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# The role of antiarrhythmic drugs and stellate ganglion block in the acute management of electrical storm

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**KEYWORDS**
Electrical storm; Ventricular arrhythmias; Antiarrhythmic drugs; Percutaneous left stellate ganglion block; Neuromodulation

Electrical storm (ES) is a life-threatening condition characterized by at least three separate episodes of ventricular arrhythmia (VAs) over 24 h, each one requiring intervention. Early recognition and prompt treatment are crucial to improving outcomes. In addition to identifying and correcting potential reversible causes, performing acute cardiac life support if required, and interrogating/reprogramming the implantable cardioverter defibrillator in present, the acute management of ES (within 12–24 h upon presentation) nowadays mostly relies on antiarrhythmic drugs and percutaneous left ganglion sympathetic block (PLSGB), that will be the focus of the present review. The choice of the drug should consider several factors, including the aetiology and mechanism of VAs, the underlying cardiac function, and the potential risk of adverse events. Intravenous amiodarone, the most used and recommended drug in the setting of high burden VAs and structural heart disorders, mostly exerts dose and rate infusion dependent antiadrenergic effects in the first hours, and may lead to severe hypotension. PLSGB has an excellent safety-efficacy profile and can be easily performed by trained cardiologists at bedside.

## Definition

Electrical storm (ES) traditionally refers to a potentially life-threatening condition characterized by multiple (at least three) episodes of ventricular tachycardia (VT storm) or ventricular fibrillation (VF storm) occurring within 24 h and each one requiring a therapeutic intervention. Incessant VTs lasting for more than 12 h are also included in the definition of ES. The importance and the widespread usage of this definition stem from early landmark studies among implantable cardioverter defibrillator (ICD) recipients with structural heart disease (SHD), showing a 2–5-fold increase in mortality, heart transplants, and hospitalisations for heart failure (HF) associated with ES.[1] Recent data point out that even more scattered combinations of ventricular arrhythmia (VA), including two episodes within 3 months, still carry significant prognostic implications.[2]

## Pathophysiology

The likelihood of experiencing an ES is influenced by a complex interplay of:

- A vulnerable electrophysiological substrate, typically characterized by either an inherited channelopathy or by a macroscopic or microscopic myocardial scarring/disarray among patients with acquired or congenital SHD. In the latter group a functional hit due to ion channel remodelling, is often associated with the anatomical one, leading to complex re-entrant circuits.

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- Precipitating factors or triggers (seldomly identified), such as acute myocardial ischaemia, acute decompensated HF, ongoing infections, endocrine emergencies, electrolyte imbalances, and non-adherence to or toxicity of antiarrhythmic drugs (AADs).
- Modulating factors, most notably autonomic imbalance, represented by a various combination of sympathetic hyperactivity and vagal withdrawal, typically characterizing all types of SHD and HF patients. In the setting of high-level sympathetic activation, additional co-transmitters other than noradrenaline are co-released from sympathetic post-ganglionic efferent fibres, including ATP, galanin, and neuropeptide Y (NPY). Adrenaline, noradrenaline and NPY all contribute to the considerable proarrhythmic potential of sympathetic activation at the ventricular level, leading to an increase in cytoplasmic calcium levels through different pathways (B1 and B2 adrenergic receptors for catecholamines and Y1 receptors for NPY). Additionally, both catecholamines (through alpha-1 adrenergic receptors) and NPY (through Y1 and Y5 receptors) exert a powerful vasoconstrictor effect at the coronary level.[3] Finally, neuronal sympathetic activation has an additional proarrhythmic potential compared with adrenal sympathetic activation due to the heterogeneous spatial distribution of cardiac sympathetic fibres, that is even more pronounced in SHD due to a dynamic and progressive neuronal remodelling process.

## Clinical presentation, first evaluation, and acute management

ES may present with diverse symptoms based on myocardial function, VAs characteristics and the presence of an ICD. Patients may experience severe issues like syncope or cardiac arrest, or milder symptoms such as palpitations. In those with ICDs, effective device programming with antitachycardia pacing can even lead to an asymptomatic presentation, while frequent shocks may worsen heart function. Initial assessment should include hemodynamic evaluation and identification of reversible causes. Risk stratification focuses on the arrhythmia's impact on hemodynamic status and existing comorbidities, with high-risk patients referred to critical care. Among ICD recipients, ICD interrogation to confirm the appropriateness of the previous interventions, assess arrhythmia characteristics (onset and termination modalities, duration, cycle, morphology) and reprogramming the device to avoid further inappropriate/unnecessary therapies, particularly shocks, is crucial. From a therapeutic point of view, in addition to identifying and correcting potential reversible causes and performing acute cardiac life support if required, the acute management of ES (within 12–24 h upon presentation) nowadays mostly relies on AADs and acute neuronal sympathetic block strategies, that will be the focus of the present review. Monomorphic VT is the most common presenting rhythm within an ES (75–80% of cases).

## Antiarrhythmic drugs

AADs play a pivotal role in ES management, despite a definitive impact on mortality remaining unsubstantiated. The choice of the drug should consider several factors, including the aetiology and mechanism of VAs, the underlying cardiac function, and the potential risk of adverse events, including proarrhythmic ones. This kind of pathophysiological approach to AAD choice, as opposed to the empirical one, has been promoted since 1991 by the so-called Sicilian Gambit,[4] an international consensus document on AAD usage written by a dedicated Task Force and based on a comprehensive understanding of the pharmacology of each molecule, combined to the attempt to unravel and target the most vulnerable parameters of the ongoing arrhythmia. Discussion of all AADs is beyond the scope of the present work; only the most used in the acute setting outside channelopathies will be highlighted. *Figure 1* summarizes the molecular targets of the presented AADs, as well as those indirectly affected by percutaneous neuronal sympathetic blockade.

### Beta blockers

Beta blockers (BBs) are strong competitive antagonists of adrenergic receptors. As such, they should constitute the first-line pharmacological approach to most cases of ES, with the exception of VAs occurring in the setting of J-wave syndromes that are typically favoured by vagal activation and require isoproterenol. Non-selective BBs such as propranolol or nadolol should be preferred over selective ones according to both 2022 European Guidelines[5] and 2024 EHRA Consensus on VAs[6] to maximize pharmacological adrenergic blockade. Indeed, the physiological cardiac B1:B2 adrenergic receptor ratio of 3:1 decreases in SHD due to B1 down-regulation in favour of B2. Additionally, B2 adrenergic receptor blockade in the skeletal muscle, liver, and kidney blunts sympathetically induced hypokalaemia. In addition to cardiogenic shock (SCAI level $\geq$ C), where all BBs should be considered with extreme caution, the only true contraindication to non-selective BBs is severe primary or secondary asthma. Propranolol offers additional advantages over nadolol due to its short half-life [making it safer for patients with advanced left ventricular (LV) dysfunction/impending shock], its hepatic metabolism (in case of renal failure), the lipophilic properties (conferring central adrenergic blocking properties) and the mild sodium channel blocking properties. Accordingly, a Greek randomized study[7] including 60 ICD carriers presenting with ES and severe LV dysfunction but stable hemodynamics (SCAI A), showed that short-acting oral propranolol (40 mg every 6 h) was significantly better in preventing VAs recurrences than short-acting oral metoprolol (50 mg every 6 h), both associated with i.v. amiodarone (loading dose 300 mg in 10 min, than 1000 mg/die for 48 h). Still, 35% of patients in the propranolol group experienced recurrences in the first 6 h, underlying the need of additional, faster treatments. Notably, i.v. propranolol is no longer available in several European countries, limiting the i.v. BBs to the cardio-selective metoprolol, esmolol, and landiolol (showing an increasing B1 to B2 selectivity ratio of 3, 33, and 255, respectively). Intravenous metoprolol has a rapid peak plasma time (5–15 min), but a relatively long elimination half-life (median 3–4 h). Esmolol and landiolol are particularly useful in case of initial hemodynamic compromise thanks to their short elimination half-life (approximately 9 and 3–4 min, respectively).

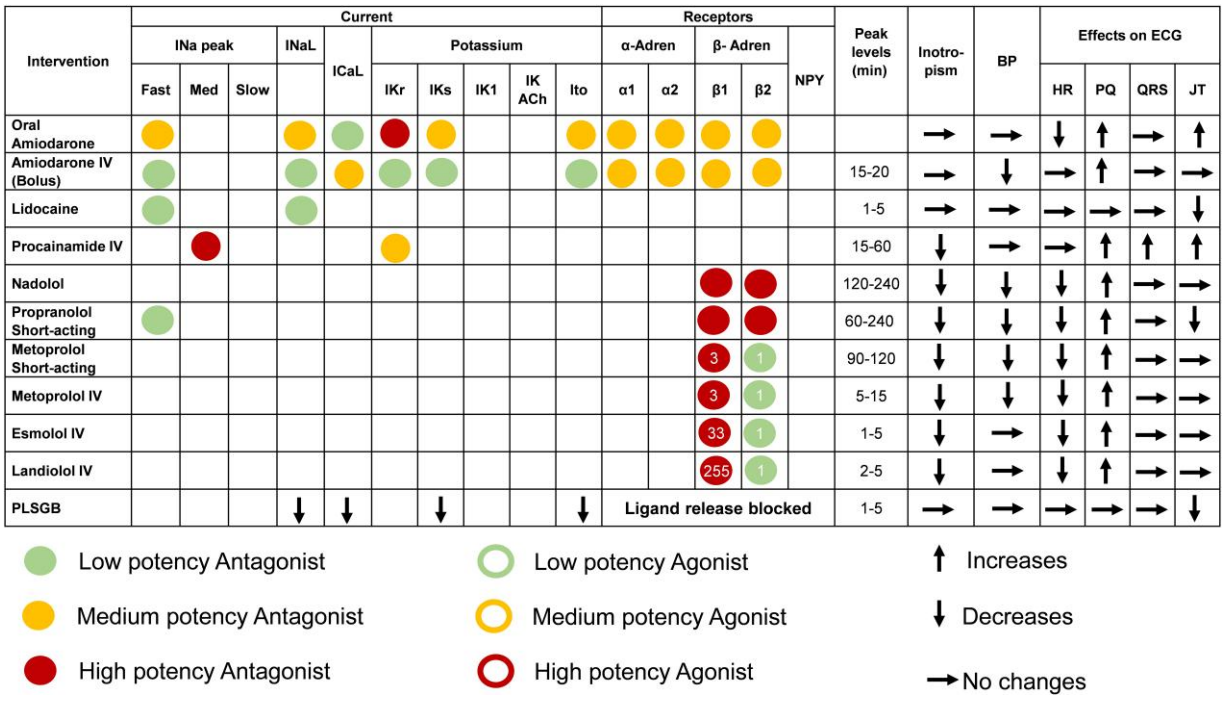


**Figure 1** Main electrophysiological, clinical, and electrocardiographic effects of the antiarrhythmic drugs most used for the acute management of refractory VAs. BP, blood pressure; HR, heart rate.

## Amiodarone

Oral amiodarone at steady state, together with its major, active hepatic metabolite *n*-desethylamiodarone (DEA), has multi-channel blocking properties that encompasses all four of Vaugan-Williams conventional classes, with Ikr blockade (Class III effect) being the most powerful one. Notably, i.v. amiodarone acutely administered has significantly different relative blocking properties towards most of the molecular targets compared with the oral formulation at steady state. Indeed, i.v. amiodarone mostly acts as a modest (still stronger than the oral counterpart) but faster non-competitive beta- and alpha-adrenergic receptor blockade and has more pronounced AH interval slowing properties, while potassium and sodium channel blocking properties are quite low, as well as the slowing of Phase 4 depolarisation in the sinus node.[8] The main hypothesis for this observed difference is that the manifestation of amiodarone's chronic electrophysiological effects requires prolonged administration. This extended exposure enhances tissue penetration of both the drug itself and DEA (that has a much stronger class III effect). Intravenous amiodarone may also cause acute hypotension, which is mostly attributed to the solvent commonly used in its pharmaceutical formulations, polysorbate 80. In case of bolus administration, the package leaflet indicates a maximum of 5 mg/kg over at least three minutes; the faster the infusion rate, the higher the probability of interrupting an ongoing VA, but the greater the hypotensive effect. Indeed, depending on the dose and rate of infusion, the time to onset of action after i.v. bolus may vary between 1 and 30 min (peak 15–20 min). Accordingly, small heterogeneous observational studies from the 1980s and 90s performed using a bolus of 5 mg/Kg administered in 5–15 min indicated an acute cardioversion rate between 63% and 80%.[8] On the other side, the recent (2017), randomized PROCAMIO study[9] that compared 1:1 i.v. bolus of amiodarone (5 mg/kg/20 min) vs. procainamide (10 mg/kg/20 min) for hemodynamically tolerated wide QRS tachycardias in 62 patients with an average LVEF of 40% (79% with SHD, 48% with coronary artery disease, mean presenting VT rate 178 b.p.m.), demonstrated a cardioversion rate at 40 min of 38% vs. 67% respectively ($P = 0.03$), associated with a higher incidence of major cardiac adverse events (41% vs. 9%, almost all represented by severe hypotension). The higher incidence of severe hypotension with amiodarone was confirmed in the SHD sub-group, in which, however, the difference in efficacy was not significant, albeit with a trend in favour of procainamide. Finally, in the late 1990s three randomized studies with similar population characteristics (LVEF 30%, most with acute or chronic coronary artery disease) assessed the efficacy of different doses of amiodarone (bolus plus continuous infusion) in preventing hemodynamically unstable VAs refractory to lidocaine, procainamide and in 2 studies also bretylium, at 24 h.[8] Survival free from VAs at 24 h with 1000 mg/24 h continuous infusion was around 40%, and efficacy results with 2000mg/24 h were not significantly better. Of note, there was no dose-related increase in drug-induced hypotension during continuous infusion. Overall, there are no recent studies supporting a specific amiodarone i.v. dosage in the acute setting for ES. Both the latest 2022 European Guidelines[5] and 2024 EHRA Consensus on VAs[6] strongly recommend (Class I) the usage of amiodarone, together with BBs and mild sedation, for patients

presenting with monomorphic VT storm and a high arrhythmic burden, with a loading dose of 5 mg/kg in 20 min–2 h, repeatable for a maximum of 2–3 times/24 h, followed by 600–1200 mg/die i.v. continuous infusion. Of note, the conventional recommended scheme in case of ACLS[10] is a rapid bolus (3–5 min) of 300 mg (i.v. or i.o.), with a repeated dose of 150 mg, possibly followed by a continuous infusion of 1 mg/min for 6 h and then 0.5 mg/min for 18 h (1000 mg/24 h). Overall, unless BP is prohibitive, it would seem reasonable also in the setting of ES to prefer a quick (5–10 min) i.v. bolus of 300 mg of amiodarone. The possibility of using 5 mg/Kg for patients weighing more than 80 Kg should also be considered. Notably, since amiodarone i.v. and oral effects are not the same, combining i.v. and oral loading may shorten the time to VAs control. Also, for the same reason, patients already on chronic amiodarone therapy may benefit from acute amiodarone bolus, which mostly acts as a non-competitive antiadrenergic intervention complementary to BBs. Finally, the possibility of regularly using amiodarone and DEA plasmatic dosages to monitor chronic amiodarone exposure and the potential need for adjustment of the oral dosage is still a matter of debate due to previous inconsistent associations with efficacy, but might be considered.

## Lidocaine

Due to its larger binding affinity for inactivated fast sodium channels (prevalent in the setting of partially depolarized cardiomyocytes) compared with resting channels, lidocaine, a Vaughan Williams Class Ib AAD, finds a specific application for VAs complicating acute myocardial ischaemia. Although its efficacy is mostly modest outside this condition, its rapid onset (45–90 s) and offset (half-life 8–15 min) of action after a bolus and the trivial negative inotropic effect, allow its efficacy to be evaluated in various forms of VAs. Back in 1996,[11] a randomized trial compared 1:1 i.v. procainamide 10 mg/kg at 100 mg/min with i.v. lidocaine 1.5 mg/kg in 2 min, among 29 patients with SHD (mean LVEF 30%, 79% with previous old MI, mean presenting VT rate 158 b.p.m.). Acute VT termination rate was 19% with lidocaine compared with 79% with procainamide ($P < 0.001$), confirmed after cross-over in non-responders. The suggested lidocaine dosages are 1–1.5 mg/Kg for the bolus (repeatable up to a total of 3 mg/Kg) and 1–4 mg/min for the continuous infusion (~20–50 μg/kg/min). The main safety issue with the drug is represented by the dose and time-dependent onset of neurological side effects (delirium, psychosis, epileptic seizures, and tinnitus), that may typically start to develop after 24 h of continuous infusion and/or for infusion rates larger than 30 μg/kg/min. Due to the large (90%) hepatic metabolism, lidocaine is safe even in case of severe renal impairment, although hyperkalemia may increase sodium channel block sensitivity at the central as well as cardiac level and mandates caution. In case of efficacy and to prevent acute neurological side effects, lidocaine might be quickly imbricated with the oral Ib agent mexiletine (150–300 mg every 8–12 h), that shares its very good cardiac safety profile. Finally, another specific application of lidocaine (as well as mexiletine) is for the treatment/prevention of bradycardia-related polymorphic VT in the setting of congenital or acquired long QT syndrome. Indeed, due to the late sodium channel (INaL) blocking properties and depending on how much INaL is pathologically enhanced, Vaughan Williams Class Ib AADs may significantly reduce ventricular action potential duration, QT interval and EAD associated arrhythmias.

## Procainamide

Procainamide, a drug not yet easily available in several European countries, is a potent sodium channel inhibitor with high affinity for the open state of the channel and intermediate dissociation kinetics (Vaughan Williams Class Ia); its main hepatic metabolite, *n*-acetylprocainamide, whose production has high interindividual variability, exhibits moderate IKr- blocking effects. As such, the drug can lead to significant prolongation of the PQ interval, QRS and QT interval, and strict ECG monitoring is mandatory. Further caution is warranted due to its negative inotropic effect. Intravenous procainamide onset of action time is between 10 and 30 min, with peak effect at 15–60 min, and an elimination half-life of 3–5 h. As already mentioned, in two separate head-to-head randomized comparisons, i.v. procainamide bolus of 10 mg/kg showed a significantly higher and quite consistent (>65%) acute cardioversion rate of hemodynamically tolerated sustained monomorphic VT compared with both i.v. amiodarone[9] and lidocaine bolus.[11] Furthermore, a 2010 non-randomized Japanese study[12] including a total of 90 patients supported a greater efficacy of procainamide compared with lidocaine (76% vs. 35%) even in patients with hemodynamically tolerated monomorphic VT and SHD of mostly non-ischaemic aetiology (mean LVEF 48%, 24% only with previous MI, mean VT rate 183 b.p.m.). The initial bolus was 100 mg in 1–2 min for procainamide and 50 mg for lidocaine, and both could be repeated until VT termination and/or a maximum overall dosage of 800 mg for procainamide and 150 mg for lidocaine; the mean administered dosages were $358 \pm 50$ mg for procainamide and $81 \pm 30$ mg for lidocaine. Notably, the authors calculated similar success rates (80% for procainamide vs. 26% for lidocaine), in the combined cases from the literature (112 and 143, respectively). Based on these findings, the latest ESC guidelines[5] recommend the use of procainamide (Class IIa, LOE B), for patients with hemodynamically tolerated sustained monomorphic VT and known or suspected SHD; the drug is contraindicated in advanced HF.

## Bedside neuronal sympathetic modulation

The direct modulation of neuronal sympathetic activity from and towards the heart at bedside and potentially even in an out of hospital setting is a powerful weapon for VAs refractory to AADs and mild sedation and its clinical usage has been exponentially increasing in the last decade. As previously mentioned, the pro-arrhythmic effects of sympathetic hyperactivity extend far beyond those antagonized by BBs, even if not selective. Indeed, noradrenaline concentration in the synaptic cleft may considerably overcome the competitive antagonism provided by BBs; furthermore, the pro-arrhythmic effects of NPY are left completely unopposed.[13] Finally, afferent sympathetic blockade reduces central sympathetic activation as well as central parasympathetic withdrawal. Most cardiac sympathetic efferent fibres originate from preganglionic neurons situated in the

spinal cord between the T1 and T4 vertebral levels and subsequently synapse with post-ganglionic neurons in the paravertebral thoracic sympathetic ganglia from T1 to T4. Typically, the C8 and T1 ganglia are fused to form the stellate ganglion, which can be easily targeted percutaneously from the neck; C8 innervates the eye and its block results in Horner's syndrome (miosis, ptosis, and enophthalmos). Two bedside neuromodulation techniques are currently available: percutaneous stellate ganglion block (PSGB, left-sided, PLSGB or bilateral) and thoracic epidural anaesthesia (TEA). Notably, TEA technically provides a more extensive sympathetic block then PLSGB (bilateral and from T1 to T4, as opposed to the unilateral block of C8 and T1) but requires anaesthesiologic skills and the lateral decubitus to be performed. Furthermore, it cannot be performed in patients on dual antiplatelet and/or anticoagulation therapy and carries a non-trivial infective risk.

## Percutaneous left sympathetic ganglion block

PLSGB with a local anaesthetic can be performed using either an anatomical (or anterior) approach, known as the Moore technique, or an ultrasound-guided lateral approach. Both techniques can be executed by trained cardiologists while the patient lies in a supine position, and there are no significant safety issues even on full antithrombotic therapy. Combining a fast-acting drug (such as lidocaine) with a long-acting one (like bupivacaine or ropivacaine) offers the benefit of achieving a rapid onset of antiarrhythmic effects alongside prolonged protection. Notably, the protective effects of PLSGB may extend beyond the anaesthetic's half-life, highlighting the significance of breaking down the acute vicious cycle of sympathetic activation. The STAR study,[14] published in early 2024, is the largest clinical experience of PLSGB for refractory ES; it is an observational study including 131 patients (median 68 yrs, 83% male, mean LVEF $25 \pm 12\%$) from 19 Italian centres receiving a total of 184 PSGBs. Almost one third of the patients had ongoing acute myocardial ischaemia and a total of 56% had coronary artery disease (either acute or chronic); a quarter were in cardiogenic (21%) or septic shock (5%) and 8% in refractory cardiac arrest. Most of the procedures were left-sided PSGB (98%) and were performed as bolus only (83%) and as a single procedure (73%) due to i.v. amiodarone and/or lidocaine refractory VAs (88% of cases); the anatomical approach was slightly predominant over the ultrasound guided (58% over 42%). The majority of PSGBs (64%) were performed due to VT storm, the rest for VF storm (19%), or combined VT/VF storm, with a median heart rate of the last VT before PSGB of 167 b.p.m. (IQR 158–176). Only 20% of the procedures were performed on intubated patients. Lidocaine was the most used drug for the bolus, either alone (200 mg, almost one third of the cases) or in association. Most of the patients (92%) achieved the primary efficacy outcome represented by a reduction of treated VAs (ATPs/shocks) of at least 50% in the 12 h after compared with before PSGB (from a median of 6, IQR 3-16, to a median of 0, IQR 0-10, $P < 0.001$), with a dramatic drop in VAs starting from the first hour after each PSGB. The safety profile was excellent, despite 86% of patients being on antithrombotic therapy: only one major complication occurred (respiratory depression, 0.5% incidence), most probably due to local anaesthetic systemic toxicity that was quickly and successfully treated with lipid infusion. The development of anisocoria (that indeed reflects ocular not cardiac fibres block) and the enrolling volume of the centre did not influence efficacy. The latter analysis strongly supports the widespread usage of the technique even in small spoke centres. Notably, among the 26% of patients who received more than one PSGB boluses, the second and even the third attempt on the left side provided a significant additional antiarrhythmic benefit, supporting the practice. On the other side, a smaller previous American study ($n = 30$ patients)[15] demonstrated that, in case of recurrences after PLSGB, systematically blocking the right PSGB does not provide additional benefit, while potentially exposing at risk of bilateral phrenic paralysis. However, in case of major recurrences following a second left bolus, a right PSGB may still be contemplated after thoroughly ruling out any asymptomatic left-sided phrenic nerve paralysis (or if the patient is under general anaesthesia). This approach seems particularly reasonable when a negative chronotropic effect is being pursued and/or when VAs originate from the anterior surface of the right ventricle, due to the larger right-sided sympathetic control on these structures.[16] Few months after STAR, another large observational multicentre study of 117 patients (mean LVEF 27%, 70% with an ICD, 56% under general anaesthesia/sedation at the time of PSGB) confirmed the excellent efficacy and safety of PSGB for refractory VAs, despite efficacy being only assessed at 24 and 48 h in the second study.[17] Notably, patients with acute myocardial ischaemia were excluded, and the efficacy of PSGB proved to be similar independently from the underlying cardiomyopathy (ischaemic or not ischaemic). Also, 18% of the patients received a bilateral block and 45% repeated injections. Concerning the choice of performing PLSGB as bolus rather than as a continuous infusion (C-PSLGB, almost constantly preceded by a bolus) through an epidural catheter within the neck nearby the target, other than the operator experience, the trigger of ES, and the possible invasive treatment planning (e.g. catheter ablation or cardiac sympathetic denervation) should be considered. If the local expertise is supportive, C-PLSGB might be the best option if the trigger cannot be resolved (e.g. ADHF), and/or a definitive treatment cannot be performed within 24-48 h. We recently reported[18] the largest case-series of C-PLSGB ($n = 26$ patients, 32 procedures, median duration 3 days, IQR 1–7) together with a systematic review of all cases of C-PSGB ($n = 68$ procedures) and TEA ($n = 22$) reported in literature. C-PSLGB proved to be feasible, safe, and effective for VAs management, with an infusion starting rate (after the bolus), of 12 mg/h for ropivacaine and 100 mg/h for lidocaine. No major complications occurred, yet, TEA discontinuation rate due to side effects was higher than C-PSGB (18% vs 1%, $p = 0.01$). Efficacy of C-PLSGB and TEA could not be directly compared due to patients' heterogeneity, yet 63% had a complete VAs suppression during C-PLSGB and 93% an overall clinical benefit. Concerning PLSGB efficacy according to the underlying VA cycle length, a sub-analysis of the multicenter STAR study[19] showed that, despite being

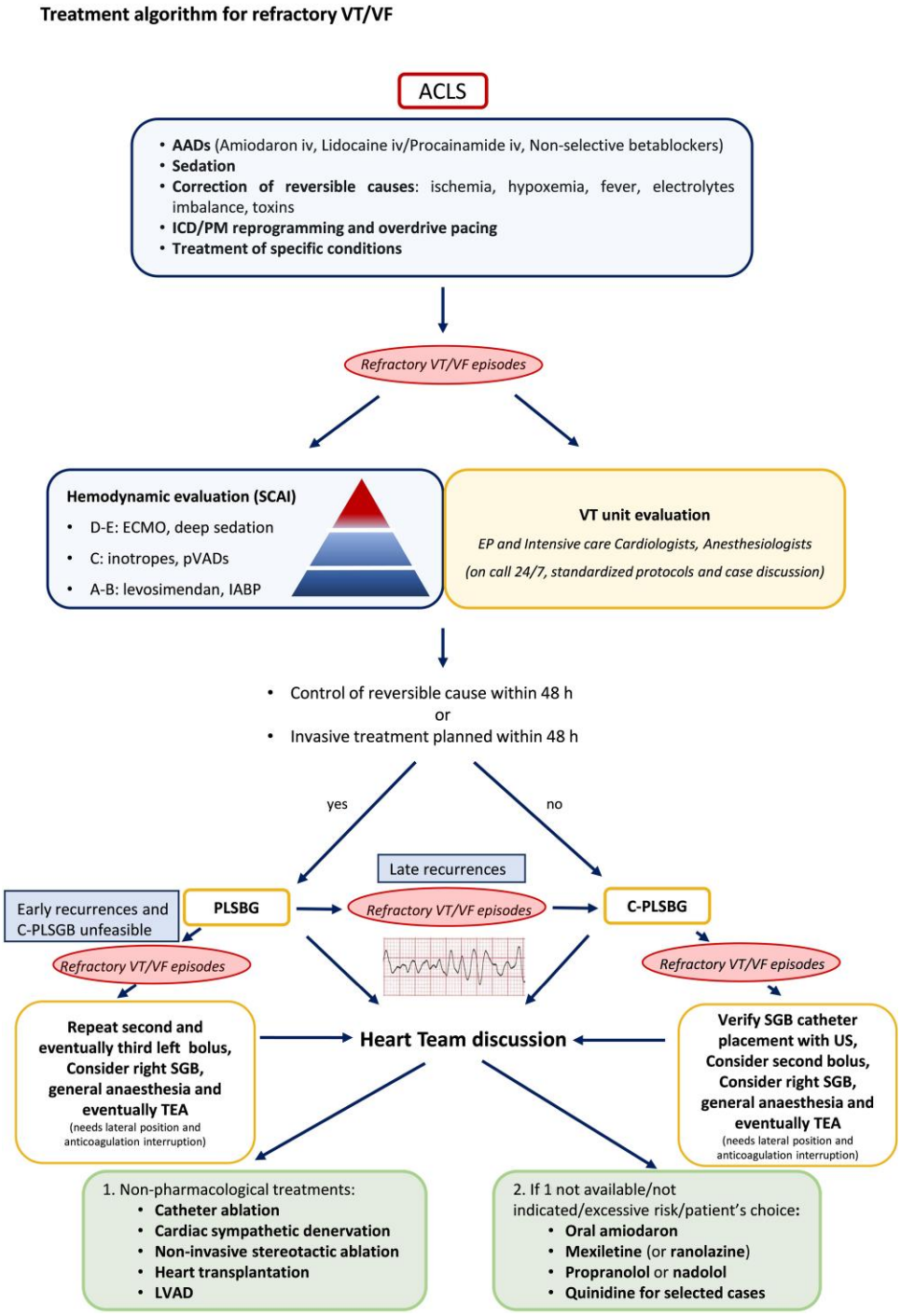


**Figure 2** Modified from Dusi *et al.*[18] Our current approach to acute neuromodulation for refractory VAs. AADs, antiarrhythmic drugs; ACLS, acute cardiac life support; C-PLSGB, continuous percutaneous left stellate ganglion block; LVAD, left ventricular assistance device; TEA, thoracic epidural anaesthesia; US, ultrasound; VA, ventricular arrhythmias; VF, ventricular fibrillation; VT, ventricular tachycardia.

PLSGB highly effective in reducing the arrhythmic burden in all cases, the amount of reduction (assessed as absolute number not as percentage) in the hour after compared to the hour before the block, was significantly more pronounced in cases with VF only (37%) compared to those with fast-VTs (VT cycle<375 msec, 32%) or slow-VTs (VT cycle≥375 msec, 31%). VF was also independently associated with the probability of reduction in treated events after PSGB. Of note, the arrhythmic burden in the hour before PLSGB was higher in the VF group than in the other 2 groups, and in almost half of the cases refractory FV occurred in the setting of acute myocardial ischemia before or peri-reperfusion, both conditions being associated with an extremely high level of sympathetic

activation. Notably, the percentage of patients free from treated arrhythmic episodes in the hour following PSGB was not significantly different in the three groups: 82% in slow VTs, 86% in fast VTs and 73% in VF ($p = 0.23$), once again supporting the overall high efficacy of the procedure. Additionally, as already demonstrated for cardiac sympathetic denervation,[20] PLSGB may also reduce VAs cycle length in case of recurrences, leading to an improved response to antitachycardia pacing and to an increased proportion of mappable, hemodynamically stable VTs, more suitable for invasive VT ablation.

Finally, concerning the timing of PLSGB, recent preliminary data stemming from a retrospective sub-analysis of the STAR study,[21] report that, in the setting of ES, the efficacy of PLSGB, assessed both as VAs burden at 1 h and percentage of patients free from recurrences at 1, 3, and 12 h after PLSGB, was similar whether PLSGB was performed before (early PSGB, often due to AAD contraindication, $n = 26$) or after (delayed-PSGB, $n = 154$) i.v. AADs other than BBs. These preliminary data, reinforced by the pathophysiological rationale that the time of onset of local anaesthetic induced neuronal sympathetic block after a proper hitting of the target may take seconds-few minutes as opposed to that of amiodarone bolus requiring 10–15 min at best, and the fact that amiodarone bolus mostly acts as an antiadrenergic intervention, support the idea of an earlier usage of PLSGB in the setting of ES.

Overall, all the available literature data up to this point, unfortunately not entirely available yet at the time of the latest 2022 European Guidelines[5] and 2024 EHRA Consensus on VAs[6] writing, fully support the usage of PLSGB before general anaesthesia and mechanical circulatory support with antiarrhythmic purposes only, in case of AADs refractory VAs. *Figure 2* summarizes our current approach to percutaneous neuromodulation for refractory VAs. Notably, despite currently available data[18] not specifically supporting the usage of TEA in case of major recurrences during C-PSGB or after bilateral PSGB, pre-clinical experience suggests that a stepwise cardiac sympathetic block may be more effective than a single site one. As such, TEA might be considered as last resort after intubation and general anaesthesia. Once the patient has been acutely stabilized, further strategies should be discussed, within a dedicated heart team for patients with SHD and HF. Depending on patient's and arrhythmia's characteristics, non-pharmacological antiarrhythmic strategies encompass catheter ablation, cardiac sympathetic denervation and stereotactic arrhythmia radioablation, as discussed elsewhere.[22]

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## Data availability

No new data were generated or analysed in support of this research.

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