



EMERGENCY CARDIOLOGY SYMPOSIUM

Third Time's NOT the Charm?! Management of Electrical Storm

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No Financial Disclosures

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— OBJECTIVES —

- 1 | DEFINE ELECTRICAL STORM
- 2 | OVERVIEW ETIOLOGIES OF VENTRICULAR TACHYDYSRHYTHMIAS
- 3 | REVIEW THE MEDICAL MANAGEMENT OF ELECTRICAL STORM

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Outline

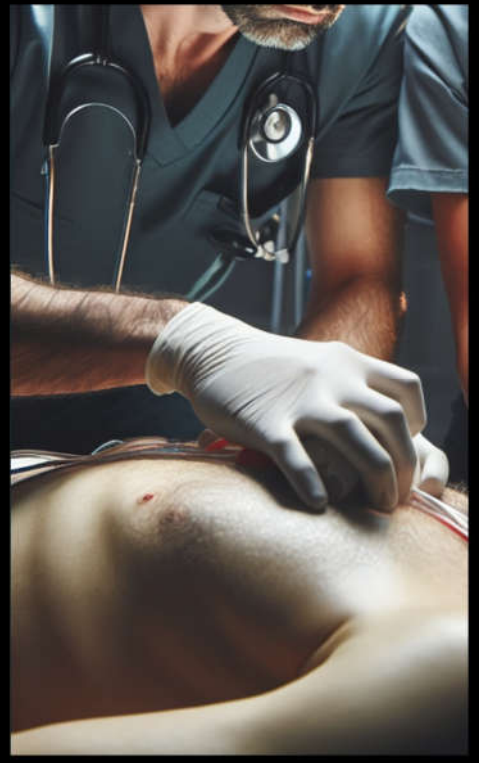
- 1 | CLINICAL CASES
- 2 | DEFINITION
- 3 | S.T.O.R.M.S.
- 4 | EPIDEMIOLOGY AND RISK FACTORS
- 5 | ETIOLOGIES OF VT
- 6 | GENERAL MANAGEMENT
- 7 | MECHANICAL SUPPORT AND ADVANCED THERAPIES
- 8 | SYMPATHETIC BLOCKADE
- 9 | CASE CONCLUSIONS
- 10 | OVERVIEW

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SECTION 1 | CLINICAL CASES

Cases of Recurrent **Ventricular Tachycardia**



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Introduction

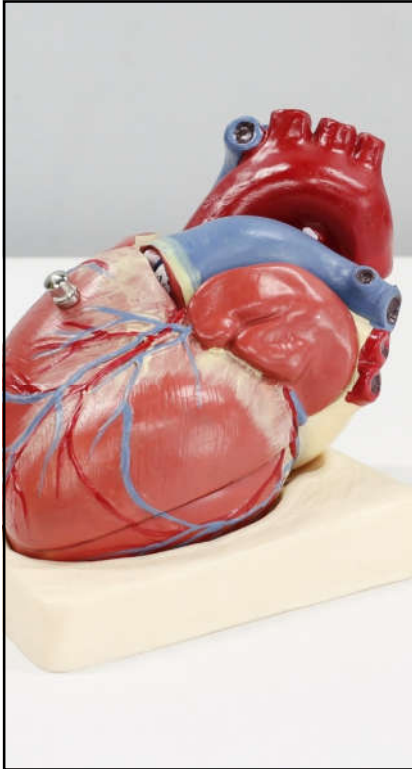
35 YO M UNKNOWN PMHX WITNESSED ARREST WITH POLYMORPHIC VT (PMVT) AS INITIAL RHYTHM

- EMS believes they may have seen Torsades briefly
- ROSC obtained after defibrillation; however patient rearrested with PMVT within 5 minutes requiring second defibrillation
- Currently en route to your facility and begins to have PMVT again...

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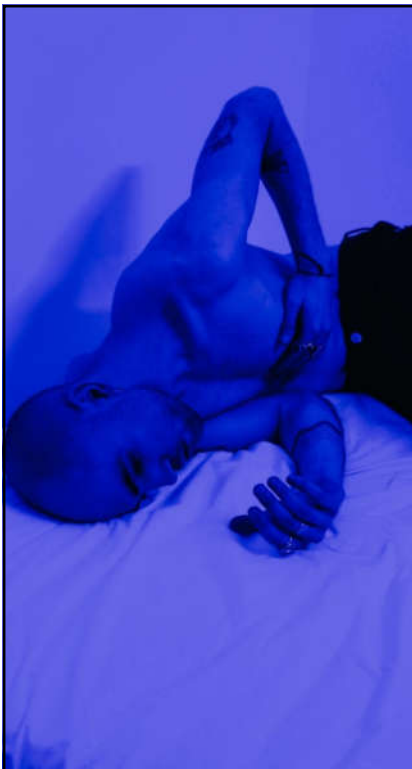


Introduction

45 YO F PMHX OF NONISCHEMIC CARDIOMYOPATHY WITH AICD PRESENTING WITH MULTIPLE SHOCKS

- EMS notes monomorphic VT on rhythm strip
- Patient continues to go unresponsive, but AICD fires and is currently alert
- Patient states this is the 4th time since she woke up that her AICD has fired

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Introduction

55 YO M PMHX OF DM, HTN, HLD WITH CHEST PAIN WHO WAS FOUND DOWN

- EMS notes polymorphic VT
- They are en route to your facility; however the patient keeps arresting
- They have received epinephrine x 3, Amiodarone 300 mg

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What is going on?!

- S
- T
- O
- R
- M
- S

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S.T.O.R.M.S!

- SEDATION
- TREAT UNDERLYING CAUSE
- OVERDRIVE PACING
- RHYTHM CONTROL
- MECHANICAL SUPPORT
- SYMPATHETIC BLOCKADE

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- 3+ EPISODES OF VF OR SUSTAINED VT REQUIRING INTERVENTION WITHIN 24 HOURS
- PATIENTS WITH ICD MAY PRESENT WITH RECURRENT APPROPRIATE SHOCKS OR ANTITACHYCARDIA PACING

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SECTION 3 | EPIDEMIOLOGY AND RISK FACTORS

Who is at risk for **Electrical Storm**?



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- **MYOCARDIAL ISCHEMIA**

- Kwaśniewski et al. noted scarring of inferior wall especially predisposes a patient to a re-entry VT

- **HEART FAILURE WITH REDUCED LVEF**

- **NYHA CLASS III OR IV**

- **OTHER STRUCTURAL HEART DISEASE**

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- **ADVANCED AGE**
- **MALE SEX**
- **CHRONIC RENAL FAILURE**
- **BRUGADA SYNDROME**

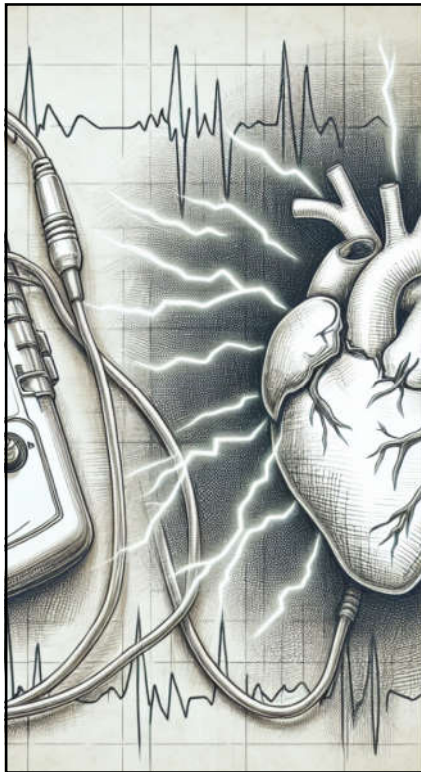
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ICD Patients Are a High Risk Group!

- **ZIPES 1995: OVERALL 10-20% INCIDENCE OF ELECTRICAL STORM**
- **AVID 1997: ELECTRICAL STORM OCCURRED 9 +/- 11 MONTHS AFTER ICD IMPLANTATION**
- **MADIT-II 2002: 4% DEVELOPED ELECTRICAL STORM OVER AN AVERAGE OF 21 MONTHS**

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ICD Patients Rarely Have a Trigger

- **CREDNER ET AL 1998: 74% OF PATIENTS WITHOUT A TRIGGER**
 - 26% with acute heart failure, acute MI, hypokalemia
- **SHIELD 2004: 87% OF PATIENTS WITHOUT A TRIGGER**
 - 13% with Acute MI, electrolyte disturbances, worsening HF, sepsis, poor medication compliance

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ICD Patients Cont.

- **ANALYSIS OF STORED INTRACARDIAC ELECTROGRAMS DURING STORM IN PATIENTS WITH ICD SHOW THE REPRESENTATION OF TYPES OF VENTRICULAR ARRHYTHMIAS**
 - Monomorphic VT - 86 to 97%
 - Primary VF - 1 to 21%
 - Mixed VT/VF - 3 to 14%
 - Polymorphic VT - 2 to 8%

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S.T.O.R.M.S.

- SEDATION
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- SYMPATHETIC BLOCKADE

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S.T.O.R.M.S.

- SEDATION

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SECTION 4 | SEDATION

What is the utility of Sedation?



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SEDATION

- ALL PATIENTS WHO HAVE ELECTRICAL STORM SHOULD BE GIVEN ANALGESICS, ANXIOLYTICS, OR SEDATION
- Patients may have severe anxiety and increased catecholamine levels
- Anesthetics such as propofol, benzodiazepines and other agents of general anesthesia have been associated with conversion and suppression of VT
- Current guidelines recommend intubation/sedation in intractable ES refractory to drug treatment



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SEDATION

- **ALL PATIENTS WHO HAVE ELECTRICAL STORM SHOULD BE GIVEN ANALGESICS, ANXIOLYTICS, OR SEDATION**
- Bundgaard et al 2020 reported results in 15 patients with treatment refractory ventricular arrhythmia who received deep sedation and intubation. Complete resolution was achieved within minutes in 80% of patients and partial resolution in 13%



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SEDATION

- **ALL PATIENTS WHO HAVE ELECTRICAL STORM SHOULD BE GIVEN ANALGESICS, ANXIOLYTICS, OR SEDATION**
- Martins et al 2020 developed a multicenter retrospective analysis of 116 patients who received multiple shocks in the previous 15-240 minutes before deep sedation
 - Among these patients 55 had ES terminate within 15 minutes
 - Acute response to deep sedation was associated with a 55% lower risk of in-hospital death



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S.T.O.R.M.S.

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- SYMPATHETIC BLOCKADE

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S.T.O.R.M.S.

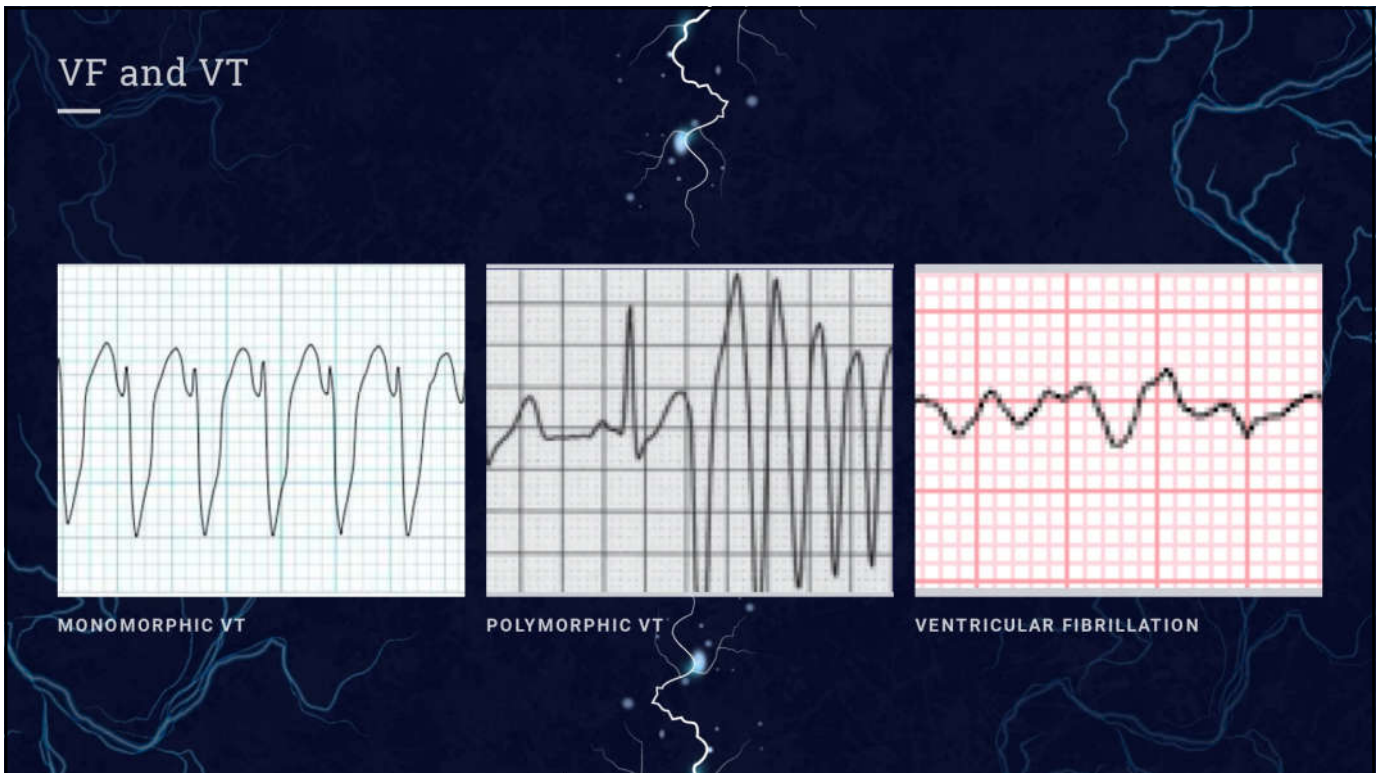
- TREAT UNDERLYING CAUSE

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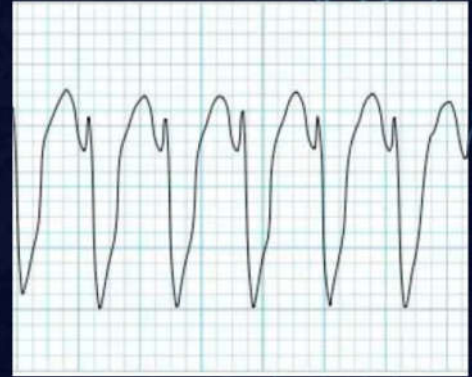


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Monomorphic VT Storm General Considerations

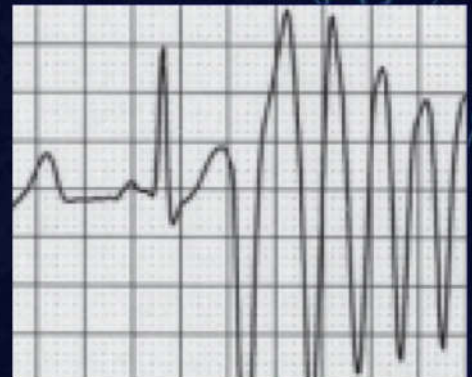
- **ASSOCIATED WITH STRUCTURAL HEART DISEASE AND REENTRY**
- **ADDRESSING UNDERLYING CAUSES**
 - Treat Underlying Causes
 - Electrolyte Abnormalities: Hypokalemia, Hypomagnesemia
 - 2g Mg despite Mg levels
 - Mg > 2, K > 4
 - Minimize Pro-arrhythmic drug toxicity
 - Thyrotoxicosis
 - Sepsis
 - Volume Overload



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Polymorphic VT Storm General Considerations

- **HIGH SUSPICION FOR ISCHEMIA (ESPECIALLY WITH NORMAL QTC)**
- **ADDRESSING UNDERLYING CAUSES**
 - Revascularization
 - Revascularization
 - Revascularization



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Polymorphic VT Storm - Torsades (Prolonged QTc)

- **RISK FACTORS:**

- Female Sex
- Bradycardia / Heart Block
- QT-Prolonging Medications
- Hypokalemia
- Long QT Syndromes (associated with sudden cardiac death, less likely electrical storm)



- **ADDRESSING UNDERLYING CAUSES**

- Treat Underlying Causes (ESC 2022 Class I)
 - Electrolyte Abnormalities: Hypokalemia, Hypomagnesemia, Hypocalcemia (Class I)
 - Hypothyroidism
 - Stop QT Prolonging Medications

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VF Storm



- **MORTALITY RATES CITED BETWEEN 85-97%**
- **ISCHEMIA IS THE PRIMARY MECHANISM AND SHOULD BE THE FOCUS**

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Summary

- **MONOMORPHIC VT - THINK STRUCTURAL HEART DISEASE AND UNDERLYING CAUSES**
- **VF / PMVT - THINK ISCHEMIA FIRST**
- **PMVT WITH PROLONGED QTC - THINK MEDICATION CAUSES AND ELECTROLYTES**

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S.T.O.R.M.S.

- **SEDATION**
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- **MECHANICAL SUPPORT**
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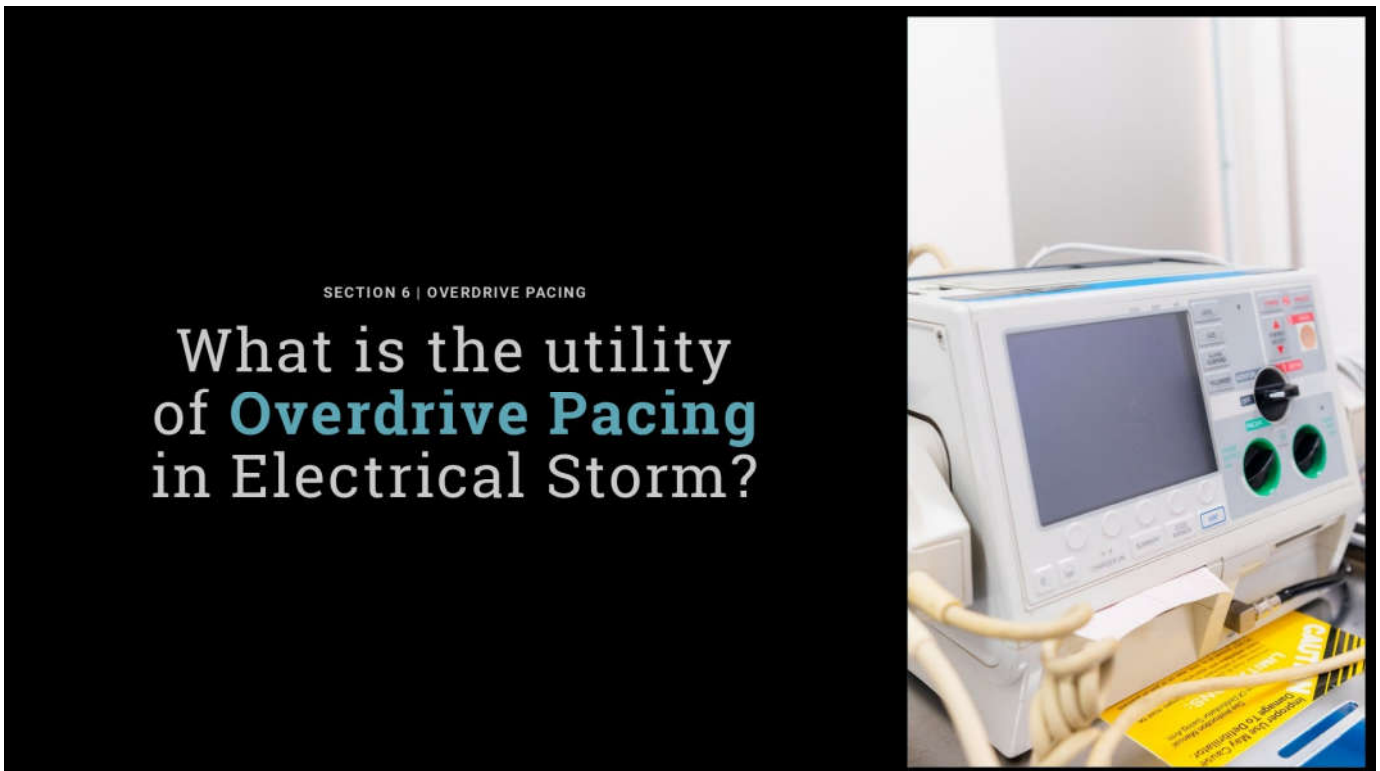


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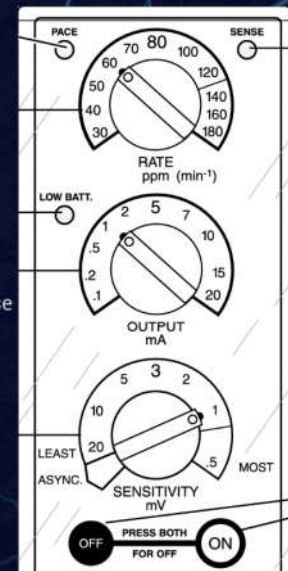
Overdrive Pacing

- **INDICATIONS:**

- VT with intermittent bradycardia or heart block
- Slow VT
- PVC Mediated VT
- ESC 2022 Class I Recommendation: Electrical Storm in Long QT Syndrome OR Torsades despite correction of precipitating conditions
- ESC 2022 Class IIa Recommendation: Recurrent ventricular arrhythmias in the acute phase of STEMI

- **TECHNICAL ASPECTS**

- Best to float a TVP; limited efficacy of transcutaneous pacing
 - Rate - Tachycardic: Start at 100 BPM
 - Output - Enough to obtain electrical and mechanical capture: Start at 20 mA and wean
 - Sensitivity - Higher Sensitivity means closer to Asynchronous Mode: Start at 20 mV



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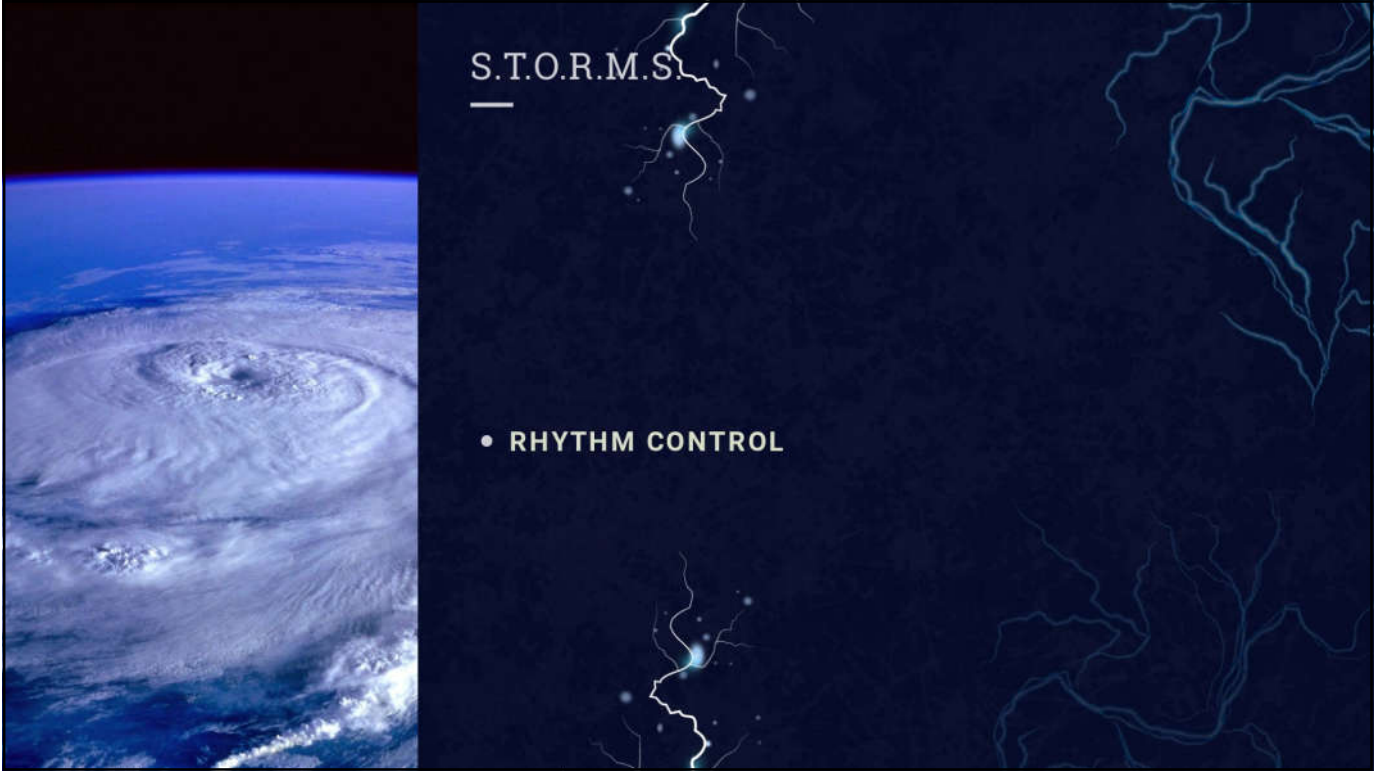
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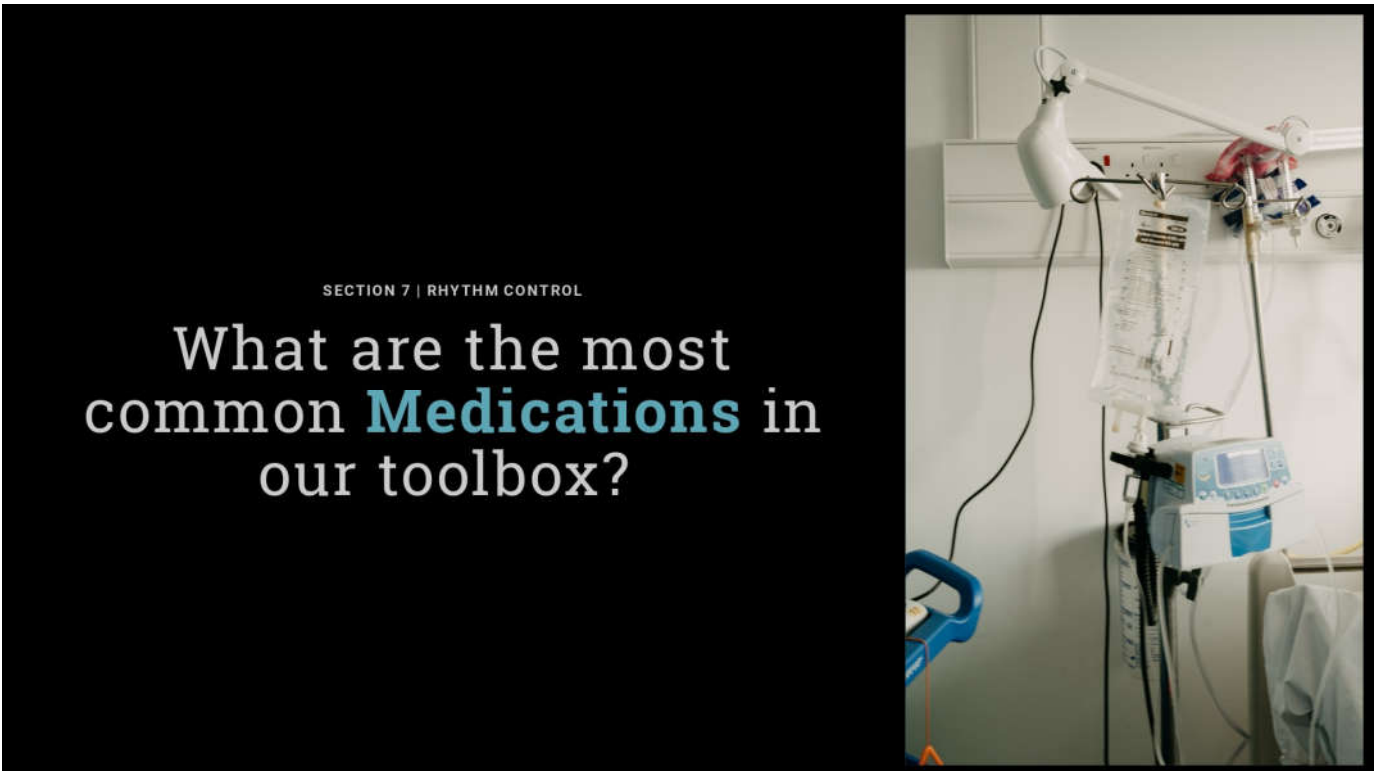


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Amiodarone

- **MECHANISM: EVERYTHING - SODIUM CHANNEL BLOCKER, INHIBITS NOREPINEPHRINE RELEASE, BLOCKS L-TYPE CALCIUM CHANNELS**
- **SAFE IN PATIENTS WITH DEPRESSED SYSTOLIC FUNCTION**
- **IV HYPOTENSION DUE TO BUFFER SOLUTION**
- **ORIGINAL STUDIES:**
 - Kudenchuk, 1999 - 504 Patients with cardiac arrest with VF or VT who had not been resuscitated after receiving 3+ shocks were assigned 300 mg amiodarone vs. Placebo
 - More patients in Amiodarone group survived to hospitalization (44% vs. 34%, P 0.03)



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Amiodarone

- **AMIODARONE STUDIES CONT:**
 - Scheinman et al 1995: In a study of 342 patients with electrical storm, IV amiodarone significantly reduced the recurrence of ventricular arrhythmias in a dose-related pattern up to 1000 mg / 24 hours
 - Levine et al 1996: In a study of 273 patients with ES refractory to lidocaine, procainamide and bretylium, IV amiodarone prevented recurrence in 40% of patients



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Lidocaine

- **MECHANISM: BINDS TO FAST SODIUM CHANNELS; BINDING THOUGHT TO INCREASE UNDER CELLULAR CONDITIONS COMMON IN ISCHEMIA**
- Conversion from VT to sinus rhythm: 8-30%
- **Wagner et al 2023:** Retrospective cohort study of 14,630 patients with in hospital VT/ VF arrest, lidocaine (n=4,572) was associated with higher odds of ROSC, 24h survival, survival to hospital discharge and favorable neurological outcome compared to amiodarone (n=10,058)



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ALPS - Amio vs. Lido vs. Placebo in Out of Hospital Arrest

- **KUDENCHUK ET AL 2017:** PER-PROTOCOL POPULATION STUDY OF 3026 PATIENTS RANDOMLY ASSIGNED TO AMIODARONE (974), LIDOCAINE (993), OR PLACEBO (1059)
- **24.4% (AMIO), 23.7% (LIDO), 21.0% (PLACEBO) SURVIVED TO HOSPITAL DISCHARGE**
- **A LARGE SUBGROUP 66% OF THE PATIENTS HAD A WITNESSED ARREST**
 - Amiodarone (27.7%) and Lidocaine (27.8%) did have significant differences compared to Placebo (22.7%)
 - ALPS may illustrate that Amiodarone and Lidocaine could be effective in bystander witnessed arrest... but there is also the confounding factor of immediate response and good quality CPR

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PROCAINAMIDE

- **MECHANISM: BLOCKS FAST SODIUM CHANNELS; ACTIVE METABOLITE BLOCKS POTASSIUM CHANNELS**
- **PROCAMIO 2017**
 - Question: In adult patients that present to the emergency department with wide complex tachycardia, comparing bolus infusions of procainamide and amiodarone, which is better in terms of efficacy and safety
 - Multicenter open label prospective randomized controlled trial of 74 patients
 - Primary outcome: incidence of major cardiac events* within 40 minutes of drug exposure
 - *MCE = shock, pulmonary congestion, tachycardia/VT
 - Findings: 9% of Procainamide vs. 41% of Amiodarone
 - Procainamide almost twice as successful at conversion (67% vs. 38%) during the 40 minute period



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S.T.O.R.M.S.

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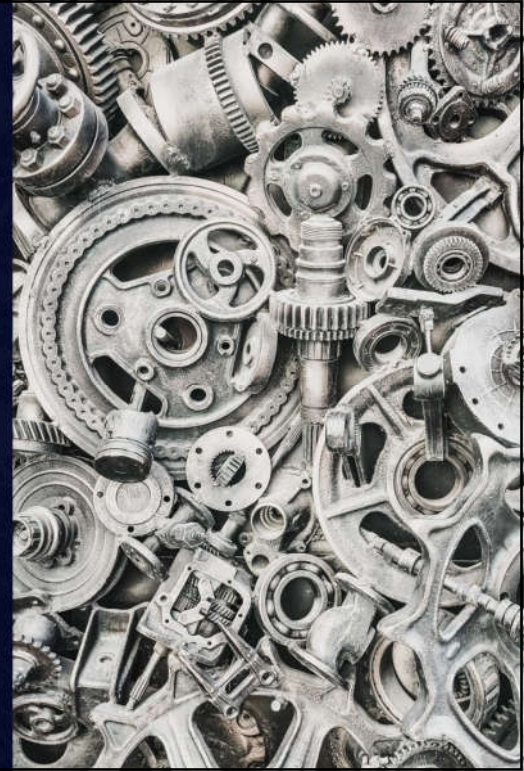


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Mechanical Support

- **ECMO**
 - Le Pennec-Prignet et al 2017: 26 patients with electrical storm secondary to mostly ischemic cardiomyopathy
 - 61.5% of patients had immediate restoration of normal sinus rhythm
 - Remainder had restoration at a median time of 3 hours
 - 50 % survived to discharge but did require extensive rehabilitation
- **DISCUSS THE BENEFIT OF BALLOON PUMPS AND IMPELLA WITH CARDIOLOGY**
 - Limited Evidence
 - Most beneficial when inotropic medications become ineffective or harmful due to arrhythmogenic effects



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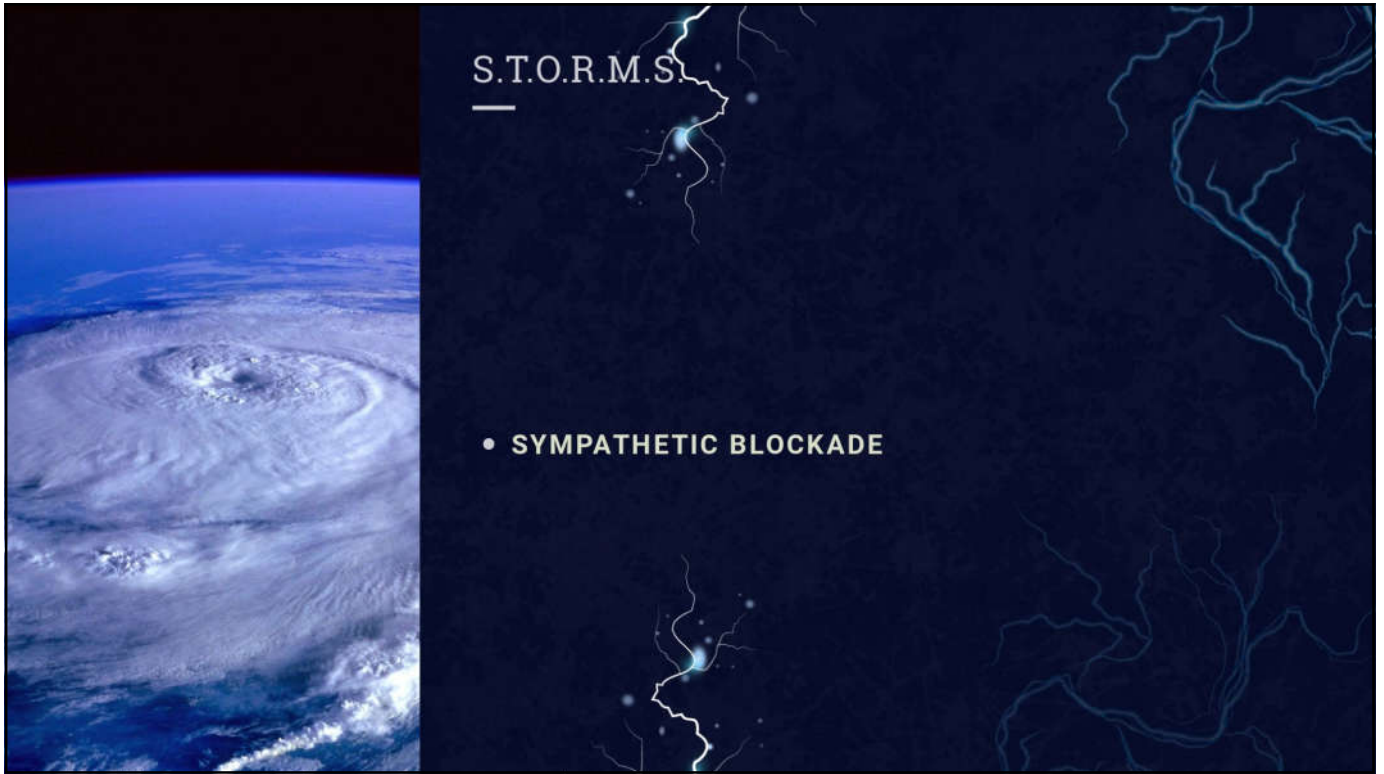
S.T.O.R.M.S.

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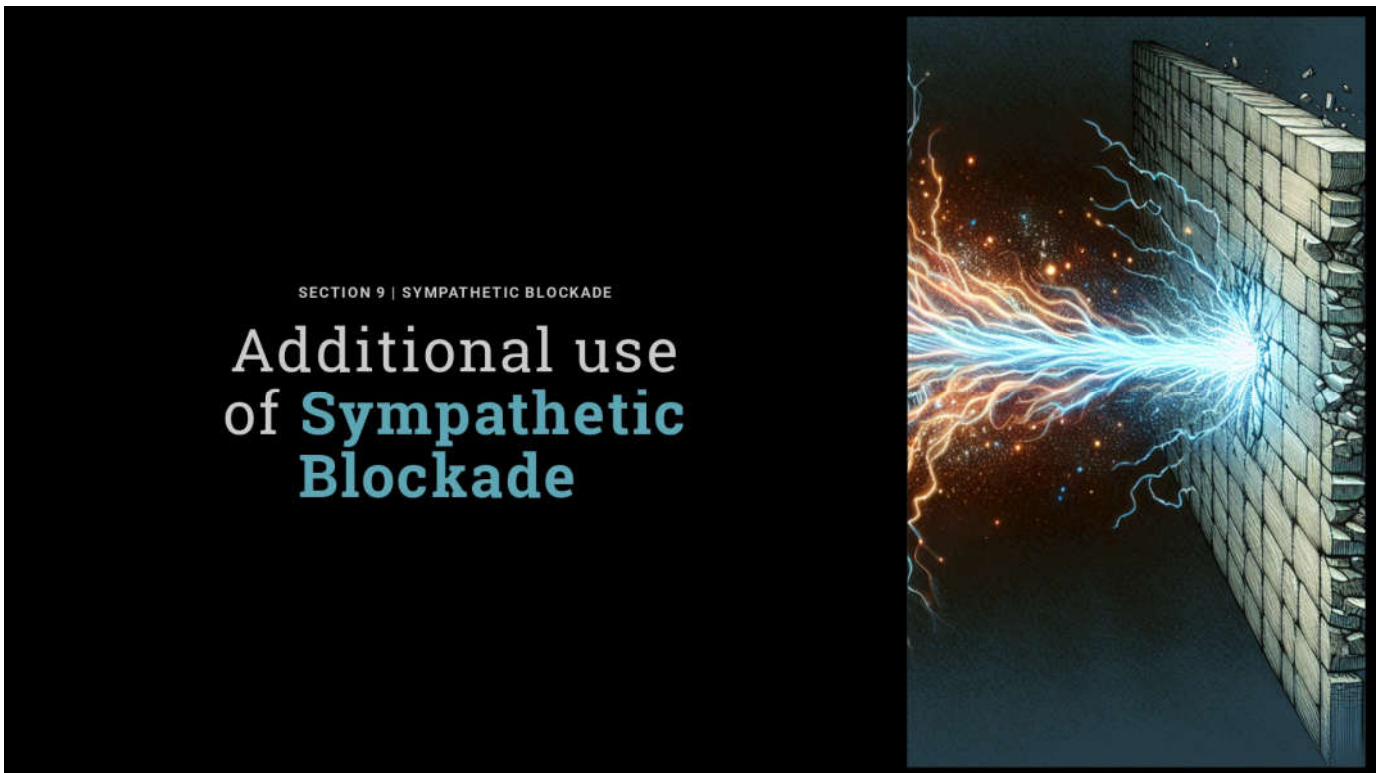


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Sympathetic Blockade

- **LAST RESORT?...**
 - Nademanee et al 2000: 49 patients with storm and recent MI were separated into 2 groups.
 - Group 1 (n= 27) received sympathetic blockade treatment - 6 left stellate ganglion blockade (LSGB), 7 esmolol, and 14 propranolol
 - Group 2 (n =22) antiarrhythmic medication by ACLS
 - 1 week mortality: Sympathetic Blockade: 6 of 27 deaths (22%) vs. ACLS 18 of 22 deaths (88%)
 - Overall Survival: Group 1 (67%) vs. Group 2 (5%)



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BETA BLOCKERS

- **MECHANISM: BLOCKS RELEASE OF ADRENALINE AND NORADRENALINE**
- **NONSELECTIVE BETA BLOCKERS PREFERRED**
 - Chatzidou randomized propranolol vs. metoprolol in 60 patients with ES (all patients received amiodarone)
 - Propranolol had a 2.67 fold reduction in the incidence of ventricular arrhythmia events compared with metoprolol over a 48-h period
- **CONTRAINDICATIONS: SEVERE SINUS NODE DYSFUNCTION, CORONARY VASOSPASM, BRUGADA SYNDROME, SEVERE ASTHMA, DECOMPENSATED HEART FAILURE**



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PROPRANOLOL	ESMOLOL	METOPROLOL
<ul style="list-style-type: none"> • Studied Dose: PO 40 mg q6h • IV Propranolol has limited availability based on institution and is used in EP labs • Proposed dosing: IV 0.15 mg/kg (~10 mg) over 10 minutes 	<ul style="list-style-type: none"> • Few case reports • Proposed in patients with low LVEF due to short acting nature • High Volume • Proposed dosing: 0.5 mg/kg bolus + 0.05 mg/kg/min 	<ul style="list-style-type: none"> • Studied Dose: 50 mg PO q6h • IV dosing has not been studied • Proposed dosing: IV 2-5 mg q 5 min up to 3 times

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Left Stellate Ganglion Block

- **MENG ET AL 2017 REVIEWED 3,376 PUBLICATIONS - 38 PATIENTS FROM 23 STUDIES!**
 - Patients were in ES refractory to antiarrhythmic therapy
 - SGB resulted in a significant burden of ventricular arrhythmias
 - 80.6% of patients survived to discharge
 - Mean volume of bupivacaine 9 +/- 5.6 mL
 - Ultrasound in 21 patients, fluoroscopy in 4 patients, 13 anatomic only

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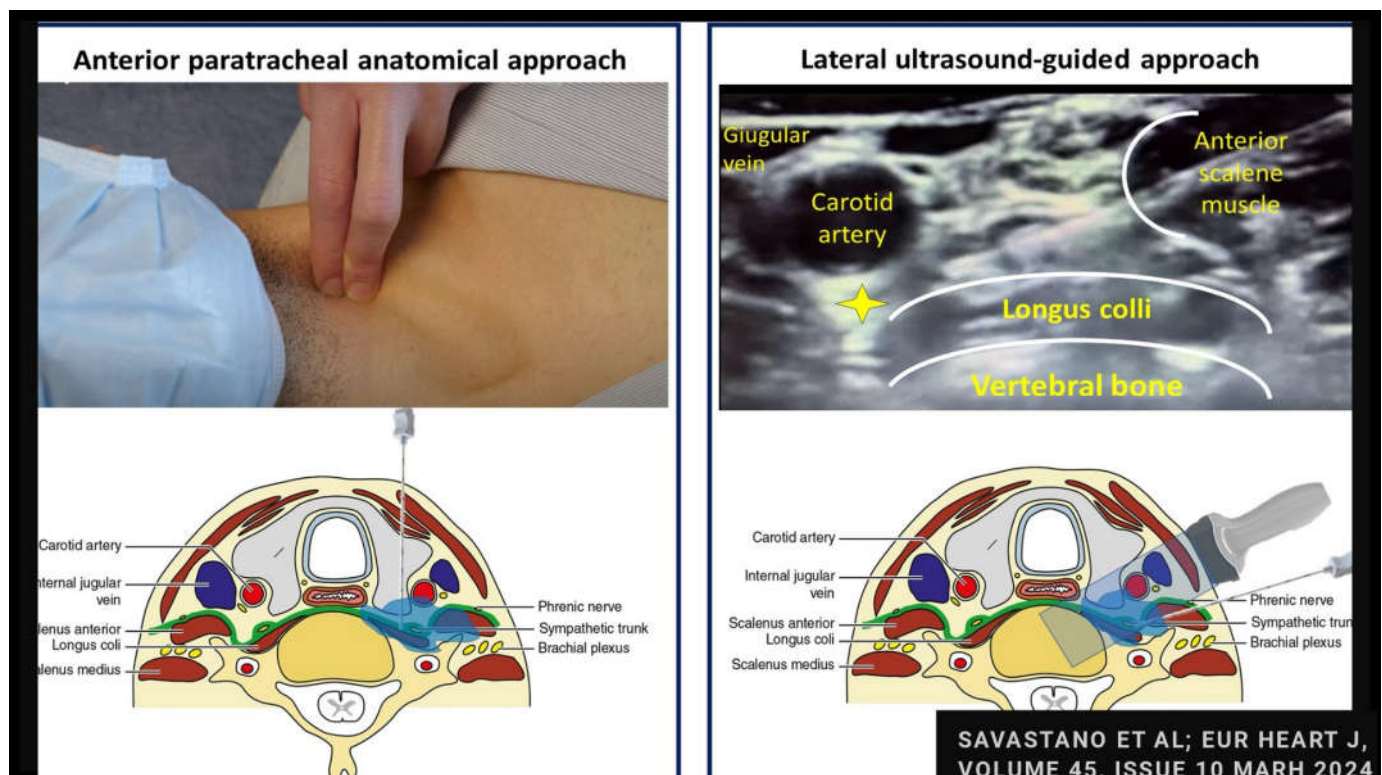
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Left Stellate Ganglion Block

- **SAVASTANO ET AL 2021**

- Study included 18 PLSGB in 11 patients all performed by cardiologists with the anatomical approach
- Study demonstrated reducing the burden of arrhythmias to 0 only 1 hour after each block was complete
- 83% of patients remained free of arrhythmias

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Left Stellate Ganglion Block cont.

- **STAR STUDY (JANUARY 2024!) BY SAVASTANO ET AL.**
 - Multicenter observation study across 19 centers from July 1 2017 - June 30 2023
 - Primary end point of reduction of arrhythmic events by at least 50% comparing 12 hours before and after SGB
 - Operators included cardiologists, intensivists, and emergency physicians underwent 8 hours of training
 - 131 Patients undergoing 184 percutaneous left stellate ganglion blocks

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Left Stellate Ganglion Block cont.

Table 2 Characteristics of PSGBs (*n* = 184)

Characteristic	<i>n</i> = 184
Approach, <i>n</i> (%)^a	
Anterior anatomical	106 (57.6)
Lateral ultrasound-guided	78 (42.4)
Side, <i>n</i> (%)^a	
Left	181 (98.4)
Right	3 (1.6)
Mode of administration, <i>n</i> (%)^a	
Bolus	152 (82.6)
Bolus and infusion	32 (17.4)

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Left Stellate Ganglion Block cont.

Anaesthetic used for bolus, <i>n</i> (%)^a	
Lidocaine	53 (28.8)
Bupivacaine	8 (4.3)
Ropivacaine	1 (0.5)
Mepivacaine	3 (1.7)
Lidocaine + bupivacaine	44 (23.9)
Lidocaine + ropivacaine	63 (34.2)
Lidocaine + mepivacaine	11 (6)
Lidocaine + levobupivacaine	1 (0.5)
Anaesthetic used for infusion, <i>n</i> (%)^a	
Lidocaine	21 (65.6)
Ropivacaine	11 (34.4)
Anaesthetic infusion duration, min^b	
	3660 (1440–7203.8)

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Left Stellate Ganglion Block cont.

Pre-PSGB intervention, <i>n</i> (%) ^a	
Intubation	37 (20.1)
Sedation	40 (21.7)
IABP	18 (9.8)
ECMO	7 (3.8)

Pre-PSGB i.v. medication, <i>n</i> (%) ^a	
Amines	47 (25.5)
Amiodarone	34 (18.5)
Lidocaine	67 (36.4)
Amiodarone and lidocaine	61 (33.2)
Procainamide	5 (2.7)
Beta-blockers	21 (11.4)

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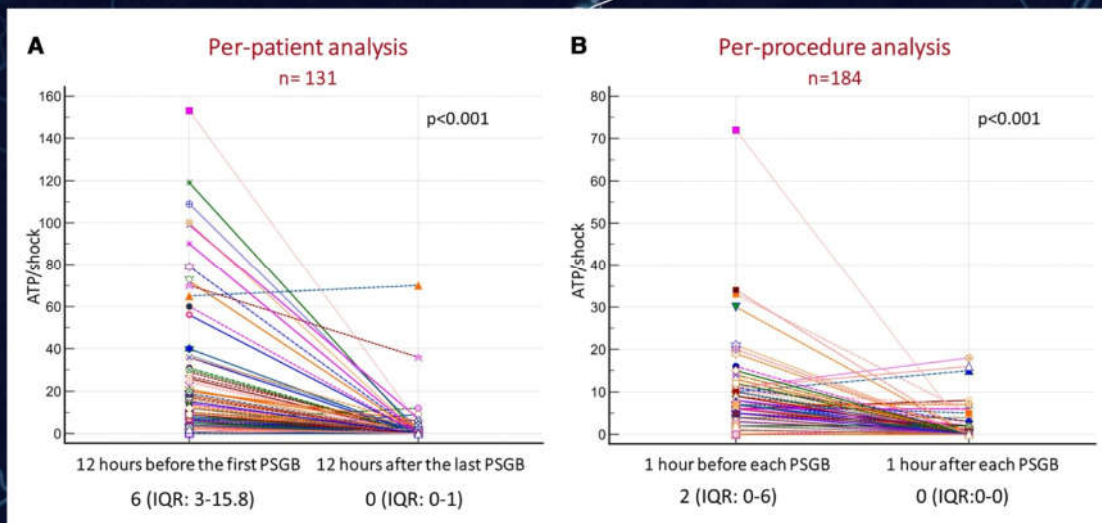
Left Stellate Ganglion Block cont.

PSGB major complications, <i>n</i> (%) ^a	
Respiratory depression	1 (0.5)
PSGB minor complications, <i>n</i> (%) ^a	
Bradycardia	1 (0.5)
Hypotension	1 (0.5)
PSGB described side effects, <i>n</i> (%) ^a	
Temporary brachial plexus paralysis	3 (1.6)
Hoarseness	2 (1.1)
Dysphonia	1 (0.5)
Neck pain	1 (0.5)
Vomiting	1 (0.5)

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Left Stellate Ganglion Block cont.



SAVASTANO ET AL; EUR HEART J,
VOLUME 45, ISSUE 10 MARH 2024

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Left Stellate Ganglion Block cont.

• STAR STUDY RESULTS

- 1 (0.5%) Major Adverse event (Respiratory Depression)
- Significant decrease both post procedurally and at 12 hours in the number of arrhythmia / ATP events
- No significant differences between bolus and infusion
- No significant differences between anatomic and ultrasound approach
- Similar efficacy at low and high-volume centers

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SECTION 10 | CASE CONCLUSIONS

Case Conclusions



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Introduction

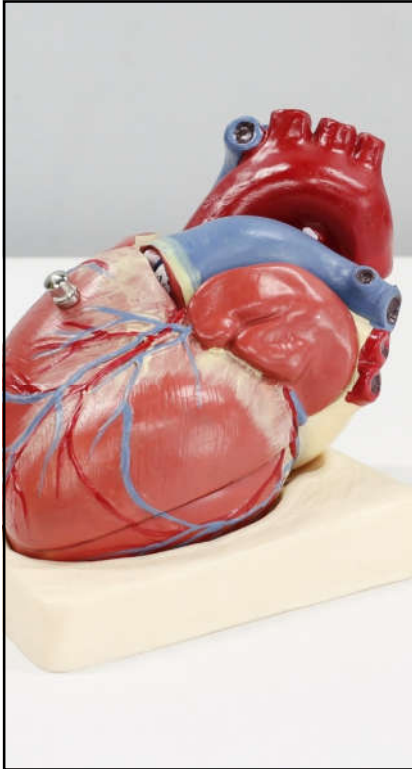
35 YO M UNKNOWN PMHX WITNESSED ARREST WITH POLYMORPHIC VT (PMVT) AS INITIAL RHYTHM

- Pain Control, Anxiolysis
- Treat Underlying Causes: Low K, Mg, Ca
- Overdrive Pacing
- Lidocaine
- Mechanical Support and Sympathetic Blockade if needed



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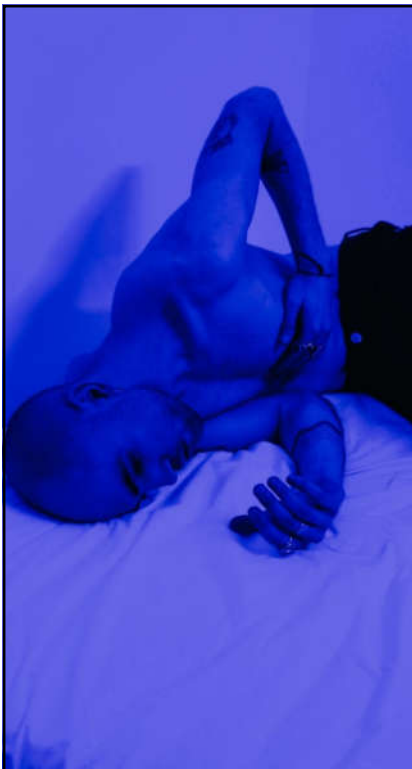


Introduction

45 YO F PMHX OF NONISCHEMIC CARDIOMYOPATHY WITH AICD PRESENTING WITH MULTIPLE SHOCKS

- Confirm that this is not a phantom nor inappropriate shock
- Cardiology consult to reprogram intervals
- Analgesics, Anxiolytics or deep sedation as needed
- Underlying causes: infection, medication nonadherence, electrolytes, etc.
- Amiodarone, Lidocaine
- MCS
- Beta blockade

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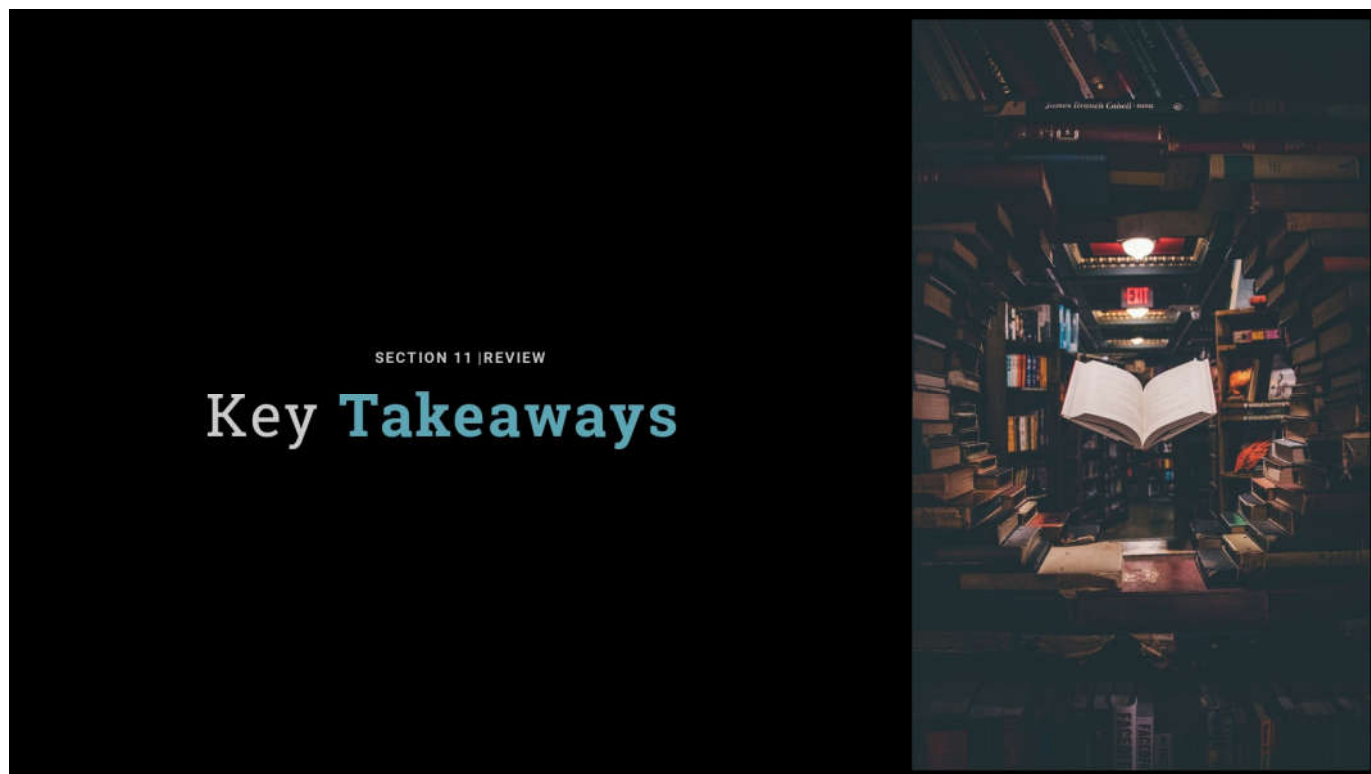
Introduction

55 YO M PMHX OF DM, HTN, HLD WITH CHEST PAIN WHO WAS FOUND DOWN

- Avoid additional use of epinephrine
- Sedation, Intubation
- Treat underlying cause: ASA, Heparin, Activate Cath Lab
- Overdrive Pacing
- Amiodarone, Lidocaine
- ECMO if available and unable to stabilize for revascularization
- Sympathetic Blockade if arrhythmia is incessant

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— SALIENT POINTS —

- 1 | ELECTRICAL STORM IS A DEVASTATING CONDITION WITH HIGH MORTALITY
- 2 | UNDERSTANDING THE DIFFERENT TYPES OF VENTRICULAR ARRHYTHMIAS WILL GUIDE TREATMENT
- 3 | IN GENERAL: S.T.O.R.M.S.
 1. Early Sedation / Anxiolysis
 2. Treat any underlying causes
 3. Consider Overdrive Pacing
 4. Rhythm Control with Amiodarone and Lidocaine
 5. Consider Advanced Mechanical Support and Sympathetic Blockade

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