of the middle cardiac vein showed a ventricular R wave in one subject, a qR in another; in the proximal portions of this vein there was recorded a ventricular QS in one case, an rs in another. These middle cardiac vein potentials correspond respectively to left and right ventricular epicardial potentials, the inscription of a small initial Q or R wave apparently depending upon the relation of the electrode to the interventricular septum.

The electrical potentials recorded in the coronary sinus and the great cardiac vein of 6 individuals with normal hearts showed a large rapid upward auricular deflection with the intrinsic deflection recorded at the height of or during the latter half of the P wave of simultaneously recorded Lead V5. This deflection may continue as an Sa wave apparently depending upon whether more atrial muscle is stimulated beyond the position of the recording electrode. The ventricular complex consists of a broad prominent Q wave followed by a prominent R wave and an inverted or biphasic T wave. These tracings probably represent the composite effect of the accessible left atrial and ventricular cavity and epicardial potentials.

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