Among the most memorable classic bedside teaching discussions in electrophysiology is the consideration of a narrow complex beat in a patient with fixed bundle branch block. The discussion would frequently extend to questioning how narrow complex tachycardias can arise from the ventricles. As in many aspects of medicine, exceptional cases serve to further understanding of fundamental concepts germane to frequently encountered arrhythmias. In this installment of the Teaching Rounds in Cardiac Electrophysiology, Kusa et al continue this educational tradition by guiding us through an intriguing case of ventricular tachycardia (VT) with multiple morphologies that was successfully ablated at a single location. They teach us about the need to think imaginatively, yet logically, when considering the components of the infra-Hisian conduction system that may participate in tachycardia. After combining insight and electrogram analysis and excluding some candidate possibilities, they hypothesize one possible explanation for their findings and success with ablation of the right bundle branch.

_About the Author_ Samuel J. Asirvatham, MD

**Editor’s Perspective**

**Bundles Branch Reentry**

Samuel J. Asirvatham, MD; William G. Stevenson, MD

A among the most memorable classic bedside teaching discussions in electrophysiology is the consideration of a narrow complex beat in a patient with fixed bundle branch block. The discussion would frequently extend to questioning how narrow complex tachycardias can arise from the ventricles. As in many aspects of medicine, exceptional cases serve to further understanding of fundamental concepts germane to frequently encountered arrhythmias. In this installment of the Teaching Rounds in Cardiac Electrophysiology, Kusa et al continue this educational tradition by guiding us through an intriguing case of ventricular tachycardia (VT) with multiple morphologies that was successfully ablated at a single location. They teach us about the need to think imaginatively, yet logically, when considering the components of the infra-Hisian conduction system that may participate in tachycardia. After combining insight and electrogram analysis and excluding some candidate possibilities, they hypothesize one possible explanation for their findings and success with ablation of the right bundle branch.

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**H-V Interval Is a Pseudo-Interval in Bundle Branch Reentry**

A commonly asked question is whether the H-V interval measured during bundle branch reentrant VT is shorter or longer than the H-V interval measured in sinus rhythm. Figure A illustrates the important distinction between true and pseudo-intervals in electrophysiology. The H-V interval in sinus rhythm is a true conduction interval with conduction passing through the region of the recording electrodes near the His bundle and then exiting to the ventricles through the distal bundle branches such that it truly reflects the conduction time from His depolarization to ventricular activation. However, during typical bundle branch reentry, conduction proceeds from a common branch point (marked as A) to the His and concurrently down the right bundle toward the ventricular exit. Thus, there is no actual linear conduction from the His to the V but rather from a common branch point to both of these structures. This phenomenon is referred to as a pseudo-interval, and variations are seen during atrioventricular node reentry, the H-V interval, during pre-excited atrial tachycardia, and the V-A interval during junctional tachycardia. Put another way, the His is a bystander to the bundle branch reentry circuit. Thus, the H-V interval during bundle branch reentry may be less than, equal to, or greater than the H-V interval measured during sinus rhythm. In contrast, however, the right bundle to ventricular electrogram (RB-V interval) is a true conduction interval during typical bundle branch reentry and generally will be the same or greater than the same interval in sinus rhythm. Why is it then that the H-V interval is often described as usually being equal to or more than the H-V interval in sinus rhythm? First, often the measured His is in fact the right bundle, and second, the wave front curvature and anisotropy of the turnaround from the left bundle to the right bundle and possibly decremental conduction in the right bundle itself, which may be diseased, create delay, resulting in a longer H-V interval during tachycardia than sinus rhythm.

In their report, Kusa et al uniquely hypothesize possible longitudinal dissociation of the right bundle. To explain the known facts of this case, in this instance, it is possible for the H-V interval to be a true conduction interval during bundle branch reentry (Figure C), because as proposed, one portion of the right bundle arises high from the His bundle, and thus the recorded His bundle that region may be the portion of the conduction system used in the circuit.

**Narrow Complex Ventricular Tachycardia**

Simultaneous conduction through the various branches of the infra-Hisian conduction system (right bundle and fascicles of the left bundle) builds a narrow QRS interval with supraventricular arrhythmia and normal infra-Hisian conduction. Occasionally, VT arising from the midseptal myocardium is narrow because of entrance into conduction systems of both ventricles at about the same time. Fascicular VT may have a relatively normal QRS duration but usually with a typical bundle branch block pattern (left fascicular with right bundle branch block pattern). Thus, in general, when a narrow complex tachycardia with no consistent V-A relationship is induced, supraventricular tachycardia that may present with A-V dissociation needs to be carefully excluded. Atrioventricular node reentry with upper common pathway block, junctional tachycardia, and proximal His bundle tachycardia would all be expected to have an infra-Hisian sequence that suggests supraventricular origin. Thus, the proximal His bundle is activated before the mid, which in turn is activated before the distal His bundle. However, reversed intra-Hisian activation should prompt a careful search for rare VTs that may be narrow complex. Concealed nodofascicular pathways with a reentrant circuit that involves the nodofascicular tract retrograde and the normal conduction system antegrade (right bundle or left bundle with

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the contralateral bundle serving a bystander role) may give rise to a relatively narrow complex tachycardia with atrioventricular dissociation. Careful attempts to reset the tachycardia with capture of the conduction system, right ventricle, and left ventricular conduction system may be required to completely exclude this possibility. The intra-Hisian sequence would resemble supraventricular tachycardia, and the H-V interval represents a true conduction interval with this rare arrhythmia.

### Changing Morphology VT

In severely diseased hearts with multiple myocardial scars and fibrosis, one VT may induce and transition to another VT or induce and maintain a second loop of reentry or change morphology from varying decrement in components of the circuit, as well as bystander elements. In a patient with a normal heart, as described in their report, considerations would include fascicular origin with multiple exits and possibly supravalvular origin again with varying transannular exits.

Can bundle branch reentry present with varying morphologies, including narrow complex tachycardia? At first glance, this seems unlikely. Being a single circuit (down the right bundle and up the left bundle), 1 morphology would be expected with a QRS at least as wide as one would expect from bundle branch block. Changing morphology, however, is not uncommon because of the varying exits of the distal right bundle and whether conduction through bystander fascicles of the left bundle occurs. Kusa et al. hypothesize an ingenious construct involving longitudinal dissociation of the right bundle to explain not only varying morphology but also the potential for narrow complex tachycardia that can be ablated from the proximal right bundle. Although reentry in the left infra-Hisian conduction system is recognized as a cause of a relatively normal QRS duration because conduction down one fascicle and up the second could allows wave fronts to propagate antegrade through the right bundle and the remaining left-sided fascicles nearly simultaneously, narrowing the QRS duration, this potential mechanism has not been appreciated in the right ventricle, given our usual understanding of the right bundle branch as being a single bundle with no major fascicular branches. Kusa et al. hypothesize longitudinal dissociation in the right bundle, producing a similar possibility in the right ventricle wherein right bundle ablation is curative.

Alternative possibilities include focal origin tachycardia in the proximal right bundle (Figure B). A relatively narrow QRS would be anticipated with conduction down both bundles, but with antegrade block in the right bundle (producing a right bundle branch block tachycardia) or antegrade block down the left bundle (producing a left bundle branch block tachycardia), varying morphology can also be possible. The changes in cycle length that corresponded with the change in morphology would, however, make focal origin with changing exits less likely.

### Variations in the Infra-Hisian Conduction System

The embryological development of the infra-Hisian conduction system is complex, and as a result, multiple variations in the construct of the bundle branches, fascicle, and distal His-Purkinje system are possible. From the classical descriptions of Tawara, we know that the classical description of 2 left fascicles and 1 single right bundle branch has many variations. Endocavitary structures that house distinct branches of the bundles further complicate the potential for both exits and multiple reentry circuits. Figure D shows a construct where the longitudinally dissociated fascicles are separated spatially as well, in essence a mirror image of the usual left bundle bifurcation. In such a situation, varying reentrant tachycardias, including classic bundle branch reentry, reverse bundle branch reentry, or a right interfascicular tachycardia with antegrade conduction down the primary right bundle and left bundle concurrently producing a narrow QRS tachycardia, are possible. Unfortunately, decades after Tawara’s description, further definition of the exact variations of the infra-Hisian conduction system in human hearts.

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**Figure. A.** In bundle branch reentry with antegrade conduction down the right bundle branch and retrograde via the left bundle branch (typical bundle branch reentry), the H-V interval is a pseudo-interval. Propagation proceeds simultaneously from a branch point A at the junction of the bundle branches and His bundle. Depending on the relative activation time from this point to the His or to the ventricular exit via the distal right bundle branch, the H-V interval may theoretically be zero, positive, or negative and is not necessarily related to the H-V interval measured during sinus rhythm, which is a true conduction interval from the His to the exit from the bundle branch. B. Diagrammatic description of how a focal tachycardia in the proximal right bundle branch can present as a right bundle, left bundle, or normal QRS morphology with antegrade block down the right bundle. Conduction proceeds down the left bundle branch, and the tachycardia will have a right bundle branch block morphology. With antegrade conduction but block down the left bundle, a left bundle branch block tachycardia would result. With conduction down both bundles, narrow QRS tachycardia could result. C. A unique depiction suggested by Kusa et al. Here, the proximal portion of the right bundle arises high on the His such that the His is part of the circuit of this type of bundle branch reentry, and thus the H-V interval would be expected to be a true interval as seems to be the case in the present report. D. An alternative explanation to longitudinal dissociation would be simply having 2 different fascicles or branches of the right bundle branch. Here, tachycardia involving the right-sided fascicles could theoretically produce a narrow QRS tachycardia with near-simultaneous antegrade conduction down one of the right bundle branches and the left bundle system.
is limited. In one sense, longitudinal right bundle dissociation, right interfascicular tachycardia, and concealed nodo-fascicular tachycardia all represent subtle variations on a theme with longitudinal dissociation. A single right bundle that is somehow internally separated or insulated is present. With multiple fascicles, the single right bundle branches into 2 fascicles, and with a nodofascicular tract, the accessory bundle arises even higher from the distal compact atrioventricular node.

Perhaps the main teaching point from the instructive description of Kusa et al 1 is that one needs to logically and systematically exclude known possibilities, yet possess the imagination and basic understanding of electrophysiology to create a model that fits the known facts and, in this case, allows for an elegant, single-site ablation solution.

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