A Split Second From Disaster: Management of R-on-T Phenomenon

A presentation for HealthTrust Members
June 3, 2026

Madison Spicer, PharmD
PGY1 Pharmacy Resident
HCA Florida Memorial Hospital
Jacksonville, FL

Preceptor: Carol W. Barthel, PharmD
Pharmacy Clinical Manager
Memorial Hospital Jacksonville

CONFIDENTIAL – Contains proprietary information. Not intended for external distribution.

Disclosure Statement

- Neither the presenter nor her preceptor have conflicts of interest related to this presentation.
- This program may contain the mention of suppliers, brands, products, services or drugs presented in a case study or comparative format using evidence-based research. Such examples are intended for educational and informational purposes and should not be perceived as an endorsement of any supplier, brand, product, service or drug.
- The content presented is for informational purposes only & is based upon the presenter(s) knowledge & opinion. It should not be relied upon without independent consultation with & verification by appropriate professional advisors. Individuals & organizations shall have sole responsibility for any actions taken in connection with the content herein. HealthTrust, the program presenter(s) & their employers expressly disclaim any & all warranties as to the content as well as any liability resulting from actions or omissions of any individual or organization in reliance upon the content.

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

Abbreviations

- ECG: Electrocardiogram
- PVT: Polymorphic Ventricular Tachycardia
- TdP: Torsades dePointes
- CPB: Cardiopulmonary bypass
- CABG: Coronary artery bypass grafting
- OR: Operating Room
- HR: Heart rate
- NYHA: New York Heart Association
- Bpm: Beats per minute
- PVC: Premature ventricular contraction

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Learning Objectives

- After this presentation, participants will be able to:

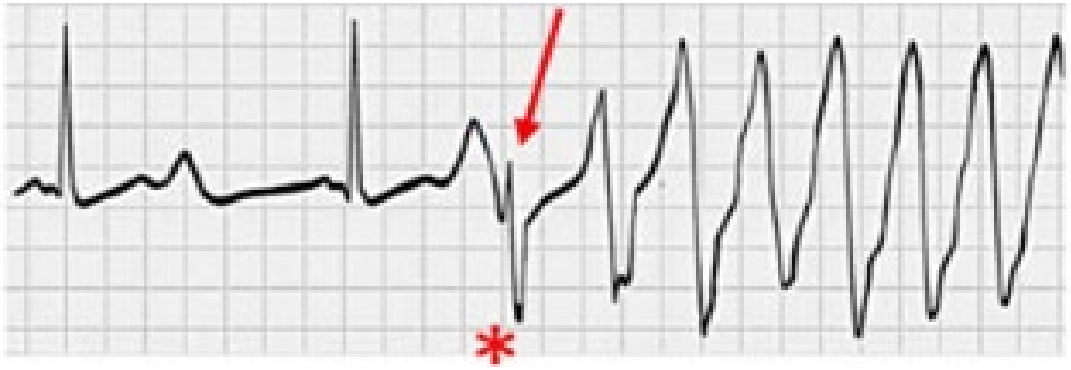
1. Identify the mechanism of R-on-T phenomenon.
2. Recognize common pharmacologic and nonpharmacologic causes of R-on-T phenomenon.
3. Recall management of R-on-T phenomenon.

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

What is R-on-T Phenomenon?

- Definition:
  - When the R wave of a PVC coincides with the T wave.
- Can trigger a life-threatening ventricular arrhythmia:
  - During acute myocardial infarction
  - In severe hypokalemia
  - In prolonged QT interval



 Source: Liu MB, et al. *Circ Arrhythm Electrophysiol*. 2019;12:e007571.

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Pathophysiology

- **Initiation of reentry by R-on-T mechanism:**
  - Autonomic reentry
  - Functional reentry
  - Electrical/mechanical reentry
- **Mechanisms of reentry:**
  - Early afterdepolarizations
  - Delayed afterdepolarizations
  - Automaticity

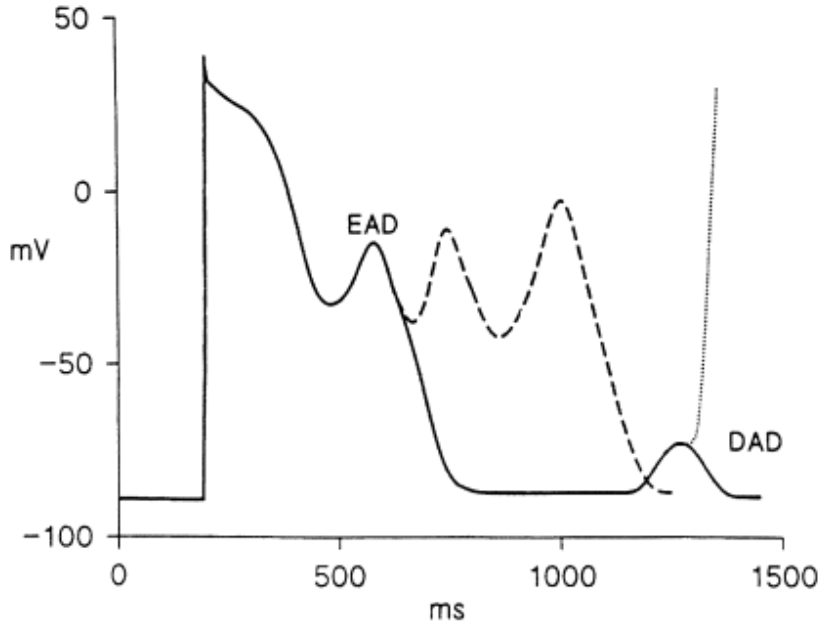


Image Source: Fozzard, HA. Cardiac Adaptation in Heart Failure. Steinkopff. 1992.

Sources: Qu Z, et al. *Heart Rhythm*. 2022 Aug;19(8):1369-1383.
Weiss J, et al. *Heart Rhythm*, 2010; 7:1891-1899.

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Clinical Manifestations

- Sign/Symptoms
  - Chest pain or palpitations
  - Dizziness
  - Syncope
  - Shortness of breath
  - Loss of consciousness
  - Tachycardia
  - Sudden cardiac arrest

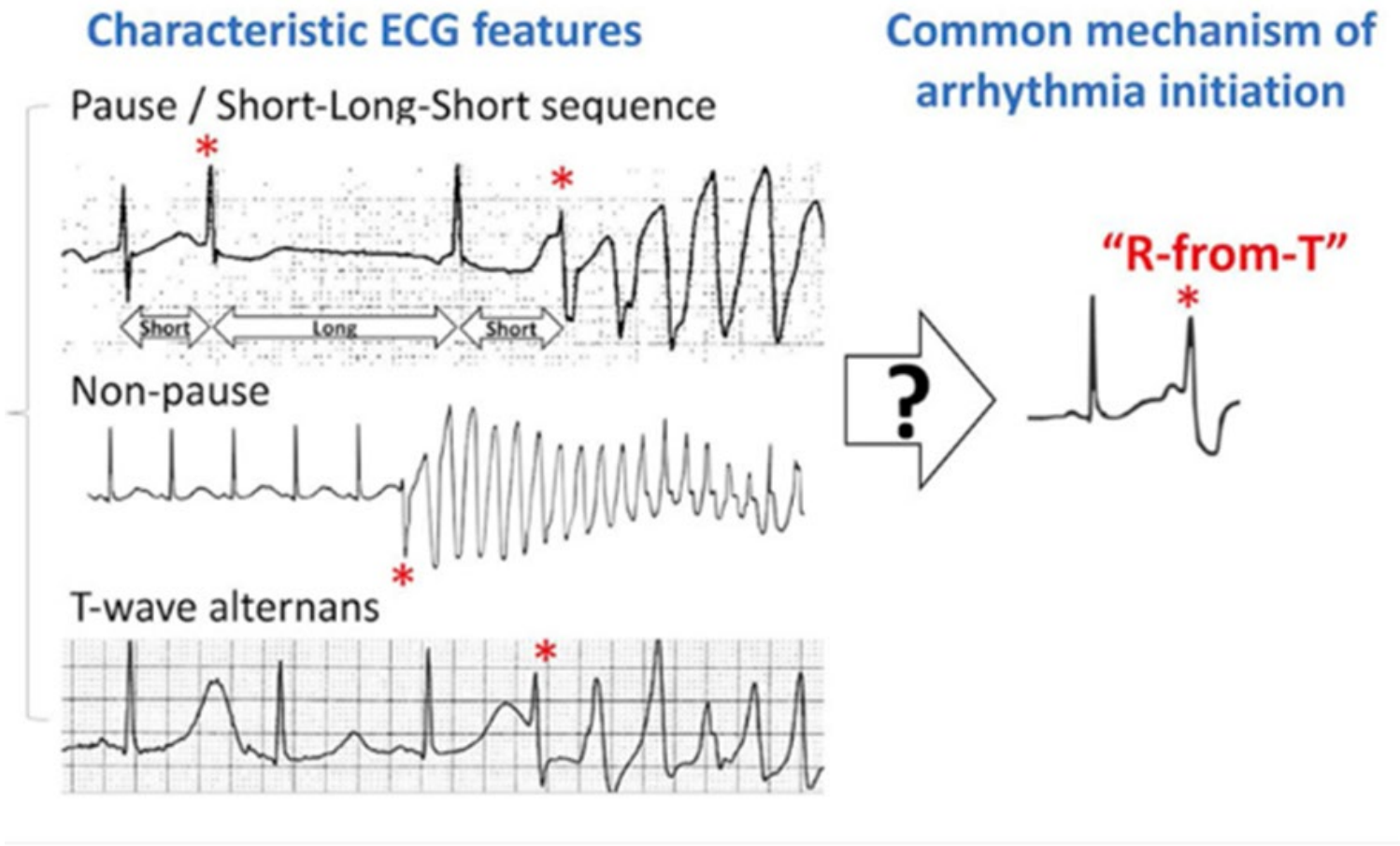
Sources: El-Sherif N, et al. *Heart*. 1976; 38:415-422.
Oksuz F, et al. *Indian Heart J.* 2015 Jul-Aug;67(4):392-4.

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Diagnosis

- Initial premature ventricular complex (PVC) with a wide QRS complex (>0.12 seconds)
- 12-Lead ECG/Telemetry:
  - Visual of the early PVC striking the T-wave.
  - Premature beat that lands on the T wave

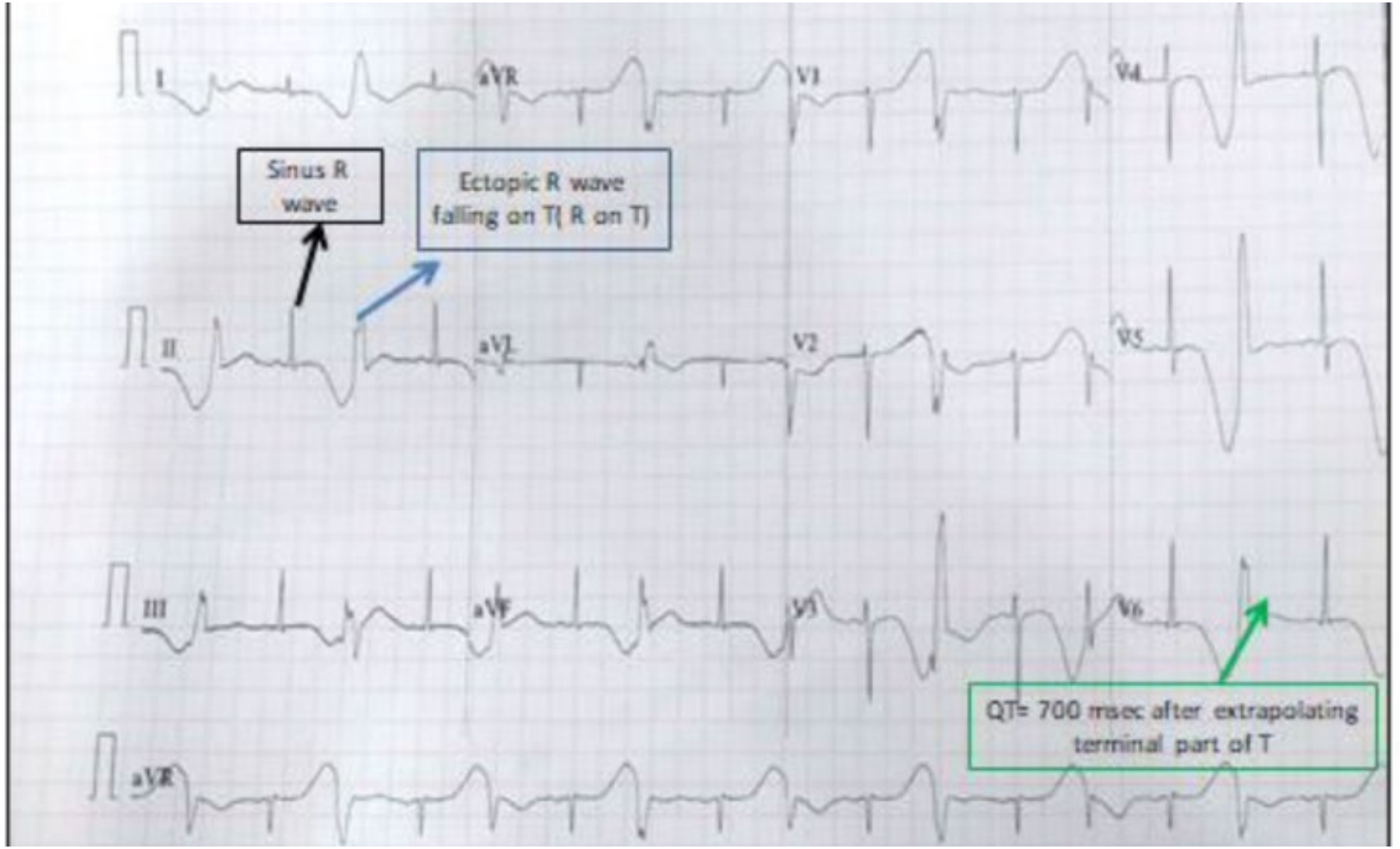


Source: Liu MB, et al. *Circ Arrhythm Electrophysiol*. 2019;12:e007571.

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

R-on-T Phenomenon

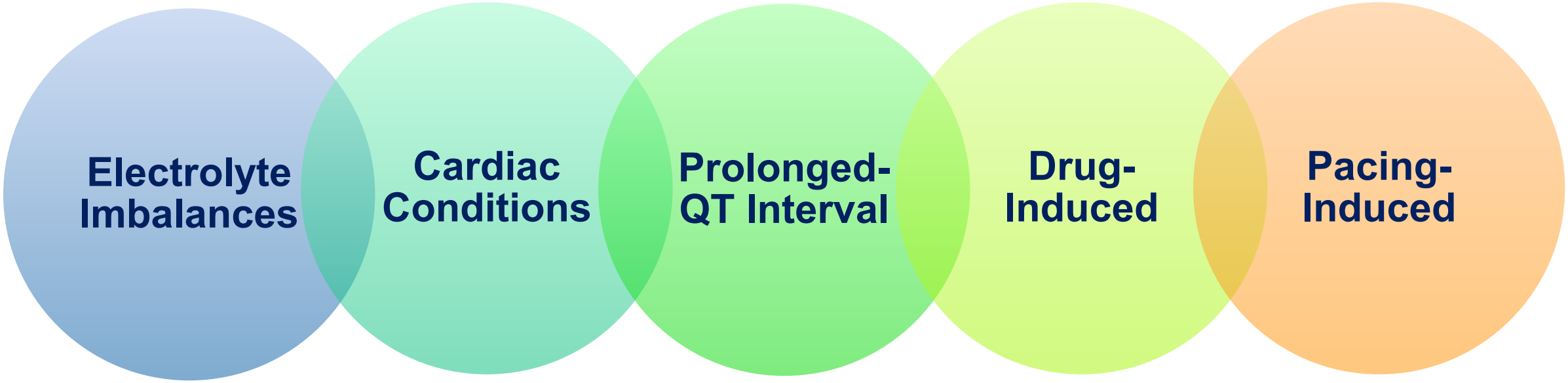


Source: Manhanta DS, et al. *Visual Journal of Emergency Medicine*. 2023;32:2405-4690.

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Precipitating Factors



Source: Manhanta DS, et al. *Visual Journal of Emergency Medicine*. 2023;32:2405-4690.

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Electrolyte Imbalances Contributing to R-on-T

- Imbalances can delay repolarization and prolong the QT interval
  - Hyperkalemia (> 5 mEq/L)
  - Hypokalemia (< 3.5 mEq/L)
  - Hypomagnesemia (<1.3 mEq/L)
  - Hypocalcemia (<2.5 mg/dL)

 Source: *Circulation*. 2005. 24:IV121-25.

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Cardiac Conditions Contributing to R-on-T

- Myocardial infarction
- Acute myocardial ischemia
- Congestive heart failure
- Congenital heart conditions
- Hypertrophic cardiomyopathy

Source: Manhanta DS, et al. *Visual Journal of Emergency Medicine*. 2023;32:2405-4690.

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Medications Contributing to R-on-T

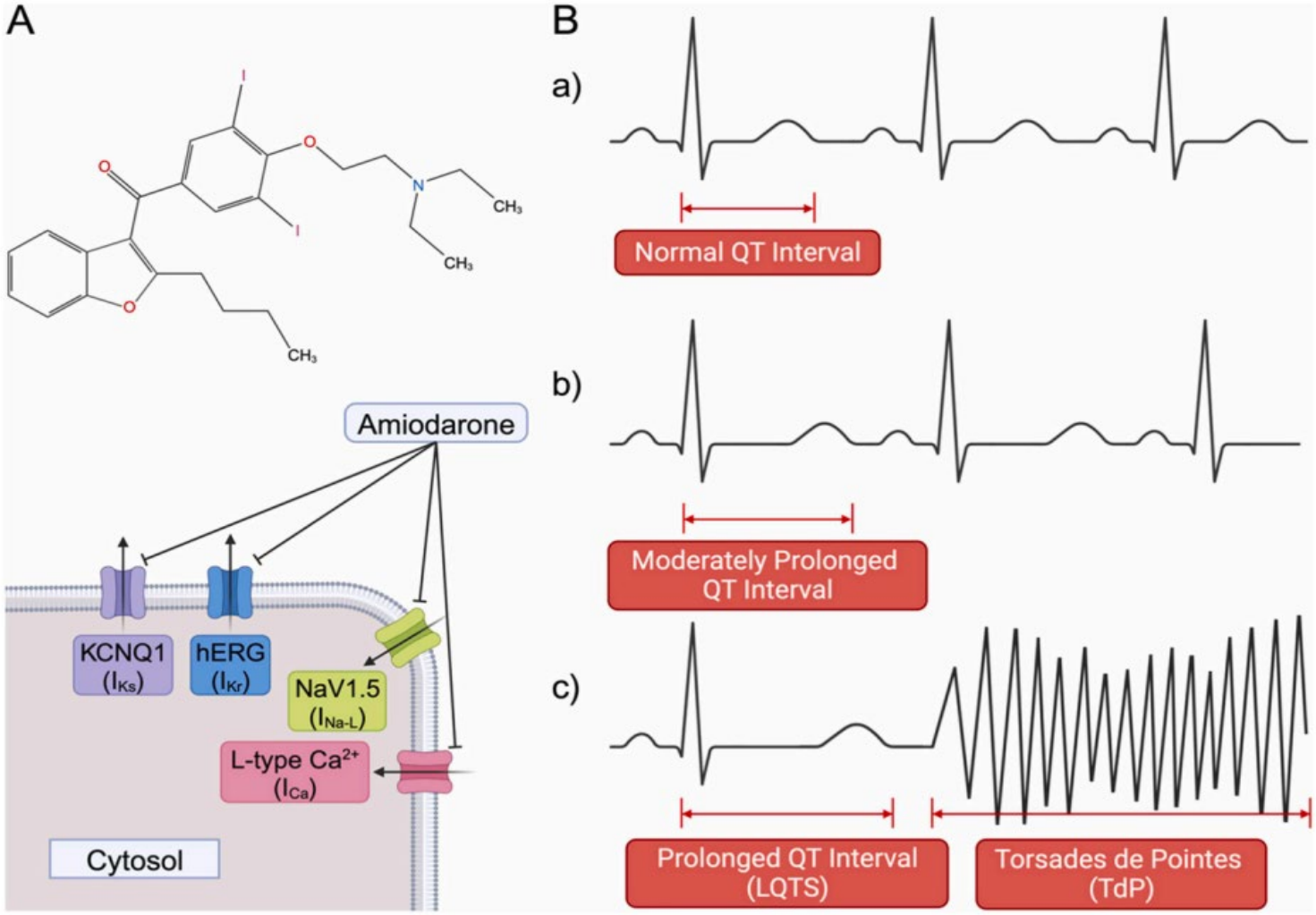
Antiarrhythmics	Antibiotics	Other
Amiodarone* Droperidol Dofetilide Procainamide Quinidine Sotalol	Clarithromycin Erythromycin Fluoroquinolones (Ciprofloxacin, Levofloxacin, moxifloxacin, etc.)	Chloroquine Chlorpromazine Haloperidol Methadone

 Source: Drew BJ, et al. *Circulation*. 2010;121:1047–60.

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Amiodarone-induced R-on-T Phenomenon



Source: Gelman I, et al. *Biomedicine & Pharmacotherapy*. 2024; 174:116513.

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Knowledge Review #1

Which of the follow best describes the mechanism of R-on-T phenomenon?

a) A PAC occurring after the QRS complex

b) Delayed atrioventricular nodal conduction

c) A PVC occurring during ventricular repolarization

d) A PVC occurring during ventricular depolarization

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Knowledge Review #1

Which of the follow best describes the mechanism of R-on-T phenomenon?

a) A PAC occurring after the QRS complex

b) Delayed atrioventricular nodal conduction

c) A PVC occurring during ventricular repolarization

d) A PVC occurring during ventricular depolarization

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

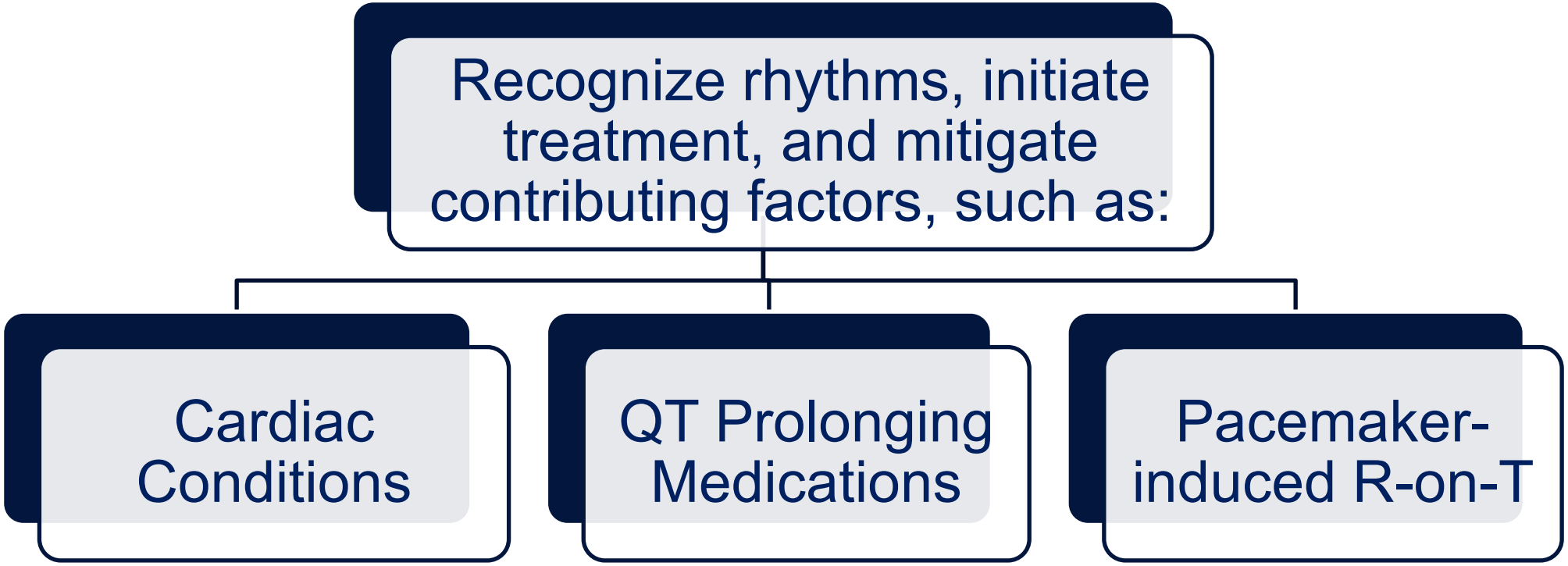
HCA Florida Healthcare®

Pacemaker-induced R-on-T Phenomenon

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Management of R-on-T Phenomenon



Goal: To correct and/or prevent life-threatening arrythmias

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Pacing-induced R-on-T Phenomenon

Administer Magnesium Sulfate 2 grams IV x 1, then repeat with 2 grams IV, if necessary (total 4 grams in 1 hour), then may start a continuous infusion.

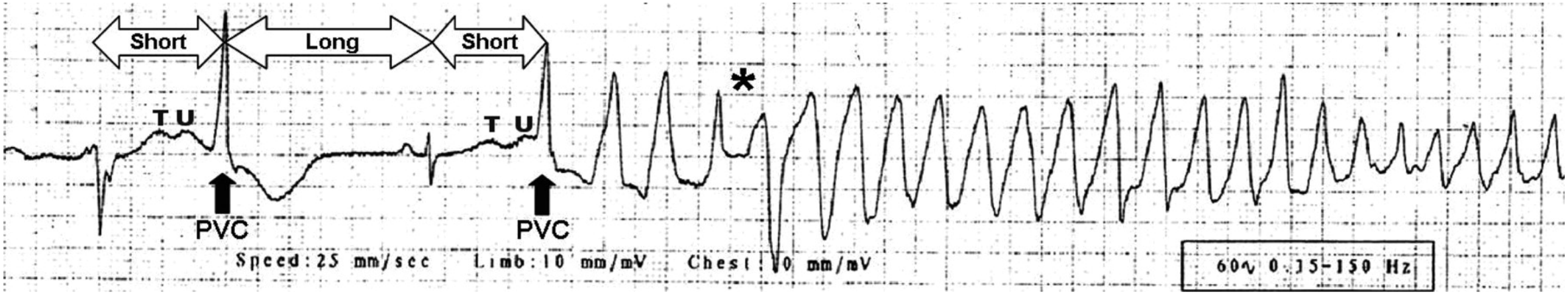
Check and correct electrolytes urgently: magnesium ≥2.0 mEq/L and consider targeting potassium ≥4.5 mEq/L

Source: Nakamori Y, et al. *JA Clin Rep*. 2016;2(1):3.

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Torsades dePointes (TdP)



Administer Magnesium Sulfate 2 grams IV x 1, then repeat with 2 grams IV, if necessary (total 4 grams in 1 hour), then may start a continuous infusion.

Check and correct electrolytes urgently: magnesium ≥2.0 mEq/L and consider targeting potassium ≥4.5 mEq/L

 Source: Drew BJ, et al. *Circulation*. 2010;121:1047–60.

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Torsades dePointes (TdP) Case Report #1

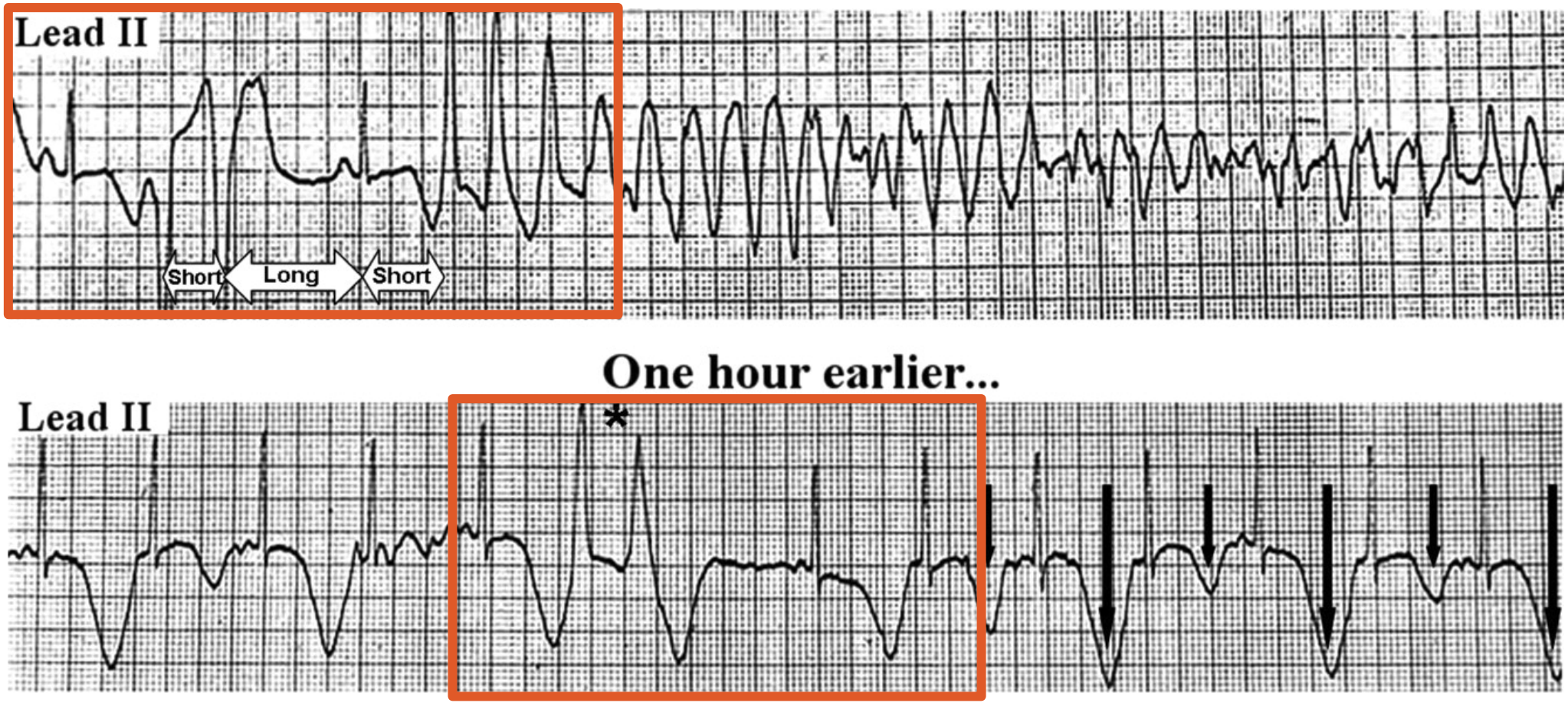
Chief Complaint	• 83-year-old female hospitalized in the ICU for pneumonia
Past Medical History	• Not reported
Clinical Course	• Initiated on IV erythromycin for pneumonia • Several hours later, the patient experienced a cardiac arrest

 Source: Drew BJ, et al. *Circulation*. 2010;121:1047–60.

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Torsades dePointes (TdP) Case Report #1



Source: Drew BJ, et al. *Circulation*. 2010;121:1047–60.

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Torsades dePointes (TdP) Case Report #1

Outcome

- Drug-induced QT-prolongation leading to TdP

Recommendation

- Discontinuation of QT-prolonging agent
- Administration of IV magnesium

Summary

- Prompt interpretation and treatment of TdP is necessary to promote positive outcomes.
- It's important to ensure all contributing agents are discontinued

 Source: Drew BJ, et al. *Circulation*. 2010;121:1047–60.

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Pacemaker-Induced R-on-T: Case Report #2

Chief Complaint	• 65-year-old male undergoing a mitral valve replacement, tricuspid annuloplasty, and maze surgery.
Past Medical History	• Atrial fibrillation, severe mitral valve regurgitation, moderate tricuspid regurgitation, heart failure with reduced ejection fraction (NYHA class II).
Pre-procedural Workup	• HR: 65 bpm • ECG: baseline atrial fibrillation, narrow QRS, no QT prolongation noted.
Procedure	• Required VVI pacing at 50 bpm due to experiencing bradycardia and AV block when withdrawing from CPB

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Pacemaker-Induced R-on-T: Case Report #2

Chief Complaint	• 65-year-old male undergoing a mitral valve replacement, tricuspid annuloplasty, and maze surgery.
Past Medical History	• Atrial fibrillation, severe mitral valve regurgitation, moderate tricuspid regurgitation, heart failure with reduced ejection fraction (NYHA class II).
Pre-procedural Workup	• HR: 65 bpm • ECG: baseline atrial fibrillation, narrow QRS, no QT prolongation noted.
Procedure	• Required VVI pacing at 50 bpm due to experiencing bradycardia and AV block when withdrawing from CPB

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

Pacemaker-Induced R-on-T: Case Report #2

Post-procedure Workup	• Sodium: 143 mEq/L • Potassium 4.4 mEq/L • Chloride: 116 mEq/L • Standard base excess: - 3.1 mmol/L • HR: 30 bpm post-procedure
Post-operative Management	• The VVI pacing was then adjusted to 90 bpm, due to heart rate of 30 bpm.
ECG Findings	• Patient then developed two episodes of VF requiring defibrillation while transferring to the ICU.

 Source: Nakamori Y, et al. *JA Clin Rep*. 2016;2(1):3.

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Pacemaker-Induced R-on-T: Case Report #2

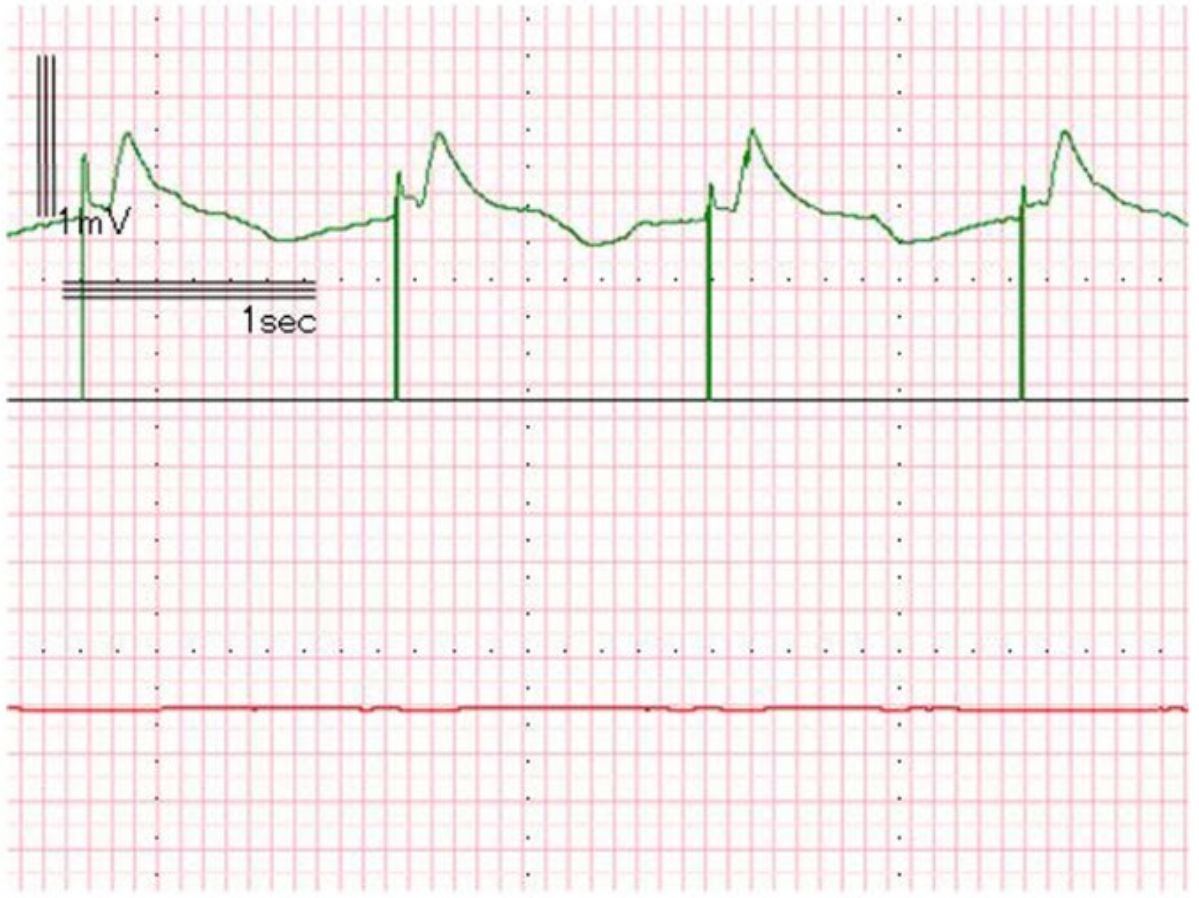


Fig. 1 ECG and pressure waveform at 50 bpm VVI pacing. Each VVI pacing spike captures a QRS wave

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Pacemaker-Induced R-on-T: Case Report #2

Fig. 2 ECG and pressure waveform showing Mobitz type AV block. Each AOO pacing spike captures a P wave, but every third P wave does not induce a QRS wave

 Source: Nakamori Y, et al. *JA Clin Rep*. 2016;2(1):3.

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Pacemaker-Induced R-on-T: Case Report #2

Fig. 3 ECG and pressure waveform during the first episode of ventricular fibrillation. This ECG shows the R-on-T phenomenon resulting from undersensing of a PVC. A pacing spike hit the T wave (large arrow) following a PVC (small arrow)

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Pacemaker-Induced R-on-T: Case Report #2

Fig. 4 ECG and pressure waveform during the second episode of ventricular fibrillation. This ECG also shows the R-on-T phenomenon resulting from undersensing of a PVC. A pacing spike hit the T wave (large arrow) following a PVC (small arrow) in this episode, as well

 Source: Nakamori Y, et al. *JA Clin Rep*. 2016;2(1):3.

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Pacemaker-Induced R-on-T: Case Report #2

Intervention

- External defibrillation (270 Joules) during both episodes of VF.
- Pacemaker sensing threshold lowered (10 mV to 2 mV).
- Switched to AOO pacing mode (70 bpm).

Outcome

- Return to normal Sinus Rhythm
- No further VF events occurred after defibrillation and pacing interventions.

Summary

- Rapid defibrillation is necessary to promote positive outcomes.
- Adjustments of the external pacemaker were crucial in preventing further occurrences of R-on-T and subsequent arrythmias.

 Source: Nakamori Y, et al. *JA Clin Rep*. 2016;2(1):3.

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Pacemaker-Induced R-on-T: Case Report #3

Chief Complaint	• 65-year-old male who presented for a CABG procedure
Past Medical History	• Hypertension, pulmonary vascular disease, chronic obstructive pulmonary disease
Procedure	• Underwent CABG procedure. • Temporary epicardial pacing wires were left in place for backup pacing.

Source: Chemello D, et al. *Can J Cardiol*. 2010;26(1):e13-e14.

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Pacemaker-Induced R-on-T: Case Report #3

Post-procedure Pacing	• After 24 hours, patient developed sinus bradycardia, requiring temporary ventricular pacing. • Settings: VVI mode with backup pacing at 50 bpm
Laboratory Findings	• Electrolytes: Potassium: 3.8 mEq/L, magnesium: 0.6 mEq/L
Cardiac Event	• ECG findings: PVT identified, corrected QTc 440 ms.

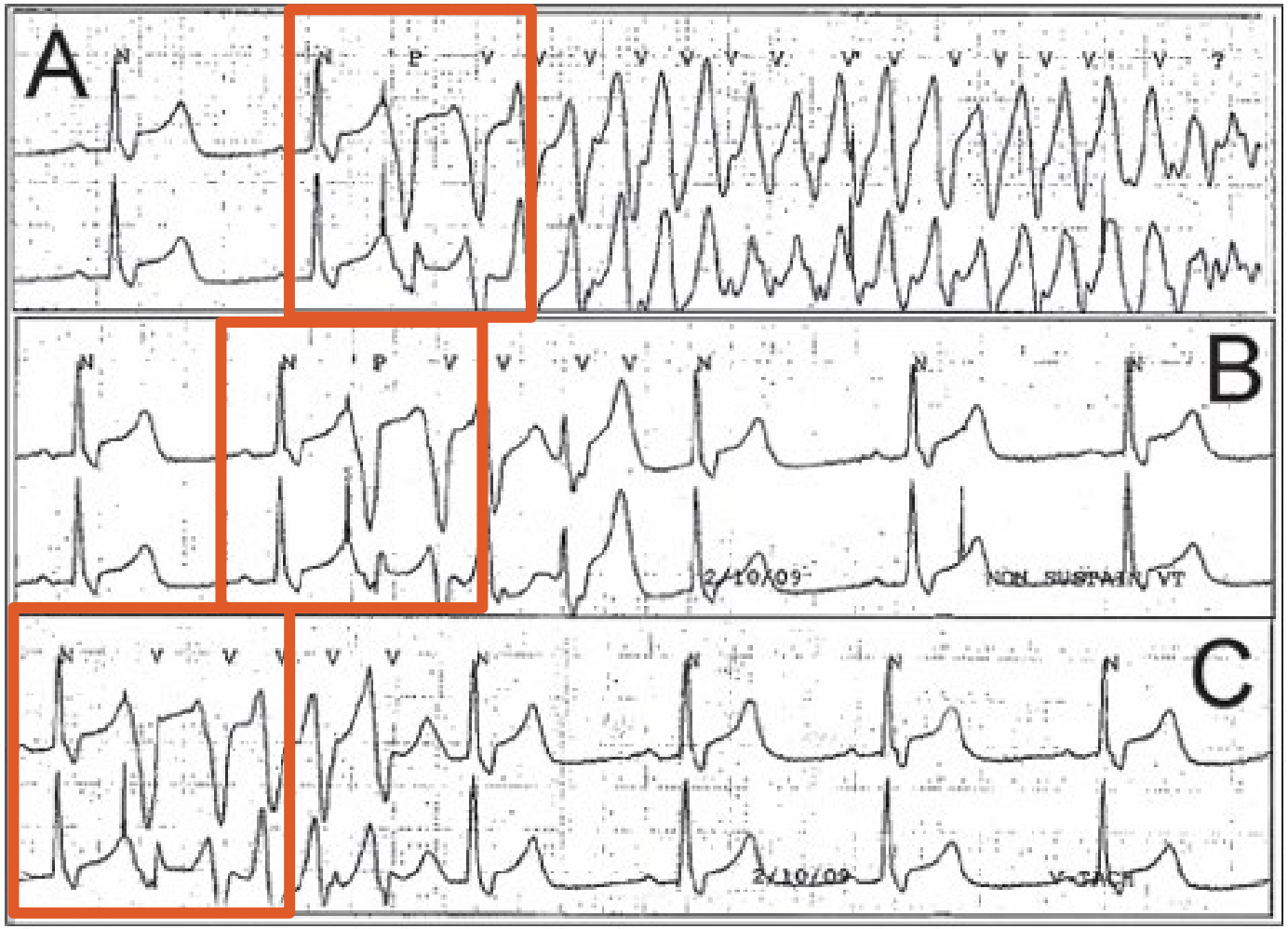
Source: Chemello D, et al. *Can J Cardiol*. 2010;26(1):e13-e14.

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Pacemaker-Induced R-on-T: Case Report #3

Pacemaker Evaluation	• Intermittent loss of R-wave sensing leading to asynchronous pacing
Diagnosis	• R-on-T Phenomenon triggering polymorphic VT and cardiac arrest



Source: Chemello D, et al. *Can J Cardiol*. 2010;26(1):e13-e14.

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Pacemaker-Induced R-on-T: Case Report #3

Intervention

- Pacemaker interrogation and deactivation.
- Likely contributing factors: intermittent loss of sensing, post-CABG, temporary epicardial wire dysfunction.

Outcome

- Patient stabilized and return to normal sinus rhythm.
- No additional arrythmias were reported during the patient's admission.

Summary

- R-on-T phenomenon can be triggered by temporary epicardial pacemaker sensing failures.
- Early recognition of R-on-T pacing may prevent subsequent life-threatening arrythmias and cardiac arrest.

Source: Chemello D, et al. *Can J Cardiol*. 2010;26(1):e13-e14.

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Monitoring

- Monitor telemetry continuously until the QTc normalizes and R-on-T pattern dissipates.
- Routine ECG monitoring
- Daily electrolyte monitoring and adjustments, as necessary.
- Perform a medication reconciliation and discontinue any QT-prolonging medications.

Source: Drew BJ, et al. *Circulation*. 2010;121:1047–60.

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Knowledge Review #2

Which of the following is a common pharmacologic cause of R-on-T phenomenon?

A) Moxifloxacin

B) Lisinopril

C) Atorvastatin

D) Metformin

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Knowledge Review #2

Which of the following is a common pharmacologic cause of R-on-T phenomenon?

A) Moxifloxacin

B) Lisinopril

C) Atorvastatin

D) Metformin

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Knowledge Review #3

Which of the following medications is contraindicated for use in R-on-T phenomenon?

A) Lidocaine

B) Amiodarone

C) Procainamide

D) Metoprolol tartrate

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Knowledge Review #3

Which of the following medications is contraindicated for use in R-on-T phenomenon?

A) Lidocaine

B) Amiodarone

C) Procainamide

D) Metoprolol tartrate

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Summary

- Lack of clinical evidence and guidance provided regarding the occurrence of R-on-T phenomenon.
- Recognizing R-on-T phenomenon promptly is crucial to preventing precipitating life-threatening arrythmias.
- Providers and disciplinary team members should be well educated on the precipitating factors of R-on-T for optimal patient care.

 Source: Drew BJ, et al. *Circulation*. 2010;121:1047–60.

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

References

1) Miret R, Martinez Nunez A, Almanzar Zorrilla C, et al. A pacemaker goes rogue: cardiac arrest due to R-on-T phenomenon. *CHEST*. 2023 Oct;164(4): 2105-2106.
2) Oksuz F, Sensoy B, Sahan E, et al. The classical "R-on-T" phenomenon. *Indian Heart J.* 2015 Jul-Aug;67(4):392-4.
3) Engel TR, Meister SG, Frankl WS, et al. The "R-on-T" Phenomenon: An Update and Critical Review. *Ann Intern Med*. 1978; 88:221-225.
4) Fries R, Steuer M, Schäfers H, et al. The R-on-T phenomenon in patients with implantable cardioverter-defibrillators. *American Journal of Cardiology*. 2003 Mar;91(6):752-55.
5) Smirk FH. WAVES INTERRUPTING T WAVES. *Heart,* 1949;11(1): 23-36.
6) El-Sherif N, Myerburg RJ, Scherlag BJ, et al. Electrocardiographic antecedents of primary ventricular fibrillation. Value of the R-on-T phenomenon in myocardial infarction. *Heart*. 1976; 38:415-422.
7) Liu MB, Vandersickel N, Panfilov AV, et al. R-From-T as a Common Mechanism of Arrhythmia Initiation in Long QT Syndromes. *Circ Arrhythm Electrophysiol*. 2019;12: e007571.
8) Naito M, Michelson EL, Kaplinsky E, et al. Role of early cycle ventricular extrasystoles in initiation of ventricular tachycardia and fibrillation: Evaluation of the R on T phenomenon during acute ischemia in a canine model. *The American Journal of Cardiology*. 1982; 49(2):317-322.
9) Gelman I, Sharma N, Mckeeman O, et al. The ion channel basis of pharmacological effects of amiodarone on myocardial electrophysiological properties, a comprehensive review. Biomedicine & Pharmacotherapy. 2024; 174:116513.
10) Mondal S, Vijay J, Namboodiri N. Pacing-induced R-on-T phenomenon: What is the mechanism? *Pacing Clin Electrophysiol.* 2024;47:650-652.

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

References

1) Oupadia P, Ramaswamy K. Images in clinical medicine. "R-on-T" phenomenon. *N Engl J Med*. 1998;338(25):1812.
2) Nakamori Y, Maeda T, Ohnishi Y. Reiterative ventricular fibrillation caused by R-on-T during temporary epicardial pacing: a case report. *JA Clin Rep*. 2016;2(1):3.
3) Zhao X, Li X, Liu C, et al. A new ECG sign for sudden death: Transient prolonged QT interval following premature contraction. Zhong Nan Da Xue Xue Bao Yi Xue Ban. 2021 Apr 28;46(4):444-448.
4) Qu Z, Liu MB, Olcese R, et al. R-on-T and the initiation of reentry revisited: Integrating old and new concepts. Heart Rhythm. 2022 Aug;19(8):1369-1383.
5) Nguyen AP, Sarmast SA, Kowal RC, et al. Cardiac arrest due to torsades de pointes in a patient with complete heart block: the "R-on-T" phenomenon. *Proc (Bayl Univ Med Cent)*. 2010;23(4):361-362.
6) Chemello D, Subramanian A, Kumaraswamy N. Cardiac arrest caused by undersensing of a temporary epicardialpacemaker. *Can J Cardiol*. 2010;26(1): e13-e14.
7) Lander MJ, Nikolic G. R-on-T phenomenon. *Heart Lung*. 2001;30(1):85-86.
8) Rosenbaum MB, Chiale PA, Haedo A, et al. Ten years of experience with amiodarone. *Am Heart J*. 1983; 106:957-964.
9) Sundaram C, Namboodiri N, Ajitkumar VK, et al. Two pacing spikes on the T wave in a single-chamber pacemaker: What isthe mechanism? *Indian Pacing Electrophysiol J*. 2022;22(1):42-43.
10) Manhanta DS, Barik RC, Acharya D. R on T phenomenon, a dangerous ECG sign. *Visual Journal of Emergency Medicine*. 2023; 32:2405-4690.
11) Drew BJ, Ackerman MJ, Funk M et al. Prevention of torsade de pointes in hospital setting: a scientific statement from the American Heart Association and the American College of Cardiology Foundation. *Circulation*. 2010; 121:1047–60.

CONFIDENTIAL – Contains proprietary information.
Not intended for external distribution.

HCA Florida Healthcare®

Thank You

Any Questions?

Madison Spicer, PGY1 Pharmacy Resident

Email: madison.spicer@HCAhealthcare.com

CONFIDENTIAL – Contains proprietary information. Not intended for external distribution.