Outcome of Alcohol Septal Ablation for Obstructive Hypertrophic Cardiomyopathy

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Background—The clinical efficacy of alcohol septal ablation for drug-refractory hypertrophic cardiomyopathy remains unclear. This study examines the outcome of alcohol septal ablation performed at a tertiary hypertrophic cardiomyopathy referral center.

Methods and Results—Among 601 patients with severely symptomatic obstructive hypertrophic cardiomyopathy referred for alcohol septal ablation or myectomy from 1998 to 2006, 138 patients (median age, 64 years; 39% men) chose to undergo ablation. Procedural complications included death in 1.4%, sustained ventricular arrhythmias in 3%, tamponade in 3%, and pacemaker implantation in 20%. This rate was higher than a combined complication rate of 5% in age- and gender-matched patients who had undergone septal myectomy at Mayo Clinic (P<0.0001). Four-year survival free of all mortality was 88.0% (95% confidence interval, 79.4 to 97.5%), which was similar to that of the age- and gender-matched patients who had undergone myectomy (P=0.18). Six patients had documented ventricular arrhythmias after ablation, 4 of whom had successful intervention. Four-year survival free of death and severe New York Heart Association class III/IV symptoms after septal ablation was 76.4%, and 71 patients (51%) became asymptomatic. Myectomy patients ≤65 years of age had significantly better survival free of death and severe symptoms (P=0.01).

Conclusions—Alcohol septal ablation is an efficacious procedure if performed in an experienced institution and may resolve symptoms in a subset of patients with obstructive hypertrophic cardiomyopathy. However, the procedural complication rate exceeds that of myectomy. Patients ≥65 years of age have better symptom resolution with myectomy. No impairment in short-term survival was noted in this nonrandomized study, but the long-term outcome remains unknown. (Circulation. 2008;118:131-139.)

Key Words: ablation ■ alcohol ■ cardiomyopathy, hypertrophic ■ prognosis

Dynamic left ventricular outflow tract (LVOT) obstruction contributes significantly to the development of symptoms of dyspnea, angina, and syncope in a subset of patients with hypertrophic cardiomyopathy (HCM).1–3 For those with LVOT obstruction and severe, drug-refractory symptoms, surgical septal myectomy is the time-honored standard of therapy that achieves durable symptom relief in most patients with a low mortality in experienced centers.4–11 Percutaneous alcohol septal ablation has emerged as a potentially less invasive, alternative mode of treatment and is increasingly being performed in a number of cardiac centers worldwide.12–21 Nonetheless, concerns about the efficacy of septal ablation compared with septal myectomy remain, in terms of acute complications, potential for arrhythmias, and overall outcome.22,23 This study therefore was undertaken to examine the outcome of septal ablation compared with surgery in patients referred to a tertiary HCM referral center.

Editorial p 107
Clinical Perspective p 139

Methods

Patients

This study was approved by the Mayo Clinic Institutional Review Board. All patients presenting with criteria for septal reduction therapy were evaluated at the Mayo HCM Clinic. Eligibility criteria for septal ablation were (1) severe cardiovascular symptoms, defined New York Heart Association (NYHA) class III/IV dyspnea and/or Canadian Cardiovascular Society class III/IV, that were refractory to medical therapy; (2) dynamic LVOT obstruction caused by systolic anterior motion of the mitral valve (gradient ≥30 mm Hg at rest or ≥50 mm Hg with provocation); (3) ventricular septal thickness ≥15 mm; (4) the absence of significant intrinsic mitral valve disease; (5) the absence of need for concomitant cardiac surgical procedure (eg, bypass grafting, valve replacement); and (6) informed patient...
consent. Informed consent required full understanding of the paucity of long-term data on survival after the procedure, the relatively lower success rate resulting from its dependence on coronary anatomy, the risk of pacemaker dependency, and potential complications related to instrumentation of the coronary arteries. This detailed discussion was undertaken with each patient. After full discussion of the known risks, outcomes, and limitations of both procedures, patients were offered the choice of surgical septal myectomy or septal ablation. Between December 1998 and December 2006, 141 patients, including 3 patients who were turned down by a cardiac surgeon for myectomy, underwent septal ablation for treatment of severe, drug-refractory symptoms resulting from obstructive HCM at the Mayo Clinic (Rochester, Minn). Over this same time period, 460 patients chose to undergo surgical myectomy. Three patients who underwent septal ablation refused authorization for use of their medical records for research purposes. All other patients provided informed consent in accordance with Minnesota law, leading to 138 patients analyzed in the present study. The diagnosis of HCM was based on typical clinical, ECG, and echocardiographic features, with ventricular myocardial hypertrophy occurring in the absence of any other cardiac or systemic disease that could have been responsible for the hypertrophy. The magnitude of myocardial hypertrophy was assessed with M-mode and 2-dimensional transthoracic echocardiography using standard techniques.

**Hemodynamic Evaluation**

Cardiac catheterization was completed under conscious sedation in the fasting state. Transseptal puncture was performed for evaluation of left ventricular (LV) pressure to avoid catheter entrapment in 112 patients (81%). In the remaining patients, LV pressure was obtained by retrograde access across the aortic valve with placement of the catheter near the LV apex. In all patients, simultaneous ascending aortic pressures with 6F or 7F guide catheters were obtained via transseptal puncture for measurement of the LVOT gradient. Provocable LVOT gradients were assessed during Valsalva strain, isoproterenol infusion, and/or examination of the LVOT gradient on echocardiography. Cardiac catheterization was completed under conscious sedation in the fasting state. Transseptal puncture was performed for evaluation of left ventricular (LV) pressure to avoid catheter entrapment in 112 patients (81%). In the remaining patients, LV pressure was obtained by retrograde access across the aortic valve with placement of the catheter near the LV apex. In all patients, simultaneous ascending aortic pressures with 6F or 7F guide catheters were obtained via retrograde femoral access for measurement of the LVOT gradient. Provocable LVOT gradients were assessed during Valsalva strain, isoproterenol infusion, and/or examination of the LVOT gradient on the post–premature ventricular complex beat. For all hemodynamic variables, rapid-acquisition (5-ms intervals) digital records were obtained with pressure records from 3 to 5 end-expiratory cardiac cycles for subsequent offline analysis.

**Septal Ablation**

Septal ablation was performed in all patients using previously described techniques. Briefly, a slightly oversized, over-the-wire angioplasty balloon was placed in the septal perforator artery from a 6F or 7F left coronary guide catheter using standard methods. After inflation of the balloon, angiographic contrast and echocardiographic contrast were injected through the balloon catheter to identify the perfusion bed of the septal perforator artery. After delineation of the targeted myocardium with echocardiographic contrast, 1 to 3 mL desiccated ethanol was infused slowly over a period of 3 to 5 minutes, followed by normal saline flush. For patients who had <50% reduction of either the resting or provoked LVOT gradient, other septal perforator arteries were targeted and treated in a similar fashion. As a precaution against the development of high-grade atrioventricular block, patients without permanent pacemakers underwent placement of a temporary device during the procedure. Patients were monitored in an intensive care unit setting for at least 3 days after septal ablation.

**Follow-Up**

Vital status, NYHA functional class, need for additional septal reduction therapy (eg, surgical myectomy, repeat septal ablation), and potential complications related to septal ablation (eg, ventricular arrhythmias, pacemaker dependency, device malfunction, or infection) were ascertained by follow-up evaluation consisting of mailed questionnaires, telephone contact, and interrogation of the Social Security Death Index. For deceased patients, procurement of death certificates and interviews with next of kin were performed to determine cause of death. Sudden cardiac death was defined as instantaneous and unexpected death with or without documented ventricular fibrillation within 1 hour after a witnessed collapse in patients who previously were in stable clinical condition or nocturnal death with no antecedent history of worsening symptoms. Appropriate discharge of an implanted internal cardioverter-defibrillator (ICD) device for therapy of a lethal arrhythmia (ie, sustained ventricular tachycardia or fibrillation) was considered sudden cardiac death. Occurrence of stroke was defined according to standard criteria.

**Myectomy Patients**

To compare the outcomes of septal ablation with surgical myectomy from our institution, data on patients from a previously described cohort of patients who underwent isolated myectomy were analyzed. Patients from this cohort were matched by age and gender in a 1:1 fashion to patients who underwent septal ablation in the present study. Eleven of the 13 ablation patients who were >80 years of age could not be matched to a myectomy patient because of the few patients in this age group who underwent isolated septal myectomy. Thus, comparisons of the outcome of septal ablation versus myectomy were restricted to patients ≤80 years of age. Each ablation patient ≤80 years of age was successfully matched to a myectomy patient (n=123 for both patient groups).

**Data Analysis**

Procedural success was defined as a ≥50% reduction in the peak LVOT gradient observed at rest or, among those with predominantly labile obstruction, after provocation with a final residual resting gradient of <20 mm Hg in the absence of death or need for emergency surgery. The Kaplan–Meier method was used to estimate survival of the various end point events with 95% confidence intervals (CIs). Survival comparisons between groups were made with a 2-sample log-rank test. Comparisons of continuous variables were made with the appropriate test: a t test in cases in which the variable distributions were symmetric and a Wilcoxon rank-sum test otherwise. A 1-sample test was used for paired comparisons; a 2-sample test was used for unpaired comparisons. All continuous variables are reported as median with interquartile range (IQR) in parentheses.

A comparison of the ablation and myectomy patients also was performed with the development of a propensity score. The propensity score to discriminate between ablation and myectomy was constructed with a logistic regression model. Each of the factors of interest were inserted into the model. These factors included age, gender, coronary artery disease, atrial fibrillation, prior stroke, diabetes mellitus, hypertension, obesity, and severe pulmonary disease. The score from this model was subsequently used as an adjusting variable to determine its effect on the survival difference between patients who had ablation and those who had myectomy. This final model was fit by a Cox proportional-hazards model that included the propensity score and the indicator for ablation versus myectomy. Statistical significance was set a priori at P<0.05.

All authors had full access to and take full responsibility for the integrity of the data. All authors have read and agree to the manuscript as written.

**Results**

**Patient Population**

Table 1 lists the baseline characteristics of the 138 patients who underwent septal ablation (age, 64 [21] years; range, 26 to 86 years; 39% men). All patients had severe cardiovascular symptoms (NYHA class III/IV dyspnea, 99%; Canadian Cardiovascular Society class III/IV angina, 20%). Significant LVOT obstruction on echocardiography was present at rest (gradient, ≥30 mm Hg) in the majority (76.8%) and provokable (gradient ≥50 mm Hg on Valsalva strain or after amyl nitrate inhalation) in the others.
Two patients had previously failed surgical myectomy. Eleven patients (8%) previously had failed dual-chamber pacing therapy for relief of symptomatic LVOT obstruction. The baseline indications for pacemaker therapy in 3 other patients were symptomatic bradycardia (n=2) and high-grade atrioventricular block (n=1). Among 5 patients who had previously undergone ICD implantation, the indications were primary prevention of sudden cardiac death in each case.

Cited reasons for selecting septal ablation over surgical septal myectomy as a therapeutic strategy are listed in Table 2. In 27 of the 601 patients (4.5%) evaluated, the patient’s surgical perioperative risk was believed to be significantly increased (>5%); the decision to proceed with septal ablation in these patients was made after discussion of the risks versus benefits of each procedure.

**Procedural Outcome**

Successful relief of the LVOT gradient occurred in 114 patients (83%; Figures 1 and 2 and Table 3). Septal ablation resulted in residual resting LVOT gradients of 10 (19) mm Hg in the overall population and 10 (17) mm Hg in the subgroup of patients with resting baseline obstruction. Among the 24 patients without procedural success, a residual LVOT gradient >20 mm Hg occurred in 23 patients, and 1 patient with predominantly labile obstruction had >50% reduction in the provoked LVOT gradient. The median residual LVOT gradient among these 24 patients without procedural success was 40 (30) mm Hg.

**In-Hospital and 30-Day Clinical Events**

Two patients subsequently had urgent cardiac surgery during the same hospitalization for cardiac tamponade from left atrial perforation caused by transseptal puncture (n=1) and right ventricular perforation from temporary pacemaker placement (n=1; Table 4). Two other patients had cardiac tamponade from temporary pacemaker placement, both of whom were treated successfully with pericardiocentesis. Of

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### Table 1. Baseline Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value (n)</th>
</tr>
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<tbody>
<tr>
<td>Age, y</td>
<td>64 (21)</td>
</tr>
<tr>
<td>Men, n (%)</td>
<td>54 (39.1)</td>
</tr>
<tr>
<td>NYHA class III/IV, n (%)</td>
<td>137 (99.3)</td>
</tr>
<tr>
<td>CCS class III/IV, n (%)</td>
<td>28 (20.2)</td>
</tr>
<tr>
<td>Atrial fibrillation, n (%)</td>
<td>26 (18.8)</td>
</tr>
<tr>
<td>Prior stroke, n (%)</td>
<td>3 (2.2)</td>
</tr>
<tr>
<td>Hypertension, n (%)</td>
<td>75 (54.3)</td>
</tr>
<tr>
<td>Diabetes mellitus, n (%)</td>
<td>19 (13.8)</td>
</tr>
<tr>
<td>Coronary artery disease, n (%)</td>
<td>19 (13.8)</td>
</tr>
<tr>
<td>Prior myectomy, n (%)</td>
<td>2 (1.4)</td>
</tr>
<tr>
<td>Family history of HCM, n (%)</td>
<td>27 (19.6)</td>
</tr>
<tr>
<td>Family history of sudden death caused by HCM, n (%)</td>
<td>7 (5.1)</td>
</tr>
<tr>
<td>Asymmetric hypertrophy, n (%)</td>
<td>87 (63.0)</td>
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<tr>
<td>Concentric hypertrophy, n (%)</td>
<td>51 (37.0)</td>
</tr>
<tr>
<td>Maximum ventricular wall thickness, mm</td>
<td>20 (6)</td>
</tr>
<tr>
<td>Interventricular septal thickness, mm</td>
<td>20 (6)</td>
</tr>
<tr>
<td>Posterior wall thickness, mm</td>
<td>13 (4)</td>
</tr>
<tr>
<td>End-diastolic diameter, mm</td>
<td>45 (9)</td>
</tr>
<tr>
<td>End-systolic diameter, mm</td>
<td>26 (6)</td>
</tr>
<tr>
<td>Left atrial volume index, cm³/m²</td>
<td>37 (23)</td>
</tr>
<tr>
<td>LV ejection fraction, %</td>
<td>73 (6)</td>
</tr>
<tr>
<td>Resting LVOT gradient, mm Hg</td>
<td>74 (59)</td>
</tr>
<tr>
<td>&gt;=30 mm Hg, n (%)</td>
<td>106 (76.8)</td>
</tr>
<tr>
<td>ICD, n (%)</td>
<td>5 (3.6)</td>
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<tr>
<td>Permanent pacemaker, n (%)</td>
<td>14 (10.1)</td>
</tr>
<tr>
<td>Medications, n (%)</td>
<td></td>
</tr>
<tr>
<td>β-Receptor antagonist, n (%)</td>
<td>103 (74.6)</td>
</tr>
<tr>
<td>Calcium-channel blocker, n (%)</td>
<td>51 (37.0)</td>
</tr>
<tr>
<td>Disopyramide, n (%)</td>
<td>12 (8.7)</td>
</tr>
<tr>
<td>ACE inhibitor or ARB, n (%)</td>
<td>20 (14.5)</td>
</tr>
<tr>
<td>Amiodarone, n (%)</td>
<td>4 (2.9)</td>
</tr>
</tbody>
</table>

CCS indicates Canadian Cardiovascular Society; ACE, angiotensin-converting enzyme; and ARB, angiotensin-receptor blocker. Coronary artery disease was defined as either a >50% stenosis in the left main or a >70% stenosis in other major epicardial coronary arteries from invasive angiography. Resting gradient was from echocardiography.
note, 3 of these 4 patients were elderly women (70, 73, and 73 years of age). After these events, no cardiac perforations occurred following the adoption of a policy of avoidance of transseptal puncture in elderly women and the use of the relatively less traumatic Medtronic temporary pacemaker (model 6416-140, Medtronic Minneapolis, Minn). There also were no complications (eg, dissection, abrupt closure, perforation) related to instrumentation of the left anterior descending artery. Median length of in-hospital stay for the entire patient population was 5.0 (1.0) days.

New pacemaker implantation after ablation occurred in 28 patients (20%). The indications for implantation were transient (n = 9) or persistent (n = 16) third-degree atrioventricular block in 25 patients, new left bundle-branch block in 2 patients, symptomatic sinus bradycardia in 1 patient, and unstable junctional rhythm after surgery for cardiac perforation in 1 patient. One patient who had transient third-degree atrioventricular block during hospitalization had implantation of a permanent pacemaker 18 days after hospital discharge for symptomatic complete atrioventricular block.

Two in-hospital deaths occurred. One patient was transferred from another hospital with cardiogenic shock and severe obstructive hypertrophic cardiomyopathy. Eight days after septal ablation, ventricular fibrillation occurred in the setting of multiorgan failure, and the patient could not be resuscitated. Another patient had severe pulmonary hypertension caused by end-stage interstitial fibrosis and developed cardiogenic shock after noncardiac surgery. Despite a reduction in the resting LVOT gradient from 90 to 10 mm Hg with septal ablation, she continued to be dependent on intravenous vasoactive medications and died 2 days after the procedure of progressive low output failure.

Sustained ventricular arrhythmias occurred within 1 week of septal ablation in 4 patients. One was the patient who died with intractable ventricular fibrillation in the setting of multiorgan failure described above. Two other patients developed ventricular fibrillation (1 and 2 days after ablation, respectively), were successfully resuscitated, and then underwent ICD implantation. One other patient presented with sustained ventricular tachycardia 5 days after septal ablation. This patient refused ICD implantation and underwent successful radiofrequency ablation of her ventricular tachycardia.

**Survival**

Clinical follow-up was completed in 134 patients (98%) with a median follow-up duration of 2.2 (2.8) years (range, 9 days to 7.6 years). One of the patients lost to clinical follow-up moved to a foreign country. Two other patients were alive but could not be reached for clinical assessment.

Overall survival free of all mortality (including ICD discharge for treatment of ventricular fibrillation or tachycardia) was 93.5% (95% CI, 88.7 to 98.4) at 2 years and 88.0% (95% CI, 79.4 to 97.5) at 4 years (Figure 3). Thirteen total deaths (9%) occurred in the study population, including the 2 aforementioned in-hospital deaths. Sudden cardiac death occurred in 1 patient after subsequent surgical myectomy for recurrent obstruction after ablation. This patient died suddenly 15 days after surgery. One additional patient experienced ICD discharge for treatment of monomorphic ven-

### Table 3. Procedural Results

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>Septal arteries injected, n</td>
<td>1.0 (1.0)</td>
</tr>
<tr>
<td>Volume of ethanol injected, mL</td>
<td>1.8 (0.5)</td>
</tr>
<tr>
<td>Fluoroscopy time, min</td>
<td>30 (16)</td>
</tr>
<tr>
<td>Procedure time, min</td>
<td>137 (48)</td>
</tr>
<tr>
<td>Contrast volume, mL</td>
<td>150 (66)</td>
</tr>
<tr>
<td>Change in LVOT gradient, mm Hg</td>
<td></td>
</tr>
<tr>
<td>All patients (n = 138)</td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>80 (50)</td>
</tr>
<tr>
<td>Postablation</td>
<td>10 (19)</td>
</tr>
<tr>
<td>(P)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Patients with resting obstruction (n = 106)</td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>84 (50)</td>
</tr>
<tr>
<td>Postablation</td>
<td>10 (17)</td>
</tr>
<tr>
<td>(P)</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

**Figure 2.** Pressure tracings from a patient with successful septal ablation. At baseline, an LVOT gradient of 120 mm Hg is present, resulting from obstructive HCM (left). After successful septal ablation, this gradient was obliterated (right). The patient remains asymptomatic 3 years after the procedure. Ao indicates aorta; LA, left atrium.

**Figure 3.** Pressure tracings from a patient with successful septal ablation. At baseline, an LVOT gradient of 120 mm Hg is present, resulting from obstructive HCM (left). After successful septal ablation, this gradient was obliterated (right). The patient remains asymptomatic 3 years after the procedure. Ao indicates aorta; LA, left atrium.
tricular tachycardia 66 days after septal ablation. Additional causes of death were noncardiac surgery (n = 2), sepsis (n = 1), ovarian cancer (n = 1), acute myelogenous leukemia (n = 1), and unknown causes in 4 other patients.

**Symptom Improvement**

Median NYHA functional class improved from 3.0±0.0 at baseline to 1.5±1.0 after septal ablation (P < 0.0001 versus baseline; Figure 4), including 71 patients who were in NYHA class I (51% of all patients). Among the 24 patients without initial procedural success, 16 later improved to mild or no symptoms (NYHA class I/II and Canadian Cardiovascular Society class I/II) (Figure 5). Five patients (4%) underwent repeat septal ablation. Persistent or recurrent NYHA class III/IV symptoms remained in 12 patients. Nine of these patients (6%) later underwent surgical myectomy, including the aforementioned 2 patients who had urgent surgery for cardiac perforation. Four-year survival free of death, severe NYHA class III/IV symptoms, and need for septal myectomy was 76.4% (95% CI, 64.8 to 87.9).

**Comparison With Surgical Myectomy**

Patients who underwent surgical myectomy were similar in age (myectomy versus ablation, 60±19 years versus 61±19 years) and gender (39% male) to the septal ablation patients (both P > 0.05). Patients who had septal ablation had a higher prevalence of hypertension (52.8% versus 24.8%; P < 0.0001) and coronary artery disease (13.8% versus 2.4%; P = 0.001) than the myectomy patients. The resting LVOT gradient among the myectomy patients before surgery was lower (55 [29] versus 84 [60] mm Hg; P = 0.01) than among the septal ablation patients. No other significant differences were found in the baseline characteristics listed in Table 1 between the 2 patient groups.

Fewer procedural complications occurred among the myectomy patients compared with the ablation patients. After septal myectomy, 1 patient was successfully resuscitated from ventricular fibrillation that occurred in hospital 2 days after surgery. In comparison, 4 patients sustained ventricular tachycardia or ventricular fibrillation within 1 week of septal ablation. One patient died after emergency myectomy for severe LVOT obstruction and cardiogenic shock. Three patients developed complete heart block in hospital and required permanent pacemaker implantation compared with 28 patients who required permanent pacemaker after septal ablation. One other patient underwent successful pericardio-centesis for cardiac tamponade that occurred after hospital discharge. The combined rate of postprocedural ventricular arrhythmia, pacemaker implantation, tamponade, and death in the myectomy patients was 5%. Conversely, this rate was 26% among the 123 matched patients who had septal ablation, which was significantly higher than among the myectomy patients (χ² = 20.9; unadjusted P < 0.0001; adjusted P < 0.001).

Among patients ≤80 years of age, median follow-up duration was 5.1 [5.0] years for the myectomy patients and 2.3±2.8 years for the ablation patients. Among patients ≤80 years of age who underwent septal ablation, 4-year survival (86.4%; 95% CI, 76.7 to 96.1) was similar to that of the myectomy patients (94.3%; 95% CI, 90.1 to 98.4%; P = 0.18; Figure 6). After adjustment with the propensity score, there also was no significant difference in survival between the ablation and myectomy patients (P = 0.40).

Survival free of death and severe symptoms overall (76.4%; 95% CI, 64.8 to 87.9) was similar to that of myectomy patients (82.5%; 95% CI, 75.5 to 89.5; unadjusted P = 0.38; adjusted P = 0.27; Figure 7). However, survival free of death and severe symptoms was lower among patients ≤65 years of age who underwent ablation than among patients of the same age who underwent myectomy (71.0% versus 88.5%; unadjusted P = 0.01; adjusted P = 0.03; Figure 7).

**Discussion**

This report describes the outcome of percutaneous alcohol septal ablation compared with surgery performed at a tertiary HCM referral center. Thus, all patients presenting with severe, drug-refractory symptoms underwent a full comprehensive evaluation by a medical team with expertise in HCM. If deemed candidates for septal reduction therapy, patients were offered either septal myectomy or alcohol septal ablation after full discussion of the goals and risks of each procedure. The patients included in this study were thus older with more comorbidity compared with prior reports12–21 because younger, more active patients tended to undergo surgical septal myectomy. This approach reflects the recommendations of the American College of Cardiology/European Society of Cardiology expert consensus document on HCM.
and these patients should be more representative of accepted clinical practice. The principal findings of this nonrandomized, retrospective study are the following. First, alcohol septal ablation has a short-term (4-year) survival similar to that of a matched group HCM patients who undergo septal myectomy. Second, symptom improvement may occur in a subset of patients, with ≈50% becoming NYHA class I. Third, survival and symptom relief with septal myectomy are significantly better in patients ≤65 years of age. Finally, procedural complications with alcohol septal ablation are significantly more frequent than for septal myectomy, including mortality, need for permanent pacemaker, and the occurrence of sustained ventricular arrhythmias.

The present investigation found no overall impairment of longevity after septal ablation on short-term follow-up (4-year survival rate, 88%) compared with a cohort of age- and gender-matched septal myectomy patients from our institution (P=0.18 versus myectomy). Comparisons to a similar cohort of myectomy patients were performed to help account for unique demographic attributes in this population of ablation patients, particularly because the median age in the present investigation exceeds that of patients in most other septal ablation series. Although the present results suggest that septal ablation overall is not associated with incremental

Figure 5. Flowchart demonstrating the change in symptoms during follow-up after acute procedural success or failure.

Figure 6. Comparison of survival after septal ablation with a matched cohort of surgical myectomy patients. The 4-year survival free of all mortality (including defibrillator discharge for lethal arrhythmia) among septal ablation patients was similar to that observed among age- and gender-matched patients who underwent isolated surgical myectomy.

Figure 7. Survival free of death and severe symptoms. A, Survival free of death and severe symptoms (either NYHA class III/IV dyspnea or Canadian Cardiovascular Society class III/IV angina) for patients who had septal ablation vs surgical myectomy. B, Survival free of death and severe symptoms among patients ≤65 years of age. Survival free of death and severe symptoms after septal ablation was similar to that of myectomy patients in the overall population but was lower among those ≤65 years of age.
short-term risk of death, it must be noted that ventricular fibrillation occurred in hospital in 3 patients and that documented sustained ventricular tachycardia occurred after discharge in 2 other patients. Aggressive treatment by defibrillation, ventricular tachycardia ablation, or ICD firing terminated these life-threatening arrhythmias in 4 of the 6 patients. Thus, it is still unknown as to whether this procedure enhances the propensity toward ventricular arrhythmias.\(^{22,23}\)

This issue may be particularly relevant in a younger population who may have a greater underlying propensity for ventricular arrhythmias and a longer latency period before a sudden catastrophic event.

The present investigation demonstrated acute relief of LVOT obstruction (82%) that was achieved with a low incidence of periprocedural death (1.4%). Both deaths occurred in patients who presented in cardiogenic shock. However, procedural complications from septal ablation were frequent and considerably more common than with surgical myectomy, including patients who had lethal ventricular arrhythmias or heart block requiring permanent pacemaker implantation after ablation. Of note, cardiac perforation occurred in 3% of patients, principally related to the need for temporary pacing wires in elderly women. The subsequent use of a less traumatic, small-bore temporary pacemaker has overcome this complication. Because septal ablation has a steep learning curve,\(^{34}\) this procedure has been performed by only 3 interventionalists at our institution to ensure a high level of expertise. Notably, no complications (eg, dissection) related to instrumentation of the left anterior descending artery were found.

In the overall study population, the rate of permanent pacemaker implantation was higher than in previous series of septal ablation,\(^{13–21}\) despite the use of myocardial contrast echocardiography in all procedures. The threshold for implantation of a permanent pacemaker at our institution was lower than at other institutions. This is based on our prior experience of postoperative transient atrioventricular block progressing to complete heart block.\(^{35}\) Persistent third-degree atrioventricular block, for which pacemakers were placed in other studies, was seen in 16 patients (12%). We have previously reported on conduction abnormalities after septal ablation and myectomy, noting patients who develop late heart block after transient complete heart block during the procedure.\(^{36}\)

The long-term evaluation of clinical efficacy is important. In that short-term hemodynamic results may not translate into durable symptom improvement. Although septal ablation resulted in symptomatic improvement in most patients, the 4-year survival free of death, NYHA class III/IV symptoms, or septal myectomy was only 76%. Septal ablation failed in a subset of patients because of the inability to target the exact myocardium involved in contact with systolic anterior motion of the mitral valve. Unlike septal myectomy, in which direct visualization guides myocardial removal, septal ablation is entirely dependent on the vascular bed of visible septal perforator arteries. If the region of the obstruction is proximal and no septal artery supplying this area is visible, the eventual outcome of the procedure may be poor despite short-term relief of the LVOT gradient. A stepwise approach of ablation followed by myectomy may not be optimal because patients who have this sequential approach may have a higher incidence of surgical complications, especially permanent heart block.\(^{37,38}\)

We have previously reported on the outcome of 289 patients undergoing septal myectomy at our institution.\(^{31}\) Compared with similar patients from this cohort, the survival free of death and severe symptoms among the ablation patients approached that observed with myectomy. However, among those \(\leq 65\) years of age, severe recurrent symptoms were more common after ablation than after myectomy. This observation may be a result of less complete relief of gradients after ablation that have a more significant symptomatic effect on these younger, more active patients. Surgery also was associated with fewer in-hospital complications, including life-threatening arrhythmias. With these considerations and the established efficacy reported in prior surgical series, septal ablation cannot be advocated as therapy to replace surgical myectomy. Nonetheless, if the risks and outcome of both septal ablation and septal myectomy are fully discussed with the patient, septal ablation can be viewed as a less invasive therapy for patients with severe, drug-refractory symptoms caused by obstructive HCM. An integrated team approach with the ability to offer either percutaneous or surgical options is essential in the management of these patients.

**Study Limitations**

The present investigation was a nonrandomized, retrospective comparison of septal ablation and myectomy. Thus, the present investigation is subject to selection bias, which should be considered in the interpretation of its results. In prior studies, ventricular remodeling localized to and remote from the site of septal ablation has been observed in the subacute phase (6 months to 2 years) after septal ablation.\(^{39–41}\) In the present investigation, 16 of the 24 patients who initially had a poor procedural outcome later became asymptomatic. Whether favorable ventricular remodeling was responsible for the change in symptoms among patients in the present study was not analyzed because the present study focused on the short- and medium-term success of septal ablation. The lack of data on LVOT gradients and exercise performance in follow-up is a limitation of our data. Although clinical follow-up for the study population was 98%, causes of death remain undetermined in 4 of the 12 patients who died. Thus, the true risk of ventricular arrhythmias or sudden death cannot be determined from these data.

**Conclusions**

Septal ablation is a viable, alternative treatment option for patients with drug-refractory symptoms caused by obstructive HCM, with sustained improvement of symptoms in 76% of patients at 4 years. In the present study, septal ablation was not associated with impairment of survival at short-term follow-up, but the question of enhanced propensity for ventricular arrhythmia remains unanswered. The in-hospital complication rate is higher with ablation than with myectomy when both are performed at a tertiary referral center. In those patients \(\leq 65\) years of age, symptom relief is better after myectomy. These findings should be considered when the
choice of septal reduction therapy is offered to these patients. Long-term follow-up is required to determine the ultimate role of ablation in the treatment algorithm of these patients with HCM.

Disclosures
None.

References

**CLINICAL PERSPECTIVE**

As an alternative mode of therapy for patients with symptomatic obstructive hypertrophic cardiomyopathy, alcohol septal ablation has emerged and is increasingly being performed in centers worldwide. However, there continue to be questions about the efficacy of septal ablation, particularly when compared with septal myectomy. In this study, which was performed at a single tertiary hypertrophic cardiomyopathy referral center, the overall survival after either septal ablation or myectomy was similar. Septal ablation was associated with a higher rate of acute complications. Survival free of severe symptoms also was comparable in the overall population, but patients ≥65 years of age had a lower rate of persistent or recurrent symptoms if they had myectomy. Septal ablation is an efficacious procedure if performed in an experienced institution and may improve symptoms in a subset of patients with obstructive hypertrophic cardiomyopathy. However, the in-hospital complication rate is higher with septal ablation and symptom relief is better with myectomy, especially in younger patients. These findings should be considered when the choice of septal reduction therapy is offered to hypertrophic cardiomyopathy patients. Long-term follow-up is required to determine the ultimate role of ablation in the treatment algorithm of these patients with hypertrophic cardiomyopathy.

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Circulation. 2008;118:131-139; originally published online June 30, 2008;
doi: 10.1161/CIRCULATIONAHA.107.738740
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0009-7322. Online ISSN: 1524-4539

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