# 8 Role of 3DE in Assessment of Functional Mitral Regurgitation

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Functional mitral regurgitation (FMR) is defined as mitral regurgitation (MR) secondary to ischemic or dilated cardiomyopathy in the absence of structural abnormality in the mitral valve (MV) [1, 2]. The underlying cause of MR in this setting is regional or global left ventricular (LV) dysfunction and dilatation. The LV remodeling that ensues leads to apical and lateral papillary muscle displacement as a result of global LV enlargement or focal myocardial scarring, and can affect one or both papillary muscles [1, 2]. Additionally, the normal saddle-shape of the mitral annulus, important for maintaining low leaflet stress is lost [3], and annular flattening with LV remodeling results in increased leaflet stress and secondary MR [1–3]. Moreover, LV systolic dysfunction reduces the strength of MV closing. These aforementioned pathomorphologic changes result in leaflet tethering, tenting, and malcoaptation (Figs. 8.1 and 8.2) [1, 2].

In ischemic MR (the more frequent etiology of FMR), LV remodeling may be regional or global and symmetric or asymmetric mitral leaflet tethering may occur [1, 2]. Symmetric tethering typically causes mitral leaflet tenting and is associated with substantial LV systolic dysfunction, global remodeling with increased LV sphericity, and a central regurgitant jet. Asymmetric tethering typically involves the posterior leaflet and results from localized remodeling affecting the posterior papillary muscle and adjacent mid to basal myocardial segments, but global left ventricular ejection fraction (LVEF) does not have to be reduced [1, 2]. A characteristic feature of asymmetric posterior leaflet tethering is anterior leaflet override (Fig. 8.1) and secondary posteriorly directed jet of mitral regurgitation. Sufficient mitral leaflet tethering can result in severe MR. 3D echocardiography (3DE) is useful for assessing the morpho-anatomic changes associated with FMR, and for providing insight into the underlying mechanism of mitral regurgitation in this setting (Fig. 8.1). A better appreciation of the variability in mitral valve geometry due to differences in infarct location and size, and extent of left ventricular remodeling may help improve surgical planning [4].

Non-ischemic MR, most commonly due to longstanding hypertension or idiopathic dilated cardiomyopathy, is characterized by global LV dilation with increased sphericity and (typically) a centrally located regurgitant jet. Mitral annular dilation typically occurs late in the pathophysiology of secondary MR, and is often asymmetric, with greater involvement of the posterior annulus [3]. Symmetric mitral annular dilation correlates with the severity of LV dysfunction [3]. Isolated left atrial enlargement, with or without atrial fibrillation, is a relatively infrequent cause of severe secondary MR, due to dilated mitral annulus and reduced leaflet coaptation despite normal LV function and mitral leaflets [1].

Flow quantitation has emerged as the cornerstone for assessment of MR severity [5]. The smallest cross sectional area through which any regurgitant jet passes through before expanding into the receiving chamber is called its vena contracta (VC) [5]. Because regurgitant blood flow accelerates as it approaches the mitral valve orifice, conventional 2-dimensional (2D) Doppler derived quantitation of MR severity relies on the proximal isovelocity surface acceleration (PISA) method [5]. The PISA method assumes a circular regurgitant orifice geometry also referred to as the effective regurgitant orifice area or EROA for short [5]. However, the EROA is not circular in most patients, and MR severity may, therefore, be significantly underestimated when the orifice is elliptical as is typical in functional MR (Figs. 8.2 and 8.3), and this is compounded if multiple jets

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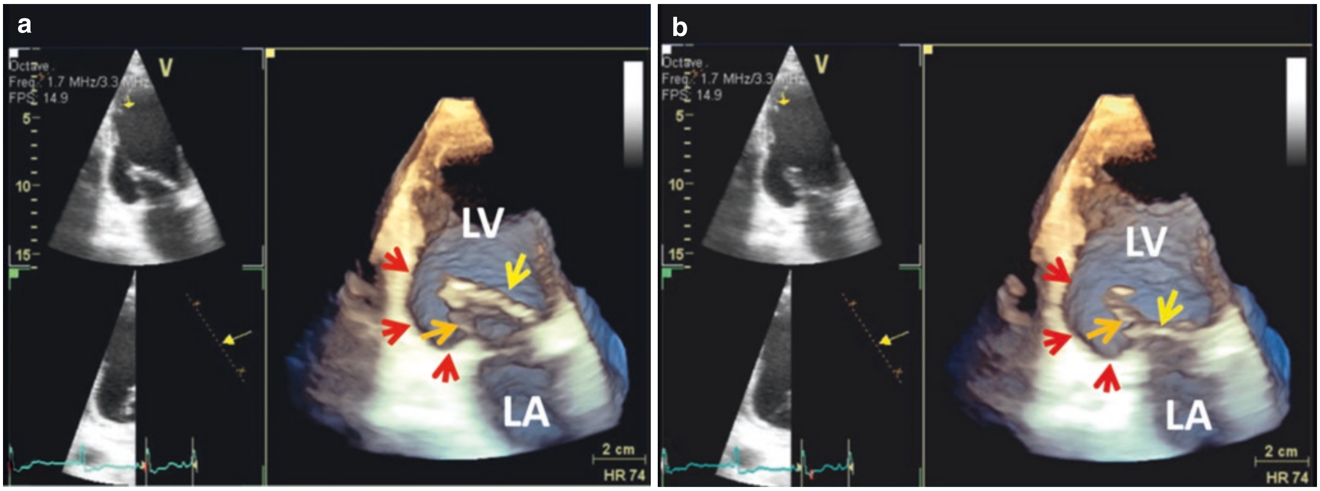


**Fig. 8.1** Mechanism of IMR on 3D TTE; Orange arrow points to PML and yellow arrow points to AML (**a**) Valve tenting. (**b**) Tethered PML with AML override. Note the adjacent aneurysmal basal myocardial segment (red arrows). Used with permission of Mayo Foundation for Medical Education and Research. All rights reserved. AML, anterior mitral leaflet; IMR, ischemic mitral regurgitation; LA, left atrium; LV, left ventricle; PML, posterior mitral leaflet

are present [6–8]. 3DE overcomes this limitation by permitting direct planimetry of the vena contracta area (VCA) which in fluid mechanics corresponds to the EROA [7], regardless of orifice shape or number of jets (Figs. 8.3 and 8.4) [6, 7].

Compared with MRI, quantification of mitral EROA and regurgitant volume with 3D TEE is accurate and results in less underestimation of the regurgitant volume as compared with 2D TEE [9].

Notwithstanding the aforementioned merits of 3D, both 2D and 3D color flow Doppler tend to overestimate the regurgitant orifice area because of their inability to resolve the high velocity jet core due to aliasing and blooming artifacts (see Figs. 8.3 and 8.4) [6, 8]. FMR severity also varies during the cardiac cycle, and can peak in early or late systole, further complicating evaluation, which is traditionally done in mid-systole. There is also marked variability of shape, size, and number of VCAs on real time 3D color Doppler [6, 8]. Another important obstacle to 3D assessment of MR severity remains the limited temporal and spatial resolution of 3D color Doppler data.

For all the aforementioned reasons, 3D derived VCA has not yet become part of routine clinical practice, and there are no agreed upon cut off values for VCA for severe FMR. Therefore, more studies are needed, and because at present, no single parameter is sufficient to quantify the degree of FMR, multimodality assessment including both 2D and 3D echocardiography is optimal [5–8].

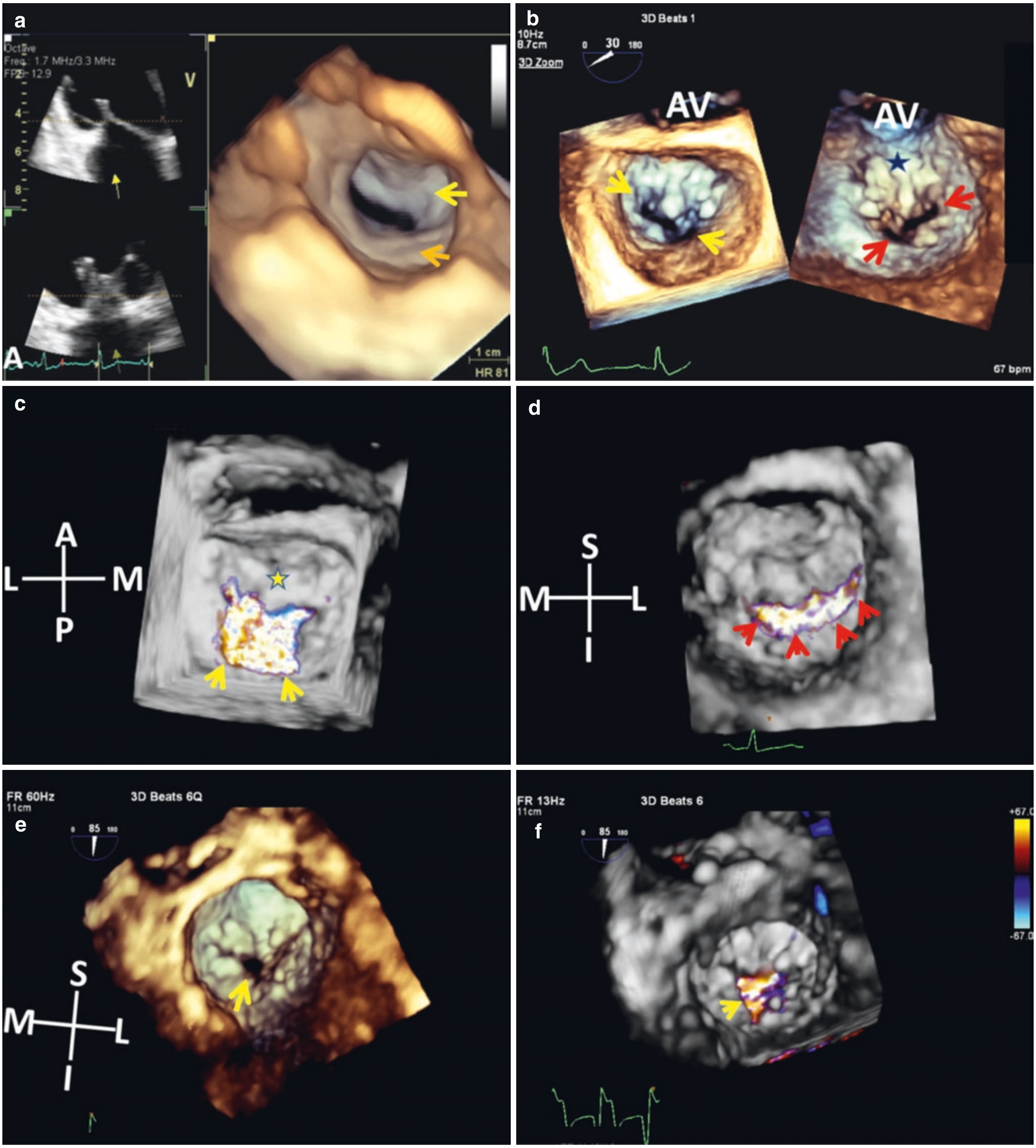


**Fig. 8.2** **Top panel**: (**a**) Live 3D TTE LA view from patient with IMR in Fig. 8.1 showing lack of MV leaflet coaptation in systole (yellow arrow points to AML and orange arrow points to PML). (**b**) Live TEE 3D Zoom simultaneous dual layout enface LA (left) and LV (right) systolic views of MV in a patient with FMR due to non-ischemic cardiomyopathy. Note the lack of leaflet coaptation (arrows), star points to AML; **Middle panel**: 3D TEE CFD enface LA (**c**) and LV (**d**) views from another patient with FMR. (**a**) MR jet fans out in the LA (yellow arrows), star points to AML. (**b**) LV view shows that MR spans the entire mitral valve coaptation surface (red arrows). **Bottom panel**: (**e**) Multibeat 3D TEE FV enface LV views of FMR in a patient with a tethered P2 segment of the PML resulting in localized central malcoaptation of the MV (arrow). (**f**) 3D CFD in same patient showing MR through the localized malcoaptation site (arrow). Note the drop in volume rate or frame rate from 60 to 13 when color flow Doppler is added. Also note that regardless of etiology, the origin of MR is best appreciated from the enface LV perspective. Used with permission of Mayo Foundation for Medical Education and Research. All rights reserved. A, anterior; AML, anterior mitral leaflet; AV, aortic valve; CFD, color flow Doppler; FMR, functional mitral regurgitation; FV, Full Volume; I, inferior; IMR, ischemic mitral regurgitation; L, lateral; LA, left atrium; LV, left ventricular; M, medial; MR, mitral regurgitation; MV, mitral valve; P, posterior; PML, posterior mitral leaflet; S, superior; TEE, transesophageal echocardiography; TTE, transthoracic echocardiography

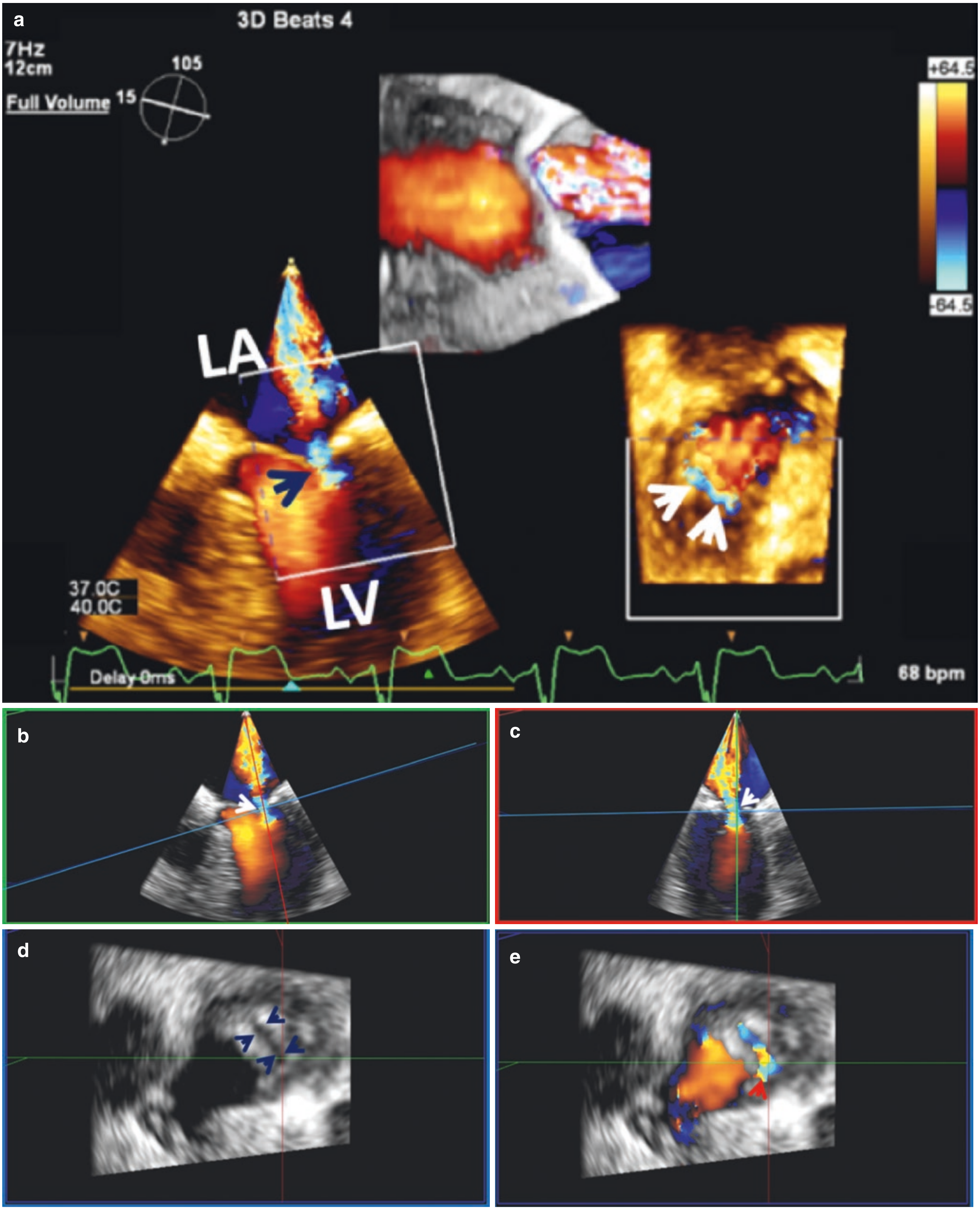
a
3D Beats 4
7Hz
12cm
Full Volume
105
15
+64.5
-64.5
LA
LV
37.0C
40.0C
Delay 0ms
68 bpm
b
c
d
e

**Fig. 8.3** MR VC. (**a**) iCrop (Philips Healthcare) of multibeat 3D FV CFD showing a narrow VC when viewed sideways from the mid-esophagus (dark blue arrow) as opposed to a broad based VC that spans the entire MV coaptation surface (white arrows) when viewed enface from the LV perspective on the orthogonal MPR plane. (**b–e**) MPR of 3D CFD volumetric data set. (**b**) Alignment of the transverse plane (blue line) and orthogonal sagittal plane (red line) at VC (white arrow) in the coronal plane (Green rectangle). (**c**) Alignment of the transverse plane (blue line) and orthogonal coronal plane (green line) at VC (white arrow) in the sagittal plane (red rectangle). (**d**) elliptical shaped VC (dark blue arrows) as it appears in the transverse plane (Blue rectangle) with color Doppler off. (**e**) Same VC with CFD on. Note the slight color bleed beyond the anatomic boundaries of the VC cross-sectional area (red arrow) due to blooming artifact. Used with permission of Mayo Foundation for Medical Education and Research. All rights reserved. CFD, color flow Doppler; EROA, effective regurgitant orifice area; FV, Full Volume; LA, left atrium; LV, left ventricle; MPR, multiplanar reconstruction; MR, mitral regurgitation; MV, mitral valve; VC, vena contracta

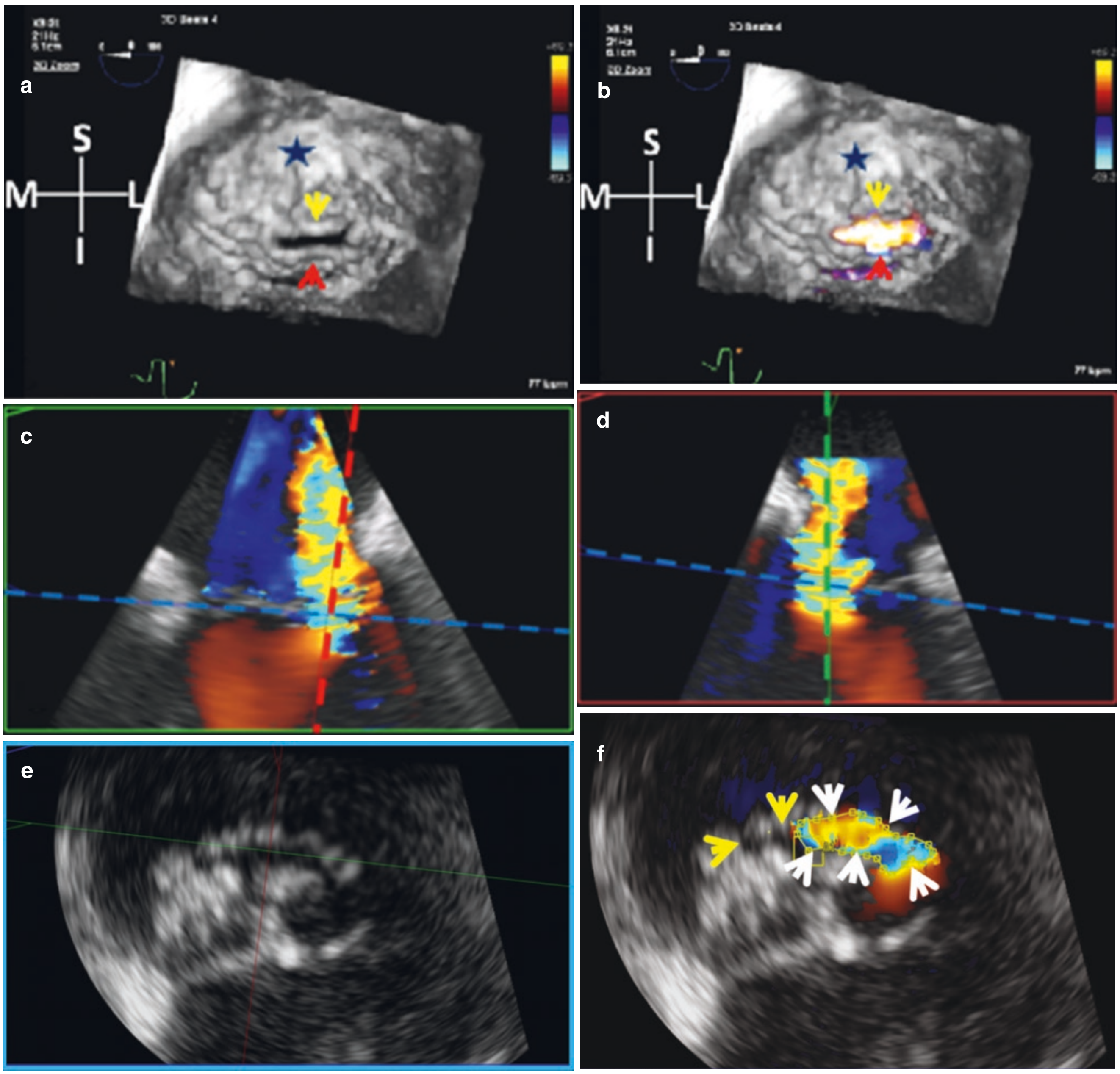


**Fig. 8.4** (**a**) Multibeat TEE 3D Zoom enface LV views from a patient with FMR showing lack of anterior (yellow arrow) and posterior (red arrow) leaflet coapation. (**b**) secondary MR on CFD (star points to LVOT). (**c–f**) MPR of 3D CFD volumetric data set from same patient. (**c**) coronal plane (green rectangle) showing alignment of the transverse plane (blue line) and sagittal plane (red line) with the narrowest region of the MR jet just downstream to the orifice of the MV. (**d**) sagittal or vertical plane (red rectangle) and similar alignment of the transverse plane (blue line) and coronal plane (green line). (**e**) The resultant VC cross sectional area with color Doppler suppressed. (**f**) VC with CFD on. Note the dropout artifacts that are not covered by the CFD map (yellow arrows). Also note that the VC area measurement is limited to the high velocity core of the jet (white arrows). Used with permission of Mayo Foundation for Medical Education and Research. All rights reserved. CFD, color flow Doppler; FMR, functional mitral regurgitation; I, inferior; M, medial; MPR, multiplanar reconstruction, MR, mitral regurgitation; L, lateral; LV, left ventricle, LVOT, left ventricular outflow tract; S, superior; VC, vena contracta

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