Correlation between Murmurs and Echocardiographic Findings; From an Imaging Cardiologist Point of View

Sahrai Saeed[a*], Abukar Mohamed Ali[a], Daanyaal Wasim[a], Ivar Risnes[a], and Stig Urheim[a,b]

From the [a] *Department of Heart Disease, Haukeland University Hospital, Bergen, Norway and* [b] *Department of Clinical Science, University of Bergen, Bergen, Norway.*

Abstract: A heart murmur in adults is a common reason for referral for echocardiography at most general cardiology clinics in Europe. A murmur may indicate either a mild age-related valvular calcification or regurgitation, or represent a significant heart valve disease requiring valvular intervention. Generally, the correlation between murmurs by auscultation and severity of heart valve disease by echocardiography is poor. Particularly, the severity and characterization of diastolic murmurs by auscultation may poorly correlate with echocardiographic findings. This narrative review aims to summarize the differential diagnoses of physiological and pathological murmurs, describes the current referral practice of murmur patients for echocardiography, and presents a single-center experience on the correlation of auscultation and echocardiographic findings with a particular focus on aortic and mitral valve diseases. A careful auscultation of the heart prior to the echocardiogram is mandatory and may help to predict the echocardiographic findings and their interpretation in view of the clinical information. The correlation between clinical examination, point of care ultrasound and standard echocardiography is a matter of continued exploration. (Curr Probl Cardiol 2023;48:101479.)

Curr Probl Cardiol 2023;48:101479
0146-2806/$ – see front matter
https://doi.org/10.1016/j.cpcardiol.2022.101479

Introduction

The prevalence of valvular heart disease (VHD) is increasing in developed countries due to longer life expectancy. VHD is a major public-health concern and causes significant morbidity and mortality if not timely treated.[1-2] Early detection of VHD patients and referral to specialist valve clinics for follow-up is essential to ensure timely intervention, which has been shown to improve outcome.[3-4] In Norway, similar to other European countries,[5-7] heart murmur is one of the most common reasons for referral for transthoracic echocardiogram (TTE) at "Cardiology Evening Clinics" to exclude significant VHD or congenital heart disease. Physiological murmurs are often related to increased flow where the valve essentially is normal. Innocent murmurs occur where the heart in fact is normal. A murmur may indicate either a mild age-related non-significant valvular calcification or regurgitation, or represent a significant heart valve disease requiring valvular intervention. Generally, the correlation between murmurs by auscultation and severity of VHD by echocardiography is poor. Studies from UK and Holland have shown that only less than a third of patients who were referred from community for a TTE because of asymptomatic murmur had a VHD of any grade.[5-7] However, the referral practice among general practitioners (GPs) in the community and hospital physicians varies. The quality of description of heart murmurs also differ between physicians in primary and secondary care. Auscultation by GPs has been shown to be less sensitive and non-specific in terms of detection of VHD.[8-9] Overall, there have been few large-scale phonographic studies exploring the correlation of murmurs with echocardiographic findings. After reviewing relevant literature in the field, as well as considering our own experiences from general cardiology clinics and specialist valve clinics, we present here: (1) an overview of the differential diagnoses of physiological and pathological murmurs; (2) describe the current referral practice of murmur patients for TTE and highlight the role of murmur clinics, and (3) discuss the correlation of auscultatory and echocardiographic findings. Focus is mainly directed towards aortic and mitral valve diseases related murmurs.

Methods

The electronic database PubMed was systematically searched for relevant original studies and review articles in English. The keywords "Auscultation", "Heart valve disease", "Murmur" and "Transthoracic echocardiography" were used.

Normal Heart Sounds and Murmurs

A normal beating heart makes 2 sounds commonly characterized as *"lub-dupp"*. "Lub" is the first sound produced by the closure of mitral and tricuspid valves and *"Dupp"* or *"Dub"* is the second sound caused by the closure of aortic and pulmonary valves. A systematic auscultation should include 4 standard points, and the intermediate positions between these points with the patient at 45°, and at the left sternal edge while patient sitting forward, and at the apex and axilla lying on the left side.[5] Carotid arteries should also be gently auscultated on both sides and primary stenotic sounds due to carotid artery stenosis should be differentiated from the heart murmurs (primarily due to aortic valve disease) radiating towards carotid artery sites.

Murmurs are unusual cardiac sounds caused by turbulent blood flow, forced through a narrowed heart valve (stenosis), intraventricular or arterial obstruction, or leaking backward through the valve when it should be closed (regurgitation or insufficiency). Murmurs are either physiological/benign or pathological (Fig 1 and Table 1). Some heart murmurs are innocent, commonly found in children, and may not require treatment or strict follow-up. In most cases, these murmurs disappear with age. Innocent murmurs can also be present in adults and an echocardiogram may not always clarify their etiology. Benign murmurs in healthy hearts are common during pregnancy, fever and in some other non-cardiac conditions such anemia, polycythemia, liver cirrhosis and thyrotoxicosis. These murmurs are often changeable in character, intensity and over the course of the day/night. A careful TTE, if needed combined with change in posture and/or physical maneuvers (Valsalva, leg rising, etc) is required to reveal the cause of less severe murmurs. By contrast, pathological murmurs are caused by valvular stenosis or regurgitation, congenital heart disease (coarctation of aorta, patent ductus arteriosus, ventricular septal defect, atrial septal defect with subsequent increased pulmonary flow), rheumatic heart disease or infective endocarditis. Generally, systolic murmurs are caused by aortic and pulmonary valve stenosis, and mitral and tricuspid valve regurgitation, and diastolic murmurs include aortic and pulmonary regurgitation murmurs and mitral and tricuspid valve rumbles.

A newly detected murmur in a patient with acute myocardial infarction may be an alarming sign for serious complications, such as acute mitral regurgitation due to papillary muscle/chordae ruptur or ventricular septal rupture. Similarly, a new murmur in a patient with infective endocarditis may indicate valvular dysfunction or structural valve deterioration in

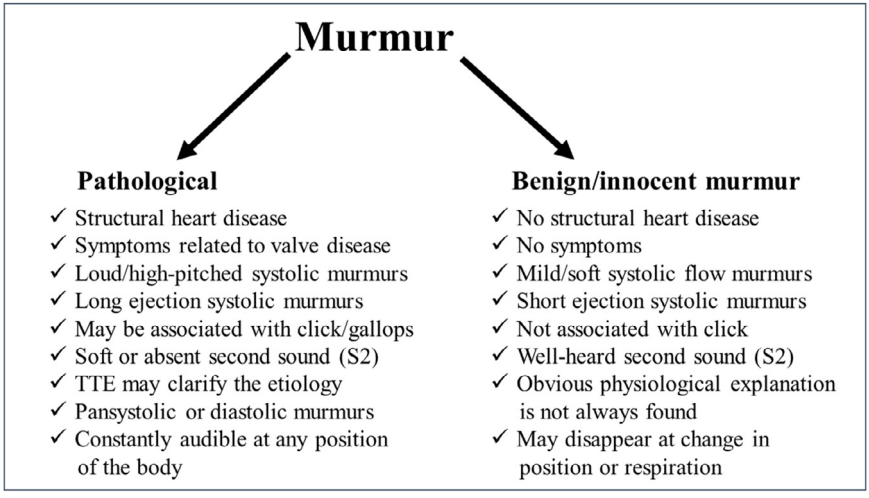

FIG 1. The differential characteristics of benign (physiological) and pathological murmurs.

patients with a prosthetic heart valve. Acute aortic syndromes, particularly aortic dissection type A and aortic aneurysm, may be associated with aortic regurgitation (AR) and diastolic murmur. In these life-threatening situations an urgent echocardiogram should be arranged to clarify the etiology of murmur and guide further treatment. Furthermore, a loud systolic murmur at the aortic area of the chest in elderly patients admitted with new syncope should immediately rise the suspicion of aortic stenosis (AS) and prompt a standard TTE.

In some young female patients with milder form of VHD or congenital heart disease, a relatively rapid increase in the intensity of murmur during pregnancy may suggest load-dependent worsening of the VHD, which is an indication for extra clinical and echocardiographic control to assess the hemodynamic significance of the associated VHD.

Murmurs in Aortic Valve Disease

After mitral regurgitation, AS is the most prevalent form of VHD caused by either progressive degeneration/calcification of a trileaflet aortic valve (TAV) or bicuspid aortic valve (BAV).[10] A number of predictors of rapid hemodynamic progression including male sex, smoking, dyslipidemia, diabetes mellitus, hypertension, chronic kidney disease and coronary artery disease have been identified.[11] In Western countries, degenerative AS is highly prevalent, while in South Asian and African countries, rheumatic heart disease is a common cause of VHD. The

Table 1. Auscultatory characteristics/description of cardiac murmurs.

Description	Criteria
Phase	• Early, mid or late systolic/diastolic, holosystolic • Continuous "machine-like" murmurs (PDA) • Mid-ejection click – late systolic murmur (Barlow)
Location	• Aortic valve: 2nd intercostal space at the RSB • Pulmonary valve: 2nd intercostal space at the LSB • Tricuspid valve: 4th intercostal space at the LSB • Mitral valve: 5th intercostal space at the left midclavicular line
Radiation	• Murmurs may radiate and can be audible at remote locations such as axilla, carotids, back (coarctation of the aorta) and epigastrium
Intensity	• Grade I: hardly audible (faint murmur) • Grade II: soft murmur • Grade III: easily audible but without a palpable thrill • Grade IV: easily audible with a palpable thrill • Grade V: loud murmur, audible with stethoscope lightly touching the chest • Grade VI: loudest murmur, audible with stethoscope not touching the chest
Pitch	• High or low frequency
Characteristics	• Blowing, harsh, musical, rumbling, squeaky • Loud ejection systolic murmur (aortic stenosis) • Normal splitting of the second heart sound (S2) • Second sound (S2): Preserved or silent (severe aortic stenosis)
Profile	• Crescendo: a murmur increasing in intensity • Decrescendo: a murmur decreasing in intensity • Crescendo-decrescendo: a murmur first increasing in intensity, reaches peak, and then declines in intensity • Plateau: stable intensity

PDA, patent ductus arteriosus; RSB, right sternal border; LSB, left sternal border.

systolic murmur in AS has a crescendo-decrescendo characteristic, best heard along the left sternal border radiating to the upper right sternal border and carotid arteries, or in some cases to the left ventricle (LV) apex mistaken with mitral regurgitation murmur. During the progression of AS severity, the duration of the murmur increases, peaking at mid-to-late systole. However, the intensity of the murmur does not always correspond to the severity of AS. Despite a similar peak aortic jet velocity and severity of AS, the grade of murmur may vary from patient to patient (Fig 2–3). Heart rate and rhythm (particular rapid atrial fibrillation), stroke volume and systemic hypertension all may possibly affect the character and intensity of heart murmurs. Furthermore, LV systolic function can affect the intensity/severity of murmur in AS. For example in patients with severely reduced LV ejection fraction and advanced stage of low flow low gradient AS with reduced ejection fraction, the intensity of systolic murmur may

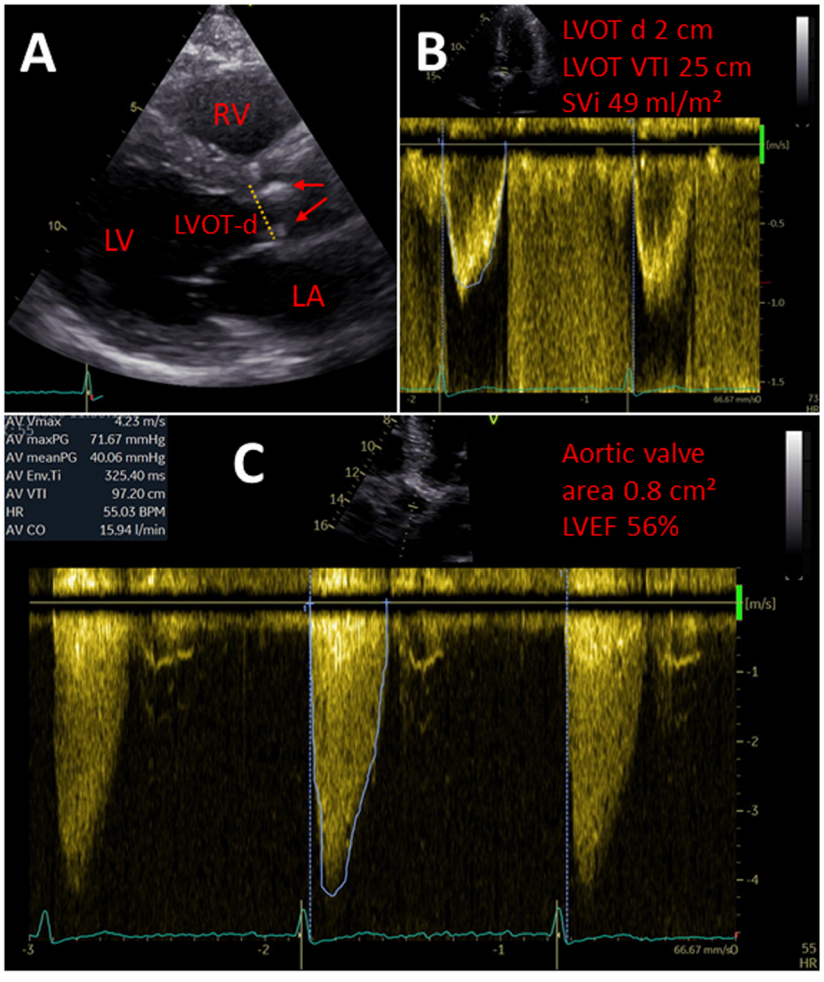

FIG 2. Echocardiographic images of a 90-year-old male patient with severe aortic stenosis (AS) who presented with a systolic murmur grade 3/6 on aortic valve location (Second right and Third left intercostal space near sternum) and preserved second heart sound. On parasternal long-axis view (A), aortic valve is not so calcified (red arrows), and aortic flow is normal (stroke volume index [49 ml/m^2]) (B). However, peak aortic jet velocity is 4.2 m/s (C), consistent with severe AS. Left ventricular ejection fraction (LVEF) was 56%. Color version of figure is available online.

be diminished. Finally, in patients who have smaller LV chambers, proximal septum hypertrophy and a paradoxical low flow, low gradient AS with preserved LV ejection fraction, a loud systolic murmur may be heard both at the aortic area and on the entire precordium (Fig 4). In these cases, subvalvular flow acceleration may augment the intensity and duration of systolic murmurs with late peaking.

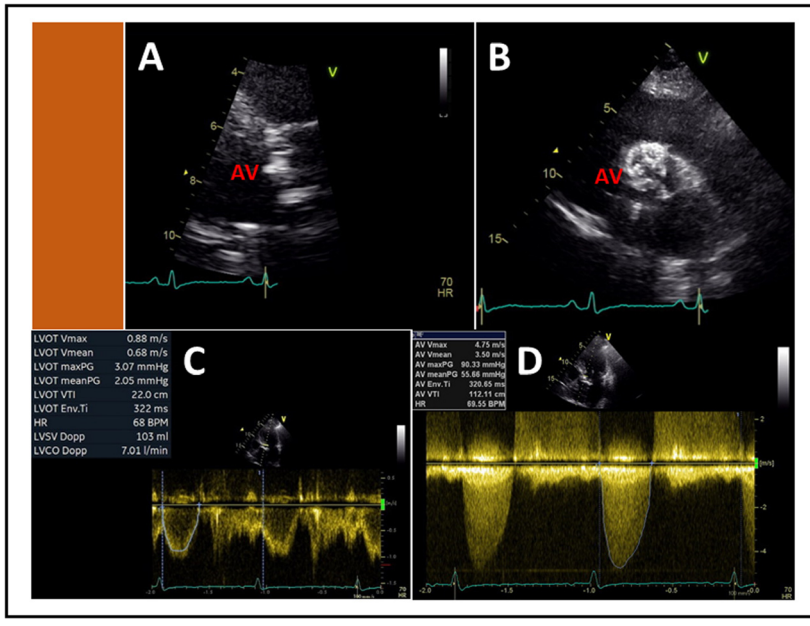

FIG 3. Echocardiographic images of a male patient in his late 80s, with aortic stenosis (AS) presented with a grade 4/6 systolic murmur on aortic position and a weakened second heart sound. There was no obvious audible diastolic murmur. Parasternal long-axis (A) and short-axis (B) show densely calcified aortic valve (AV). C shows stroke volume of 103 ml consistent with a mild aortic regurgitation. D displays peak aortic jet velocity of 4.7 m/s and mean pressure gradient of 56 mmHg, consistent with severe AS. Left ventricular ejection fraction was 55%.

Compared to systolic murmurs, diastolic murmurs in AR are more difficult to hear and require careful auscultatory skills. The severity of chronic AR is often difficult to assess by auscultation. Diastolic murmur starts with the second heart sound and is decrescendo, usually described as high-frequency blowing sounds. In sinus tachycardia or other tachyarrhythmias in which the duration of diastole is shortened, it may be even more difficult to hear an AR-related diastolic murmur, or it may be mistaken with AS murmurs because of shortening of the diastole or equalization of diastolic phase with systolic phase. A wide pulse pressure and typical bounding peripheral pulses may help confirm the diagnosis of aortic incompetence. Furthermore, in severe AR an Austin Flint rumble, a low-pitched mid-to-late diastolic rumble, may be best heard at the apex of the heart. The regurgitant jet in AR can cause fluttering/vibration of the anterior mitral valve leaflet and keeps it in partial closure state (functional mitral stenosis),[12] leading to anterior mitral valve leaflet remodeling in the longer term.[13] Furthermore, a diastolic mitral regurgitation due to elevated LV end-diastolic pressure (rapid filling

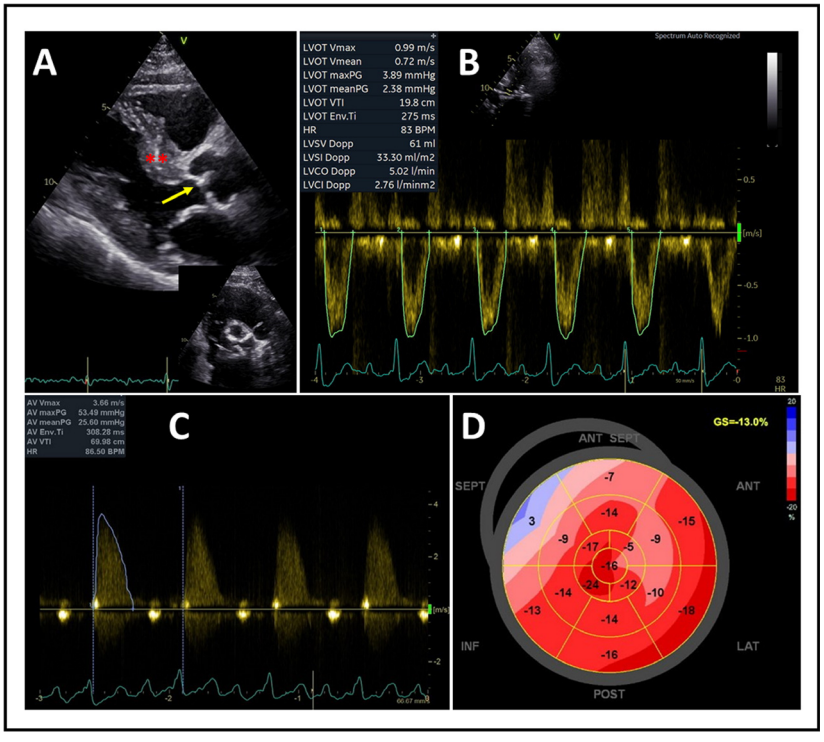

FIG 4. Echocardiographic images of a male patient in his 90s diagnosed with paradoxical low flow, low gradient severe aortic stenosis (tricuspid aortic valve) who presented with a loud (grade 5/6) systolic murmur over the entire precordium with a late systolic peaking, and a silent second heart sound. No diastolic murmur was noted. A is parasternal long-axis view illustrating proximal septal hypertrophy (septal bulging, asterisks) and calcified aortic valve (yellow arrow). B shows low flow (stroke volume index 33 ml/m^2) and C shows low gradient (peak aortic jet velocity of 3.7 and mean pressure gradient of 26 mmHg). Although left ventricular ejection fraction was normal (64%), global longitudinal strain (GLS) was significantly reduced (-13%) (D). Color version of figure is available online.

by both regurgitant volume and antegrade mitral flow) may also indicate a severe AR – and often acute. Overall, the character and intensity of diastolic murmurs in patients with hemodynamically significant AR on TTE may vary. In a patient with severe AR, the diastolic murmur may be absent (Fig 5), while in other patients with less severe AR by echocardiography, the diastolic murmur may be easily heard on auscultation (Fig 6).

Other signs associated with AR which should be noted during clinical examination are "de Musset's sign" in which the head of the patient nods, together with *"Traube's sign"* or a "pistol shot" with the pulse auscultation over the femoral arteries.[14] In severe AR, the nail beds may also show systolic capillary pulsations upon light compression, referred to as *Quincke's sign.*

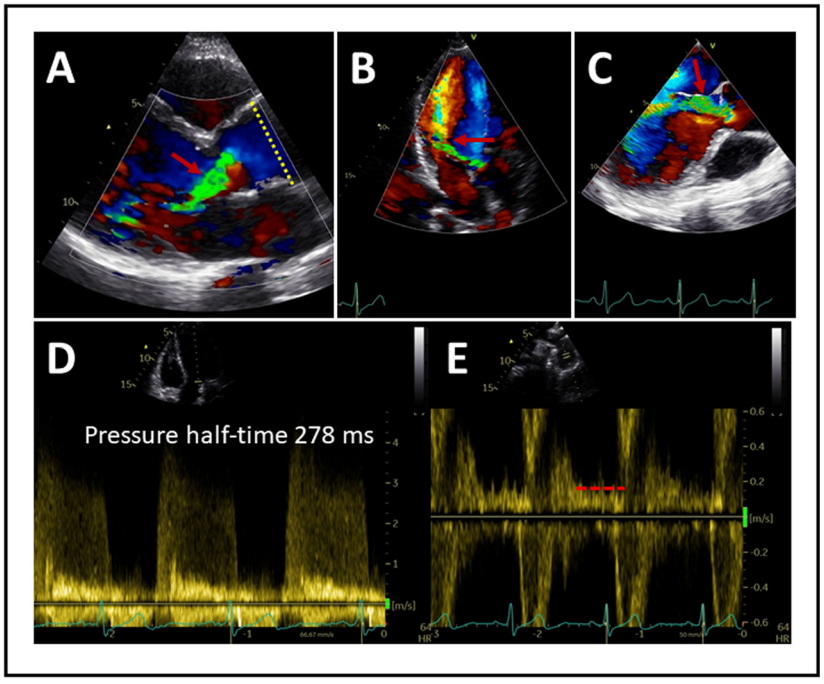

FIG 5. Echocardiographic images of a female patient in her late 30s with newly diagnosed severe aortic regurgitation. No diastolic murmur on heart auscultation was noted by the referral cardiologist. A repeated careful auscultation at Heart Valve Clinic did not reveal any murmur either. A demonstrates parasternal long-axis and B apical 3 chamber views on transthoracic echocardiography, and C is long-axis view on transesophageal echocardiography showing large aortic regurgitant jet (A-C), dilated ascending aorta (A, dotted line) with a tricuspid aortic valve. Pressure half-time was 278 ms (D), and there was a holo-diastolic flow reversal with end-diastolic velocity of 0.2 m/s (E, dotted line). Regurgitant volume was 55 ml, regurgitant fraction 50% and left ventricular ejection fraction of 56% (data not shown).

Murmurs in Mitral and Tricuspid Valve Disease

The auscultatory findings are low- to medium-pitch diastolic rumbles (mid-diastolic murmur, often decrescendo) at the apex, heard best in left lateral decubitus position. The sound is caused by the turbulence of blood flow across the stenotic valve as the left atrium contracts during diastole (Fig 7). There is also often a loud first heart sound accompanied by an opening snap. The murmur in mitral regurgitation is often soft holosystolic heard best at the apex usually radiating to axilla or forward depending on the valve morphology. In rheumatic heart disease affecting the mitral valve, the valve leaflets are thickened with restricted motion both in systole and diastole, leading to both stenosis and regurgitation (Carpentier type 3A), and hence both systolic and diastolic murmurs may be

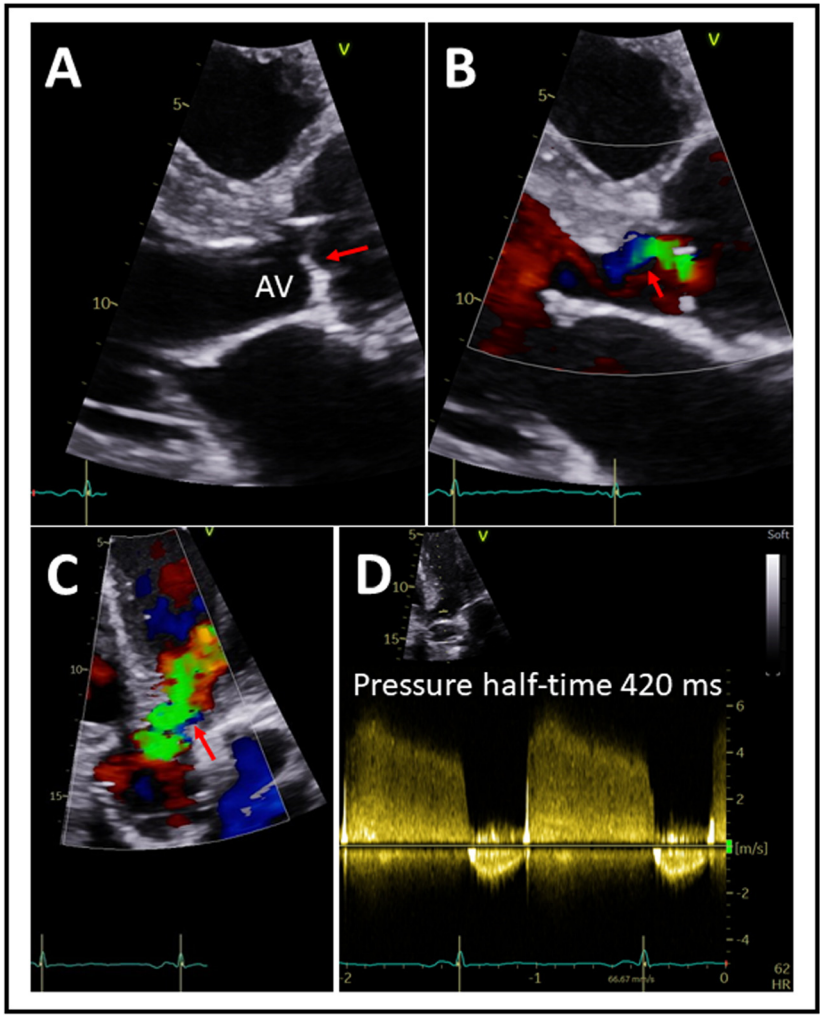

FIG 6. Echocardiographic images of a young patient with moderate aortic regurgitation. On auscultation a grade 2-3 diastolic murmur of blowing character on aortic valve points of the chest wall could be heard. A and B display parasternal long-axis views and C apical 5-chamber view with a slightly calcified aortic valve (AV) and an abnormal motion of non-coronary cusp (probably prolapse) (A, red arrow) leading to an eccentric regurgitant jet (B-C, red arrows), with a pressure half-time of 420 ms (D). Color version of figure is available online.

audible. The anterior mitral valve leaflet may show a typically "Hockey stick" morphology in mitral stenosis. Other signs of pulmonary hypertension may also be present in patients with moderate to severe mitral stenosis.

A "mitral honk" murmur has been described in several conditions,[15] including tricuspid and mitral valve prolapse, but it is more commonly

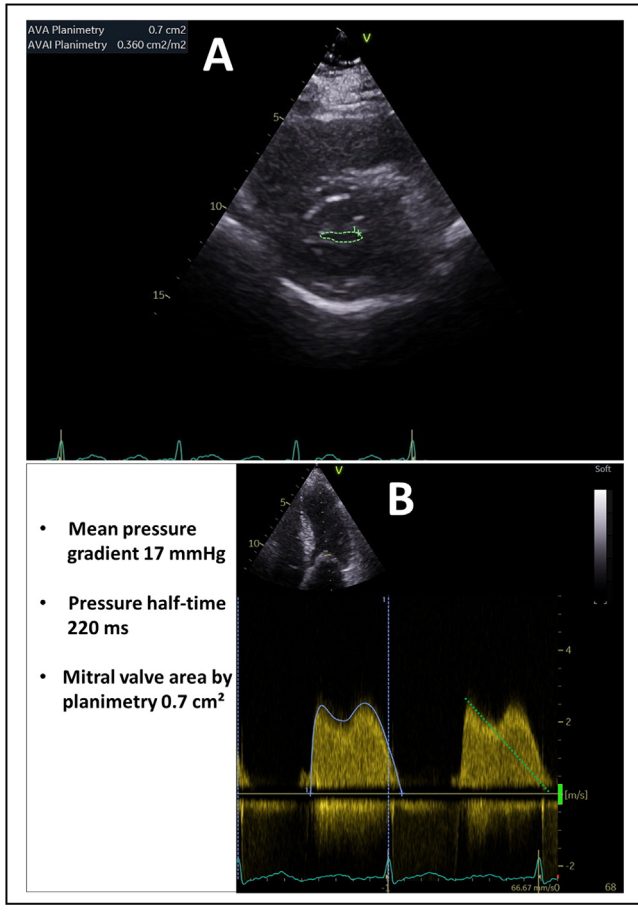

FIG 7. Echocardiographic images of a young female patient with mitral stenosis who presented with dyspnea and a low-pitch (grade 1-2) mid-diastolic rumble. A is a parasternal short-axis view demonstrating stenotic mitral valve with a valve area of 0.7 cm^2 by planimetry. B is a continuous wave Doppler signal through mitral valve showing pressure half-time of 220 ms and a mean pressure gradient of 17 mmHg, consistent with severe mitral stenosis.

described in the setting of mitral valve prolapse. The intensity of a prolapse murmur typically increases with change in position, inhalation, or Valsalva maneuver; that is manipulation of preload with resultant change in LV size. In Barlow's disease with mitral valve prolapse and regurgitation, a typical "late systolic murmur-mid ejection click" due to progressive superior shift of mitral valve coaptation line toward the left atrium during systole is described (Fig 8). Furthermore, a so-called "curling" movement which is an unusual systolic motion of the posterior mitral ring and the adjacent myocardium, may contribute to an abrupt systolic

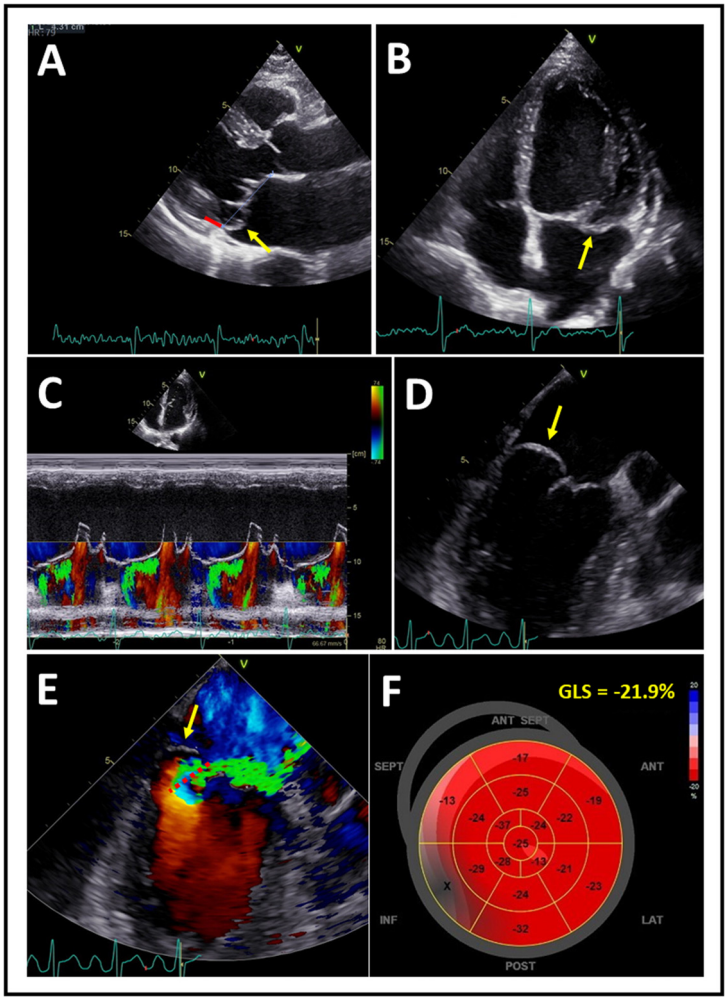

FIG 8. Echocardiographic images of a male patient in his 50s who presented with severe mitral regurgitation, posterior (P2) mitral valve leaflet prolapse and a Barlow-like mitral valve apparatus with dilated annulus. The referral physician at primary care noted a grade 3 systolic murmur without further detailed description. In particular, no mid-systolic click was noted. During a careful auscultation prior to mitral valve surgery, a grade 4/6 systolic murmur with late systolic peaking and blowing character best heard at the apex and radiating to the left axilla was noted. In addition, a clear mid-systolic click was noted. A is a parasternal long-axis and B apical 4-chamber view (both end-systolic frames) on transthoracic echocardiography, revealing a dilated left ventricle and a prolapse (systolic shift towards left atrium) of posterior mitral valve leaflet (arrows) and a mitral annulus disjunction with a distance of 13 mm (A, red line). C is color Doppler M-mode through mitral valve demonstrating a mid-late regurgitant jet with late systolic increase. D and E are long-axis view on transesophageal echocardiography showing billowing of posterior mitral valve leaflet (prolapse) towards left atrium (arrow), causing a severe eccentric mitral regurgitation with a proximal isovelocity surface area (PISA) radius of 1.3 cm (E, dotted red line). F is a Bull eye plot showing normal global longitudinal strain of -21%. 3D left ventricular ejection fraction was 69%. Color version of figure is available online.

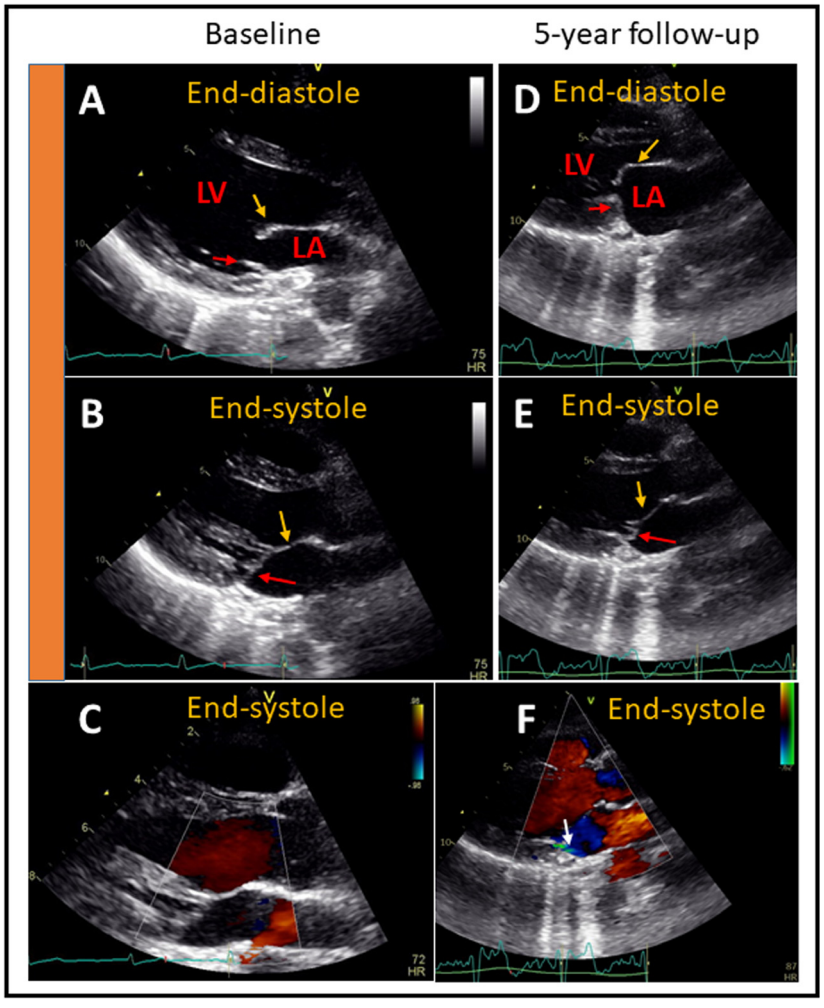

FIG 9. Echocardiographic images of a female patient in her 30s who was referred to general cardiology clinic for a standard transthoracic echocardiogram due to a low-grade, newly detected systolic murmur. At initial assessment (A-C), the anterior mitral valve leaflet was noted to be slightly elongated but had normal motion (A, yellow arrow), with no prolapse of mitral valve leaflets (B, yellow arrow shows anterior and red arrow posterior mitral valve leaflet) or mitral leak (C). At 5-year follow-up (D-F), the anterior valve leaflet was again slightly elongated but had normal motion and left atrium size was normal (D). Posterior mitral valve leaflet (red arrow) which showed a mild (1 mm) bulging towards left atrium (E). A trace/mild mitral regurgitation was noted (F, white arrow). At 5-year follow, the systolic murmur was mild (grade II) with a blowing character changeable with respiration, hearable in expiration and disappearing in inspiration, suggesting an inspiratory decrease and expiratory increase in blood flow into the left atrium and ventricle affecting the intensity of the murmur. There was a "curling" movement of the basal part of the heart/atrioventricular junction, without any signs of mitral annulus disjunction or true prolapse. Acoustic windows were poor in apical views and respiratory change in mitral regurgitation could not be evaluated. Color version of figure is available online.

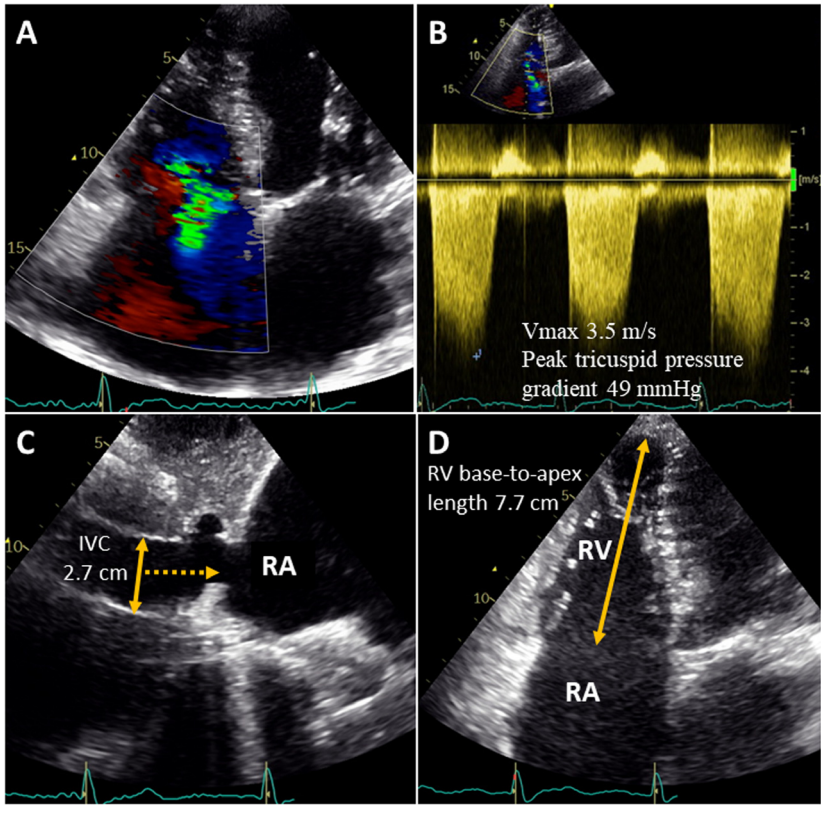

FIG 10. Echocardiographic images of a male patient with severe tricuspid regurgitation. Despite severe tricuspid regurgitation, only a mild systolic murmur was hearable. A is apical 4-chamber view showing dilated RV and RA, and tricuspid regurgitant jet by color Doppler. B is a continuous wave Doppler signal through tricuspid valve and shows a TR Vmax of 3.5 m/s and peak tricuspid pressure gradient of 49 mmHg. C is subcostal view showing slightly dilated IVC of 2.7 cm (RA pressure was 10 mmHg based on the inspiratory changes in the dimension of inferior vena cava), yielding a systolic pulmonary artery pressure of 59 mmHg. D shows RV base-to-apex length of 7.7 cm. IVC, inferior vena cava; RA, right atrium/atrial; RV, right ventricle/ventricular; TR Vmax, peak velocity of tricuspid regurgitant jet.

click.[16] However, this phenomenon is still poorly understood and need further exploration.

Respiratory changes in venous return to the heart affect the character and intensity of mitral and tricuspid regurgitation rumbles. A decrease in venous return to the left side of the heart during inspiration may diminish the intensity of the mitral murmurs, whereas an increase in venous return during expiration can have the opposite effect. This makes it often difficult hear a mild/soft systolic murmur in younger patients with otherwise

healthy heart (Fig 9). A septal bounce in constrictive pericarditis is another example of an exaggerated response to respiration-related inflow swing.[17]

Infective endocarditis, rheumatic heart disease, right atrial myxoma, carcinoid syndrome and Ebsteins' anomaly are causes of tricuspid valve involvement and dysfunction leading to either regurgitation or stenosis. However, in our routine clinical practice we experience that systolic murmurs in tricuspid regurgitation are often difficult to hear (Fig 10).

Murmurs in Hypertrophic Cardiomyopathy

In patients with hypertrophic cardiomyopathy, either obstructive or non-obstructive phenotypes, a number of mitral leaflet abnormalities has been related to the mechanism of mitral systolic anterior motion (SAM), which causes both subaortic obstruction and mitral regurgitation. The obstruction typically causes a loud systolic ejection murmur at the left sternal edge, radiating to the right upper sternal edge and apex.[18] The intensity of the murmur increases with reduction in preload (from the squatting to the standing position or during the strain phase of the Valsalva maneuver) or afterload. Most patients with obstruction also have a mitral regurgitation.[18] Furthermore, a SAM-associated sound has often dynamic changes, and its assessment on auscultation is important to understand the distinct hemodynamic features of hypertrophic obstructive cardiomyopathy even in the era of advanced multimodality imaging. Of note, in patients with hypertrophic cardiomyopathy, a heart murmur or electrocardiographic abnormality (often T-wave inversion) prompt to echocardiographic or cardiac MR evaluation, and hence the correct diagnosis.

Finally, pericardial friction rub and pleural rub should be distinguished from cardiac murmurs. The former is caused by pericarditis and is often synchronous with heart rhythm, while the latter is caused by pleuritis and is synchronous with respiration. Noisy pneumothorax is another condition associated with sounds described in the literature as bubbling, scraping, clicking or crunching sounds.[19] initially described by Louis Hamman in late 1930s (also called Hamman's sign) in a case of pneumomediastinum.[20]

Current Practice of Referring Individuals With Murmurs for Echocardiogram

Hospital doctors, particularly those who work in medical wards, are generally expected to better describe the grade, severity and possible etiology of murmurs, and may be therefore able to distinguish age-related

mild expected murmurs (aortic sclerosis in the elderly) from more severe symptomatic murmurs suggesting significant VHD or complications in acute coronary artery syndromes. However, auscultation skills are dependent on the overall clinical experience. Some in-patients scheduled for surgery are referred for echocardiogram by anesthesiologists when a murmur is heard during preoperative clinical assessment. Knowing the cause of murmur and severity of underlying VHD is important regarding their implications for per-operative risk stratification and the course of post-operative recovery.

GPs may have a tendency to refer patients to a cardiologist for echocardiogram rather than provide a more in-depth description of the murmur. In a previous study, it was demonstrated that auscultation by GPs had a low sensitivity of only 44% and specificity of 69% for the detection of significant VHD on TTE.[8] A possible explanation for this observation was that GPs might not have enough time to undertake a thorough auscultation due to their long patient lists.[21-23] However, it is also known that some GPs may not routinely perform cardiac auscultation in their patients.[20-21] In a 2015 European survey on 8860 people aged ≥60 years, more than half of the respondents (54.2%) reported that their GPs only occasionally or never used a stethoscope to check their heart sounds for a murmur, which in turn contributes to the underappreciation of VHD.[21] A repeated VHD awareness survey in 2017 including 12820 people ≥60 years in 11 European countries aimed to re-evaluate the concerns and knowledge about VHD after 2 years.[22] The survey showed that nearly 51% of the respondents still reported that they rarely or never underwent auscultation of their hearts by their GPs compared with 54% in 2015 ($P<0.001$). However, it is also important to highlight that some GPs tend to routinely perform serial assessment of the murmurs during consultations, and refer patients for TTE only when they notice progression in the intensity or change in the character of murmur in light of other clinically relevant information.

The Role of Murmur Clinics in Detecting VHD

It has been previously demonstrated that a specialist murmur clinic for patients referred for open access echocardiography by GPs, was feasible whether it was served by a consultant cardiologist or clinical scientists performing both auscultation and the point-of-care scan.[5] Up to 70% of patients referred from the community with a murmur had structurally normal hearts and could be screened with a point-of-care scan. The sensitivity of auscultation by the scientist was 83% and by the cardiologist 91%. However, the point-of care scan had a sensitivity of 100% whether it was

performed by the scientists or cardiologist. Although patients attend clinics for an already planned TTE, the scientist or the Cardiologist serving the clinic should always conduct a careful prior auscultation in order to interpret the echocardiographic findings in light of clinical examination. A number of uncommon abnormalities such as muscular ventricular septal defect or aortic coarctation would normally be associated with clear systolic murmurs but may not be detected by a point-of-care scan. On the other hand, diastolic murmurs as a result of mitral stenosis or pulmonary or aortic regurgitation may be difficult to hear on auscultation particularly in obese patients or those with chronic obstructive lung disease, but may be easily detected by a point-of-care echocardiogram, which further prompts a standard 2D or 3D TTE for a more in-depth assessment.

Larger prospective studies in the future should be performed to correlate the frequency of murmurs heard in adult life and clinical diagnosis with the subsequent echocardiographic findings. Murmurs related to congenital heart disease was briefly touched upon and was beyond the scope of this focused clinical review. It is a broad topic and should be discussed in more details in future works.

Conclusion

In most European countries, murmur is a common cause of referral for an echocardiography. Auscultation by general practitioners have generally low sensitivity and specificity in terms of detection of significant heart valve disease. The correlation between murmurs and severity of heart valve disease by echocardiography is poor. However, a careful auscultation of the heart is an effective screening and diagnostic tool and should be routinely performed prior to the echocardiogram in every individual patient at general cardiology or heart valve clinics to predict echocardiographic findings and their interpretation in view of the clinical information. The correlation between clinical examination, point of care ultrasound and standard echocardiography is a matter of continued exploration.

Statement of Ethics

The presented cardiac images were obtained as part of routine medical care. Ethical approval for the use of these samples for research purposes was not required in accordance with local guidelines. Written informed consent was obtained from the patients for the publication of the accompanying images.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Acknowledgments

Not applicable.

REFERENCES

1. Global Burden of Disease Study 2013 Collaborators. Global, regional, and national incidence, prevalence, and years lived with disability for 301 acute and chronic diseases and injuries in 188 countries, 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* 2015;386:743–800.
2. Nkomo VT, Gardin JM, Skelton TN, et al. Burden of valvular heart diseases: a population-based study. *Lancet* 2006;368:1005–11.
3. Zilberszac R, Lancellotti P, Gilon D, et al. Role of a heart valve clinic programme in the management of patients with aortic stenosis. *Eur Heart J Cardiovasc Imaging* 2017;18:138–44.
4. Lancellotti P, Rosenhek R, Pibarot P, et al. Heart valve clinics: organisation, structure and experiences. *Eur Heart J* 2013;34:1597–606.
5. Draper J, Subbiah S, Bailey R, Chambers JB. Murmur clinic: validation of a new model for detecting heart valve disease. *Heart* 2019;105:56–9.
6. Chambers J, Kabir S, Cajeat E. Detection of heart disease by open access echocardiography: a retrospective analysis of general practice referrals. *Br J Gen Pract* 2014;64:e105–11.
7. van Heur LM, Baur LH, Tent M, Lodewijks-van der Bolt CL, et al. Evaluation of an open access echocardiography service in the Netherlands: a mixed methods study of indications, outcomes, patient management and trends. *BMC Health Serv Res* 2010;10:37.
8. Gardezi SKM, Myerson SG, Chambers J, et al. Cardiac auscultation poorly predicts the presence of valvular heart disease in asymptomatic primary care patients. *Heart* 2018;104(22):1832–5.
9. Otto CM. Mind the gap: missed valve disease diagnosis. *Heart* 2018;104(22):1810–1.
10. Maganti K, Rigolin VH, Sarano ME, Bonow RO. Valvular heart disease: diagnosis and management. *Mayo Clin Proc* 2010;85:483–500.
11. Kamath AR, Pai RG. Risk factors for progressionof calcific aortic stenosis and potential therapeutic targets. *Int J Angiol* 2008;17:63–70.
12. Walker HK, Hall WD, Hurst JW. Diastolic Murmurs. Clinical Methods: The History, Physical, and Laboratory Examinations. 3rd ed Boston: Butterworths; 1990 Chapter 27.
13. Hirasawa K, Izumo M, Sasaoka T, et al. Effect of aortic regurgitant jet direction on mitral valve leaflet remodeling: a real-time three-dimensional transesophageal echocardiography study. *Sci Rep* 2017;7:8884.

14. Kumar and Clark's Clinical Medicine 9th Edition Published by Elsevier (2016) Page 1014 and Oxford Handbook of Clinical Medicine 9th Edition published 2014 Oxford University Press Pages 30 and 45.
15. Constant JBedside. Cardiology. Boston: Little, Brown; 1976.
16. Perazzolo Marra M, Basso C, De Lazzari M, et al. Morphofunctional abnormalities of mitral annulus and arrhythmic mitral valve prolapse. *Circ Cardiovasc Imaging* 2016;9:e005030.
17. Saeed S, Haaverstad R, Blomberg B, Bleie Ø, Lunde T. Long-term echocardiographic follow-up of a patient with constrictive pericarditis treated with antituberculosis drugs and pericardiectomy. *BMJ Case Rep* 2021;14:e244665.
18. Elliott PM, Anastasakis A, Borger MA, Borggrefe M, Cecchi F, Charron P, et al. 2014 ESC guidelines on diagnosis and management of hypertrophic cardiomyopathy: the task force for the diagnosis and management of hypertrophic cardiomyopathy of the European society of cardiology (ESC). *Eur Heart J* 2014;35:2733–79.
19. Hedger MH, Saeed S. A young man with chest pain. *Tidsskr Nor Laegeforen* 2012;132:1874–5.
20. Hamman L. Spontaneous interstitial emphysema of the lungs. *Trans Assoc Am Physicians* 1937;52:311–9.
21. Gaede L, Di Bartolomeo R, van der Kley F, Elsässer A, Iung B, Möllmann H. Aortic valve stenosis: what do people know? A heart valve disease awareness survey of over 8,800 people aged 60 or over. *EuroIntervention* 2016;12:883–9.
22. Gaede L, Aarberge L, Brandon Bravo Bruinsma G, et al. Heart valve disease awareness survey 2017: what did we achieve since 2015? *Clin Res Cardiol* 2019;108:61–7.
23. Webb J, Thoenes M, Chambers J. Identifying heart valve disease in primary care: differences between practice in Germany, France and the United Kingdom. *Eur J Cardiovasc Med* 2014;3(1):10.