Diagnostic value of configuration of left ventricular outflow pressure gradient in differentiating hypertrophic obstructive cardiomyopathy from discrete types of aortic stenosis

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SUMMARY Since obstruction to left ventricular (LV) outflow in hypertrophic obstructive cardiomyopathy (HOCM) is dynamic, whereas that in discrete aortic stenosis is fixed, the shape of the transaortic pressure gradient should be characteristically altered in HOCM and thereby provide a means of differentiating these two disparate types of aortic stenosis. In all 22 HOCM patients, peak arterial pulse always occurred in the initial half of the systolic ejection period, while in 37 of 40 patients with discrete types of aortic stenosis it appeared in the final half. Peak left ventricular pressure was delayed significantly (P < 0.01) in HOCM compared with fixed aortic stenosis. Furthermore, the interval from onset of ejection to peak left ventricular pressure divided by ejection period was increased in HOCM, 0.59 compared with 0.49 (P < 0.01) in fixed aortic stenosis. The early arterial and late left ventricular pressure pulse peaks in HOCM are related to absence of obstruction to ejection early in systole. Moreover, the ratio of mean pressure gradient during the first half of ejection to that of the last half averaged 0.59 in HOCM. In contrast, this ratio averaged 1.24 in 23 patients with valvular aortic stenosis, 1.13 in 12 patients with discrete subvalvular stenosis, and 1.85 in 5 patients with supravalvular stenosis. This ratio allowed complete separation of HOCM from fixed aortic stenosis; < 0.80 identified HOCM while greater indicated fixed aortic stenosis. Whether brachial arterial pulse, appropriately adjusted for time, or central aortic pressure pulse was used did not alter these results.

The pathogenesis of obstruction to aortic outflow in hypertrophic obstructive cardiomyopathy (HOCM) is fundamentally different from that in patients with discrete fixed narrowing at the valvular, supravalvular, or subvalvular level (Ross et al., 1966; Reis et al., 1974; Mason et al., 1975). In patients with discrete forms of aortic obstruction, the area of the stenotic orifice remains constant during haemodynamic interventions which alter the systolic volume or the contractile state of the left ventricle.

In contrast, in patients with HOCM, distinct variations in the magnitude of the intraventricular pressure gradient may be induced by a variety of physiological and pharmacological stimuli. Thus the dimensions of the obstructing outlet are not fixed in HOCM and the size of the left ventricular outflow tract varies, depending upon the contractile state of the myocardium, the venous return to the heart, and the distention of the ventricle during systole as governed by systemic arterial pressure (Braunwald and Ebert, 1962; Braunwald et al., 1964; Mason et al., 1965, 1966, 1967; DeMaria et al., 1974; Wampold et al., 1976). In the past, identification of HOCM by haemodynamics has required interventions to alter these determinants of left ventricular volume. The purpose of this report is to delineate

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a newly recognised haemodynamic characteristic of HOCM in the resting state: the configuration of the transaortic pressure gradient. Analysis of this gradient allows precise differentiation between HOCM and discrete aortic stenosis without the need for any provocative manoeuvre.

**Patients**

The left ventricular outflow pressure gradient was examined in 22 patients with HOCM (idiopathic hypertrophic subaortic stenosis) and in 40 patients with the discrete types of aortic stenosis. The patients with fixed aortic obstruction included 23 with valvular stenosis, 12 with discrete subvalvular membranous stenosis, and 5 with supravalvular stenosis. Left ventricular pressures were measured either by the transseptal method or by retrograde arterial catheterisation. In all 62 patients simultaneous intra-arterial pressure was obtained from the brachial artery and, in addition, sequential pressures were recorded by retrograde catheter pull-back across the obstructing area in 55 patients. The peak transaortic outflow systolic pressure gradient averaged 74 mmHg (range 32 to 119 mmHg) in HOCM, 96 mmHg (52 to 150 mmHg) in valvular aortic stenosis, 77 mmHg (55 to 115 mmHg) in membranous subvalvular stenosis and 105 mmHg (65 to 160 mmHg) in supravalvular aortic stenosis. The configuration of the transaortic outflow pressure gradients was analysed in the following manner in each of the patients. The left ventricular pressure pulse upstream to the obstruction was compared with the simultaneously recorded arterial pressure pulse (Fig. 1). Five consecutive beats were examined and the results averaged in each patient. The upstroke of the brachial arterial pressure pulse was superimposed with the rise of left ventricular pressure to adjust for the brief temporal delay of brachial artery pressure transmission. Whether the brachial arterial pulse, properly adjusted for time, or the ascending aortic pressure pulse was used did not significantly affect the results. In the patients in whom both the left brachial artery and ascending aortic pressures were recorded, the peak systolic brachial artery pressure was only 4·8 ± 0·7 mmHg (SEM) greater than the simultaneously recorded peak systolic ascending aortic pressure. The duration of the ejection period was obtained from the onset of the upstroke of arterial pressure to the dicrotic notch of this pressure pulse. The ejection period was divided equally into its initial and final halves. The onset of ejection to peak left ventricular pressure was measured and the ratio of this interval to the duration of ejection calculated. Whether the peak of the arterial pressure pulse occurred in the first or second half of the systolic ejection period was also determined.

**Fig. 1** Representative recordings of simultaneous left ventricular (LV) and brachial arterial (BA) pressures in a patient with hypertrophic obstructive cardiomyopathy (IHSS) (A) and in a patient with fixed valvular aortic stenosis (AS) (B). The systolic ejection period is divided into its initial (A) and final (B) halves by the vertical dashed lines in the middle tracings in each panel. The trans-left ventricular outflow mean pressure gradient during the first half of ejection is indicated by the dotted area (A), while the mean gradient during the second half of ejection is depicted by the downward-dashed lines (B). The ratio of the time (seconds) from the onset to peak of the left ventricular pressure pulse related to the total duration (seconds) of the ejection period is indicated for the IHSS (HOCM) patient and the AS patient respectively. In addition, the characteristic ratio of the mean transaortic pressure gradient in the initial half of ejection (A) to that occurring in the second half of ejection (B) is also indicated for both representative patients.
**Transaortic pressure gradient configuration in HOCM**

The configuration of the transaortic pressure gradient was compared in HOCM and fixed aortic stenosis by measuring the mean pressure gradient during the first half of the ejection period relative to that during the second half (Fig. 1) by planimetry. The ratio of the mean pressure gradient of the initial one-half of the ejection period to the final one-half ejection period was then calculated.

**Results**

Representative recordings in HOCM and fixed valvular aortic stenosis are shown in Fig. 1 and the complete data from all of the patients are given in Figs. 2 and 3.

**Peak Arterial Pulse**

In each of the 22 patients with HOCM, the peak of the arterial pressure pulse occurred in the initial half of the systolic ejection period (Fig. 1A). In contrast, in 37 of the 40 patients with discrete aortic stenosis the arterial pressure pulse peak appeared in the final half of the ejection period (Fig. 1B). The 3 patients with discrete aortic stenosis in whom the arterial pressure pulse occurred in the first half of the ejection period had subvalvular membranous stenosis. In these 3 patients, the average peak systolic transaortic pressure gradient was 103 mmHg and there was considerable gross left ventricular hypertrophy; no evidence of muscular dynamic subaortic stenosis was detected by pre- or post-operative left heart catheterisation.

**Onset of Ejection to Peak Left Ventricular Pressure**

Peak left ventricular pressure was delayed significantly ($P < 0.01$) in HOCM (Fig. 1A) compared with the total group of 40 patients with discrete aortic stenosis (Fig. 1B). Therefore, the relation between the interval from the onset of the peak of
the left ventricular pressure pulse divided by the
ejection period was significantly greater (P < 0.01)
in HOCM (0.59 ± 0.01, SEM) than this ratio in
the 40 individuals with fixed aortic stenosis (0.49
± 0.01) (Fig. 2). This ratio was also significantly
greater in HOCM compared with the patients with
valvular aortic stenosis (P < 0.01), the patients with
discrete subvalvular membranous stenosis (P <
0.01), and the patients with supravalvular stenosis
(P < 0.01).

**RATIO OF MEAN PRESSURE GRADIENT DURING INITIAL TO FINAL HALF OF EJECTION**
The ratio of the mean pressure gradient which
occurred within the first half of systolic ejection to
the mean pressure gradient during the second half
of the ejection period was considerably less in
HOCM (P < 0.01) (Fig. 1A) than in fixed aortic
stenosis (Fig. 1B). Thus in HOCM the ratio of the
initial to final mean pressure gradient was 0.59
± 0.04; whereas this pressure gradient relation was
1.24 ± 0.06 in valvular aortic stenosis, 1.13 ± 0.06
in discrete subvalvular stenosis, and 1.85 ± 0.09 in
supravalvular aortic stenosis (Fig. 3). Moreover, this
ratio provided complete separation of all patients
with HOCM from all individuals with the fixed
types of aortic stenosis. Thus all patients with
HOCM had a first to second half mean transaortic
pressure gradient ratio of less than 0.80, whereas
this ratio was always greater than 0.80 in all of those
with discrete aortic stenosis (horizontal dashed line
depicted on Fig. 3).

**Discussion**

Obstruction to left ventricular outflow in HOCM
has recently been shown to be the result of para-
doxal forward motion of the anterior mitral
leaflet during cardiac contraction abutting against
the relatively immobile hypertrophied interven-
tricular septum (King et al., 1973a, b, 1974; Reis et
al., 1974; Mason et al., 1975). The obstruction to
left ventricular outflow in HOCM is thereby
dynamic and forms with each systole. Furthermore,
this dynamic obstruction in HOCM is incomplete
in the initial phase of ejection, so that the earliest
portion of ejection is not accompanied by obstruc-
tion while nearly complete impedance to left
ventricular ejection takes place in the final one-half
of systole (Pierce et al., 1964; Gault et al., 1966). In
contrast, in the discrete types of aortic stenosis the
obstruction to aortic outflow remains fixed through-
out the entire period of systolic ejection and is
thereby constant during the resting state and the
haemodynamic interventions which alter contracti-
lity, venous return, and the systolic distending
pressure of the left ventricular outflow tract.

The present study clearly documents that the
configuration of the resting transaortic pressure
gradient in patients with HOCM differs con-
siderably from that of the fixed types of discrete
obstruction to left ventricular outflow (Fig. 1). Thus,
the peak of the brachial artery pressure pulse always
occurred in the initial half of the ejection period in
HOCM, while in the fixed types of aortic stenosis
the peak arterial pressure pulse occurred in the
second half of the ejection period. In addition, the
onset of ejection to the peak of the left ventricular
pressure pulse is related to the total duration and
nature of obstruction to left ventricular outflow.
Since peak left ventricular pressure is delayed in
HOCM, the ratio of onset of ejection to peak left
ventricular pressure relative to the duration of the
systolic ejection period is greater in HOCM com-
pared with the fixed, discrete types of aortic
stenosis (Fig. 2). In addition, in contrast to HOCM,
the left ventricular pressure pulse in the fixed forms
of aortic stenosis was triangular in shape resembling
an isovolumetric contraction, resulting in the peak
left ventricular pressure pulse occurring in the
middle or in the first half of the ejection period
(Fig. 1B).

The aforementioned observations indicate that
the early arterial and late ventricular pressure pulse
peaks in HOCM are related to the absence of
obstruction to ejection early in systolic ejection in
HOCM (Fig. 1A). In contrast, in discrete aortic
stenosis (valvular, subvalvular or supravalvular), as
exemplified by the patient with valvular aortic
stenosis shown in Fig. 1B, the constant obstruction
to left ventricular outflow results in the peak arterial
pressure pulse occurring in the final half of the
ejection period and the peak left ventricular systolic
pressure appearing in the mid-portion of the trans-
aortic pressure gradient.

Most importantly, the ratio of the mean pressure
gradient in the first half of ejection to that of the
second half of ejection provided complete differenti-
ation of HOCM from the fixed types of aortic
stenosis at rest without provocative manoeuvres
(Fig. 1 and 3). From these findings, it is clear that
the examination of the configuration of the trans-
left ventricular outflow pressure gradient at rest
separates dynamic subaortic stenosis (HOCM) from
the discrete forms of aortic stenosis.

**References**

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Transaortic pressure gradient configuration in HOCM


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