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Anomalous insertion of the papillary muscle causing left ventricular outflow obstruction: visualization by real-time three-dimensional echocardiography

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Anomalous insertion of the papillary muscle (PM)/chordae tendineae is a rare but important cause of dynamic left ventricular outflow tract (LVOT) obstruction in patients with hypertrophic cardiomyopathy or cardiac amyloidosis. These anomalies are often challenging to diagnose with 2-D Echo, yet accurate diagnosis is critical in determining whether to proceed with an extended septal myectomy instead of a standard septal myectomy for relief. We report two cases of anomalous insertion of the PM causing LVOT obstruction with diagnosis facilitated by real-time 3-D echocardiograms.

Introduction

Anomalies of the papillary muscle (PM) have been reported in up to 13% of necropsy specimens of obstructive hypertrophic cardiomyopathy (HOCM).[1] The reported incidence of congenital anomalous PM is 1% in otherwise normal patients.[1] Anomalous insertion of the PM/chordae tendineae can result in left ventricular outflow tract (LVOT) obstruction. These anomalies are often challenging to diagnose with 2-D Echo. We report two cases of anomalous insertions of PM/chordae tendineae causing LVOT obstruction with diagnosis facilitated by real-time 3-D echocardiograms (RT3DE).

Case 1

A 43-year-old man presented intermittent dizzy spells over the last few years, particularly when climbing stairs or standing. He had a family history of coronary artery disease. A subsequent echocardiogram demonstrated increased septal thickness, and his cardiac catheterization found normal coronary arteries and normal left ventricular (LV) function with a maximum LVOT gradient of 25 mmHg. He was referred to our institution for further evaluation of possible HOCM. Physical examination revealed an S4 with a grade II/VI systolic ejection murmur, decreasing with squatting and increasing during the Valsalva manoeuvre. A transthoracic 2-D echo revealed asymmetric interventricular septal hypertrophy of LV walls (septum 22 mm and posterior wall 14 mm at end-diastole). At rest, there was no significant LVOT obstruction; during amyl nitrite provocation, there was significant LVOT obstruction with systolic anterior motion (SAM) of the anterior mitral valve leaflet (AMVL) (*Figures 1* and 2) with increasing mild mitral regurgitation (MR). RT3DE clarified the spatial relationship of an abnormal PM, which connected directly to the base of the AMVL (A2/A3) (*Figure 3*), tethering the AMVL, and producing dynamic LVOT obstruction. We recommended family screening, and prescribed beta blockers and a statin while discontinuing Verapamil, and planned a follow-up in order to reassess his haemodynamics and pharmacotherapeutic regimen.

Case 2

A 66-year-old man presented shortness of breath on minimal exertion for several months. Physical examination showed a grade III/VI systolic ejection murmur along the left sternal edge. A transthoracic 2-D echo revealed increased concentric LV wall thickness with an ejection fraction of 40%, severe bi-atrial enlargement with elevated LV filling pressure (E/e′ 17), and thickened right ventricular walls (10 mm).There was a significant pressure gradient at the sub-aortic level (*Figure 4*), with an anomalous PM. No prominent valvular SAM or increase in the amount of MR was noted

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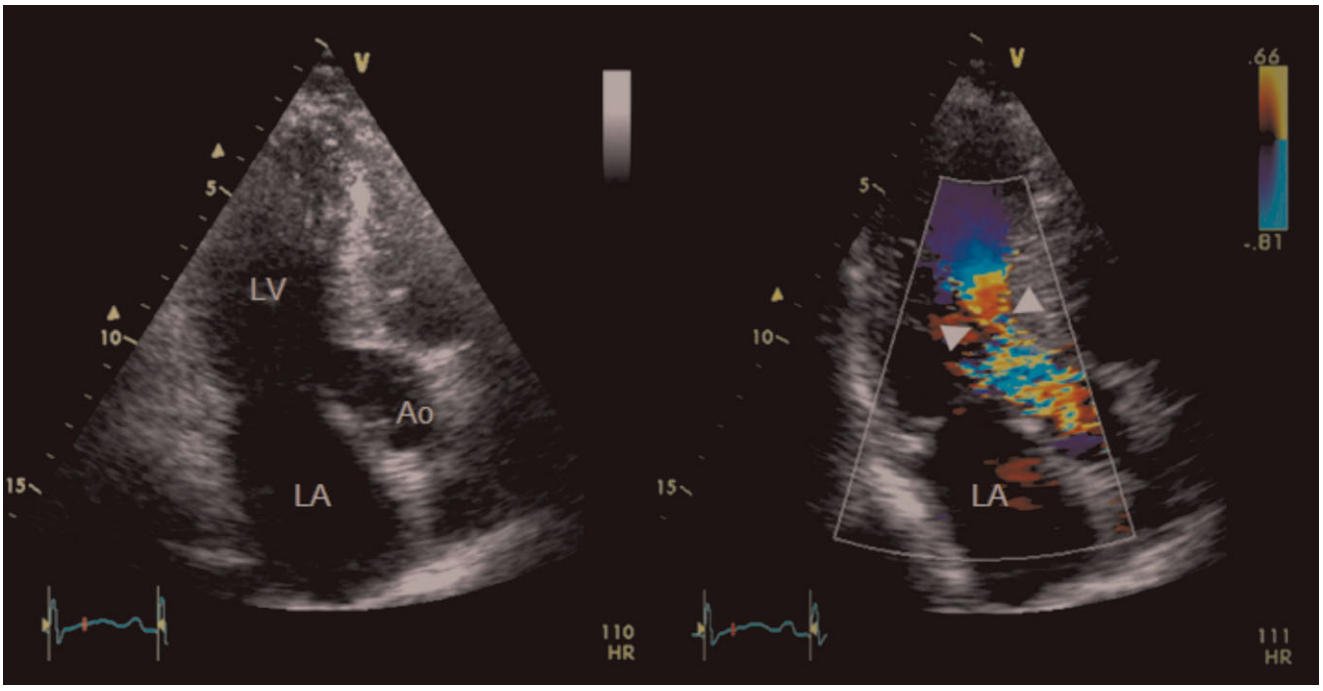

Figure 1 2D and colour Doppler transthoracic echocardiogram of the apical long-axis view reveals flow acceleration with aliasing at the level of dynamic obstruction (arrowheads) during the amyl nitrite inhalation.

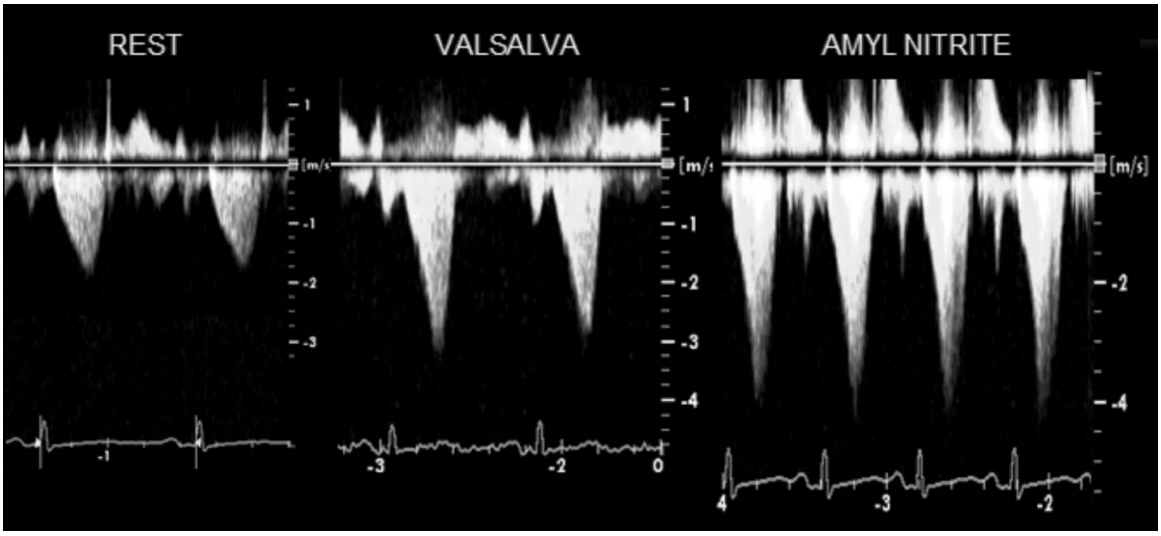

Figure 2 Continuous wave Doppler tracing of the LVOT shows the peak and mean pressure gradient at rest (12/6 mm Hg), during the Valsalva manoeuvre (40/15 mm Hg), and with amyl nitrite (64/19 mm Hg). During the amyl nitrite inhalation, heart rate increased from 69 to 114 bpm with a high velocity late-peaking pattern.

during the amyl nitrite provocation (*Figure 5*). He exercised on the supine bike for 5 min to a maximum of 50 W with a peak LVOT gradient of 31 mm Hg. RT3DE revealed a severely thickened anomalous PM directly inserted into the base of the AMVL (A2/A3) resulting in LVOT narrowing (*Figure 6* and Supplementary data online, *Movie I*). His right ventricular endomyocardial biopsy showed prominent interstitial and nodular amorphous eosinophilic deposits consistent with amyloid (confirmed by a positive sulfated alcian blue stain) (*Figure 7*). His haemodynamics is consistent with significant right heart failure with restrictive LV filling—the pulmonary artery pressure was 55/27 mm Hg, and the pulmonary capillary wedge pressure 27 mm Hg. He was finally diagnosed with AL cardiac amyloidosis associated with multiple myeloma Ig G kappa. At the time of this diagnosis, he was not a candidate for stem cell transplantation or systemic intravenous chemotherapy secondary to his poor Eastern Cooperative Oncology Group (ECOG) performance status. After 4 months had passed from the pathologic diagnosis of cardiac amyloidosis, we were informed of his death from the hospice centre.

Discussion

The diagnosis of an anomalous PM leading to dynamic LVOT obstruction can be challenging with 2-D echo. Due to the

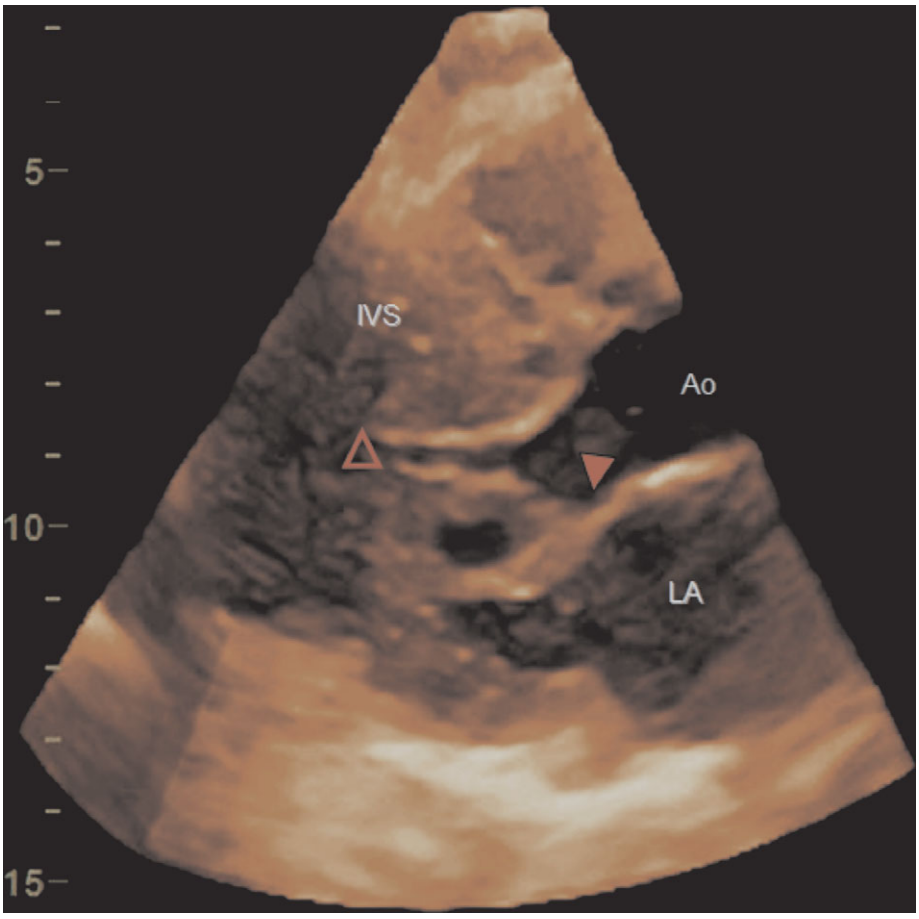

Figure 3 RT3DE demonstrates the origin of the anomalous papillary muscle in the postero-medial (empty arrowhead) and its abnormal insertion at the base of AMVL (filled arrowhead). IVS, interventricular septum; LA, left atrium; Ao, aorta.

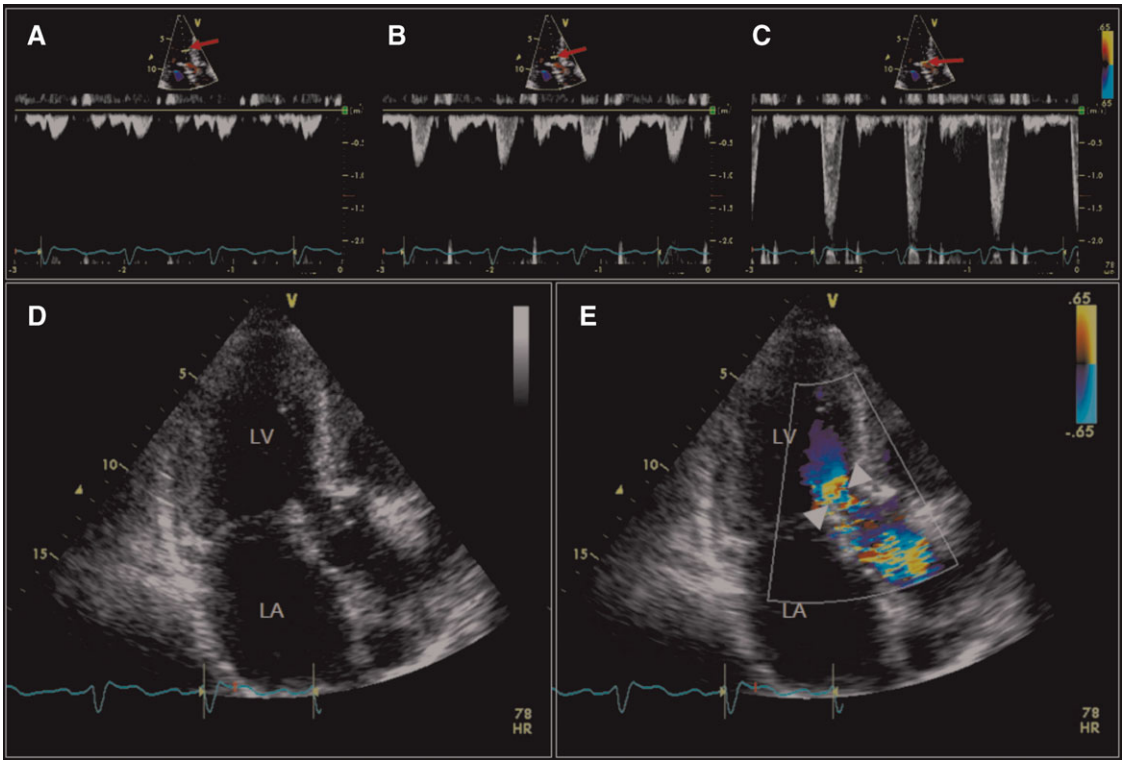

Figure 4 Pulsed wave Doppler tracing along the LVOT (*A*–*C*) points out the obstruction level with a high velocity profile (C)—no mid cavity of LV obstruction is demonstrated. A 2-D echo (*D*) with colour Doppler (*E*) shows flow acceleration with aliasing at the sub aortic level.

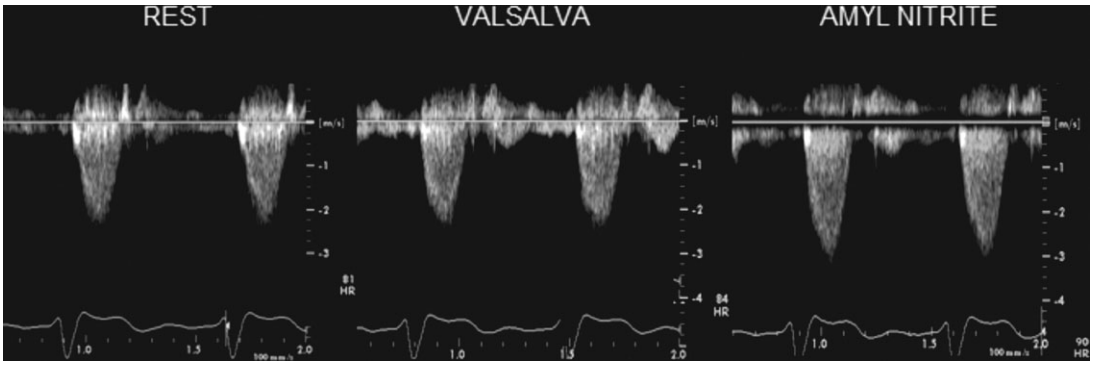

Figure 5 Continuous wave Doppler tracing of the LVOT shows the peak pressure gradient at rest (29 mm Hg), during the Valsalva manoeuvre (31 mm Hg), and with amyl nitrite (49 mm Hg) with an uniform systolic Doppler spectral profile.

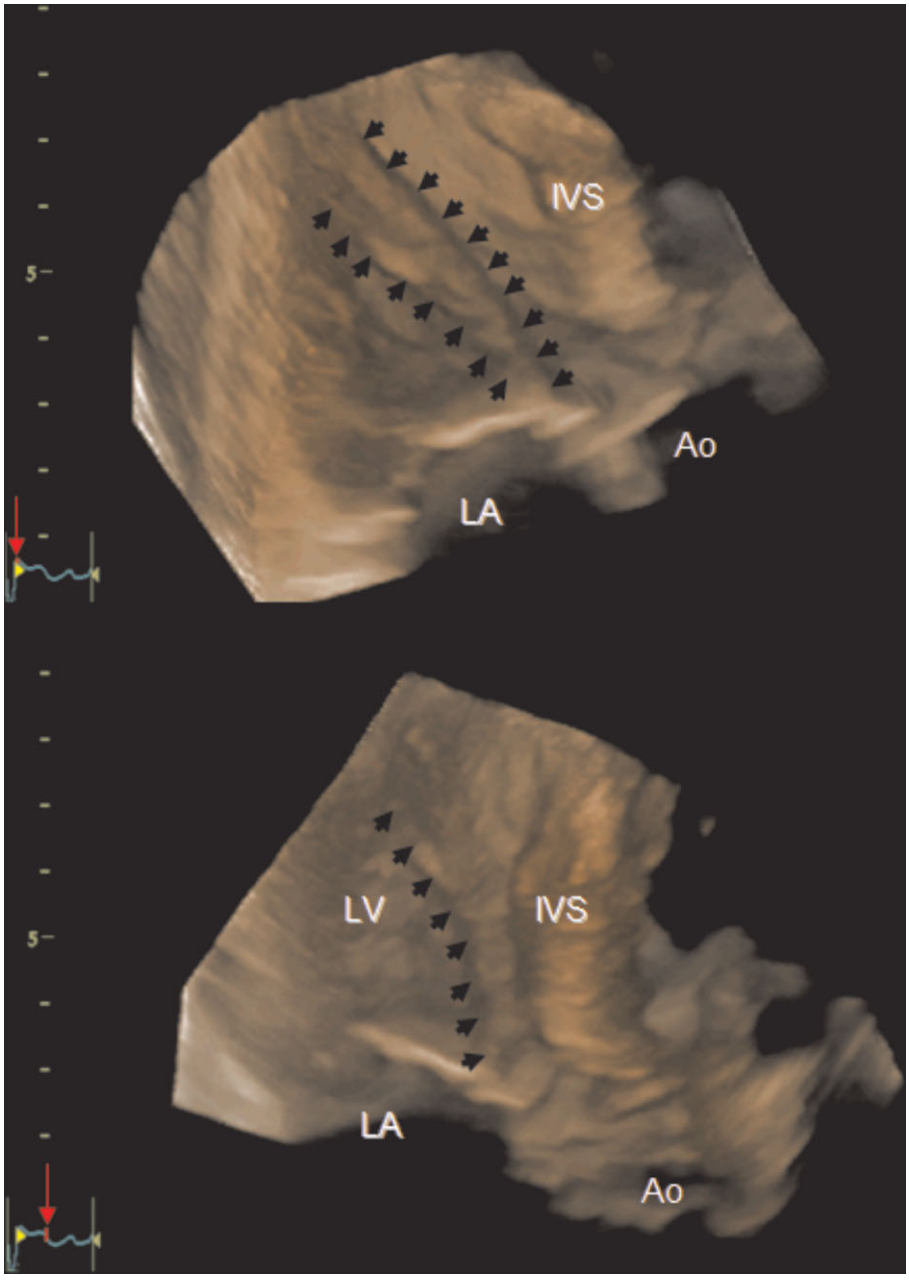

Figure 6 RT3DE demonstrates the thickened postero-medial papillary muscle directly inserted at the base of the AMVL (arrows) (Supplementary data online, *Movie 1*). IVS, interventricular septum; LV, left ventricle; LA, left atrium; Ao, aorta.

oblique course of the PM, complete delineation of the muscle frequently requires multiple off-axis images and is time-consuming. Compare 2-D echoes of one optimal plane with flow acceleration and aliasing in LVOT (*Figure 4*d) where an anatomical discontinuity appears between the base of the mitral annulus and the LV walls; RT3DE (*Figure 6*) reveals entire course of PM/chordae tendineae, including the anomalous insertion at the base of AMVL. RT3DE provides ease of complete anatomical imaging of the anomalous PM.

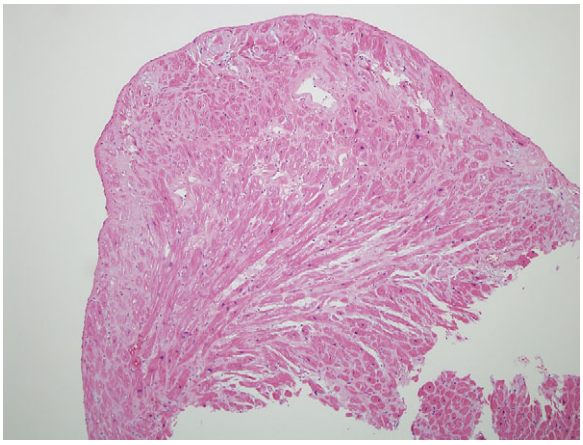

Figure 7 Cardiac amyloidosis with interstitial and nodular deposits (haematoxylin and eosin, ×100).

The mechanisms leading to dynamic LVOT obstruction are complex. In HOCM, substantial variations in mitral valvular anatomy have been reported.[2] Amongst these, anomalous PM has been described as causing dynamic obstruction, leading to recurrent LVOT obstruction after septal myectomy for obstructive HOCM.[3] It is, therefore, clinically important to carefully rule out the presence of an abnormal PM causing dynamic obstruction, a finding which would require more interrogation of the subvalvular region during the operation and an extended septal myectomy[4,5] instead of a standard septal myectomy for relief. In the presence of muscular mid-cavity obstruction (due to the anomalous PM/chordae tendineae which is inserted directly into the base of mitral valve), a much more substantial myectomy is required by combining the standard operation with an extended mid-ventricular resection and an additional resection around the bases of the PM. So all areas of PM fusion to the septum or ventricular walls are divided, and anomalous chordal structures and fibrous attachments of the mitral leaflets to the ventricular septum or free wall are divided or excised.[4,5]

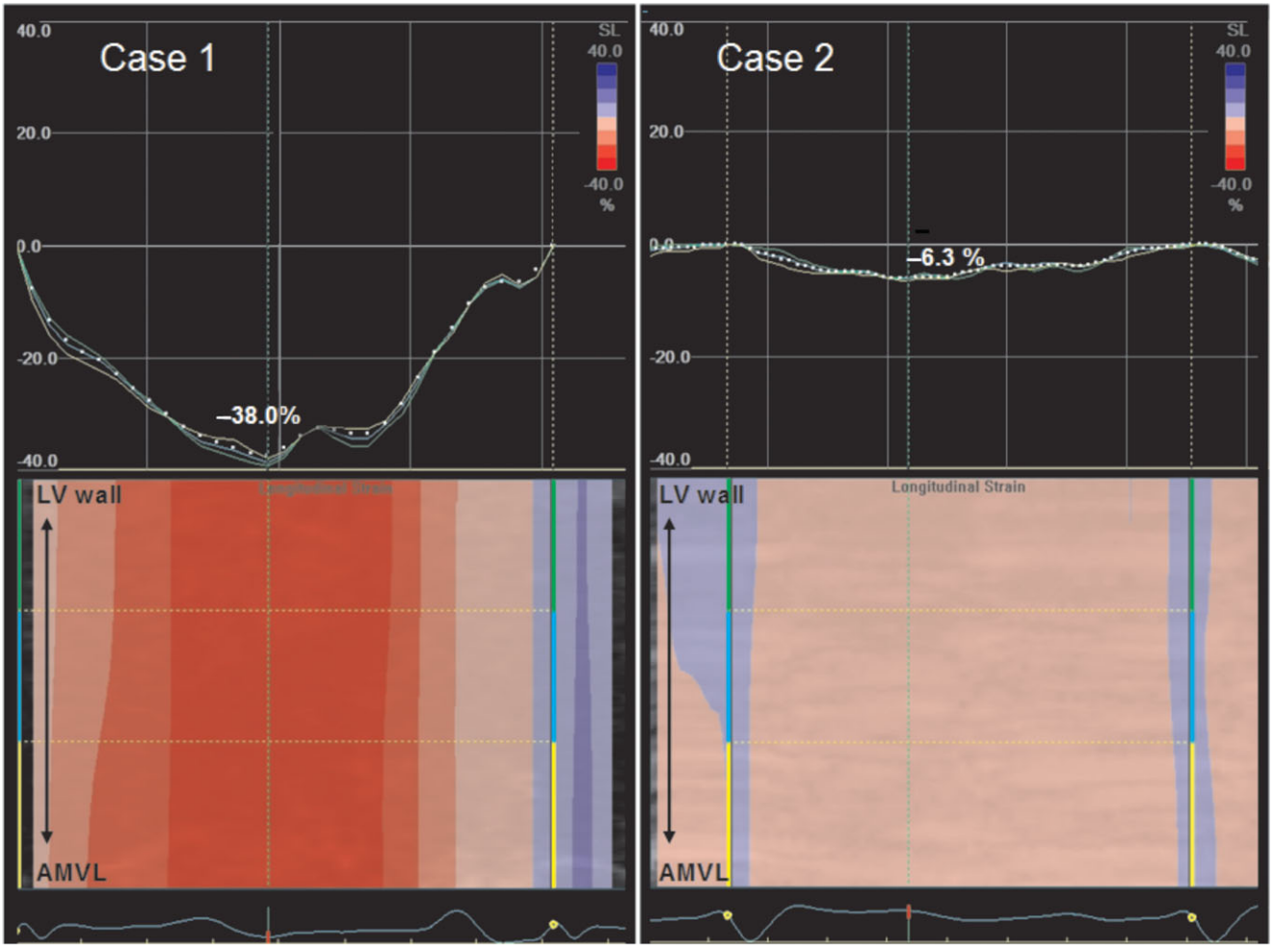

Figure 8 Comparison of the strain curves of the anomalous papillary muscle between the two cases. The peak negative strain of case 1 (HOCM) is −38.0%, whereas that of case 2 (Cardiac amyloidosis) is −6.3%. LV, left ventricle, AMVL, anterior mitral valve leaflet.

We also reported an amyloid heart disease with LVOT obstruction secondary to thick and anomalous insertion of PM. There have been a few reports of patients with cardiac amyloidosis and dynamic LVOT obstruction,[6,7] but none related to anomalous PM. A thickened PM was identified by 2-D echo in a case series of 5/13 patients with biopsy-proven amyloidosis.[8] In case 2, although the mechanism is not clearly defined, it is reasonable to consider amyloid infiltration on the anomalous PM. The role of amyloid infiltration along with the anomalous PM insertion and stiffening of the mitral leaflet can be emphasized on different haemodynamic and muscle mechanics.[1] During the amyl nitrate provocation, case 1 showed marked SAM with an increase of MR extent and of the pressure gradient along the LVOT with late-peaking systolic continuous wave Doppler (*Figure 2*). However, in case 2, the obstruction level is closer to the thick, rigid anomalous PM insertion point with less SAM and without the increase of MR extent and less increase of the pressure gradient showing the uniform systolic continuous wave Doppler spectral profile (*Figure 5*).[2] Comparison of the negative strain of the abnormal PM between cases 1 and 2 reveals relatively less regional contraction in case 2—the PM thickening reflecting amyloid infiltration rather than contractile muscle cells (*Figure 8*). Despite the overall poor prognosis of severe cardiac amyloidosis, there are several reported cases of attempts to reduce the dynamic LVOT obstruction by various methods including CABG with septal myectomy[9] or isolated percutaneous transluminal septal myocardial ablation.[10] It would be important to identify the presence of anomalous PM—simply resolving the thickened septal muscle may not relieve the pressure gradient.

Sometimes the LVOT obstruction related to the congenital PM anomaly could be found in parachute or parachute-like mitral valves due either to a huge single PM and its relation to LVOT or to chordae tendineae confluence on a single PM and its relationship to LVOT.[11] Echocardiography establishes the diagnosis—the typical parachute deformity of the mitral valve is best demonstrated in the short-axis view of the mitral valve at the mid and apical segments of the LV revealing a single PM accepting all the chordae tendineae insertions.

In summary, anomalous insertion of the PM/chordae tendineae is a rare but important cause of dynamic LVOT obstruction in patients with HOCM or cardiac amyloidosis. To our knowledge, this is a first report of the anomalous insertion of PM causing LVOT obstruction in a patient with biopsy-proven cardiac amyloidosis—we emphasized the role of amyloid infiltration along the anomalous PM. RT3DE provides clear benefits over 2-D Echo in accurate imaging and delineation of the spatial relationship between the anomalous PM and LVOT and should be considered in cases in which the diagnosis is suspected with 2-D Echo.

Supplementary data

Supplementary data are available at *European Journal of Echocardiography* online.

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