

Sudden death in hypertrophic cardiomyopathy¹

Harry M. Lever, M.D.
William A. Schiavone, D.O.
Carl C. Gill, M.D.

Hypertrophic cardiomyopathy affects people of all ages, and with the advent of echocardiography, it is being recognized more frequently. Death is usually sudden and unexpected. Factors reviewed that may play a role in sudden death include anatomic, hemodynamic, and electrophysiologic mechanisms. The results of medical and surgical treatment are also discussed.

Index terms: Death, sudden • Heart surgery • Myocardial diseases

Cleve Clin Q 51: 65–70, Spring 1984

Hypertrophic cardiomyopathy (HC) is transmitted as an autosomal dominant trait or may occur sporadically. It occurs in patients of all ages, and it is recognized much more frequently since the advent of echocardiography. Patients with HC may present with symptoms of left ventricular outflow obstruction such as chest pain, dyspnea, dizziness, syncope, or sudden death or they may be completely asymptomatic and present with a heart murmur or an abnormal electrocardiogram. Mortality is 3% to 4% per year in natural history studies,^{1–3} and death is usually sudden. We review the factors that may play a role in sudden death and discuss the medical and surgical treatment for this disease.

Limitations of current data

Although initial studies of hypertrophic cardiomyopathy describe no clinical predictors of sudden death, a recent study by McKenna et al⁴ suggests that a combination of (1)

¹ Departments of Cardiology (H.M.L., W.A.S.) and Thoracic and Cardiovascular Surgery (C.C.G.), The Cleveland Clinic Foundation. Submitted for publication Aug 1983; revision accepted Nov 1983.

young age (less than 14 years), (2) syncope, (3) severe dyspnea, and (4) a positive family history for HC best predicts sudden death. The etiology of sudden death in patients with HC, however, remains a dilemma. From the outset, one must understand the limitations of the available data. First, of the three natural history studies published, the longest average follow-up is only 7.4 years.² Second, in order for a patient to participate in the earlier natural history studies, cardiac catheterization was usually required to make a definitive diagnosis, as echocardiography was not available. This tended to exclude older patients because of the reluctance to catheterize them, and to include sicker patients, as asymptomatic patients usually were not catheterized. Third, no published studies evaluate progression of the disease in a systematic fashion. Only 4 cases have been reported in which gradually worsening left ventricular outflow tract obstruction is documented.^{2,5,6} In the natural history studies, most patients were catheterized initially and subsequent follow-up was only clinical.

Possible etiologies

Anatomic and hemodynamic factors

Early investigators suggested obstruction of left ventricular egress as the cause of sudden death,⁷⁻⁹ but subsequent studies have not supported this concept.^{1,3,4} Unfortunately, most patients in these studies were not catheterized serially, and death occurred years after catheterization. In children with HC with symptoms prior to age 15, Maron et al² found that 8 of 20 with documented subaortic obstruction died, but only one of 11 patients without obstruction died during a follow-up of 7.4 years. It should be noted that among the 126 patients reported by Frank and Braunwald,¹⁰ 10 died; 6 died suddenly and 4 suffered progressive deterioration. The average basal gradient was only 23 mm Hg in the group that died suddenly, but 2 of the 6 patients were not given provocative drugs such as isoproterenol or amyl nitrite. In one patient with a gradient of 4 mm Hg, a gradient of 34 developed with isoproterenol. Two of the 4 patients with progressive deterioration had subvalvular gradients at the time of initial catheterization, but only one of the remaining 2 patients without a documented gradient was given isoproterenol. If the 3 patients who had lower gradients at rest had been provoked and a more substantial gradient documented, the data would have been

entirely different. Interestingly, the patients in this study who were functional class III and IV had higher gradients and a much higher incidence of sudden death. Shah et al¹ and McKenna et al⁴ demonstrated no correlation between sudden death and the measured subaortic gradient; however, the deaths were always remote in time from the catheterization. It is well known that gradients measured at catheterization vary from study to study.

One interesting case report¹¹ from Japan describes a patient who underwent cardiac catheterization because of recurrent episodes of syncope and convulsions. During catheterization, he was found to have no gradient at rest; however, with isoproterenol, he displayed a gradient of 65 mm Hg, complained of chest pain, had a "mild convulsive seizure," and lost consciousness. During this episode, he remained in sinus rhythm, and aortic pressure dropped to 40 mm Hg despite the absence of arrhythmias. This unique report of syncope during catheterization suggests that obstruction probably played a role.

Presence of a subvalvular gradient may be only one factor in the etiology of sudden death. For a number of years, Goodwin¹² has considered poor diastolic compliance a significant factor in functional limitation and in sudden death of patients with HC. Glancy et al¹³ have clearly shown that with onset of atrial fibrillation and sudden loss of atrial systole in the hypertrophied, poorly compliant left ventricle, cardiac output is markedly reduced. Further, James and Marshall¹⁴ have speculated that decreased ventricular compliance may provoke fatal ventricular fibrillation. Webb-Peploe et al¹⁵ and Goodwin¹² have shown that abnormalities of diastolic function are aggravated by adrenergic stimulation and ameliorated by beta blockade. These factors may further compromise the patient with HC in whom sudden tachycardia develops. As the inotropic state of the heart increases, compliance decreases, the diastolic filling time is shortened, and, consequently, cardiac output is further compromised.

Electrophysiologic factors

Patients with HC are prone to arrhythmias.¹⁵ There are individual case reports of heart block,¹⁶ asystole,¹⁷ and cases of sudden death associated with an accessory pathway.¹⁸ James and Marshall¹⁴ studied the conduction system in detail in 22 patients who died suddenly of HC and found a number of structural abnormalities.

Twelve patients had significant sinus node fibrosis, and 13 had marked fragmentation or division of the A-V node or His bundle. This fragmentation is typical of fetal hearts and has been associated with pre-excitation syndromes. There were also areas of focal fibrosis in the A-V node and His bundle in 4 patients, and multiple cysts in the central fibrous body in 4 patients. James and Marshall¹⁴ speculated that these structural abnormalities could lead to significant atrial arrhythmias, which in turn, might result in fatal ventricular arrhythmias.

Many authors have documented that atrial arrhythmias lead to rapid clinical deterioration in patients with HC. Glancy et al¹³ studied 16 patients with HC who had atrial fibrillation. Clinical deterioration was marked: congestive heart failure developed in 11, syncope or presyncope in 7, and hypotension in 5. Five patients were studied both in atrial fibrillation and sinus rhythm, and a consistently higher cardiac output was documented in sinus rhythm. However, the subvalvular gradients were also slightly higher during sinus rhythm. These authors emphasized that atrial fibrillation causes large variations in stroke volume. After a short diastole, there is little or no ejection of blood. With a beat that occurs after a longer pause, there is an increase in stroke volume and an accentuation of the subvalvular gradient similar to that seen after a premature ventricular contraction. In addition, with the loss of synchronous atrial contraction, a noncompliant ventricle ejects less blood. These factors together significantly reduce cardiac output.

Many authors have attempted to correlate the prevalence of arrhythmias in patients with HC and their prognoses. All have found Holter recordings to be more sensitive than exercise testing. In 83 consecutive patients, McKenna et al¹⁹ documented paroxysmal supraventricular tachycardia in 21 and atrial fibrillation in 12. Sixty-two percent of the patients had ventricular arrhythmias. Eighteen of 20 patients with frequent premature ventricular beats also had high-grade arrhythmias, but only 35% of patients with multiform or paired premature ventricular beats had frequent extrasystoles. Twenty-four patients had at least one episode of ventricular tachycardia. Ventricular tachycardia, as well as the combination of multiform and paired premature ventricular contractions, strongly correlated with sudden death. Of 7 patients in McKenna's series who died suddenly, 5 had ventricular tachycardia during Holter recording. Supraventricular arrhyth-

mias, on the other hand, did not correlate with sudden death. Maron et al²⁰ studied 84 patients by Holter recording. Ventricular tachycardia was found in 17 patients. In this series, 4 patients died suddenly, and 2 were resuscitated from ventricular fibrillation. Of these 6 patients, 4 had previously documented ventricular tachycardia on a 24-hour Holter recording. Supraventricular tachycardia again did not correlate with sudden death. Combining the studies, 9 of the 13 patients who died suddenly had previously documented ventricular tachycardia.

In an attempt to determine prospectively what types of arrhythmias patients with HC may be prone to, Schiavone et al²¹ studied 8 patients with HC using electrophysiologic techniques. All patients had syncope or presyncope. Two patients had had sustained atrial fibrillation from the onset of the study. All patients underwent two-dimensional echocardiography, cardiac catheterization, 24-hour Holter monitoring, resting electrocardiography, and atrial and ventricular programmed electrical stimulation. Echocardiography revealed a mean left atrial size of 47 mm and a mean septal thickness of 24 mm, and 6 patients had systolic anterior motion at rest. During cardiac catheterization, the mean resting left ventricular outflow tract gradient was 37 mm Hg, and with provocation, the mean peak gradient increased to 89 mm Hg. Twenty-four hour Holter recordings revealed chronic atrial fibrillation in 2, paroxysmal supraventricular tachycardia in one, and paroxysmal atrial fibrillation in one. Unsustained ventricular tachycardia was present in 2 patients.

Programmed atrial stimulation in the 6 patients without chronic atrial fibrillation produced sustained atrial fibrillation in 2, sustained atrial flutter in 2 others, and no atrial arrhythmias in the last 2. Ventricular fibrillation could be provoked in only one patient with use of double extrastimuli in the right ventricular apex. These patients were therefore much more susceptible to sustained atrial arrhythmias than to sustained ventricular arrhythmias.

Anderson et al²² used programmed ventricular stimulation in the operating room prior to myectomy. With two extra stimuli, they found that sustained ventricular tachycardia developed in 3 of 17 patients, while with three extra stimuli, sustained ventricular tachycardia developed in 11. No attempt was made to induce atrial arrhythmias. Although the numbers of patients in these studies are small, such evaluations do indi-

Table 1. Mortality in patients with HC treated with beta blockers

	No. of patients	Deaths due to HC	Mean follow-up (yr.)	Annual mortality (% yr.)
Swan et al ²⁶ London	47	5	3.0	3.5
Adelman et al ²⁷ Toronto	18	2	2.0	5.5
Shah et al ¹ Rochester, NY	101	19	4.7	4.0
Canedo et al ²⁹ Augusta, GA	24	0	4.4	0
				3.4 Weighted Mean

* High dose propranolol.

HC = Hypertrophic cardiomyopathy.

cate the potential usefulness of programmed electrical stimulation prospectively to determine the types of arrhythmias for which the patient is at risk.

Although arrhythmias had been noted in a large percentage of patients who died suddenly, a recent case report by McKenna et al²³ suggests that other factors are involved. A 52-year-old woman with HC and a resting subvalvular gradient of 50 mm Hg had experienced repeated episodes of syncope. Holter recordings revealed numerous asymptomatic short episodes of ventricular tachycardia. On one occasion when she experienced a syncopal episode while wearing a Holter recorder, she maintained a sinus rhythm. When her heart rate increased from 70 to 130 beats/min, she lost consciousness. There was no ventricular tachycardia throughout the episode. However, in the recovery period, marked ST depression developed with atrioventricular dissociation and a junctional rhythm at 50 beats/min. This episode implicates a hemodynamic cause for syncope and suggests obstruction or poor ventricular filling as a result of the tachycardia, rather than the arrhythmia alone. Using simultaneous echocardiographic indices of out-flow obstruction and Holter monitoring, Shah and Lever²⁴ found a positive correlation between gradient and serious ventricular or supraventricular arrhythmias in a group of 30 patients with HC. However, Doi et al²⁵ in a similar study found no correlation between echocardiographic indications of obstruction and arrhythmias.

Treatment

Since the causes for syncope and sudden death in HC are probably multifactorial and related to

anatomic, hemodynamic, and electrophysiologic factors, treatment is complex. Patients treated with beta blockers reported in previous series^{1,26,27} have a sudden death rate similar to that in the natural history studies (Table 1). McKenna et al,²⁸ using a mean dose of 280 mg/day of propranolol, did not demonstrate any reduction in ventricular or supraventricular arrhythmias. On the other hand, Candeo et al²⁹ suggest that sudden death can be reduced by rigid control of documented arrhythmias. They recommend large doses of propranolol alone or in conjunction with quinidine, disopyramide, or diphenylhydantoin. No deaths occurred in their group of 33 patients. McKenna et al³⁰ recently suggested that amiodarone is helpful in controlling supraventricular and ventricular arrhythmias, but there have been no long-term studies to prove this. Calcium channel-blocking agents may be helpful in some patients with supraventricular arrhythmias, but offer little or no help for ventricular arrhythmias. Digitalis is contraindicated except when no other agent slows the ventricular response to atrial fibrillation.

Septal myectomy, as described by Cleland³¹ and popularized by Morrow et al³² at the NIH, has become the standard surgical procedure. Numerous studies have clearly documented that patients with the severe symptoms associated with HC are markedly improved after surgery. The natural history study of Shah et al¹ suggested that survival might be better with surgery; however, the 26% operative mortality was unacceptable. A recent study by Beahrs et al³³ also suggests that surgery may prolong life. Their early mortality for patients after myectomy was only 1.9% per year. Other groups are summarized in Table 2.^{1,34-36} In late survival, myectomy patients do better than unoperated, natural history patients, and far better than those treated with beta blockers alone. Surgery, however, does not uniformly protect patients from sudden death, and continued close follow-up and medical management are mandatory. It appears that patients with HC who have a resting or provokable gradient greater than 50 mm Hg and severe symptoms despite a good medical regimen should undergo surgery. Patients who have a mild degree of obstruction at rest or with provocation should be managed medically and monitored for the development of arrhythmias and the progression of disease. Patients with severe subvalvular gradient at rest or with provocation, but with few symptoms present

Table 2. Mortality among survivors of septal myectomy or myotomy for HC

	No. of patients	Surgical survivors	Deaths due to HC	Mean follow-up (yr.)	Annual mortality (% yr.)
Maron et al ³⁴ Bethesda 1960–75	120	110	12	5.6	1.9
Agnew et al ³⁵ New Zealand 1962–76	49	47	6	7.4	1.7
Reis et al ³⁶ Miami 1971–76	30	30	1	3.1	1.1
Shah et al ¹ Rochester, NY 1960–73	58	43	4	5.2	1.8
					1.8 Weighted Mean

HC = Hypertrophic cardiomyopathy.

a difficult management problem. Some authors recommend surgical intervention in this group; however, this remains uncertain.

Summary

A number of factors, anatomic and hemodynamic as well as electrophysiologic, apparently contribute to sudden death in patients with HC. How these factors interact is yet to be determined. In the future, careful prospective evaluation of patients with HC may elucidate the mechanism of sudden death.

References

- Shah PM, Adelman AG, Wigle ED, et al. The natural (and unnatural) history of hypertrophic obstructive cardiomyopathy—a multicenter study. *Circ Res* 1974; **35** (suppl II):179–195.
- Maron BJ, Henry WL, Clark CE, Redwood DR, Roberts WC, Epstein SE. Asymmetric septal hypertrophy in childhood. *Circulation* 1976; **53**:9–19.
- Hardarson T, De La Calzada CS, Curiel R, Goodwin JF. Prognosis and mortality of hypertrophic obstructive cardiomyopathy. *Lancet* 1973; **2**:1462–1467.
- McKenna W, Deanfield J, Faruqui A, England D, Oakley C, Goodwin J. Prognosis in hypertrophic cardiomyopathy: role of age and clinical, echocardiographic and hemodynamic features. *Am J Cardiol* 1981; **47**:532–538.
- Williams RG, Ellison RC, Nadas AS. Development of left ventricular outflow obstruction in idiopathic hypertrophic subaortic stenosis: report of a case. *N Engl J Med* 1973; **288**:868–871.
- Tafur E, Guntheroth WG, Baum D, Blackmon JR. The development of outflow tract obstruction of the left ventricle in idiopathic myocardial hypertrophy. *Circulation* 1964; **30**:569–577.
- Brock R. Functional obstruction of the left ventricle; acquired aortic subvalvar stenosis. *Guy's Hospital Report* 1957; **106**:221–238.
- Goodwin JF, Hollman A, Cleland WP, Teare D. Obstructive cardiomyopathy simulating aortic stenosis. *Br Heart J* 1960; **22**:403–414.
- Braunwald E, Morrow AG, Cornell WP, Aygen MM, Hilbisch TF. Idiopathic hypertrophic subaortic stenosis: clinical, hemodynamic and angiographic manifestations. *Am J Med* 1960; **29**:924–945.
- Frank S, Braunwald E. Idiopathic hypertrophic subaortic stenosis: clinical analysis of 126 patients with emphasis on the natural history. *Circulation* 1968; **37**:759–788.
- Nishiyama S, Yamaguchi H, Shiratori K, et al. Two-dimensional echocardiographic findings during syncopal attack due to obstruction in the outflow tract of the left ventricle in a patient with hypertrophic obstructive cardiomyopathy. *J Cardiol* 1981; **11**:439–448.
- Goodwin JF. Prospects and predictions for the cardiomyopathies. *Circulation* 1974; **50**:210–219.
- Glancy DL, O'Brien KP, Gold HK, Epstein SE. Atrial fibrillation in patients with idiopathic hypertrophic subaortic stenosis. *Br Heart J* 1970; **32**:652–659.
- James TN, Marshall TK. De subitaneis mortibus: XII. Asymmetrical hypertrophy of the heart. *Circulation* 1975; **51**:1149–1166.
- Webb-Peploe MM, Oakley CM, Croxson RS, et al. Cardioselective beta-adrenergic blockade in hypertrophic obstructive cardiomyopathy. *Postgrad Med J* 1971; (Suppl) **47**:93–97.
- Tajik AJ, Giuliani ER, Frye RL, McGoon DC, Nunn SL. Muscular subaortic stenosis associated with complete heart block. *Am J Cardiol* 1973; **31**:101–104.
- Joseph S, Balcon R, McDonald L. Syncope in hypertrophic obstructive cardiomyopathy due to asystole. *Br Heart J* 1972; **34**:974–976.
- Krikler DM, Davies MJ, Rowland E, Goodwin JF, Evans RC, Shaw DB. Sudden death in hypertrophic cardiomyopathy: associated accessory atrioventricular pathways. *Br Heart J* 1980; **43**:245–251.
- McKenna WJ, England D, Doi YL, Deanfield JE, Oakley C, Goodwin JF. Arrhythmia in hypertrophic cardiomyopathy, I: Influence on prognosis. *Br Heart J* 1981; **46**:168–172.
- Maron BJ, Savage DD, Wolfson JK, Epstein SE. Prognostic significance of 24 hour ambulatory electrocardiographic monitoring in patients with hypertrophic cardiomyopathy: a prospective study. *Am J Cardiol* 1981; **48**:252–257.
- Schiavone WA, Lever HM, Maloney JD. Atrial and ventricular programmed electrical stimulation in patients with symptomatic hypertrophic cardiomyopathy. *Am J Cardiol* (In press).
- Anderson KP, Stinson EB, Derby GC, Oyer PE, Mason JW. Vulnerability of patients with obstructive hypertrophic cardiomyopathy to ventricular arrhythmia induction in the operating room: analysis of 17 patients. *Am J Cardiol* 1983; **51**:811–816.
- McKenna W, Harris L, Deanfield J. Syncope in hypertrophic cardiomyopathy. *Br Heart J* 1982; **47**:177–179.
- Shah PM, Lever HM. Natural history of hypertrophic obstructive cardiomyopathy with or without resting outflow obstruction.

- tion: correlation of ambulatory arrhythmias with outflow obstruction. Proceedings of the Eighth World Congress of Cardiology, International Congress Series No. 470, pp 553–560, Sep 1978.
25. Doi YL, McKenna WJ, Chetty S, Oakley CM, Goodwin JF. Prediction of mortality and serious ventricular arrhythmia in hypertrophic cardiomyopathy: an echocardiographic study. *Br Heart J* 1980; **44**:150–157.
26. Swan DA, Bell B, Oakley CM, Goodwin J. Analysis of symptomatic course and prognosis and treatment of hypertrophic obstructive cardiomyopathy. *Br Heart J* 1971; **33**:671–685.
27. Adelman AG, Wigle ED, Ranganathan N, et al. The clinical course in muscular subaortic stenosis: a retrospective and prospective study of 60 hemodynamically proved cases. *Ann Int Med* 1972; **77**:515–525.
28. McKenna WJ, Chetty S, Oakley CM, Goodwin JF. Arrhythmia in hypertrophic cardiomyopathy: exercise and 48 hour ambulatory electrocardiographic assessment with and without beta adrenergic blocking therapy. *Am J Cardiol* 1980; **45**:1–5.
29. Candeo MI, Frank MJ, Abdulla AM. Rhythm disturbances in hypertrophic cardiomyopathy: prevalence, relation to symptoms, and management. *Am J Cardiol* 1980; **45**:848–855.
30. McKenna WJ, Harris L, Perez G, Krikler DM, Oakley C, Goodwin JF. Arrhythmia in hypertrophic cardiomyopathy. II: Comparison of amiodarone and verapamil in treatment. *Br Heart J* 1981; **46**:173–178.
31. Cleland WP. The surgical management of obstructive cardiomyopathy. *J Cardiovasc Surg* 1963; **4**:489–491.
32. Morrow AG, Reitz BA, Epstein SE, et al. Operative treatment in hypertrophic subaortic stenosis: techniques and the results of pre- and postoperative assessments in 83 patients. *Circulation* 1975; **52**:88–102.
33. Beahrs MM, Tajik AJ, Seward JB, Giuliani ER, McGoon DC. Hypertrophic obstructive cardiomyopathy: 10- to 21-year follow-up after partial septal myectomy. *Am J Cardiol* 1983; **51**:1160–1166.
34. Maron BJ, Merrill WH, Freier PA, Kent KM, Epstein SE, Morrow AG. Long-term clinical course and symptomatic status of patients after operation for hypertrophic subaortic stenosis. *Circulation* 1978; **57**:1205–1213.
35. Agnew TM, Barratt-Boyes BG, Brandt PWT, Roche AHG, Lowe JB, O'Brien KP. Surgical resection in idiopathic hypertrophic subaortic stenosis with a combined approach through aorta and left ventricle: a long-term follow-up study in 49 patients. *J Thor Cardiovasc Surg* 1977; **74**:307–316.
36. Reis RL, Hannah H III, Carley JE, Pugh DM. Surgical treatment of idiopathic hypertrophic subaortic stenosis (IHSS): postoperative results in 30 patients following ventricular septal myotomy and myectomy (Morrow procedure). *Circulation* 1977; **56** (Suppl II):128–132.