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STATE OF THE ART REVIEW

# How valuable is physical examination of the cardiovascular system?

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## ABSTRACT

Physical examination of the cardiovascular system is central to contemporary teaching and practice in clinical medicine. Evidence about its value focuses on its diagnostic accuracy and varies widely in methodological quality and statistical power. This makes collation, analysis, and understanding of results difficult and limits their application to daily clinical practice. Specific factors affecting interpretation and clinical application include poor standardisation of observers' technique and training, the study of single signs rather than multiple signs or signs in combination with symptoms, and the tendency to compare physical examination directly with technological aids to diagnosis rather than explore diagnostic strategies that combine both. Other potential aspects of the value of physical examination, such as cost effectiveness or patients' perceptions, are poorly studied. This review summarises the evidence for the clinical value of physical examination of the cardiovascular system. The best was judged to relate to the detection and evaluation of valvular heart disease, the diagnosis and treatment of heart failure, the jugular venous pulse in the assessment of central venous pressure, and the detection of atrial fibrillation, peripheral arterial disease, impaired perfusion, and aortic and carotid disease. Although technological aids to diagnosis are likely to become even more widely available at the point of care, the evidence suggests that further research into the value of physical examination of the cardiovascular system is needed, particularly in low resource settings and as a potential means of limiting inappropriate overuse of technological aids to diagnosis.

### Introduction

Some of the earliest accounts of the interaction between a patient and his or her doctor concern the physical examination of the cardiovascular system.[1] The primary purpose of such examination is to assess the presence, nature, and severity of cardiovascular disease. Several specific components of the physical examination have been described to support these aims.

Substantial evidence of the diagnostic value of specific elements of the physical examination of the cardiovascular system exists,[2 3] but its methodological quality varies widely. Since the advent of technological aids to diagnosis (TAD) such as echocardiography in the late 1970s,[4] the central role of physical examination in the practice of clinical cardiology has been challenged,[5-7] and its standard of practice has declined in some countries.[8-12]

Despite this, many clinicians still use and attach significance to physical examination techniques in daily practice. In acute general internal medicine, the combination of history and physical examination without recourse to TAD still accounts for most diagnoses.[13] Findings from the physical examination of the cardiovascular system are central to diagnostic scoring systems for conditions such as pulmonary embolism,[14] risk stratification in acute coronary syndromes,[15] and "early warning scores" in patients admitted to hospital.[16] In medical education, the physical examination is still regarded as a core component of undergraduate and postgraduate curriculums.

This review will summarise the evidence relevant to the value of the physical examination of the cardiovascular system in contemporary clinical practice, comment on the quality and limitations of the evidence, and highlight areas where further investigation may be most appropriate. It is aimed at clinicians interested in the evidence base for the physical examination they undertake in daily clinical practice and those who teach doctors in training. It is also relevant to people with a research interest in diagnostic methods, the doctor-patient relationship, and over-investigation and overuse of technology in healthcare.

### Sources and selection criteria

The physical examination of the cardiovascular system is traditionally divided into several components, summarised in figure 1.

| Component | Specific features of interest |
|---|---|
| Palpation of arterial pulse | • Rate<br>• Rhythm<br>• Volume<br>• Character or contour<br>• Vessel wall<br>• Bruits<br>• Symmetry |
| Measurement of arterial blood pressure | • Systolic pressure<br>• Diastolic pressure<br>• Pulse pressure |
| Examination of jugular veins | • Venous pressure<br>• Venous waveform |
| PRAECORDIAL EXAMINATION: | |
| Inspection | • Scars<br>• Abnormal movements |
| Palpation | • Apical impulse (location and character)<br>• Praecordial impulses<br>• Thrills |
| Percussion | • Cardiac dullness |
| Auscultation | • Heart sounds (normal and added)<br>• Murmurs<br>• Pericardial rub |
| General and other systems examination | • Cyanosis<br>• Clubbing<br>• Oedema<br>• Cutaneous features of peripheral arterial or venous disease<br>• Peripheral signs of infective endocarditis<br>• Transverse earlobe crease<br>• Arcus lipidus<br>• Xanthelasma and xanthoma<br>• Calf tenderness and swelling<br>• Capillary refill time<br>• Pulmonary crepitations (rales)<br>• Hepatomegaly<br>• Splenomegaly<br>• Funduscopy |

**Fig 1 | Components of physical examination of the cardiovascular system**

The purpose of each component of the physical examination is to identify physical signs, defined here as a variation from an expected or normal clinical observation or finding. As the evidence base on physical examination of the cardiovascular system primarily focuses on the diagnostic accuracy of physical signs, this review also focuses on diagnostic accuracy but acknowledges that the value of physical examination may extend beyond this single parameter.

We have not:

- Provided a detailed account of the physiology underlying normal findings in the physical examination or the pathophysiology causing specific physical signs suggestive of cardiovascular disease.
- Reviewed the value of any aspect of the physical examination in which a device other than a stethoscope or a sphygmomanometer is used.
- Considered paediatric practice or the evaluation of congenital heart disease in adults.
- Reviewed the prognostic value of measurements of systolic or diastolic blood pressure, their mean, or their difference (pulse pressure), as their use in cardiovascular risk assessment and treatment is established.
- Reviewed established diagnostic scoring or risk stratification systems, or early warning scores that include components of the physical examination—for example, those used in the diagnosis of pulmonary embolism,[14] deep venous thrombosis,[17] infective endocarditis,[18] or chronic venous insufficiency.[19]

Although we did an extensive literature review, we did not apply specific methods demanded of formal systematic reviews or meta-analyses. We used an electronic search of PubMed based on a strategy recommended in relation to the diagnostic value of physical examination to identify studies published between May 1965 and May 2015.[20] This combined terms relating to clinical entities (AND)* terms relating to clinical skills (AND)* terms relating to diagnostic testing. Figure 2 shows the terms used.

We also identified and reviewed all references in the three existing major contemporary sources of collated evidence on physical examination,[2-21] as well as publications citing these references since their publication date. We included clinical practice guidelines, but physical examination is not always included in such guidelines and often not evaluated in similar detail to data from other sources. We reviewed only English language publications, and we did not consider further any articles that established pathophysiological mechanisms underlying physical signs, single case reports of associations between signs and specific diseases, and articles that provided no numerical data to enable estimation of diagnostic accuracy.

The primary electronic search strategy failed to identify approximately 20% of the publications found in the three collated sources, their references, or their citations. The difficulty of identifying publications relating to the diagnostic value of physical examination has been previously identified.[22]

## Interpreting the literature

The following factors should be considered when interpreting the literature on the value of physical examination of the cardiovascular system.

### Definition of value

In the context of physical examination, the word "value" is generally taken to be synonymous with the diagnostic accuracy of physical signs when specific diagnoses are being considered—that is, whether the presence or absence of a sign or combination of signs makes a diagnosis more or less likely. Most studies of physical examination are based on this construct and typically compare the physical examination with a diagnostic reference standard, usually an imaging or invasive haemodynamic study.

This definition may underestimate the true value of physical examination, and a broader definition could include the factors shown in figure 3. The literature contains little information on factors other than diagnostic accuracy and contributions to clinical care beyond diagnosis.

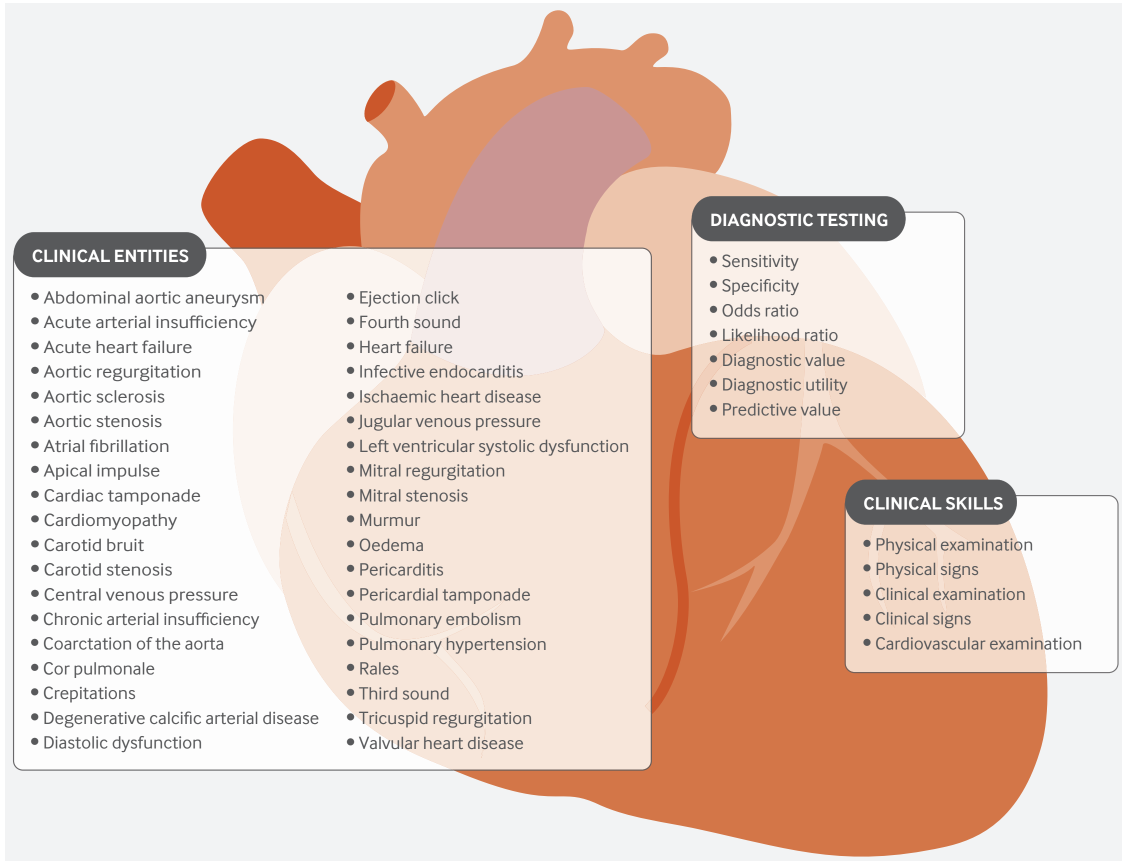


**Fig 2 | Search terms used in electronic search**

### Methodological considerations

Ideal standards for tests of diagnostic accuracy have been described, but many studies of the diagnostic accuracy of physical examination fail to meet such criteria.[22] For example, studies are generally small; participants are often poorly characterised beyond age, sex, and primary diagnosis; analyses are typically univariate rather than multivariate; and there are relatively few systematic reviews or meta-analyses. The following factors must also be considered.

*Characteristics of clinician observers and observer variability*

In studies of the diagnostic accuracy of physical examination, observations provided by clinicians provide the data on which analysis of diagnostic value is based. The number of clinician observers is highly variable—typically less than six—and some studies include only one observer. Studies in which a single clinician does all observations show that high levels of accuracy and low levels of intra-observer variability for some signs can be obtained.[27-29]

Most studies include more than one clinician observer and describe varying degrees of inter-observer variability but provide no information to indicate how the observers' technique of physical examination was assessed, standardised, or compared and characterise observers only according to their specialty, job title, or training grade. Inter-observer variability varies according to the experience or seniority of the participating clinicians and can be reduced with training of observers.[30-32] These findings suggest that observers' technique influences inter-observer variability; although the overall contribution of observers' characteristics to such variability is difficult to quantify, it is likely to be substantial.

*Characteristics of clinical observations*

Estimations of the diagnostic accuracy of physical examination assume that a sign is binary—that is, it is either present or absent. In many clinical situations, however, clinicians accord diagnostic weight according to the degree of positivity of a sign or their level of certainty that it is present or absent. For example, a trace of peripheral oedema may be ascribed lower diagnostic significance than oedema that is present above the knee. In general, the literature takes no account of this. In addition, the evanescent nature of some signs (such as pericardial rub) makes structured analysis of diagnostic value challenging.

*Characteristics of clinical practice*

The literature on physical examination of the cardiovascular system typically compares physical examination directly with TAD. In reality, clinicians use combinations of diagnostic modalities that typically include history, physical examination, blood tests, and imaging. Few studies attempt to evaluate the comparative efficacy of strategies that use combinations of diagnostic modalities (for example, physical examination plus TAD) compared with single modality (for example, physical examination alone or TAD alone) approaches. In addition,


**Fig 3 | Factors contributing to the value of physical examination of the cardiovascular system. TAD=technological aids to diagnosis**

combinations of signs and symptoms are typically used in clinical diagnostic and therapeutic decision making, but much of the literature attempts to evaluate single signs in isolation from other physical examination findings or ancillary clinical information such as the history. Exceptions are prediction scores for pulmonary embolism or deep venous thrombosis and some studies in heart failure diagnosis.

*Global variation of disease prevalence*

Most studies of the diagnostic utility of physical examination have been conducted in the United States or Europe. This may account for the lack of studies from which evidence relating to the utility of the physical examination in the diagnosis of conditions now less commonly seen in Western populations, such as rheumatic mitral stenosis, can be derived.

*Diagnostic reference standards*

TAD are typically used as the diagnostic reference standard in studies of physical examination, which raises two methodological considerations. Firstly, different definitions of abnormality may be applied in different studies of the same sign. For example, the ultrasound definition of a "significant" arterial stenosis varies in studies of the diagnostic value of pulse palpation or bruits. Secondly, many studies provide no information on the (intra- or inter-)observer variability of the diagnostic reference standard, either as used in the study or in general use. Studies in which inter-observer variability is described show the presence of varying degrees of such variability in the interpretation of commonly used TAD. For example, echocardiographic assessments of various parameters of left ventricular systolic and diastolic function contain observer variability,[33 34] which may both influence the interpretation of study results and be underappreciated by many clinicians.[2]

*Range of statistical indices used*

The diagnostic value of a test is determined by its accuracy and precision (reliability).[35] A wide variety of statistical indices are used to express diagnostic value in studies of physical examination of the cardiovascular system,[36] and comparison between or pooling of studies is challenging, particularly as the raw data necessary to calculate missing indices are often absent from the published papers.

Likelihood ratios provide information on the probability of disease in an individual[37]; when available, they are the preferred statistical index of comparison in this review. Figure 4 shows the definition of likelihood ratios and their method of calculation, and figure 5 illustrates the relation between a likelihood ratio and diagnostic pretest and post-test probability.

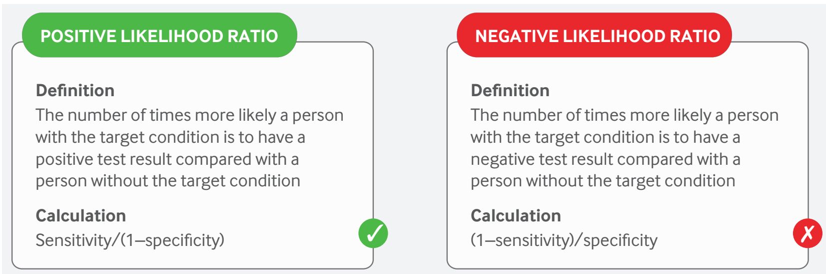


**Fig 4 | Statistical indices of diagnostic accuracy in studies of physical examination of the cardiovascular system**

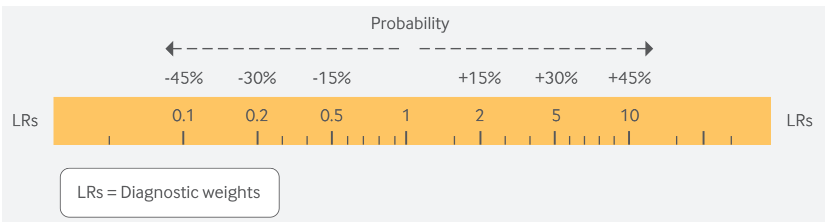


**Fig 5 | Approximating probability with likelihood ratios (LRs). Reproduced from McGee[2] with permission**

| Clinical question | Example context |
|---|---|
| Does this patient have cardiovascular system disease? | • Screening examination in an asymptomatic patient<br>• Systems' examination as part of routine clerking<br>• An abnormality is found by a technical aid to diagnosis and clinical evidence of cardiac disease is sought |
| Does this patient have a specific type of cardiovascular system disease? | • Evaluation of a patient with dyspnoea for evidence of heart failure |
| What kind of heart disease does this patient have? | • A murmur is heard, and physical examination is used to determine the cause |
| Is this patient responding to treatment? | • A patient with heart failure is examined for evidence of decompensation |
| How severe is this patient's cardiovascular system disease? | • A murmur is found, and evidence of severity of valvular disease is sought |
| What is the prognosis of heart disease? | • A patient with acute coronary syndrome is examined for clinical signs indicating prognosis |

**Fig 6 | Clinical questions and contexts in which physical examination of the cardiovascular system is applied**

## Comparing relative value of components of physical examination

Clinicians and educators may wish to know which components of the physical examination of the cardiovascular system are "most useful" to guide clinical use or plan teaching programmes,[38 39] but comparisons of the relative value of single components of the physical examination are difficult for several reasons.

### *Focus of literature*

Most of the literature on physical examination is focused on the comparative value of physical examination and TAD, rather than the comparative value of different components of the physical examination.

### *Frequency of use*

The frequency of use of a component of the physical examination, and the frequency of its study in the literature, is in part related to the prevalence of the condition the sign relates to. For example, pulsus paradoxus is infrequently sought, as cardiac tamponade is a relatively uncommon condition. Thus, frequency of use should not be used in isolation to determine the relative value of different signs.

### *Clinical context*

Value is in part dependent on the clinical context in which a sign is sought or used. Figure 6 outlines these contexts.

A specific sign may have greater diagnostic value in one clinical context but less value in a different clinical context. For example, palpation of the abdomen is less valuable in the accurate assessment of the size of an abdominal aortic aneurysm than in determining its potential presence.

Clinical context is also important, as it may influence the relative importance of the different statistical elements of a diagnostic test. For example, the clinical consequences of a false negative test, which may lead to a missed diagnosis, may be greater in some contexts than in others, and greater or less than the clinical consequences of a false positive test, which may lead to further unnecessary testing.[40]

For these reasons, simple comparisons of statistical indices of diagnostic accuracy can be misleading and should not be undertaken without setting the diagnostic test, in this case a component of the physical examination of the cardiovascular system, in the relevant clinical context.

## Summary of evidence of clinical value of physical examination of the cardiovascular system

Table 1 summarises the evidence for a range of physical signs or physical examination manoeuvres of relevance to the assessment of cardiovascular system disease. This table does not include every component of the physical examination described; if a sign is not included, either an evidence base for its diagnostic or clinical value is entirely lacking or its potential clinical application is limited. Given the considerations described above, lack of evidence of diagnostic value cannot be taken to mean that the sign or manoeuvre has no diagnostic value. This is particularly the case for signs that are sought or present only in rare or uncommon conditions or diagnostic contexts, which are implicitly more difficult to study.

Many of the signs included in the table have not been studied in sufficient detail to enable estimation of diagnostic accuracy. This includes some signs that are widely used in clinical practice. For the reasons discussed above, particularly the heterogeneous nature of the studies available, a formal ranking of the quality of collated evidence is unlikely to be useful or meaningful and has not been included. If we found no evidence in the literature search that enabled estimation of diagnostic accuracy, a general comment based on observational or descriptive studies of the sign such as "Low specificity or sensitivity" is included in the column entitled "Suggested clinical value." For other signs, for which some data to estimate diagnostic accuracy were available, a comment and a reference are provided. Finally, signs that met three specific

**Table 1 | Summary of evidence of clinical value**

| Sign or manoeuvre | What is this sign purported to indicate? | Suggested clinical value |
|---|---|---|
| **Arterial pulses** | | |
| Rate | Cardiac rate | Non-specific diagnostically but has prognostic value in several acute settings.[41] Resting heart rate predicts mortality in population settings[42] |
| Postural tachycardia | Hypovolaemia | A rise of 30 beats/min on standing suggests large blood loss[43] |
| Rhythm | Cardiac rhythm | See detailed discussion of specific signs |
| Volume and contour | Changes in stroke volume or vascular compliance | |
| Slow rising/plateau | Aortic stenosis (AS) | Supports diagnosis of AS in patients with systolic murmur[29] |
| Collapsing/water-hammer | Aortic regurgitation (AR) | Insensitive and non-specific when assessed by palpation. High (>80 mm Hg) measured pulse pressure has LR+ of 10.9 for moderate to severe AR in a single study[44] |
| Pulsus bisferiens | Aortic valve disease (AS, AR), HCM | Low specificity and sensitivity |
| Dicrotic | Mitral regurgitation, high SVR, low stroke volume | Low specificity and sensitivity |
| Jerky | HCM | Said to be pathognomic |
| Small volume/weak/thready | Shock, impaired LV function, AS | Low specificity and sensitivity |
| Other: | | |
| Pulsus paradoxus | Cardiac tamponade | In patients known to have a pericardial effusion, if pulsus paradoxus of >12 mm Hg is present, the LR+ for cardiac tamponade is 5.9 (95% CI 2.4 to 14.3) and if pulsus paradoxus is absent the LR– is 0.03 (0 to 0.2)[45 46] |
| Pulsus alternans | LV systolic impairment | Moderate specificity but low sensitivity[47] |
| 31 eponymous signs of AR | Presence or severity of AR | Generally specific findings but low sensitivity[48] |
| Absence of specific pulses | Obstructive disease at or proximal to site of palpation | See detailed discussion of specific signs |
| | Hypovolaemic shock | One study suggests that a palpable femoral pulse means shock is less likely[49] |
| Buerger's test | Peripheral arterial disease (PAD) | May suggest more severe PAD when present[50] |
| Capillary refill time | Peripheral hypoperfusion | See detailed discussion of specific signs |
| Pulse asymmetry: upper limbs | Obstruction at specific site | |
| | Aortic dissection | See detailed discussion of specific signs |
| | Subclavian stenosis and steal syndrome | Asymmetry has high sensitivity in patients with suggestive symptoms[51] |
| Pulse asymmetry: upper and lower limbs | Coarctation of the aorta | Combinations of blood pressure and pulse findings have high sensitivity in children[52] |
| Bruits at specific sites | Obstructive arterial disease | |
| Abdominal | Renovascular disease | See detailed discussion of specific signs |
| Carotid | Carotid artery disease | See detailed discussion of specific signs |
| Pulsatile abdominal mass | Abdominal aortic aneurysm | See detailed discussion of specific signs |
| **Jugular venous pulse** | | |
| Jugular venous pressure | Central venous/right atrial pressure | See detailed discussion of specific signs |
| Kussmaul's sign | Constrictive pericarditis | Low sensitivity |
| Response to Valsalva | Elevated left heart filling pressure | LR of >5 in a single study[53] |
| Abdominojugular test (hepatojugular reflux) | Elevated left heart filling pressure | See detailed discussion of specific signs |
| Character of the venous waveform | Abnormalities of intracardiac blood flow or cardiac rhythm | |
| Giant v wave | Tricuspid regurgitation | LR+ of 10.9 in a single study[29] |
| Other abnormalities of a/c/v waves or x/y descent | Abnormalities of blood flow into heart or heart rhythm | Generally, low sensitivity and specificity |
| Cannon waves | Atrioventricular dissociation | In a single study of induced ventricular tachycardia, cannon waves in the jugular venous waveform had a negative LR of 0.1[31] |
| Other veins: | | |
| Peripheral venous collapse | Elevated central venous pressure | One study suggests low sensitivity but high specificity[54] |
| **Praecordium** | | |
| Percussion of the heart | Cardiac size | Single study suggests value in excluding cardiomegaly[55] |
| Palpation of apical impulse: | | |
| Location | Cardiac size and LV function | See detailed discussion of specific signs |
| Size/area | Cardiac size | See detailed discussion of specific signs |
| Character (thrusting, sustained, tapping, retracting) | A variety of abnormalities of LV structure and function | Single studies suggest potential utility in several contexts[2] |
| Parasternal impulses | Abnormalities of cardiac and valvular function | Single studies suggest potential utility in several contexts[2] |
| Palpable pulmonary second sound | Pulmonary hypertension | A single study suggests value in excluding PHT in mitral stenosis[56] |
| Auscultation: | | |
| Intensity of first heart sound | Closure of mitral and tricuspid valves | |
| Loud/quiet/inaudible | | Single studies suggest utility in several contexts[57-59] |
| Variable | | A single study suggests utility in tachycardia diagnosis[31] |
| Splitting of first heart sound | Bundle branch block, extrasystoles | No documented utility |
| Intensity of second heart sound | Closure of pulmonary and aortic valves | |
| Loud pulmonary second sound | Pulmonary hypertension | No discriminatory value for detection of PHT[60] |
| Quiet/inaudible aortic second sound | Abnormal closure of the aortic valve | See detailed discussion of specific signs |
| Splitting of second heart sound (physiological/fixed/reversed) | A variety of valvular and congenital abnormalities | Absence of fixed splitting useful in excluding atrial septal defect[61] |
| Third heart sound | Increased early diastolic filling | See detailed discussion of specific signs |

**Table 1 | continued**

| Sign or manoeuvre | What is this sign purported to indicate? | Suggested clinical value |
|---|---|---|
| Fourth heart sound | Late diastolic filling related to atrial systole | Low specificity and sensitivity |
| Systolic/ejection clicks | A variety of valvular abnormalities | See detailed discussion of specific signs |
| Diastolic/opening snap | Pliant mitral valve leaflet in mitral stenosis | No data on diagnostic value. Proximity to second sound correlates with severity of mitral stenosis |
| Systolic murmur | A variety of abnormalities of central CVS blood flow | |
| Ejection/pan/late | | See detailed discussion of specific signs |
| Pattern of radiation | | See detailed discussion of specific signs |
| Effect of respiration | Increases or decreases venous return | |
| Louder on inspiration | Suggests murmur origin in right heart | LR+ of <5 in two studies of detection of tricuspid regurgitation and pulmonary stenosis [2] |
| Effect of other manoeuvres (Valsalva/posture change/hand grip/leg elevation/amyl nitrite) | Increase or decrease venous return or SVR | LR+ of >5 in small number of studies in variety of diagnostic contexts[2] |
| Diastolic murmur | A variety of abnormalities of central CVS blood flow | See detailed discussion of specific signs |
| Decrescendo/early | Aortic or pulmonary regurgitation | |
| Mid | Mitral or tricuspid stenosis | |
| Pericardial rub | Pericardial inflammation | The finding is pathognomic of pericarditis. As such it is of high specificity, but sensitivity is unknown |
| Peripheries and other organ systems | | |
| Xanthelasmata | Dyslipidaemia | Presence independently predicts increased risk of IHD and MI[62] |
| Arcus lipidus | Dyslipidaemia | Of no independent diagnostic or prognostic value[62] |
| Transverse earlobe crease | | Presence independently predicts increased risk of IHD and MI[62] |
| Male pattern baldness | | Presence independently predicts increased risk of IHD and MI[62] |
| Hair greying | | Of no independent diagnostic or prognostic value[62] |
| Cutaneous features of arterial insufficiency | | See detailed discussion of specific signs |
| Oedema | Extravascular fluid overload | See detailed discussion of specific signs |
| Pulmonary rales (crepitations) | Interstitial fluid | Low sensitivity and specificity in diagnosis of CHF in isolation |
| Hepatomegaly | | Low sensitivity and specificity for CHF. When pulsatile, strongly supports diagnosis of tricuspid regurgitation[29] |
| Splenomegaly | | May provide supportive evidence of infective endocarditis, but non-specific and of low sensitivity |
| Finger clubbing | | May provide supportive evidence of infective endocarditis, but non-specific and of low sensitivity. Of moderate sensitivity and specificity in some forms of cyanotic heart disease |
| Funduscopy | | Roth spots may provide supportive evidence of infective endocarditis, but non-specific and of low sensitivity. Hypertensive retinopathy provides evidence of target organ damage and some features predict increased risk of CVS disease[63] |

AR=aortic regurgitation; AS=aortic stenosis; CHF=congestive heart failure; CVS=cardiovascular system; HCM=hypertrophic obstructive cardiomyopathy; IHD=ischaemic heart disease; LR=likelihood ratio; LV=left ventricular; MI=myocardial infarction; PAD=peripheral arterial disease; PHT=pulmonary hypertension; SVR=systemic vascular resistance.

criteria for more detailed consideration are discussed and referenced in detail in the next section and indicated as such in the table.

### Detailed discussion of selected signs

The signs included for detailed discussion in this section meet each of the following criteria:

- More than one study exists from which conventional indices of diagnostic accuracy can be derived.
- Where available, the positive likelihood ratio (LR+) for the sign is 5 or more, the negative likelihood ratio (LR−) is less than 0.2, or both. These values categorise a test as providing strong diagnostic evidence,[64] and they increase or decrease pre-test probability by around 30% (fig 5).
- The information obtained is of practical assistance in patient care, taking into account the additional information that is available or can be accessed through history, bedside tests, and additional investigations.

We stress that the exclusion of a sign from this section does not imply that the sign is of no value but simply that there is less evidence of its value than for signs that are included. For example, a pericardial rub is pathognomic of pericarditis, but no studies quantify its diagnostic value.

#### Jugular venous pulse and estimation of central venous pressure

Table 2 summarises studies evaluating the value of examination of the jugular venous pulse (JVP) as a means of assessing the central venous pressure (CVP).

The difficulties in collating studies of clinical assessment of the JVP have been described.[74] Differences in the preferred anatomical reference point, side of the neck used, preference for internal or external jugular vein, position of the patient, experience of observers, and clinical status of studied patients, including their volume status, severity of illness, presence of percutaneous cannulas in the veins assessed, and whether patients were breathing spontaneously or with mechanical support, all pose specific problems. In a minority of patients in these studies and in clinical practice, no attempt at pressure measurement can be made as the veins cannot be visualised (for example, in obese patients), but this proportion may decline with observers' training and experience.

Several studies suggest that clinical measurement of the JVP tends to underestimate the CVP measured by cardiac catheterisation. In some studies, this may reflect underestimation of the distance between the classical anatomical reference point of the sternal angle and the central right atrium, now recognised as 8 cm rather than

Table 2 | Studies of clinical assessment of jugular venous pressure (JVP) for estimation of central venous pressure (CVP)

| Reference | What was done | Patients | Clinicians | No of patients (observations) | Summary of study conclusions |
|---|---|---|---|---|---|
| Davison,[65] 1974, USA | External and internal JVP versus invasive CVP | "Seriously ill" | Two clinicians | 39 (128) | IJV not usually visible. EJV measurement correlated poorly with CVP |
| Connors,[66] 1983, USA | JVP versus invasive CVP | ICU | Medical student to attending physician | 62 (310) | JVP underestimated CVP in ICU patients |
| Ducas,[67] 1983, USA | JVP and HJR versus invasive CVP | Not defined | Not defined | 48 | CVP predicted from JVP in 44/48 comparisons |
| Cook,[68] 1990, USA | JVP versus invasive CVP | ICU | 15 different clinicians; medical student to staff physician | 50 (150) | JVP inaccurate in ICU patients |
| Stein,[69] 1997, USA | JVP versus IVC ultrasound RAP and invasive CVP | Patients with severe CHF | Not stated | 22 | Clinical estimates of RAP from JVP were accurate when RAP was normal, but systematically underestimated elevated RAP |
| Vinayak,[70] 2006, USA | External JVP versus invasive CVP | Critically ill in ICU | Student to attending | 35 (118) | JVP using EJV highly reliable for assessing elevated CVP (AUC 0.97, 95% CI 0.92 to 1.00) by attending physicians |
| Sinisalo,[71] 2007, Finland | JVP with patient sitting versus invasive CVP | Pre-cardiac catheterisation | Two cardiologists | 96 | JVP using IJV in sitting patients had sensitivity of 65% and specificity of 85% to identify elevated CVP |
| Brennan,[72] 2007, USA | JVP versus invasive CVP and indirect comparison with ultrasound IVC | Pre-cardiac catheterisation | Four internal medicine residents | 40 (44) | IJV not identified in 37% of patients. Sensitivity of JVP for elevated CVP 14% |
| Deol,[73] 2011, USA | External and internal JVP clinically and by ultrasound versus invasive CVP | ICU | Not defined | 38 | EJV better than IJV in correlation with CVP, but ultrasound superior to both. Clinical and ultrasound measurement both underestimated CVP. |
| Rizkallah,[30] 2014, Canada | JVP clinically versus ultrasound RAP | Routine echocardiography patient population | One student, one resident, one fellow | 325 | JVP sensitivity 86% by cardiology fellow |

AUC=area under curve; CHF=congestive heart failure; EJV=external jugular vein; HJR=hepatojugular reflux; ICU=intensive care unit; IJV=internal jugular vein; IVC=inferior vena cava; RAP=right atrial pressure.

5 cm.[75] Although the right internal jugular vein has traditionally been regarded as the most accurate manometer, studies using either the left internal jugular vein or either external jugular vein have yielded accurate results.[76]

On the basis of the available literature, determining whether the JVP, and by inference the CVP, is high, normal, or low, is preferable to attempting to define a specific value of the CVP derived from the JVP measurement. If the clinical measurement is made from the sternal angle, in whatever position the top of the pulsating venous column can be seen, a JVP of more than 3 cm above the sternal angle has an LR+ of 10.4 (95% confidence interval 5.5 to 19.9) and an LR− of 0.1 (0 to 0.6) for a CVP of more than 12 cm $H_2O$.[2] In a single study, in which the external jugular vein was used, a JVP of less than 3 cm above the sternal angle had an LR+ of 8.4 (2.8 to 25) and an LR− of 0.1 (0 to 0.7) for a CVP below 5 cm $H_2O$.[70] The abdominojugular test (hepatojugular reflux) may also be performed when examining the jugular veins and has an LR+ of 8.0 (no confidence interval) for elevated left heart filling pressures.[77-79] The JVP is discussed further in the section on heart failure.

### Signs of peripheral perfusion and shock syndromes

The diagnostic accuracy of physical examination markers of poor peripheral perfusion has been assessed in comparison with invasive haemodynamic indices in an intensive care setting. In a sub-study of 513 patients in intensive care with acute lung injury randomised to receive a pulmonary artery catheter, the combined presence of three physical examination findings (capillary refill time >2 s, knee mottling, or cool extremities) was highly specific but insensitive for identifying low cardiac output (<2.5 L/min/m$^2$; specificity 98%; sensitivity 12%; LR+ 7.5) and low mixed venous oxygen saturation (<60%; specificity 99%; sensitivity 8%; LR+ 8.0).[80]

In intensive care patients with septic shock, capillary refill time greater than 2.4 s at the fingertip (LR+ 3.0; LR− 0.25) or less than 4.9 s at the knee (LR+ 5.1; LR− 0.21) six hours after diagnosis was predictive of death at 14 days.[81] In a large study of consecutive acute adult medical admissions, prolonged capillary refill time on admission predicted one day and seven day mortality, independently of other demographic and clinical variables, with odds ratios of 1.69 (95% confidence interval 1.20 to 2.39; P=0.003) and 1.38 (1.12 to 1.69; P=0.002), respectively.[82]

Physical examination signs of impaired peripheral perfusion may therefore hold both diagnostic and prognostic value in shock syndromes. Accordingly, assessment of capillary refill time and other markers of peripheral perfusion is recommended for the initial rapid evaluation of circulatory status in a wide variety of settings.[83 84]

### Pulsatile abdominal mass and abdominal aortic aneurysm

In studies in which aneurysmal dilatation is defined as greater than 3 cm, a pulsatile abdominal mass has an LR+ of between 8.0 (4.2 to 15.3)[85-90] and 12 (7.4 to 19)[91] for the presence of an aneurysm of this dimension. In general, the higher the aortic diameter used to define aneurysmal dilatation and the lower the abdominal girth,[92] the higher the sensitivity of palpation. Therefore, a finding of a pulsatile mass in the abdomen on opportunistic physical examination suggests the presence of an abdominal aortic aneurysm and should prompt consideration of imaging.[93]

### Arterial pulse rhythm and atrial fibrillation

Studies of the value of pulse palpation as a screening tool for atrial fibrillation are comparatively large and have been included in systematic reviews and consensus guidance.[94 95] Data pooled from three major studies indicate that the opportunistic finding of "any pulse irregularity" has an LR+ of 3.3 (3.0 to 3.7) for the presence of atrial fibrillation on electrocardiography.[96-98] When such irregularity is absent, this has an LR− of 0.1 (0.1 to 0.2). This modest positive diagnostic value is greatly increased if the definition used is "continuous pulse irregularity," when the LR+, derived from one large study,[96] rises to 24.1 (15.2 to 38). On the basis of these findings, pulse palpation for detection of atrial fibrillation is likely to have the greatest practical utility when used as an initial opportunistic screening method, identifying patients who need an electrocardiogram to confirm the underlying rhythm.

### Absent peripheral pulses and bruits and peripheral arterial disease

A systematic review and subsequent studies have investigated the value of peripheral pulse palpation and auscultation in detecting peripheral arterial disease (PAD).[28-100] In patients with symptoms suggestive of PAD, such as claudication, a palpable pulse abnormality and a lower limb bruit both have significance (LR+ 4.70 (2.20 to 9.90) and 5.60 (4.70 to 6.70), respectively).[99] Cool skin (LR+ 5.90, 4.10 to 8.60) and wounds or sores on the foot (LR+ 5.90, 2.60 to 13.40) also support the diagnosis, but other features such as hair loss, skin colour, and Buerger's test are of little or no value.[50 101] In asymptomatic people, a femoral bruit has an LR+ of 4.80 (2.40 to 9.50) and "any pulse abnormality" has an LR+ of 3.10 (1.40 to 6.60). The absence of these signs does not exclude PAD but reduces the likelihood of severe disease.[99]

Thus, the presence of abnormal physical examination findings may help to confirm the need for further investigation in patients with symptoms compatible with PAD. Insufficient evidence exists to support the use of physical examination in isolation as a screening tool in asymptomatic people, but further investigation may be reasonable following opportunistic detection of abnormalities in patients at moderate to high risk of PAD.

### Pulse deficits and aortic dissection

A palpable pulse deficit of the carotid or upper limb pulses in patients with clinical presentations suggestive of acute thoracic aortic dissection supports the diagnosis, with a pooled LR+ of 6.0 (no confidence interval presented).[2-103] Patients with aortic dissection who have pulse deficits have more in-hospital complications and have higher mortality.[104] Aortic dissection is underdiagnosed, and the absence of these findings should never dissuade a clinician from the diagnosis. All clinical clues may be of value, and relevant imaging should always be undertaken when clinical suspicion is present.

### Abdominal bruits and renovascular hypertension

In patients with hypertension, abdominal bruits with systolic-diastolic components are strongly supportive of a diagnosis of renovascular disease (LR+ 39; LR− 0.6; no confidence interval presented) [105] and bruits with isolated systolic components less so (LR+ 5.6, 4 to 7.7; LR− 0.6, no confidence interval presented).[106-109] Accordingly, auscultation for abdominal bruits may help to identify patients who need renal Doppler ultrasound. However, the absence of bruits does not exclude the presence of renal artery stenosis.

### Carotid bruits and carotid stenosis

Meta-analysis suggests that carotid bruits are of moderate value in the detection of clinically relevant (>70%) carotid stenosis, with pooled sensitivity of 0.53 (0.50 to 0.55), specificity of 0.83 (0.82 to 0.84), and diagnostic odds ratio of 4.32 (2.78 to 6.66).[110] Patients with known or suspected carotid territory cerebrovascular disease should undergo appropriate imaging of the vessel regardless of carotid auscultatory findings, as absence of a bruit does not exclude disease. However, opportunistic detection of a bruit in other settings should prompt consideration of further investigation, as detection of significant carotid stenosis may have important therapeutic implications such as the need for secondary preventive measures.[111]

### Physical examination in heart failure

Cardiac failure is associated with several characteristic physical examination findings. Salt and water retention, together with elevated ventricular filling pressures, may lead to signs of congestion such as an elevated JVP, peripheral (usually lower limb) oedema, pulmonary rales (crepitations), and, less frequently, ascites or hepatomegaly. A third heart sound caused by abrupt deceleration of rapid ventricular (usually left ventricular) filling occurs when the rate of filling exceeds ventricular compliance and usually signifies the combination of elevated mean left atrial pressure and left ventricular dysfunction. A displaced apex beat suggests structural left ventricular remodelling and correlates with increased left ventricular end diastolic volume and mass, as well as reduced left ventricular ejection fraction.

Table 3 summarises the clinical value of the physical examination of the cardiovascular system in patients with known or suspected heart failure. One difficulty in evaluating the diagnostic value of physical examination findings in cardiac failure lies in the lack of a single diagnostic test to use as a reference standard. Guidelines recommend diagnosis based on a combination of typical symptoms, physical examination findings (described above), and demonstration of a relevant abnormality of cardiac structure and/or function.[124 125] For the studies of diagnostic accuracy in table 3, the reference standard for "heart failure" was therefore final consensus diagnosis based on a combination of all available clinical and investigational data. Studies using left ventricular systolic dysfunction (LVSD) as a reference standard may tend to underestimate the diagnostic value of physical examination findings, as the clinical syndrome of heart failure may occur in the absence of LVSD. However, we have presented data for the diagnostic accuracy of physical examination findings for detecting LVSD in a primary care setting.

In general, physical examination findings in heart failure lack sensitivity, and their absence has minimal value in excluding the diagnosis (table 3). Additionally, dependent oedema and pulmonary rales are relatively non-specific and have, at best, modest value for ruling in heart failure. However, elevated JVP, third heart sound, and displacement of the apex beat are each highly specific and substantially increase the likelihood of heart failure (table 3). When present, a third heart

**Table 3 | Clinical value of physical examination of the cardiovascular system in patients with known or suspected heart failure (HF)**

| Clinical context | Raised JVP | Peripheral oedema | Rales | Third heart sound | Displaced apex | Comments |
|---|---|---|---|---|---|---|
| **Diagnostic accuracy** | | | | | | |
| Pooled LR+ (CI) for HF in emergency department patients with dyspnoea[112] | 5.1 (3.2 to 7.9) | 2.3 (1.5 to 3.7) | 2.8 (1.9 to 4.1) | 11.0 (4.9 to 25) | | LR− >0.5 for all except displaced apex |
| Pooled LR+ (CI/range) for LVSD in community patients with suspected HF[113] | 4.36 (range 2.7-7.4) | 1.18 (range 1.0-1.5) | 1.53 (1.2 to 2.2) | 7.34 (range 1.6-32.4) | 16.0 (8.2 to 30.9) | LR− >0.5 for all |
| LR+ range for HF (any ejection fraction) in community patients with suspected HF | 4.8 to 7.5[114 115] | 1.9 to 3.0[114 115] | 3.0 to 3.4[114 115] | 22.3[115] | 6.7[115] | LR− >0.5 for all |
| **Independent prognostic value** | | | | | | |
| Asymptomatic LVSD†[116]: | | | | | | Patients with third heart sound also at increased risk of hospital admission for HF: 1.47 (1.06 to 2.05) |
| Progression to clinical HF | 1.51 (1.04 to 2.19) | | | 1.38 (1.09 to 1.73) | | |
| Death or development of HF | 1.54 (1.11 to 2.12) | | | 1.34 (1.09 to 1.64) | | |
| Suspected HF in community: | | | | | | Congestion stronger predictor of outcomes than LVEF. Multivariate analysis included NT-proBNP |
| All cause mortality‡[114] | 1.45 (1.16 to 1.83) for rales plus JVP or oedema | | | | | |
| Stable CHF (NYHA I-IV)†[117]: | | | | | | All cause death: 1.17 (1.02 to 1.35) for JVP and third heart sound |
| Hospital admission for HF | 1.32 (1.08 to 1.62) | | | 1.42 (1.21 to 1.66) | | |
| Death or hospital admission for HF | 1.30 (1.11 to 1.53) | | | 1.40 (1.14 to 1.71) | | |
| Stable CHF (NYHA III-IV)[118]: | | | | | | |
| All cause mortality | 1.52 (1.22 to 1.91) | NS | | | | 1.61 (1.18 to 2.20) for oedema + JVP |
| Hospital admission for HF | 1.21 (1.02 to 1.43) | 1.25 (1.06 to 1.48) | | | | 1.37 (1.08 to 1.73) for oedema + JVP |
| Stable CHF with AF[119]: | | | | | | JVP, oedema, rales, and third heart sound each strongly predictive of all cause death on univariate analysis |
| CV mortality | NS | 1.25 (1.0 to 1.57) | 1.41 (1.07 to 1.86) | NS | | |
| Hospital admission for HF | NS | NS | 1.42 (1.05 to 1.90) | NS | | |
| Acute decompensated HF: | | | | | | JVP and oedema form part of composite congestion scores that predict post-discharge mortality |
| In-hospital mortality‡[120] | NS | NS | NS | 1.69 (1.19 to 2.41) | | |
| Post-discharge mortality[121]-[123] | See comment | See comment | | | | |

CHF=congestive heart failure; JVP=jugular venous pressure; LR=likelihood ratio; LVEF=left ventricular ejection fraction; LVSD=left ventricular systolic dysfunction; NT-proBNP=N-terminal pro-hormone of brain natriuretic peptide; NYHA=Hew York Heart Association.
*All results based on multivariate analysis including clinical, biochemical, electrocardiographic, and echocardiographic variables +/− NT-proBNP. Data expressed as hazard ratios unless otherwise stated.
†Relative risk (95% CI).
‡Odds ratio (95% CI).

sound strongly supports the diagnosis of heart failure, although it is detected infrequently in community settings (1-5%), which may limit its practical value. In contrast, a displaced apex beat was the most helpful physical examination finding in a meta-analysis of primary care studies and, in a subsequent study, retained substantial diagnostic value after adjustment for other physical examination findings and symptoms (odds ratio 5.4, 2.8 to 10.5). A raised JVP increases the probability of heart failure across all clinical settings and, in primary care, has diagnostic value independent of all other clinical variables and electrocardiography findings (odds ratio 8.7, 2.6 to 29.2).[126]

In patients with stable or decompensated heart failure, signs of congestion or the presence of a third heart sound predict a range of adverse outcomes independently of other established prognostic variables including age, New York Heart Association class, and left ventricular ejection fraction (table 3). Relief of congestion is a key therapeutic goal in patients with heart failure and requires titration of therapies to physical examination findings.[124 125] Importantly, effective relief of congestion (assessed using composite scores incorporating JVP and/or oedema) in patients admitted to hospital reduces the risk of subsequent adverse outcomes compared with those with residual congestion.[113 114]

### Abnormal systolic murmur and valvular heart disease

As systolic murmurs are often detected in patients without significant valvular or other structural heart disease,[127] an important aspect of clinical evaluation is to distinguish such "functional" murmurs from pathological murmurs. Guidelines do not recommend echocardiographic evaluation of suspected functional murmurs in asymptomatic people.[128 129] In four separate studies of patients with a systolic murmur examined by a cardiologist, classification of the murmur as "abnormal" significantly increased the likelihood of valve disease, with likelihood ratios ranging from 3.8 to infinity, whereas classification as "normal" reduced the likelihood (likelihood ratios of 0-0.3).[130-133]

The physical examination, whether performed by cardiologists or non-cardiologists, is also useful for diagnosing valvular heart disease in asymptomatic patients without known cardiac disease and in patients attending the emergency department,[134 135] with a pooled LR+ of 15 (11 to 20)[3] for an "abnormal" murmur and 0.25 (0.17 to 0.36) for a functional murmur or no murmur. Substantial agreement existed between non-cardiologist emergency department physicians for identification of a systolic murmur (κ=0.8).[127]

Intensity and duration of the murmur are the most helpful features to differentiate functional from pathological murmurs. A loud murmur and holosystolic timing help to rule in and rule out underlying valve disease, with an LR+ of 6.5 (2.3 to 19) and 8.7 (2.3 to 33) and an LR− of 0.08 (0.02 to 0.31) and 0.19 (0.08 to 0.43), respectively.[130] A systolic thrill is strongly suggestive of significant valve disease, but its absence is not useful in ruling out a pathological murmur (LR+ 12, 0.76 to 205; LR− 0.73, 0.58 to 0.93).[130]

**Table 4 | Clinical features that influence the likelihood of aortic stenosis in patients with a systolic murmur**

| Clinical feature | Significance (95% CI) |
|---|---|
| **Findings that make moderate to severe aortic stenosis less likely** | |
| Murmur not heard over right clavicle | LR− 0.10 (0.02 to 0.44)[137] |
| Lack of carotid radiation | LR− 0.1-0.29 [29-137] |
| Mid-systolic timing | LR− 0.05 (0 to 0.3)[29] |
| Grade 1 intensity | LR− 0.2 (0.1 to 0.50[29] |
| **Findings that make moderate to severe aortic stenosis more likely** | |
| Delayed upstroke of carotid pulse | (LR+ 6.8 (4 to 11.5) to 130 (33 to 560)[29-137] |
| Reduced or absent second heart sound | (LR+ 7.5 (3.2 to 17) to 50 (24 to 100)[29-137] |
| Carotid radiation | (LR+ 8.1 (4 to 16) to 12.4 (4.5 to 34)[29 137] |
| Reduced carotid volume | (LR+ 2.0 (1 to 3.2) to 2.3 (1.7 to 3.0)[29 137] |

LR−=negative likelihood ratio; LR+=positive likelihood ratio.

Auscultation for a systolic murmur is therefore helpful in determining the likelihood of valvular heart disease and allows patients with suspected valve disease to receive further investigation (usually echocardiography) to confirm the nature and severity of valve pathology while avoiding unnecessary investigation in patients with low likelihood of valve disease.

## Characteristic murmurs and specific valve lesions

### *Aortic stenosis*

In most studies, the absence of a systolic murmur effectively excludes the diagnosis of significant aortic stenosis, with negative likelihood ratios ranging from 0 to 0.05.[29-137] In a cohort of patients admitted with hip fracture, the LR− for moderate to severe aortic stenosis when no murmur was heard was 0.36 (0.20 to 0.62). However, the negative predictive value remained high (96.8% for moderate or greater stenosis; 99.6% for severe stenosis).[138] Among patients with a systolic murmur, several clinical signs have diagnostic value for aortic stenosis (table 4).

None of these, in isolation, has sufficient accuracy to rule in aortic stenosis, but moderate to severe stenosis is highly likely if three or more are present (LR+ 40, 6.6 to 239).[137] Among non-cardiologist examiners, moderate agreement existed for detection of a soft or absent second heart sound (κ=0.54) and fair agreement for identification of radiation to right clavicle (κ=0.36), radiation to right carotid (κ=0.33), delayed carotid upstroke (κ=0.26), and reduced carotid volume (κ=0.24).[137]

### *Mitral regurgitation*

In unselected hospital inpatients undergoing echocardiography, a murmur that extends from the apex to at least the anterior axillary line suggests moderate or greater mitral regurgitation (LR+ 6.8, 3.9 to 11.9).[29] Importantly, the absence of a murmur is not helpful in excluding mitral regurgitation in the setting of acute myocardial infarction (LR− 0.66, 0.25 to 1.0),[139] However, in patients with known mitral valve prolapse, the absence of a holosystolic or late systolic murmur, identified by a cardiologist, makes moderate or severe mitral regurgitation unlikely (LR− 0, 0 to 0.8).[140] The intensity of the murmur correlates with the severity of regurgitation. Very loud murmurs (grade 4-5) substantially increase the likelihood of severe mitral regurgitation (LR+ 14, 3.3 to 56), whereas grade 1-2 murmurs are unlikely to reflect severe regurgitation (LR+ 0.19, 0.11 to 0.33).[29]

### *Tricuspid regurgitation*

In patients referred for echocardiography, the presence of a characteristic murmur, as determined by a cardiologist, strongly predicts the presence of tricuspid regurgitation (LR+ 10.1, 5.8 to 18).[141] However, the absence of a murmur is not helpful in excluding tricuspid regurgitation (LR− range 0.41-0.60).[133 142]

Specific features of the murmur with diagnostic value include localisation to the lower left sternal edge (not audible above the third intercostal space or lateral to the mid-clavicular line), which strongly supports the diagnosis[142] (LR+ 8.4, 3.5 to 20.3) and an increase in intensity with inspiration, which, among experienced cardiologists, distinguishes tricuspid from mitral regurgitation (LR+ ∞, 3.1 to ∞; LR− 0.20, 0.07 to 0.45).[142] Additionally, the presence of a giant V wave in the jugular veins helps to rule in the diagnosis of tricuspid regurgitation (LR+ 10.9, 5.5 to 22).[142]

### *Aortic regurgitation*

A systematic review indicates that auscultation for the typical early diastolic, high pitched decrescendo murmur of aortic regurgitation is helpful for both ruling in and ruling out aortic regurgitation.[143] In the two highest quality studies, the presence of a typical aortic regurgitation murmur had an LR+ of 8.8-32 for detecting aortic regurgitation of at least mild severity and 4.0-8.3 for moderate to severe aortic regurgitation.[144 145] Conversely, the absence of a typical aortic regurgitation murmur had an LR − of 0.2-0.3 for excluding any aortic regurgitation and 0.1 (0 to 0.3) for moderate to severe aortic regurgitation. The clinical context of a diastolic murmur is important, as patients with end stage renal failure and volume overload may have transient early diastolic murmurs that resolve with correction of volume overload.[146]

The physical examination is of limited value in assessing the severity of aortic regurgitation. However, severe aortic regurgitation is unlikely with very quiet (grade 1) murmurs (LR+ 0, 0 to 0.9) and more likely when either a third heart sound (LR+ 5.9, 1.4 to 25) or grade 3 murmur (LR+ 4.5, 1.6 to 14) is present.[44 147]

Overall, these findings indicate that physical examination findings are valuable in identifying or excluding the presence of specific valve lesions. Although most patients with suspected valve disease in contemporary practice should undergo formal evaluation with echocardiography, identification of the likely underlying lesion may help to inform the urgency of echocardiography or guide initial management when echocardiography is not immediately available. Specific clinical settings in which insight from the physical examination may be particularly helpful include patients needing urgent surgery, those with suspected endocarditis, and those with new onset of decompensated heart failure.

## Clinical context

Physical examination is immediately available, rapid and repeatable, relatively inexpensive, safe, and non-invasive. The data presented in this review provide evidence that some of its elements can still support the investigation and ongoing care of patients with known or suspected cardiovascular disease in contemporary healthcare.

**GLOSSARY OF ABBREVIATIONS**

| | |
|---|---|
| CVP | central venous pressure |
| JVP | jugular venous pressure |
| LR– | negative likelihood ratio |
| LR+ | positive likelihood ratio |
| LVSD | left ventricular systolic dysfunction |
| PAD | peripheral arterial disease |
| TAD | technological aids to diagnosis |

In emergency care, physical examination of the cardiovascular system can direct initial treatment in the period before TAD can be accessed, determine the choice and urgency of investigation, and support monitoring of response to treatment. A firm clinical impression of decompensated heart failure in the emergency department does not obviate the need for echocardiography but does permit prompt starting of diuretic and vasodilator therapy, as well as avoidance of potentially inappropriate treatments. Once a diagnosis is established, repeated physical examination can help in optimising management, most notably through identifying the presence of residual congestion that, if untreated, is associated with repeated hospital admission and poorer survival.

In the community setting, or other settings where TAD are less readily available, the physical examination holds particular value in rationalising and targeting specialist investigation. An abnormal murmur in a patient with dyspnoea establishes the need for echocardiography, and the coexistence of physical findings of heart failure would mandate urgent referral. The physical examination also provides a simple method for opportunistic detection of asymptomatic but potentially important disease such as atrial fibrillation, valvular heart disease, and abdominal aortic aneurysm, which can then be assessed further by appropriate investigation.

## Conclusions

Despite its apparent benefits, physical examination is increasingly poorly practised, understood, and trusted in some contemporary healthcare settings. These changes have occurred despite continued focus on the teaching and assessment of relevant skills in undergraduate medical education, although this is not always sustained into postgraduate education with similar intensity.[148] The use of TAD has increased substantially over the same period that the practice of the physical examination of the cardiovascular system has declined. However, this may reflect factors not primarily related to the diagnostic accuracy of physical examination, such as models of reimbursement of physicians and patients' expectations, rather than considered comparisons of the efficacy of diagnostic strategies that use physical examination and TAD alone or in combination.[149-151]

Whatever the explanations for the relative change in use, concerns have arisen about the implications. Underuse or absence of physical examination can lead to misdiagnosis and may adversely affect the doctor-patient relationship.[23 152] Overuse of TAD can lead to unwarranted financial expense and physical harm to patients. Major professional organisations now stress the potential role of physical examination in reducing unnecessary technological testing,[128] and initiatives such as Choosing Wisely promote more judicial selection of investigations (http://www.choosingwisely.org).

**RESEARCH QUESTIONS**

- Cost effectiveness of strategies that combine physical examination and technological aids to diagnosis (TAD) versus those using TAD alone
- Relation between use of physical examination and use of TAD
- Patients' attitudes to care strategies including and excluding physical examination
- Diagnostic error rate in care strategies that include and exclude physical examination
- Diagnostic value of combinations of signs or of signs and symptoms
- Value accorded to physical examination by physicians in contemporary practice
- Diagnostic accuracy of signs of cardiac disease now uncommon in developed countries

However, whether improved physical examination, which is not without its own financial cost, can effectively reduce diagnostic error, the overuse of TAD, or the costs of care is not known. Although enhanced physical examination skills could lead to improved confidence in bedside decision making, clinicians' understanding of statistical data derived from clinical assessment is often poor,[40] and intolerance of perceived "uncertainty" in the absence of the results of a TAD may still drive use, even in situations in which subsequent diagnostic probability may be unaffected.[153] Whether patients will now trust judgments based on clinical assessment alone or be comfortable with treatment decisions made in the absence of TAD is also uncertain.

Furthermore, the increasing availability and decreasing cost of point of care TAD, such as portable bedside handheld ultrasound, is likely to further question the value of traditional physical examination techniques, particularly in the elucidation and detection of murmurs and evaluation of CVP.[154] However, the costs of providing such technology to clinicians, delivering the education and training required to implement and sustain widespread use, and the diagnostic accuracy of bedside ultrasound during routine clinical care in non-specialist settings have yet to be defined or compared with those of the physical examination. Such background should provide a continuing incentive to reappraise the value of the physical examination.

Given the infrequent occurrence of some signs, the difficulty in ensuring that observers' ability and technique are standardised, and the necessity to include large numbers of observations to generate robust estimates of diagnostic accuracy, it is unlikely that further research based around the simple association of specific signs with specific diagnoses is likely to be practicable or informative. Future research may thus be more usefully focused on the areas listed in the "Research questions" box.

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