Implantable Cardioverter-Defibrillators
Step by Step
AN ILLUSTRATED GUIDE
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Implantable Cardioverter-Defibrillators
Step by Step

AN ILLUSTRATED GUIDE

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Implantable Cardioverter-Defibrillators Step By Step is the logical sequel to our first book, Cardiac Pacemakers Step by Step, published in 2004. The pacemaker book should obviously be studied before starting this book because pacing constitutes an integral part of the function of an implantable cardioverter-defibrillator (ICD). The original pacemaker book was so well received that we decided to keep the same format. In addition, 65 carefully selected ICD recordings have been included.

As one picture is worth a thousand words, we have tried to avoid unnecessary text and focused on visual learning. Many of the figures are self-explanatory and the text in the appendix provides a summary of the field. The relevant figures are cited in the appended text. This arrangement promotes learning as an enjoyable and fun experience.

We have discussed the electrophysiologic aspects of ICD implantation but omitted a description of the standard surgical implantation procedures, which are well described elsewhere. Furthermore, the major ICD trials are mentioned only briefly to avoid reduplication of the abundant literature on the subject. Barring these two issues, which might have rendered the work unwieldy, the book provides a comprehensive review of the basic and clinical aspects of ICD therapy. A section on cardiac resynchronization was added because most patients with such devices also receive an ICD. The rapid evolution of technology made our task a moving target, with the continual need to upgrade some of the material. Despite our efforts, it is possible that some dated material might have escaped our attention, and we apologize for this.

We have discussed only the devices from the three US manufacturers as models, merely for the sake of convenience. We are well aware that manufacturers outside of the United States produce excellent devices. Although a full description of non-US ICDs is beyond the scope of the book, such ICDs share many characteristics with US devices so that the book will be universally applicable to the clinical evaluation of all devices regardless of their origin. We are particularly indebted to representatives of Medtronic Inc., St. Jude Medical and Boston Scientific for helping and guiding us with this project. However, we remain responsible for any mistakes related to ICD technology.

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Alfons F. Sinnaeve
Carsten Israel MD (Frankfurt, Germany), Michael O. Sweeney MD (Boston, MA), Bengt Herweg MD (Tampa, FL), and representatives from Medtronic Inc., Boston Scientific and St. Jude Medical kindly provided a number of tracings.

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The authors would also like to thank the nurses and technicians: Veerle De Meyer, Myriam Peleman, Rudy Colpaert, Guy De Cocker of the University Hospital, Ghent, Belgium, and Filip Vandenbulcke of the A.Z. Damiaan Hospital, Ostend, Belgium, for their dedicated care of ICD patients and ability to recognize the teaching value of a number of recordings included in this book.
Sudden cardiac death remains a major public health problem and accounts for 450,000 deaths annually in the United States and 400,000 in Europe. Michel Mirowski began developing an implantable defibrillator in the mid-1960s. The first automatic defibrillator was finally implanted in a human patient in 1980. The device presently known as an implantable cardioverter-defibrillator (ICD) has proven effective in preventing sudden cardiac death. Since 1980, technologic advances in device therapy including miniaturization, improved leads, optimal waveforms and transvenous implantation have revolutionized the treatment of malignant ventricular tachyarrhythmias and sudden cardiac death. These advances have made ICDs easier and safer to implant and better accepted by patients and physicians. Thus, ICDs have evolved from a treatment of last resort to the gold standard for patients at high risk for life-threatening ventricular arrhythmias. Recent advances include dual-chamber ICDs, additional therapy for atrial arrhythmias, and ICDs combined with biventricular pacing for selected heart failure patients. Device-based monitoring of contemporary ICDs can also record data unrelated to arrhythmias such as activity and the status of lung fluid in patients with congestive heart failure. Finally, ICDs provide health benefits with efficiency comparable to other well-accepted forms of health care such as renal dialysis.

The ICD does not prevent arrhythmias from occurring, and it is sometimes likened to having a miniature ambulance crew inside the chest. Shock delivery is the final step in a cascade of events beginning with arrhythmia detection. The device can detect ventricular tachyarrhythmias, determine whether they should be converted to a normal rhythm with a shock or rapid ventricular pacing, and then administer therapy. After successful treatment, the device must recognize the nontachycardic rhythm and reset the therapy sequences for the next event. Afterwards, the device keeps a complete record of what it has done. An ICD also gives bradycardia and post-shock bradycardia support like a conventional pacemaker.

Cardioversion and defibrillation are both forms of high-energy therapy or shocks. If the patient is conscious at the time of a shock, it is painful and usually described as feeling like a kick in the chest. Patients should be advised of this in advance. Their families should be advised that someone touching them is not harmed if the ICD discharges.

ICDs are multiprogrammable devices capable of delivering therapy for ventricular tachyarrhythmias in the form of high-energy defibrillation shocks, low-energy (cardioversion) shocks or antitachycardia pacing, and conventional pacing therapy for bradycardias (Fig. 0.01). Today’s devices have a longevity of about 5–7 years, depending on shock and pacing frequency.
An ICD or implantable cardioverter-defibrillator is an electronic device implanted in the body to protect against dangerous high ventricular rates. It is designed to defibrillate the heart by delivering high voltage shocks or to stop malignant tachycardias by antitachycardia pacing (short burst of rapid pacing sequence). Contemporary ICDs also contain a classic pacemaker for bradycardia pacing.

**Let's get this straight and avoid all confusion!**

Pacing and shocking are done by electric impulses, therefore the electric current is often depicted on the heart and the thorax. By international convention the electric current flows from the positive connection (anode) to the negative connection (cathode). This convention is used throughout the book! Note that electrons (as in the metal wires) are flowing in the opposite direction. In the body tissue, however, the electric current is due to the movement of ions.

**ABBREVIATIONS:** ICD = implantable cardioverter-defibrillator; SVC = superior vena cava; RV = right ventricle; VT = ventricular tachycardia.

Figure 0.01
**CARDIAC TACHYARRHYTHMIAS**

* Cardiac Tachyarrhythmias - a summary
* Genesis of reentrant tachycardias
* Mechanisms of supraventricular tachycardias (SVT) - part 1
* Mechanisms of supraventricular tachycardias (SVT) - part 2
* Mechanisms of supraventricular tachycardias (SVT) - part 3
* Mechanisms of supraventricular tachycardias (SVT) - part 4
* Mechanisms of supraventricular tachycardias (SVT) - part 5
* Mechanisms of supraventricular tachycardias (SVT) - part 6
* Analysis of dual chamber EGMs - 1
  Tachycardia with 1:1 AV relationship
* Analysis of dual chamber EGMs - 2
  Tachycardia with 1:1 AV relationship
* Wide QRS tachycardias - part 1 Causes
* Wide QRS tachycardias - part 2 Stepwise approach
* Wide QRS tachycardias - part 3 Stepwise approach cont’d
* Bundle branch reentry tachycardia (BBR)
* Diagnosis of supraventricular tachycardia from stored EGMs
* Ventricular ATP with atrial entrainment and AV response after ventricular ATP
* Ventricular ATP with atrial entrainment and AAV response after ventricular ATP
* Ventricular ATP without atrial entrainment
* Ventricular ATP terminates the tachycardia without depolarization of the atria
Abbreviations: SVT = supraventricular tachycardia; VT = ventricular tachycardia;

Figure 1.01
GENESIS OF REENTRANT TACHYCARDIAS

Reentry is considered the primary mechanism of ventricular tachycardias (VTs). Reentrant pathways may consist of bundle branches, Purkinje fibers with or without the surrounding muscle cells, as well as infarcted or fibrotic muscle cells. Most sustained monomorphic VTs are due to reentry involving a scar from an old myocardial infarction.

PREREQUISITES FOR A REENTRANT TACHYCARDIA TO OCCUR IN AN ANATOMIC CIRCUIT

1. Pathologic zone with unidirectional block
2. Pathologic slow retrograde conduction
3. Re-excitation of tissue

The tachycardia is sustained if the tissue proximal to the site of the (unidirectional) block is no longer refractory when it is excited by retrograde activation. It follows that the total time to go around the circuit has to be shorter than the refractory period:

Refactory period $RP \leq t_1 + t_2$

or:

$RP \leq \frac{L_1}{v_1} + \frac{L_2}{v_2}$

where $L_1$ and $L_2$ are the lengths of the two sections of the circuit, and $v_1$ and $v_2$ are the velocities of conduction in those sections.

A REENTRANT TACHYCARDIA CAN BE TERMINATED BY:
1. Prolongation of the refractory period in the anatomical circuit (e.g. by drugs)
2. Increase of the conduction velocity $v_1$ in the anatomical circuit
3. Decrease of the length of the anatomical circuit ($L_1 + L_2$)
4. Electrically-induced ventricular depolarization during the excitable gap which is the region in the circuit not yet activated by the circulating wavefront.

Figure 1.02
MECHANISMS of SUPRAVENTRICULAR TACHYCARDIAS (SVT) - part 1

1. AV NODAL REENTRANT TACHYCARDIA (AVNRT)
   common type: “Slow-Fast”

30% of the normal population has two pathways in their AV node (dual AVN physiology) but only a small fraction will develop AVNRT. The fast pathway has a rather long refractory period and the slow pathway has a short refractory period.

*Sinus rhythm*: the antegrade conduction over the slow pathway is blocked by retrograde invasion of the impulse.

*An early atrial extrasystole*: is only conducted over the slow pathway since the fast one is still refractory.

The slow path is the antegrade limb and the fast one is the retrograde limb of the tachycardia circuit.

Abbreviations: AES = atrial extrasystole; AVNRT = AV nodal reentrant tachycardia.

Figure 1.03
MECHANISMS of SUPRAVENTRICULAR TACHYCARDIAS (SVT) - part 2

ORTHODROMIC RECIPROCATING TACHYCARDIA (ORT)

- The accessory pathway conducts only in the retrograde direction during ORT.
- An ORT often starts with a ventricular premature complex (VPC).
- Since conduction over the AV node (AVN) is slower than the conduction over the accessory pathway (AccP), it follows that RP' < PR (R = QRS complex and P' = retrograde P wave).
- The QRS complex is the same as during sinus rhythm unless there is rate-related bundle branch aberrancy.

Abbreviations: AccP = accessory pathway; AV = atioventricular; AVN = AV node; AVNRT = AV nodal reentrant tachycardia; PVC = premature ventricular complex; ORT = orthodromic reciprocating tachycardia; ORT-CL = ORT cycle length.

Figure 1.04
MECHANISMS of SUPRAVENTRICULAR TACHYCARDIAS (SVT) - part 3

3 ATRIAL TACHYCARDIA (AT)

- The morphology of P waves during AT is different from those during sinus rhythm.
- P waves during AT are difficult to identify because they are often superimposed on T waves (e.g. when the AT gradually accelerates).
- The atrial rate is generally between 150 and 200 bpm (minimum 100, maximum 250).
- On the ECG, there are isoelectric segments between the P waves.
- Since conduction to the ventricles occurs through the AV node, the QRS complex is the same as during sinus rhythm.

Atrial tachycardias can be generated in every part of the atria. ATs are called focal atrial tachycardias but the true mechanism is unclear. If there is reentry, it would involve only a very localized “focal” area.

Abbreviations: A = atrium; AT = atrial tachycardia; AV = atrioventricular; SA node = sino-atrial node (sinus node); V = ventricle.

Figure 1.05
MECHANISMS of SUPRAVENTRICULAR TACHYCARDIAS (SVT) - part 4

4 ATRIAL FLUTTER (AFL)

**COMMON FLUTTER (CCW)**

- SVC
- RA
- IVC
- CS

**COMMON “REVERSED” FLUTTER (CW)**

- SVC
- RA
- IVC
- CS

Did you know that my atrial flutter is caused by a circus movement?!

- Negative flutter waves in the inferior leads (lead II, III & aVF)
- Positive flutter waves in the inferior leads (lead II, III & aVF)

**e.g. Atrial flutter with varying AV block 2:1, 4:1, etc.**

(The atrial rate is 300 bpm and the ventricular rate varies from 150 bpm to 75 bpm)

**Abbreviations**: AFL = atrial flutter; CCW = counterclockwise; CW = clockwise; CS = coronary sinus; IVC = inferior vena cava; SVC = superior vena cava; TS = tachycardia sense; VS = ventricular sense.

Figure 1.06
MECHANISMS of SUPRAVENTRICULAR TACHYCARDIAS (SVT) - part 5

5 ATRIAL FLUTTER THAT CAN BE INTERPRETED AS VT BY AN ICD

Abbreviations: A = atrium; AV = atrioventricular junction; AFL = atrial flutter; TS = tachycardia sense; V = ventricle; VS = ventricular sense.

I tangled it up a bit! They will have a tough job to differentiate those tachycardias!

Figure 1.07
MECHANISMS of SUPRAVENTRICULAR TACHYCARDIAS (SVT) - part 6

The electrophysiologic basis of atrial fibrillation remains unclear. Two major hypotheses prevail: (1) multiple wavelets of depolarization propagating within the atria, dividing, coalescing and extinguishing each other as they travel in an apparently random fashion seeking tissue that is excitable and (2) a single or a small number of high-frequency sources ("motors" or "drivers") of stable micro-reentry ("mother wave") primarily located at the left atrium/pulmonary vein junction with passive fibrillatory conduction giving rise to "daughter waves". Both mechanisms may co-exist!

6

ATRIAL FIBRILLATION (AF)

During AF the fibrillatory waves (f waves) have a rate of 350-500 per minute. Only some of the numerous atrial beats are transmitted at irregular intervals through the filter of the AV node to the ventricles. The single reliable diagnostic ECG feature therefore is the irregular ventricular response. Only in combination with complete AV block the ventricular rate is regular.

Abbreviations: A = atrium; AV = atrioventricular junction; AF = atrial fibrillation; AVN = AV node; FS = fibrillation sense; IVC = inferior vena cava; SN = sinus node; SVC = superior vena cava; TS = tachycardia sense; V = ventricle;

Figure 1.08
ANALYSIS OF DUAL CHAMBER EGMs - 1 TACHYCARDIA with 1 : 1 AV RELATIONSHIP

If the atrial rate equals the ventricular rate (i.e., a 1:1 tachycardia), it is very hard for an ICD to differentiate between SVT and VT. Even a physician has to look very carefully!

The vast majority of tachycardias with 1:1 AV association are SVT mainly sinus tachycardia. Normally an ST accelerates gradually with fairly stable PR interval.

SVT or sinus tachycardia with 1:1 conduction in a patient with 1st degree AV block

VT (ventricular tachycardia) with 1:1 retrograde conduction

NOTE: The chamber of onset may give an indication of the kind of tachycardia

VT with 1:1 VA conduction constitutes 2-3% of VTs detected by ICDs. Note: VT may exhibit a few beats of AV dissociation before stable 1:1 VA conduction becomes established.

Continuous registration and interpretation of the PP and the RR intervals may be used as an additional discriminator in ICDs!

VEGM morphology identical to that in sinus rhythm strongly suggests SVT. A VEGM morphology different from that of sinus rhythm indicates VT in about 90% of cases.

In tachycardias with 1:1 association:
* Transient AV block indicates SVT
* VA block during ATP is diagnostic of VT.

Abbreviations: ATP = antid Hearts cardia pacing, AV = atrioventricular; ST = sinus tachycardia; SVT = supraventricular tachycardia; TS (marker) = tachycardia sense; VA = ventriculoatrial; VEGM = ventricular electrogram; VT = ventricular tachycardia. 

Figure 1.09
ANALYSIS OF DUAL CHAMBER EGMs - 2
TACHYCARDIA with 1 : 1 AV RELATIONSHIP

Important diagnostic information can be obtained about the mechanism of tachycardia by analyzing what happens with unsuccessful ventricular ATP.

If there is entrainment (i.e. the atrial rate accelerates during ventricular ATP and becomes equal to the stimulation rate), and the original tachycardia resumes with an AAV response at the end of the ATP sequence, the arrhythmia is AT.

SVT is the most probable diagnosis if the atrial rate remains constant. Note: the ATP rate is faster than the AT rate!

SUMMARY : Atrial response to ventricular ATP

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<th>VT vs SVT</th>
<th>No acceleration of atrial rate</th>
<th>Acceleration of atrial rate</th>
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<td>No termination of tachycardia by ATP</td>
<td>Highly suggestive of AT if atrial rate remains constant</td>
<td>AT if AAV response</td>
</tr>
<tr>
<td>Termination of tachycardia by ATP</td>
<td>Not AT</td>
<td>Not decisive</td>
</tr>
</tbody>
</table>

Abbreviations: AT = atrial tachycardia; ATCL = atrial tachycardia cycle length; < ATCL = shorter than ATCL; ATP = antitachycardia pacing; P’ = retrograde P wave; St = stimulus; Markers: AS = atrial sense; TS = tachycardia sense; VP = ventricular pace

Figure 1.10
### Wide QRS Tachycardias

#### Causes

1. VT is the most common form of wide QRS complex tachycardia (60% of cases).

   A regular wide QRS complex tachycardia should always be considered as being VT until proven otherwise. VT is rare in structurally normal hearts.

2. SVT (including ST, AT, AVNRT) with pre-existing or tachycardia-related BBB or functional aberrant conduction.

3. Antidromic AVRT

4. Orthodromic AVRT with pre-existing or rate-related BBB or functional aberrant conduction.

5. SVT with conduction over an accessory pathway

6. Antidromic AVRT using Mahaim fiber

#### Abbreviations:
- AF = atrial fibrillation
- AT = atrial tachycardia
- AVNRT = AV nodal reentry tachycardia
- AVRT = AV re-entrant tachycardia
- BBB = bundle branch block
- LBB = left bundle branch
- MI = myocardial infarction
- RBB = right bundle branch
- ST = sinus tachycardia
- SVT = supraventricular tachycardia
- VT = ventricular tachycardia
- WPW = Wolff-Parkinson-White
Figure 1.12

**WIDE QRS TACHYCARDIAS**

**STEPWISE APPROACH - part 1**

**WHAT?**
- MONOPHASIC: R
- BI-PHASIC: QR
- TRI-PHASIC: qRS

**HOW?**

**STRATEGY:**
1. Are there RS complexes in any of the precordial leads?
   - **NO**
   - **YES**
     - RS interval > 100 ms
       - **YES**
         - VT
       - **NO**
         - Is there AV dissociation? (fusion beats / capture beats)
           - **NO**
           - Look at the morphology of the QRS complex in V1 - V6
             - RBBB morphology
             - see next page
           - **YES**
             - LBBD morphology

**AV dissociation** is present in approximately 50% of VTs but identified in the surface ECG in only half the patients with AV dissociation. Independent atrial and ventricular activity during wide QRS tachycardia is a hallmark of VT. In VT the ventricular rate is faster than the atrial rate in sinus rhythm. An ICD uses this information to make the diagnosis for VT.

**Capture beats** occur with complete ventricular activation over the AV conduction system.

**Fusion beats** are noted when activation of the ventricles occurs by both VT depolarization and activation over the AV conduction system.

Abbreviations: AV = atrioventricular; VT = ventricular tachycardia; LBBB = left bundle branch block; RBBD = right bundle branch block.
WIDE QRS TACHYCARDIAS

STEPWISE APPROACH - part 2

Look at the morphology of the QRS complex in V1 & V6

**REBBB morphology**
- most likely SVT
  - rsR' triphasic
  - V1: RsR'
  - V6: RsR'
  - R/S > 1

**LBBB morphology**
- most likely SVT
  - monophasic QR or R
  - V1: monophasic QR or R
  - V6: no Q wave

VT
- Duration of QRS complex > 140 ms
- QRS axis in the frontal plane
  - Suggestive for VT

A frontal axis of between -90° and ±180° suggests VT. Predominantly negative QRS complexes in leads I, II, III and aVF are useful criteria for identifying a VT.

Concordant negative ECG patterns in the precordial leads. If all precordial leads are predominantly negative, a VT is the likely diagnosis. If all precordial leads are predominantly positive, the differential diagnosis is an antidromic tachycardia using a left-sided accessory pathway or a VT.

Abbreviations: LBBB = left bundle branch block; RBBB = right bundle branch block; SVT = supraventricular tachycardia; VT = ventricular tachycardia.
Figure 1.14

**GENESIS**
- His bundle
- Retrograde block due to long refractory period
- Ventricular depolarization starts at the RV apex

**CONTINUATION**
- Slow retrograde conduction
- Recovery of anterograde conduction

**BBR tachycardia!**

Recognition of BBR is important for several reasons:
- BBR responds poorly to pharmacologic therapy
- It has a high rate of recurrence
- BBR can account for syncope, sudden death, and frequent defibrillator therapies
- BBR tachycardia can be eliminated by catheter ablation

**DIAGNOSTIC FEATURES WITH BBR**
1. Tachycardia morphology is a typical LBBB (rarely RBBB)
2. Induction of the tachycardia depends upon His-Purkinje conduction delay
3. The tachycardia terminates with a block within the His-Purkinje system
4. During BBR, a His potential precedes each QRS complex
5. Variations in the V-V intervals are preceded by similar changes in the H-H intervals

Interfascicular tachycardia is also a possibility, usually proceeding in the anterograde direction over the LAF and retrograde through the LPF

**Abbreviations:**
- LAF = left anterior fascicle; LB = left bundle branch;
- LBBB = left bundle branch block; LPF = left posterior fascicle;
- RB = right bundle branch; RBBB = right bundle branch block;
- HBE = His bundle electrogram;
16

**Figure 1.15**

**DIAGNOSIS OF SUPRAVENTRICULAR TACHYCARDIA FROM STORED ELECTROGRAMS**

**WHAT CAN BE REVEALED BY VENTRICULAR ATP (ANTITACHYCARDIA PACING)?**

**NO TERMINATION OF TACHYCARDIA BY ATP**

1. **ACCELERATION** of the atrial rate to the ATP cycle length
   
   **A.** After ATP, the tachycardia resumes with an **A-V RESPONSE**:
   
   - A-V response is **diagnostic** for:
     * AV nodal reentrant tachycardia (**AVNRT**)  
     * or Orthodromic reciprocating tachycardia (**ORT**)  
   
   - A-V response **rules out** atrial tachycardia (**AT**)  

   **B.** After ATP, the tachycardia resumes with an **A-A-V RESPONSE**:
   
   - A-A-V response is **diagnostic** for:
     * Atrial tachycardia (**AT**)  
   

2. **NO ACCELERATION** of the atrial rate to the ATP cycle length
   
   - Highly **suggestive of AT** if the atrial rate remains constant
   
   - **Dissociation** of A and V during ATP **excludes ORT**

**TERMINATION OF TACHYCARDIA BY ATP**

1. **ACCELERATION** of the atrial rate to the ATP cycle length
   
   - Not **decisive** if the atrial rate was entrained by RV pacing

2. **NO ACCELERATION** of the atrial rate to the ATP cycle length
   
   - Termination without atrial depolarization **excludes AT**
Figure 1.16

**AV NODAL REENTRANT TACHYCARDIA (AVNRT)**

Anti-tachycardia pacing (ATP) at a slightly higher frequency than the tachycardia (i.e., overdrive pacing) may cause entrainment, i.e., the atrial cycle length (ACL) shortens to the ATP cycle length. All atrial electrograms are advanced.

If the AVNRT resumes after ATP, it will start at the last retrograde P' and an A-V sequence will be registered by the stored atrial and ventricular electrograms.

After the last ventricular paced beat in the ATP sequence, the antegrade limb of the tachycardia (slow pathway) is not refractory. The last retrograde atrial complex can therefore conduct to the ventricle producing a **DIAGNOSTIC AV RESPONSE**. This response **RULES OUT AN ATRIAL TACHYCARDIA**.

**ORTHODROMIC RECIPROCATING TACHYCARDIA (ORT)**

After the last ventricular paced beat in the ATP sequence, the antegrade limb of the ORT tachycardia (AV node) is not refractory. The last retrograde atrial complex can therefore conduct to the ventricle producing a **DIAGNOSTIC AV RESPONSE**. This response **RULES OUT AN ATRIAL TACHYCARDIA**.

Abbreviations: AscP = accessory pathway; ACL = atrial cycle length; ATP = anti-tachycardia pacing; AVN = AV node = atrioventricular node; St = stimulus.
DIAGNOSIS OF SUPRAVENTRICULAR TACHYCARDIA
FROM STORED ELECTROGRAMS - part 2

Ventricular ATP with atrial entrainment
and AAV response after ventricular ATP

I have no time to lose. I have a diagnosis to
make about the tachycardia of my ICD patient!

Take your time, John! Haste makes waste!
Important diagnostic information can be obtained
about the mechanism of a tachycardia by analyzing
what happens after unsuccessful ventricular ATP.

If there is entrainment (i.e., the atrial rate accelerates
during ventricular ATP and
becomes equal to the stimulation rate),
and the original tachycardia resumes
with an AAV RESPONSE at the end of the ATP sequence,
the ARRHYTHMIA IS AT.
Retrograde VA conduction occurs through the AV node.
Therefore the last retrograde atrial complex related
to ventricular pacing (ATP) cannot conduct anti-
gradely to the ventricle because the AV node is refractory
for antegrade conduction, hence the AAV response.
AAV response EXCLUDES AVNRT and ORT as mechanism
of the tachycardia.

Abbreviations: AccP = accessory pathway; ACL = atrial cycle length;
ATP = atrial tachycardia pacing; AS = atrial sense;
AVN = AV node; ATCL = atrial tachycardia cycle length;
AVNRT = AV nodal reentrant tachycardia;
ORT = orthodromic reciprocating tachycardia;
St = stimulus; TS = tachy sense; VP = ventricular pace.

Figure 1.17
DIAGNOSIS OF SUPRAVENTRICULAR TACHYCARDIA
FROM STORED ELECTROGRAMS - part 3

Ventricular ATP without atrial entrainment

So, I have to pace in the ventricle at a pacing rate faster than the tachycardia rate and look if the atrial rate is changing. If I can note dissociation between ventricular and atrial rates, atrial tachycardia (AT) is very likely !?

Yes, make the cycle length of the ventricular pacing (ATP-CL) shorter than the cycle length of the tachycardia (ATCL).

**AT IS THE MOST PROBABLE DIAGNOSIS** if the atrial rate remains constant !

Note that dissociation between the tachycardia and the ventricular pacing, without termination of the tachycardia, **EXCLUDES** orthodromic reciprocating tachycardia (ORT).

Abbreviations : ATCL = atrial cycle length ; AT = atrial tachycardia ; ATP = antitachycardia pacing ; ATP-CL = ATP cycle length ; AVN = AV node = atrioventricular node ; St = stimulus ; VP = ventricular pace ;
**DIAGNOSIS OF SUPRAVENTRICULAR TACHYCARDIA FROM STORED ELECTROGRAMS - part 4**

**Ventricular ATP terminates the tachycardia without depolarization of the atria**

A tachycardia in an ICD patient was terminated by antitachycardia pacing (ATP) at a slightly higher rate than the original tachycardia rate and no atrial depolarization was seen. What can be learned from this information?

Well, tachycardia termination by ATP without depolarization of the atria, **EXCLUDES AT** as a mechanism of the tachycardia.

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**Abbreviations:**
- ATCL = atrial cycle length
- AS = atrial sense
- AT = atrial tachycardia
- ATP = antitachycardia pacing
- ATP-CL = ATP cycle length
- AVN = AV node = atrioventricular node
- St = stimulus
- VP = ventricular pace
- VGS = ventricular sense

**Figure 1.19**