Editorial

The Knot That Binds Mitral Valve Prolapse and Sudden Cardiac Death

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Solving the puzzle that ties mitral valve prolapse (MVP) to sudden cardiac death necessarily means overcoming 2 central challenges: establishing a mechanistic association between a very common disorder (MVP) and a rare outcome (sudden cardiac death) and discerning the cause and effect of an increasing array of associated structural, electrocardiographic, and now pathological findings.

In this issue of Circulation, Basso et al1 demonstrate an important and possibly critical piece of this association: magnetic resonance imaging (MRI) evidence of an underlying arrhythmogenic substrate. Studying 2 distinct and complementary populations (young patients who died suddenly with MVP as the sole structural cardiac abnormality and a group of patients with MVP and complex ventricular arrhythmia) and suitable control groups, they report pathological and MRI findings that strongly suggest pathology in the region of the mitral valve apparatus that may explain a hitherto missing link between MVP and sudden cardiac death.

The Second Hit

A tenable assumption, given the widespread prevalence of MVP, is that, when sudden death occurs, the typically innocent valvular abnormality is a bystander with no pathogenic significance. However, researchers in this field have cyclically readdressed a putative link with a series of anecdotes and retrospective analyses. This would appear as futile an endeavor as trying to link gray hair to the risk of developing atypical atrial flutter! Except for the fact that the population of interest, as is the one studied by Basso et al,1 is young and otherwise healthy and should not be dying suddenly. Given that MVP is so common, it seems likely that patients who develop malignant arrhythmia have a second, unrelated proarrhythmic factor that (although by itself may be relatively benign) creates a potentially fatal admixture of trigger and substrate. In a recent report, benign outflow tract ectopy was associated with malignant MVP syndrome.2 Both entities (outflow tract ectopy and MVP) are common and independently benign but, with the potential for relative entrance block and nonsuppressibility as a result of heterogeneous tissue at the semilunar valve and papillary muscle region, may have been the mutual second hit needed for malignant arrhythmia generation.

Chickens and Eggs

Several other potential pathogenic risk factors with MVP have been explored in trying to explain why only a minority of patients have major arrhythmia. Bileaflet MVP was found in 70% of affected patients in the present study and was nearly universal in a prior report.3 Complex ectopy, including nonsustained arrhythmia and now the fibrosis/scar reported by Basso et al,1 may well be the differentiating factors for malignant outcomes. However, defining these associations as causative is problematic. For example, in fetal development, dysplastic and progressive changes in the perimitral apparatus may be the forerunner for myxomatous prolapsing leaflets and not vice versa.3 Similarly, complex ectopy may exaggerate the amount of regurgitation or prolapse detected with echocardiography done during arrhythmia.

Pushes and Pulls

The structural changes noted around the mitral valve apparatus could be, as pointed out by Basso et al,1 a result of increased tension on the chordae and transmission of this force to the mitral support apparatus. However, perhaps equally important are the contact lesions that result from the redundant valve flutter! Except for the fact that the population of interest, as is the one studied by Basso et al,1 is young and otherwise healthy and should not be dying suddenly. Given that MVP is so common, it seems likely that patients who develop malignant arrhythmia have a second, unrelated proarrhythmic factor that (although by itself may be relatively benign) creates a potentially fatal admixture of trigger and substrate. In a recent report, benign outflow tract ectopy was associated with malignant MVP syndrome.2 Both entities (outflow tract ectopy and MVP) are common and independently benign but, with the potential for relative entrance block and nonsuppressibility as a result of heterogeneous tissue at the semilunar valve and papillary muscle region, may have been the mutual second hit needed for malignant arrhythmia generation.

Regionality

A unique finding in the present study is that the second hit discussed above (scarring and possibly mechanical triggers) may well arise from the first hit (MVP) itself. The regionality of the structural changes at MRI and autopsy is striking. On pathology, 88% of sudden death victims have fibrosis in the papillary muscle or inferobasal portions of the left ventricle, and on MRI, 93% of patients with complex arrhythmia had scarring in this region. We do not know the clinical follow-up of these potentially abnormal controls, but presumably, the structural abnormalities may precede clinically manifest severe arrhythmias.
**Electrocardiographic Abnormalities**

Abnormal T waves were clearly evident and were present in 10 of 12 of the patients who had an ECG available for analysis. Endocardial and superficial midmyocardial changes on the papillary muscles and neighboring left ventricle could conceivably create an abnormal repolarization gradient and cause inverted T waves. If true, such a finding is relevant for the type of arrhythmias that cause sudden death, that is, polymorphic ventricular tachycardia (VT) rather than monomorphic and inducible reentrant VT.

The patients studied by Basso et al had what appears to be exclusively right bundle-branch block morphology PVCs and VT. However, in the figures they supply, it is clear that the arrhythmia morphology changes, suggesting either multiple sources or multiple exits from a single source. The morphology of the PVCs in their figures is also conspicuous for a rapid initial portion of the QRS, implying fascicular origin. Fascicular PVCs are now well established as particularly important in triggering ventricular fibrillation. Also noteworthy in their examples are varying coupling intervals of the PVCs, a finding that in some circumstances suggests reentrant PVCs, which would also explain why, when they induced VT in the electrophysiology laboratory, the VT morphology resembled the discrete and single PVCs. Often in ischemic VT, automatic PVCs that trigger sustained monomorphic VT will have a completely different morphology, and this finding is used by clinicians to distinguish an automatic PVC from monomorphic VT. However, in the figures they supply, it is clear that the PVCs in their figures is also conspicuous for a rapid initial portion of the QRS, implying fascicular origin. Fascicular PVCs are now well established as particularly important in triggering ventricular fibrillation. Also noteworthy in their examples are varying coupling intervals of the PVCs, a finding that in some circumstances suggests reentrant PVCs, which would also explain why, when they induced VT in the electrophysiology laboratory, the VT morphology resembled the discrete and single PVCs. Often in ischemic VT, automatic PVCs that trigger sustained monomorphic VT will have a completely different morphology, and this finding is used by clinicians to distinguish an automatic mechanism of the tachycardia itself when there is no difference between single PVCs and the VT itself. This discrepancy may be explained in the Basso et al study by the PVCs themselves being single echo beats of reentry. This distinction may be important for ablationists who would need to induce the VT to map and ablate with standard techniques, including entrainment, because simply finding the earliest site of activation of the PVCs themselves would not work when the mechanism is reentrant.

**The Crux of Maneuver**

An increasing number of ventricular arrhythmia substrates have been recognized in proximity to the central fibrous skeleton of the heart. The atrial mitral continuity and atrioventricular conduction system are important examples. Similarly, supraventricular and atrial arrhythmias have been established. Perhaps the heterogeneity of the tissue in these regions and its unique innervation is a primary abnormality and excessive motion and stretch with resulting fibrosis from MVP is the second hit.7

**The Perfect Storm**

Just as MVP itself is common, the multiple imputed second, third, or fourth hits that may be a part of malignant MVP syndrome are frequently encountered. Perhaps for the unfortunate individuals who die suddenly of this seemingly benign structural problem, a perfect storm of stretch- and contact-induced fibrotic changes, mechanically triggered PVCs, a just-right autonomic milieu, bileaflet and excessively redundant mitral valve tissue, and being young and female creates a lurking danger, greater than the sum of its parts.

Basso et al have clearly demonstrated that MVP is common among those who die suddenly (13% of young female patients in their autopsy series) and that findings of fibrosis are widespread. This study is a veritable catechization for cardiac epidemiologists and electrophysiologists to find the best ways to effectively identify patients at risk and to prevent their untimely death from malignant arrhythmia. To answer these summons, we need to acknowledge that we cannot unravel this gordian knot with retrospective studies but rather we need to cut it (surgically treat less severe forms of MVP) or ablate it (the abnormal fibrotic and heterogeneous substrate) and determine in large prospective studies whether we can have a positive impact on the natural history of malignant MVP. Until such time, it may be prudent in patients with MVP and perimitr annular and papillary muscle–related complex arrhythmias to consider MRI and possibly electrophysiology study for risk stratification. Indeed, the findings of Basso et al now make it difficult to universally reassure patients with MVP and nonsustained ventricular arrhythmia without further scrutiny.

**Disclosures**

None.

**References**


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