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CARDIAC TACHYARRHYTHMIAS

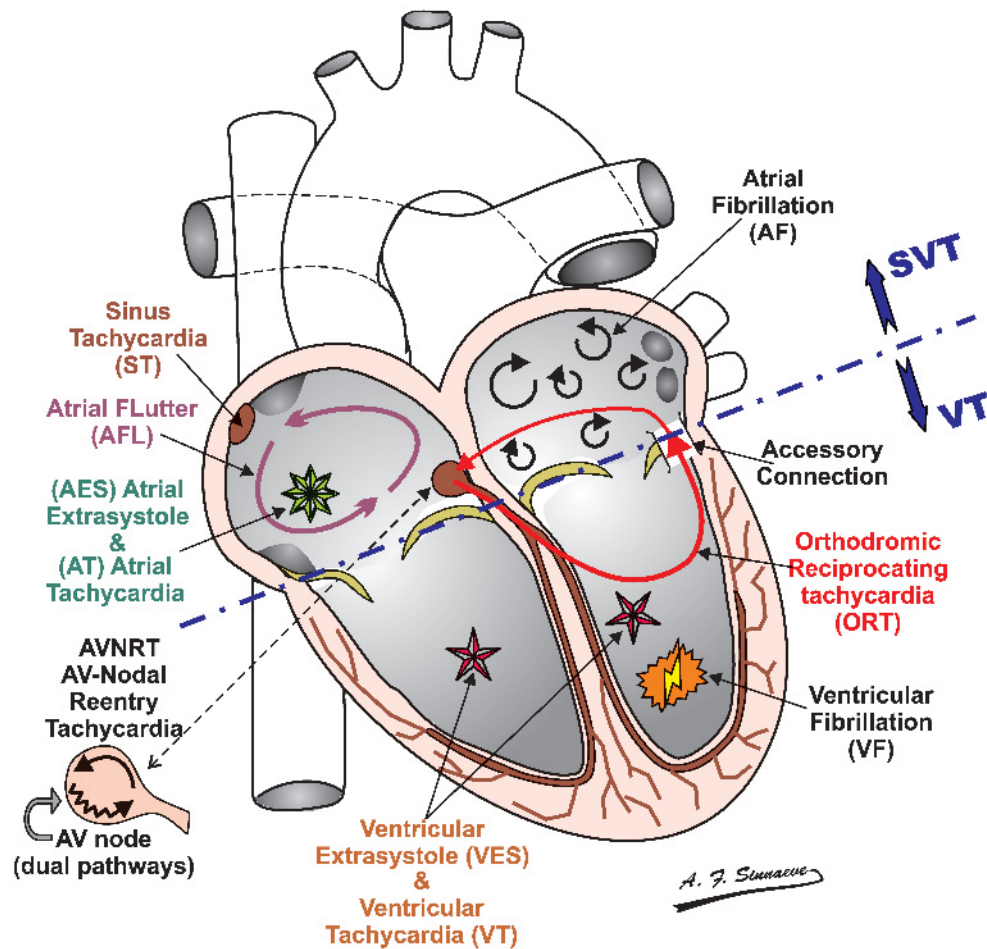
- * Cardiac Tachyarrhythmias - a summary
- * Genesis of reentrant tachycardias
- * Mechanisms of supraventricular tachycardias (SVT) - part 1
- * Mechanisms of supraventricular tachycardias (SVT) - part 2
- * Mechanisms of supraventricular tachycardias (SVT) - part 3
- * Mechanisms of supraventricular tachycardias (SVT) - part 4
- * Mechanisms of supraventricular tachycardias (SVT) - part 5
- * Mechanisms of supraventricular tachycardias (SVT) - part 6
- * Analysis of dual chamber EGMs - 1
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- * Analysis of dual chamber EGMs - 2
 - Tachycardia with 1:1 AV relationship
- * Wide QRS tachycardias - part 1 Causes
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- * 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

Figure 1.00



I never knew how many things could go wrong with my heart !

CARDIAC TACHYARRHYTHMIAS



Abbreviations : SVT = supraventricular tachycardia; VT = ventricular tachycardia;

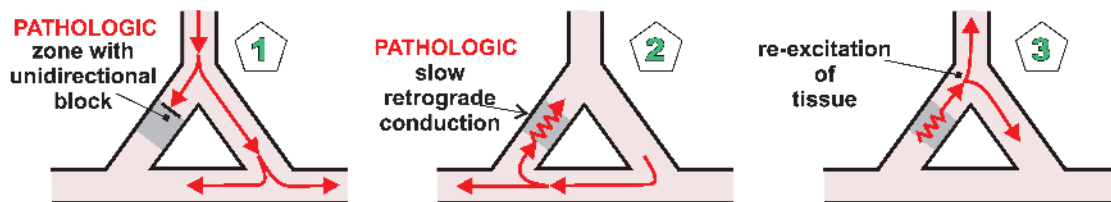
Figure 1.01

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

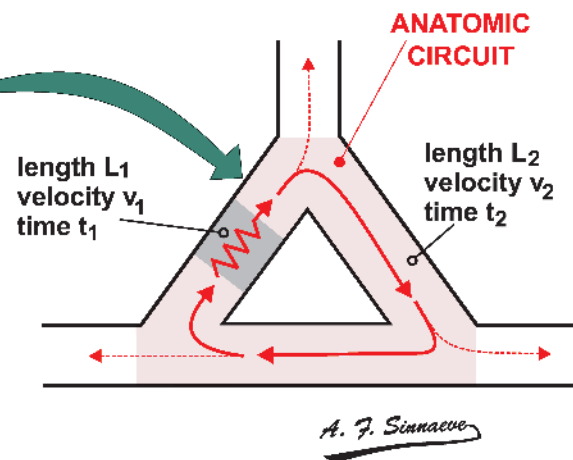


The tachycardia is sustained if the tissue proximal to the site of the (unidirectional) block is no longer refractory when it is excited by retrograde activation. It follows that the total time to go around the circuit has to be shorter than the refractory period :

$$\text{Refractory period } RP \leq t_1 + t_2$$

or :

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



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

Here you can see how an AES starts an AVNRT. It isn't as difficult as you might think !



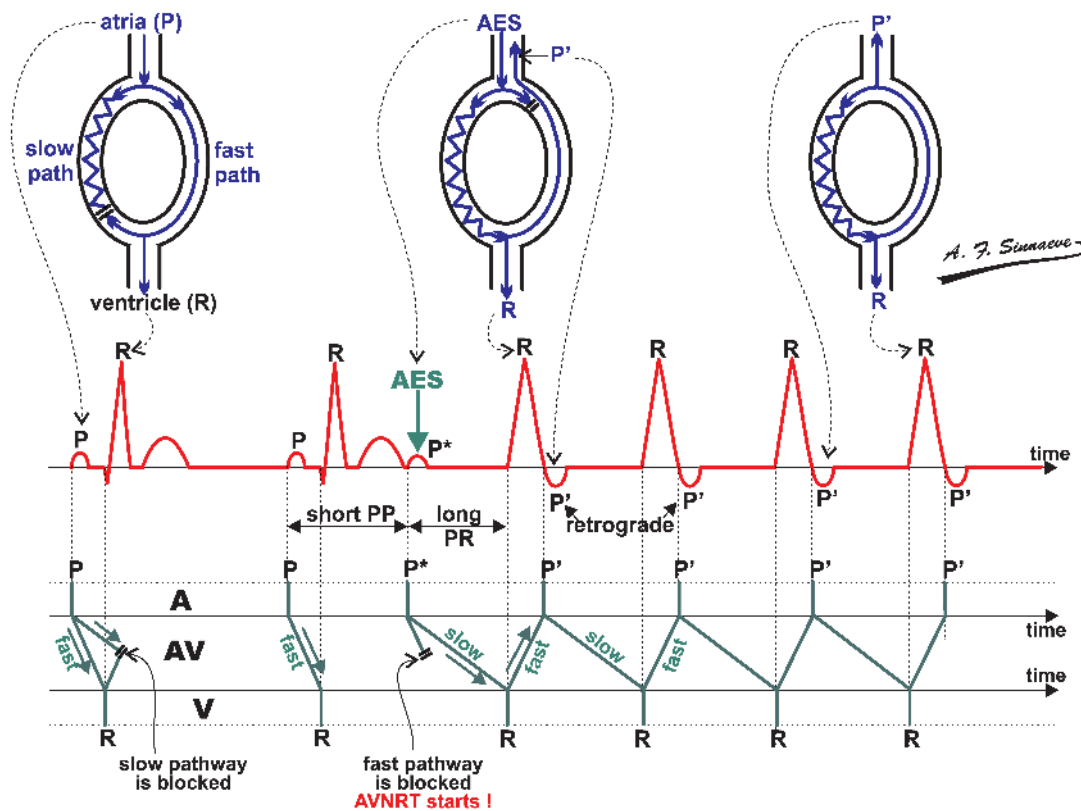
1 AV NODAL REENTRANT TACHYCARDIA (AVNRT) common type : "Slow-Fast"

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 .

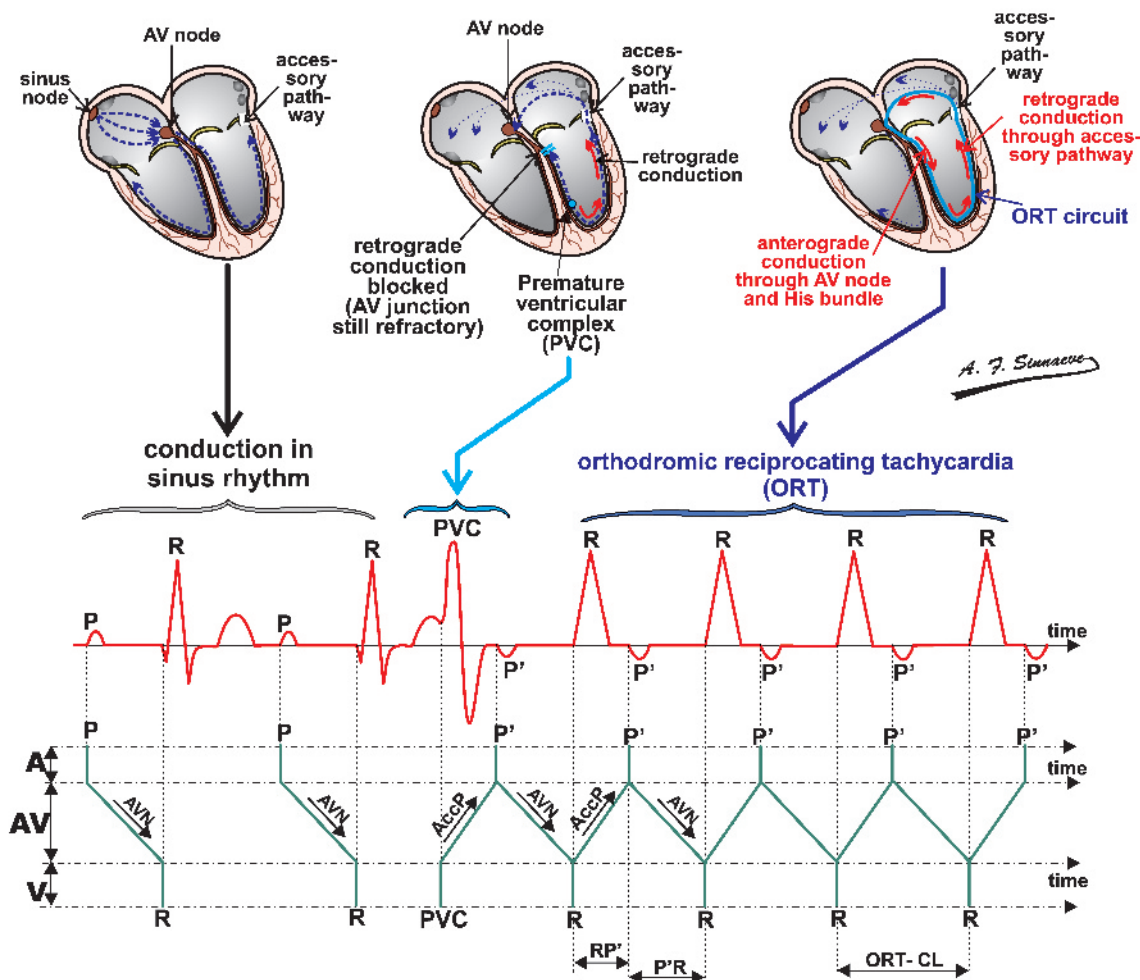
Figure 1.03

MECHANISMS of SUPRAVENTRICULAR TACHYCARDIAS (SVT) - part 2

The mechanism of an ORT closely resembles that of an AVNRT. The difference is in the loop which is much larger for ORT !

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 $RP' < P'R$ (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.



$RP' \cong 140$ ms during ORT !
(in contrast to AVNRT where the retrograde P' wave is merged with the preceding QRS).

Other designations for ORT : reciprocating supraventricular tachycardia ; orthodromic AV reentrant tachycardia ; AV reentrant tachycardia ; AV reciprocating tachycardia ;

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

Figure 1.04

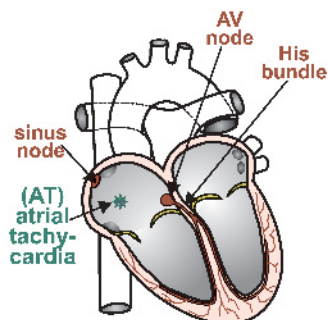
MECHANISMS of SUPRAVENTRICULAR TACHYCARDIAS (SVT) - part 3

This is a tough task for the discriminators in every ICD !



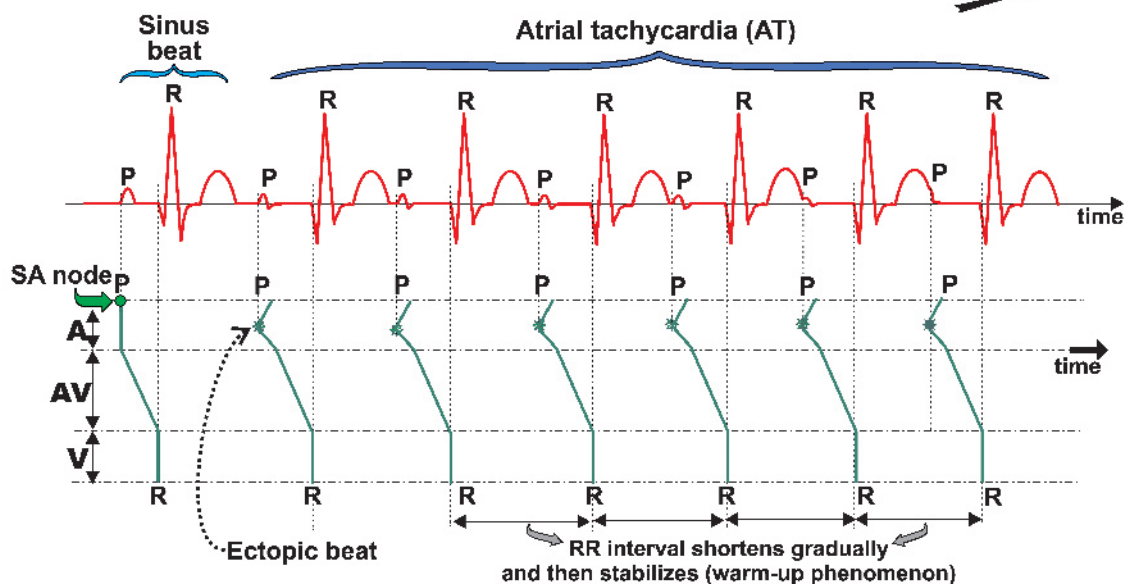
3 ATRIAL TACHYCARDIA (AT)

- * 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.

A. F. Sinaev



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

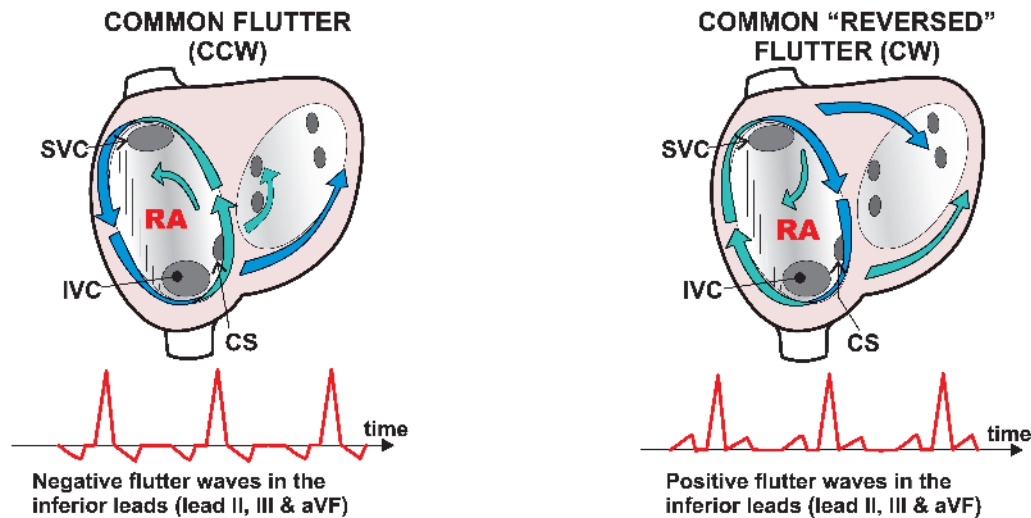
Figure 1.05

MECHANISMS of SUPRAVENTRICULAR TACHYCARDIAS (SVT) - part 4



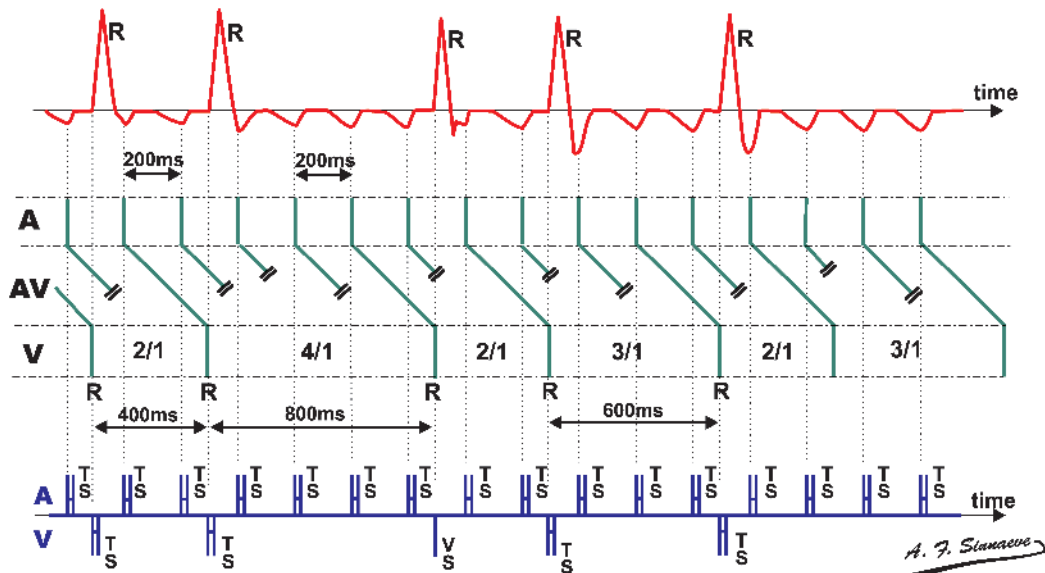
Did you know that my atrial flutter is caused by a circus movement ?!

4 ATRIAL FLUTTER (AFL)



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 .

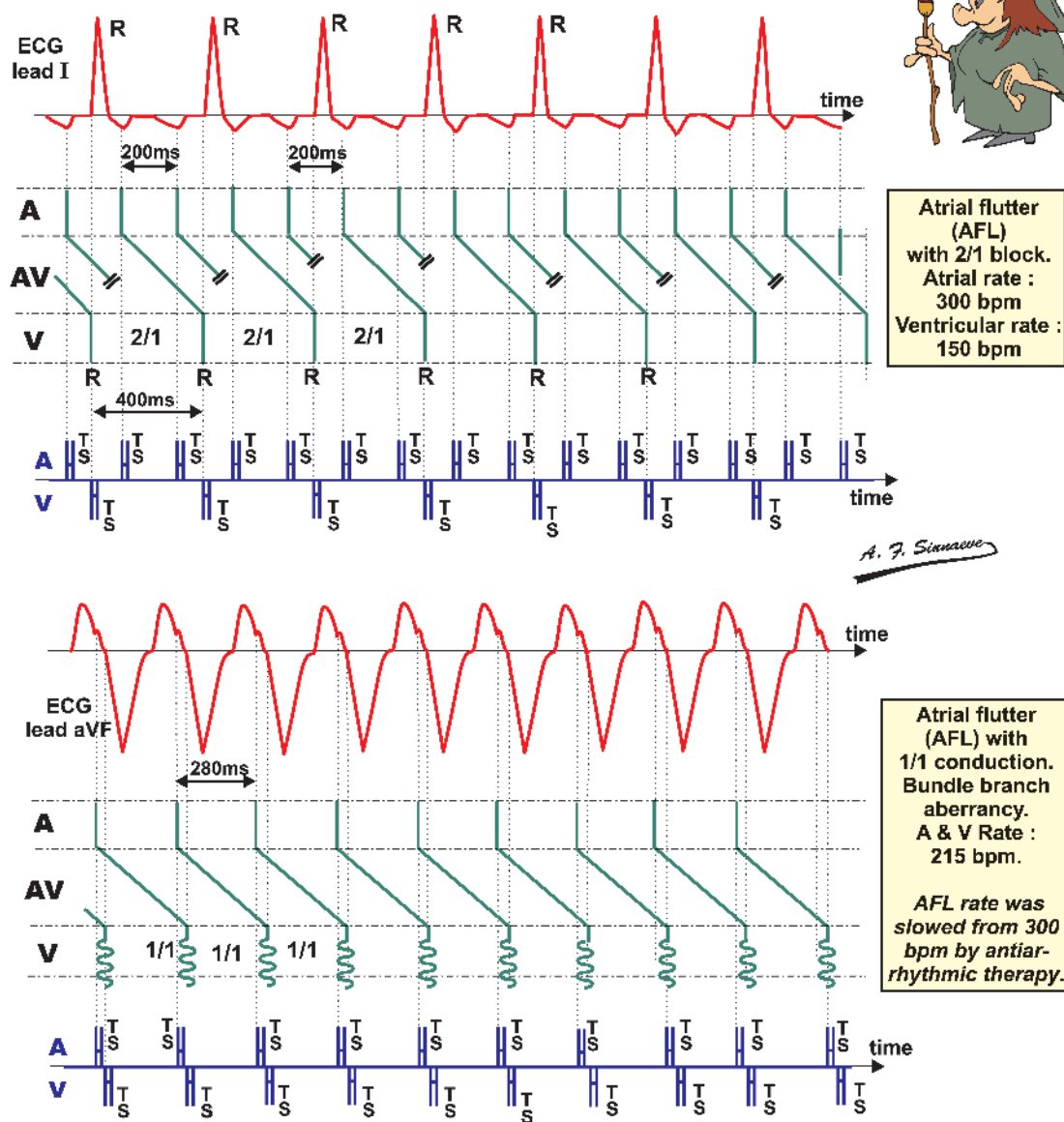
Figure 1.06

MECHANISMS of SUPRAVENTRICULAR TACHYCARDIAS (SVT) - part 5

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



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

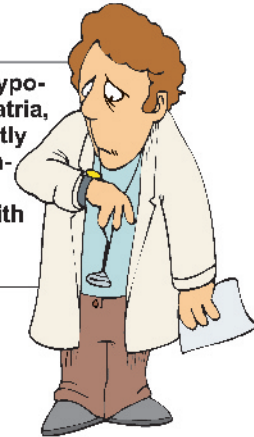


Abbreviations: A = atrium; AV = atrioventricular junction; AFL = atrial flutter; TS = tachycardia sense; V = ventricle; VS = ventricular sense.

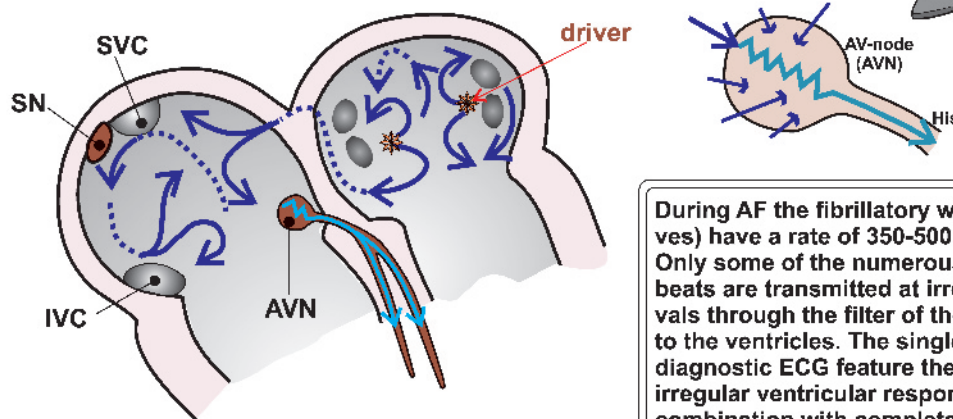
Figure 1.07

MECHANISMS of SUPRAVENTRICULAR TACHYCARDIAS (SVT) - part 6

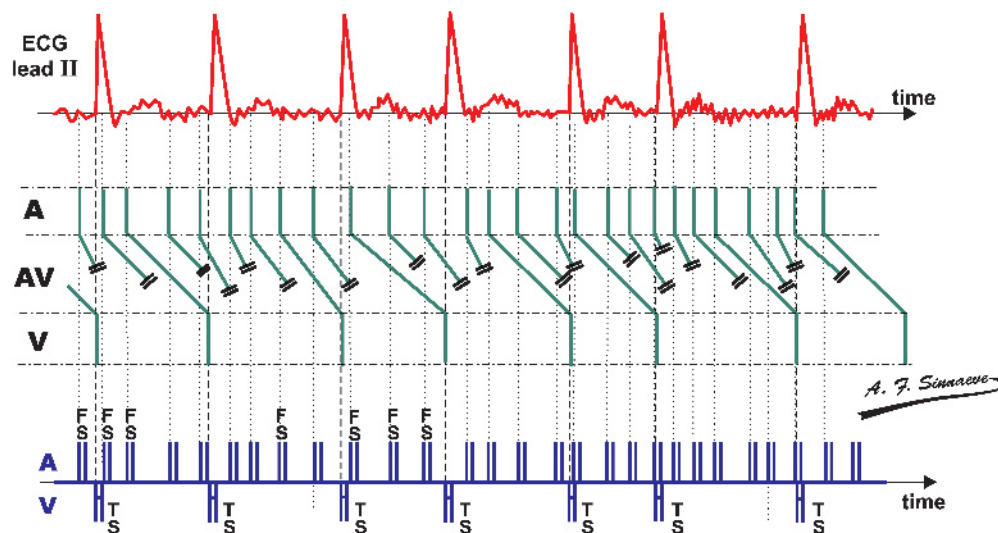
The electrophysiologic basis of atrial fibrillation remains unclear. Two major hypotheses prevail : (1) **multiple wavelets** of depolarization propagating within the atria, dividing, coalescing and extinguishing each other as they travel in an apparently random fashion seeking tissue that is excitable 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.

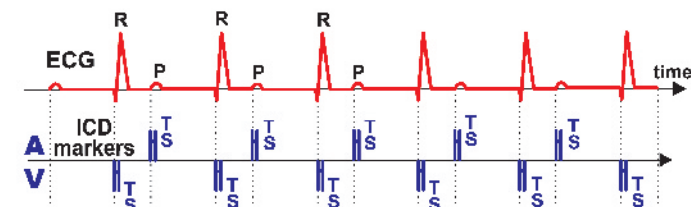


Abbreviations : A = atrium ; AV = atrioventricular junction ; AF = atrial fibrillation ; AVN = AV - node ; FS = fibrillation sense ; IVC = inferior vena cava ; SN = sinus node ; SVC = superior vena cava ; TS = tachycardia sense ; V = ventricle ;

Figure 1.08

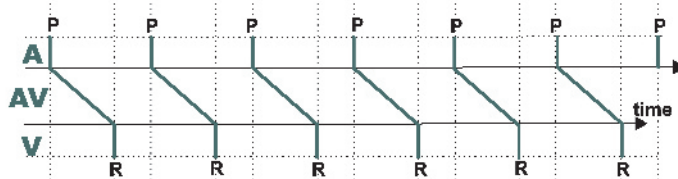
ANALYSIS OF DUAL CHAMBER EGMs - 1 TACHYCARDIA with 1 : 1 AV RELATIONSHIP

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 !



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

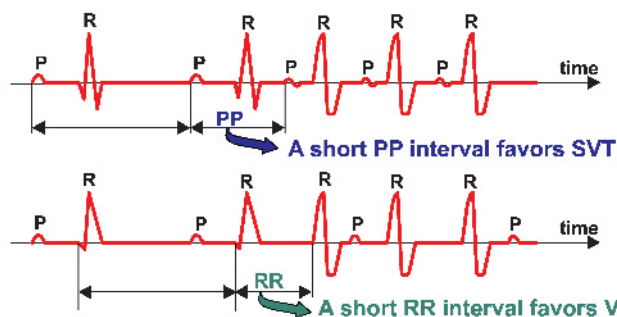
The vast majority of tachycardias with 1:1 AV association are SVT mainly sinus tachycardia. Normally an ST accelerates gradually with fairly stable PR interval.



VT (ventricular tachycardia) with 1:1 retrograde conduction

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.

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



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

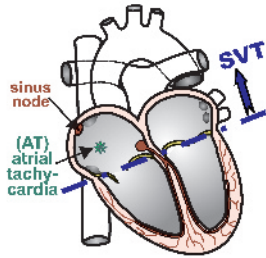
VEGM morphology identical to that in sinus rhythm strongly suggests SVT. A VEGM morphology different from that of sinus rhythm indicates VT in about 90% of cases.

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

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

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Figure 1.09

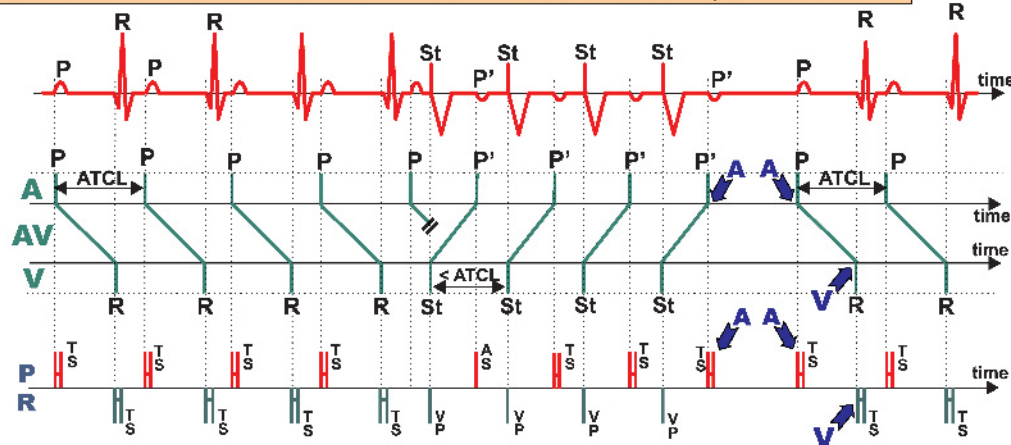


ANALYSIS OF DUAL CHAMBER EGMs - 2 TACHYCARDIA with 1 : 1 AV RELATIONSHIP

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

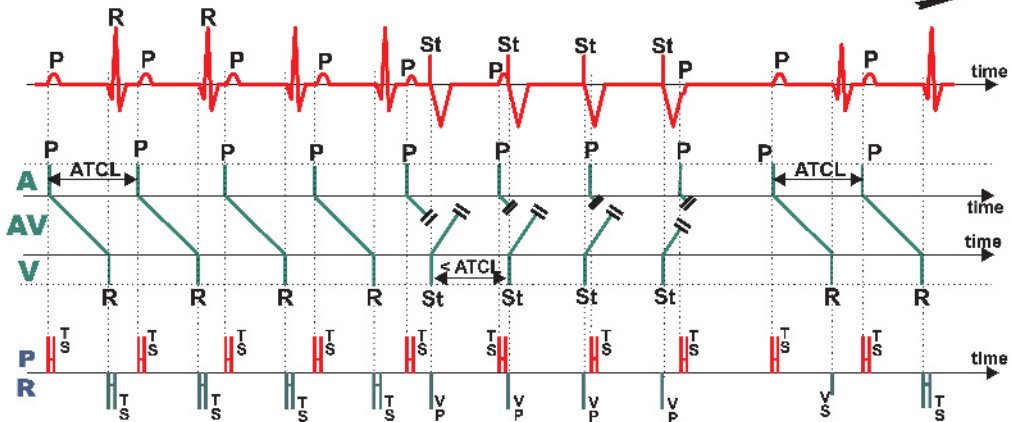


If there is entrainment (i.e. the atrial rate accelerates during ventricular ATP and becomes equal to the stimulation rate), and the original tachycardia resumes with an AAV response at the end of the ATP sequence, the arrhythmia is AT.



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

A. F. Sinaev



SUMMARY : Atrial response to ventricular ATP

VT vs SVT	No acceleration of atrial rate	Acceleration of atrial rate
No termination of tachycardia by ATP	Highly suggestive of AT if atrial rate remains constant	AT if AAV response
Termination of tachycardia by ATP	Not AT	Not decisive

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

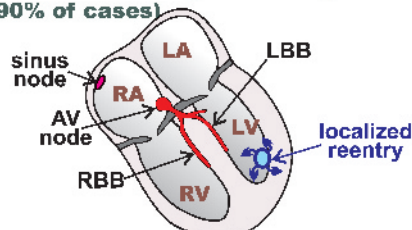
WIDE QRS TACHYCARDIAS

CAUSES

Wide or broad QRS complex is defined as being ≥ 120 ms!

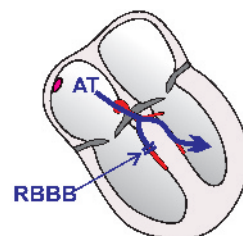


- 1 VT is the most common form of wide QRS complex tachycardia (90% of cases)**

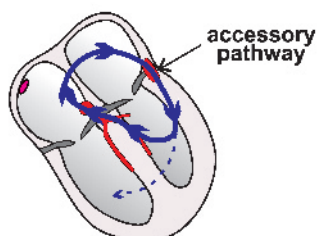


A regular wide QRS complex tachycardia should always be considered as being VT until proven otherwise. VT is rare in structurally normal hearts.

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

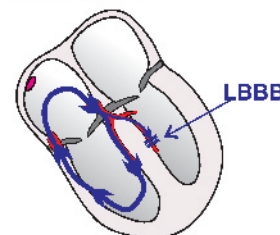


- 3 Antidromic AVRT**



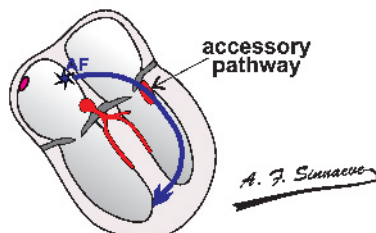
Pre-excitation (WPW); delta waves
Antidromic : anterograde over an accessory pathway and retrograde over the AV node

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



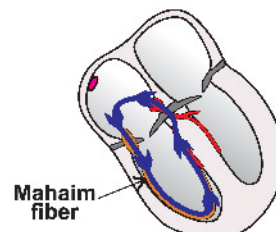
Orthodromic : anterograde over the AV node and retrograde over an accessory pathway

- 5 SVT with conduction over an accessory pathway**



AF and conduction over an accessory pathway is always : *FBI* (fast, broad, irregular). 1:1 AV conduction of atrial flutter over the accessory pathway may result in very rapid ventricular rates

- 6 Antidromic AVRT using Mahaim fiber**



Mahaim fibers form an atriofascicular accessory pathway from the right atrium to the right bundle branch

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 1.11

WIDE QRS TACHYCARDIAS

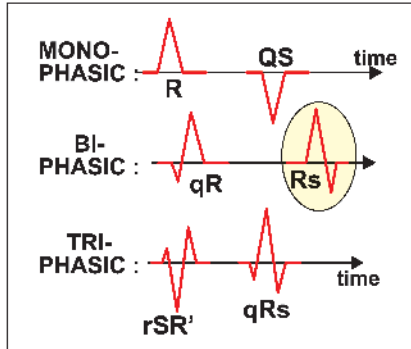
STEPWISE APPROACH - part 1

We should know 3 things :

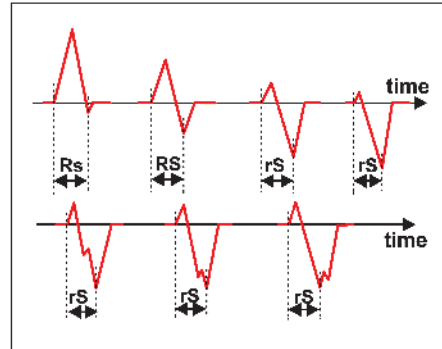
- * What should be measured ?
- * How should we measure correctly ?
- * Which strategy do we have to follow ?



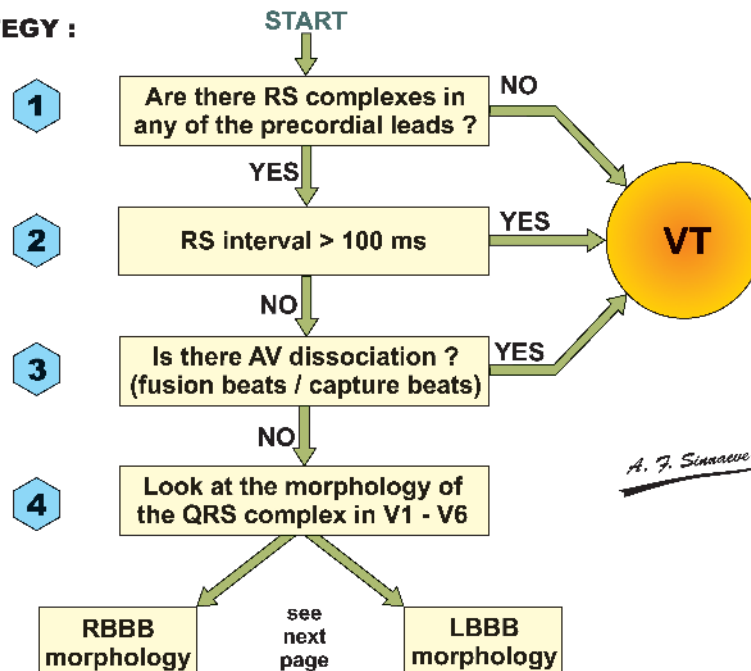
WHAT ?



HOW ?



STRATEGY :



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.

Capture and fusion beats are uncommon and found mostly in relatively slower VTs

Abbreviations : AV = atrioventricular ; VT = ventricular tachycardia ; LBBB = left bundle branch block ; RBBB = right bundle branch block .

Figure 1.12

WIDE QRS TACHYCARDIAS

STEPWISE APPROACH - part 2

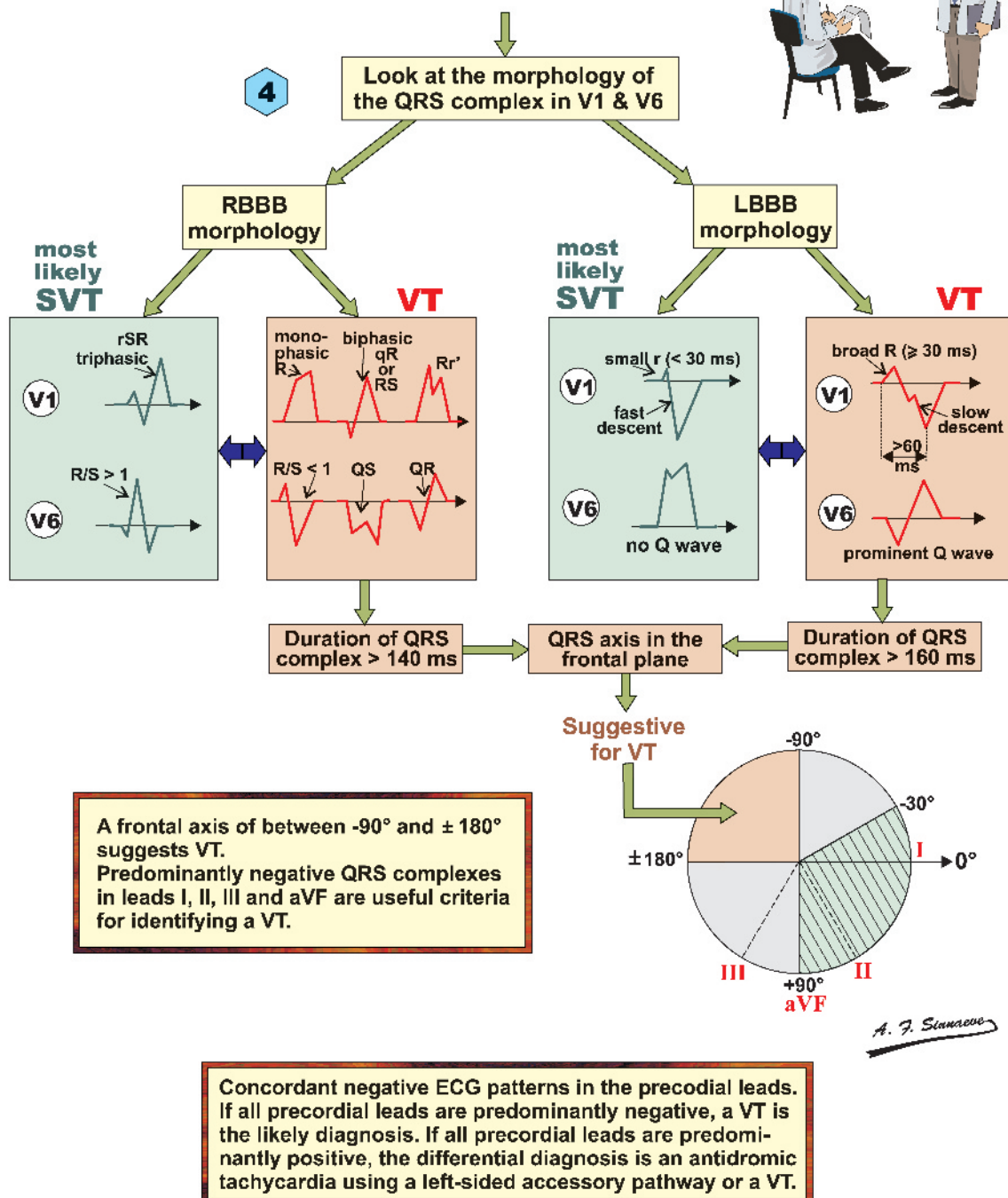
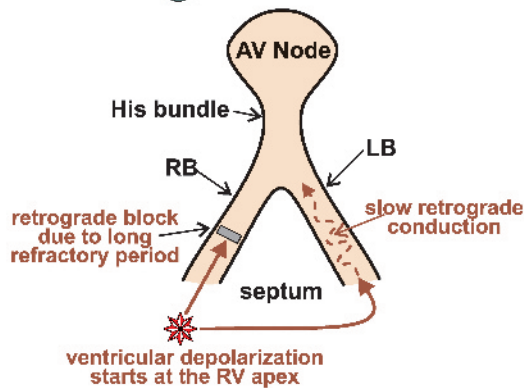


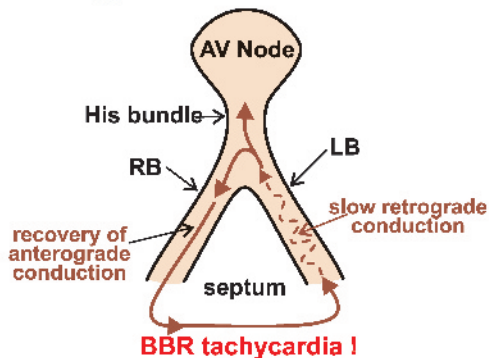
Figure 1.13

BUNDLE BRANCH REENTRY TACHYCARDIA (BBR)

1 GENESIS



2 CONTINUATION



As the length of the circuit is small, the tachycardia frequency is usually high, often 200 to 300 bpm.

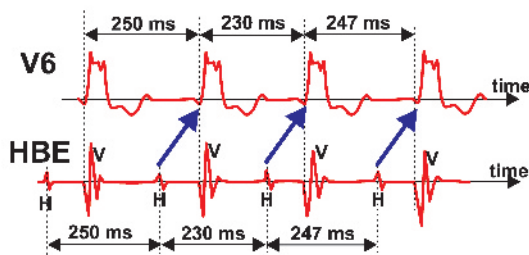
Recognition of BBR is important for several reasons :

- * 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**

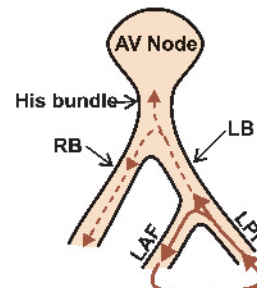


DIAGNOSTIC FEATURES WITH BBR

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;

Figure 1.14

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**)

A-A-V response **rules out** AVNRT & ORT

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**

A. J. Summace

Figure 1.15

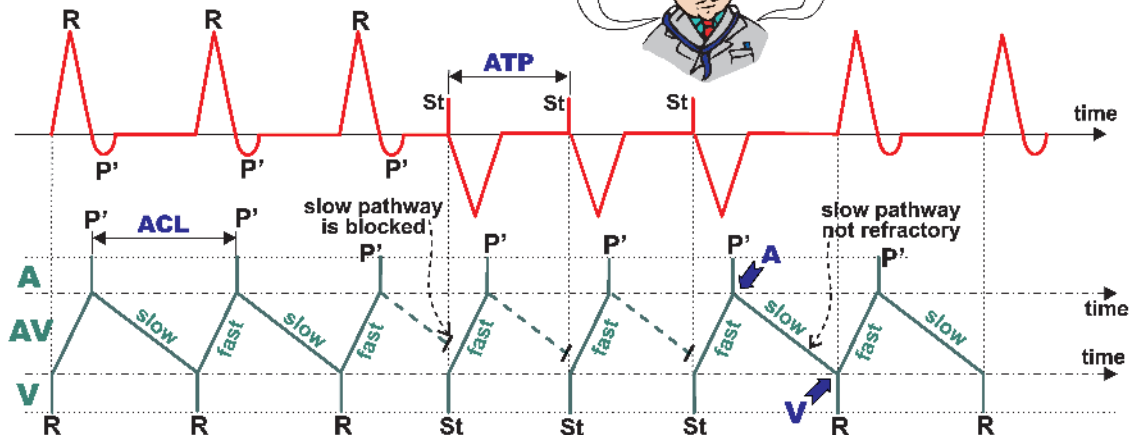
DIAGNOSIS OF SUPRAVENTRICULAR TACHYCARDIA FROM STORED ELECTROGRAMS - part 1

Ventricular ATP with atrial entrainment and AV response after ventricular ATP

1 AV NODAL REENTRANT TACHYCARDIA (AVNRT)

Antitachycardia 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.

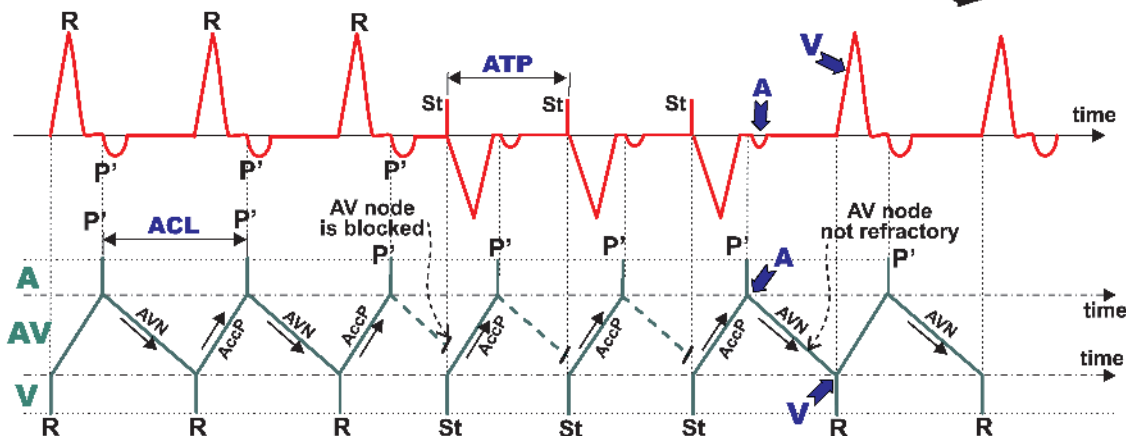
If the AVNRT resumes after ATP, it will start at the last retrograde P' and an A-V sequence will be registered by the stored atrial and ventricular electrograms.



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**.

2 ORTHODROMIC RECIPROCATING TACHYCARDIA (ORT)

A. J. Sumner



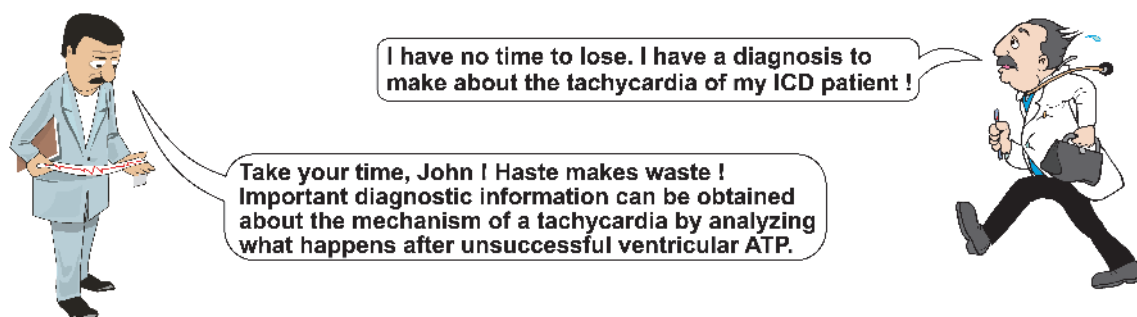
After the last ventricular paced beat in the ATP sequence, the antegrade limb of the ORT tachycardia (AV node) is not refractory. The last retrograde atrial complex can therefore conduct to the ventricle producing a **DIAGNOSTIC AV RESPONSE**. This response **RULES OUT AN ATRIAL TACHYCARDIA**.

Abbreviations : AccP = accessory pathway ; ACL = atrial cycle length ; ATP = antitachycardia pacing ; AVN = AV node = atrioventricular node ; St = stimulus .

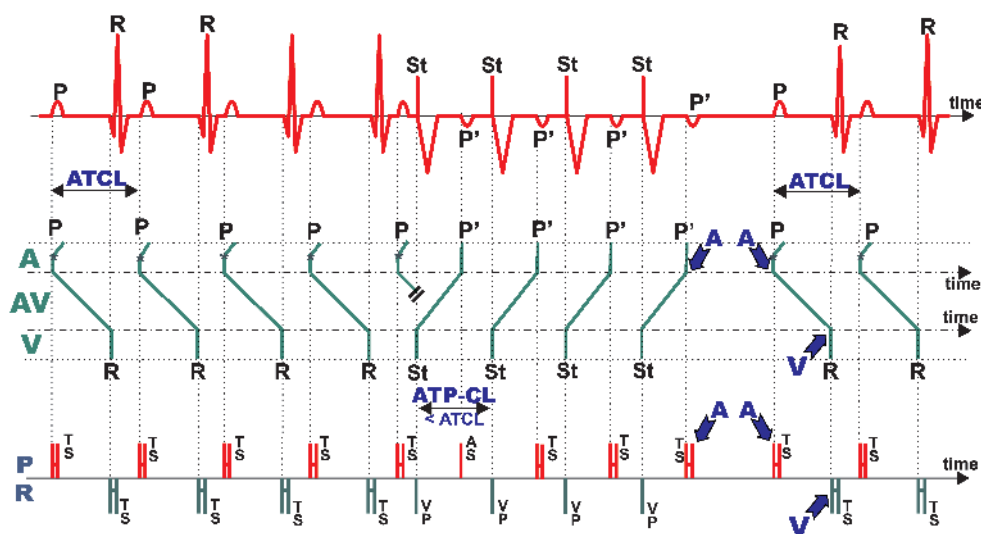
Figure 1.16

DIAGNOSIS OF SUPRAVENTRICULAR TACHYCARDIA FROM STORED ELECTROGRAMS - part 2

Ventricular ATP with atrial entrainment and AAV reponse after 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 antegradely 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 = antitachycardia pacing ; AS = atrial sense ; AVN = AV node = atrioventricular 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

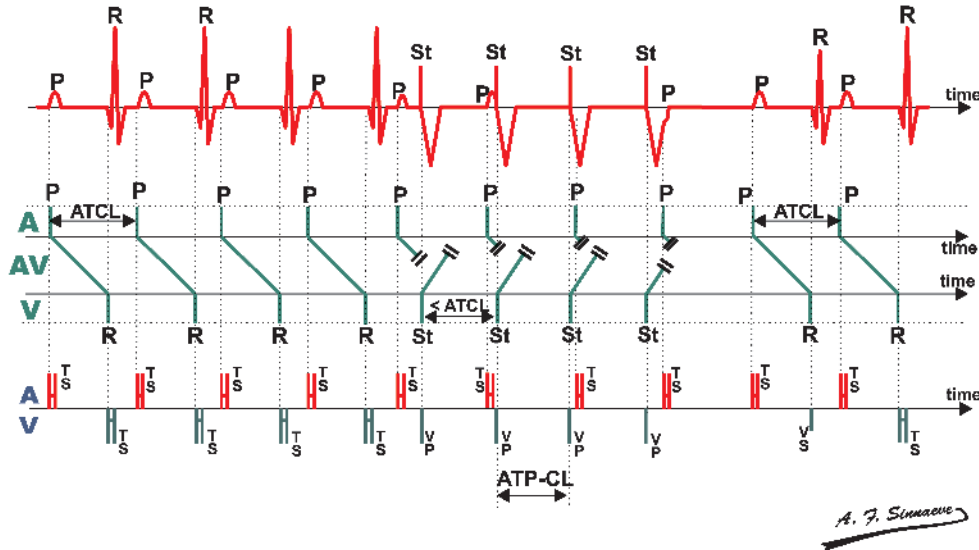


So, I have to pace in the ventricle at a pacing rate faster than the tachycardia rate and look if the atrial rate is changing. If I can note dissociation between ventricular and atrial rates, atrial tachycardia (AT) is very likely !?

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**).



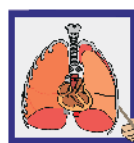
Abbreviations : ATCL = atrial cycle length ; AT = atrial tachycardia ; ATP = antitachycardia pacing ; ATP-CL = ATP cycle length ; AVN = AV node = atrioventricular node ; St = stimulus ; VP = ventricular pace ;

Figure 1.18

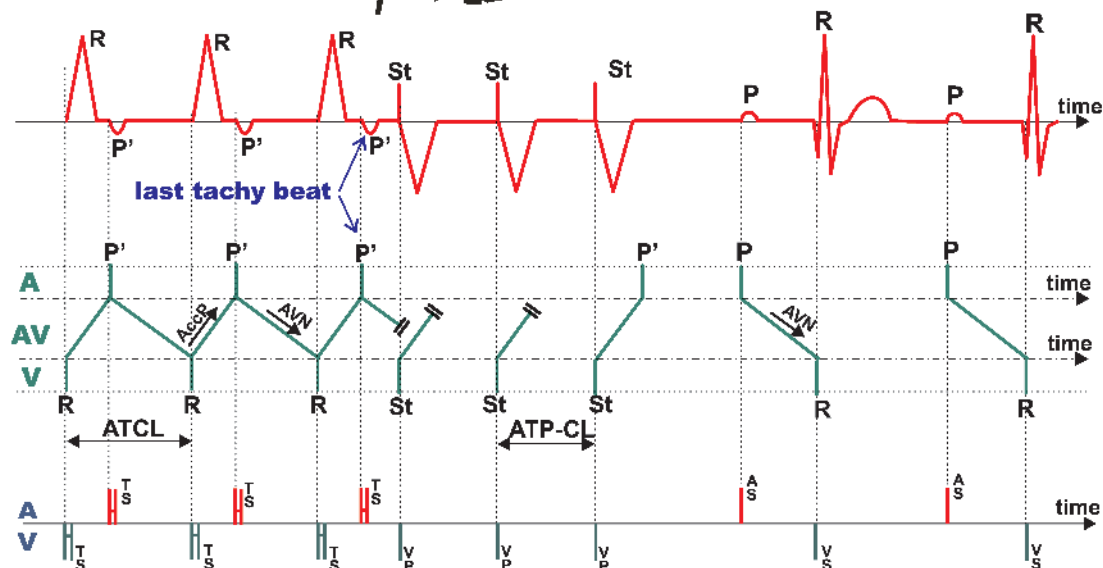
DIAGNOSIS OF SUPRAVENTRICULAR TACHYCARDIA FROM STORED ELECTROGRAMS - part 4

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.



A. J. Smeets

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 ; VS = ventricular sense ;

Figure 1.19