Complete Heart Block Induced During Cardiac Catheterization of Patients with Pre-existent Bundle-Branch Block

The Hazard of Bilateral Bundle-Branch Block

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Complete heart block results from interruption of atrioventricular conduction at the level of the atrioventricular node or bundle of His. Blockage of both the right and left bundle branches would be tantamount to block at these locations. This is the well-established concept of bilateral bundle-branch block. It highlights a hazard inherent in catheterization of the ventricle opposite that which is already the site of bundle-branch block. Since the advent of cardiac catheterization, numerous reports have been published of the induction of transient right bundle-branch block due presumably to fortuitous injury of the right bundle branch by the tip or side of an exploring catheter. If such a patient happened already to be affected with left bundle-branch block, right ventricular catheterization could then induce bilateral bundle-branch block and all the possible consequences of suddenly developed complete atrioventricular block.

Wood reported the development of 2:1 atrioventricular block during right ventricular catheterization of a patient with pre-existent left bundle-branch block. Although he did not observe the development of complete atrioventricular block under these circumstances, he predicted, on the basis of his experience with catheter-induced right bundle-branch block, that complete heart block would be expected to develop during right ventricular catheterization in 5% of patients with antecedent left bundle-branch block. We are aware of two patients catheterized by others (one from a personal communication from R. Daley, London, and the other from the National Institutes of Health cooperative study) in whom this sequence occurred. One of these patients died from ventricular asystole. To emphasize the real danger and frequency of such a catastrophe, five patients are reported from our laboratories. Each showed the abrupt development of complete heart block on catheterization of the ventricle opposite that which was already the site of bundle-branch block.

Report of Cases

Case 1

A 61-year-old laborer with a 5-year history of intermittent episodes of pulmonary edema and clinical evidence of cardiomegaly was catheterized to determine the nature of his cardiac disease. The precatheterization electrocardiogram showed left bundle-branch block (fig. 1). A standby pacemaker catheter was positioned in the right ventricle as a precaution against the development of complete atrioventricular block. In order to record pressures, a second catheter was positioned in the left ventricle (fig. 2, top) and a third catheter was to be positioned in the pulmonary artery. While passing the third catheter through the right ventricle to the pulmonary artery, the
patient developed complete heart block with ventricular standstill (fig. 2, middle). The pacemaker catheter was then turned on and its position adjusted until a ventricular response to the pacemaker impulse was achieved. Total time of ventricular asystole was 20 seconds. The diagnostic catheterization was then continued while the ventricle was being paced (fig. 2, bottom). At the conclusion of the study the pacemaker catheter was removed. Normal sinus rhythm returned. The patient suffered no ill effects from the transient complete heart block.

Case 2

A 61-year-old man with angina pectoris and left bundle-branch block was seen because of signs and symptoms suggestive of recent pulmonary embolism. A selective pulmonary angiogram was performed without complication. Thirty minutes later, while repositioning the catheter in the proximal portion of the main pulmonary artery in order to repeat the angiogram, the tip of the catheter slipped into the right ventricle. A few ventricular premature beats developed and were followed by about 10 seconds of ventricular asystole and syncope. The ventricular asystole was observed on the oscilloscope but was not recorded. The catheter was immediately withdrawn and external cardiac massage instituted. After only one or two compressions of the chest, consciousness returned. An electrocardiogram recorded at that time showed complete heart block with a ventricular rate of 33 and an atrial rate of 93 beats per minute (fig. 3). After approximately 2 minutes normal sinus rhythm returned. The catheterization was terminated. There were no residual effects.

Case 3

A 44-year-old woman with rheumatic heart disease and recent progressive worsening of her congestive heart failure was catheterized as part of a cardiac surgical evaluation. Her electrocardiogram showed left bundle-branch block. The first step of cardiac catheterization was the precautionary placement of a standby pacemaker catheter in the outflow tract of the right ventricle. Two catheters were then positioned in the aorta...
Figure 2

Case 1: (Top) Lead II, left ventricular (LV) and right atrial (RA) pressures. Sinus rhythm is present; rate, 63 beats per minute. (Middle) Lead II, left ventricular (LV) and right ventricular (RV) pressures. Complete heart block is present. P waves (P) seem to be visible at the beginning of the strip. Pacemaker artifacts (arrows) occur at pacemaker rate of 83 per minute. There is no ventricular response to pacing at this time. An interval of 5.8 seconds of ventricular asystole is shown between idioventricular beats a and b. (Bottom) Ventricle effectively paced at 83 beats per minute. A pacemaker artifact (arrow) precedes each QRS complex. Two nonconducted P waves (P) are visible. There is a single premature ventricular contraction (PVC).

in preparation for measurement of the pressure differences across the aortic valve (fig. 4, top). Another catheter was to be positioned in the pulmonary artery to record right-sided pressures. During passage of this catheter through the right ventricle, complete heart block with ventricular standstill occurred. This was visualized on the monitor but was not recorded. The catheter was immediately withdrawn to the right atrium, and the pacemaker catheter was turned on. Pacing was instantaneously achieved (fig. 4, bottom). The diagnostic procedure was continued while the ventricle was electrically stimulated. At the conclusion of the diagnostic study all of the
Case 2: Precordial lead located approximately at V₅ recorded during cardiac catheterization just after the occurrence of ventricular asystole. The paper speed was 25 mm per second. The time lines during the first part of the tracing are spaced as indicated. The closely spaced time lines in the last part of the tracing occur at intervals of 0.04 second. Complete heart block is present. The first recorded ventricular complexes occur at calculated rates of 19 and 25 beats per minute. Subsequent complexes occur at 33 beats per minute. The atrial rate is 93 beats per minute. All of the complexes retain a left bundle-branch block configuration.

Case 3: (Top) Lead II and aortic pressures (AO). The two aortic pressures, recorded simultaneously from two catheters, are nearly superimposed. (Bottom) Lead II, aortic (AO) and right atrial (RA) pressures. A pacemaker artifact (arrow) precedes each beat. Effective pacing occurs at 83 beats per minute. Some nonconducted P waves (P) are visible.

catheters were removed. The rhythm returned to a normal sinus mechanism. The patient suffered no ill effects from the cardiac catheterization.

Case 4

A 52-year-old woman with obesity and hypertension was admitted to the hospital in pulmonary
edema. An electrocardiogram showed left bundle-branch block with normal sinus rhythm. Because of the suspicion of associated pulmonary embolism, the patient was catheterized in order to perform a selective pulmonary angiogram. Entrance of the catheter into the right ventricle was associated with the production of numerous premature ventricular beats. Even though the catheter was immediately withdrawn to the right atrium, complete atrioventricular block occurred, followed by approximately 10 seconds of ventricular asystole. This was visualized on the oscilloscope but was not recorded. By the time the electrocardiogram was recorded, the rhythm had reverted spontaneously to second degree atrioventricular block (fig. 5). A recorded period of 2.6 seconds of ventricular asystole preceded the first beat. The patient never lost consciousness. Normal sinus rhythm promptly reappeared. No further attempt was made to enter the pulmonary artery; an angiogram was performed following the injection of 75% sodium and meglumine diatrizoates (75% Hypaque-M) into the right atrium.

**Case 5**

A 56-year-old woman with chronic bronchitis, emphysema, mitral insufficiency, and congestive heart failure was admitted to the hospital for cardiac catheterization in order to evaluate the severity of her mitral valve disease. Her electrocardiogram showed right bundle-branch block (fig. 6). At the time of cardiac catheterization, a pacemaker catheter was positioned in the pulmonary artery to be withdrawn to the outflow tract of the right ventricle in the event of the abrupt development of complete atrioventricular block. A second catheter was positioned in the pulmonary artery in order to record pressures. A third catheter was passed in a retrograde direction through the aortic valve into the left ventricle. Pressures and flows were recorded without incident. While the patient was being rotated

![Graphical representation of electrocardiogram data](chart.png)

**Figure 5**

Case 4: Lead II recorded during right-sided catheterization. The catheter had already been withdrawn to the right atrium. Approximately 10 seconds of ventricular asystole were observed on the monitor before the tracing was recorded. At least 2.6 seconds of ventricular asystole were recorded at the beginning of this strip. At this time and during the first three beats, the paper speed was 5 mm per second and the amplification was attenuated. The remainder of this strip was recorded at 25 mm per second with essentially normal standardization. A high degree of atrioventricular block is present throughout most of the upper strip. A return from 2:1 to 1:1 conduction is shown on the lower strip. The P-R interval preceding beat d is 0.10 second. The P-R interval preceding beat e is 0.24 second. Beats c and d show a pattern suggestive of right bundle-branch block; there is a rapid upstroke of the R wave and a wide s wave. The remaining beats show a left bundle-branch block configuration similar to the precatheterization pattern.

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into position for a left ventricular biplane angiogram, and prior to the injection of any contrast material, second degree atrioventricular block developed. The left ventricular catheter was withdrawn. Even so, about 2 minutes later during an interval when the electrocardiogram was not recorded, complete atrioventricular block developed. The pacemaker catheter was immediately turned on, but before it could be positioned properly to obtain ventricular capture, the patient had a convulsion. External cardiac massage was administered and an intravenous infusion of isoproterenol was started. When the recording was resumed, the ventricular rate was 16 to 19 beats per minute (fig. 7). After about 1 or 2 minutes, the rhythm reverted to a sinus mechanism, and the patient recovered without sequelae.

**Discussion**

Pressure upon a main branch of the bundle of His can produce transient bundle-branch block. Rothberger and Winterberg in 1917 showed in the experimental animal that if the blunt side of a knife is stroked across the right side of the interventricular septum, transient right bundle-branch block can be induced.

In a prospective study in which electrocardiograms were recorded throughout the entire cardiac catheterization, Goldman and co-workers found that the incidence of transient right bundle-branch block induced during right ventricular catheterization in man is about 12%. To our knowledge, this is the only study in which continuous electrocardiograms were obtained. Fowler and associates reported a 7% incidence of catheter-induced right bundle-branch block of several hours' duration. Carlotti, Wood, Landtman, Michel, and Fraser and their associates reported incidences of 6, 5, 1.5, 1, and 0.5% of catheter-induced right bundle-branch block, respectively. It is emphasized that these studies did not
utilize continuous electrocardiographic recordings. Wennevold and associates in 4,413 catheterizations and Bagger and associates in 5,859, studied the incidence of various complications including arrhythmias. Each study showed a 0.3% incidence of catheter-induced right bundle-branch block. Bagger and associates considered their figures for transient arrhythmias as minimal values. This would be expected in a study emphasizing complications of catheterization and not the incidence of benign and transient electrocardiographic changes. We are aware of no reports indicating the incidence of transient left bundle-branch block during left ventricular catheterization.

Complete atrioventricular block is rarely induced by catheterization of the right side of the heart. The aggregate incidence, as gathered from many reports, is 0.1% (16 of 13,282 patients). This is probably a valid figure; most physicians reporting a series of arrhythmias occurring as a complication of cardiac catheterization would probably include such a potentially dangerous arrhythmia. Goldman and associates, utilizing continuous electrocardiographic recordings, noted two transient episodes of complete atrioventricular block with nodal pacemakers producing a ventricular response of 71 beats per minute in one case and 120 beats per minute in the other. He reported no episodes of ventricular asystole or even of idioventricular rhythm.

Clearly then, catheter-induced, transient right bundle-branch block is common and catheter-induced complete atrioventricular block is rare during right ventricular catheterization. If catheter-induced complete atrioventricular block occurred during right ventricular catheterization in a patient with pre-existent left bundle-branch block, it would be much more likely that the complete atrioventricular block was due to bilateral bundle-branch block resulting from impingement of the catheter upon the right bundle branch than from direct impingement of the catheter.
upon the atrioventricular node or bundle of His.

Four patients in this study had preexistent left bundle-branch block and developed complete atrioventricular block when the tip of the catheter was in the right ventricle. One patient had preexistent right bundle-branch block and developed second degree atrioventricular block progressing to complete atrioventricular block subsequent to catheterization of the left ventricle. In three patients (cases 1, 3, and 5) the hazard of complete atrioventricular block had been predicted and a pacemaker catheter was inserted as a precautionary measure. None of the patients developed atrioventricular block as a result of injection of contrast material.

The electrocardiogram of the fourth patient (case 4) seems to satisfy Rosenbaum and Lepeschkin's criteria for the electrocardiographic diagnosis of bilateral bundle-branch block since it shows intermittently the pattern of right bundle-branch block and left bundle-branch block accompanied by changes of the P-R interval in a patient who has had complete heart block. The P-R interval preceding beat d is shorter than the P-R interval preceding beat e. Ventricular complexes e and d (fig. 5) seem to show the pattern of left bundle-branch block. However, during varying high grades of atrioventricular block, it is difficult to interpret QRS configuration in two or three beats because of the likelihood of beats of ventricular origin.

These five patients illustrate a hazard inherent in catheterization of the ventricle opposite the one that is already the site of bundle-branch block. Because of the danger of complete atrioventricular block (bilateral bundle-branch block) in such patients, placement of a standby pacemaker catheter in the outflow tract of the right ventricle as a precautionary measure is recommended as the initial step in diagnostic catheterization. In patients 1 and 3, the value of this precaution was clearly shown. Even with a pacemaker catheter in place, as in patient 5, ventricular capture may not occur immediately. Therefore, isoproterenol and an external pacemaker should also be at hand. In some cases, prompt removal of the catheter may be sufficient to abolish the disturbance.

Summary

The hazard of complete atrioventricular block during cardiac catheterization of patients with pre-existent bundle-branch block is described. A catheter-induced bundle-branch block, during catheterization of the ventricle opposite that which was already the site of bundle-branch block, would produce complete heart block in the form of bilateral bundle-branch block. Five patients in whom this complication occurred are described.

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References


Inscribed in Padua, 1602

We have listened with immense pleasure of mind to the noble and erudite William Harvey of Folkestone, an Englishman, Councillor of the famous English nation, son of the illustrious Thomas Harvey, learnedly, eloquently, and in a praiseworthy and excellent style discussing the themes in Arts and Medicine, propounded to him by the distinguished and most excellent Doctors of Arts and Medicine, ... moreover subtly replying to and lucidly resolving the arguments, doubts, and cases brought before him.

And in this examination so wonderfully and most excellently did he conduct himself, and so much force of intellect, memory and learning did he display, that very far surpassing the expectations which he had raised about himself in the minds of all, he was, by the aforesaid distinguished Doctors unanimously and with united voice, and by the votes of all (no single one of them differing in the least, or dissenting, or even hesitating) adjudged competent and perfectly qualified in Arts and Medicine.—Browne, W.: William Harvey’s Diploma from Padua. JAMA 197: 127, 1966.
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