# Alcohol Septal Ablation: A useful tool in our arsenal against hypertrophic obstructive cardiomyopathy

Sugeevan Savarimuthu[1] and Amer Harky[2]

[1]Broomfield Hospital
[2]Liverpool Heart and Chest Hospital NHS Foundation Trust

May 20, 2020

**Abstract**

Objective Affecting 1 in 500 individuals; Hypertrophic cardiomyopathy (HCM) is an autosomal dominant cardiovascular disorder which is prevalent throughout the world. Surgical myectomy and alcohol septal ablation (ASA) are two methods currently used for the management of drug refractory Hypertrophic obstructive cardiomyopathy (HOCM). ASA may prove to be a useful, less invasive tool when confronting patients with HOCM especially those who are more elderly or deemed to be a higher surgical risk. Methods Electronic literature search was conducted to identify relevant articles that discussed invasive methods to treat drug refractory HOCM. No limits were placed on timing of the publication or the type of article. Key words and MeSH terms were used to conduct the search and the results were summarized in the relevant section. Results Current evidence suggests that alcohol septal ablation is a safe and effective procedure in treating patients with HOCM with similar short- and long-term outcomes when compared with surgical myectomy. Selection of patient with appropriate assessment is the key for satisfactory outcomes. Conclusion ASA has been shown to be a safe and reliable procedure; advanced imaging techniques and dedicated multi-disciplinary teams can be used to carefully select patients with HOCM. Though surgical myectomy is recommended as gold standard treatment for drug refractory HOCM, however, ASA may play an increasing role in the near future due an ageing population; both ASA and SM can have a synergistic effect in treating those who are affected by HOCM.

**Alcohol Septal Ablation: A useful tool in our arsenal against hypertrophic obstructive cardiomyopathy**

**Running title: Management of hypertrophic cardiomyopathy**

Sugeevan Savarimuthu MD[1]; Amer Harky MRCS MSc[2,3] ++

1. Department of Medicine, Broomfield Hospital, Chelmsford UK

2. Department of Cardiothoracic Surgery, Liverpool Heart and Chest Hospital, Liverpool, UK

3. University of Liverpool, Liverpool, UK

++ **Corresponding Author:**

Amer Harky

MBChB, MRCS, MSc

Department of Cardiothoracic Surgery

Liverpool Heart and Chest Hospital

Liverpool, UK

E-mail: aaharky@gmail.com

Tel: +44-151-600-1616



**Declaration of interests**

The authors have no conflicts of interest to declare.

**Funding**

No funding has been obtained for this work

**Key words**

Alcohol Septal Ablation, ASA, Hypertrophic obstructive cardiomyopathy, HOCM, Cardiology

**Abstract**

**Objective**

Affecting 1 in 500 individuals; Hypertrophic cardiomyopathy (HCM) is an autosomal dominant cardiovascular disorder which is prevalent throughout the world. Surgical myectomy and alcohol septal ablation (ASA) are two methods currently used for the management of drug refractory Hypertrophic obstructive cardiomyopathy (HOCM). ASA may prove to be a useful, less invasive tool when confronting patients with HOCM especially those who are more elderly or deemed to be a higher surgical risk.

**Methods**

Electronic literature search was conducted to identify relevant articles that discussed invasive methods to treat drug refractory HOCM. No limits were placed on timing of the publication or the type of article. Key words and MeSH terms were used to conduct the search and the results were summarized in the relevant section.

**Results**

Current evidence suggests that alcohol septal ablation is a safe and effective procedure in treating patients with HOCM with similar short- and long-term outcomes when compared with surgical myectomy. Selection of patient with appropriate assessment is the key for satisfactory outcomes.

**Conclusion**

ASA has been shown to be a safe and reliable procedure; advanced imaging techniques and dedicated multi-disciplinary teams can be used to carefully select patients with HOCM. Though surgical myectomy is recommended as gold standard treatment for drug refractory HOCM, however, ASA may play an increasing role in the near future due an ageing population; both ASA and SM can have a synergistic effect in treating those who are affected by HOCM.

**Introduction**

Affecting 1 in 500 individuals; Hypertrophic cardiomyopathy (HCM) is an autosomal dominant cardiovascular disorder which is prevalent throughout the world. HCM can lie dormant and appear asymptomatic or can produce a variety of symptoms involving dyspnoea, angina, syncope, and can even result in sudden cardiac death. HCM is typically classified as asymmetrical septal wall hypertrophy in the absence of other causes for hypertrophy. When left ventricular outflow tract obstruction (LVOTO) occurs the disease is termed as hypertrophic obstructive cardiomyopathy (HOCM), these patients are initially managed through pharmacological means such as the use of beta blockers and calcium channel blockers. To those patients who remain symptomatic despite optimal medical management, intervention is required in order to reduce both obstruction and symptoms which can place the patient as risk of death. Surgical myectomy and alcohol septal ablation (ASA) are two methods currently used for the management of drug refractory HOCM while the former has been in use since the 50s, the latter can come into prominent since the 90s and may prove to be a useful, less invasive tool when confronting patients with HOCM especially those who are more elderly or deemed to be a higher surgical risk.

HCM is an autosomal dominant disorder and is described as left ventricular (LV) hypertrophy in the absence of any other cardiac or systemic disease. The disorder typically causes mutations in proteins involved in the contractile apparatus. There are several proteins which have been identified to be affected in HCM; the two most common being Myocyte binding protein C (MYBPC3) and Beta-Myosin heavy chain (MYH7) both of which have a frequency of around 40%. [1]

ASA may play a role in those who develop symptoms despite optimal drug therapy, it is less invasive, involves shorter hospital stays, and there are numerous centres who are producing high volumes of work and have good outcomes. The criteria for selecting these patients are crucial in order to minimise peri and post procedural mortality and maximise gradient reduction. Younger individuals tend to undergo surgical myectomy, whereas ASA is directed toward patients with advanced age, co-morbidities or deemed to be a surgical risk. [2] ASA uses angiography and contrast echocardiography to identify septal perforator arteries supplying the hypertrophied septum, this artery is then injected with small quantities of alcohol (ranging from 1-5 ml), which infarcts the region, causing necrosis and in the coming months results in remodelling of the myocardium and thus reducing the left ventricular outflow tract (LVOT) gradient. [3]

**Left Ventricular Outflow Tract Obstruction**

LVOTO is caused by systolic anterior motion (SAM) of the mitral valve. The anterior mitral valve leaflet moves into the LVOT and during systole comes into contact (severe cases) with the hypertrophied basal septum and affects blood flow through the LVOT, thus creating haemodynamic instability (figure 1). The degree of obstruction can vary and is dependent on several factors. LVOTO is dynamic and can worsen in the context of reduced preload (e.g. Valsalva), reduced afterload (vasodilators) and positive inotropes. [4]. Based on the severity of obstruction patients can experience a reduction in cardiac output, worsening of mitral regurgitation, diastolic dysfunction leading to increase in LV end diastolic pressure and affect coronary blood flow and some degree of arrhythmia (figure 2).[5]

**Indication for alcohol septal ablation**

Criteria for patients who are deemed suitable for ASA include; New York Heart Association (NYHA) class III-IV, LVOT resting gradient >30mmHG or >50mmHG on provocation, evidence of systolic anterior motion (SAM) of the mitral valve leaflet, septal wall thickness >16mm. [6] Various centres will have their own criteria for patient selection for ASA, on the whole these tend to be based on symptomology, LVOT gradients and existing o-morbidities. Concomitant significant coronary artery disease or valvular pathologies need to be ruled out as these patients will benefit from cardiac surgery rather than ASA. Favourable coronary anatomy is also crucial to outcomes as easily accessible septal branches allow for uncomplicated procedures. [7] The 2011 ACCF/AHA guidelines state that surgical myectomy should be gold standard for drug refractory HOCM and advise against the use of ASA in those with marked septal hypertrophy (>30 mm), in younger patients, in mid ventricular obstruction, and in those with concomitant disease that requires surgical intervention. They particularly advised against both surgical and percutaneous intervention in those who are asymptomatic or have normal exercise tolerance. [2,8]. Indications have been summarised in Table 1

NYHA and CCS are useful indicators of symptoms, however they remain highly subjective. Jones et al. suggest the use of other tests in order to identify patients suitable for ASA. One such test is cardiopulmonary exercise testing which can be used in HOCM patients with mild symptoms, where peak VO2 is associated with NYHA class. 6-minute walk test can also provide an objective measure of exercise tolerance. Kansas City cardiomyopathy questionnaire involves clinical and non-clinical aspects as part of its scoring system and emphasises the importance of quality of life in choosing candidates for ASA. [9] Table 2 shows the calculation of the risk of sudden cardiac death in HOCM and how it can be used to predict mortality in those with severe HOCM who remain untreated.

**Outcomes of alcohol septal ablation**

Several centres have reported promising results in both short- and long-term outcomes of patients who undergo ASA. Rosa et al. chose to use a LVOT gradient >50mmHg at rest and >70 mmHg on provocation

as part of their selection criteria. 92.5% of their patients had NYHA class III or IV prior to ASA, they observed >50% reduction of LVOT gradient in 85.7% of their patient group within a year of the procedure. The most common procedural complication was atrioventricular (AV) block which was 45% however this was either transient or permanent, as only 8.8% required permanent pacemaker (PPM) implantation. In hospital mortality was low at 3.8% and 12.5% required redo ASA or myectomy. The majority of their patients (77%) showed improved symptoms and were found to have NYHA class I or II in follow up. [10] An et al. compared the long-term survival of 233 patients with HOCM who underwent ASA and 297 patients with non-obstructive hypertrophic cardiomyopathy (NOHCM), they included patients with LVOT gradients >50 mmHg at rest and on provocation as part of their selection criteria for ASA. This study was targeted at a younger patient group; the HOCM and NOHOCM had an average age of 48.7 and 46.2 respectively. They found low peri-procedural mortality (0.89%), 4% developed ventricular arrhythmias and only 0.44% required PPM implantation. They found a significant reduction in LVOT pressure gradient immediately post ASA and at the 3 month follow up. 10-year survival from all-cause mortality was 94.7% for the ASA group and 92.9% in the NOHCM group. 6 out of the 9 patients who suffered from ventricular arrhythmias were <40 years of age which may suggest that lower age may have a higher incidence of ventricular arrhythmias in the periprocedural period. ASA is typically targeted at patients with advanced age and more studies need to be conducted in younger patient age groups to understand the safety of the procedure. [11]

The ESC guidelines suggest invasive treatment to those individuals with LVOTO >50 mmHg, and NYHA class III-IV despite maximal drug therapy. Centres may alter their selection criteria to include those with NYHA class II in the context of severe SAM related mitral regurgitation (MR) or AF. [12] Veselka et al. observed the effect of ASA on mild symptomatic patients, those with NYHA class II symptoms were selected for the study. These patients did however have a LVOTO >50 mmHg at rest or provocation. They found a 77% reduction in LVOTO gradient during clinic follow up with 69% patients with NYHA class I symptoms. Only 9.3% required repeat septal reduction therapy due to inadequate symptomatic relief. [13]

Kashtanov et al. performed a 10 year follow up of patients who underwent ASA. They found hospital mortality to be at 0%, and PPM implantation at 7.5%. Pressure gradients at rest and provocation significantly decreased when compared to baseline and 10-year values. Though there were no statistical differences between the 1 year and 10-year gradients. The same pattern can be seen for interventricular septum (IVS) thickness. Ejection fraction and left atrial diameter values remained stable, though end diastolic diameter followed a negative trend at the 1 year and 10 year stages. NYHA class had decreased between pre procedure and 1 year follow up but has not changed at the 10 year follow up. Canadian cardiovascular society (CCS) class of angina did not statistically differ between 1 year and 10-year values. 2 patients required PPM at 9 and 11 years respectively. [14] Jahnlova et al. studied the long-term effect of ASA on patients >60 years of age. 90% of selected patients suffered from NHA class III dyspnoea, while 75% had both dyspnoea and angina. 2.6% died during the first month, post procedure transient complete AV block was seen in 24.4% with 11.5% needed PPM. Sustained ventricular tachycardia or ventricular fibrillation occurred in 3.2% of patients. In terms of long term follow up 81% of patient had < NYHA class II dyspnoea and 76% had maximal LVOT gradient <30 mmHg at rest or provocation. Only 3.9% required repeat ASA and 1.3% needed SM. 51% of all mortality events were due to cardiovascular causes and compared with the expected mortality in the sex and age matched general population, patients >60 years after ASA showed greater mortality. [15]

ASA is more commonly chosen for patients with hypertrophy at the mitral valve level with SAM, less commonly around 5% of HCM patients can develop mid ventricular obstruction leading to papillary muscle hypertrophy and LV apical aneurysm; SAM with mid ventricular and outflow tract obstruction can also be seen in these patients. Tengiz et al. report a case where ASA was performed on a symptomatic individual with mid ventricular HOCM, the first septal branch was used and 3 ml were injected into the vessel. Post procedure echocardiogram revealed reduced in IVS, left atrial dimension, and mild MR without SAM, patient was asymptomatic during follow up. ASA in mid ventricular HOCM still requires extensive study but may in the future be included as part of the morphological criteria for ASA. [16] Barwad et al. interestingly report a case where a patient with known HOCM who developed sepsis due to cholangitis underwent ASA. Endoscopic retrograde cholangiopancreatography (ERCP) had failed and systemic hypotension despite fluid and inotrope

support worsened LVOT obstruction with a resting LVOT gradient of 90mmHg. Haemodynamic instability in the context of sepsis can result in unfavourable outcomes in those with HOCM, as volume depletion can worsen LVOT obstruction and inotropes in this setting can make the obstruction worse. ASA was performed as a form of rescue therapy and was successful in reducing LVOT gradient and allowed the patient to overcome the infection. [17] Kulic et al. report a case of a young individual who had SM and developed symptoms 4 years after the initial intervention due to progression of disease, underwent ASA and achieved reduction in LVOT gradient, indicating a role of ASA as a less invasive method for those who require re-intervention. [18]

**Alternative Methods**

Dual chamber pacing (DDD) may be able to relieve symptoms in those patients who are deemed high risk for ASA. Krejci et al. compared the long-term effects of DDD pacing and ASA in symptomatic patients. Patients treated with DDD pacing had reduced NYHA class symptoms, and LVOT gradient, however no significant difference in change in LVOT gradient and left ventricular ejection fraction (LVEF) was found between both groups. The ASA group showed greater improvement in NYHA class, greater reduction in interventricular septum (IVS) thickness and LV diastolic diameter. Both groups were followed up over a period of 7-8 years and revealed that ASA can provide a consistent reduction in LVOT gradient over this period. Surgical myectomy or ASA can effectively reduce the physical obstruction in HOCM by reducing basal septal hypertrophy and relieve SAM, and are the ideal methods for symptomatic patients, DDD appears to produce promising results in the long term reduction of LVOT gradients and may be useful in high risk patients, this however will require further study. [19]

Surgical myectomy (SM) has been deemed to be gold standard in the invasive treatment of HOCM, and a preferable option to younger and low risk patients (table 3). Surgical myectomy is also a convenient option to those who need concomitant cardiac surgery such as coronary artery bypass grafting or surgical valve replacement. Good results have been shown in high volume centres. Rastegar et al. performed surgical myectomy on patients with NYHA class III-IV symptoms; they found significant reduction in resting LVOT gradients. Of the 31 patients who had severe MR, 87% had no or mild MR post procedure. 30-day deaths were 0.8% and no patient required repeat intervention, and 3% had ASA prior to SM and required reintervention due to heart failure symptoms. 43 out of 482 patients needed PPM, 4 developed ischaemic stroke in the peri operative period and 21% developed atrial fibrillation. At follow up 64% had NYHA class I and 29% with class II symptoms. [20] Xin et al. evaluated the follow up results of those who underwent ASA and SM. No significant differences were noted in IVS thickness reduction, LV end diastolic diameter, or degree of SAM at follow up between the two groups. There was however greater reduction in the resting LVOT gradient in the SM group, with 81% of patients having completely eliminated their pressure gradients. Both groups showed improvement with NYHA class, but there was no significant difference. PPM implantation was 24% and 7.7% in the ASA and SM groups respectively and hospital stay was much shorter in the ASA group. [21] Yao et al. also produced promising results with SM, showing no deaths within 30 days, post-operative hospital stay was around 10 +/- 5, and NYHA reduced greatly from 2.5- and 5-years post-surgery. Severe and moderate MR had completely disappeared and the most common post-operative arrhythmia was left bundle branch block (LBBB) 24.5%. [22]

Firoozi et al. performed a non-randomised cohort study comparing ASA and SM. They found that both procedures had significant reduction in LVOT gradients; with 91% of SM patients having a gradient below 20 mmHg post procedure, compared to the 74% in the ASA group. 15% of the ASA group required PPM compares to the 4% in the SM group. The improvement in functional class was similar in both groups. Peak VO2 was greater in the myectomy group. Peak LVOT gradient at 12 months were similar in both groups. [23]

**Complications of alcohol septal ablation**

The most common complications during or post ASA involve arrhythmias. AV block is common post ASA, some may be transient or permanent and may require PPM insertion. Conduction abnormalities are expected

during ASA and so the patients will be paced during and after the procedure for an average of 48 hours. The volume of ethanol used may correlate with the occurrence of conduction abnormalities. The greater volumes of ethanol used result in larger areas of myocardial infarction and may result in conduction defects. Kazmierczak et al. monitored the Electrocardiogram (ECG) changes during and post ASA. Complete right bundle branch block (RBBB) was immediately seen (within 1 hour) in all 9 patients which is expected as these areas are supplied by the septal branches, though only 4 had RBBB at the 6 month follow up. Only one patient required PPM implantation and ventricular tachycardia was not observed in any of the patients. Anterior ST segment elevation was also seen in at least two consecutive leads immediately post procedure in 5 out of 9 patients. [24]

Ethanol dose may play a role in procedural complications and outcomes. Doses range between centres and can vary depending on the patient. Higher ethanol usage has been associated with greater risk of patients developing conduction abnormalities. Sathyamurthy et al. injected on average 2ml of alcohol into the target septal branch of their patients. They found satisfactory occlusion of the target septal branch, improvement of symptoms, and significant reduction of LVOT gradients which were found in the 6 months post procedure and remained the same 8 years after. Right bundle branch block (RBBB) was seen in 79% of patients post procedure however only 10% required PPM. [25] Akita et al observed that between the good (reduction in NYHA class $>1$) and poor (reduction in NYHA class $<1$) responder group; the good responder group required more ethanol during ablation, using 4ml as oppose to 3.1ml used by in the poor responder group. Greater incidences of arrhythmias were observed in the good responder group and may correlate with the amount of ethanol used during ASA. Those in the good responder group developed ventricular arrhythmias (6.9%), complete AV block (13.8%), and PPM implantation (11.1%), whereas the poor responder group which used less ethanol during ASA did not show any ventricular arrhythmias, PPM was not required and only 11.1% developed complete AV block. [26] Baggish et al. performed autopsies on patients post ASA. One autopsy performed soon after ASA found myocardial necrosis with marginating neutrophils at the periphery of the infraction; 3ml of ethanol was used during the procedure. Septal perforator artery and myocardium necrosis, as well as absence of nuclei from endothelial and smooth muscle cells. Another autopsy performed 14 months after ASA; only 1ml of ethanol was used and this patient required surgical myectomy as symptoms persisted as the LVOT gradient remained high. Autopsy revealed incomplete infarction showing viable myocytes surrounded by scar and thrombosed septal arteries with necrotic arterial walls. Indicating the vascular toxic role that ethanol plays, and the difference in pathology when lower and higher doses of ethanol are used. [27]

Steggerda et al. investigated the predictors of poor outcomes in ASA. They selected patients with NYHA class $>$ III, and LVOT gradient $>$30mmHG and $>$50 mmHG on provocation. 37 out of 113 were deemed to have insufficient response to ASA; elevated resting gradient, and greater distances from the origin of the left anterior descending artery (LAD) to the first septal branch were shown to be associated with poorer outcomes. Suggesting that unfavourable coronary anatomy may result in either insufficient therapeutic effect, or increased chances of the procedure being abandoned. [28] Less common periprocedural complications include coronary artery dissection, cardiac tamponade, and arterial complications which are related to access such as femoral artery pseudoaneurysm or retroperitoneal haemorrhage. [29] Cuoco et al. studied the long-term risk of ventricular arrhythmias after ASA. They collected data from 123 patients and monitored the times a shock was delivered by an implantable cardioverter defibrillator (ICD). Only 9 patients out of 123 developed a rhythm that required an ICD shock. Suggesting that ventricular arrhythmias are uncommon after ASA however they are more likely to occur in the immediate post-operative phase. Studies have suggested that the scar tissue formed by ethanol injection could be pro-arrhythmogenic.[30] El-Sabawi et al. also report low instances of ventricular arrhythmia 1.2% following ASA, whereas complete AV block was more frequent at 24.3% especially in the initial 24 hours post procedure. [31] Atrial fibrillation (AF) can occur post ASA, Moss et al. studies 132 patient with no history of AF. During follow up 10 patients (7.6%) developed AF with only 2 having permanent AF, those affected tended to be older but the NYHA class was the same as the AF free group. Despite therapeutic anticoagulation, one patient developed stroke. [32]

**Follow up**

Long-term follow up is vital in order to ascertain the effects of ASA in patients with drug refractory HOCM. Usual methods include yearly echocardiograms looking into LVEF, septal wall thickness, valvular function, LV systolic and diastolic function. Akita et al. propose the use of brain natriuretic peptide (BNP) as a prognostic indicator in patients who have had ASA. BNP is expressed in the ventricular myocytes during stress and can appear elevated in patients with LVOTO and diastolic dysfunction. They found reduction in BNP post ASA; with greater reduction up till the 3-month period and plateaus until the $12^{\text{th}}$ month, greater declines were seen in the good responder group (Drop in NYHA class >1) [26]

Exercise tolerance along with symptomology is a useful indicator of the therapeutic effects of ASA. Fernandes et al. used monitored the exercise tolerance of their ASA during follow up using the treadmill test. The patients chosen for the study had NYHA class III-IV dyspnoea; they found significant improvement in NYHA class as well as LVOT gradient at the 3 month and 1 year phase. The treadmill time significantly improved 3 months post ASA and remained elevated though fewer patients were subjected to the treadmill test in the latter stages of follow up. [6]

Cardiac MRI was used by Sohns et al. compare the short-term results of ASA when compared to conventional echocardiography and cardiac catheterization. CMR was able to assess the scar tissue formed as a result of ASA; it showed a correlation between scar size and post extrasystolic gradient reduction, whereas echocardiogram did not record similar findings. CMR also identified that greater areas of scar tissue were associated with higher doses of ethanol. CMR may be able to perform a functional assessment on tissue by measuring flow velocity and flow volume, it can also assess myocardial viability and be used to follow ventricular remodelling. CMR may be useful as a non-invasive tool in conjunction with other imaging techniques to assess the effectiveness of ASA in the short and long term. [33]

**Conclusion**

ASA has been shown to be a safe and reliable procedure; advanced imaging techniques and dedicated multidisciplinary teams can be used to carefully select patients with HOCM. Especially those who are at an advanced age or have multiple co-morbidities may experience beneficial results from ASA and in experienced high-volume centres are likely to have greater outcomes. Though surgical myectomy is recommended as gold standard treatment for drug refractory HOCM, ASA may play an increasing role in the near future due an ageing population; both ASA and SM can have a synergistic effect in treating those who are affected by HOCM.

Acknowledgment: None

Funding: None obtained

Ethical approval: not required

**Figure legends:**

**Figure 1:**

Left ventricular outflow tract obstruction due to narrowing of the left ventricular outflow tract by septal hypertrophy and anterior displacement of the papillary muscles and the mitral valve leaflet. A, B, C, and D represent doppler velocity recordings throughout systole in A (ascending aorta – forward towards transducer), B (contact between mitral valve and septum), C (left atrium), and D (apex of left ventricle). B, C, and D show that flow is away from the transducer. Aortic velocity waveform (A) indicates reduced forward flow in the presence of obstruction. Ao (aorta), LV (left ventricle), MV (mitral valve), LA (left atrium).

**Figure 2:**

Different regions of the myocardium affected by invasive HOCM treatment and the conduction abnormalities than can occur. Hypertrophic obstructive cardiomyopathy (HOCM), Right bundle branch block (RBBB), left bundle branch block (LBBB).

Table 1 Indications for alcohol septal ablation

| NYHA Class III-IV |
|---|
| LVOT gradient >50 mmHg at rest or provocation |
| Septal thickness 15-30mm at the site of obstruction |
| SAM on the mitral valve |
| Favourable coronary anatomy |
| Recurrent exertional syncope |
| Advanced age |
| Absence of pathology that requires surgical correction |
| Symptoms despite maximal drug therapy |
| Patients aversion to surgery |
| High surgical risk due to co-morbidities |

NYHA: New York Heart Association; LVOT: left ventricular outflow tract; SAM: systolic anterior motion.

Table 2 Risk of Sudden Cardiac Death (SCD) in Hypertrophic cardiomyopathy

| Age | - |
|---|---|
| Maximum LV wall thickness | 10-35mm |
| Left Atrial Size | 28-67mm |
| LVOT Gradient | 2-154 mmhg |
| Family history of SCD | Yes/No |
| Non sustained VT | Yes/No |
| Unexplained Syncope | Yes/No |

SCD: sudden cardiac death; LVOT: left ventricular outflow tract; VT: ventricular tachycardia

Table 3 Advantages and Disadvantages of Alcohol septal ablation and surgical myectomy

| Advantages of ASA | Disadvantages of ASA | Advantages of SM |
|---|---|---|
| Less invasive | AV block requiring PPM | Immediate reduction in LVOT gradient |
| Shorter hospital stays | Need for re-intervention | Beneficial in younger patients |
| Can be offered to those who are high surgical risk | Ventricular arrhythmias | Greater reduction in mitral valve regurgitat |
| Can be offered to older patients | | Can be offered to those who need cardiac su |

LVOT: left ventricular outflow tract; SAM: systolic anterior motion; ASA: Alcohol septal ablation; SM: surgical myectomy; PPM: permanent pacemaker

**References:**

1) Hypertrophic cardiomyopathy: genetics and clinical perspectives. Wolf CM. *Cardiovasc Diagn Ther* . 2019;9(Suppl 2):S388-S415. doi:10.21037/cdt.2019.02.01

2) 2011 ACCF/AHA Guideline for the Diagnosis and Treatment of Hypertrophic Cardiomyopathy. A Report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. Gersh BJ, Maron BJ, Bonow RO, Dearani JA, Fifer MA, Link MS et al. Circulation. 2011 Dec 13;124(24):2761-96. doi: 10.1161/CIR.0b013e318223e230.

3) Current state of the roles of alcohol septal ablation and surgical myectomy in the treatment of hypertrophic obstructive cardiomyopathy. Douglas JS Jr. *Cardiovasc Diagn Ther* . 2020;10(1):36-44. doi:10.21037/cdt.2019.07.02

4) Alcohol Septal Ablation for the Treatment of Hypertrophic Obstructive Cardiomyopathy. O'Mahony C, Mohiddin SA, Knight C. *Interv Cardiol* . 2014;9(2):108-114. doi:10.15420/icr.2011.9.2.108

5) Intervention in HCM: patient selection, procedural approach and emerging techniques in alcohol septal ablation. Cooper RM, Shahzad A, Stables RH. *Echo Res Pract* . 2015;2(1):R25-R35. doi:10.1530/ERP-14-0058

6) A prospective follow-up of alcohol septal ablation for symptomatic hypertrophic obstructive cardiomyopathy–the Baylor experience (1996-2002). Fernandes VL, Nagueh SF, Wang W, Roberts R, Spencer WH 3rd.*Clin Cardiol* . 2005;28(3):124-130. doi:10.1002/clc.4960280305

7) Hypertrophic Obstructive Cardiomyopathy. Batzner A, Schäfers HJ, Borisov KV, Seggewiß H. *Dtsch Arztebl Int* . 2019;116(4):47-53. doi:10.3238/arztebl.2019.0047

8) Alcohol septal ablation in hypertrophic cardiomyopathy. Mateo JJS, Gimeno JR. *Glob Cardiol Sci Pract* . 2018;2018(3):30. Published 2018 Aug 12. doi:10.21542/gcsp.2018.30

9) How Symptomatic Should a Hypertrophic Obstructive Cardiomyopathy Patient Be to Consider Alcohol Septal Ablation?. Jones BM, Krishnaswamy A, Smedira NG, Desai MY, Tuzcu EM, Kapadia SR. *J Am Heart Assoc* . 2017;6(5):e006292. Published 2017 May 16. doi:10.1161/JAHA.117.006292

10) Short- and long-term outcome after alcohol septal ablation in obstructive hypertrophic cardiomyopathy: Experience of a reference center. Aguiar Rosa S, Fiarresga A, Galrinho A, Cacela D, Ramos R, de Sousa L et al. Rev Port Cardiol. 2019 Jul;38(7):473-480. doi: 10.1016/j.repc.2019.08.003. Epub 2019 Sep 5. doi:10.1016/j.repc.2019.08.003

11) Procedural complication and long term outcomes after alcohol septal ablation in patients with obstructive hypertrophic cardiomyopathy: data from China. An SY, Yang YJ, Hang F, Wang ZM, Fan CM. *Sci Rep* . 2017;7(1):9506. Published 2017 Aug 25. doi:10.1038/s41598-017-10144-0

12) 2014 ESC Guidelines on diagnosis and management of hypertrophic cardiomyopathy: The Task Force for the Diagnosis and Management of Hypertrophic Cardiomyopathy of the European Society of Cardiology (ESC). Authors./Task Force members, Elliott PM, Anastasakis A, Borger MA, Borggrefe M, Cecchi F et al. Eur Heart J. 2014 Oct 14;35(39):2733-79. doi: 10.1093/eurheartj/ehu284. Epub 2014 Aug 29.

13) Outcome of Alcohol Septal Ablation in Mildly Symptomatic Patients With Hypertrophic Obstructive Cardiomyopathy: A Long-Term Follow-Up Study Based on the Euro-Alcohol Septal Ablation Registry. Veselka J, Faber L, Liebregts M, et al. *J Am Heart Assoc* . 2017;6(5):e005735. Published 2017 May 16. doi:10.1161/JAHA.117.005735

14) Results of Ten-Year Follow-Up of Alcohol Septal Ablation in Patients with Obstructive Hypertrophic Cardiomyopathy. Kashtanov M, Rzhannikova A, Chernyshev S, Kardapoltsev L, Idov E, Berdnikov S. *Int J Angiol* . 2018;27(4):202-207. doi:10.1055/s-0038-1675213

15) Outcome of patients [?] 60 years of age after alcohol septal ablation for hypertrophic obstructive cardiomyopathy. Jahnlova D, Tomašov P, Adlová R, et al. *Arch Med Sci* . 2019;15(3):650-655. doi:10.5114/aoms.2019.84735

16) Percutaneous septal ablation for left mid-ventricular obstructive hypertrophic cardiomyopathy: a case report. Tengiz I, Ercan E, Alioglu E, Turk UO. *BMC Cardiovasc Disord* . 2006;6:15. Published 2006 Apr 10. doi:10.1186/1471-2261-6-15

17) Rescue alcohol septal ablation in sepsis with multiorgan failure. Barwad PW, Ramakrishnan S, Seth S, Bhargava B. *Indian Heart J* . 2012;64(6):588-590. doi:10.1016/j.ihj.2012.09.004

18) SUCCESSFUL PERCUTANEOUS SEPTAL ALCOHOL ABLATION AFTER SURGICAL MYECTOMY. Kulić M, Spužić M, Tahirović E, et al. *Bosn J Basic Med Sci* . 2010;10(3):216-222.

19) Comparison of long-term effect of dual-chamber pacing and alcohol septal ablation in patients with hypertrophic obstructive cardiomyopathy. Krejci J, Gregor P, Zemanek D, et al. *ScientificWorldJournal* . 2013;2013:629650. Published 2013 Nov 11. doi:10.1155/2013/629650

20) Results of surgical septal myectomy for obstructive hypertrophic cardiomyopathy: the Tufts experience. Rastegar H, Boll G, Rowin EJ, et al. *Ann Cardiothorac Surg* . 2017;6(4):353-363. doi:10.21037/acs.2017.07.07

21) Outcome of patients with hypertrophic obstructive cardiomyopathy after percutaneous transluminal septal myocardial ablation and septal myectomy surgery. Xin J, Shiota T, Lever HM, Kapadia SR, Sitges M, Rubin DN et al. J Am Coll Cardiol. 2001 Dec, 38 (7) 1994-2000. doi: 10.1016/S0735-1097(01)01656-4

22) Long-term clinical and echocardiographic outcomes of extensive septal myectomy for hypertrophic obstructive cardiomyopathy in Chinese patients. Yao L, Li L, Lu XJ, Miao YL, Kang XN, Duan FJ. *Cardiovasc Ultrasound* . 2016;14(1):18. Published 2016 May 17. doi:10.1186/s12947-016-0060-9

23) Septal myotomy–myectomy and transcoronary septal alcohol ablation in hypertrophic obstructive cardiomyopathy. A comparison of clinical, haemodynamic and exercise outcomes. Firoozi S, Elliott PM, Sharma S, Murday A, Brecker SJ, Hamid MS et al Eur Heart J. 2002 Oct;23(20):1617-24. Doi:10.1053/euhj.2002.3285

24) Electrocardiographic changes after alcohol septal ablation in hypertrophic obstructive cardiomyopathy. Kazmierczak J, Kornacewicz-Jach Z, Kisly M, Gil R, Wojtarowicz A. *Heart* . 1998;80(3):257-262. doi:10.1136/hrt.80.3.257

25) Alcohol septal ablation for hypertrophic obstructive cardiomyopathy - 8 years follow up. Sathyamurthy I, Nayak R, Oomman A, et al. *Indian Heart J* . 2014;66(1):57-63. doi:10.1016/j.ihj.2013.12.008

26) Prognostic significance of repeated brain natriuretic peptide measurements after percutaneous transluminal septal myocardial ablation in patients with drug-refractory hypertrophic obstructive cardiomyopathy. Akita K, Tsuruta H, Yuasa S, Murata M, Fukuda K, Maekawa Y. *Open Heart* . 2018;5(1):e000786. Published 2018 May 10. doi:10.1136/openhrt-2018-000786

27) Pathological effects of alcohol septal ablation for hypertrophic obstructive cardiomyopathy. Baggish AL, Smith RN, Palacios I, et al. *Heart* . 2006;92(12):1773-1778. doi:10.1136/hrt.2006.092007

28) Predictors of outcome after alcohol septal ablation in patients with hypertrophic obstructive cardiomyopathy. Special interest for the septal coronary anatomy. Steggerda RC, Balt JC, Damman K, van den Berg MP, Ten Berg JM. *Neth Heart J* . 2013;21(11):504-509. doi:10.1007/s12471-013-0453-4

29) Alcohol Septal Ablation for the Treatment of Hypertrophic Obstructive Cardiomyopathy. A Multicenter North American Registry. Nagueh SF, Groves BM, Schwartz L, Smith KM, Wang A, Bach RG. J Am Coll Cardiol. 2011 Nov, 58 (22) 2322-2328. DOI: 10.1016/j.jacc.2011.06.073

30) Implantable Cardioverter-Defibrillator Therapy for Primary Prevention of Sudden Death After Alcohol Septal Ablation of Hypertrophic Cardiomyopathy. Cuoco FA, Spender WH 3rd, Fernandes VL, Nielsen CD, Nagueh SF, Sturdivant JL et al. J Am Coll Cardiol. 2008 Nov, 52 (21) 1718-1723. DOI: 10.1016/j.jacc.2008.07.061

31) Temporal Occurrence of Arrhythmic Complications After Alcohol Septal Ablation. El-Sabawi B, Nishimura RA, Barsness GW, Cha YM, Geske JB, Eleid MF. Circ Cardiovasc Interv. 2020 Feb;13(2):e008540. doi: 10.1161/CIRCINTERVENTIONS.119.008540.

32) Incidence of Atrial Fibrillation following Alcohol Septal Ablation for Hypertrophic Cardiomyopathy. Moss TJ, Zipse MM, Krantz MJ, Sauer WH, Salcedo EE, Schuller JL. *Ann Noninvasive Electrocardiol* . 2016;21(5):443-449. doi:10.1111/anec.12335

33) Visualization of transcoronary ablation of septal hypertrophy in patients with hypertrophic obstructive cardiomyopathy: a comparison between cardiac MRI, invasive measurements and echocardiography. Sohns

C, Sossalla S, Schmitto JD, et al. *Clin Res Cardiol* . 2010;99(6):359-368. doi:10.1007/s00392-010-0128-8

34) Percutaneous Septal Ablation in Hypertrophic Obstructive Cardiomyopathy: From Experiment to Standard of Care. Faber L. *Adv Med* . 2014;2014:464851. doi:10.1155/2014/464851

35) Twenty Years of Alcohol Septal Ablation in Hypertrophic Obstructive Cardiomyopathy. Rigopoulos AG, Seggewiss H. *Curr Cardiol Rev* . 2016;12(4):285-296. doi:10.2174/1573403x11666150107160344

36) Alcohol septal ablation: in which patients and why?. Spirito P, Rossi J, Maron BJ. *Ann Cardiothorac Surg* . 2017;6(4):369-375. doi:10.21037/acs.2017.05.09

37) hypertrophic cardiomyopathy: preliminary attempt at palliation with use of subselective alcohol ablation. Angelini P, Uribe C, Monge J, Escobar JM, Hernandez-Vila E. Apical *Tex Heart Inst J* . 2012;39(5):750-755.

38) Genetics of hypertrophic cardiomyopathy: advances and pitfalls in molecular diagnosis and therapy. Roma-Rodrigues C, Fernandes AR.*Appl Clin Genet* . 2014;7:195-208. Published 2014 Oct 3. doi:10.2147/TACG.S49126

39) Hypertrophic cardiomyopathy. Clinical spectrum and treatment. Wigle ED, Rakowski H, Kimball BP, Williams WG. Circulation. 1995 Oct 1;92(7):1680-92. doi:10.1161/01.cir.92.7.1680

40) Hypertrophic Cardiomyopathy Is Predominantly a Disease of Left Ventricular Outflow Tract Obstruction. Maron MS, Olivotto I, Zenovich AG, Link MS, Pandian NG, Kuvin JT et al. Circulation. 2006;114:2232–2239. https://doi.org/10.1161/CIRCULATIONAHA.106.644682

41) Regression of Left Ventricular Hypertrophy After Nonsurgical Septal Reduction Therapy for Hypertrophic Obstructive Cardiomyopathy. Mazur W, Nagueh SF, Lakkis NM, Middleton KJ, Killip D, Roberts R et al. Circulation. 2001;103:1492–1496. Doi:10.1161/01.cir.103.11.1492

42) Predictors of Outcome After Alcohol Septal Ablation Therapy in Patients With Hypertrophic Obstructive Cardiomyopathy. Chang SM, Lakkis NM, Franklin J, Spencer WH 3rd, Nagueh SF. Circulation. 2004 Feb 24;109(7):824-7. Epub 2004 Feb 16. doi:10.1161/01.CIR.0000117089.99918.5A

43) Comparison of Surgical Septal Myectomy and Alcohol Septal Ablation With Cardiac Magnetic Resonance Imaging in Patients With Hypertrophic Obstructive Cardiomyopathy. Valeti US, Nishimura RA, Holmes DR, Araoz PA, Glockner JF, Breen JF et al. J Am Coll Cardiol. 2007 Jan, 49 (3) 350-357. doi: 10.1016/j.jacc.2006.08.055

44) Sustained improvement in left ventricular diastolic function after alcohol septal ablation for hypertrophic obstructive cardiomyopathy. Jassal DS, Neilan TG, Fifer MA, Palacios IF, Lowry PA, Vlahakes GJ et al. Eur Heart J. 2006 Aug;27(15):1805-10. Epub 2006 Jun 14. Doi:10.1093/eurheartj/ehl106

45) Periprocedural Complications and Long-Term Outcome After Alcohol Septal Ablation Versus Surgical Myectomy in Hypertrophic Obstructive Cardiomyopathy. A Single-Center Experience. Steggerda RC, Damman K, Balt JC, Liebregts M, ten Berg JM, van den Berg M. J Am Coll Cardiol Intv. 2014 Nov, 7 (11) 1227-1234. DOI: 10.1016/j.jcin.2014.05.023

46) Myectomy versus alcohol septal ablation in patients with hypertrophic obstructive cardiomyopathy. Afanasyev A, Bogachev-Prokophiev AV, Kashtanov MG, Astapov D, Zalesov AS, Budagaev SA et al. *Interactive CardioVascular and Thoracic Surgery* . https://doi.org/10.1093/icvts/ivaa075

47) Cardiomyopathy: The diagnosis of hypertrophic cardiomyopathy. Wigle ED. *Heart* . 2001;86(6):709-714. doi:10.1136/heart.86.6.709

48) Alcohol septal ablation versus surgical septal myectomy: comparison of effects on atrioventricular conduction tissue. Talreja DR, Nishimura RA, Edwards WD, Valeti US, Ommen SR, Tajik AJ et al. J Am Coll Cardiol. 2004 Dec 21;44(12):2329-32. DOI:10.1016/j.jacc.2004.09.036

49) Effects of alcohol septal ablation on coronary microvascular function and myocardial energetics in hypertrophic obstructive cardiomyopathy. Timmer SA, Knaapen P, Germans T, Dijkmans PA, Lubberink M, Ten Berg JM et al. Am J Physiol Heart Circ Physiol. 2011 Jul;301(1):H129-37. doi: 10.1152/ajpheart.00077.2011. Epub 2011 Apr 13