CHAPTER 41 P2 SHAPE AND TERTIARY CHORDS

This chapter tests the hypothesis that the central belly of the P2 posterior leaflet deforms as an unsupported elastic membrane subjected to left ventricular pressure in the closed valve. This hypothesis produces at least three marker-testable predictions: first, that radial leaflet curvature is concave to the left ventricle throughout ejection; second, that this curvature changes very little during the nearly constant systolic pressure during ejection; and third, that this curvature flattens as LVP falls precipitously during isovolumic relaxation.

Data from 14 hearts in the DOS and SOD series, provided in Appendix S, were used to test these predictions. In each frame, a vector (V1822) was constructed from the lateral annular marker (#18) to the annular saddlehorn marker (#22), another from the lateral annular marker (#18) to the P2 belly marker (V1828 in SOD; #V1836 in DOS), and a third from the lateral annular marker (#18) to the P2 edge marker (V1827 in SOD; V1835 in DOS). P2 edge angle (Φedge, plotted in blue in Figures 41.2A, B, and C) was defined as the angle between V1822 and V1827 in SOD or between V1822 and V1835 in DOS. P2 belly angle (Φbelly, plotted in red in Figures 41.2A, B, and C) was defined as the angle between V1822 and V1828 in SOD or between V1822 and V1836 in DOS. P2 radial curvature was concave to the LV if Φbelly<Φedge, convex to the LV if Φbelly>Φedge, and flat if Φbelly=Φedge.

The findings in Figures 41.2A, B, and C do not consistently support any of these three predictions. Although P2 radial curvature during ejection was concave to the LV in 7 hearts (S1, S2, S7, S9, D1, D2, and D3), it was convex to the LV in 5 hearts (S3, S5, S6, S10, and D5), and flat in 2 hearts (S4 and D4). P2 radial curvature drifted lower throughout ejection in 10 hearts (S2, S3, S4, S5, S6, S7, S9, S10, D2, and D3), stayed roughly constant in 3 hearts (S1, D1, and D4), and increased in one heart (D5). Of the 14 hearts, only two, S1 and S9, exhibited the hypothesized concave radial curvature to the LV during ejection and flattened (as evidenced by a reduction in Φedge-Φbelly) as LVP fell during IVR. Thus it seems highly unlikely that the central belly of the P2 posterior leaflet is an unsupported elastic membrane in the closed valve. But if the posterior leaflet belly is not a straightforward collagen-like (hyper)elastic membrane, then what?

We suggest that this posterior leaflet behavior is more consistent with that expected if the leaflet belly had chordal support. We further suggest that this supporting role could be well served by the tertiary chordae described by Lam, *et al*.[1] from the LV endocardial trabeculae to the posterior leaflet. If the tertiary chordae support the posterior leaflet bellies, this would offer an explanation as to why Φbelly in most of the hearts tended to stay relatively constant or drifted somewhat downward as ejection proceeds. This could then be a function of LV long axis shortening, plotted as D1810 in Figures 41.2A, B, and C that could release the posterior leaflet belly to displace closer to the annular plane during ejection. We do not think that the support chordae likely originate from the papillary muscle tips because the leaflet belly positions are established during IVC and Askov, *et al*.[2] have shown that total papillary force is very small at this time.

[1] Lam JH, Ranganathan N, Wigle ED, Silver MD. Morphology of the human mitral valve. I. Chordae tendineae: a new classification. *Circulation.* 1970;41(3):449-458.

[2] Askov JB, Honge JL, Jensen MO, Nygaard H, Hasenkam JM, Nielsen SL. Significance of force transfer in mitral valve-left ventricular interaction: in vivo assessment. *J Thorac Cardiovasc Surg.* 2013;145(6):1635-1641, 1641 e1631.

In Chapter 19 we drew a schematic (Figure 19.1), consistent with the data analyzed to that point, to describe the relationship between the mitral annulus, LA, LV, and edge and hinge chordae originating from the papillary muscles, as well as our conception as to where the tertiary chordae might be acting. In Figure 41.1 we upgrade this schematic to now include the possibility of tertiary chordae not only acting at the mitral annular hinge regions of the posterior leaflets, but acting to support the posterior leaflet belly, as well.

With this concept, mitral valve closing would involve swinging the posterior leaflet towards closure, having the posterior leaflet belly stopped before complete closure by tertiary chordal tethering, then further rotation of the remaining posterior leaflet edge would complete coaptation with the anterior leaflet edge.

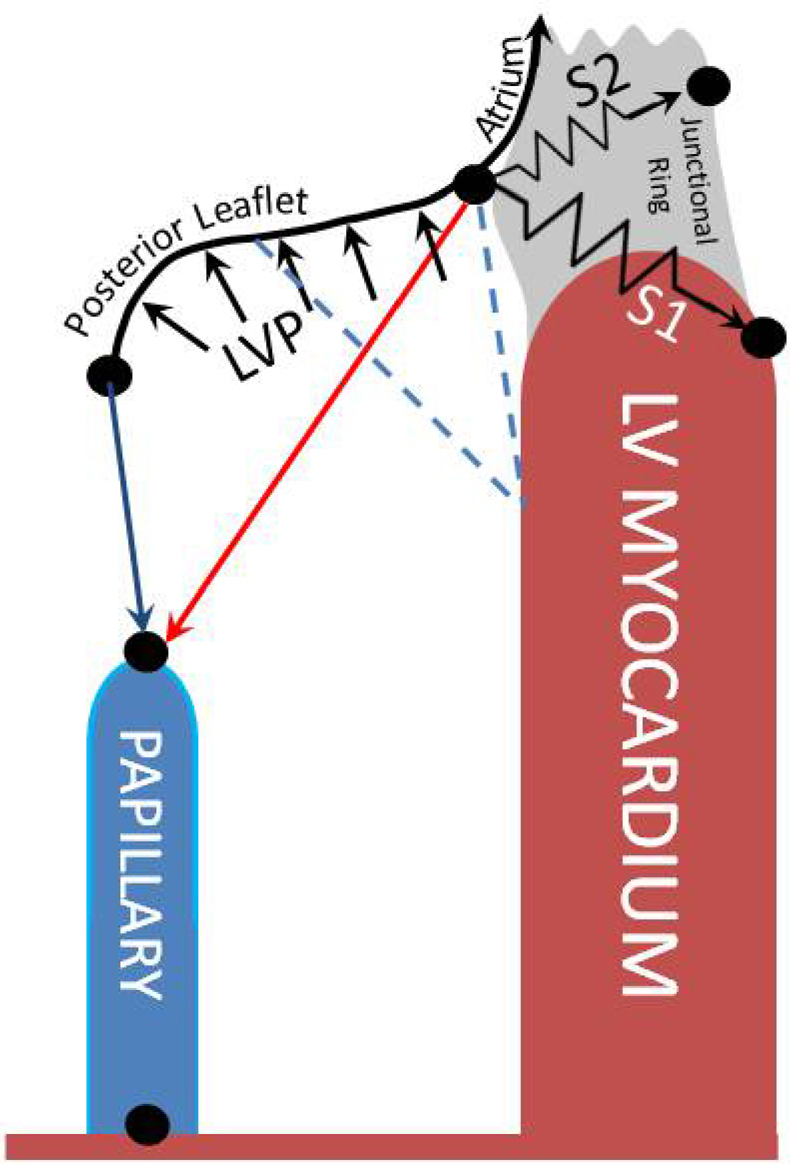

Figure 41.1 Schematic illlustrating the proposed relationship between LV myocardium, papillary muscle, edge chord (solid blue), hinge chord (red) tertiary chord (rightmost dashed blue line), left atrium, and posterior leaflet. Modified from Figure 19.1 with the addition of tertiary chord (leftmost dashed blue line) to the posterior leaflet belly. LVP=left ventricular pressure.

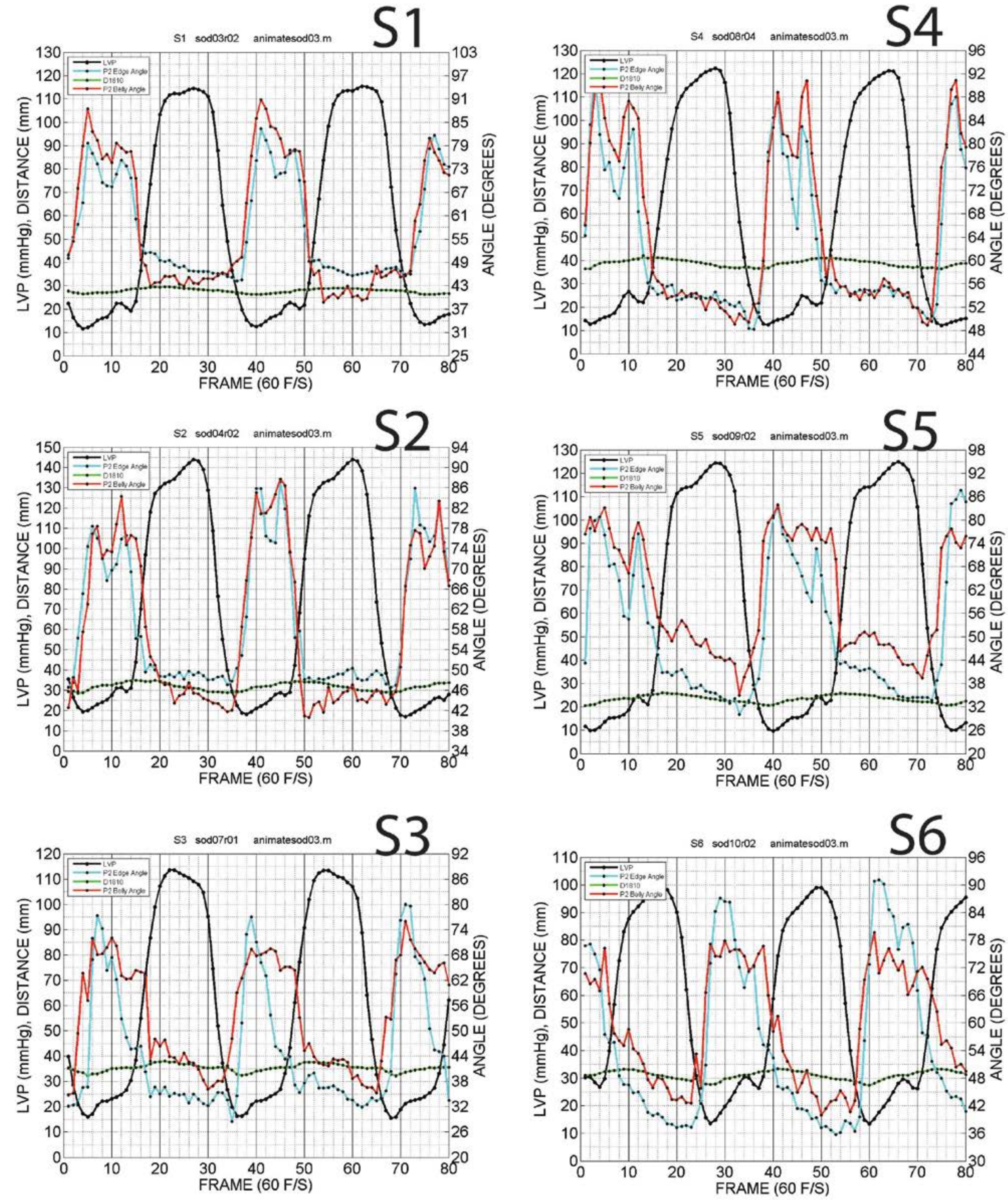

Figure 41.2A P2 Φbelly (red), Φedge (blue), left ventricular pressure (LVP, mm, black), LV lateral long-axis length from Marker #18 to Marker #10 (D1810, green) for hearts S1-S6. P2 is convex to the LV during ejection if Φbelly>Φedge (red curve above blue curve), concave during ejection if Φbelly<Φedge (blue curve above red curve), and flat if Φbelly=Φedge (red and blue curves roughly superimposed) during ejection.

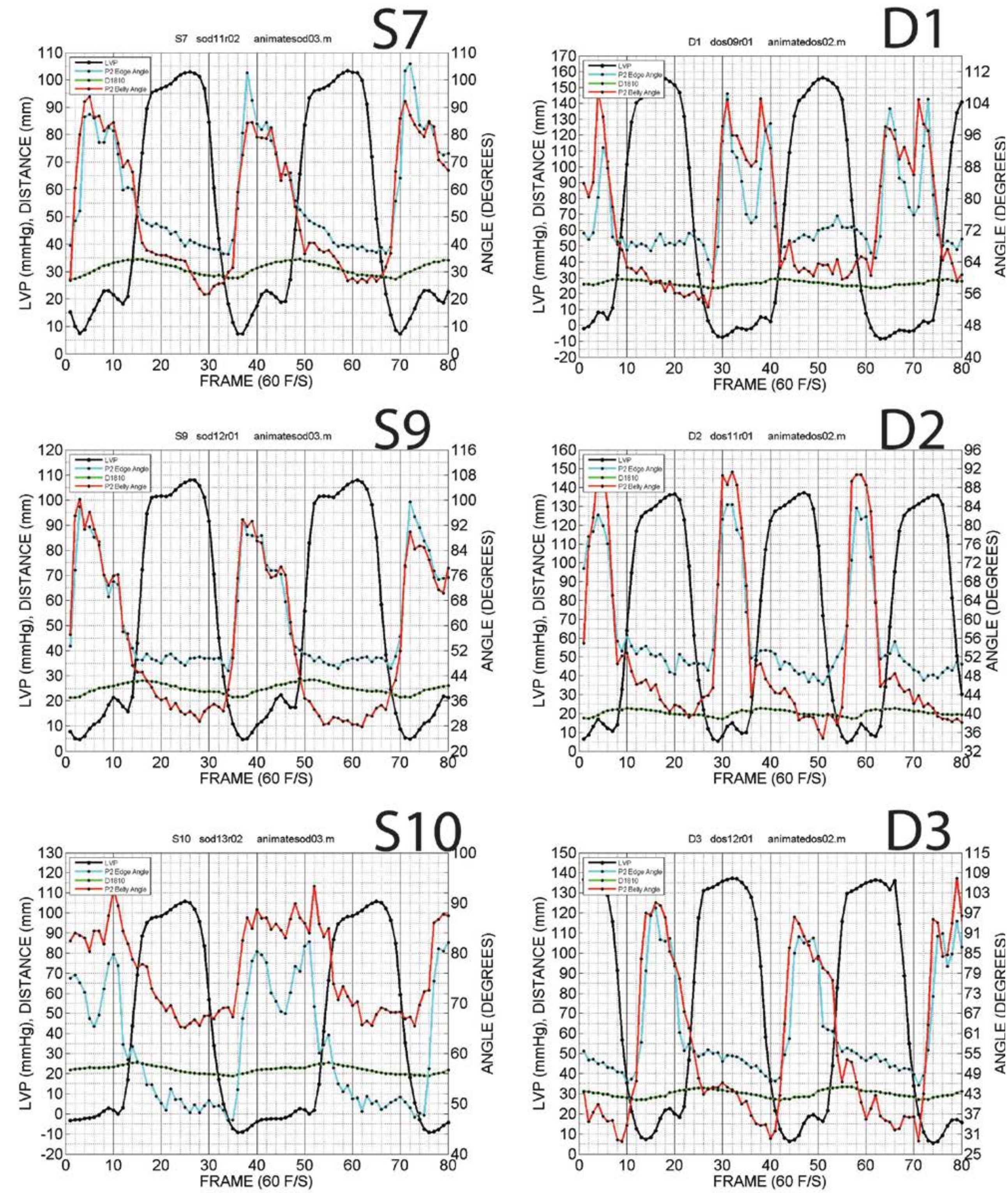

Figure 41.2B P2 Φbelly (red), Φedge (blue), left ventricular pressure (LVP, mm, black), LV lateral long-axis length from Marker #18 to Marker #10 (D1810, green) for hearts S7, S9, S10, and D1-D3. P2 is convex to the LV during ejection if Φbelly>Φedge (red curve above blue curve), concave during ejection if Φbelly<Φedge (blue curve above red curve), and flat if Φbelly=Φedge (red and blue curves roughly superimposed) during ejection.

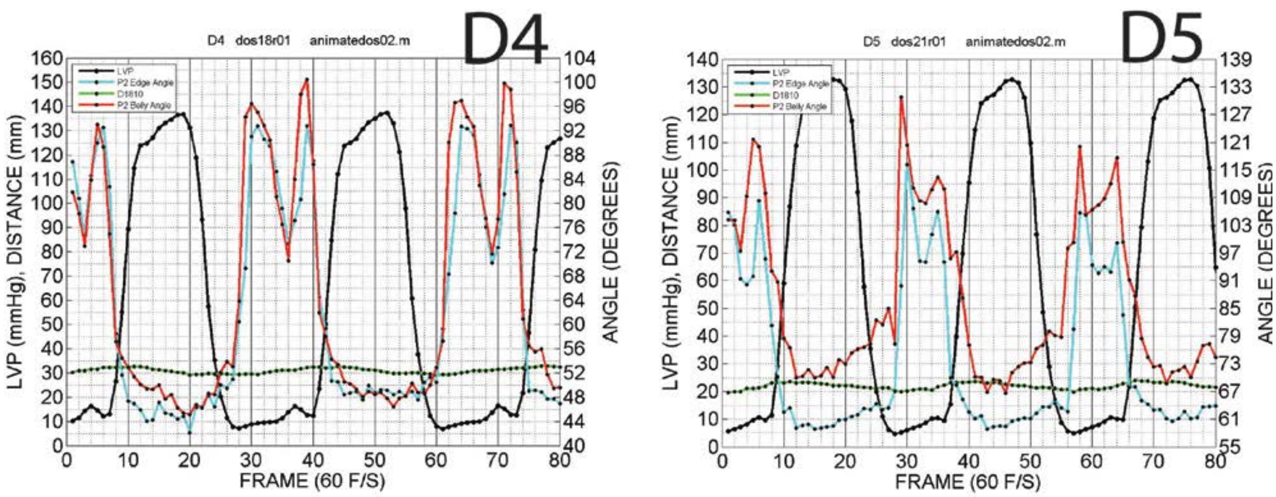

Figure 41.2C P2 Φbelly (red), Φedge (blue), left ventricular pressure (LVP, mm, black), LV lateral long-axis length from Marker #18 to Marker #10 (D1810, green) for hearts D4 and D5. P2 is convex to the LV during ejection if Φbelly>Φedge (red curve above blue curve), concave during ejection if Φbelly<Φedge (blue curve above red curve), and flat if Φbelly=Φedge (red and blue curves roughly superimposed) during ejection.