

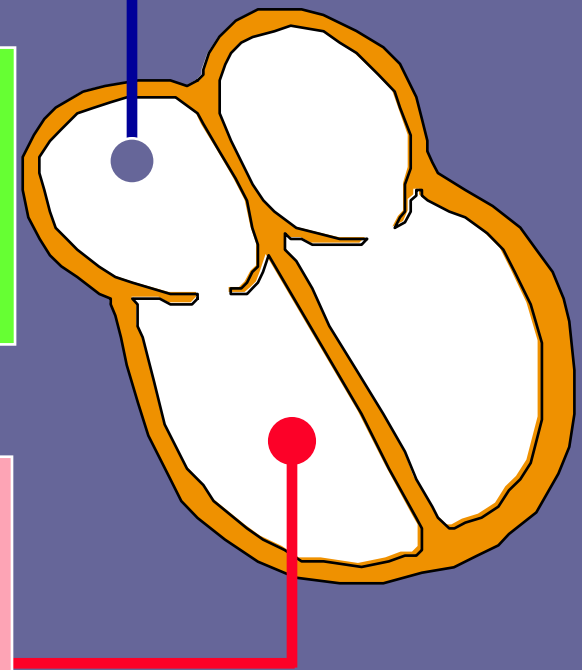
SMART-Detection

SMART-Detection Algorithms

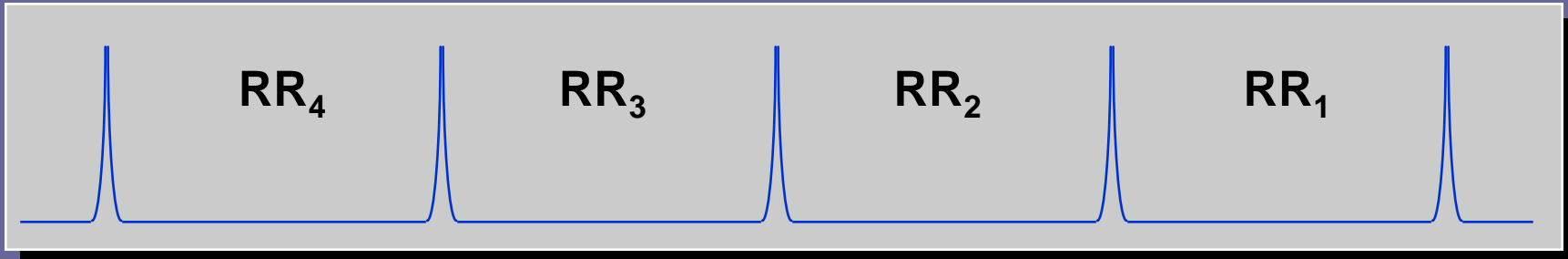
- Averaged atrial rate
- Stability of the atrial rate

- Multiplicity of the atrio-ventricular rates (N:1)
- PR interval stability

- Averaged ventricular rate
- Stability of the ventricular rate
- Ventricular onset



Average Ventricular Rate

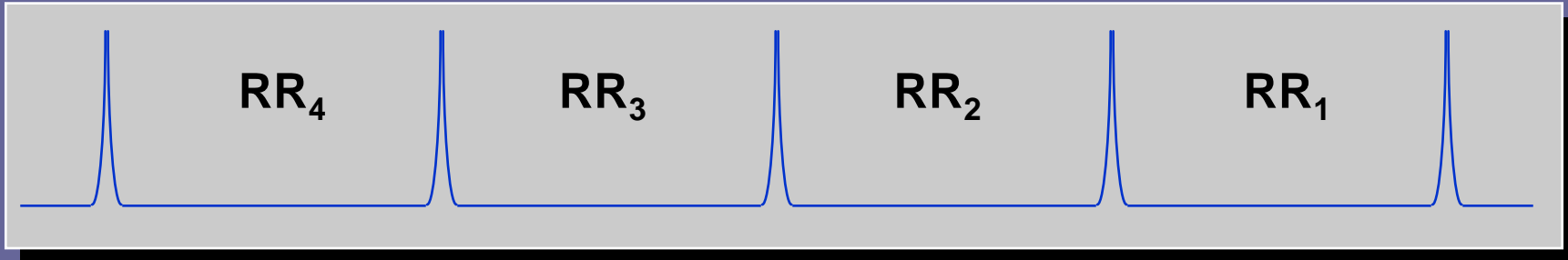


The previous four R-R intervals are used to calculate the average ventricular rate.

The average ventricular rate is then used for VT detection and VT zone discrimination.

Average Ventricular Rate = Average (RR₁, RR₂, RR₃, and RR₄)

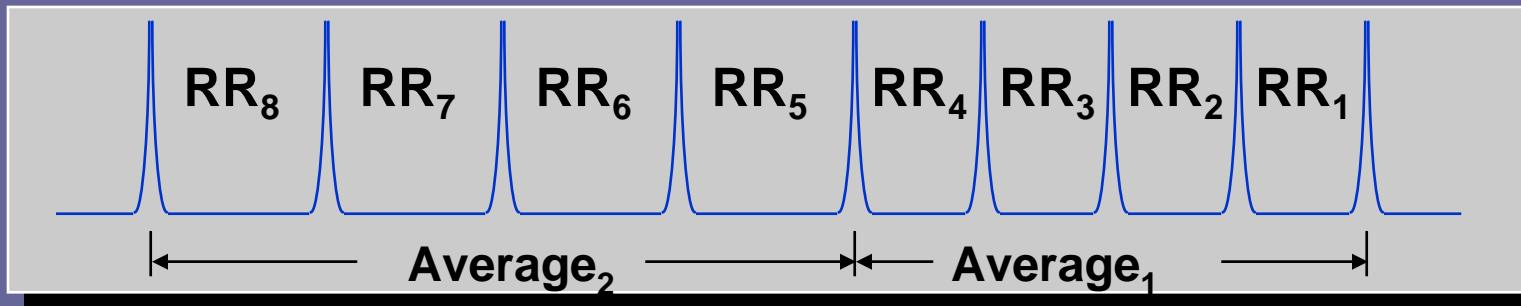
Stability of Ventricular Rate



The ventricular rhythm is considered to be stable if all of the differences between the most recent ventricular interval (RR₁) and each of the previous ventricular intervals (RR₂, RR₃, and RR₄) are less than or equal to the programmed stability limit.

$$\begin{aligned} \text{Abs}(\text{RR}_1 - \text{RR}_2) &\leq \text{Stability Limit and} \\ \text{Abs}(\text{RR}_1 - \text{RR}_3) &\leq \text{Stability Limit and} \\ \text{Abs}(\text{RR}_1 - \text{RR}_4) &\leq \text{Stability Limit} \end{aligned}$$

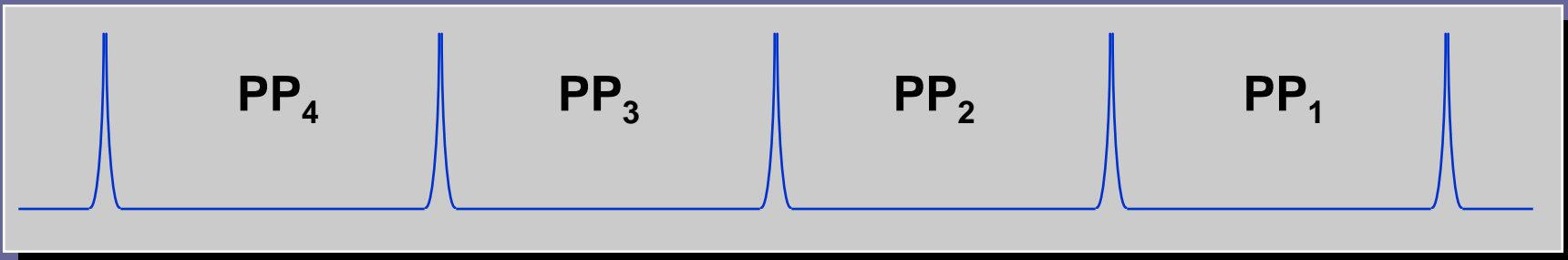
Onset of Ventricular Rate



The onset is classified as sudden if the difference between the previous four interval average and the current four interval average is greater than or equal to the programmed onset limit.

$$Average_2 - Average_1 \geq \text{Onset Limit}$$

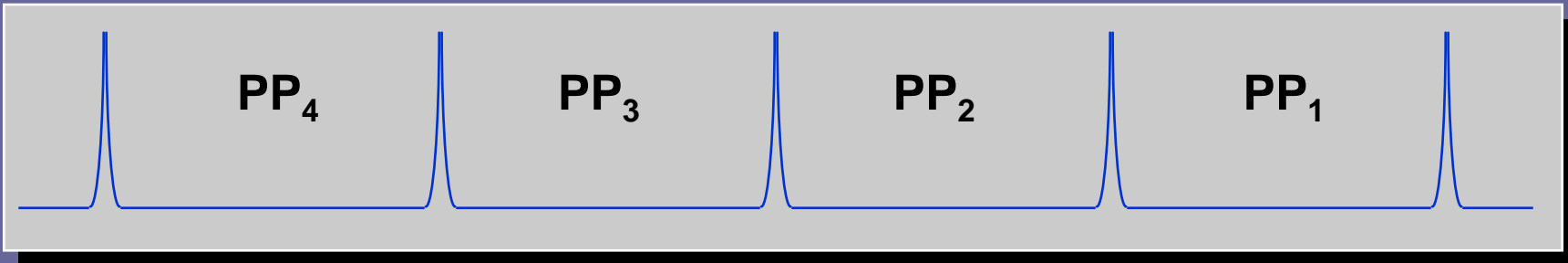
Average Atrial Rate



The previous four P-P intervals are used to calculate the average atrial rate. The average atrial and ventricular rates are then used for further analysis.

Average Atrial Rate = Average (PP₁, PP₂, PP₃, and PP₄)

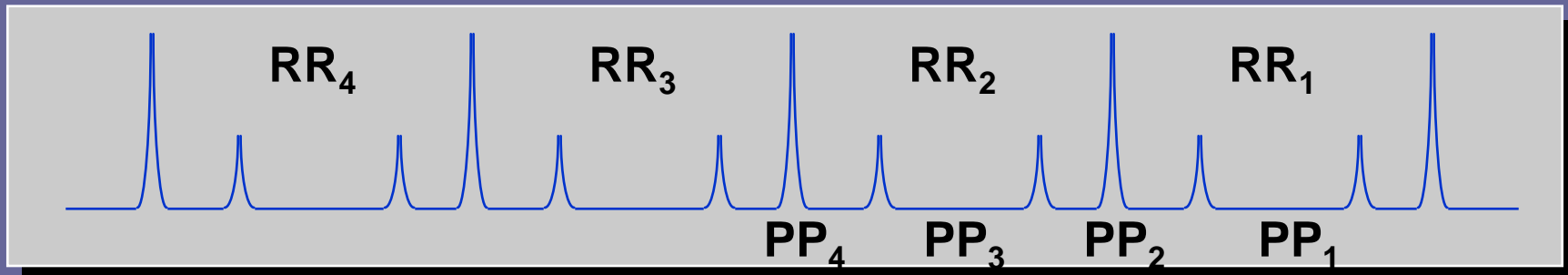
Stability of Atrial Rate



The atrial rhythm is considered to be stable if all of the differences between the most recent atrial interval (PP_1) and each of the previous atrial intervals (PP_2 , PP_3 , and PP_4) are less than or equal to the programmed stability limit.

$$\begin{aligned} \text{Abs}(PP_1 - PP_2) &\leq \text{Stability Limit and} \\ \text{Abs}(PP_1 - PP_3) &\leq \text{Stability Limit and} \\ \text{Abs}(PP_1 - PP_4) &\leq \text{Stability Limit} \end{aligned}$$

Multiplicity N:1



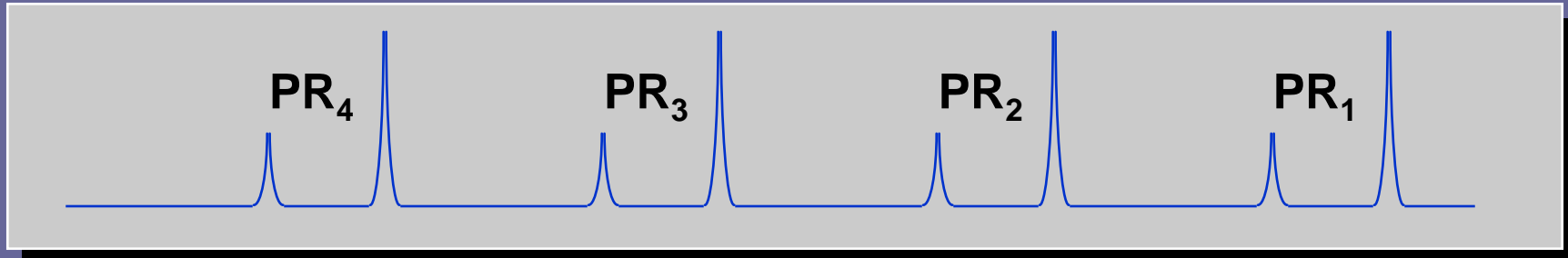
A and V signals superimposed

The multiplicity algorithm is satisfied if

- there is an N:1 ratio between atrial and ventricular events
- the average ventricular interval is equal to N times the average atrial interval

Average (RR₁ to RR₄) - N times Average (PP₁ to PP₄) ≤ Multiplicity Limit

P-R Stability

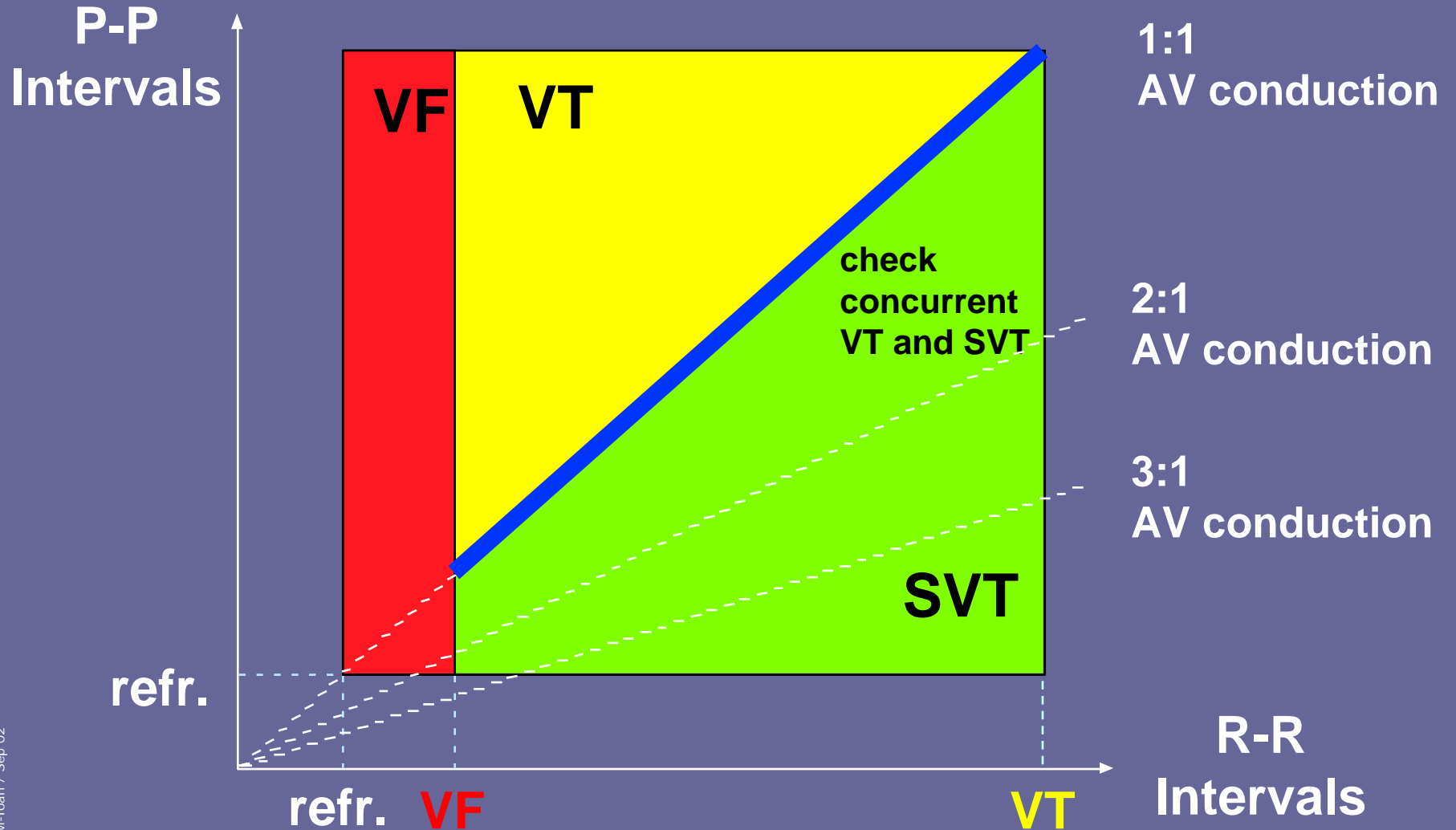


A and V signals superimposed

The P-R intervals are classified as regular if all of the differences between the current interval (PR_1) and each of the previous intervals (PR_2 , PR_3 , PR_4) are less than or equal to the regularity limit.

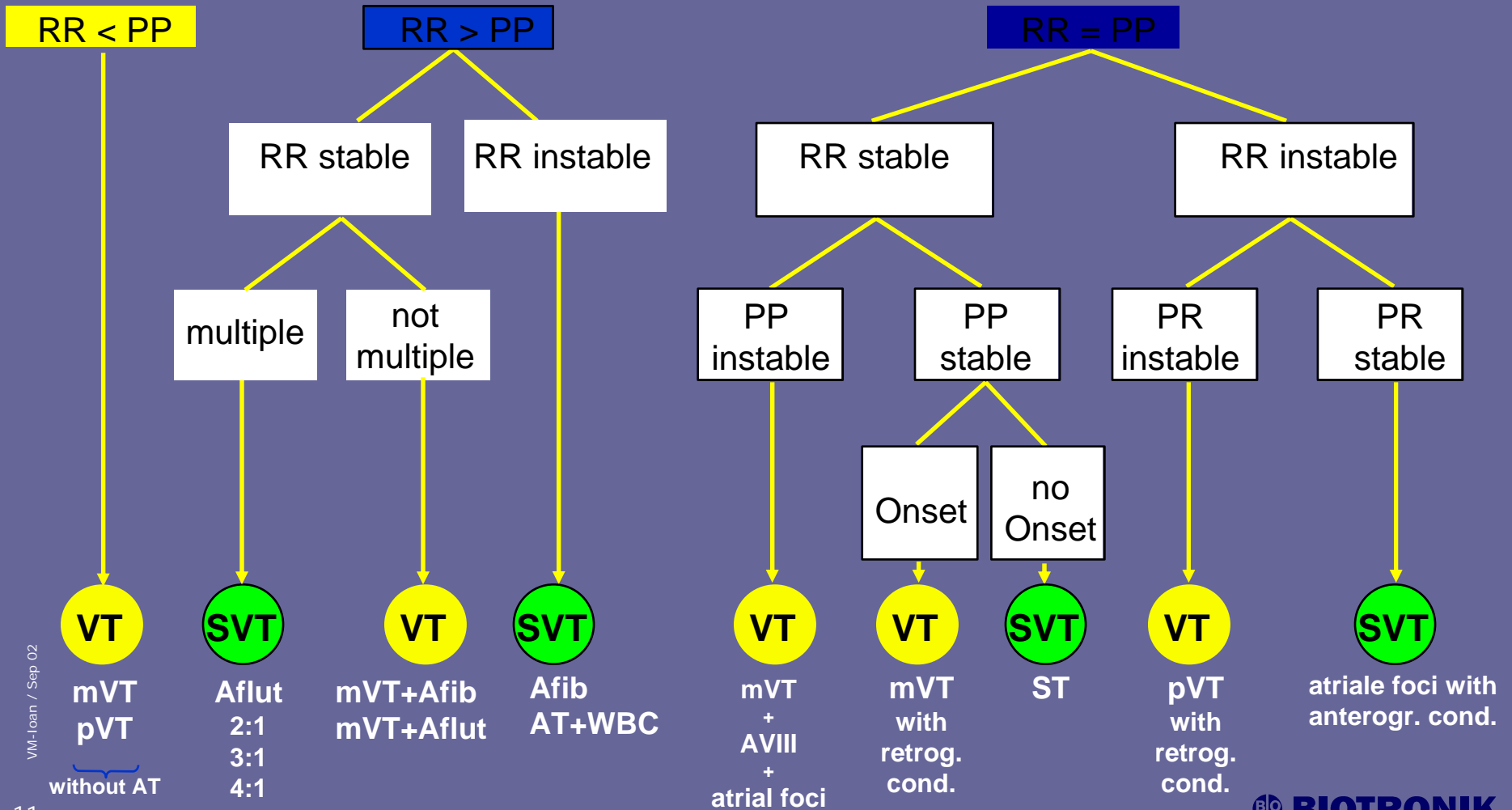
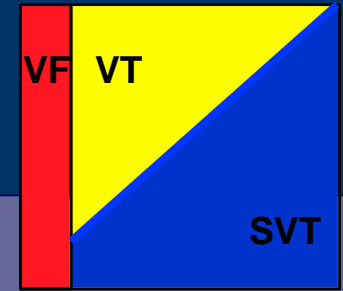
$$\begin{aligned} \text{Abs}(PR_1 - PR_2) &\leq \text{Regularity Limit and} \\ \text{Abs}(PR_1 - PR_3) &\leq \text{Regularity Limit and} \\ \text{Abs}(PR_1 - PR_4) &\leq \text{Regularity Limit} \end{aligned}$$

AV-Discrimination



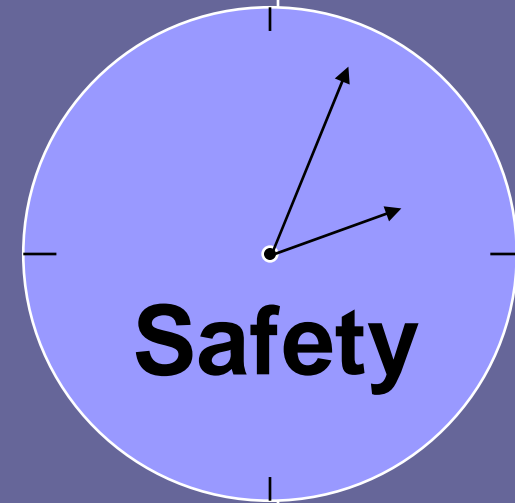
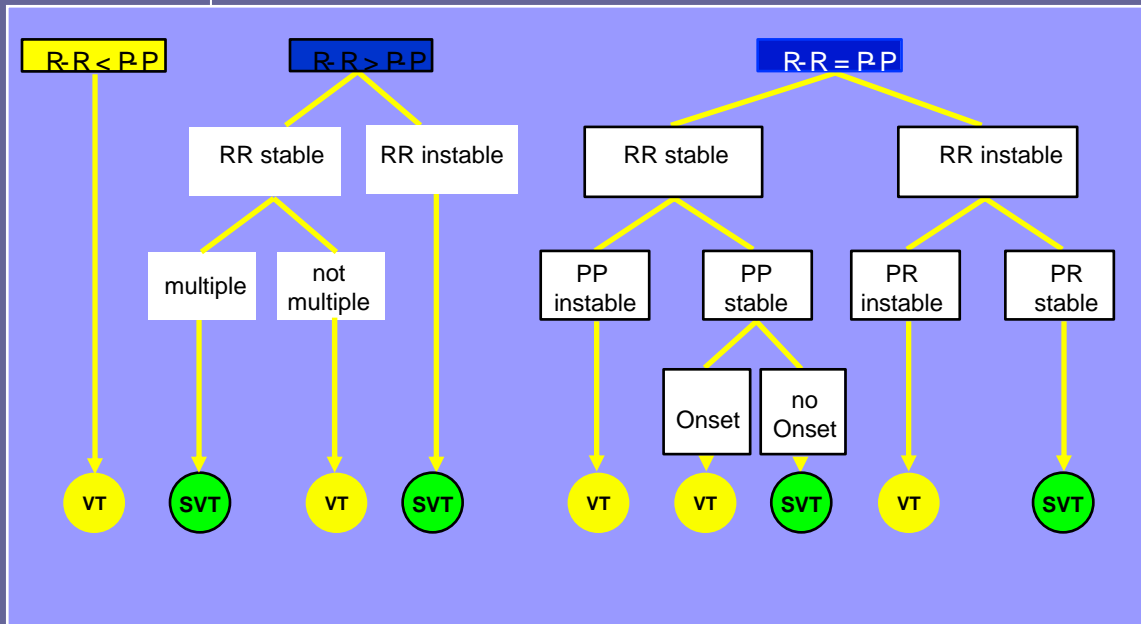
Non-averaged single RR-Interval
 (counter set: +1; -1; -1/4; reset)

AV-Discrimination



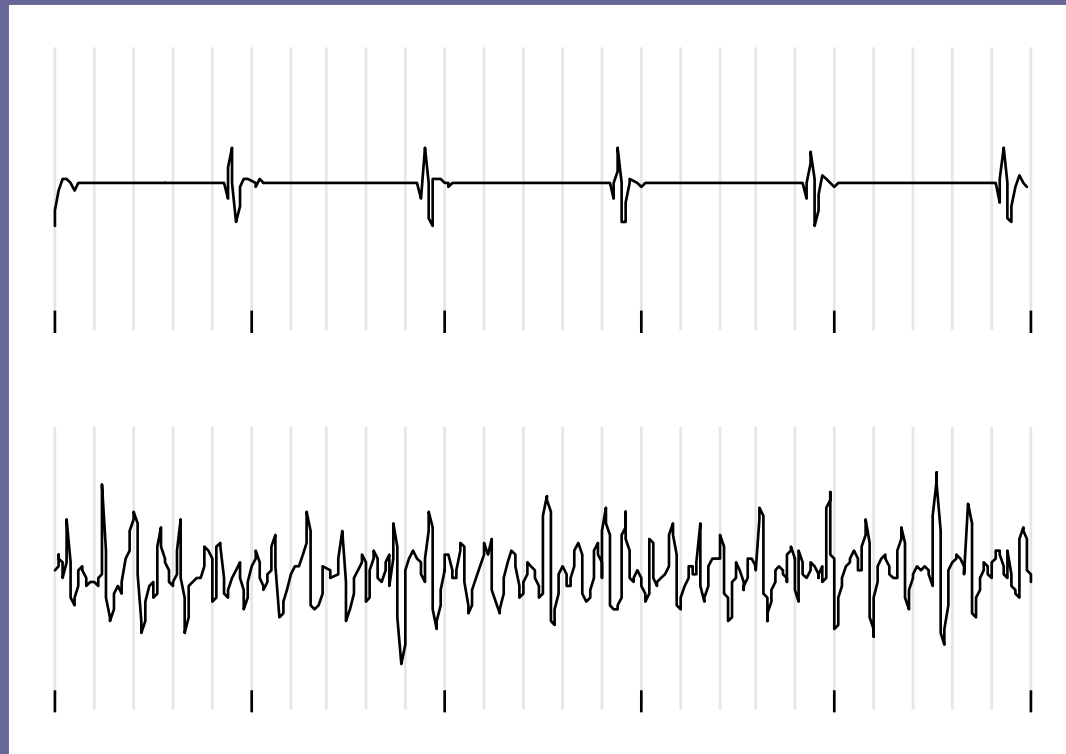
Safety Timer

VT-Detection without SMART



What is the atrial and the ventricular rhythm ? How is the SMART decision ?

Ventricular Fibrillation



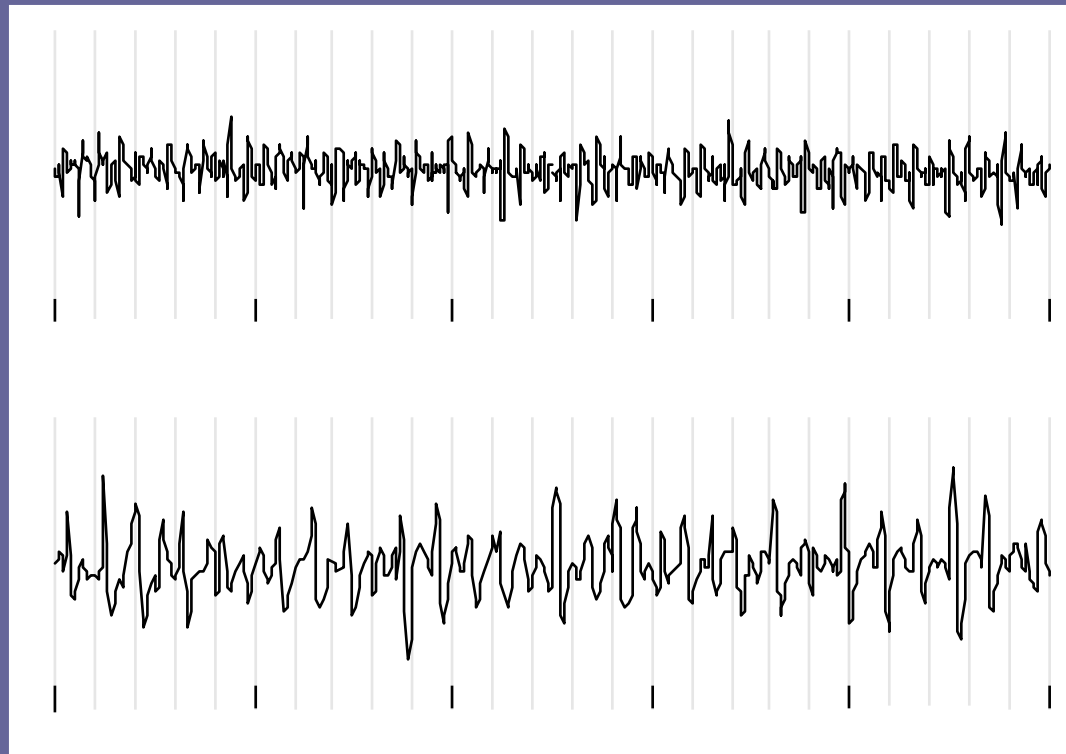
RR Intervals
in VF-Zone



Therapy

What is the atrial and the ventricular rhythm ? How is the SMART decision ?

Atrial Fibrillation and Ventricular Fibrillation



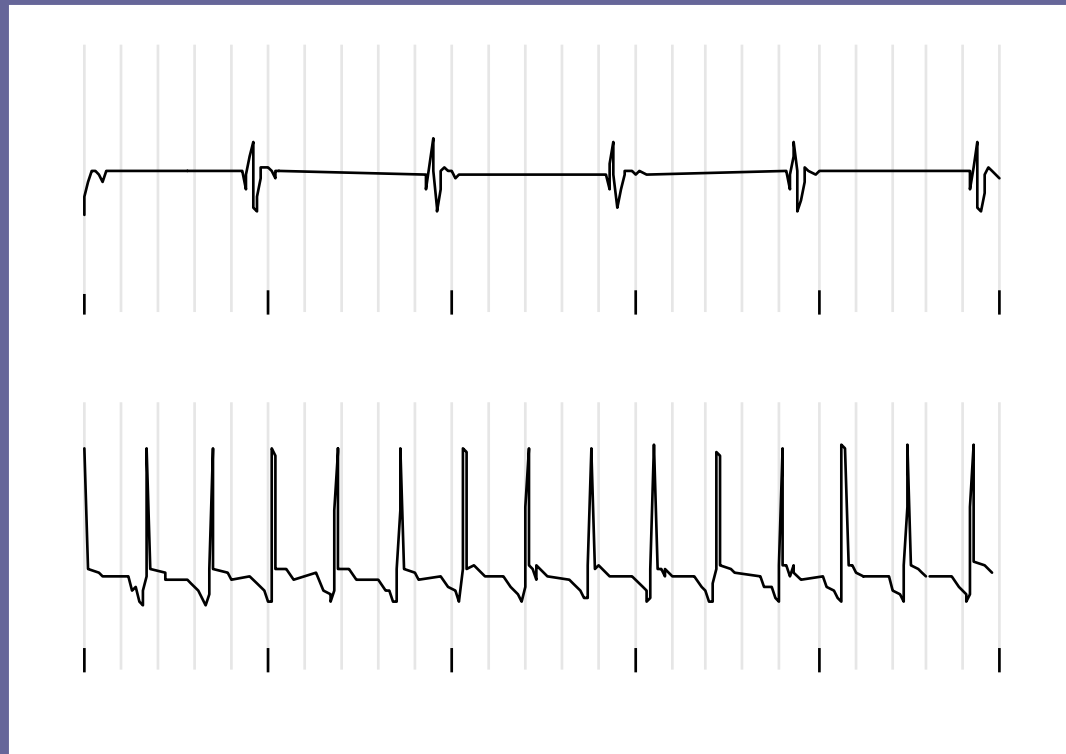
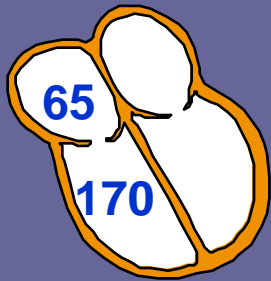
RR Intervals
in VF-Zone



Therapy

What is the atrial and the ventricular rhythm ? How is the SMART decision ?

Monomorphic Ventricular Tachycardia



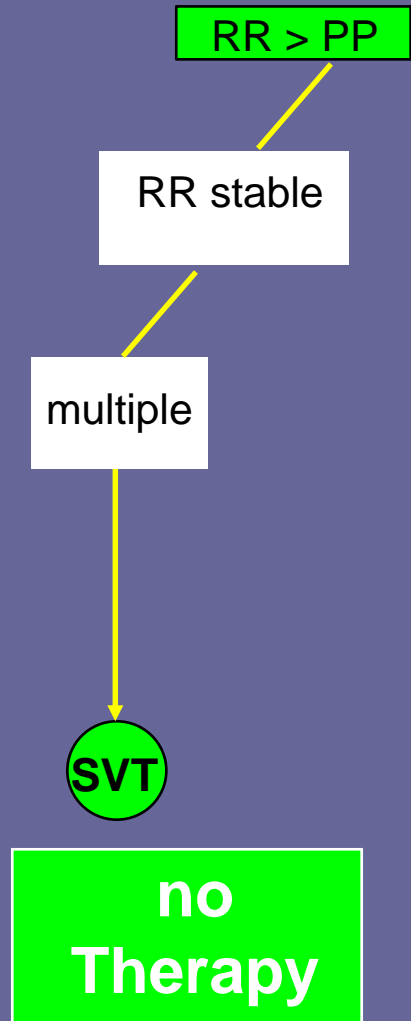
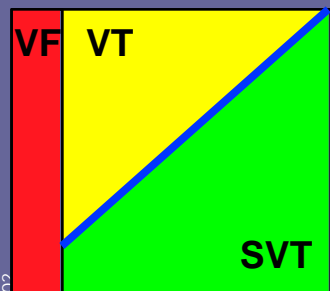
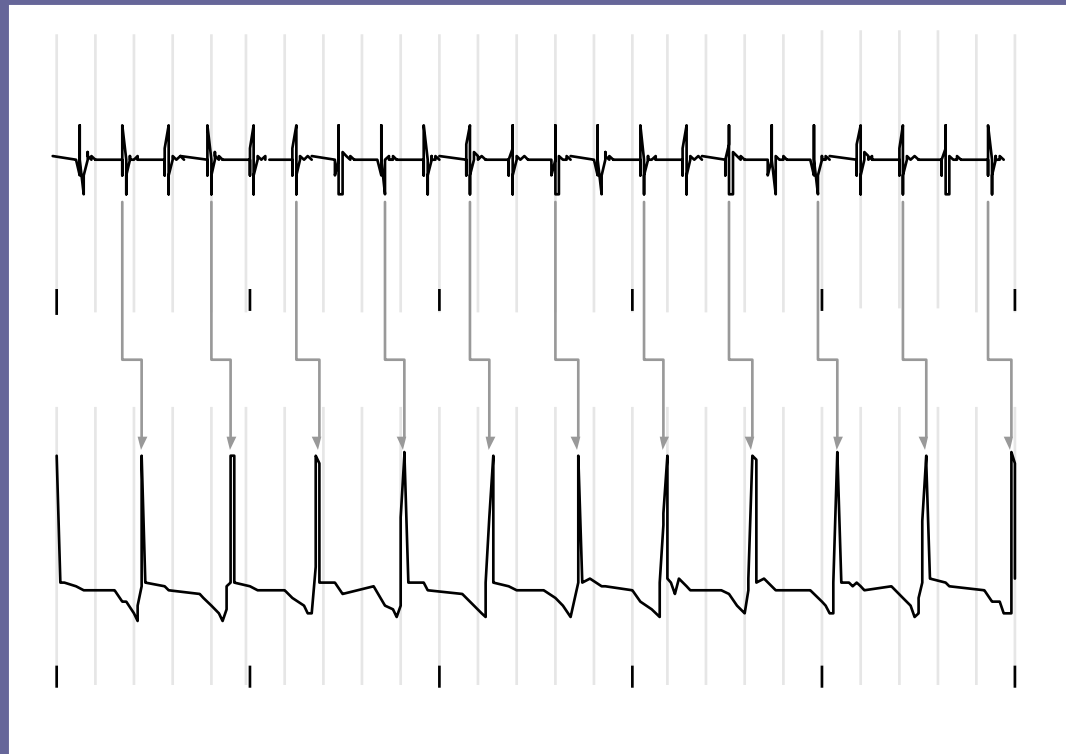
R-R < P-P

VT

Therapy

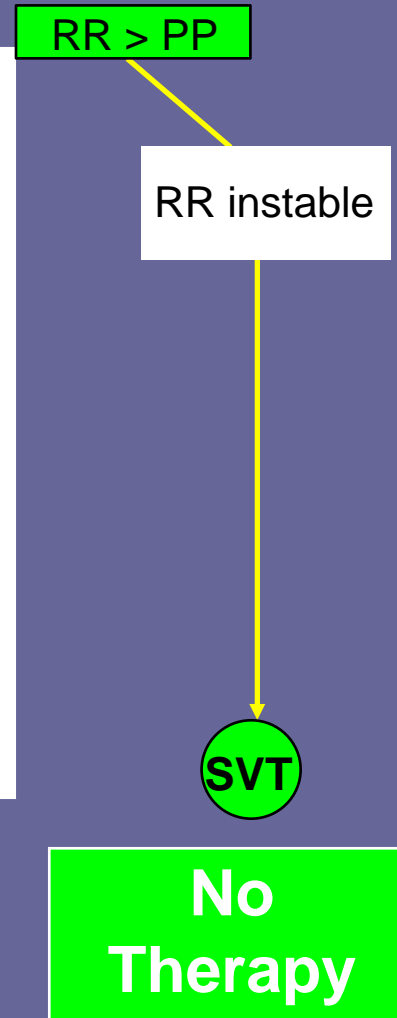
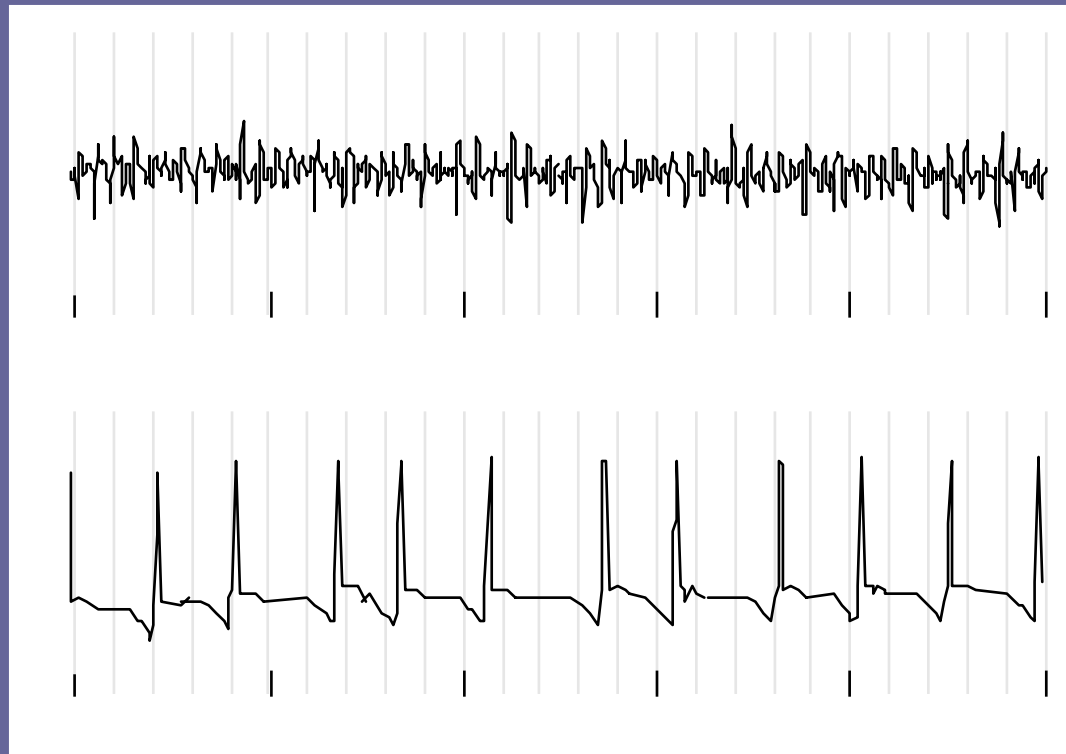
What is the atrial and the ventricular rhythm ? How is the SMART decision ?

Atrial Flutter with 2:1 Conduction



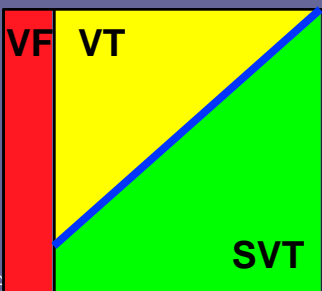
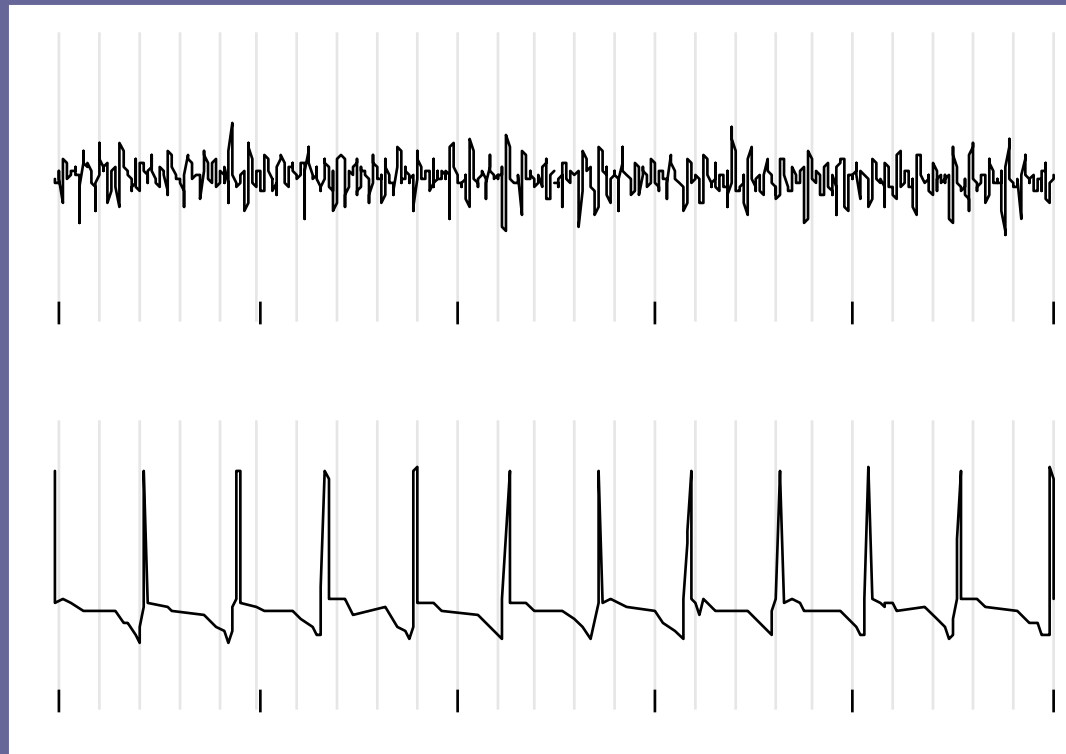
What is the atrial and the ventricular rhythm ? How is the SMART decision ?

Atrial Fibrillation with Unstable Conduction into the Ventricle



What is the atrial and the ventricular rhythm ? How is the SMART decision ?

Atrial Fibrillation and Stable Ventricular Re-entry Tachycardia



VM-Ioan / Sep 02

RR > PP

RR stable

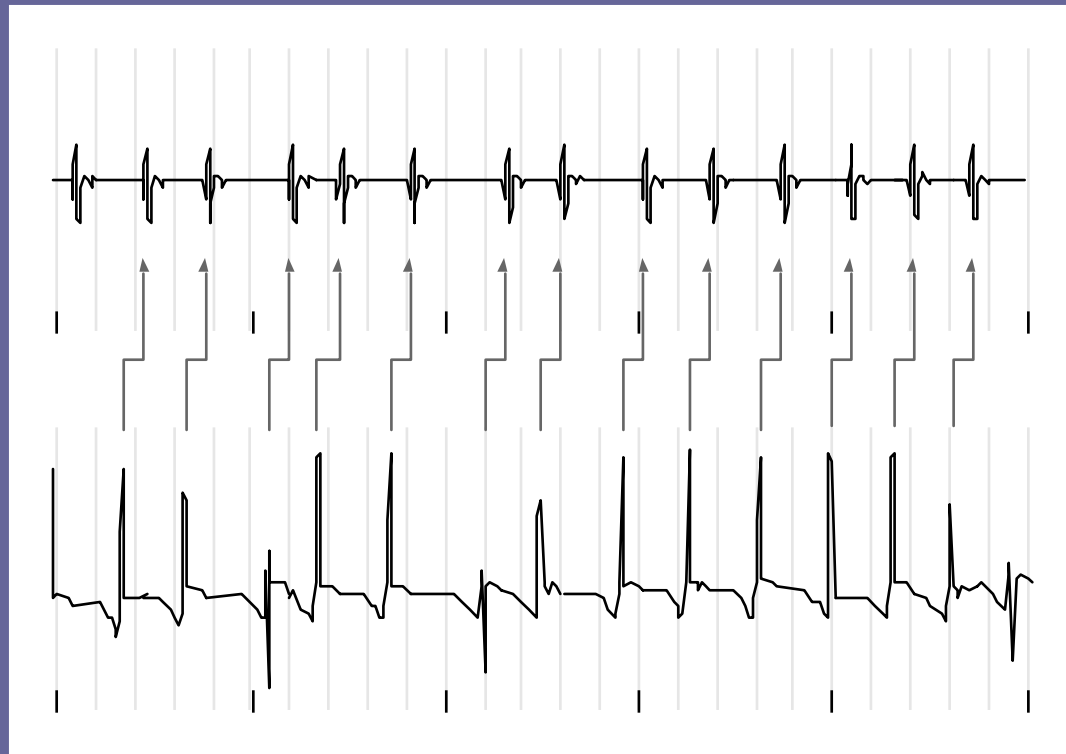
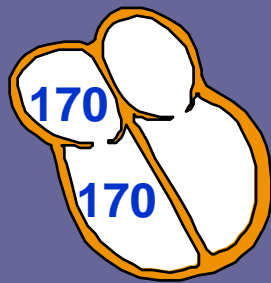
not multiple

VT

Therapy

What is the atrial and the ventricular rhythm ? How is the SMART decision ?

Polymorphic Ventricular Tachycardia with Retrograde Conduction



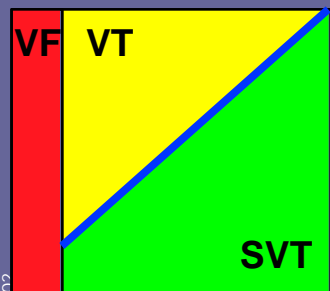
R-R = P-P

RR instable

PR instable

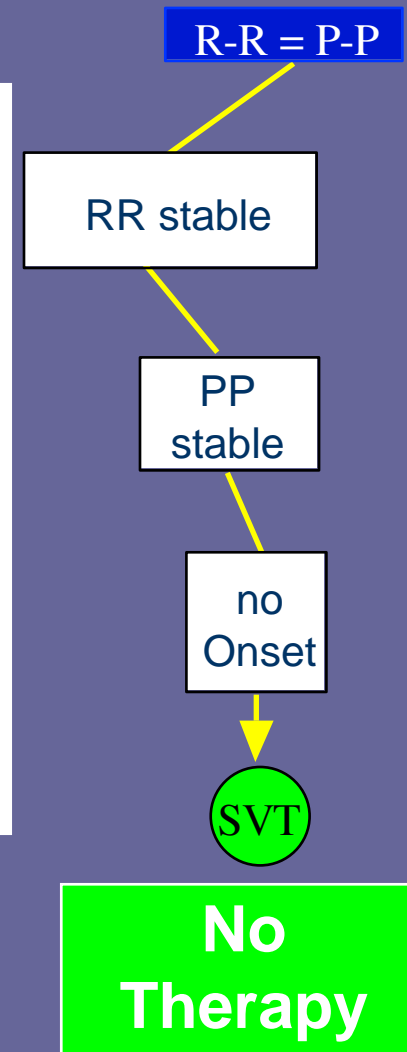
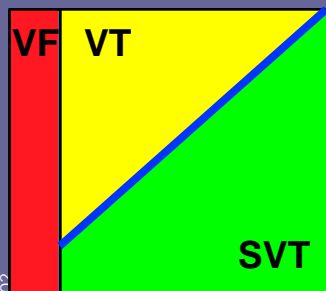
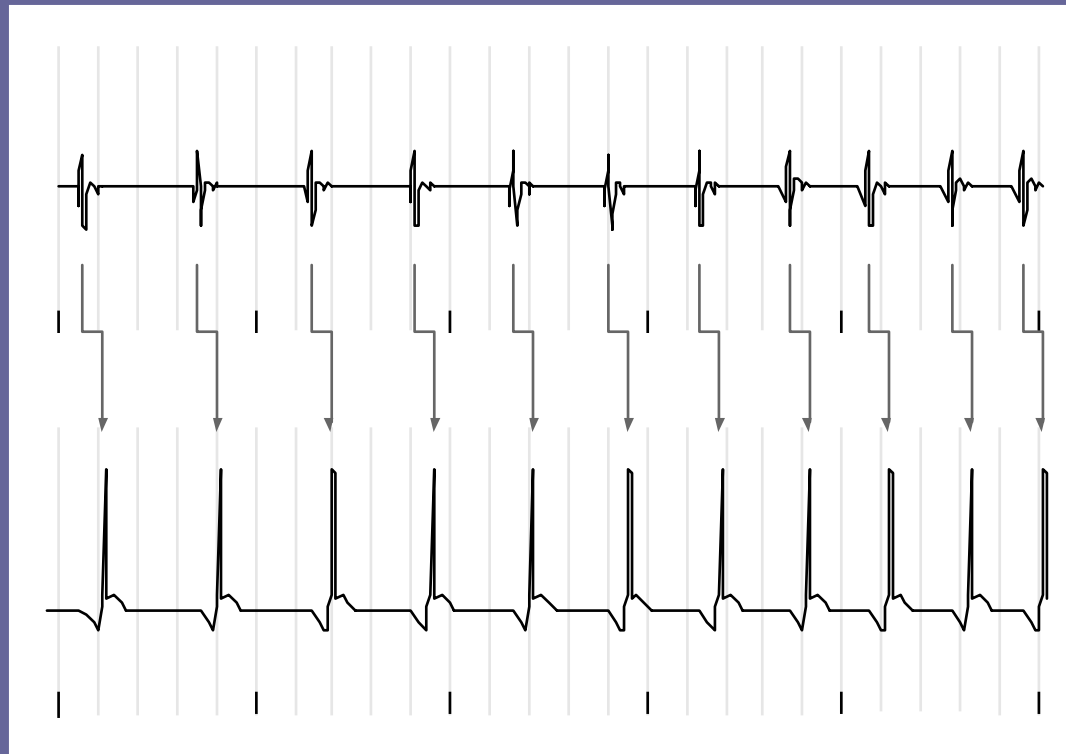
VT

Therapy



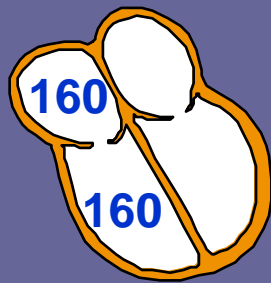
What is the atrial and the ventricular rhythm ? How is the SMART decision ?

Stable Sinus Tachycardia with 1:1 Conduction, No Sudden Onset



What is the atrial and the ventricular rhythm ? How is the SMART decision ?

Paroxysmal Ventricular Re-entry Tachycardia



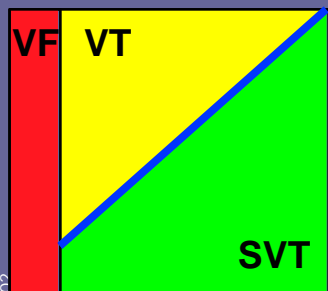
RR = PP

RR stable

PP stable

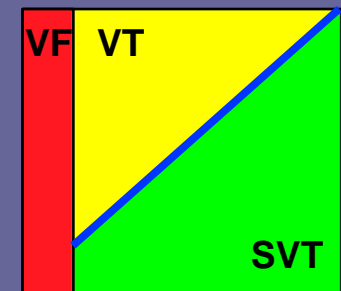
Onset

VT



What is the atrial and the ventricular rhythm ? How is the SMART decision ?

Chronical Atrial Fibrillation and Paroxysmale Polymorphic Ventricular Tachycardia

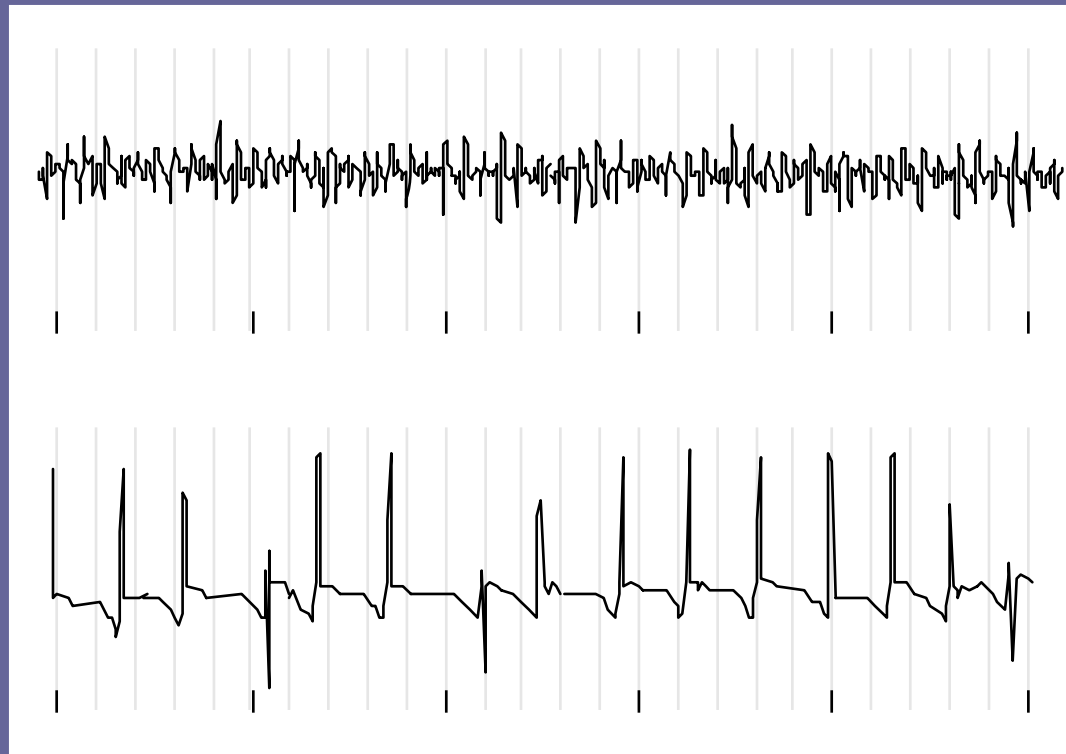


RR > PP

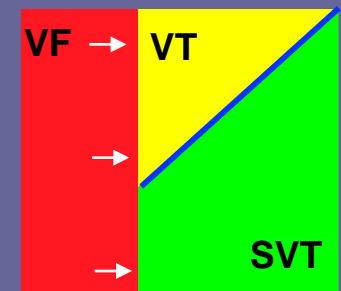
RR instable

SVT

No
Therapy



pVT should be detected in
an extended VF-zone

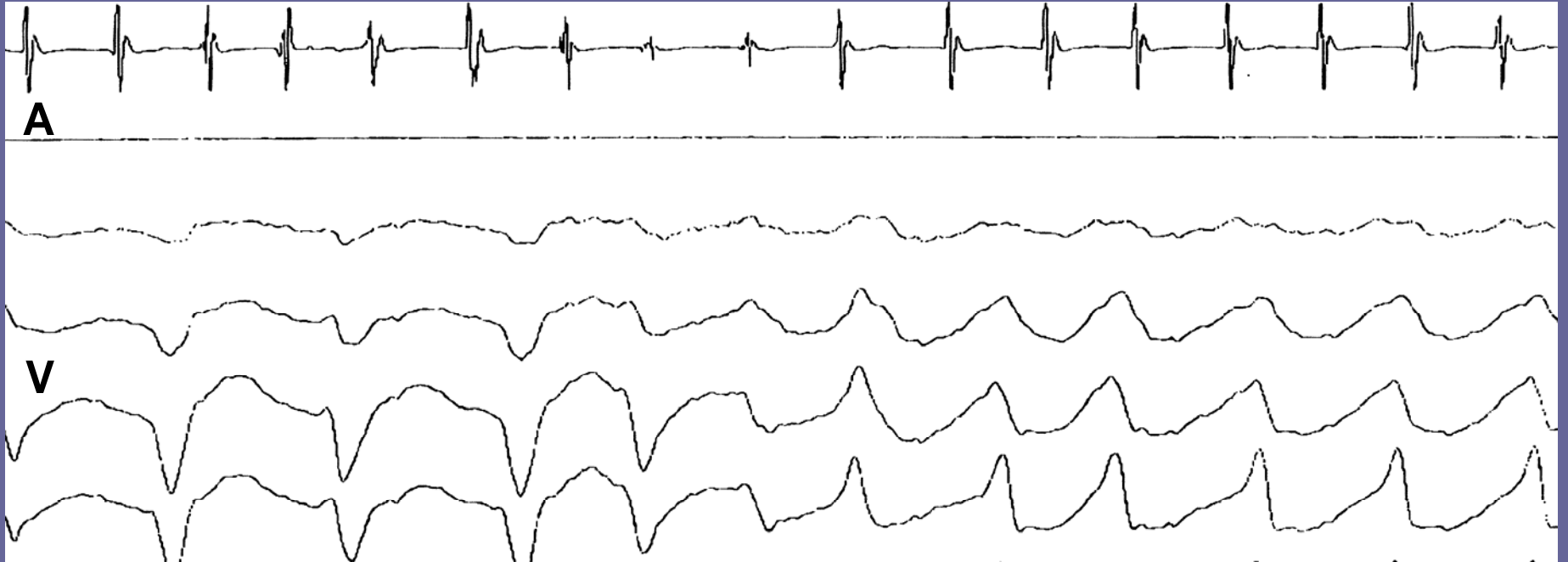


R-R Intervals
in VF-Zone

VF

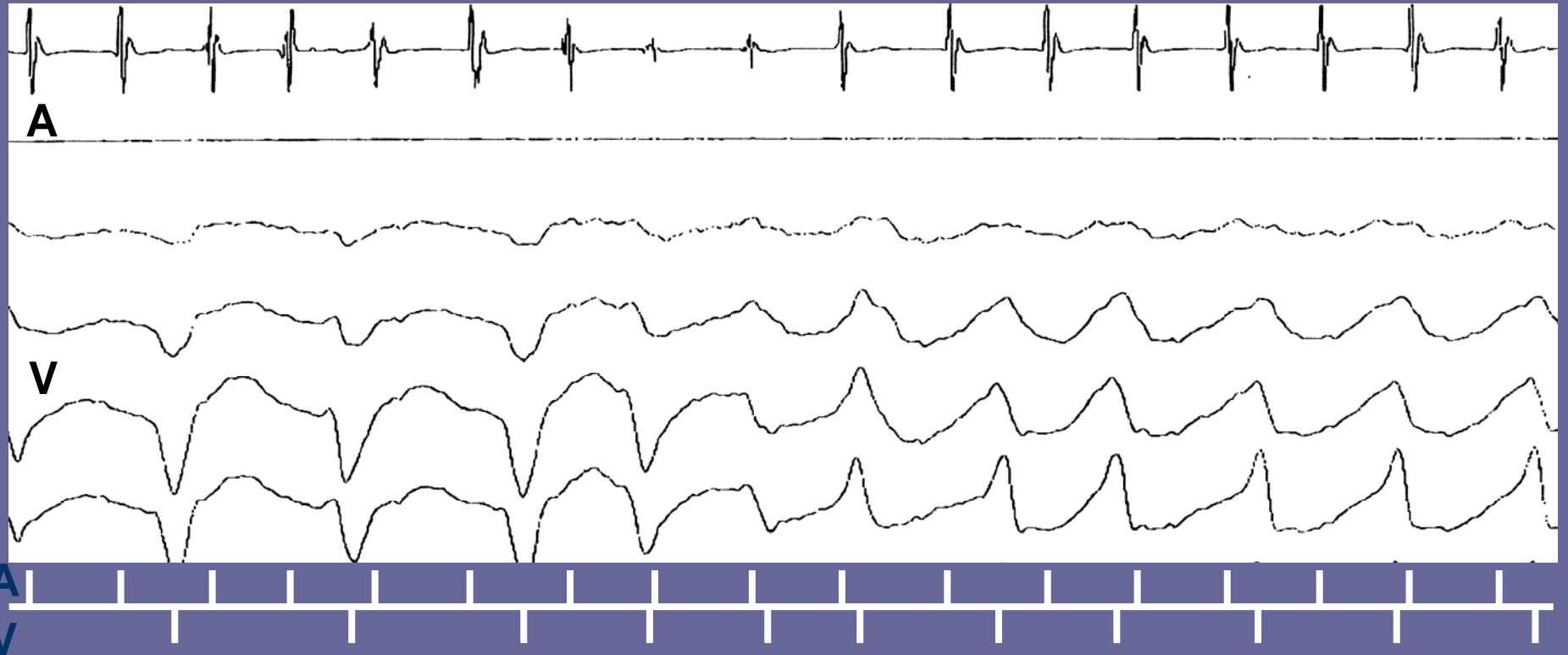
Therapy

SMART Patient ?



- Can SMART help the patient ?

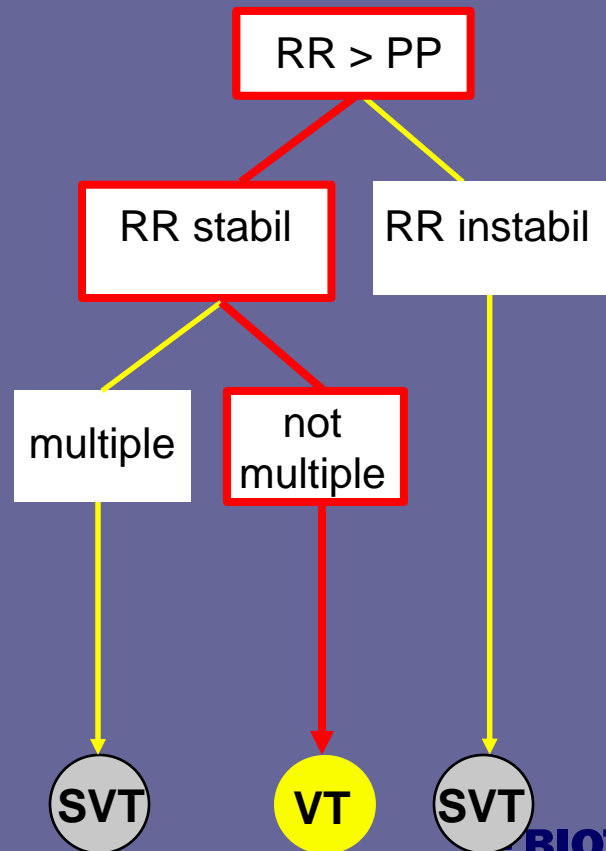
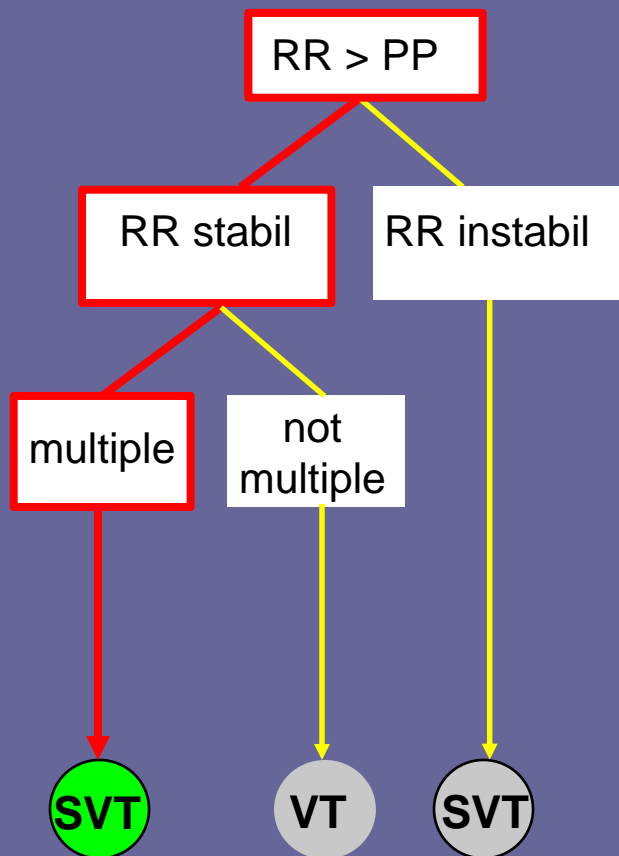
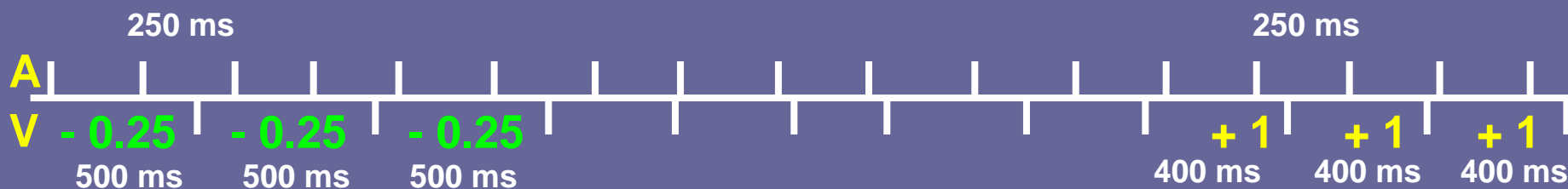
SMART Patient



Atrial flutter
2:1 conduction
PP=250 ms
RR=500 ms

Atrial flutter but
mVT
PP=250 ms
RR=400 ms

SMART Patient



Safety

Atrial undersensing

SMART → VT-Only

Atrial noise

SMART → VT-Only

Weighted counter actions

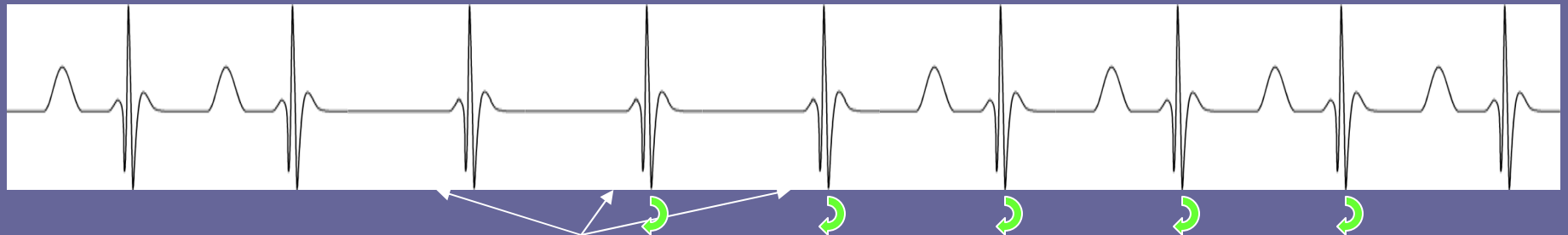
VT = +1 SVT = -1/4

Total safety timer

all SMART - SVT
decision trees will be
overruled

Reversion to 'Ventricle only'

When atrial information is missing ...



Atrial information missing
in these ventricular cycles

➤ SMART reverts to 'Ventricle only' when evaluating this ventricular event.

Reversion to 'Ventricle only'

When atrial information is noisy ...



Atrial information noisy
in these ventricular cycles

➤ **SMART reverts to 'Ventricle only' when evaluating this ventricular event.**