# Doppler echocardiographic evaluation of valve regurgitation in healthy volunteers

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**Abstract**

***Objective*—To study the prevalence and the characteristics of physiological valve regurgitation.**

***Design*—Pulsed wave Doppler echocardiography, continuous wave Doppler echocardiography and Doppler colour flow mapping were performed prospectively in healthy volunteers.**

***Setting*—Echocardiography laboratory in a city hospital.**

***Patients*—32 consecutive healthy volunteers (age 21–49 years, mean age 29·4).**

***Main outcome measures*—Identification of regurgitation with colour Doppler flow mapping and measurement of the jet area, jet length, and maximal velocity of the regurgitation.**

***Results*—Regurgitation was recorded at the pulmonary (100%), tricuspid (100%), mitral (56%), and aortic valves (6%). The velocity of pulmonary and tricuspid regurgitation was similar to that predicted from the pressure gradient calculated from the Bernoulli equation. The jet area and jet length were generally small.**

***Conclusion*—Trivial regurgitation from the pulmonary, tricuspid, and mitral valves is common in healthy people. It is important to take such regurgitation into account when valve disease is diagnosed.**

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Doppler echocardiography is specific and sensitive for the diagnosis of valve regurgitation and is as effective as cineangiography.[1] Because it is non-invasive this technique can be used to study healthy people. Several recent studies[2-4] have reported variable prevalence of valve regurgitation in subjects without evidence of cardiac disease. For all these studies only one or two Doppler modes were used.[5 6] We used pulsed wave, continuous wave, and colour Doppler echocardiography to determine the prevalence and the characteristics of cardiac valve regurgitation in healthy volunteers.

## Patients and methods

### STUDY POPULATION

Twenty five healthy men and seven healthy women aged 21–49 (mean (SD) 29·4 (7·9)) from the medical and paramedical staff and patients without heart disease agreed to be studied. Each had a "healthy heart" according to a clinical examination, electrocardiogram, chest *x* ray, and cross sectional echocardiography. The first 32 subjects examined were normal: none was subsequently excluded.

### DOPPLER TECHNIQUE

We used a commercial system (Vingmed CFM 700) with a 3 MHz transducer to provide simultaneous cross sectional echography, spectral analysis, and colour Doppler imaging. Spectral analysis with pulsed wave Doppler was obtained for a 7 mm sample volume. A wall filter was used for pulsed and continuous wave Doppler, with the lowest cut off frequencies when low velocities were read and with the highest when high velocities were read. Frequency analysis of the Doppler signal was carried out by a real time chirp Z transformer and full spectral analysis was performed at 100 mm/s. For colour Doppler imaging, the wall filter was set at 0·21 m/s, radial resolution was maximal, the frame rate used was 12–14 frames/sec, and the cineloop was used for systematic retrospective analysis.

Examination was undertaken with subjects supine or in the left lateral decubitus position. Each valve was evaluated by colour flow mapping and by pulsed and continuous wave Doppler echocardiography. We used the parasternal long axis, parasternal short axis, apical long axis, and apical four chamber views to image the mitral and aortic valves and the high left parasternal short axis view for the pulmonary valve.

For the tricuspid valve we recorded traces in the right ventricular inflow view and parasternal and apical four chamber views.

If the flow signal in colour Doppler flow mapping showed reversed flow away from the valve when the valve was closed regurgitation was said to be present. Signals of very short duration detected only at the time of valve closure were not regarded as true regurgitation. Studies with pulsed and continuous wave Doppler ultrasound were then performed to confirm the presence of regurgitation and to measure the maximal velocity of the jet.

If evidence of regurgitation was found, the last 56 colour images recorded with cineloop were studied immediately and the view showing the largest regurgitation was chosen. We used software programme incorporated into the equipment to trace the outline of the

*Table 1 Individual results for detection of right-sided regurgitation and mitral regurgitation by Doppler echocardiography*

| | | Pulmonary regurgitation | | | | Tricuspid regurgitation | | | Mitral regurgitation | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Case | Age and sex | PV (m/s) | EDV (m/s) | JA (cm²) | JL (cm) | PV (m/s) | JA (cm²) | JL (cm) | PV (m/s) | JA (cm²) | JL (cm) |
| 1 | 29 F | 0·52 | 0·36 | 2·7 | 2·6 | 1·11 | 2·2 | 1·7 | | | |
| 2 | 30 M | 2·00 | 1·06 | 1·4 | 2·4 | 2·09 | 3·2 | 3·1 | 4·00 | 1·5 | 1·7 |
| 3 | 49 F | 0·83 | 0·42 | 2·0 | 1·7 | 2·30 | 1·2 | 3·1 | 4·15 | 1·0 | 2·4 |
| 4 | 45 M | 0·69 | 0·36 | 3·0 | 2·5 | 2·05 | 2·5 | 2·5 | | | |
| 5 | 23 F | 0·67 | 0·21 | 3·0 | 2·0 | 2·34 | 4·1 | 3·8 | 4·70 | 3·8 | 2·7 |
| 6 | 27 M | 1·20 | 0·81 | 0·4 | 0·8 | 2·18 | 1·5 | 3·1 | | | |
| 7 | 43 F | 1·54 | 0·99 | 1·0 | 1·5 | 2·12 | 2·2 | 2·0 | | | |
| 8 | 26 M | 1·51 | 0·72 | 0·4 | 0·8 | 2·06 | 3·1 | 2·1 | | | |
| 9 | 30 M | 0·76 | 0·42 | 0·4 | 0·8 | 2·08 | 4·3 | 2·3 | 3·30 | 3·2 | 2·4 |
| 10 | 24 M | 1·30 | 0·65 | 0·6 | 1·4 | 2·30 | 1·5 | 2·4 | 3·45 | 0·8 | 1·9 |
| 11 | 36 M | 1·34 | 0·59 | 1·1 | 1·3 | 2·37 | 2·8 | 2·3 | | | |
| 12 | 22 M | 1·21 | 0·75 | 2·0 | 2·7 | 2·46 | 1·2 | 1·1 | 3·92 | 2·0 | 2·3 |
| 13 | 37 M | 1·75 | 0·95 | 0·5 | 1·6 | 2·14 | 1·2 | 2·5 | | | |
| 14 | 24 M | 1·23 | 0·50 | 0·6 | 1·1 | 2·26 | 1·9 | 1·8 | | | |
| 15 | 26 F | 1·06 | 0·83 | 0·4 | 1·2 | 1·86 | 1·7 | 1·8 | 3·52 | 0·8 | 1·0 |
| 16 | 22 M | 1·56 | 0·91 | 0·6 | 1·4 | 1·93 | 2·9 | 2·3 | | | |
| 17 | 25 M | 1·39 | 0·62 | 0·6 | 0·7 | 2·29 | 0·8 | 2·5 | | | |
| 18 | 22 M | 1·36 | 0·62 | 0·3 | 0·8 | 1·87 | 1·4 | 1·7 | | | |
| 19 | 40 F | 1·43 | 0·67 | 0·7 | 0·2 | 1·89 | 1·2 | 0·7 | 3·67 | 1·8 | 1·3 |
| 20 | 21 M | 1·10 | 0·75 | 1·4 | 0·6 | 1·91 | 1·3 | 0·5 | 3·71 | 1·5 | 0·6 |
| 21 | 25 M | 1·97 | 1·01 | 0·3 | 0·6 | 2·19 | 0·8 | 1·7 | 3·86 | 1·1 | 1·8 |
| 22 | 25 F | 1·48 | 0·87 | 1·1 | 0·9 | 1·98 | 0·7 | 1·5 | 4·42 | 1·4 | 0·6 |
| 23 | 32 M | 1·33 | 0·50 | 0·5 | 1·0 | 2·44 | 0·3 | 1·1 | | | |
| 24 | 23 M | 1·61 | 0·42 | 0·3 | 0·8 | 2·14 | 1·3 | 1·8 | 3·28 | 0·5 | 0·9 |
| 25 | 33 M | 1·86 | 0·97 | 0·9 | 0·5 | 2·22 | 1·0 | 1·0 | | | |
| 26 | 21 M | 1·64 | 1·06 | 0·5 | 1·0 | 2·07 | 0·3 | 0·9 | 4·86 | 0·8 | 1·4 |
| 27 | 36 M | 1·68 | 0·99 | 0·7 | 1·3 | 2·14 | 4·2 | 3·2 | 4·67 | 1·8 | 2·8 |
| 28 | 29 M | 1·59 | 1·12 | 0·7 | 1·3 | 2·22 | 0·5 | 0·7 | 3·43 | 1·3 | 0·6 |
| 29 | 27 M | 1·12 | 0·87 | 0·6 | 0·3 | 2·21 | 1·4 | 0·6 | 3·88 | 1·3 | 0·7 |
| 30 | 31 M | 1·36 | 1·00 | 1·4 | 1·0 | 2·15 | 1·4 | 1·0 | 3·64 | 1·2 | 1·6 |
| 31 | 29 M | 1·84 | 0·73 | 0·5 | 1·0 | 2·61 | 0·8 | 0·4 | | | |
| 32 | 32 M | 1·45 | 0·41 | 1·5 | 1·1 | 2·11 | 1·2 | 1·2 | 3·64 | 1·6 | 1·6 |
| Mean | 29·4 | 1·36 | 0·72 | 1·0 | 1·22 | 2·13 | 1·75 | 1·83 | 3·89 | 1·52 | 1·57 |
| (SD) | (7·9) | (0·38) | (0·25) | (0·78) | (0·65) | (0·26) | (1·11) | (0·89) | (0·49) | (0·83) | (0·74) |

EDV, end diastolic velocity; JA, jet area; JL, jet length; PV, peak velocity.

regurgitant jet area with a joystick and to calculate the area by computerised planimetry. The jet length was also measured.

All values are given as mean (SD).

## Results

Table 1 summarises the results in individual patients.

### PULMONARY VALVE

Pulmonary regurgitation (figs 1 and 2) was present in all subjects. In 50% of the subjects, a regurgitant pandiastolic flow was recorded, while in the rest no regurgitation was recorded during early diastole. All the regurgitant flows were detected with the three Doppler modes. The velocities ranged from 0·5 to 2 m/s in early diastole and from 0·2 to 1·1 m/s in later diastole. Generally the intensity of the signal was weak and the A wave was clearly visible.

### TRICUSPID VALVE

Tricuspid regurgitation (figs 3 and 4) was detected in all subjects by all three Doppler modes. In all subjects, the regurgitant flow was pansystolic. The peak velocity recorded by continuous wave Doppler ultrasound ranged from 1·1 to 2·6 m/s. The mean gradient between the right ventricle and the right atrium estimated by the simplified Bernoulli equation was 18·4 (4) mmHg. Tricuspid regurgitation was not constant and generally was recorded only during inspiration.

### MITRAL VALVE

Mitral regurgitation (figs 5 and 6) as defined in the methods was detected in 18 subjects by all three Doppler modes. The Doppler signal was pansystolic in 14 subjects and recorded only on early systole in the other four. In 13 other

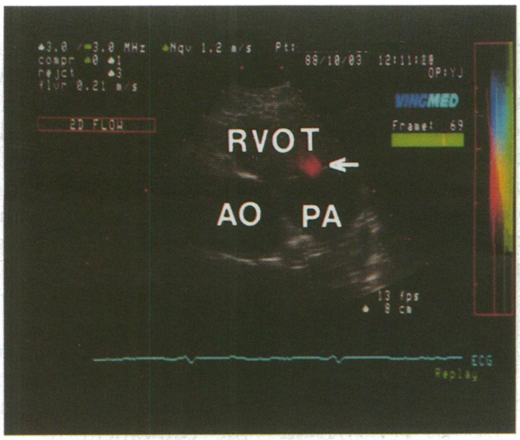


*Figure 1 Parasternal short axis view showing red signal in the right ventricular outflow tract during diastole which is indicative of pulmonary regurgitation. AO, aorta; RVOT, right ventricular outflow tract; PA, pulmonary artery.*

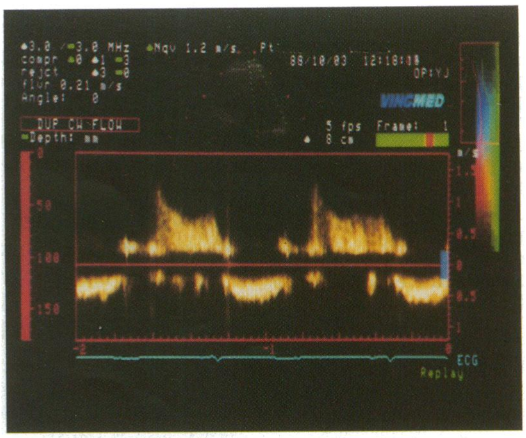

*Figure 2 Continuous Doppler echocardiogram from the same subject as in fig 1.*

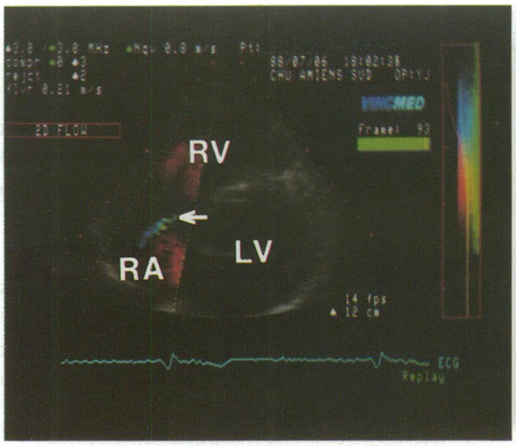


*Figure 3 Low parasternal view showing a blue and green signal in the right atrium during systole which was indicative of tricuspid regurgitation. LV, left ventricle; RA, right atrium; RV, right ventricle.*

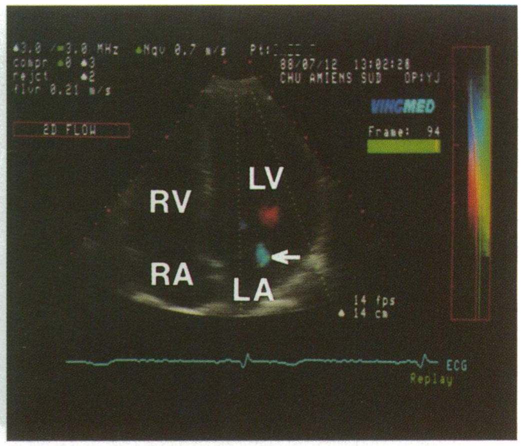


*Figure 5 Apical four chamber view showing blue and green signal in the left atrium during systole that was indicative of mitral regurgitation. LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle.*

subjects, a regurgitant colour Doppler pattern was detected only at the time of valve closure but was not confirmed by pulsed wave or continuous wave Doppler echocardiography. These flows were not regarded as true regurgitation.

AORTIC VALVE

Aortic regurgitation (fig 7) was detected by colour Doppler in two subjects (cases 2 and 5) and was characterised by a pandiastolic signal originating from the centre of coaptation of the aortic cusps. The jet areas were 0·7 and 1·8 $cm^2$, the jet lengths were 2 and 1·9 cm, and the jet sectional diameters were 0·2 and 0·25 cm respectively. A pandiastolic Doppler signal was recorded with pulsed and continuous wave Doppler but the signals were always of low intensity with a poorly defined spectral envelope. The highest velocities recorded were 2·1 and 2 m/s respectively in cases 2 and 5, but the regurgitation was clearly shown on the Colour Doppler echocardiograms.

## Discussion

PREVALENCE OF VALVE REGURGITATION IN HEALTHY VOLUNTEERS

Our results showed that pulmonary, tricuspid, and mitral regurgitation were common in healthy individuals whereas aortic regurgitation was not. Table 2 shows the results reported by others: the frequency of pulmonary regurgitation ranged from 5%[15] to 96%,[4] that of tricuspid regurgitation from 17%[15] to 100%[8], and that of mitral regurgitation from 10% [3] to 100%.[8] The reported frequency of aortic regurgitation ranged from 0%,[3,5,9] to 75%.[8] Most groups found that aortic regurgitation was rare. These discrepancies may be related to several factors including the study group and the mean age of those studied (22[10] to 66[7]). We studied a young group and there was no problem with echogenicity. Also we used the CFM 700 Vingmed and all three possible modes. It has been suggested that colour flow mapping has the highest sensitivity.[11,12] The Doppler adjustments, the experience of the examiner, and the time spent in collecting the data will also affect the results. Uniform diagnostic criteria were not used in all the studies. For example, use of pulsed Doppler echocardiography alone may lead to false diagnosis of valve regurgitation.[4] We agree with Sahn and Maciel's suggestion that velocity criteria are very important because if the velocity recorded is similar to that expected for the pressure gradient between the chambers predicted by the Bernoulli equation (velocity about 1 m/s for

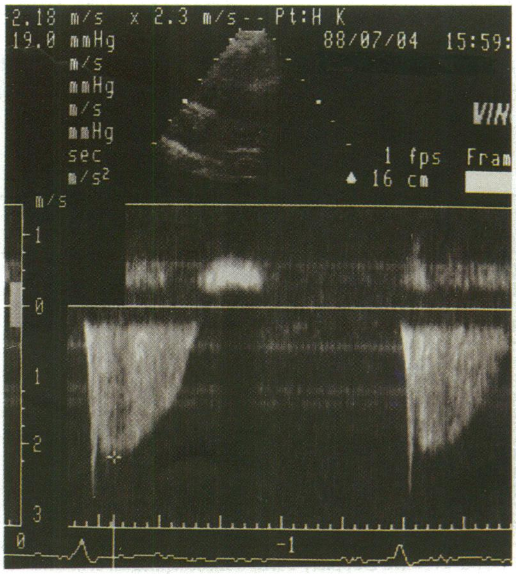


*Figure 4 Continuous Doppler echocardiogram from the same subject as in fig 3.*

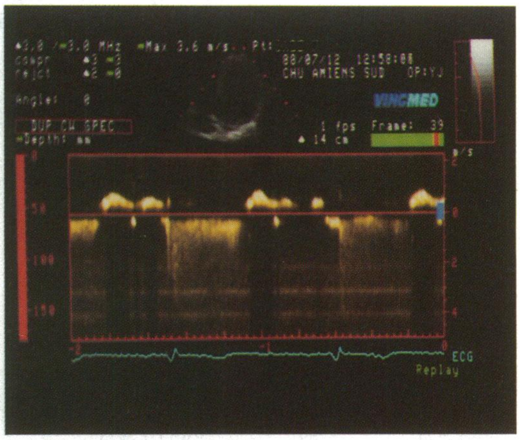


*Figure 6 Continuous Doppler echocardiogram from the same subject as in fig 5.*

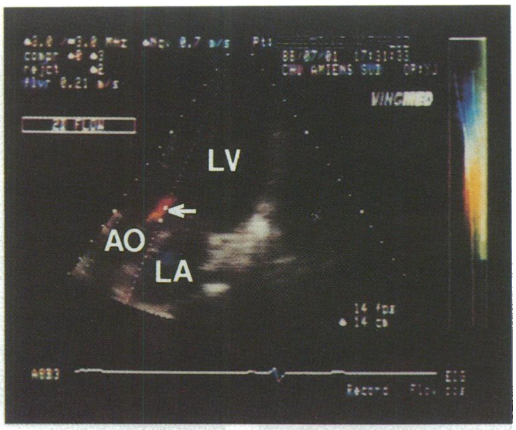


*Figure 7 Apical long axis view showing yellow and red signal in the left ventricular outflow tract during diastole that was indicative of aortic regurgitation. AO, aorta; LA, left atrium; LV, left ventricle.*

the pulmonary valve, 2 m/s for the tricuspid valve and 4 m/s for the mitral and aortic valves) regurgitation is unlikely.[13] However, for the mitral and aortic valves, velocities of about 3 m/s could be true regurgitation because according to Holen *et al*[14] Bernoulli's equation cannot be applied to minor regurgitation. Berger *et al* agreed with such diagnostic criteria. For instance, in two of our subjects the colour Doppler investigation showed obvious aortic regurgitation though the velocity measured by continuous wave Doppler was only about 2 m/s. Our study indicates that aortic regurgitation can occur in normal hearts. We did not have any problems in recording the maximum velocities of right-sided regurgitation. We found it difficult to diagnose mitral regurgitation, however, because in some subjects it was not consistently found. Perhaps all regurgitant flows that are not consistent are not true regurgitation.

CHARACTERISTICS OF PULMONARY VALVE REGURGITATION

Pulmonary valve regurgitation was very easy to record in the high left parasternal short axis view. Failure to record early diastolic flow is common, however, and may be due to the angle of incidence of the beam. The maximal velocities recorded did not show pulmonary hypertension.

CHARACTERISTICS OF TRICUSPID VALVE REGURGITATION

Tricuspid valve regurgitation too was easy to record especially during inspiration. The maximal velocities recorded did not show pulmonary hypertension. It may well be that peak velocities suggesting right ventricular systolic hypertension could indicate an abnormality. Although some[6] have suggested that an extension of true regurgitation of more than 1 cm is definitely abnormal, we found that physiological regurgitation can extend as far as 4 cm from the annulus.

CHARACTERISTICS OF MITRAL REGURGITATION

Mitral valve regurgitation was, however, not easy to record: it can take 15 minutes for the three Doppler modes. It is best recorded in the apical four chamber or two chamber views. The intensity of the Doppler signal was always weak, indicating its benign nature. We believe that neither the jet area nor the jet length are criteria that can be used to distinguish between pathological and physiological regurgitation because these values overlap.

CHARACTERISTICS OF AORTIC REGURGITATION

Aortic regurgitation though rare was easy to record with colour Doppler flow mapping. There was little difference between this normal regurgitation and slightly abnormal regurgitation. The peak velocity, however, can be difficult to record as it was in Berger *et al's* study[6] and in our study.

AGE, SEX, AND VALVE REGURGITATION

The prevalence of regurgitation is reported to be influenced by age,[7] especially of the mitral and aortic valves. The relation between age and right-sided regurgitation is not clear because the results of the different studies are contradictory. Yoshida[5] reported a decrease in regurgitation with age, whereas Akasaka[7] reported an increase. We studied young patients (mean age 29·4) and consistently found right-sided regurgitation. The reported decrease in the prevalence of right-sided regurgitation with age may be explained by the decrease in echogenicity. Wear and tear[15] may explain the reported increase in the prevalence of left-sided regurgitation with age.[5–7] The prevalence of regurgitation seems to be the same in males and females.[6] Regurgitation was reported to be associated with long distance running.[16]

CLINICAL IMPLICATIONS

Valve regurgitation was common in individuals

*Table 2 Reported prevalence of valve regurgitation*

| *Author* | *Year* | *Doppler mode* | *n* | *Mean age* | *Pulmonary valve (%)* | *Tricuspid valve (%)* | *Mitral valve (%)* | *Aortic vale (%)* |
|---|---|---|---|---|---|---|---|---|
| Takao *et al*[17] | 84 | PWD | 50 | | 78 | | | |
| Yock *et al*[3] | 84 | CWD | 20 | | 35 | 95 | 10 | 0 |
| Malergue and Laurenceau[10] | 85 | PWD | 61 | 22 | 65 | | | |
| Kostucki *et al*[4] | 86 | PWD | 25 | 24 | 92 | 44 | 40 | 33 |
| Akasaka *et al*[7] | 87 | PWD | 176 | 66 | 30 | 34 | 34 | 39 |
| Feshke *et al*[18] | 87 | CWD, CFM | 100 | | 91 | | | |
| Gregoire *et al*[19] | 88 | CFM | 25 | | | | 44 | |
| Pollak *et al*[16] | 88 | CFM | 46 | 28 | 52 | 57 | 22 | 2 |
| Wittlich *et al*[8] | 88 | TOE | 20 | 23 | | 100 | 100 | 75 |
| Yoshida *et al*[5] | 88 | CWD, CFM | 211 | 29 | 57 | 52 | 43 | 0 |
| Taams *et al*[20] | 89 | TOE | 11 | 31 | | | 36 | |
| Choong *et al*[15] | 89 | PWD | 867 | | 5 | 17 | 19 | 3 |
| Berger *et al*[6] | 89 | PWD, CWD | 100 | 45 | 31 | 50 | 21 | 1 |
| Our study | | PWD, CWD, CFM | 32 | 29 | 100 | 100 | 56 | 6 |

CFM, colour flow mapping; CWD, continuous wave Doppler; PWD, pulsed wave Doppler; TOE, transoesophageal echocardiography.

with structurally normal hearts. We found that right-sided regurgitation was almost always present and its absence was probably related to a lack of ultrasound penetration. Mitral regurgitation was also common but aortic regurgitation was rare. Regurgitation should be noted in the patient's records, but it must be stated that these flows are not abnormal.

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