Numerous studies have shown that biventricular pacing (BVP) improves symptoms and exercise capacity in patients with congestive cardiac failure (CCF) and left bundle branch block (LBBB). The mechanism of symptomatic improvement has been attributed to changes in ventricular synchrony. However, the degree of asynchrony is not a good predictor of response. The aim of this study was to assess whether the presence of a restrictive mitral filling pattern, previously shown to be a marker for diastolic ventricular interaction (DVI) in patients with CCF, might identify a cohort of patients more likely to respond to BVP.

METHODS
We studied 23 consecutively referred patients (15 males/8 females), mean (SD) age 63.4 (12.8) years (range 40–83 years) in sinus rhythm with severe refractory heart failure (New York Heart Association (NYHA) III/IV), LBBB (QRS > 120 ms), and fractional shortening (FS) < 25% on maximal tolerated doses of medication. Clinical evaluation included history, ECG, M mode and two dimensional echocardiography before and six months after BVP. At six month follow up patients were classified as responders if there was an improvement in FS > 5% from baseline.

RESULTS
Implantation of the biventricular system was successful in 19 patients (83%). Before implant, all patients were receiving either an angiotensin converting enzyme inhibitor or an angiotensin II blocker. All patients were receiving frusemide (furosemide) (mean (SD) dose was 119 (46) mg, range 62.5–250 mg). The optimised atrioventricular interval was 110 (19) ms (100–130 ms). There were no changes in medications after pacing.

In the whole population there was an improvement in mean NYHA functional class from 3.4 (0.3) to 2.3 (0.5) (p = 0.001) after six months of BVP, QRS width did not change after pacing (165.0 (24.8) ms to 158.7 (35.2) ms, p = 0.14 after pacing). At follow up FS increased in 10 (53%) patients (responders) and decreased in 9 (47%) patients (non-responders). The mean increase in %FS in responders was 52 (41)% (6–110%) and the mean reduction in %FS in non-responders was 29 (15)% (6–50%). Response to pacing was independent of the aetiology of heart failure, baseline functional class, and medication. Improvements in NYHA class were seen in both responders and non-responders (3.5 (0.5) to 2.6 (0.7), p=0.004, and 3.3 (0.6) to 2.4 (0.5), p=0.004, respectively). There was no difference in mitral regurgitation score or sphericity index before or after pacing between responders and non-responders.

Responders had a greater QRS duration at baseline than non-responders (174 (24.5) ms v 147 (20.6) ms, p = 0.05). There was a significant correlation between baseline QRS duration and change in %FS after pacing (r = 0.58, p = 0.028). Receiver operating characteristic (ROC) curves demonstrated that a QRS > 180 ms had a sensitivity of 66%, specificity of 75%, and a positive predictive value of 75% for determining improvements in %FS after BVP. There was no significant correlation between change in QRS duration and the change in %FS after pacing (p = 0.1, r = NS).

On transmitral Doppler responders had a higher E/A ratio at baseline than non-responders (2.1 v 1.3, p = 0.02). There was a correlation between baseline E/A ratio and improvements in %FS after pacing (r = 0.72, p < 0.001) (fig 1). In a bivariate analysis of baseline E/A ratio and QRS, only E/A ratio was significantly related to change in %FS after pacing. An E/A > 2.0 had a sensitivity of 70%, specificity of 100%, and a positive predictive value of 100% for predicting improvements in %FS after BVP. There was a significant reduction in E/A from 2.1 (0.8) to 1.4 (0.8) (p = 0.03) after pacing in responders, whereas E/A increased from 1.3 (0.4) to 1.6 (0.8) (p = 0.2) after pacing in non-responders (fig 1).

DISCUSSION
This study confirms that subjective improvements in symptoms occur in the majority of individuals who undergo BVP for congestive cardiac failure. Fractional shortening, however, improved in only 53% of individuals. This group was characterised by a broader QRS duration and higher E/A ratio.
and improving stroke volume.

Although this and other studies have suggested that there is a correlation between basal QRS duration and response to BVP, there seems to be little relation between paced QRS duration and outcome. Furthermore, some studies have shown that left ventricular pacing alone is as good if not better than bi-ventricular pacing, in spite of the fact that the paced QRS duration is generally greater than with BVP.\(^4\)

In this study, a restrictive filling pattern at baseline was predictive of response to pacing and improvements in left ventricular systolic function associated with a less restrictive filling pattern after pacing. Although a restrictive filling pattern may simply be a reflection of the degree of haemodynamic impairment, it has recently been shown that a restrictive filling pattern is also a marker of increased DVI, in which left ventricular filling is constrained by the right ventricle and pericardium. Normally, constraint to left ventricular filling is minimal; however, in chronic heart failure, the increased filling pressures may distend the ventricles to such an extent that the filling of the left ventricle is impeded by the surrounding pericardium and the right ventricle enhancing DVI. In early diastole, ventricular volume will be the lowest; therefore, external constraint to left ventricular filling will be minimal. In late diastole, however, further left ventricular filling will be limited by the surrounding pericardium and right ventricle, resulting in diminished late diastolic filling. Hence the transmitral gradient will be high at the onset of diastole but rapidly diminishes thereafter, resulting in restrictive filling pattern.\(^1\)

In this setting, left ventricular pacing might be expected to result in a phase shift in which left ventricular precedes right ventricular filling, thereby relieving DVI, lowering left ventricular filling pressures, and improving stroke volume.\(^6\)

This study suggests that simple Doppler parameters can identify a cohort of patients that are more likely to show improvements in systolic function after BVP. Although the clinical significance of these observations remains to be determined, we hypothesise that patients with restrictive filling pattern may have increased DVI and that BVP or left ventricular pacing may improve left ventricular systolic function by ameliorating DVI. A prospective study is required to assess the contribution of DVI to improvements in symptoms and left ventricular systolic function after BVP.

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