Additional Heart Sounds—Part 1 (Third and Fourth Heart Sounds)

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Abstract

S3 is a low-pitched sound (25–50Hz) which is heard in early diastole, following the second heart sound. The following synonyms are used for it: ventricular gallop, early diastolic gallop, protodiastolic gallop, and ventricular early filling sound. The term "gallop" was first used in 1847 by Jean Baptiste Bouillaud to describe the cadence of the three heart sounds occurring in rapid succession. The best description of a third heart sound was provided by Pierre Carl Potain who described an added sound which, in addition to the two normal sounds, is heard like a bruit completing the triple rhythm of the heart (bruit de gallop). The following synonyms are used for the fourth heart sound (S4): atrial gallop and presystolic gallop. S4 is a low-pitched sound (20–30 Hz) heard in presystole, i.e., shortly before the first heart sound. This produces a rhythm classically compared with the cadence of the word "Tennessee." One can also use the phrase "A-stiff-wall" to help with the cadence (a S4, stiff S1, wall S2) of the S4 sound.

Keywords
- ventricular gallop
- protodiastolic gallop
- physiological S3
- pathological S3
- atrial gallop
- presystolic gallop

Third Heart Sound (S3)

Definition

S3 is an early diastolic sound. It is a low-pitched sound (25–50Hz) that occurs after the second heart sound. It produces a rhythm like the cadence of the word "Kentucky" in which "CKY" represents S3.

Synonyms

Ventricular gallop, early diastolic gallop, protodiastolic gallop, ventricular early filling sound.

History

S3 was first described in 1847 by *Jean Baptiste Bouillaud* who referred to it as a gallop. *Pierre Carl Potain* described S3 as an additional sound like a bruit, completing the triple rhythm of the heart (*bruit de gallop*).[1] The phrase "Slosh-ing-IN" can also be used to describe the S1-S2-S3 sounds.

Physiology

In early diastole, when ventricular pressure falls below the atrial pressure, the atrioventricular valves open wide, and blood drains rapidly from the atria (Y descent) into the ventricles, producing S3 (►**Fig. 1**). S3 occurs at the beginning of the middle third of ventricular diastole, i.e., at the end of rapid filling phase. In fact, it represents the transition from rapid filling to slow filling phase of the ventricles. It does not occur with the beginning of diastole, because the ventricles are not sufficiently filled to create any reverberation till the middle third in a normal heart.

Mechanism

The exact mechanism of genesis of S3 is debatable. The probable theories are as follows:

1. Ventricular theory–The rapid filling in early diastole distends the ventricles. When the elastic distensibility of the ventricular wall is reached, there is sudden deceleration of the inflowing blood *with attendant vibration of the "cardio-hemic" system*.[2-4] S3 is thought to be an intracardiac sound arising from the vibration of ventricular wall as the diastolic inflow is suddenly halted.
2. Valvular theory–It is proposed that S3 is the result of vibrations of valve cusps rather than the ventricular wall when the diastolic inflow is suddenly decelerated.

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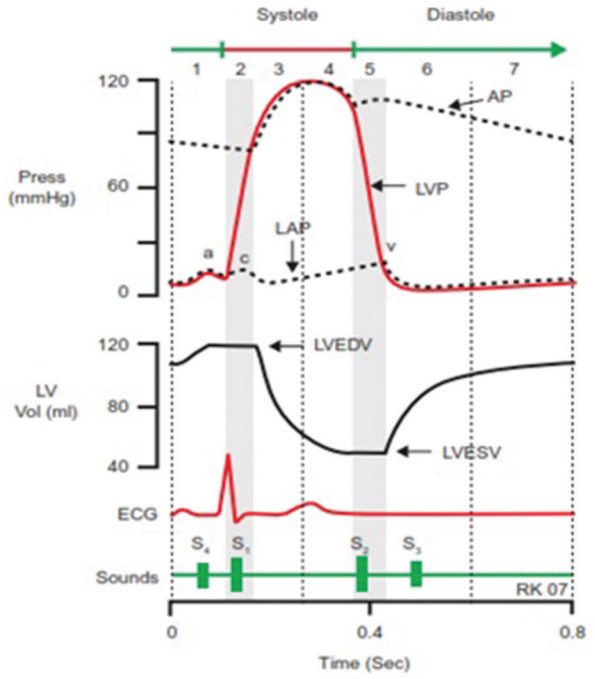

Fig. 1 Cardiac cycle showing the association of S3 with the early filling phase.

However, recent studies have shown that the third heart sound is heard loudest *external* to the left ventricular cavity, implying it to be extra-cardiac in origin.

3. Impact theory–S3 results from movement of ventricle closer to the chest wall. When the ventricle is dilated, it lies in proximity to the chest wall. When blood enters during diastole, it results in a more forceful impact producing S3.[5-7]
4. S3 may arise within the ventricular apex due to sudden limitation of longitudinal expansion of the ventricle after early rapid filling.[8,9]

Thus, S3 can be heard in the following three situations:

1. Normal ventricle receiving excessive volume of incoming blood (e.g., hyperdynamic states).
2. Dilated ventricle that is stretched and overfilled receiving relatively normal or less than normal amount of blood (e.g., systolic dysfunction).
3. Dilated ventricle received more blood, that is, diastolic volume overload (e.g., LV in ventricular septal defect [VSD], patent ductus arteriosus [PDA], mitral regurgitation [MR]; RV in tricuspid regurgitation [TR], atrial septal defect [ASD]).

Prerequisites for Genesis of S3

1. Atria–Atrial pressure.
2. Unobstructed AV valves.
3. Ventricles–Early diastolic relaxation and distensibility of the ventricles.
4. Blood volume.
5. Degree of contact with the chest wall.

Force of delivery of the blood into the ventricle, and the ability of the ventricles to accept are the most important factors influencing the occurrence of S3.

Absent S3

1. Pericardial tamponade.
2. Mitral or tricuspid stenosis.
3. Obesity, thick chest wall, and lung disease.
4. Mild LV dysfunction.
5. Diuresis or excess volume depletion.

Clinical Recognition of S3[10-12]:

S3 is a low-pitched sound heard 120 to 200 milliseconds after A2. It can be of left or right ventricular origin. Characteristic features of LV S3 and RV S3 are mentioned in ►**Table 1.**

- S3 corresponds to the rapid filling wave in the apex cardiogram (ACG) (►**Fig. 2**).
- S3 is often the most difficult heart sound to hear because it is exceptionally low in intensity and is easily obscured by extraneous sounds in the room. The patient should be examined in a quiet room in supine position.

Table 1 Characteristic features of LV and RV S3

Characteristic features	LV S3	RV S3
Site of audibility	Apex	Lower left sternal border, epigastrium, rarely over the jugular veins (right IJV as it is in line with RA and RV)
Effect of respiration	Breath-holding in expiration enhances audibility	Better heard in inspiration
Position of patient	Supine position, 30°left lateral position with the left arm extended upward away from the chest.	Supine position with passive leg raising.
Isometric hand grip	Increases the intensity	No change
Associated features	Left sided causes for S3	Raised JVP, usually prominent Y descent

Abbreviation: IJV, internal jugular vein.

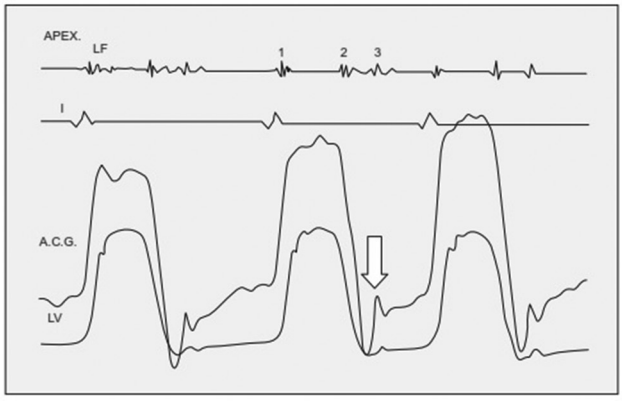

Fig. 2 ACG in a patient with heart failure showing rapid filling wave or palpable S3 (arrow). ACG, apex cardiogram.

Table 2 Differenital Diagnosis of Third heart sound.

Heart sound	Timing after A2	Pitch	Site	Associated features
S3	0.12–0.20 second	Low	Apex/LLSB	Cardiomegaly, raised JVP, MR murmur
S4	Precedes S1	Low, slightly more than S3	Apex/LLSB	Open palpable
Split S2	0.04–0.12sec	Medium to high	upper left sternal border	Varies with respiration
Opening snap	0.04–0.12 second	Medium to high	LLSB/Apex	Loud S1, MDM of mitral stenosis
Tumor plop	0.08–0.13 second	Low	Apex	Varies with position
Pericardial knock	0.09–0.12 second	Medium to high	Apex	Features of constriction

Abbreviations: LLSB, lower left sternal border; MDM, mid diastolic murmur; MR, mitral regurgitation.

- S3 is best heard with the bell of the stethoscope placed lightly.
- Simultaneous palpation and inspection of the apex should be done.
- The third heart sound may rarely be palpable and/or visible just after the apical impulse such as in a young individual with thin chest wall.
- A third heart sound is rarely palpable or visible when not audible.
- Inspiratory increase in RV S3 is absent in conditions of right ventricular distention or failure, where inspiratory augmentation of venous return does not occur.
- Intensity of RV S3 is increased by techniques that increase venous return or the size of the ventricular cavity, such as recumbent position, elevation of the legs, and volume expansion. Conversely, S3 becomes softer or disappears with standing, diuresis, hemorrhage, or dialysis.

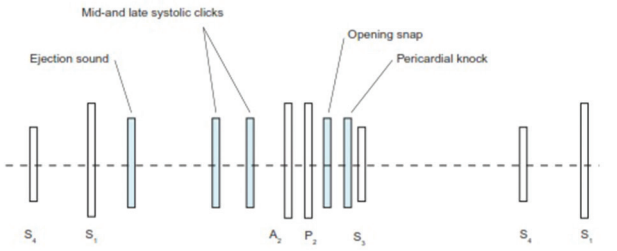

Fig. 3 Relationship of diastolic sounds to S1 and S2.

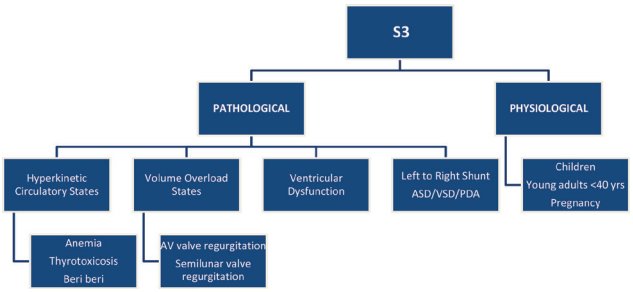

Fig. 4 Causes of S3.

Differential Diagnosis

S3 must be differentiated from other diastolic sounds (►**Table 2** and ►**Fig. 3**).

Causes

S3 can be right or left ventricular in origin (►**Fig. 4**).

Clinical Significance of S3

physiological or pathological–S3 can be appreciated normally in children and adults younger than 40 years of age, owing to the presence of a compliant ventricle with increased early diastolic filling rate and a thin chest wall. The disappearance of the physiologic S3 with age results from a decrease in early diastolic left ventricular filling and subsequent deceleration of inflow due to the development of relative left ventricular hypertrophy in adulthood.[13]

A third heart sound after the age of 40 years is usually abnormal and suggests ventricular dysfunction *or volume overload.*

Although there are no distinctive features to differentiate physiological and pathological S3, the following features favor a pathological S3:

- Presence of cardiomegaly.
- Louder S3.
- Earlier S3.

Pathological S3

Hyperkinetic Circulatory States

- S3 can be heard in severe anemia, thyrotoxicosis, beriberi, complete A–V block, renal failure, systemic AV fistula, and volume overload from excessive fluids or blood transfusion.
- S3 in these conditions is due to increased blood volume into a normal sized ventricle.
- S3 can also.. be appreciated in athletes owing to slow heart rates and increased filling volumes.[14]
- A third heart sound in the above-mentioned conditions does not indicate LV dysfunction.[15]

S3 in Shunt Lesions

- Increased blood flow and rapid early diastolic filling may occur in large left to right shunt lesions producing S3.
- Thus, LV S3 is heard in patients with VSD and PDA, and RV S3 in patients with ASD.

S3 in Mitral Regurgitation

- It is the result of emptying of large left atrial blood volume into the left ventricle under higher than normal pressure.
- It is present in any MR that is more than mild.
- Severe MR is almost always accompanied by S3 **(►Fig. 5).**
- The presence of S3 in MR does not indicate heart failure.[16]
- Absence of S3 in severe MR suggests associated significant mitral stenosis.

S3 in Aortic Regurgitation

- S3 is rarely heard in chronic aortic regurgitation patients.
- Presence of S3 suggests associated left ventricular dysfunction or MR.
- AR can produce S3 even in the presence of mitral stenosis because rapid filling can occur through the aortic valve into the left ventricle.
- In acute AR, S3 may be heard along with diminished or absent S1 in the setting of acute pulmonary edema.[17]

S3 in Aortic Stenosis

In patients with aortic stenosis, third heart sound is uncommon but it's presence indicates the presence of systolic dysfunction and elevated filling pressure.[18]

S3 in Ventricular Systolic Dysfunction

- Third heart sound is almost always heard in ventricular dysfunction.
- Presence of S3 usually indicates systolic dysfunction. Various studies have indicated that S3 less sensitive but more specific indicator of decreased ejection fraction (EF).
  - According to Patel et al, auscultated third and fourth heart sounds are associated with abnormal LV hemodynamics. The sensitivity and specificity for S3 to detect EF < 50% were 51% and 90%, respectively, with a positive predictive value of 95% and a negative predictive value of 32%.
  - Sensitivity and specificity for detecting EF of < 30% were 78% and 88%, respectively.
  - The presence of an S3 was also associated with impaired diastolic function as determined by the peak filling rate.[19]

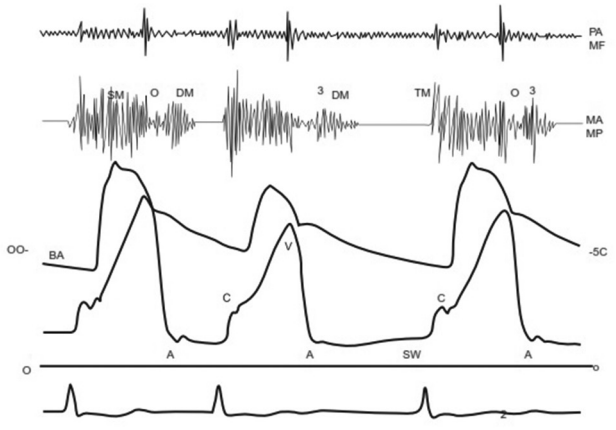

Fig. 5 Mitral phonocardiogram showing pansystolic murmur (SM), opening snap (O), S3 (3) and mid-diastolic rumble (DM) in a patient with severe mitral regurgitation.

- In heart failure patients, S3 gallop is usually associated with the following:
  - Increased left atrial pressures (>20 mm Hg).
  - Increased LV end-diastolic pressures (>15 mm Hg).
  - Elevated serum brain natriuretic peptide (BNP) concentrations.
- Sensitivity and specificity of S3 to detect elevated BNP levels is approximately 41% and 97%, respectively.[20,21]
- S3 may not be heard in mild LV dysfunction.
- The clinical use of S3 as a sign of heart failure is limited by interobserver variability.[22] This can be overcome by using an objective tool to measure heart sounds such as *phonocardiography*.
  - Marcus et al evaluated the diagnostic characteristics of phonocardiographically derived S3 and S4 for detection of LV dysfunction, in patients with heart failure who were undergoing cardiac catheterization.
  - S3 was not very sensitive (40–50 percent) for the detection of an elevated LV end-diastolic pressure or reduced LVEF.
  - S3 was highly specific (90 percent) for these parameters and for an elevated serum BNP concentration (►**Figs. 6** and **7**).[23]
- In heart failure patients, S3 is equally prevalent in both symptomatic and asymptomatic LV systolic dysfunction.
- Thus, presence of S3 in a patient with heart failure suggests ventricular dysfunction as the cause in most of the cases.
- However, absence of S3 cannot rule out ventricular dysfunction because S3 may be absent in heart failure patients associated with the following:

		LVEDP > 15mm Hg	LVEF <50%	BNP >100 pg/ml
S3	Sensitivity	41(26 – 58)	52 (31 -73)	32 (20 - 46)
	Specificity	92 (80 – 98)	87 (76 - 94)	92 (78 - 98)
S4	Sensitivity	46 (31 – 63)	43 (26 - 66)	40 (26 - 54)
	Specificity	80 (66 – 90)	72 (59 - 82)	78 (61 - 90)
S4 &/ S3	Sensitivity	68 (52 – 82)	74 (52 - 90)	57 (42 - 70)
	Specificity	73 (59 - 82)	64 (52 - 76)	72 (55 - 86)

LVEDP=Left ventricular end diastolic pressure; LVEF =Left ventricular Ejection Fraction; BNP= Brain natriuretic peptide

Fig. 6 S3 is more specific but less sensitive marker of elevated LVEDP and decreased EF. (Reproduced with permission from Marcus et al.[23]). EF, ejection fraction; LVEDP, left ventricular end-diastolic pressure.

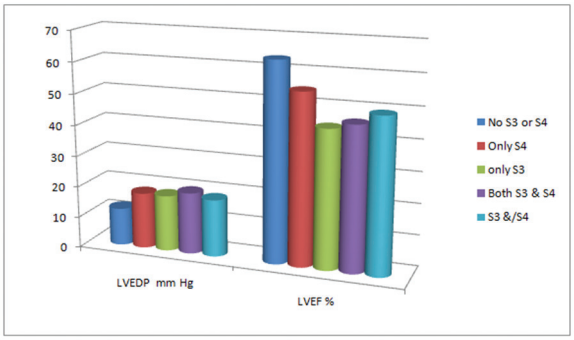

Fig. 7 S3 and or S4 suggest high LVEDP and low LV Ejection Fraction (Reproduced with permission from Marcus et al.[23]).

1. Mitral or tricuspid valve stenosis.
2. Pericardial tamponade.
3. Acute myocardial infarction–S3 may not be heard in early stages of MI. S3 may however occur in later stages due to LV systolic dysfunction or MR.

The presence of an S3 gallop in heart failure patients also has prognostic significance. In the SOLVD treatment and prevention studies, the investigators found that the presence of S3 is associated with:

- Higher risk of progression to symptomatic heart failure in asymptomatic LV dysfunction.
- Higher risk of hospitalization for heart failure (HF) or death from pump failure in patients with overt HF.
- These observations remained significant even after adjustment for markers of disease severity and were even more powerful when combined with the presence of elevated jugular vein pressure (JVP).[24,25]
- In acute myocardial infarction (MI) settings, persistent S3 is associated with increased mortality.

S3 in LV Diastolic Dysfunction

- S3 is less.. prevalent in diastolic heart failure than systolic heart failure (around 45% in diastolic vs. 65% in systolic HF).[26] However, it is difficult to differentiate systolic from diastolic heart failure by clinical signs alone.[27]
- Usually, S3 is not heard in patients with impaired relaxation of ventricles. However, rapid early diastolic emptying in the later stages, especially after the onset of systolic dysfunction, may produce a S3 along with S4 (combined systolic and diastolic heart failure).[28]

Conclusion

Third heart sound (S3) is a low-pitched early diastolic sound, often one of the most difficult sounds to appreciate clinically. Presence of a third heart sound usually signifies either ventricular dysfunction or volume overload of the ventricle. S3 is a useful diagnostic and prognostic finding in patients with either suspected or overt HF. It should be sought out carefully in all patients. Phonocardiogram can be used in difficult cases for the objective assessment of S3.

Fourth Heart Sound (S4)

Definition

S4 is a low-pitched sound (20–30 Hz) heard in pre systole, that is, shortly before the first heart sound. The rhythm produced by S4 can be compared with the cadence of the word *"Tennessee*." The phrase "*A-stiff-wall*" (a S4, stiff S1, wall S2) can also be used to describe the S4 gallop.[29]

Synonyms

Atrial gallop and presystolic gallop.

Physiology

Ventricular filling during diastole occurs in two phases. The first, or early rapid filling phase, begins with the opening of the atrioventricular valves and is passive. The second or late rapid filling phase occurs in late ventricular diastole as a result of atrial contraction (►**Fig. 8**). Fourth heart sound is associated with the second active phase of ventricular filling.[30]

Mechanism

Normally, vibrations generated by atrial contractions are neither audible nor palpable. However, in the presence of a stiff ventricular wall, atrial contractions are more forceful. The sudden deceleration of the inflowing blood following atrial systole generates vibrations in the cardio-hemic system which are heard as S4.[31]

Increased stiffness of the ventricular wall or decreased compliance of the ventricle is seen in LV hypertrophy or ischemia. In these settings, filling of the nondistensible ventricle results in abnormally increased left ventricular end diastolic pressure (LVEDP), which is seen as a large presystolic "a" wave in the ventricular pressure curve and clinically appreciated as S4 over the precordium.

The exact mechanism of genesis of S4 is not established. The possible theories areas follows:

1. Ventricular theory–Vibrations of the ventricular wall during sudden deceleration of blood flow can produce S4. This theory is no longer accepted.
2. Impact theory–Movement of the ventricle in close proximity to the chest wall after the filling of the ventricle can produces S4.[32]

Prerequisites for the Genesis of S4

1. Healthy atrium with effective atrial systole.
2. Normal sinus rhythm.
3. Non stenotic AV valve.
4. Noncompliant ventricle.

Clinical Recognition of S4: [33-35]

S4 is a low-frequency sound that is appreciated as a dull sound just before S1. Forceful atrial contractions into a stiff

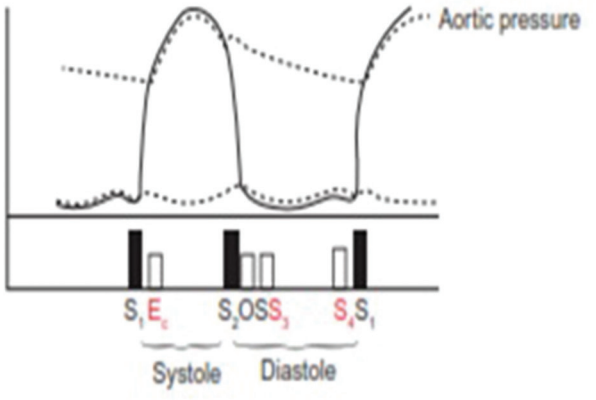

Fig. 8 Showing S4 coinciding with the atrial systole.

ventricle can produce an early, loud, and palpable S4. S4 may be LV or RV in origin (►**Table 3**).

- Palpable S4–Audible S4 may be accompanied by a palpable presystolic apical impulse (►**Fig. 9**). Appreciation of a palpable S4 increases the clinical significance of an audible S4.[36] Obesity and emphysema may mask a palpable S4. Sometimes, a presystolic outward movement of the cardiac apex may be visible. It can be better appreciated by shining a light tangentially over the cardiac apex or by taping the end of a small stick to the apical area.
- S4 can be appreciated in the apex cardiogram as increased amplitude of the "a" wave **(►Fig. 10).**[37-39]

Spodick[40] and Adolph[41] analyzed the audibility of S4 and came up with the following conclusions:

- A recordable S4 does not necessarily equate with audibility because most of the filters used in recording systems pass inaudible low-frequency vibrations.
- An audible S4 is loud and palpable **(►Fig. 11).**
- S4 virtually always indicates heart disease.

S4–S1 Interval

- S4 coincides with atrial contraction and occurs 70 milliseconds after the P wave in ECG.
- Audibility of S4 not only depends on its intensity and frequency but also on its separation from S1, which is referred to as the S4–S1 interval.
- This interval may be influenced by PR interval, P–S4 interval, and Q–S1 interval.
- In conditions where PR interval is prolonged, as in first degree heart block, there is increase in S4–S1 interval. This enables better appreciation of S4.
- In patients with tachycardia, where PR interval is short, it is difficult to appreciate S4.
- **I**ncrease in ventricular stiffness is associated with a loud and earlier S4, with increase in the S4–S1 interval **(►Fig. 12).**

Table 3 Characteristic features of LV and RV S4

Characteristic feature	LV S4	RV S4
Position	Left lateral recumbent position	Supine position
Site of audibility	Cardiac apex	Lower left sternal border or subxiphoid region
Respiratory variation	Better heard in expiration	Better heard in inspiration
Maneuvers to enhance intensity	Isometric handgrip	passive leg
Radiation of sound	LV S4 may radiate to the brachiocephalic and carotid arteries	RV S4 may be appreciated over the right internal jugular vein
Other features	Left-sided causes of S4	Prominent 'a waves' in JVP

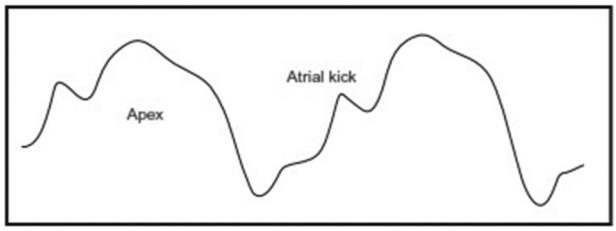

Fig. 9 Case of severe aortic stenosis showing a palpable S4 as "a wave" just before a heaving apical impulse.

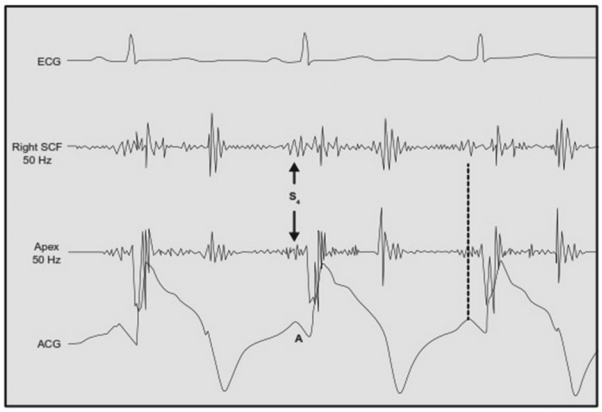

Fig. 10 Case of hypertension showing S4 coincident with the "a" wave of the simultaneously recorded apex cardiogram.

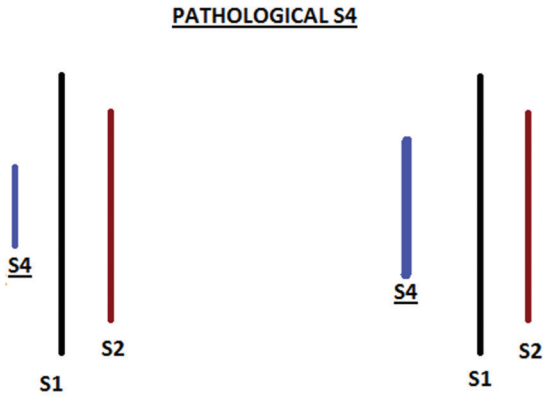

Fig. 11 Pathological S4 is loud and audible.

- In heart failure patients, longer interval between S4 and S1 represents exacerbation of heart failure.[42] and poor prognosis.[43]

Differential Diagnosis

1. Split S1–Higher in frequency, more widely heard over the precordium, and no postural variations.
2. S3.
3. Opening snap of MS.
4. Pericardial knock of constrictive pericarditis.
5. Tumor plop of atrial myxoma.

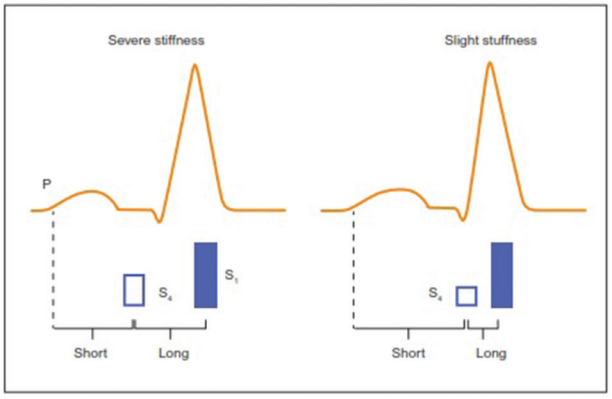

Fig. 12 Increase in ventricular stiffness is associated with increase in the S4–S1 interval.

6. Prosthetic valve sounds.

Absent S4

1. Sinus rhythm–S4 is not audible in AF or flutter.
2. Shortened PR interval–In patients with tachycardia, it is difficult to appreciate S4.
3. Severe MS or tricuspid stenosis.
4. If EDP is very high, that is, >25 mm Hg, S4 may be absent because of insufficient pumping function of atria
5. Obesity and emphysema.

S4 and Atrial Fibrillation

In patients with noncompliant ventricles, there is restriction of early filling and increased dependency on ventricular filling due to atrial contraction. However, in atrial fibrillation (AF), loss of effective atrial kick impairs ventricular filling, elevating the LV end diastolic volume and LVEDP, leading to heart failure.

- Clinically, S4 is not heard when patient develops AF.
- However, multiple, irregular medium- to high-pitched clicking sounds may be heard at the base or midparasternal areas.
- These sounds are heard in both systole and diastole at a rate of approximately 480/min and correspond to the fibrillation or f waves in ECG **(►Fig. 13).**
- The these atrial.. *sounds* are believed to arise from the forceful atrial contractions that are transmitted to mitral valve, aortic valves, and other intracardiac structures.
- They are more commonly heard in patients with congestive heart failure and coarse AF or flutter and slow ventricular rate with long diastolic pauses.
- They tend to disappear with improvement of HF or increase in heart rate.[44,45]

Causes

S4 can be of either right or left ventricular in origin (►**Fig. 14**).

Clinical Significance of S4

- S4 is an indirect sign of increased stiffness of the ventricular wall.

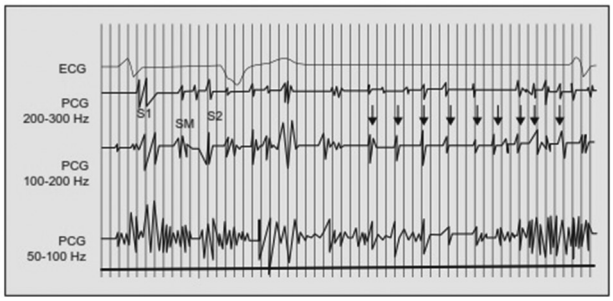

Fig. 13 Phonocardiogram showing multiple, irregular, medium frequency atrial sounds (arrows) in a patient with coarse atrial fibrillation.

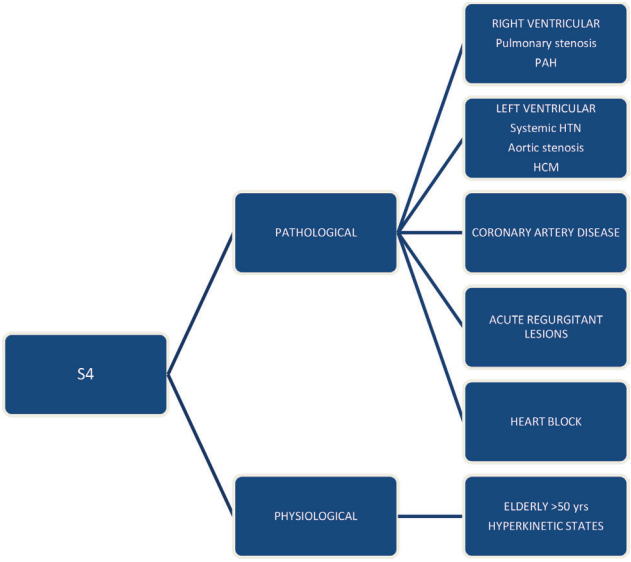

Fig. 14 Causes of S4.

- It is associated with conditions pertaining to decreased ventricular compliance such as LV hypertrophy.
- Presence of S4 usually signifies an abnormally increased ventricular end-diastolic pressure (RVEDP > 12 mm Hg and LVEDP of > 15 mm Hg).

S4 and Age

S4 is usually heard in those > 50 years of age and is attributed to decreased ventricular compliance with advanced age. Prevalence of S4 in elderly is highly variable with a prevalence of 11 to 75%, according to various phonocardiography studies.

- In a study by Collins et al:
  - Prevalence of S4 in asymptomatic adults (18–94 years) was 15.6% (95% CI, 13.2–18.2%).
  - Prevalence of S3 was 10% (95% CI,8.1–12.2%).
  - Prevalence of both S3 and S4 were 3.5% (95% CI, 2.4–5.0%).
  - Increasing age was found to decrease the odds of an audible S3 (odds ratio, 0.96; 95% CI, 0.95–0.96) and increase the odds of an audible S4 (odds ratio, 1.04; 95% CI, 1.03–1.05).[46]
- Spodick and Quarry had examined 250 consecutive ambulatory subjects in the Framingham Heart Study and found

a phonocardiographic S4 to be present in 73.1% of healthy patients and 74.3% of patients with cardiovascular (CV) disease.

- A study of 100 patients (50% healthy and 50% hypertensive)–a 70% prevalence of S4 was seen in both.[47]
- Eriksen et al studied the presence of S4 by phonocardiography and auscultation prospectively in 1714 healthy men (40–59 years). S4 was associated with higher blood pressure, coronary artery disease and its risk factors but not with age. They concluded that S4 is probably not a completely innocent finding.[48]

Thus, detection of S4, even in the elderly, should not be ignored. When S4 is loud and palpable, regardless of age, it is almost always pathological. Hypertension and coronary artery disease are the most common associated lesions.

S4 in Hyperkinetic States

- In hyperkinetic states like anemia, thyrotoxicosis, etc., vigorous atrial contractions into a volume overloaded, noncompliant ventricle may produce a S4.
- Accompanying tachycardia may fuse S3 with S4 to produce a diastolic rumble or a loud summation gallop.

S4 in Hypertension

- LV hypertrophy associated with increased afterload due to systemic hypertension decreases the compliance of the ventricles and produces a S4.
- However, when flash pulmonary edema occurs due to hypertension, S3 is more common than S4. Transient systolic dysfunction, transient diastolic regurgitation, or MR are the probable underlying mechanisms.

S4 in LV Outflow Obstruction

- In patients with aortic stenosis, presence of S4 suggests at least moderate degree of obstruction.[49]
- When there is accompanying severe mitral stenosis (MS) or AF, S4 may be absent.
- Associated coronary artery disease (CAD) may also produce a S4 in patients with mild-to-moderate aortic stenosis.

Caulifield et al studied the significance of S4 in clinical assessment of severity in 124 patients with discrete obstruction to LV outflow. The results indicate the following:

1. In patients > 40 years age, S4 is not a reliable index of severity in discrete aortic stenosis.
2. In patients < 40 years age, S4 suggests a peak systolic gradient of 75 mm Hg or more.
3. Absence of S4 in any adult suggests that the peak gradient is less than 75 mm Hg and probably less than 60 mm Hg, provided that factors hindering detection of a fourth heart sound (such as very short P-R interval, emphysema or obesity) are taken into account.[50]

- In patients with hypertrophic cardiomyopathy (HCM), S4 is consistently present irrespective of the degree of obstruction. Therefore, S4 cannot be correlated with severity of left ventricular outflow tract (LVOT) obstruction.[51]

S4 in Acute Regurgitant Lesions

- MR–In chronic MR, presence of dilated LV preludes the occurrence of S4.
- However, S4 may be heard in MR in the following conditions:
  1. Acute MR
  2. Hypertensive patients
  3. Associated CAD

  S4 in a patient with MR suggests elevated LVEDP, especially when associated with S3.[52,53]

- Aortic regurgitation (AR)–S4 is heard when AR is acute in onset. In chronic AR with decreased LV compliance due to associated lesions (e.g., systemic hypertension or CAD), S4 may occur.

S4 in Myocardial Disease

S4 is commonly heard when there is reduced LV compliance associated with acute myocarditis and restrictive cardiomyopathies, as in endomyocardial fibroelastosis.

S4 in Coronary Artery Disease

S4 is commonly heard during the early stages of acute MI. It can occur with or without signs of heart failure. It does not per se indicate LV dysfunction.

- Hill et al evaluated the diagnostic value of S4 in consecutive MI patients.
  - Most patients with acute infarction had atrial gallops.
  - S4 was absent in one patient with preexisting MS and another with left atrial fibrosis on postmortem examination.
  - They suggested that the absence of an atrial gallop in a patient presenting with chest pain and in sinus rhythm makes the diagnosis of MI less likely.[54]

S4 may become evident, or its intensity may be augmented, during episodes of angina pectoris.[55] Audible and/or palpable atrial gallops are a frequent finding in chronic LV aneurysm and are usually associated with LV dyskinesia.

S4 in LV Dysfunction

- Presence of S4 in a patient with LV dysfunction suggests underlying decreased ventricular compliance.
- The sensitivity of S4 to detect an elevated LVEDP, reduced LVEF, or elevated BNP is 46%, 43%, and 40%, respectively, and specificity is 80%, 72%, and 78%, respectively.[56]
- S4–S1 interval is a useful index in patients with heart failure. The interval is prolonged by exacerbation and shortened by improvement of HF.
  - In a study by Tabuchi et al, the S4–S1 interval was 102 ± 24 milliseconds during exacerbation of HF and shortened to 76 ± 18 milliseconds after improvement of HF.[42]

- Meyers et al studied the correlation of S4 with level of severity of LV diastolic dysfunction. S4 was audible in 35% with normal function, 42% with mild, 70% with moderate, and none with severe dysfunction ($p = 0.052$).
  - Sensitivity was 43%, specificity 65%, and accuracy 53% for discriminating normal from abnormal function.

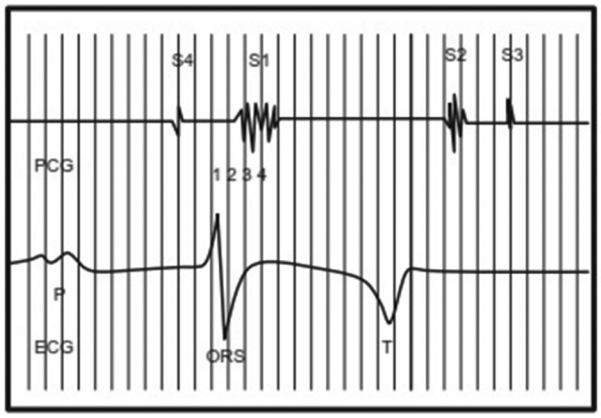

Fig. 15 First degree heart block with increased S4–S1 interval.

- They concluded that S4 is not a useful indicator of severity of LV diastolic dysfunction.[57]

S4 in Heart Block

- Prolonged PR interval in first degree AV block facilitates audibility of S4, as S4–S1 interval is increased **(►Fig. 15).**
- In second degree AV block, isolated S4 may be heard.
- In complete heart block multiple, independent S4 sounds are heard at a rate faster than the ventricular escape rate.[58]

Right Ventricular S4

RV S4 is heard in RV outflow tract (RVOT) obstruction. It can also be heard in pulmonary arterial hypertension and acute pulmonary thromboembolism, provided there is no atrial fibrillation. RV S4 usually indicates right ventricular pressures are in the systemic range. It is usually associated with a prominent "a" wave in JVP.

- In patients with RVOT obstruction, RV S4 suggests there is, at least, moderate degree of obstruction.
- In patients with pulmonary stenosis, RV S4 suggests intact atrial and ventricular septum. If there is an associated ASD or VSD, S4 will not be heard.

Conclusion

S4 or atrial gallop is a low-pitched diastolic sound heard just before S1. When S4 is loud and palpable, it is always pathological and indicates decreased compliance of the ventricles. In a patient with chest pain, presence of S4 usually indicates myocardial ischemia as the cause, provided the patient is in sinus rhythm. In patients with heart failure, S4–S1 interval is useful in early detection of exacerbations and may emerge as a useful prognostic tool in the future.

Conflict of Interest
None.

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