Review Article

The Utility of Surgical Cardiac Sympathetic Denervation in the Management of Ventricular Arrhythmias for all Etiologies: A Systematic Review

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Abstract

Background: The antiadrenergic and antifibrillatory effects of cardiac sympathectomy in pathological states such as long QT syndrome are well established. The indications for the procedure have expanded since the video-assisted thoracoscopic approach was first used. However, the procedure is currently largely used in cases where medication has failed to prevent recurrence of symptomatic ventricular arrhythmia, or in cases of medication intolerance, and large randomised controlled trials are thus non-existent in the literature. The aim of this study was to perform a systematic review of the available literature to examine the utility of cardiac denervation in the management of all ventricular arrhythmias.

Methods: A total of 17 studies published between 2009 and 2019 were evaluated for bias using the Risk of Bias in Non-Randomised Studies of Interventions (ROBINS-I) tool. In addition the Harbour and Miller Grading System (2001) was used to assess the significance of the evidence in this review.

Results: All studies demonstrated a protective effect of sympathectomy against ventricular arrhythmias in both primary and secondary prevention strategies. The following risk of bias was observed: low in 5 studies, moderate in 8 studies, and serious risk in 4 studies. The highest level of evidence observed was 2++ in 3 studies.

Conclusion: Cardiac sympathetic denervation provides benefit for patients with ventricular arrhythmias, in cases of refractory disease or in patients who require a primary prevention strategy where first-line therapies are not tolerated.

Keywords: Video-assisted thoracoscopic (VATS) sympathectomy; Ventricular arrhythmia; Thoracoscopic sympathectomy; Left cardiac sympathetic denervation

Introduction

The term cardiac sympathectomy describes the approaches to interruption of the sympathetic nervous system at the level of the sympathetic chain [1] leading to cessation of pre-ganglionic signals and reduction in sympathetic tone [2]. This may prove useful in states such as Long QT Syndrome (LQTS) or cardiomyopathies, where sympathetic stimulation acts as potent stimulus for Ventricular Arrhythmia (VA). There are two primary proposed mechanisms of action: antiadrenergic and pro-vagal. Canine model studies have shown that left sympathectomy leads to antagonism of ischaemia-induced sympathetic activation [3]. The relationship of nerves in the cardiac Autonomic Nervous System (ANS) does not follow a strict left-right pattern (left ANS has a greater effect on the posterior and apical segments, and on the left ventricular wall), therefore targets for prevention of left ventricular fibrillation have historically been left-sided or bilateral, but rarely right-sided alone [3]. It is thought that the threshold for ventricular fibrillation is substantially lowered due to the net reduction in noradrenaline in the left ventricle [4]. Significant clinical and experimental data show that blunted stimulation from the vagus nerve leads to life-threatening arrhythmias [5,6]. The role

of sympathectomy in this regard is that sympathetic nerves further downstream of the sympathetic trunk have an inhibitory effect on the vagus nerve; therefore interruption at a higher level leads to increased vagal tone.

In addition, left-sided sympathectomy allows the heart to preserve some sympathetic function; the heart's pacemaker, the sino-atrial node, is innervated by the right-sided sympathetic system [5]. The preservation of the right may also prevent post denervation supersensitivity, which is a pro-arrhythmic condition [5,7].

The current standard technique is Left Cardiac Sympathetic Denervation (LCSD), which involves removal of the lower half of the stellate ganglion, along with T2-T4 thoracic ganglia [7], providing adequate denervation with significantly lower risk of Horner's syndrome [5].

A number of different approaches to the sympathetic trunk have been described. Open thoracotomy may be used, but this has mostly been superseded by Video Assisted Thoracoscopic Surgery (VATS) [8]. The VATS technique was first described for use in sympathectomy for ventricular arrhythmia in 2003 [9]. In this method, 2 or 3 small

incisions are made near the mid axillary line to gain access to the chest [8]. A camera is then passed through one of the incisions to visualise the operation. A supraclavicular approach may also be used, whereby a small incision is made just above the left clavicle. Platysma and sternocleidomastoid muscles are then transected and the subclavian vein, phrenic nerve and subclavian artery are all isolated and mobilised in sequence to expose the thoracic ganglia outside the pleura [10].

The mainstay of management of VA syndromes is beta-blockade and Implantable Cardioverter-Defibrillator (ICD) in many patients, however there remains a clear role for sympathectomy in patients who are unamenable or refractory to first line therapies. At present, the European guidelines advise that the use of CSD may be appropriate in the management of the following inherited arrhythmias only [11]: congenital Long QT Syndrome (LQTS) and Catecholaminergic Polymorphic Ventricular Tachycardia (CPVT). Thus, this excludes patients with structural heart disease who experience intractable VAs, such as patients with cardiomyopathies, or patients with more rare arrhythmias and structurally normal hearts, such as idiopathic ventricular arrhythmia.

With the expanding use of CSD for different etiologies of arrhythmia, the objective of this article was to systematically review the available literature for best level evidence and risk of bias therein regarding the utility of surgical cardiac sympathectomy (either left-sided or bilateral) in the management of VA of any cause.

Methods

The primary outcomes examined for this review were reduction in cardiac deaths and cardiac events. The search was limited to case series or higher level evidence. No language limits were imposed, due to the rare nature of the conditions treated by cardiac sympathetic denervation. In order to include contemporaneous studies while maintaining sufficient literature for a systematic review, studies from 2009 to 2019 were examined.

A detailed literature search was performed from July 2019 to October 2019 using the following scientific databases: PubMed, Scopus, Ovid and the Cochrane Library, in order to identify the potentially eligible studies. Titles and abstracts were screened for relevance using the MeSh terms "Video-Assisted Thoracoscopic (VATS) sympathectomy" and "ventricular arrhythmia" or "thoracoscopic sympathectomy" and "ventricular arrhythmia" or "left cardiac sympathetic denervation" and "ventricular arrhythmia".

Inclusion criteria were case series or higher-level evidence, studies from 2009-2019, case series studying >10 patients. Exclusion criteria were case reports, case series studying ≤10 patients, studies that did not report postoperative cardiac event rate, stellate ganglion blockade, review articles, sympathectomy for hyperhidrosis, sympathectomy for angina, or animal studies. Case series that included fewer than ten patients were excluded from the review, given the risk of bias due to small sample size and low event rate. Literature from conference proceedings was excluded due to risk of incomplete data.

The Risk of Bias in Non Randomised Studies of Interventions (ROBINS-I) tool was used to assess for risk of bias [12]. The Harbour and Miller Grading System, as shown in (Table 1), was used to assess the significance of evidence in this systematic review, which focuses on study design and methodological quality [13].

Results

The search yielded 1,146 results between the databases: 714 from PubMed, 417 from Scopus, and 15 from Embase, with no relevant articles found within the Cochrane Library (Figure 1). All of these results were screened in accordance to relevance to the clinical question and utilising the exclusion criteria. A total of 17 publications were found to be appropriate for inclusion. Of these publications, 1 was a systematic review [14], 1 was a meta-regression analysis of 14 studies [15], 6 were observational studies [8,16-20], and 9 were case series [8,21,22,24-29]. Given that sympathectomy is generally considered a last-line treatment, studies that address the procedure are overwhelmingly observational with no comparator. The only other treatment options for these patients are Thoracic Epidural Anaesthesia (TEA), or Stellate Ganglion Blockade (SGB) by percutaneous injection of local anaesthetic. However these may be considered temporary measures, they have not been evaluated in the literature to the same extent as the surgical option [7], and no studies could be found comparing sympathectomy with SGB. One cohort study in the literature compared TEA with left CSD [21] and this was analysed as part of the review.

The baseline characteristics and outcomes of interest in the included studies are outlined in (Table 1). Of the 17 studies reviewed, 9 examined outcomes of CSD for inherited arrhythmia syndromes, 6 dealt with patients with structural heart disease, and 2 included patients from both cohorts. Post-operative ventricular arrhythmias were examined either in terms of symptoms (breakthrough cardiac events BCEs) or post-operative ICD discharges. All studies reported resolution of arrhythmia in a significant proportion of individuals,

Table 1: Harbour and Miller Grading System.

Level of Evidence	Descriptor
1++	High quality meta-analyses, systematic reviews of RCTs, or RCTs with a very low risk of bias
1+	Well conducted meta-analyses, systematic reviews of RCTs, or RCTs with a low risk of bias
1-	Meta-analyses, systematic reviews of RCTs, or RCTs with a high risk of bias
2++	High quality systematic reviews of case-control or cohort studies or High quality case control or cohort studies with a very low risk of confounding, bias, or chance and a high probability that the relationship is causal
2+	Well conducted case-control or cohort studies with a low risk of confounding, bias or chance with a moderate probability that the relationship is causal
2-	Case-control or cohort studies with a high risk of confounding, bias or chance and a significant risk the relationship is not causal
3	Non-analytic studies
4	Expert opinion

Table 2: Baseline characteristics and outcomes of interest in selected studies.

Author	Year of Study	Study Design	No. Data Subjects	VA Aetiology	Outcomes	Results	Follow Up
Sgrò et al [15].	2019	Meta-regression	647	LQTS	Post-operative BCEs	68% freedom from BCEs	32.3+/-32.5 months
				CPVT	Change in QTC Outcomes of VATS vs open	QTc reduction from 522+/-61.6ms to 494+/-52.3ms No difference between VATS and open in terms of post-op BCE and complications	
Shah et al [14].	2019	Systematic review	173	SHD	Freedom from cardiac events	Variable 1 year event-free survival: 58% -100%	N/A
						Hypotension 9%, pneumothorax 5%, neuropathic pain 4%, Horner Syndrome 3%, abnormal sweating 3%	
Téllez et al [29].	2019	Case series	20	SHD	Reduction in ICD shock burden	90% reduction in shock burden in the first 3 months	1-9 months
					Resolution of electrical storm	80% patients showed total symptoms resolution of during the study period	3 year study period
					Freedom from cardiac events	100% resolution of electrical storms	
						No reported major complications, pneumothorax in 5%	
Haranal et al [24].	2018	Case series	12	Symptomatic VAs of all causes	Resolution of symptoms	No post-op BCEs	Mean 4.8+/-0.96 years
						No perioperative surgical complications	
Vaseghi et al [18].	2017	Case-control	121	SHD	Event-free survival	58.2% freedom from VA in 1 year	Mean 1.5 +/- 1.4 years
					Burden of ICD shocks	76.1% freedom from death or OHT in 1 year 88% reduction in shock burden	
					Characteristics associated with VA recurrence	Advanced NYHA class, longer VT cycle lengths, and left-sided only procedure associated with poorer outcomes	
						No reported complications	
Jang et al [26].	2017	Case series	15	Inherited arrhythmia	Post op BCE	86% no BCE	Mean 927 +/- 350 days
					Event rate/year pre and post op	Event rate reduction from 0.97/year to 0.19/year	
						No reported complications	
Antiel et al [19].	2016	Quality of life	62	Any aetiology	Pre and post operative number of ICD shocks per patient (mean +/-SD)	Pre-op shocks: 16.4+/-32.1	N/A (single time-point)
					Incidence of pot-operative side effects (mean +/-SD)	Post-op shocks:	
					Correlation between side-effects and worse quality of life	2.4+/-5.6	
						4.1+/-1.8	
						No significant correlation	
Waddell-Smith et al [20].	2015	Quality of life study	47	LQTS	Post-op BCEs	89% patients with no BCEs during follow-up	Median 29 months (range1-67 months)
				CPVT	Change in QTc	No significant difference in pre and post-op QTc	
					Physical and psychological complications of LCSD	Most common complications: Dry skin (67%), unilateral facial flushing (63%), hyperhidrosis (56%)	
						79% post-op satisfaction	
Roston et al [28].	2015	Case series	18	CPVT	General outcomes of LCSD	83% Asymptomatic at latest follow-up	Not specified
						17% lost to follow-up	
						Complications reported in 16%: transient Horner syndrome in 11%, haemothorax in 5%	
DeFerrari et al [23].	2015	Case series	63	CPVT	Post-op BCE	76% no BCE	Median 37 months
						24% ≥1 BCE	
						65% reduction in BCEs post op	
						93% reduction in ICD shocks/person/year	
						No reported complications of LCSD	

Vaseghi et al [17].	2014	Cohort study	41	SHD	Event-free survival	41% mortality during study period	Mean 367 +/- 251 days
					Burden of ICD shocks	30% ICD shock-free at last follow-up	
					Comparison of left CSD versus bilateral	89% reduction in ICD shock burden	
						Outcomes for bilateral group significantly better than LCSD group	
						Haemothorax in 5% pneumothorax in 2%, transient ptosis in 5%, persistent ptosis in 2%, hypotension in 2%, abnormal sweating in 10%, altered skin sensitivity in 12%	
Nordkamp et al [27].	2014	Case series	17	Inherited arrhythmia	Pre- and post-op BCE	87% reduction in event rate	Median 34 (IQR 16-77) months
					Surgical outcomes	Decrease in median cardiac events from 5 to 0	
						47% of symptomatic patients remained event-free post op	
						Major non-reversible complications in 12%: 1 mortality and 1 irreversible Harlequin facial flushing	
						Minor complications in 24%: pneumothorax (18%), transient Horner's syndrome in 6%	
Hofferberth et al [25].	2014	Case series	24	LQTS	Change in QTc interval	58% no BCE	Median 28 months
				CPVT	Post op BCE	8% lost to follow-up	
				IVT		Pneumothorax in 13%, temporary unilateral facial flushing in 4%	
Bos et al [16].	2013	Case-control	52	LQTS	BCE Event-free survival	77% no BCE 23% ≥1 BCE	Mean 3.6 +/- 1.3 years
					Complications	10% non- responders Transient ptosis 8%, pneumothorax 6%	
Coleman et al [22].	2012	Case series	27	Non-LQTS	Post op BCE Event- free survival	85% no BCE 15% ≥1 BCE	Median 1.2 years
					Complications	No long-term. Horner Syndrome 11%, pneumothorax 11%, conversion to open 4%	
Bourke et al [21].	2010	Cohort Study	14	SHD	2 groups: TEA and LCSD	TEA group (n=8): 62.5% survival at follow-up	Median 6.2+/- 4.6 months (range 1.5-15 months)
					Post procedural survival TEA vs LCSD	75% showed significant reduction in arrhythmia burden	
					Post procedural ICD shock TEA vs LCSD	LCSD group (n=9):	
					Complications	78% survival at follow up	
						56% complete/partial response	
						21% cross-over from TEA to LCSD	
						TEA: catheter infection 12%	
						LCSD: Horner's syndrome 11%, pneumothorax 11%, facial anhydrosis 11%	
Collura et al [8].	2009	Case Series	20	LQTS	Post-op BCE in primary prevention group (n=9)	No post-op BCEs in 9/9 patients	Mean 16.6+/-9.5 months
				CPVT	Post-op ICD shocks/ACAs in secondary prevention group (n=11)	No ACA/shocks in 8/11 patients	
						No major complications reported	
ICD implantable cardioverter-defibrillator, SD standard deviation, BCE breakthrough cardiac events, LQTS long QT syndrome, CPVT catecholaminergic, polymorphic ventricular tachycardia, SHD structural heart disease, ACA aborted cardiac arrest, IVT idiopathic ventricular tachycardia, IQR interquartile range, LCSD left cardiac sympathetic denervation, TEA thoracic epidural anaesthesia, VA ventricular arrhythmia, NYHA New York Heart association, OHT orthotopic heart transplant							

and an overall reduction in event-rate in the patients who remained symptomatic post-operatively. Reporting of complications varied between studies, however, the most commonly reported complications across all studies were pneumothorax (5-18%), Horner Syndrome (3-11%), and unilateral facial flushing (Harlequin syndrome) (3-63%). The two studies which focused on quality of life [19,20] reported much higher complication rates than the rest of the studies included in this review, however this was not linked with worse quality of life or dissatisfaction with the procedure. There was markedly variable follow-up observed amongst the studies, although the vast majority followed patients for >1 year on average, with the exception of one study by Téllez et al [29].

The risk of bias and overall level of evidence for included studies are outlined in (Tables 2 and 3). The majority of studies reviewed were at low or moderate risk of bias, assessed by the ROBINS-I tool. Studies were considered at serious risk of bias if serious risk was observed in >1 domain, or if serious risk was observed in 1 domain and moderate risk observed in >2 domains. With the exception of one case-control study [20], there was an at-least moderate risk of bias of confounding across all studies, due to the lack of formal control groups, the inclusion of asymptomatic patients within the patient cohort, or low patient numbers. Patients across all studies were selected based on physician assessment, and the lack of RCTs in the review meant that all studies demonstrated moderate selection
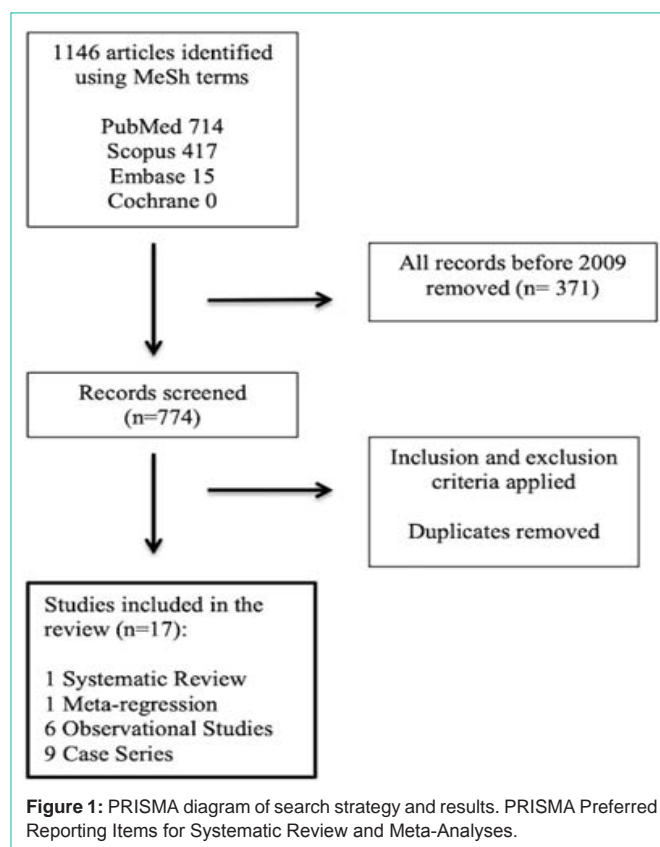
Table 3: Categorisation of risk of bias in included studies. S: serious risk of bias, M: moderate risk of bias, L: low risk of bias.

Author	Bias due to Confounding	Bias due to Selection of Participants	Bias in Classification of Intervention	Bias due to Missing Data	Bias in Outcome Measurement	Bias in Selection of Reported Result
Sgrò et al. [15]	M	N/A	N/A	N/A	L	L
Shah et al. [14]	M	N/A	N/A	N/A	L	M
Téllez et al. [29]	S	M	L	M	L	L
Haranal et al. [24]	S	M	L	L	M	L
Vaseghi et al. [18]	L	M	L	L	L	L
Jang et al. [26]	S	S	L	L	L	L
Antiel et al. [19]	M	M	L	M	L	L
Waddell-Smith et al. [20]	M	M	L	L	L	L
Roston et al. [28]	M	M	L	L	L	L
DeFerrari et al. [23]	M	M	L	L	L	L
Vaseghi et al. [17]	M	M	L	L	L	L
Nordkamp et al. [27]	M	M	L	L	M	M
Hofferberth et al. [25]	S	M	L	L	L	L
Bos et al. [16]	S	M	L	L	L	L
Coleman et al. [22]	M	M	L	L	L	L
Bourke et al. [21]	M	M	M	L	L	L
Collura et al. [8]	S	M	L	M	L	L

Table 4: Overall risk of bias and level of evidence for included studies.

First Author	Overall Risk of Bias	Class Evidence
Sgrò [15]	Low	2++
Shah [14]	Moderate	2+
Téllez [29]	Serious	3
Haranal [24]	Serious	3
Vaseghi 2017 [18]	Low	2++
Jang [26]	Serious	3
Antiel [19]	Low	2-
Waddell-Smith [20]	Low	2+
Roston [28]	Moderate	2-
DeFerrari [23]	Low	2++
Vaseghi 2014 [17]	Moderate	2-
Nordkamp [27]	Moderate	3
Hofferberth [25]	Moderate	3
Bos [16]	Moderate	3
Coleman [22]	Moderate	3
Bourke [21]	Moderate	2-
Collura [8]	Serious	3

Figure 1: PRISMA diagram of search strategy and results. PRISMA Preferred Reporting Items for Systematic Review and Meta-Analyses.

bias, with high risk of selection bias in the case series by Jang et al [26]. This was due to the selection of patients based on post-operative epinephrine testing, a characteristic observed after the start of the intervention. One cohort study by Bourke et al. [21] was deemed to have a moderate risk of bias in classification of intervention as 3 patients in the TEA arm subsequently underwent left CSD, which would not have been defined at the start of intervention. The majority of the studies showed a low risk of bias due to missing data, with the exception of three: Antiel et al. [19], with a 61% survey response rate,

Collura et al. [8], in which 10% of patients (n=2) had significantly shorter follow-up than the rest of the cohort, and Téllez et al. [29], in which one patient was followed for 1 week post-operatively, but given the small size of the cohort this meant that 5% of the follow-up data

were missing. Overall risk of bias was found to be low in five studies [15,18-20,23], moderate in eight studies [14,16,17,21,22,25,27,28], and serious in four studies [8,24,26,29]. The highest observed level of evidence in the literature examined was 2++ by the Harbour and Miller system: systematic reviews or case-control or cohort series, where there is a high probability that the relationship observed is causal. Eight of the studies were case series, and thus classed as level evidence level 3.

Discussion

Quality of Evidence

At last review, the only placebo-controlled trial that examined CSD was performed in 1992 [31], whereby beta-blockade or CSD was administered to high-risk patients post myocardial infarction (MI), and compared to beta-blockade or placebo in low-risk patients. While there are 2 randomised studies of CSD underway currently, both compare CSD alone to CSD and optimal medical treatment and neither have had results published at last review. Thus, patient data examined for this review were based on observational studies only.

Patients across all studies were referred for denervation due to failure, intolerance or non-adherence to first-line therapies. This demonstrates the limited feasibility of randomised control trials in this setting: in the first instance, superiority or non-inferiority trials would not apply to a last-line therapy. Secondly, there would be compelling ethical issues surrounding the randomisation of patients to an arm with no treatment in the absence of other options.

Stellate ganglion blockade, as mentioned above, has also been used to manage patients with intractable VA, but the desired outcome of SGB is to manage patients in the acute phase of ventricular arrhythmia, and the patient is no longer protected once the anaesthetic agent had been metabolised. Thoracic epidural anaesthesia utilises injection or infusion of the T1- T5 nerve roots with local anaesthetic agents, thereby blocking stimulation from the sympathetic chain [32] but has not been evaluated in the literature to the extent of CSD. Apart from the study by Bourke et al. mentioned in this paper [21], its appearance in the literature is limited to one case report [33], animal studies [34,35] and review articles such as Dusi, Zhu and Ajijola, 2019 [32]. This treatment modality is also considered a temporary measure in contrast to the definitive strategy of CSD. Accordingly, suitable controls are scarce in medical practice, and this explains the use of case-control studies to assess the efficacy of the procedure. Equally, trials for diseases considered rare (less than 1/2000 patients, such as LQTS and CPVT) are less likely to be randomised or double-blinded, with fewer active comparators, and predictably, fewer patients enrolled [30]. Thus, with diminishing feasibility of RCTs, investigation of CSD for ventricular arrhythmias may always be limited to observational studies.

The only studies with prospectively collected data on review of the literature were those that examined QoL and satisfaction with surgery, and were not focused on the actual success of the procedure in terms of arrhythmia control. Ten of the studies examined utilised some form of comparator group, but this mostly referred to pre- and post-operative status. The study by Bourke et al. [21] was the only study in the review for which the comparator group was a different treatment modality. Regression models were used in three studies only, to account for confounding variables. Interestingly, the study by Vaseghi et al. [17] that compared LCSD to Bilateral Cardiac Sympathetic Denervation (BCSD) did not use propensity matching or regression models, which may have been due to the low numbers in each arm of the study group. Selection bias was noted in this study, and this may have led to overestimation of difference in outcomes between BCSD and LCSD. It is possible to evaluate CSD effectively utilising well-designed observational studies, and some of the publications in this review fulfil this criteria. Consistent reporting of positive outcomes gives some generalizability to the less rigorous studies, but case series cannot be used in isolation to assess CSD.

Indication for CSD

Etiology/LCSD vs. BCSD: Studies of reasonably high evidence level (2+) demonstrated a clinical benefit of CSD in both structural heart disease and inherited arrhythmias, but overall, there was a bigger evidence base, due to the presence of larger and more rigorous studies, in the congenital population. One case-control study by Vaseghi et al [18]. reported worse outcomes for patients with symptomatic VA who underwent left-sided denervation over bilateral. However, this result is somewhat confounded by the fact that VT cycle length was significantly longer in the left-sided group, which was found to be an independent predictor of recurrence itself. Despite the limitations of the evidence, the data reviewed demonstrated survival benefit, as well as reduction or resolution of symptomatic VA in patients with LQTS and CPVT across all relevant studies. This could be a justification for the re-classification of CSD in this context from class II to class I evidence in the next iteration of the European Guidelines, which would be in keeping with the guidelines issued by the American Heart Association (AHA) [35].

For patients with symptomatic VA and structural heart disease, an improvement in survival and VA recurrence was also observed, though not to the same extent as the congenital population due to a much poorer baseline. There may be an additional benefit of bilateral denervation in patients with symptomatic VA and structural heart disease only, although more data is needed on this matter.

Primary Prevention

There were six studies examined for this systematic review that analysed outcomes of symptomatic patients only. Asymptomatic patients who underwent CSD as a primary prevention strategy were included in all other studies in small numbers, apart from the review by Bos et al. [16], in which 61% of the patients studied were asymptomatic, and none experienced symptoms during the 3.6 year follow-up period. One critique of the inclusion of asymptomatic patients is that the follow-up period required to detect symptoms becomes unclear. Nonetheless, in all studies where CSD was used for primary prevention, apart from Hofferberth et al. [25] (one asymptomatic patient experienced postoperative cardiac events), and the studies examining QoL (outcomes for primary prevention not discussed separately in either paper), all patients remained asymptomatic for the duration of follow-up. Though follow-up duration was varied, the studies by Jang et al. [26], De Ferrari et al. [23], Roston et al. [28], and Bos et al. [16] all followed patients for over 2 years. In summary, consistency in positive outcomes was seen across the studies reviewed regarding the use CSD in asymptomatic patients with inherited arrhythmias, therefore it would be reasonable

to consider CSD as a primary prevention strategy in this patient population.

Assessment of Complications

Acute complications were discussed in most of the literature reviewed, with the exception of two studies, possibly due to the variation in surgical technique and length of study duration seen in these studies. The rest of the publications reported similar low rates of pneumothorax, haemothorax and transient ptosis or Horner's syndrome. One study [22] described one case of conversion to open thoracotomy. This may have been an outlier in a small study group, but a 4% conversion to open thoracotomy is higher than described in other sympathectomy studies [4] and adds undesired morbidity to the procedure.

There was greater inconsistency in the reporting of chronic sequelae, and many of the studies reported no lasting complications. However, Vaseghi et al. [17] reported persistent abnormal sweating in 9.7% and skin sensitivity in 12.3% of patients who underwent BCSD. Jang et al. [16] reported abnormal sweating in all patients at follow-up, and the two studies that focused on chronic complications, Antiel et al. [19] and Waddell-Smith et al. [20] reported that almost all patients had persistent changes, such as abnormal sweating, dry skin, shoulder tip pain, or unilateral temperature changes, and permanent ptosis. Both of these studies found that, despite a high rate of minor postoperative complications, patients tended to be satisfied with the outcome across both adult and pediatric populations. Overall, the data demonstrated inconsistent reporting of chronic complications, with a rate of persistent postoperative symptoms that may be significantly higher than some studies have reported. More evidence is needed in this regard, and would be useful for patient counseling in the preoperative period.

Surgical Technique

All but two studies [14,28] described the surgical technique used for sympathectomy, with VATS featuring as the main approach to the thorax. None of the studies included patients who had undergone the procedure using Robotic Assisted Thoracic Surgery (RATS) as the approach to the chest. Two studies [23,27] included patients who underwent a supraclavicular approach to the thorax. Four studies [14,17,18,29] included patients who underwent bilateral sympathectomy. Where described, the studies assessed for this article used a VATS 3 port technique to remove the lower half of the stellate ganglion, along with roots of T2 to T4. Of the patients who underwent a VATS procedure, the majority underwent single lung ventilation. One study [8] used bronchial blockade for their ventilation strategy. The majority of the studies described histological confirmation of the specimen intraoperatively. One study only [18] utilised chest drains in the perioperative period.

Conclusion

Cardiac sympathetic denervation was found to provide benefit for patients with ventricular arrhythmias and either structural heart disease or inherited arrhythmia syndromes, in cases of refractory disease or in patients who require a primary prevention strategy where first-line therapies are not tolerated. The evidence for this is entirely observational, however the risk of bias observed was largely moderate or low.

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