Implantable Cardioverter Defibrillators (ICDs) Fundamentals Overview

Beth Davenport, MSN, CCDS, FHRS, Clinical Translation Specialist

BIOTRONIK
excellence for life

1

Objectives

- Review History of the ICD
- Discuss Indications
- Describe ICD Sensing & Detection
- Provide Basics of ICD Therapies & Diagnostics
- Present ICD Electrograms
- Review ICD Therapy Case Studies

BIOTRONIK
excellence for life

2

ICD System Historical Milestones

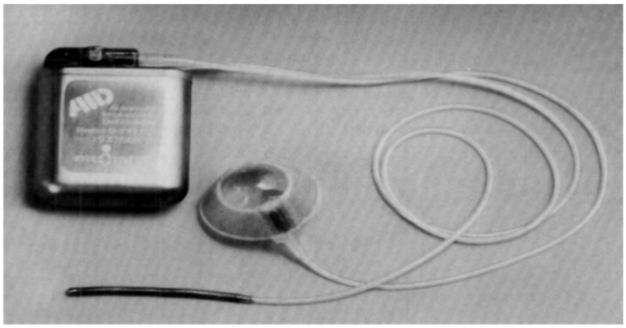
- 1966 Conception
- 1969 First experimental model
- 1969 First transvenous defibrillation
- 1975 First animal implant
- 1980 First human implant
- 1982 Addition of cardioverting capability
- 1985 FDA approval
- 1988 First programmable ICD implanted

Dr. Michel Mirowski
1924 - 1990

Mirowski M, Mower M, Staewen W, Tabatznick B, Mendeloff A, (1970), Standby automatic defibrillator. An approach to prevention of sudden coronary death. Arch Intern Med 126:158 - 161

BIOTRONIK excellence for life

3



1980

The original ICD device (Intec) had two electrodes:

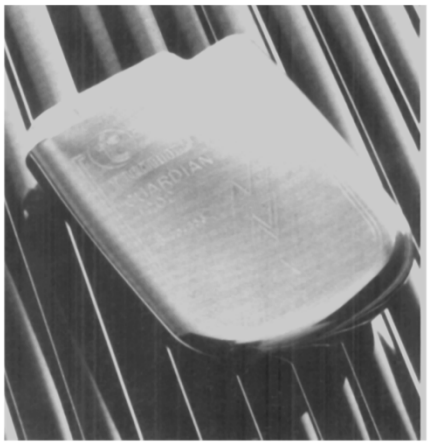
- One, a spring, was placed in the Vena Cava
- The other, a cup, designed to conform to the cardiac apex

BIOTRONIK excellence for life

4

1988

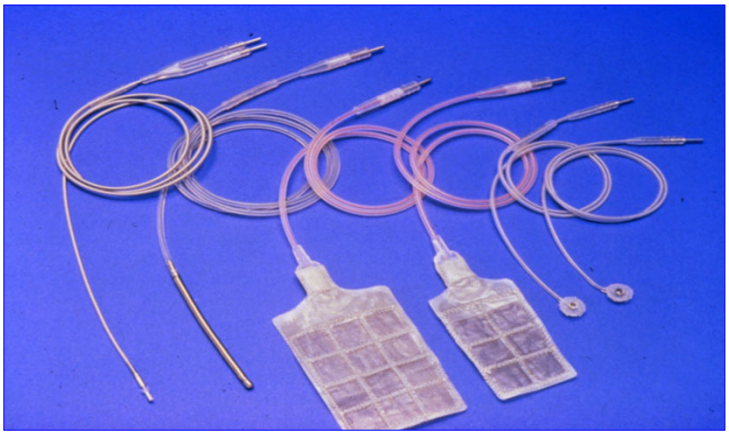
Telectronics developed the first ICD with an "on board" VVI pacemaker



BIOTRONIK excellence for life

5

ICD Lead History



BIOTRONIK excellence for life

6

ICD Evolution 1989 - 2000

BIOTRONIK excellence for life

7

Today's ICD

Bradycardia Pacing
- Dual chamber and CRT

Antitachycardia Pacing
- Multiple algorithms

Low-Energy Cardioversion
- Widely programmable

High-Energy Cardioversion
- Fast charge times
- Energy waveforms

Improved Algorithms
- AV discrimination
- Dual chamber sensing
- Detection enhancements
- Hemodynamic monitoring

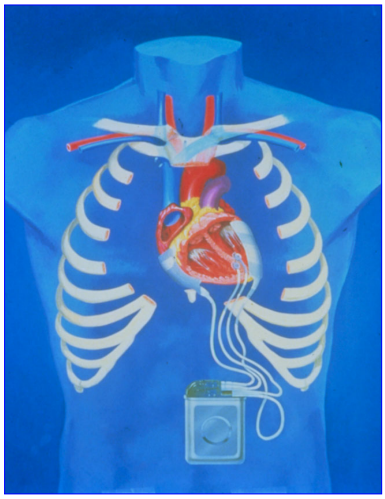
CIED Diagnostics
- Stored electrograms
- Device integrity
- Remote monitoring

BIOTRONIK excellence for life

8

The ICD Procedure – In the beginning

The patient admitted AFTER surviving Sudden Cardiac Death…



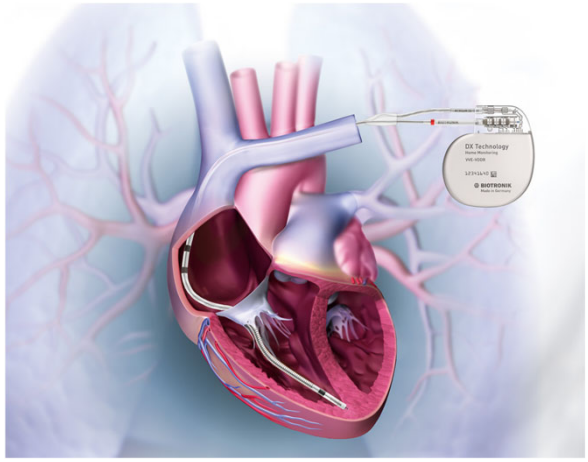
- EP testing required
- DFT testing routine
- Sternal thoracotomy
- Average 18 months battery longevity

BIOTRONIK excellence for life

9

The ICD Procedure - Now

Patient at high risk for SCD:



- Admitted as an outpatient majority of the time
- Discharged the same or next day
- DFTs only performed in select patients
- 8+ years battery longevity common

BIOTRONIK excellence for life

10

ICD Indications: Primary

Primary Prevention Guidelines:

- ICD therapy is recommended to reduce total mortality by a reduction in SCD in patients who have ischemic heart disease and whose MI was greater than 40 days ago, with EF less than 30%, NYHA II or III symptoms and optimal medical therapy
- ICD therapy is recommended to reduce total mortality by a reduction in SCD in patients with non-ischemic cardiomyopathy, EF less than 30%, NYHA II or III symptoms with optimal medical therapy

(Primary = Prevention)

2017 AHA/ACC/HRS Guideline for Management of Patients With Ventricular Arrhythmias and the Prevention of Sudden Cardiac Death
A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines and the Heart Rhythm Society
Sana M. Al-Khatib, Michael J. Ackerman,William J. Bryant,David J. Callans,Anne B. Curtis,Barbara J. Deal,Timm Dickfeld Michael E. Field,Gregg C. Fonarow,Anne M. Gillis,Christopher B. Granger,Stephen C. Hammill,Mark A. Hlatky,José A. Joglar,G. Neal KayDaniel D. Matlock,Robert J. Myerburg andRichard L. Page
Originally published1 Aug 2018https://doi.org/10.1161/CIR.0000000000000549Circulation. 2018;138:e272–e391

11

ICD Indications: Secondary

- Cardiac arrest due to VF or VT not due to a transient or reversible cause
- Nonsustained VT with CAD, previous MI, left ventricular dysfunction, and inducible VF or sustained VT at EP study not suppressible by Class I antiarrhythmic drug
- Spontaneous sustained VT in a normal heart when alternative therapies have failed
- Syncope of undetermined origin with clinically relevant, hemodynamically significant sustained VT or VF induced at EP study when drug therapy is ineffective, not tolerated or not preferred

2017 AHA/ACC/HRS Guideline for Management of Patients With Ventricular Arrhythmias and the Prevention of Sudden Cardiac Death
A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines and the Heart Rhythm Society
Sana M. Al-Khatib, Michael J. Ackerman,William J. Bryant,David J. Callans,Anne B. **Curtis**,Barbara J. Deal,Timm Dickfeld Michael E. Field,Gregg C. Fonarow,Anne M. Gillis,Christopher B. Granger,Stephen C. Hammill,Mark A. Hlatky,José A. Joglar,G. Neal KayDaniel D. Matlock,Robert J. Myerburg andRichard L. Page
Originally published1 Aug 2018https://doi.org/10.1161/CIR.0000000000000549Circulation. 2018;138:e272–e391

12

Common Diagnosis/Indications for ICD, CRT-Defibrillator Implant

Why did the patient receive the implant?

- Cardiac arrest
- Ventricular tachycardia (VT)
- Ventricular fibrillation (VF)
- Ischemic cardiomyopathy
- Non-ischemic cardiomyopathy
- Left ventricular (LV) dysfunction due to prior myocardial infarction (MI), minimum 40 days post-MI, LV ejection fraction (EF) < 30% with New York Heart Association (NYHA) functional class I heart failure (HF)
- Hypertrophic cardiomyopathy
- Brugada syndrome
- Catecholaminergic polymorphic VT (CPVT) with syncope
- Cardiac sarcoidosis
- Arrhythmogenic right ventricular dysplasia (ARVD)
- Long QT syndrome

Courtesy of Amy Tucker, MSN, RN, CCDS Sanger Heart & Vascular Institute

BIOTRONIK excellence for life

13

Indications for Implantable Cardioverter-Defibrillator (ICD) in Patients with Ischemic Heart Disease (IHD) to Prevent Sudden Cardiac Death (SCD)

Patient with ischemic heart disease (IHD) with a meaningful survival >1 year expected

Do all of the following apply?

- Low left ventricular ejection fraction (LVEF) due to IHD
- ≥40 days post-myocardial infarction
- ≥90 days postrevascularization

If LVEF ≤ 35%

- NYHA class II or III HF despite guideline-directed management and therapy

Yes

If LVEF ≤ 30%

- NYHA class I HF despite guideline-directed management and therapy

Yes

ICD is recommended for the **primary** prevention of SCD

OR

Do any of the following apply?

- Sudden cardiac arrest due to ventricular tachycardia (VT) or ventricular fibrillation (VF)*
- Hemodynamically unstable VT*
- Stable VT*
- Unexplained syncope plus inducible sustained monomorphic VT on EP study

Yes

ICD is recommended for the **secondary** prevention of SCD

*Not due to reversible causes. Al-Khatib, S.M., et al. J Am Coll Cardiol. 10.1016/j.jacc.2017.10.052

BIOTRONIK excellence for life

14

Sensing: Two Important Definitions

SENSITIVITY

The ability of the ICD to **detect** VT 100% of the time for fast arrhythmias

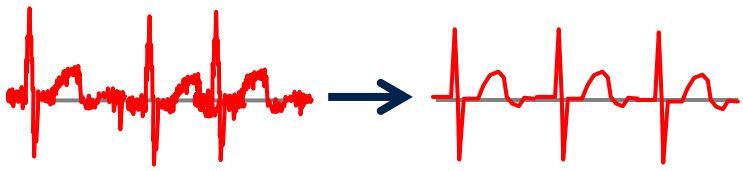
SPECIFICITY

The ability of the ICD to **discriminate** between VTs and SVTs

BIOTRONIK excellence for life

15

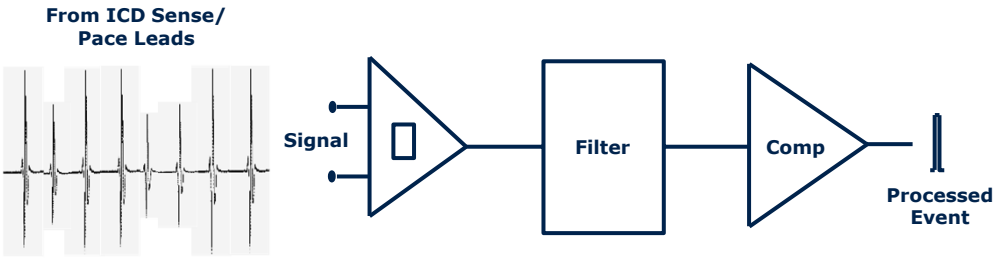
Sensing



BIOTRONIK excellence for life

16

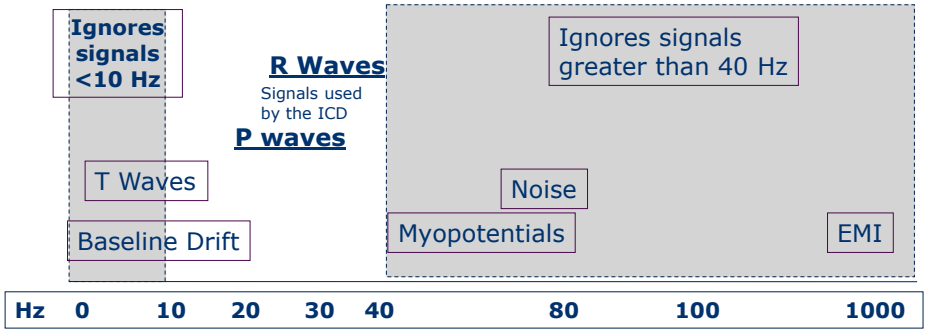
Sensing



BIOTRONIK excellence for life

17

High and Low Bandpass Filters



BIOTRONIK excellence for life

18

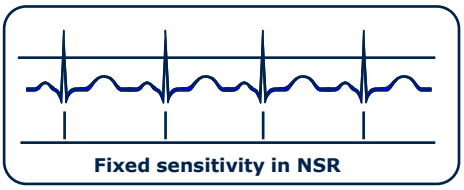
ICD Signal Processing Summary

- The intra-cardiac signal is sensed and converted into an electronic signal
- The intervals between the electronic signals can then be processed by the device
- Due to the varying amplitudes of tachyarrhythmia signals, an automatic sensing system is needed

BIOTRONIK excellence for life

19

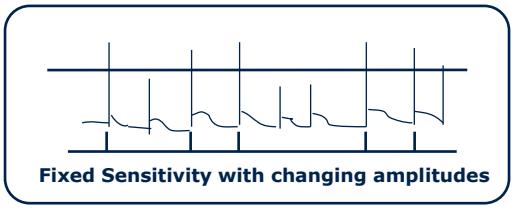
Sensing: A Review



Fixed sensitivity in NSR

Pacemaker sensitivity

A fixed sensitivity setting cannot be used with an ICD

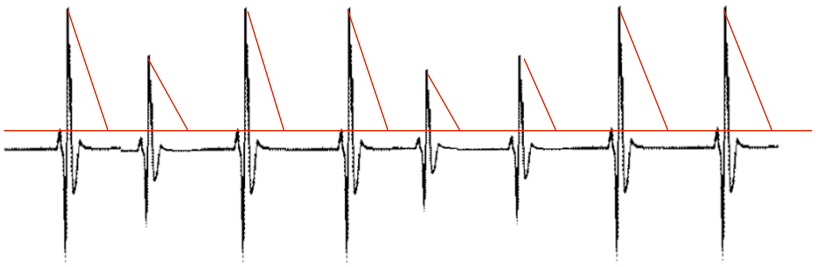


Fixed Sensitivity with changing amplitudes

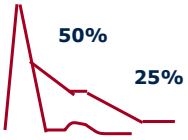
BIOTRONIK excellence for life

20

Automatic Sensing



A system of **automatically adapting sensitivity** settings is used in ICDs

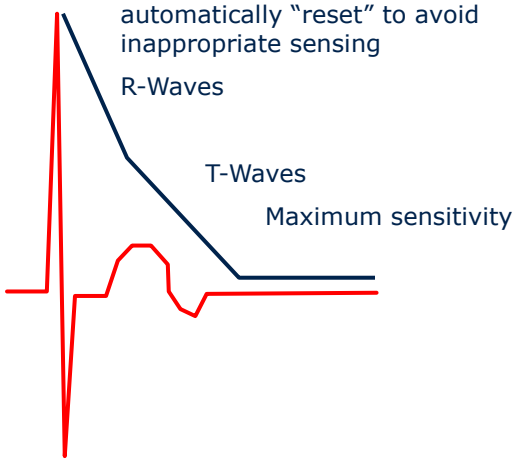


BIOTRONIK excellence for life

21

Automatic Sensing

The sensitivity settings are automatically "reset" to avoid inappropriate sensing



BIOTRONIK excellence for life

22

Detection Criteria for Fast Arrhythmias:

Rate
- Programmed rate to begin detection

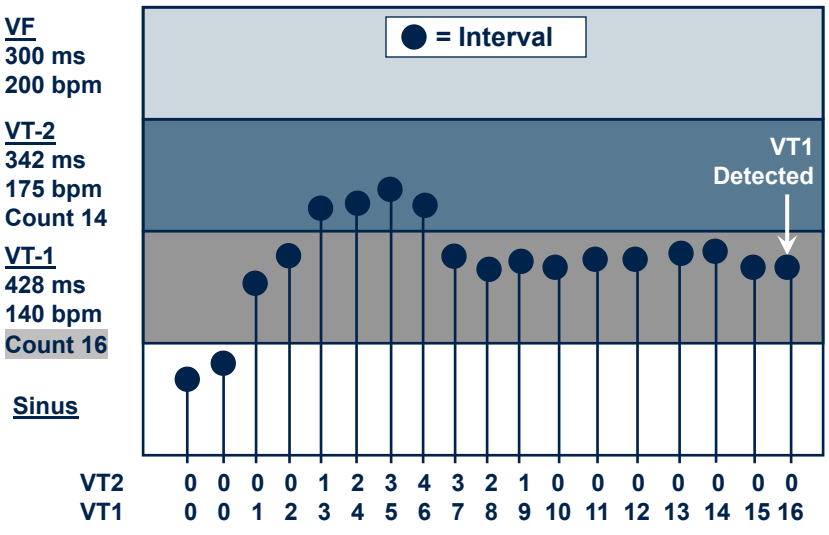
Specificity Discrimination
- Onset detector
- Stability detector
- Morphology comparison

Fibrillation Detection
- Quick delivery of defibrillation therapy

BIOTRONIK excellence for life

23

Single Chamber VT Detection

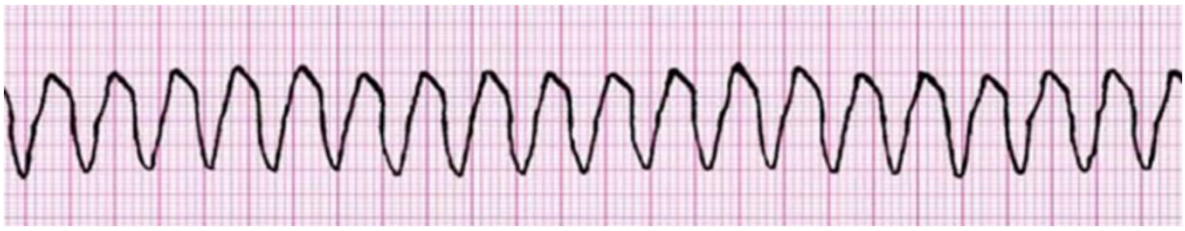


BIOTRONIK excellence for life

24

Onset: A Hallmark of VT

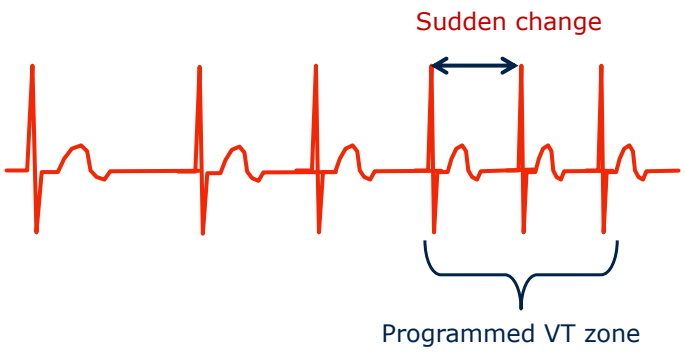
- **Sudden Onset** is used to differentiate sinus tachycardias (normally a slow onset), from VTs which have a rapid onset
- With Onset ON, Onset *AND* the Detection Counter must be satisfied before Detection is met and therapy is delivered.



25

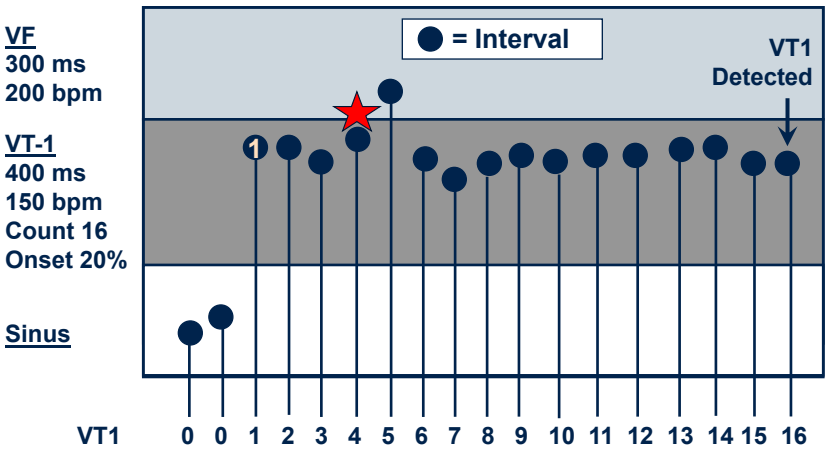
Onset

- The increase in rate from previous average of four beats to new average of four beats is greater than the programmed Onset
- The most recent interval falls into VT or VF zone



26

VT Detection with Onset



BIOTRONIK excellence for life

27

Stability: Inhibit or Treat?

Stability is used to differentiate SVTs that conduct irregularly to the ventricles (atrial fibrillation) from monomorphic VTs which are stable

- *Atrial fibrillation (with high ventricular rate response) is the most common reason for inappropriate shock*

With Stability ON, Stability AND the Detection Counter must be satisfied before Detection is met

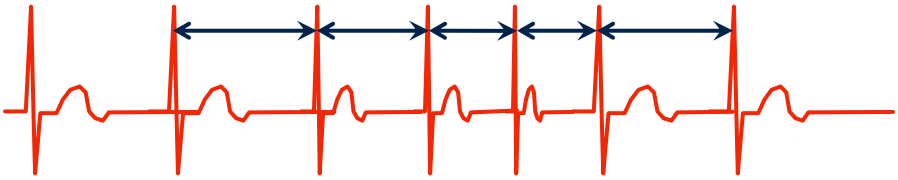
BIOTRONIK excellence for life

28

Stability: Inhibit or Treat?

Stability delays detection in the presence of an unstable R-R interval

- Unstable R-R decrements VT counter by 20



Inappropriate ICD shocks were attributed to atrial fibrillation (44%), supraventricular tachycardia (36%), and abnormal sensing (20%).(What is the rate of inappropriate shocks from implantable cardioverter-defibrillators (ICDs)? Updated: Oct 11, 2019 Author: Daniel M Beyerbach, MD, PhD; Chief Editor: Jeffrey N Rottman). https://emedicine.medscape.com/article/. Visited March 18, 2024.

BIOTRONIK excellence for life

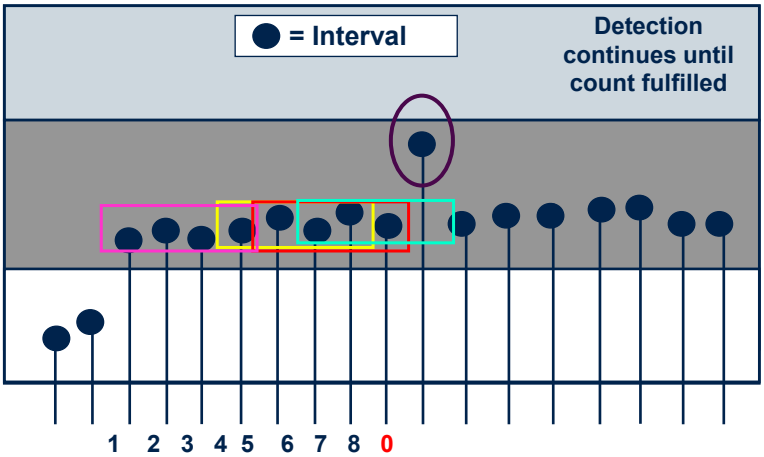
29

Stability

VF
300 ms
200 bpm

VT-1
400 ms
150 bpm
Count 16
Stability
24ms

Sinus



The interval falling outside of the stability range results in the VT counter being set back to 0

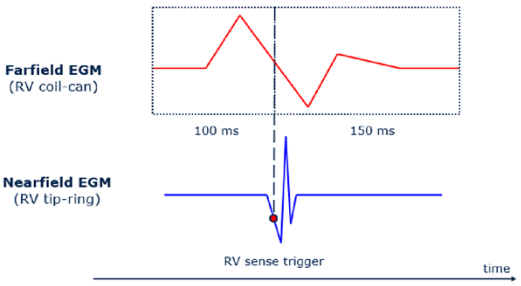
BIOTRONIK excellence for life

30

Morphology Discriminator

Compares the QRS morphology of the intrinsic ventricular beats (normal) with those in a fast arrhythmia

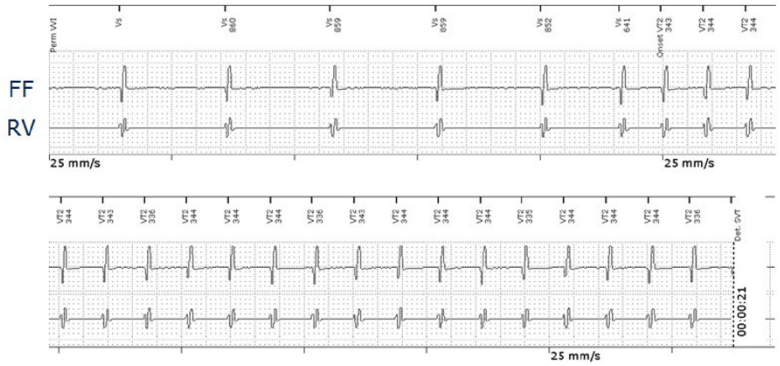
- **MorphMatch (BIOTRONIK specific)** compares far-field signals obtained during sinus rhythm to those occurring in the VT zone(s)
- The reference QRS is updated on a beat-by-beat basis for sinus rhythm
- Once the morphology reference is created, the device can then compare the reference QRS to the current or actual QRS
- MorphMatch is programmable OFF, ON or Monitoring



BIOTRONIK
excellence for life

31

Example



Recordings - Details		Episode: 53
Detection		
Zone		SVT
Measured Onset in V [%]	(fulfilled)	57
Measured stability in V [ms]		4

Remark
SVT (MorphMatch)

BIOTRONIK
excellence for life

32

Tiered Therapy

BIOTRONIK excellence for life

33

Pain-Free Therapy – ATP (Anti-Tachycardia Pacing)

- ATP is rapid pacing at a cycle length shorter than VT
- ATP can terminate reentrant VT by penetrating the circuit and depolarizing the excitable gap which will block reentry
- Mostly effective treating monomorphic VTs
- ATP can reduce painful shocks, improve quality of life, and lengthen pulse generator life
- "Successful termination of VT by ATP was 89% in the Pacing Fast Ventricular Tachycardia Reduces Shock Therapies (PainFREE Rx) study,[19] 81% in the PainFREE Rx II study,[20] 91% in the EMPIRIC study,[21] 88% in the Automated Antitachycardia Pacing study,[22] and 74% in the Nippon Storm Study.[23]"

Laurence D. Sterns, Angelo Auricchio, Edward J. Schloss, Dan Lexcen, Luke Jacobsen, Paul DeGroot, Amy Molan, Takashi Kurita,

Antitachycardia pacing success in implantable cardioverter-defibrillators by p atient, device, and programming characteristics, Heart Rhythm, Volume 20, Issue 2,2023,Pages 190-197,ISSN 1547-5271,https://doi.org/10.1016/j.hrthm.2022.10.015.

BIOTRONIK excellence for life

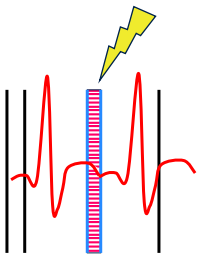
34

Theory of ATP

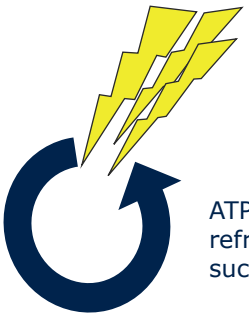
BIOTRONIK excellence for life

35

Programming ATP therapies



VT Re-entry circuit



ATP Schemes:

- **Burst** – Number of paced beats at a set rate
- **Ramp** – Programmed paced beats will get shorter at a set interval

Enhancements:

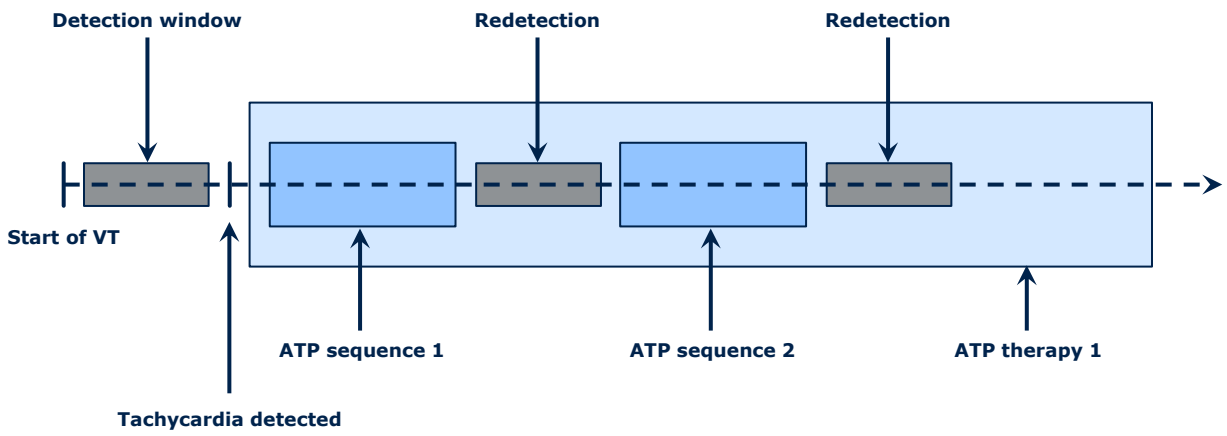
- Add one more scheme
- Scan decrement

ATP must hit *outside* the absolute refractory period of the VT to be successful

BIOTRONIK excellence for life

36

Start of VT



Schema of an ATP therapy. https://doi.org/10.1371/journal.pone.0219533.g00

BIOTRONIK excellence for life

37

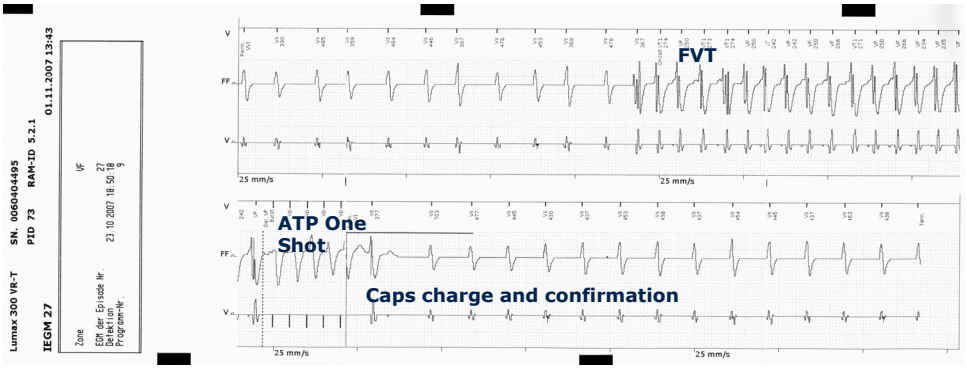
ATP One Shot®

- Allows the programming of **one train of ATP** to treat stable, **fast VT** occurring in the VF zone
- Delivery: Initial detection criterion met and meets **stability criterion** of +/-12% (nonprogrammable)
- ATP is delivered **immediately** before charging of the shock capacitors
- Pulse amplitude of **7.5 V with pulse width of 1.5 ms**, and in a VOO mode
- **Shock confirmation** occurs to confirm efficacy of ATP
- Capacitors bleed off the energy if confirmation criterion of ¾ slow intervals is met

BIOTRONIK excellence for life

38

ATP One Shot®



Key Points

- In the presence of true VF shock delivery is immediate
- Battery longevity is not compromised due to Confirmation during charge

39

BIOTRONIK excellence for life

39

VF Detection

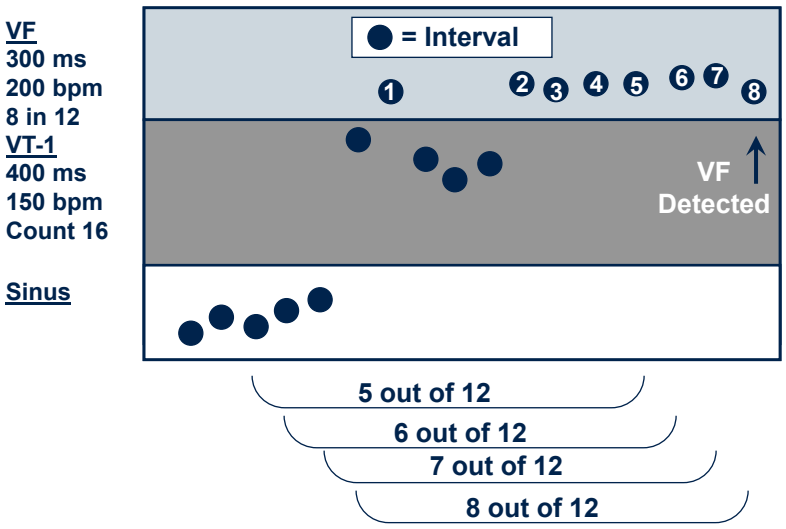
- Single VF zone set in an ICD
- VF Detection: Based on the VF Heart Rate/Interval limit and an X out of Y criterion (Ex: 8/12)
- X/Y detection compensates for undersensing of fine VF

40

BIOTRONIK excellence for life

40

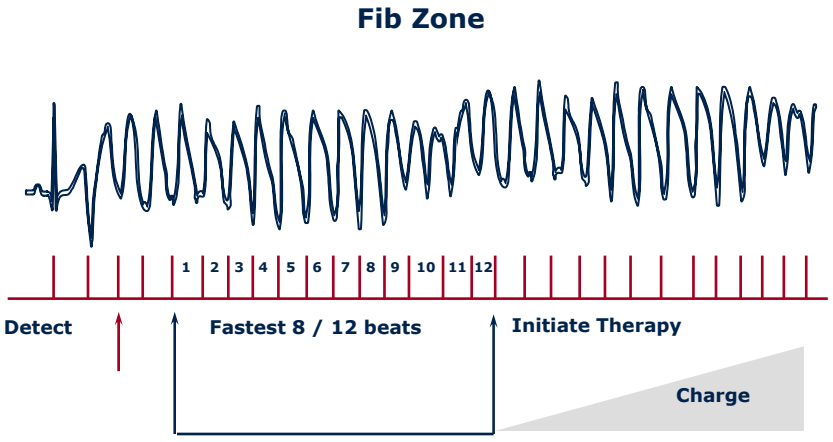
VF Detection



BIOTRONIK excellence for life

41

VF Detection



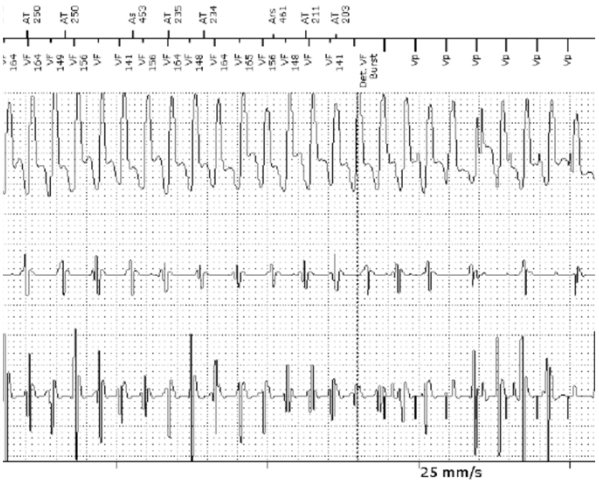
BIOTRONIK excellence for life

42

ICD Diagnostics

A few added diagnostic features for ICD optimization

- Statistics
- Stored IEGMs
- Event counters (interval plots)
- Shock times
- Capacitor reformation (charge time)



BIOTRONIK excellence for life

43

A clinical magnet placed on an ICD:

SUSPENDS tachyarrhythmia detection & therapies (for BIOTRONIK this is up to 8 hours while the magnet remains positioned over the ICD)

A magnet placed on an **ICD** will *not* affect pacing response

Device manufacturer specific - so always contact tech support to be sure of the effect of clinical magnet placement on your patient's device.

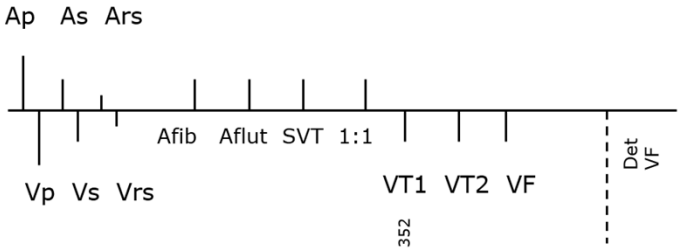
BIOTRONIK excellence for life

44

IEGM Markers: Tell You Everything

Therapy markers include:

- Heavy black line when device charging
- Shock energy and impedance — 15J 45Ω
- ATP therapy type — Ramp
- ATP optimization train — *Burst
- Pacing mode — Psh DDI / Msw DDI
- Termination — Term



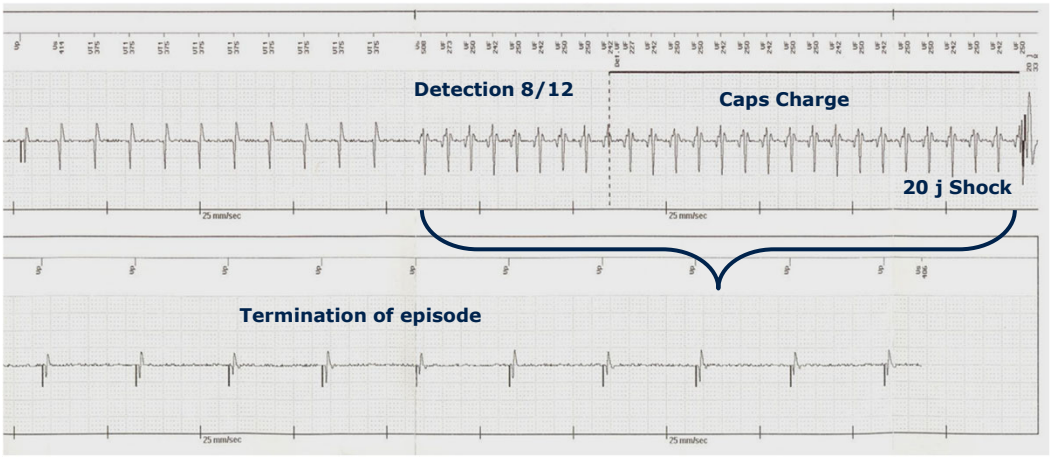
BIOTRONIK excellence for life

45

BIOTRONIK excellence for life

46

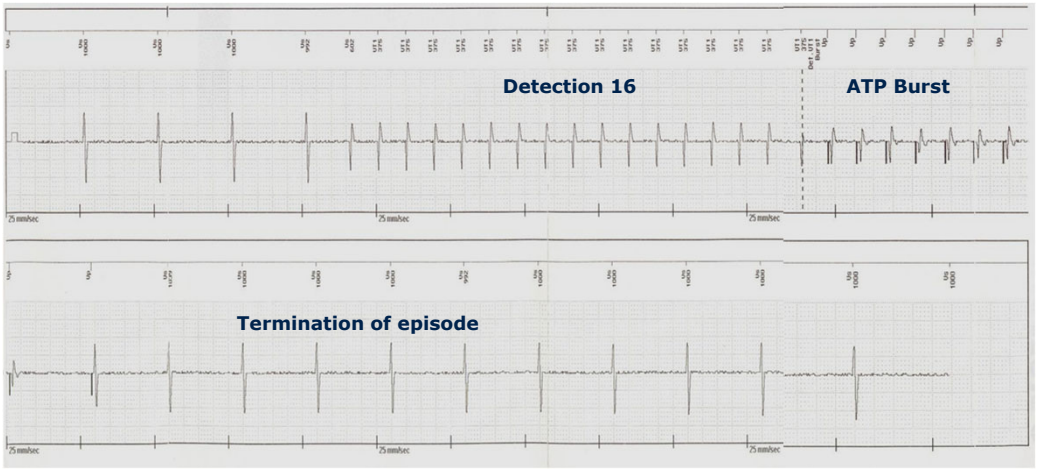
Example 1: VF Detection with Shock



BIOTRONIK excellence for life

47

Example 2: VT Detection with successful ATP

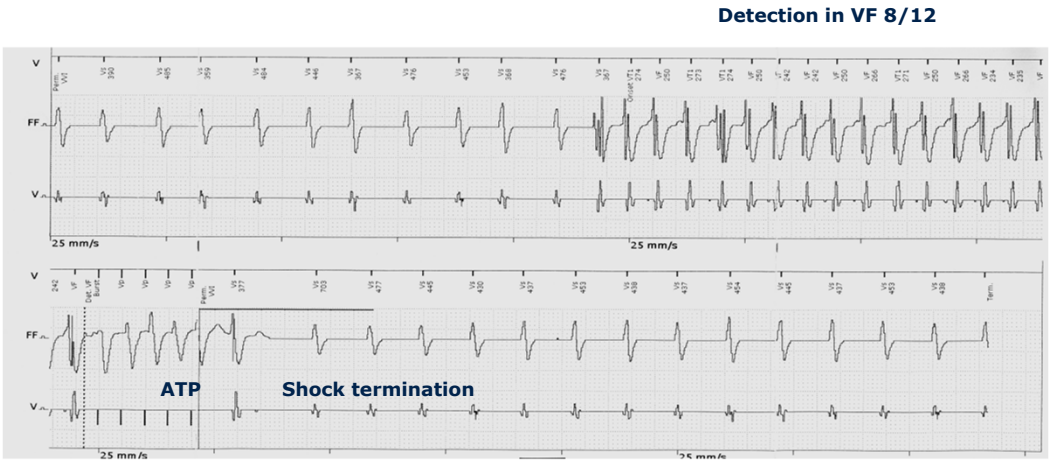


BIOTRONIK excellence for life

48

Example 3: ATP During VF

ATP may be very effective for FVT in the VF zone

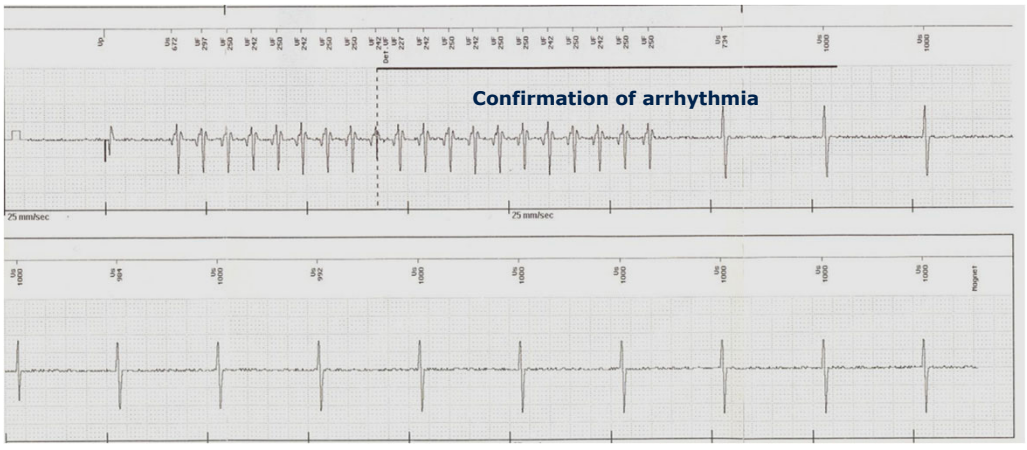


BIOTRONIK excellence for life

49

Example 4: Aborted Shocks

Confirmation during charge: Another way to optimize ICD therapy



BIOTRONIK excellence for life

ICDs and Patient Education

Continuous Patient Education = Patient Engagement

- Why did they have an ICD implant?
  (with a pacemaker)
- Detection heart rates/therapy parameters
- ATP vs a Shock
- Shock Plan
- ERI

51

Questions?

BIOTRONIK
excellence for life

52