The Apical A Wave versus the Fourth Heart Sound in Assessing the Severity of Aortic Stenosis

By Morton A. Kavalier, M.D., Janie Stewart, and Morton E. Tavel, M.D.

SUMMARY
The height of the "a" wave of the apexcardiogram was evaluated as a marker for critical aortic stenosis in patients over 40. Critical aortic stenosis was defined as an aortic valve area < .75 cm² with no more than mild aortic insufficiency. Phonocardiograms and apexcardiograms were performed on 72 patients with catheterization proven aortic stenosis and on 14 normal controls, all over age 40. The height of the "a" wave of the apexcardiogram was measured as a percentage of the e to o excursion (a/e-o). Fourth heart sound gallops (S₄G) were recorded in 71% (11 of 14) of normal controls, 86% (6 of 7) of patients with less than critical aortic stenosis, and 85% (55 of 65) of patients with critical aortic stenosis. The a/e-o was less than 16% in all normals or patients with less than critical aortic stenosis. The a/e-o exceeded 16% in 45% (29 of 65) with critical aortic stenosis. Audibility of the S₄G bore no relationship to recordability, apical "a" wave height, or the severity of the aortic stenosis.

In conclusion, therefore, we believe that when one is confronted with findings suggestive of aortic stenosis, the finding of a palpable apical "a" wave (or an "a" wave height of greater than 16% of the total complex on the apexcardiogram) is an important positive feature, suggesting severe aortic stenosis. Its absence, however, does not exclude severe valvar obstruction. Probably because of auscultatory inaccuracy in this condition, the apparent presence or absence of an S₄G has not been of much aid in this evaluation. This sound, however, might be more useful in a carefully performed prospective study.

Additional Indexing Words:
Apexcardiogram  Phonocardiography

THE NONINVASIVE ASSESSMENT of the severity of aortic stenosis remains a problem despite the long list of clinical and graphic criteria. Goldblatt et al., noting the correlation between a fourth heart sound gallop (S₄G) and a thickened non-compliant left ventricle, concluded that the presence of an S₄G in aortic stenosis predicted a peak aortic valve gradient of at least 75 mm Hg. Caulfield et al. modified these conclusions when they noted that the reliability of an S₄G as a predictive factor of severe aortic stenosis diminished in patients over the age of 40. While the absence of S₄G was felt to indicate less than severe aortic stenosis, its presence did not indicate severe aortic stenosis with significant reliability.

In the present study, we examined phonocardiograms and apexcardiograms from normal patients and those with less than critical aortic stenosis as well as critical aortic stenosis. Correlations between the S₄G, apical "a" wave height, left ventricular "a" wave pressure and severity of the aortic stenosis were made to better assess the severity of aortic stenosis in patients over 40 years of age.

Methods
Phonocardiograms and apexcardiograms were recorded in 14 normal controls, seven patients with less than critical aortic stenosis, and 65 patients with critical aortic stenosis, all over age 40. Critical aortic stenosis was defined as an aortic valve area of less than 0.75 cm² with no more than mild aortic insufficiency. One patient had mild mitral insufficiency. Patients with idiopathic hypertrophic subaortic stenosis or significant coronary artery disease were excluded from the study. Normal patients were screened for a history of hypertension or coronary artery disease. All had normal electrocardiograms and chest X-rays. Less than critical aortic stenosis was defined as an aortic valve area of greater than 0.75 cm² and less than a 50 mm Hg aortic valvular peak systolic pressure gradient.

Phonocardiograms were obtained with a Cambridge microphone and were routinely recorded in the second right and second left intercostal space, lower left sternal border and apex. All recordings were made within 24 hours of cardiac catheterization.

Electronic signals were recorded graphically with an Electronics for Medicine recorder (Model DR-8). The apexcardiogram was recorded using the technique of Benchimol and Dimond. The time constant for this circuit was determined to be 1.8 seconds as described in previous work from this laboratory. We have compared these tracings with
those recorded with an infinite time constant and have found no significant differences in wave morphology or "a" wave height measurements. This observation is in agreement with that of Kesteloot et al. Apical sounds were recorded simultaneously with a dynamic microphone (Hewlett Packard #62-1500-C13). Band-pass filters were set as follows: Apexcardiograms, 0.1 to 20 cycles per second; sounds, 120-500 cycles per second. Attenuation of waves outside these frequency limits was at the rate of 6 decibels per octave.

Clinical records were reviewed to determine the audibility of the fourth heart sound (S₄G) at the bedside. Phonocardiograms were analyzed for the presence or absence of a recordable S₄G. The height of the "a" wave of the apexcardiogram was measured as a percentage of the e to o height (fig. 1). The height of the "a" wave of the left ventricular pressure tracing at rest was measured and correlated with the apical "a" wave excursion.

Results

An S₄G was recorded in 11 (71%) of 14 normals, six (86%) of seven patients with less than critical aortic stenosis and in 55 (85%) of 65 patients with critical aortic stenosis. The height of the "a" wave as a percentage of the e to o height was less than 16% in all seven patients with less than critical aortic stenosis (fig. 2). The "a" wave height exceeded 16% in 29 of 65 patients (45%) with critical aortic stenosis. An S₄G was thought to be audible in 43% (3 of 7) of those with less than critical aortic stenosis and in 29% (19 of 65) of those with critical aortic stenosis (table 1). The "a" wave of the left ventricular tracing correlated weakly with the apical "a" wave height (a/e-o), with an r value of 0.53.

Discussion

The "a" wave of the apexcardiogram has been shown to be due to the late diastolic anterior displacement of the left ventricular wall as a result of atrial systole. It synchronizes with the fourth heart sound, and is frequently more easily palpated than is the fourth heart sound heard. An S₄ has been shown to be phonocardiographically present in a high percentage of normal patients over age 50, but an "a" wave of > 12% is felt to be an abnormal finding. Whether or not this recordable S₄ is commonly audible is less clear. An S₄ was recorded in 71% of our normal patients, 86% of patients with less than critical aortic stenosis and in 85% of patients with critical aortic stenosis, clearly a poor discriminator in detecting the severity of the aortic obstruction. We also observed poor correlation between severity of aortic stenosis and the audibility of the S₄, noting detection of an S₄G in 43% of the patients with less than critical aortic stenosis and in only 29% of those with critical aortic stenosis. The audibility of the S₄G did not correlate with the height of the "a" wave of the apexcardiogram. These data support those of Caulfield et al., who noted that in patients over age 40 the presence of

![Figure 1](image1.png)

**Figure 1**

Simultaneous phonocardiogram and apexcardiogram from a patient with critical aortic stenosis. a = a wave height; e-o = total height of apexcardiogram from e point to o point; S₄ = fourth heart sound; SM = systolic murmur; 2 = aortic second sound.

![Figure 2](image2.png)

**Figure 2**

Mild aortic stenosis in a 66-year-old male with systolic aortic pressure gradient of 20 mm Hg. A fourth heart sound (4) is recorded, but in this example, the apical A wave is diminutive and well within normal limits.
Table 1

Clinical and Phonocardiographic Data of Normal Patients and Patients with Aortic Stenosis

<table>
<thead>
<tr>
<th></th>
<th>Normal patients</th>
<th>Mild AS patients</th>
<th>Critical AS patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients</td>
<td>14</td>
<td>7</td>
<td>65</td>
</tr>
<tr>
<td>S4 heard</td>
<td>0</td>
<td>3 (43%)</td>
<td>19 (29%)</td>
</tr>
<tr>
<td>S4 recorded</td>
<td>11 (71%)</td>
<td>6 (86%)</td>
<td>55 (85%)</td>
</tr>
<tr>
<td>a/e-o &gt; 16%</td>
<td>0</td>
<td>0</td>
<td>29 (45%)</td>
</tr>
<tr>
<td>Average age</td>
<td>53.8</td>
<td>54.3</td>
<td>57.2</td>
</tr>
</tbody>
</table>

Abbreviations: a/e-o = a wave height percentage; AS = aortic stenosis; S4 = fourth heart sound.

an S4 was an unreliable predictor of significant disease. When the accompanying “a” wave of the apexcardiogram was analyzed in the same group of patients a clear discriminator was evident. While a small “a” wave did not rule out significant aortic stenosis, in every instance that the “a” wave ratio was greater than 16%, critical aortic stenosis was present. The “a” wave ratio has been shown by others to correlate with the peak “a” wave pressure in the left atrium. In addition, the palpability of the “a” wave has been correlated with an “a” wave ratio of 14%, suggesting that if one is able to feel this presystolic apical impulse in a given patient, aortic stenosis, if present, is apt to be severe. One of course must take into consideration such factors as emphysema, chest wall configuration, obesity, large breasts, and short P-R intervals, any of which might reduce the palpability of the S4.

Similar to the finding of Voigt and Friesinger, we noted a poor correlation between left ventricular end-diastolic pressure and apical “a” wave height, noting many elevated pressures which were not associated with large “a” wave percentages. There was, however, a weak correlation between left ventricular “a” wave height and apical “a” wave size. This is expected since both these phenomena reflect the results of a vigorous atrial contraction on a noncompliant ventricle. The low order of correlation and degree of scatter, however, precludes the clinical use of apexcardiography in prediction of left ventricular “a” wave height in the individual patient. The work of Gibson et al. using a diastolic stiffness factor more thoroughly explores these interrelationships.

Our study was not specifically designed to test the clinician’s ability to detect the S4, although experienced auscultators were used for most of the examinations. We feel that the masking effect of the loud systolic murmur likely interfered with detection of this sound, since in other conditions these sounds are usually heard in the presence of large apical “a” waves.

In conclusion, therefore, we believe that when one is confronted with findings suggestive of aortic stenosis, the finding of a palpable apical “a” wave (or an “a” wave of greater than 16% of the total complex on the apexcardiogram) is an important positive feature, suggesting severe aortic stenosis. Its absence, however, does not exclude severe valvar obstruction. Probably because of auscultatory inaccuracy in this condition, the apparent presence or absence of an S4 has not been of much aid in this evaluation. This sound, however, might be more useful in a carefully performed prospective study.

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