CARDIOVASCULAR MEDICINE

Analysis of myocardial deformation based on pixel tracking in two dimensional echocardiographic images enables quantitative assessment of regional left ventricular function

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Objective: To evaluate whether myocardial strain and strain rate calculated from two dimensional echocardiography by automatic frame-by-frame tracking of natural acoustic markers enables objective description of regional left ventricular (LV) function.

Methods: In 64 patients parasternal two dimensional echocardiographic views at the apical, mid-ventricular and basal levels were obtained. An automatic frame-by-frame tracking system of natural acoustic echocardiographic markers was used to calculate radial strain, circumferential strain, radial strain rate and circumferential strain rate for each LV segment in a 16 segment model. Cardiac magnetic resonance imaging (cMRI) was performed to define segmental LV function as normokinetic, hypokinetic or akinetic.

Results: Image quality was sufficient for adequate strain and strain-rate analysis from two dimensional echocardiographic images obtained from parasternal views in 88% of segments. Obtained radial strain data were highly reproducible and analysis was affected by only small intraobserver (mean 4.4 (SD 1.6)%) and interobserver variabilities (7.3 (2.5)%). Each of the analysed strain and strain-rate parameters was significantly different between segments defined as normokinetic, hypokinetic or akinetic by cMRI (radial strain 36.8 (10.5)%, 24.1 (7.5)% and 13.4 (4.8)%, respectively, $p < 0.001$). Peak systolic radial strain enabled detection of hypokinesis or akinesis with a sensitivity of 83.5% and a specificity of 83.5% (cut off value 29.1%, receiver operating characteristic (ROC) curve area 0.905, 95% CI 0.883 to 0.923). Peak systolic radial strain analysis also enabled detection of akinesis versus hypokinesis with a sensitivity of 82.7% and a specificity of 94.5% (cut off value 21.0%, ROC curve area 0.946). Peak systolic radial strain-rate analysis was less accurate than peak systolic radial strain analysis to detect cMRI-defined segmental function abnormalities. The accuracy of peak systolic circumferential strain and strain rate was similar to that of corresponding radial parameters.

Conclusions: Frame-by-frame tracking of acoustic markers in two dimensional echocardiographic images enables accurate analysis of regional systolic LV function.

Assessment of regional left ventricular (LV) function is essential for the evaluation and management of patients with heart disease. Currently applied methods for analysis of regional function integrate a visual assessment of inward motion and wall thickening from two dimensional echocardiographic images. They are subjective and limited by substantial reader variability.¹ Doppler-based velocity, strain and strain-rate analysis has been suggested for quantification of regional LV function.²⁻⁴ Compared with myocardial velocity measurements a major advantage of strain analysis is its independence from translation motion, tethering effects from other regions of the heart and the uniformity of measurements throughout the normal LV myocardium.⁶⁻⁹ Important limitations of Doppler-derived strain and strain rate are a considerable angle dependency and substantial noise artefacts.⁸

Recent improvements in two dimensional echocardiographic image resolution have enabled detection of tissue pixels and tracking of these acoustic markers from frame to frame. Assessment of radial and longitudinal strain and strain rate from a tissue pixel tracking system on two dimensional echocardiographic images has recently been described.¹⁰⁻¹¹ The basis for this analysis is that the geometric

shift of an acoustic marker corresponds to local tissue movement. No angle dependency of the analysis and fewer noise artefacts are potential advantages compared with Doppler-based myocardial deformation imaging.

In this study, we sought to evaluate whether radial and circumferential strain and strain rate derived from tracking of acoustic markers within two dimensional echocardiographic images allow accurate description of regional myocardial function. Regional LV function defined by cardiac magnetic resonance imaging (cMRI) was used as reference to determine regional function.

METHODS

Patients

This study enrolled 64 patients (20 women, mean age 42.3 (SD 8.1) years): 54 consecutive patients who underwent cMRI for clinical purposes and 10 participants assumed to have normal LV function, which was confirmed by cMRI. These participants were evaluated to define normal values for two dimensional echocardiography-based strain and

Abbreviations: cMRI, cardiac magnetic resonance imaging; LV, left ventricular; ROC, receiver operating characteristic

strain-rate parameters. Echocardiography was performed within 1 h of cMRI. The 54 patients had ischaemic heart disease with a myocardial infarction within the preceding year (location: 31 anterior, 16 inferior, 7 posterior). This study was approved by the local ethics committee and all participants gave written informed consent.

Echocardiography

All studies were performed with a Vivid Seven digital ultrasound scanner (General Electric, Horten, Norway). LV ejection fraction was determined by manual tracing of end systolic and end diastolic endocardial borders in the apical four-chamber and two-chamber views by biplane Simpson's method. End systole was marked as aortic valve closure in apical long-axis views. The time difference from the QRS complex was transferred to the other views. Parasternal short-axis views at the basal, mid-ventricular and apical levels of the left ventricle were acquired by two dimensional tissue harmonic imaging. The focus was adjusted to the centre of the LV cavity to optimise myocardial tissue characterisation of all segments of the short-axis views. The frame rate for these studies was between 56–92 frames/s. The parasternal short-axis two dimensional echocardiographic images were analysed off line on a personal computer with the aid of a customised software package (EchoPAC; General Electric) on two consecutive cardiac cycles of acquired loops. This system enables analysis of peak systolic radial and circumferential strain and strain rate based on detection of natural acoustic markers within the myocardium and an algorithm that follows the acoustic markers accurately during several consecutive frames.^{10,11} It is assumed that the natural acoustic markers change their position from frame to frame in accordance with the surrounding tissue motion.¹¹ Peak systolic radial strain and strain rate as parameters of radial deformation relate to motion from the endocardium to the epicardium. Peak systolic circumferential strain and strain rate as parameters of circumferential deformation relate to motion along the curvature of the left ventricle in the parasternal short axis. A medium degree of spatial and temporal smoothing was selected in the analysis algorithm of deformation parameters. The system calculates mean strain and strain-rate values for whole predefined LV segments. Thus, it is also a mean of endocardial and epicardial values.

All three acquired parasternal short-axis views were analysed by using the system to obtain quantitative function parameters for each segment in a 16 segment LV model (six segments for the basal and mid-ventricular short-axis view and four segments for the apical short-axis view). The analysis package has been described.¹¹ The system automatically grades each segment on tracking quality on a scale ranging from 1.0 for optimal to 3.0 for unacceptable. Segments with suboptimal tracking quality (grading > 2.0 by the system) were systematically eliminated from the analysis. For the remaining segments tracking quality was monitored visually to ensure adequate automatic tracking.

Strain rate is equivalent to the spatial gradient of pixel movements. It is characterised by the equation strain rate = $[d(r) - d(r + \Delta r)] / \Delta r \cdot t$ (where d is distance of movement, r is location in space and t is time), which equals the equation for strain rate reported for Doppler imaging techniques.³ The time integral of incremental strain rate yields logarithmic strain $\epsilon = \int_0^t \text{strain rate } dt = \log(L/L_0)$, where L is the instantaneous segment length and L_0 is the segment length at time 0. The logarithmic strain is converted to lagrangian strain by $\epsilon = L - L_0/L_0$.

For 10 participants the analysis of peak systolic strain and strain-rate data was repeated four weeks apart by the same observer on the same two dimensional echocardiographic loop and the same cardiac cycle to define the intraobserver

variability in the analysis. In addition a second independent observer analysed the same cardiac cycle to define the interobserver variability in the analysis of tissue tracking-derived deformation parameters. For each segment the difference of strain data was calculated and given as the relative deviation between these two measurements. The indicated variability is a sum of all 16 segments and 10 participants.

Cardiac magnetic resonance imaging

All patients and healthy participants underwent cMRI within 1 h of the echocardiographic study. This examination was performed on a 1.5 T whole-body magnet (Intera; Philips, Best, The Netherlands) with a five-element phased-array cardiac coil. Four-chamber, two-chamber and short-axis views with a slice thickness of 8 mm (2 mm gap) were acquired in the basoapical direction with a temporal resolution of ≤ 50 ms. An experienced independent reader in cMRI evaluated regional myocardial function considering a 16 segment model of the LV. Regional systolic function was determined for each of 16 segments considering wall thickening during systole as well as endocardial inward motion. For each segment myocardial function was described as normokinetic, hypokinetic, akinetic or dyskinetic. To obtain the best possible geometric matching of regional function assessment by cMRI and by echocardiography, the LV outflow tract as well as the papillary muscles were used for matching purposes.

To analyse interobserver variability in the visual analysis of cMRIs regarding segmental function, two readers analysed 10 cMRI studies (160 segments). The interobserver agreement between the two readers on segmental wall motion assessment as normokinetic, hypokinetic or akinetic was $\kappa = 0.855$.

Statistical analysis

Data are expressed as mean (SD). Continuous variables were compared by Student's t test or analysis of variance as appropriate. Non-parametric analysis of overall sensitivities and specificities as well as areas under the receiver operating characteristic (ROC) curves were applied. ROC curves were used to assess the optimal cut off point of the peak systolic radial and circumferential strain rate and peak strain rate for the detection of segments with any regional myocardial wall motion abnormality (hypokinesis, akinesis or dyskinesis) and for detection of akinesis or dyskinesis. In these curves, the sensitivity versus 1 – specificity of a test was plotted. Sensitivity and specificity were determined with regard to any segmental wall motion abnormality defined by cMRI and with regard to akinesis versus hypokinesis. The overall significance level was 0.05.

RESULTS

Ejection fraction defined by biplane echocardiography was 47 (13)%. Visual analysis of regional LV function was possible in 92% of segments. Image quality was sufficient to allow strain and strain-rate analysis from parasternal short-axis views in 88% of segments (tracking quality > 2.0 as defined by the analysis software). The segments did not differ in the rate of adequate tracking quality. For the 901 segments with adequate tracking of acoustic markers, segmental analysis of regional LV by cMRI indicated normal function in 399 segments, hypokinesis in 392 segments and akinesis in 110 segments.

Observer variability and reproducibility of strain-rate parameters

Intraobserver variability in the analysis of peak systolic radial strain was found to be 4.4 (1.6)% of the absolute measured

Figure 1 Radial and circumferential strain (top) and strain rate (bottom) for each of the 16 left ventricular segments in the 10 normal participants. Strain and strain-rate values were very similar for all 16 left ventricular segments in normal participants.

values and interobserver variability was found to be 7.3 (2.5)% of the absolute measured values. For peak systolic radial strain rate, intraobserver and interobserver variabilities were 5.3 (2.6)% and 8.4 (3.7)%, respectively. Findings for circumferential strain and strain rate were similar.

Two dimensional echocardiography for 10 patients was repeated by the same examiner two days after the first study to determine reproducibility of peak systolic strain and strain-rate measurements. Haemodynamic conditions were similar during the two studies. Relative variability was 8.7 (7.1)% for peak systolic radial strain, 10.1 (5.6)% for peak systolic radial strain rate, 6.7 (4.2)% for peak systolic circumferential strain and 8.0 (5.4)% for peak systolic circumferential strain rate between the two studies.

Strain and strain rate in normal LV function

For the 10 participants without prior myocardial infarction and without coronary artery disease, strain and strain-rate

parameters were evaluated on a segmental basis. Peak systolic radial and circumferential strain and strain-rate values were found to be homogeneous between the 16 LV segments (fig 1). Strain and strain-rate data did not differ significantly between the segments (SC (circumferential strain): $p = 0.859$; SrC (circumferential strain rate): $p = 0.315$; SR (radial strain): $p = 0.504$; SrR (radial strain rate): $p = 0.291$).

Radial strain and strain rate related to segmental LV function

Figures 2 and 3 illustrate an example of regional function impairment detected by cMRI and corresponding radial strain images. Table 1 gives peak systolic radial strain and strain-rate results related to regional LV function defined by cMRI. Peak systolic radial strain for segments defined as hypokinetic was 35% lower and for segments defined as akinetic 64% lower than for segments defined as

Figure 2 Colour coded radial strain images (left) and cardiac magnetic resonance images (cMRIs) (right) at end systole (top) and end diastole (bottom) of a patient with hypokinesis of the anteroseptal wall. Images are short axis views. At end diastole purple colouring indicates minimal strain. At end diastole normal contracting segments are red and the segment showing little thickening in the cMRIs is coloured only purple.

normokinetic (fig 4). The peak systolic radial strain rate of hypokinetic segments was 20% and of akinetic segments 44% lower than for normokinetic segments. Thus, peak systolic radial strain and strain rate were significantly different between segments defined as normokinetic, hypokinetic and akinetic by cMRI. The differences were more pronounced, however, for peak systolic strain than for strain-rate values.

ROC curves were analysed for peak systolic radial strain and radial strain rate to determine the accuracy in the detection of dyssynergy (hypokinesis, akinesis and dyskinesis) defined by cMRI. Peak systolic radial strain enabled detection of dyssynergy with a sensitivity of 83.5% and a specificity of 83.5% (cut off value 29.1%, ROC curve area 0.905, 95% confidence interval (CI) 0.883 to 0.923). Peak systolic radial strain analysis also enabled detection of akinesis versus hypokinesis. The sensitivity was 82.7% and the specificity 94.5% (cut off value 21.0%, ROC curve area 0.946). Peak systolic radial strain-rate analysis enabled detection of dyssynergy defined by cMRI with a sensitivity of 67.4% and a specificity of 89.6% with a cut off value of 1.43 1/s (ROC curve area 0.866, 95% CI 0.842 to 0.887). The cut off value to detect akinesis versus hypokinesis for peak systolic radial strain rate was 1.18 1/s, resulting in a sensitivity of 84.4% and a specificity of 92.7% (ROC curve area 0.933, 95% CI 0.915 to 0.949).

Circumferential strain and strain rate related to segmental LV function

Table 1 gives peak systolic circumferential strain and strain-rate results related to regional LV function defined by cMRI. Peak systolic circumferential strain and strain rate were significantly different between segments defined as normokinetic, hypokinetic and akinetic by cMRI.

ROC curve analysis defined for peak systolic circumferential strain a cut off value of -16.7% to detect dyssynergy with a sensitivity of 93.5% and a specificity of 85.7%. The ROC curve area was 0.947 (95% CI 0.930 to 0.960). Peak systolic circumferential strain-rate analysis enabled detection of dyssynergy defined by cMRI with a sensitivity of 82.2% and a specificity of 79.4% with a cut off value for peak systolic circumferential strain rate of -1.37 1/s (ROC curve area 0.886, 95% CI 0.863 to 0.906).

Comparison of radial and circumferential strain and strain rate to define segmental LV function

Comparison of ROC curves showed a greater accuracy for peak systolic radial strain than for peak systolic radial strain rate in the detection of dyssynergy defined by cMRI ($p = 0.003$). Similarly, peak systolic circumferential strain compared with peak systolic circumferential strain rate had a significantly larger ($p < 0.001$) area under the ROC curve in the detection of dyssynergy. There was no difference between peak systolic radial strain and peak systolic circumferential strain or between peak systolic radial strain rate and peak systolic circumferential strain rate in the detection of dyssynergy defined by cMRI.

DISCUSSION

The major findings of this study are, firstly, that quantitative analysis of regional LV function is possible for most patients by calculation of myocardial strain and strain rate from frame-by-frame tracking of acoustic markers in two dimensional echocardiographic images; secondly, that the data obtained are highly reproducible in repetitive echocardiographic studies and affected by only small intraobserver and interobserver variabilities; thirdly, that the derived peak

Figure 3 Radial strain tracings for one cardiac cycle obtained from the parasternal short axis view in the same patient as in fig 2 (hypokinesis of the anterior wall). There are six tracings for the six evaluated segments within the circumference. The strain rate (SR) tracing of the anterior segment shows a lower peak systolic radial strain than in the other segments. AVC, aortic valve closure; MVO, mitral valve opening.

systolic radial and circumferential strain and strain-rate data enable distinction between normokinetic, hypokinetic and akinetic segments defined by cMRI; and lastly, that peak systolic radial and circumferential strain analysis, compared with corresponding peak systolic strain-rate analysis, enabled better distinction between different functional states defined by cMRI.

Analysis of regional myocardial function

Accurate identification of regional myocardial dysfunction is crucial for the diagnosis and management of patients with coronary artery disease. Currently applied methods rely on a subjective visual assessment of endocardial excursion and wall thickening. Substantial reader dependence with significant interobserver variability in the interpretation of regional function has been documented.¹ Several techniques for more objective evaluation of regional function have been

described such as colour kinesis, which evaluates the endocardial excursion.¹² Owing to cardiac translation and rotation, however, endocardial excursion is not an adequate indicator of regional LV function. Thus, techniques that rely solely on analysis of endocardial excursion have important limitations in the accurate definition of regional function.

Doppler-derived methods to define regional myocardial function

Tissue Doppler-derived myocardial velocities are independent from recognition of local endocardial borders and are therefore less image quality dependent. An important limitation of Doppler-derived myocardial velocity analysis is a considerable non-uniformity of myocardial velocities throughout the left ventricle.^{4,8} If myocardial velocities are analysed from apical views there is a basoapical gradient. In addition, local myocardial velocities are affected by tethering

Table 1 Radial and circumferential strain and strain rate related to regional left ventricular function defined by cardiac magnetic resonance imaging

	Normokinesis (n = 399 segments)	Hypokinesis (n = 392 segments)	Akinesis (n = 110 segments)	p Value
Circumferential strain (%)	-21.4 (3.8)	-14.1 (3.2)	-9.4 (3.0)	<0.001
Radial strain (%)	36.8 (10.5)	24.1 (7.5)	13.4 (4.8)	<0.001
Circumferential strain rate (1/s)	-1.62 (0.25)	-1.26 (0.24)	-0.90 (0.27)	<0.001
Radial strain rate (1/s)	1.58 (0.27)	1.27 (0.23)	0.89 (0.26)	<0.001

Data are mean (SD).

Figure 4 Radial strain values related to segmental function defined by cardiac magnetic resonance imaging (cMRI) for all analysed left ventricular segments. The upper line shows the best cut off value to define normokinesia versus wall motion abnormality defined by cMRI based on the radial strain value. The lower line shows the best cut off value to define hypokinesia versus akinesia defined by cMRI based on the radial strain value.

effects from adjacent segments, further impairing the ability to define local myocardial function.⁴⁻⁸ Doppler-derived strain and strain-rate analysis has been suggested to circumvent these difficulties.⁴⁻⁶⁻⁸ Considering the velocity difference between two points in space, the tissue deformation between these points is calculated. Analysis of regional LV function has been shown to have improved accuracy compared with mere tissue velocity analysis.⁸⁻¹³ Values of myocardial strain and strain rate were also found to be relatively homogeneous in all regions of the heart, reflecting independence from the apicobasal location of the evaluated segment.⁴⁻⁵⁻¹¹ Doppler-derived strain and strain-rate analysis has, however, been shown to be very angle dependent. Urheim *et al*⁸ showed in a study with 13 dogs that at an intermediate angle of about 45°, strain values close to zero will be measured, and directionally opposite strain values are measured if the angle between the ultrasonic beam and the LV axis is > 45°. Thus, the method can be applied only if small angles between the Doppler beam and the direction of the evaluated myocardial function are achieved. Correct orientation of the echo beam is therefore critical and will often be obtained only by limiting echocardiographic images to a small viewing angle. In addition, significant noise artefacts may limit the evaluation of Doppler-derived strain-rate data in clinical practice.

Two dimensional echocardiography-derived strain and strain rate

The two dimensional echocardiography-based technique applied in this study tracks acoustic markers from frame to frame. This technique has become possible with the availability of ultrasound equipment enabling high frame-rate second harmonic imaging. This new generation of ultrasound equipment enables the required high resolution to be achieved and lowers the speckle noise, both of which are required for reliable tracking of acoustic markers. Analysis of radial as well as circumferential strain and strain rate is possible based on the tracking of acoustic markers through several frames. Radial strain relates to the extent of myocardial wall thickening, whereas radial strain rate relates to the velocity of wall thickening. Circumferential strain and strain rate relate to fibre shortening along a circumferential line. Compared with previous Doppler-based studies that determined strain and strain rate based on velocity gradients

between different points in space, defining deformation parameters based on the tracking of acoustic markers relates to different distances in movement over time between different points in space. Owing to the association of velocity and distance by the factor time, strain and strain rate defined on Doppler-based analysis or pixel tracking-based analysis come to similar results as has been shown previously.¹⁴

The major advantage of the new imaging technique is that it enables analysis of radial and circumferential strain and strain rate from short-axis views. Thus, we focused on analysis of the new available parameters. A previous study showed that the technique enables distinction between infarcted and non-infarcted myocardial segments based on longitudinal strain and strain rate.¹¹ The current study compared peak systolic circumferential and radial strain and strain rate obtained by acoustic marker tracking versus regional LV function defined by cMRI. A clear difference in peak systolic strain and strain-rate values was found between different regional functional states. Furthermore, impaired regional function (hypokinesia, akinesia and dyskinesia) was detectable with high accuracy based on radial and circumferential strain values. Thus, it is possible to detect impaired regional function based on this objective, rapidly performed analysis algorithm. Strain analysis had a higher accuracy than strain-rate analysis for the assessment of regional myocardial function. This may be due to the greater noise artefacts encountered with strain-rate analysis than with strain analysis. Urheim *et al*⁸ also noted the significant noise artefacts as a possible limitation for Doppler-derived strain-rate analysis. Possibly because of this limitation, Leitman *et al*¹¹ found that the correlation between strain rate defined by two dimensional echocardiography and strain rate defined by Doppler tissue imaging was weaker than the correlation between strain values defined by the two imaging modalities. Radial strain, which reflects the extent of wall thickening, may also relate better to the visual assessment of wall thickening as an important component in the regional function analysis of cMRIs, whereas radial strain rate reflects the velocity of wall thickening, a parameter not specifically defined by visual analysis or regional myocardial function. Longitudinal and circumferential strain-rate analysis has been the preferred strain and strain-rate analysis based on Doppler echocardiography. This has been due to a better alignment of the Doppler beam with the circumferential myocardial deformation axis in most cases.

We are used to describing regional function mainly on the basis of myocardial thickening, however, which is described better by radial strain and strain-rate analysis. In this respect, two dimensional echocardiography-derived strain analysis allows use of a form of myocardial function analysis to which we are more accustomed. An important advantage of the applied strain analysis based on two dimensional echocardiographic images compared with previous Doppler-based strain and strain-rate analysis is the automatic calculation of mean values from total predefined LV segments. This approach reflects segmental function better than does the analysis of only one point in space used in previous Doppler-based strain and strain-rate analysis.

Limitations

This study did not compare strain and strain rate obtained by tracking of acoustic markers within two dimensional echocardiographic images against cMRI tissue tagging. cMRI tagging would have been the ideal method to quantify regional LV function. cMRI tissue tagging is, however, still mainly used as an investigational tool and is affected by potential noise artefacts. In clinical practice, distinguishing between normal and abnormal regional function or categorising regional function into three different states such as

normokinesis, hypokinesis and akinesis or dyskinesis is still common practice. Visual analysis of regional function based on cMRI is subjective but considered reliable due to an excellent image quality in most cases and was associated with a high interobserver agreement in this study.

Conclusion

The present study showed the ability of radial and circumferential strain and strain rate derived by tracking of acoustic markers within two dimensional echocardiographic images to describe regional LV function. Radial and circumferential strain appear more accurate than strain-rate parameters to delineate contraction states. The rapid mode of application, high success rate and lack of angle dependency support the use of the obtained parameters for quantitative analysis of regional myocardial function in clinical practice.

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IMAGES IN CARDIOLOGY

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Perforated aortic valve leaflets

A 59-year-old woman with intractable left heart failure caused by severe aortic regurgitation underwent emergency aortic valve replacement. She had originally presented four months earlier with dyspnoea, pyrexia (38.8°C) and signs of pneumonia. Blood cultures were not taken and she was treated with intravenous antibiotics. After four weeks her dyspnoea improved but four weeks later she deteriorated and signs of aortic regurgitation were noticed. Echocardiography confirmed moderate aortic regurgitation and a suspected vegetation on the aortic valve. Blood cultures were negative but despite intravenous antibiotics the aortic regurgitation worsened rapidly. She deteriorated clinically with the development of pulmonary oedema and subsequently signs of congestive cardiac failure despite high doses of diuretics. She was then referred for surgery. Cardiac catheterisation was impossible because of her desperate clinical state and she underwent emergency aortic valve replacement. The illustration shows large perforations in two aortic valve cusps without evidence of vegetations. The valve was successfully replaced by a 21 mm porcine Mosaic valve (Medtronic) and although she required a prolonged period of postoperative care, the signs of congestive cardiac failure resolved.

Culture-negative endocarditis, as in this case, is frequently caused by prior treatment with antibiotics. The presentation with severe pneumonia suggests that the responsible organism may have been *Streptococcus pneumoniae* which may cause aortic valve endocarditis and subsequently cusp perforation, progressively severe aortic regurgitation, and intractable

cardiac failure. Congestive cardiac failure may result from severe aortic regurgitation caused by endocarditis and treatment necessitates urgent surgical intervention. Prompt diagnosis and referral to a tertiary centre is essential before this serious late complication develops.

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