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Tachycardia Discrimination Algorithms in ICDs

Martin Seifert

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1. Introduction

The detection of cardiac arrhythmia and the differential algorithm used for the recognition of ventricular tachycardia (VT) or ventricular fibrillation (VF) necessitating internal cardiac defibrillator (ICD) therapy is one of the most critical issues in ICD patients. Main goal is to develop algorithms with the highest possible sensitivity to avoid untreated arrhythmias and highest possible specificity to avoid inappropriate ICD therapies. Currently, several device discrimination algorithms and their combinations are available. The following chapter tries to explain the functionality, means, possibilities and restrictions of these ICD discrimination algorithms.

2. Cycle length / heart rate

The cycle length (CL) or heart rate (HR) is a fundament in the detection of tachycardia in ICD patients. A sustained ventricular HR in adults >250 bpm or a CL <250 ms is very specific for fast VT or VF (figure 1 red zone). However, artificial sensing of external impulses (noise), sensing caused by lead dysfunction (cluster) or inappropriate recognition of signals (T-wave-oversensing) present diagnostic challenges even in this HR zone. Below this HR almost every type of cardiac arrhythmia should be considered as well for differential diagnosis. The cycle length of both VTs and SVTs are influenced by most antiarrhythmic drugs. Therefore programming of the ICD should be accordingly adjusted.

3. VT/VF zone

In the last decade of ICD therapy the programming of a single detection zone {eg. SCD-HeFT[1]} have been replaced by the programming of up to three detection zones with differ-

ent discrimination algorithms and therapies (table 1). Moreover, data on the programming of zones up to 260ms CL with a long detection time are also available {ADVANCE III study [2]}. Until now, no consensus is accepted concerning the number of detection zones (not at least in primary prevention indication), nor clear definition of detection windows is given. Until 2010 most ICDs had no SVT/VT discrimination algorithm available in the VF zone. In primary prevention a VT zone from 360ms CL with long detection time, SVT/VT discrimination up to 260ms CL and anti-tachycardia-pacing (ATP) prior or during charging, along with a VF zone from 260ms CL without SVT/VT discrimination and maximal energy shock delivery was widely recommended. Depending from device a FVT zone was needed to program an ATP prior or during charging shock up to 280-250ms CL. Newer devices have now independent discrimination algorithm for every detection zone (Medtronic), and provide SVT/VT discrimination algorithms also in VF zone. Furthermore, ATPprior or during charging is available in all zones. In secondary prevention patients with documented VTs, the first zone should be programmed 10-20ms above (or 10 bpm below) its cycle length. In younger patients with channel rhythm disorders like long QT syndrome a single zone (<280ms) can be considered. Patients with secondary prevention, very low ejection fraction or repetitive syncope need an individualized, more conservative programming with shorter detection intervals and less ATPs. Different programming examples for tachycardia detection and therapies in recent studies with primary prevention patients with ICDs of different manufacturers are listed in table 1.
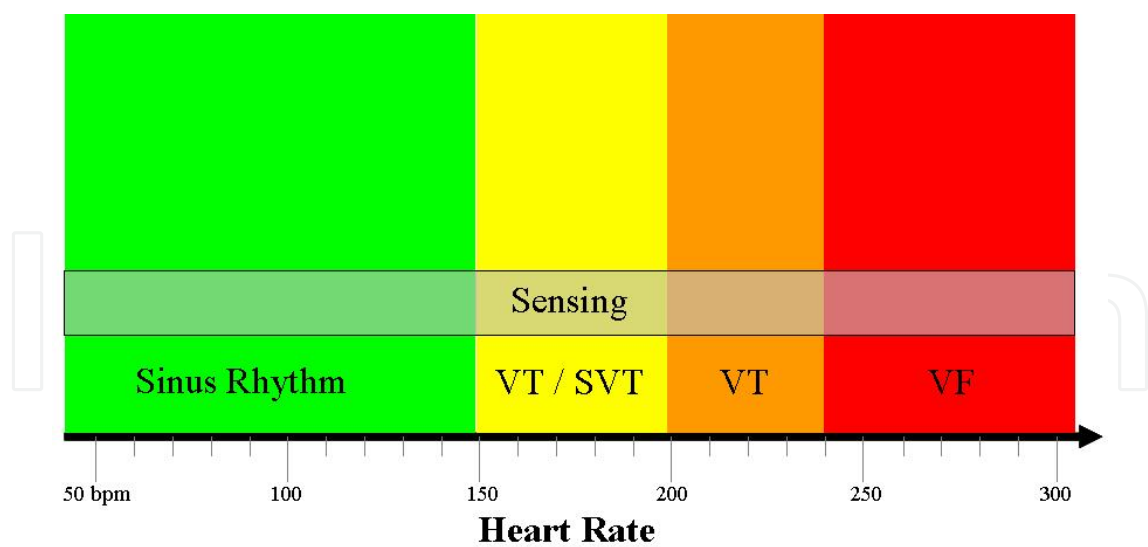

Figure 1. Notice critical area of VT and VF discrimination in yellow and orange up to 460ms cycle length

Practically, devices in primary prevention patients can be programmed using either single or two zones with long detection intervals. The programming should be adjusted during the follow-up in case of arrhythmic events.

zone	VT	FVT	VF
Study, date and manufactures	**150bpm**	**200bpm**	**250bpm**
SCD-HeFT[1] 2005 Medtronic		187bpm [18/24 beats) only Shocks	
PAINFREE[13] I 2001 Medtronic	Rx – 188 bpm[12/16] ATPx2 → Shocks	188 – 250 bpm[12/16 beats) ATPx2 → Shocks	>250 bpm[12/16 beats) Shocks only
PAINFREE[14] II 2005 Medtronic	167 – 188 bpm[18/24] ATPx3 → Shocks	188 – 250 bpm[18/24 beats) ATPx1 → Shocks vs Shocks only	>250 bpm[18/24 beats) Shocks only
EMPIRIC[15] 2006 Medtronic	150 – 200 bpm[16 beats) ATPx3 → Shocks	200 – 250 bpm[18/24 beats) ATPx1 → Shocks	>250 bpm[18/24 beats) Shocks only
PREPARE[16] 2008 Medtronic	167 – 182 bpm [32 beats) Monitor	182 – 250 bpm[30/40 beats) ATPx1 → Shocks	>250 bpm[30/40 beats) Shocks only
ADVANCE III[2] Medtronic 2012		187bpm [30/40 beats) ATP during change	
MADIT[17] 1996 Boston	no clear definition	no clear definition	
MADIT II[6] 2002 Boston	170 – 200 bpm, [1-5 sec delay) discrimination free, therapy free or Monitor	>200 bpm[1-3 sec delay) Shocks	
MADIT CRT[18] 2011 Boston Scientific	170 – 200 bpm [60s delay), Rhythm ID ATPx1 → Shocks	200 – 250 bpm [12 sec delay) Rhythm ID ATPx1 → Shocks	>250 bpm[2.5 sec delay) Quick Convert ATP → Shocks
PROVIDE St.Jude Medical ongoing 2008-"/> (NCT00743522]	181 – 214 bpm [25 beats) SVT Discr. ATPx2 → Shocks	214 – 250 bpm[18 beats) ATPx1 → Shocks	>250bpm [12 beats) Shocks only

Table 1. Change in detection for defibrillation therapy over the last ten years in corner stone studies of different manufactures.

4. Inappropriate ICD therapy

Inappropriate ICD therapy is a delivered ATP and/or shock in absence of VT/VF episode. Inappropriate ICD therapy has serious consequences: proarrhythmic effect, reduced quality of life, psychological stress with depression, unnecessary hospitalisation, early battery de-pletion duration and even elevated mortality [3]. Up to 80% of inappropriate ICD therapies are registered in the first year following device implantation [4, 5] figure 2. Atrial fibrillation

(AF) is the most common cause of inappropriate ICD therapy {MADIT II [6], figure 3}. However, concerning the rising number of lead dysfunction resulting in oversensing this can be changed in the future. In the SCD-HeFT[3] study with single zone of detection and therapy (18 of 24 beats at a rate ≥188 bpm or ≤320 ms CL) the effect of inappropriate versus appropriate ICD therapy to the hazard ratio for death (CI 95%) was 1.98 (p=0.002) for inappropriate therapy only (figure 4).It is unclear whether the inappropriate therapy is a cause or only a marker of higher mortality. By all means, consensus exists about the importance of avoiding inappropriate ICD therapies. The incidence of inappropriate ICD therapy depends on the programming of the device – both detection and therapy, and considerable changes were observed over the last years (table 2).
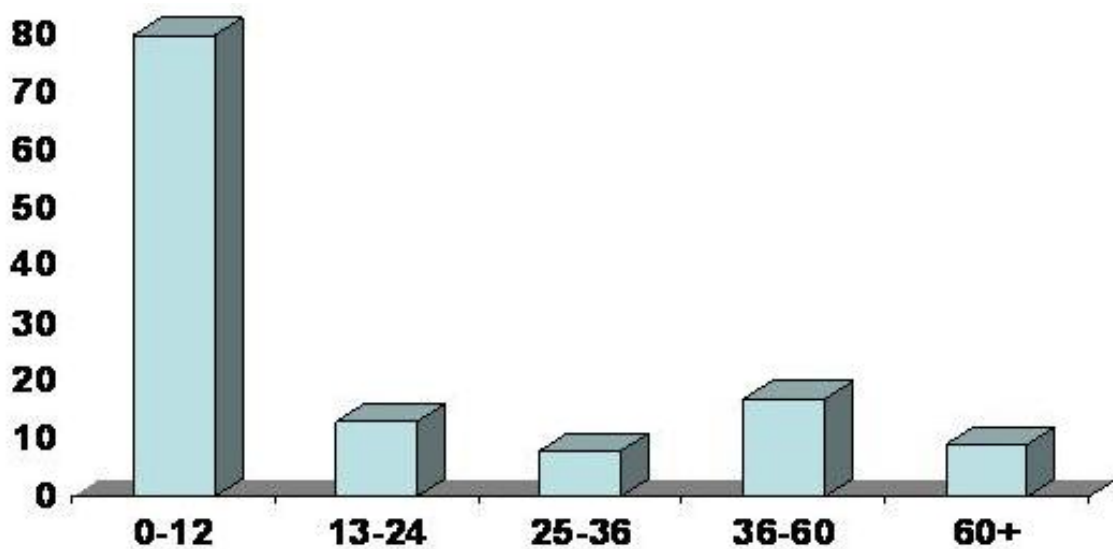

Figure 2. Frequency (y line in %) of inappropriate ICD therapies after ICD implantation (x line in month, y line in %) Nanthakumar K et al[5].
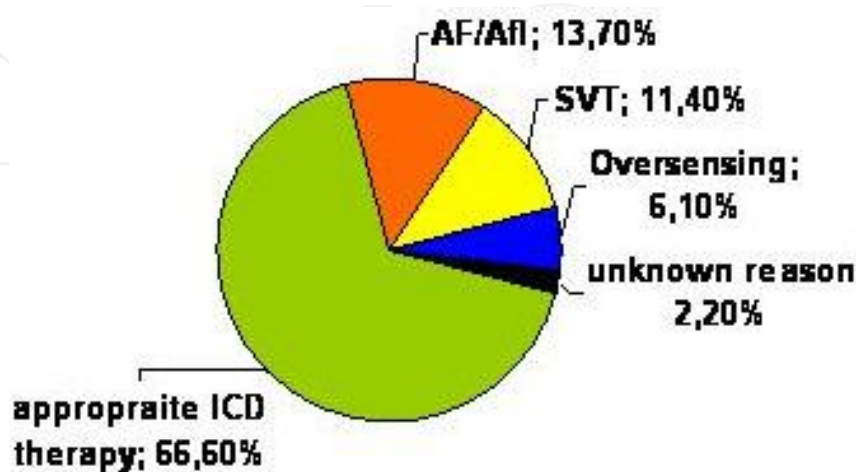

Figure 3. Reasons of inappropriate ICD therapy in MADIT II [4].
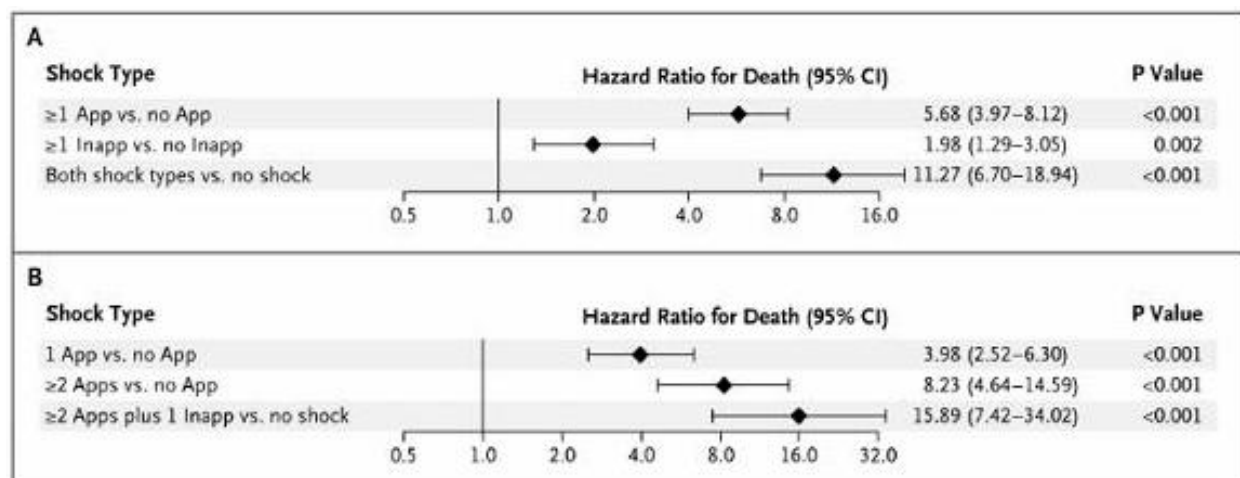
Figure 4. Relation of appropriate and inappropriate ICD therapy in SCD-HeFT to mortality [3].

Year	Author	Mean age	Patients (n)	% appropriate ICD therapy	% inappropriate ICD therapy
1996	Weber et al[19]		462	55	18
2002	Daubert et al[4]	63	719	66	11,5
2003	Nanthakumar et al[5]	60	261	54	44
2004	Rinald et al[20]	60	155		14
2007	Anselmeet al[21]	64	802	28	15
2008	Wilkoff et al[16]	67	700	5,4 (shock, not ATP)	3,6 (shock, not ATP)

Table 2. Incidences of appropriate and inappropriate ICD therapies over the last years. Notice the influence of SVT/VT discrimination algorithm until CL of 260ms and longer detection intervals.

5. Detection Time (DT) or Number of Interval Detection (NID)

Detection of tachycardia occurs after the registration of a certain amount of heartbeats within or above the programmed HR zone. Signals with CL according to VF zone have priority to signals in VT zone(s). Various algorithms are currently used for validation of a tachycardia: registering of a specified and programmed number of beats - x out of y (Medtronic and Biotronik, figure 5), a programmed number of beats (x) with resetting after 5 consecutive below-zonebeats (St. Jude Medical, figure 6) or after a programmed time interval (Boston, figure 7). During the last years programming of a long detection time has been established in primary prophylactic indication (figure 8 and table 1).
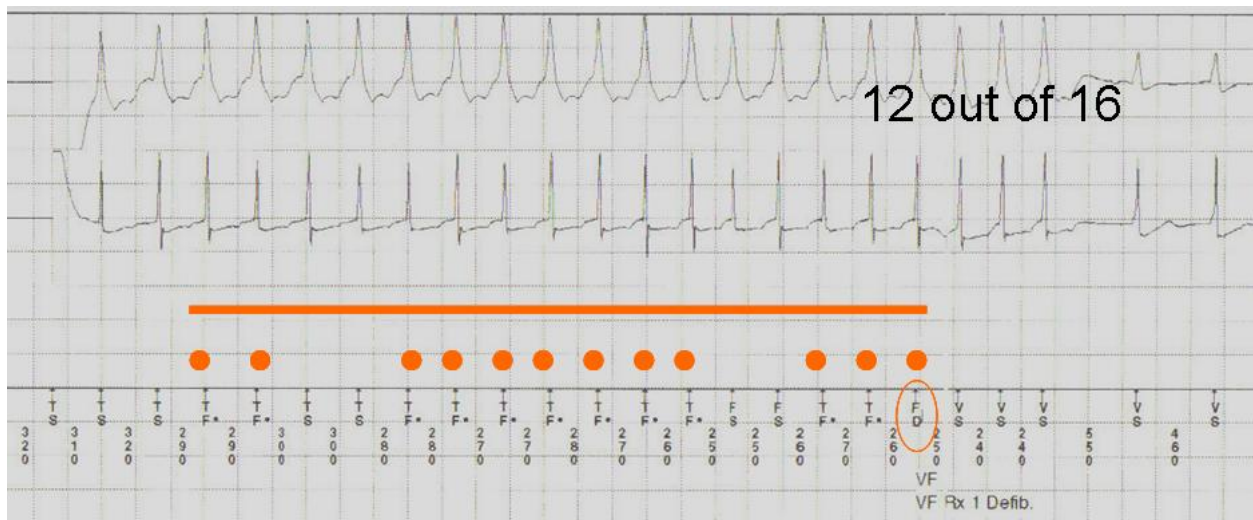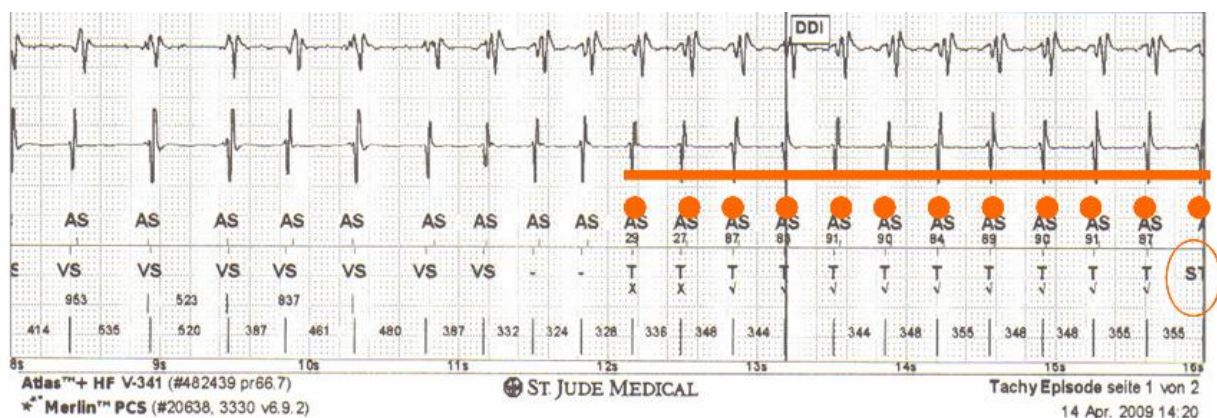
Figure 5. Tachycardia detection of a Medtronic device: TS tachycardia sense in VT1 zone; VS ventricular sense; TF fibrillation sense via VT2 zone; FS fibrillation sense. In this case x=12 (<300ms orange points) out of y=16 signals counted for detection of a VF episode with spontaneous conversion to sinus rhythm after 22 beats.
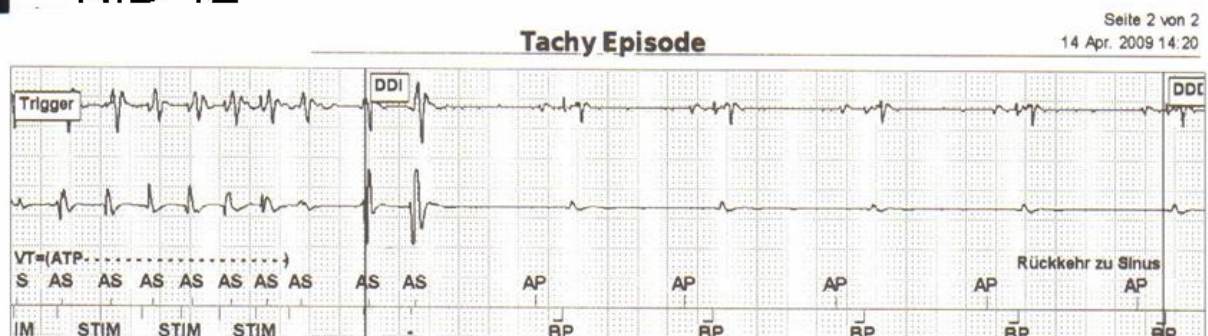

Figure 6. Tachycardia detection of a CRT device from St. Jude Medical (dual chamber detection): VS ventricle sense; AS atrial sense; T tachycardia sense in VT zone; ST tachycardia episode sense; X no correspondence with stored QRS templet; little minced meat correspondence with stored templet, NID x=12 (orange points) counted to VT episode with successful ATP. The episode shows a short VA interval with accelerated CL and corresponding templet to intrinsic activation. That means episode could diagnose as VT with VA conduction and wrong stored templet or as SVT (atrio-ventricular node reentry tachycardia) with atypical start.

Figure 7. Tachcardia detection of a dual chamber device Boston: VS ventricle sense; AS atrial sense (AS) refracted; PVP atrial refracted after ventricle sense; VT ventricular tachycardia sense; VF ventricular fibrillation in VF zone sense; V-Epsd ventricular episode ready for duration; V-Dur duration time complete; Stb stability criteria is right; V-Detect ventricular episodes is detected and therapy ATP begins.

Figure 8. Gunderson at al [23] demonstrate ICD shock therapy which is delivered or aborted in the same VT episode according to detection interval NID 12 or 18.

6. Discrimination SVT/VT

Discrimination of SVT and VT may present a challenge not only for devices using artificial intelligence and programmed algorithms but even for experienced physicians. Principally the following wide QRS complex arrhythmias should be considered: VT, SVT with bundle branch block, SVT with accessory pathway or pacing in left (via coronary sinus) or right ventricle. Table 3 shows the discrimination criteria of the 12 channel ECG for SVT/VT. No single criterion is sensitive and specific enough to provide sufficient discrimination value. Therefore, combination of several criteria should be implemented in the device algorithms to correctly diagnose arrhythmias. Table 4 shows the availability of discrimination criteria in single or dual chamber ICDs.

ECG criteria	sensitivity	specificity
QRS width	high	low
VA dissociation	low	high
capture beats	low	high
northwest axis	low	high
rS missed or long rS in V1	low	medium
concordance +/-	low	high
Brugada criteria LBBB/RBBB[22]	medium	high

Table 3. Sensitivity (in sense of frequency) and specificity of different ECG criteria for differentiation SVT and VT.

criteria	ECG	Single chamber	Dual chamber
CL or heart rate	+	+	+
stability	+	+	+
Sudden onset	+ (Holter ECG)	+	+
morphology	+	+	+
AV rate branch	-	-	+
QRS axis (*Rhythm ID™ Boston)	+	+(*)	+(*)
AVA interval	-	-	+
Sinus Interval History (*St. Jude Medical)	-	+(*)	-
Capture beats (*PR Logic™Medtronic)	+	-	+(*)
RBBB and LBBB criterias	+	-	-

Table 4. Variation of SVT and VT discrimination criteria in single and dual chamber ICDs (+ achievable; - not achievable).

7. Stability

Stability is the variability of tachycardia CL (figure 9). In general, VTs have a reasonably stable CL while numerous SVTs have beat-to-beat variability in their CL (AF, Sinus tachycardia, etc). However, some SVTs may have stable CL as well: circus movement tachycardia, atrioventricular nodal re-entry tachycardia or atrial flutter (Aflut) – so this criterion has his limitations. Even AF may have a quite stable CL in the case of very high frequency. Anyway, several randomized controlled studies {e.g. MADIT II [7]} proved a significant decrease (p=0.030) of inappropriate ICD therapies (table 5). Therefore, programming of stability criterion is recommended in single chamber devices up to 260ms CL and indual chamber devices in the case V <A. The programmed value depends on the manufacturer, and lies in general for single and dual chamber devices around 40ms (-20 to + 20ms) [8]. Boston and St. Jude Medical use the last 12 consecutive intervals and compare the second longest and the shortest interval to calculate the difference in ms (or percentage ratio). Medtronic and Biotronik use the last 3 and 4 consecutive intervals to calculate mean difference.
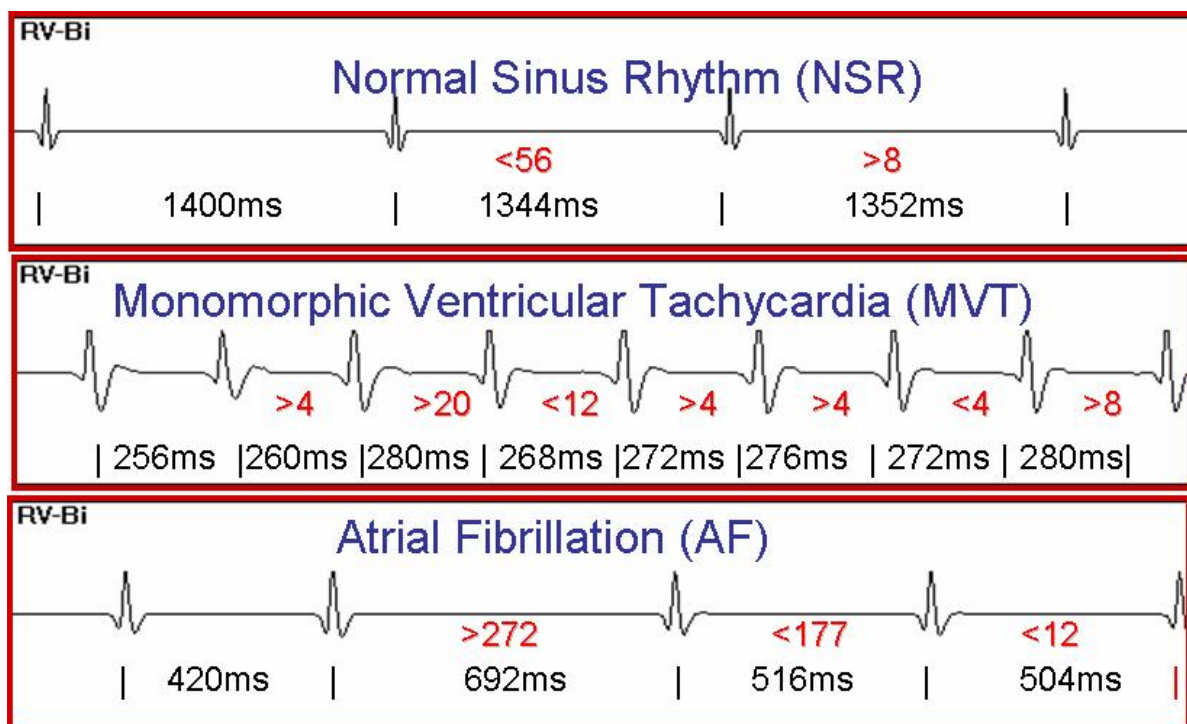

Figure 9. Notice variability of CL in ms (in red numbers) from beat to beat in normal sinus rhythm, monomorphic ventricular tachycardia and atrial fibrillation AF.

8. Sudden onset

Initiation of the tachycardia may also provide information on the mechanism and origin of the arrhythmia. The heart rate in the case of a sinus tachycardia at physical activity rises

slowly and gradually. Other SVTs or ventricular arrhythmias cause a sudden and marked jump in the heart rate (or fall in CL). Primary role of the Sudden onset criterion is therefore the diagnose of sinus tachycardia (figures 10 and 11). However, in some studies the algorithm using this criterion resulted in delayed VT detection (figure 12) or could not show significant reduction of inappropriate ICD therapy (table 5). Therefore, programming of sudden onset criterion is recommended above all in younger patients who could reach high HR at physical activity and could tolerate longer the hemodynamic consequences of a potential VT. This group is generally underrepresented in large ICD studies, which may be the reason why the effect on the incidence of inappropriate ICD therapy could not be proven.
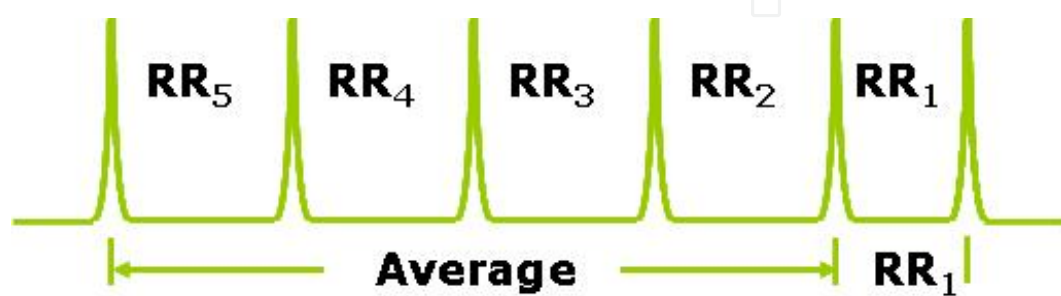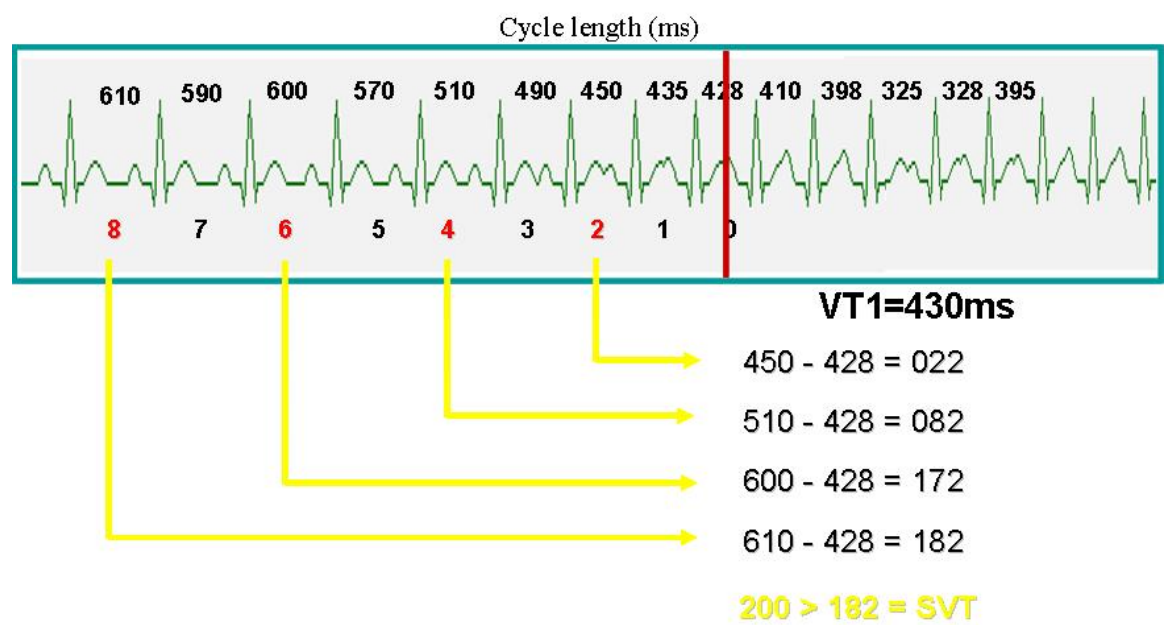

Figure 10. Demonstration of sudden onset calculation: The device compares RR1 with mean from RR2 to RR5 (Biotronik), onset (%) = (RR1*100]/mean from RR2 to RR5 for Boston, standard 10% or for Medtronic graduated onset (%) mean from RR1 to RR4 / mean RR5 to RR8, standard 81%

Figure 11. Demonstration of the St. Jude Medical algorithm for sudden onset (standard Δ150-160]. In this case of Δ <200ms the algorithm decides for SVT.

Programming	Inappropriate shock	No inappropriate shock	P value
Single chamber			
Number of patients	83	83	
Lowest VT zone (beats/min)	169.3 ± 19.9	171.9 ± 14.5	0.540
Lowest VT zone detection time (s)	2.45 ± 1.99	2.42 ± 2.07	0.830
Stability on % (n)	17 (14)	36 (30)	0.030
Sudden onset on % (n)	16 (13)	23 (19)	0.160
Dual chamber			
Number of patients	32	36	
V>a on% (n)	31 (10)	50 (18)	0.054
Atrial fibrillation discriminator on % (n)	34 (11)	44 (16)	0.210

Table 5. Influences of discrimination algorithms to inappropriate ICD-shock according to single and dual chamber detection in MADIT II trial [4].
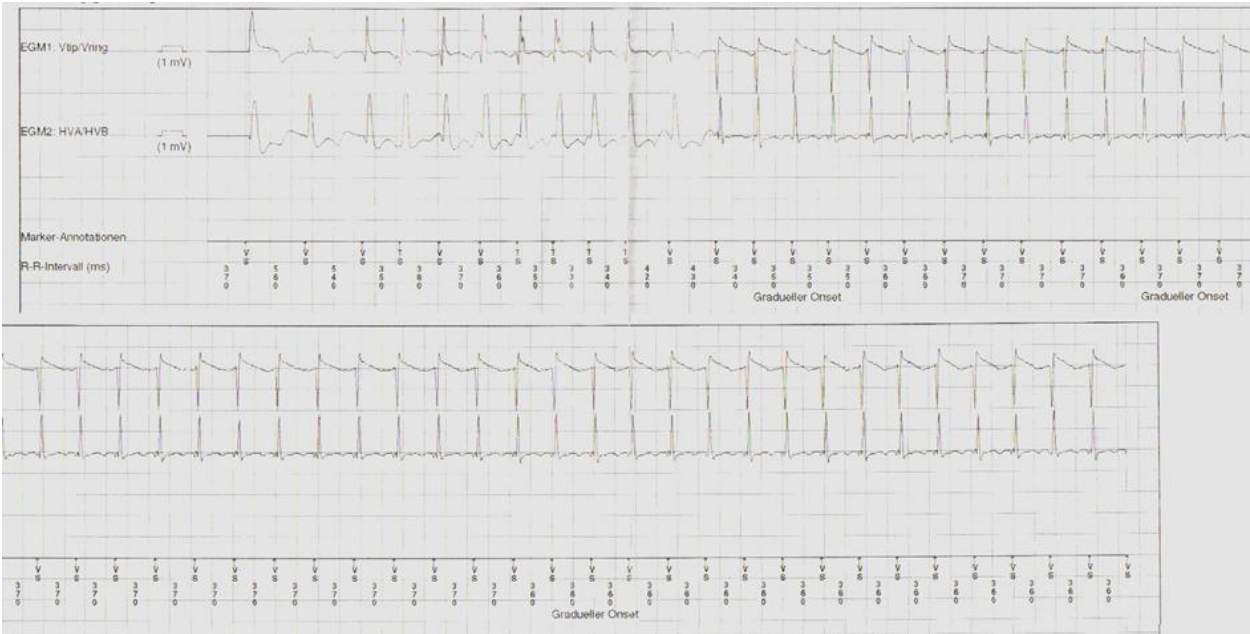

Figure 12. Notice prolonged detection of sustained VT caused by graduated onset algorithm of a Medtronic device. There is a VT with obviously change in vector and stable CL of 370 ms. The graduated onset is calculated graduated caused by 10 beats of another tachycardia leads to a negative sudden onset criteria.

9. Timer

Depending from manufacturers a time window can be defined for SVT/VT discrimination in VT zones. In case of an episode identified as SVT the device may suspend the programmed

therapy only within this specified time interval, when the time runs out, the device delivers VT therapy (SVT time out). Also in case of an episode identified as VT the device may switch to the VF therapy after a specified time interval (VT time out). Generally these counters are not recommended because SVTs usually continue for longer time periods and such timer could force an ATP or shock delivery inappropriately. However, in individual cases (e.g. in patients with very low ejection fraction who could not tolerate higher HR for a longer time) programming a time out intervals may be considered for safety reasons.

10. Morphology criteria

Morphology and width of QRS complexes is a primary tool for physicians to differentiate SVT from VT (table 3 and 4). Accordingly, almost all manufacturers have developed QRS complex morphology algorithms. The device compare 8 or more voltage points on the EGM signals at different time points (figure 13). A point to point assessment of each complex to a defined standard complex (template) follows. Finally, decision is made based on a previously programmed matching-ratio in percentage (figure 14). Currently, programming of this criterion is recommended in single chamber devices and in dual chamber devices in case of V<A and V=A. The algorithms use either EGM only or a combination of EGM and a can to coil lead (figure 15). In case of no intrinsic activation like third degree atrioventricular block or continuous biventricular pacing the automatic storing algorithm of QRS complex template may be problematic or even not possible. In the latter case QRS template should be stored manually during pacing inhibition. In case of HR dependent bundle branch block this algorithm may also fail to differentiate tachycardias.
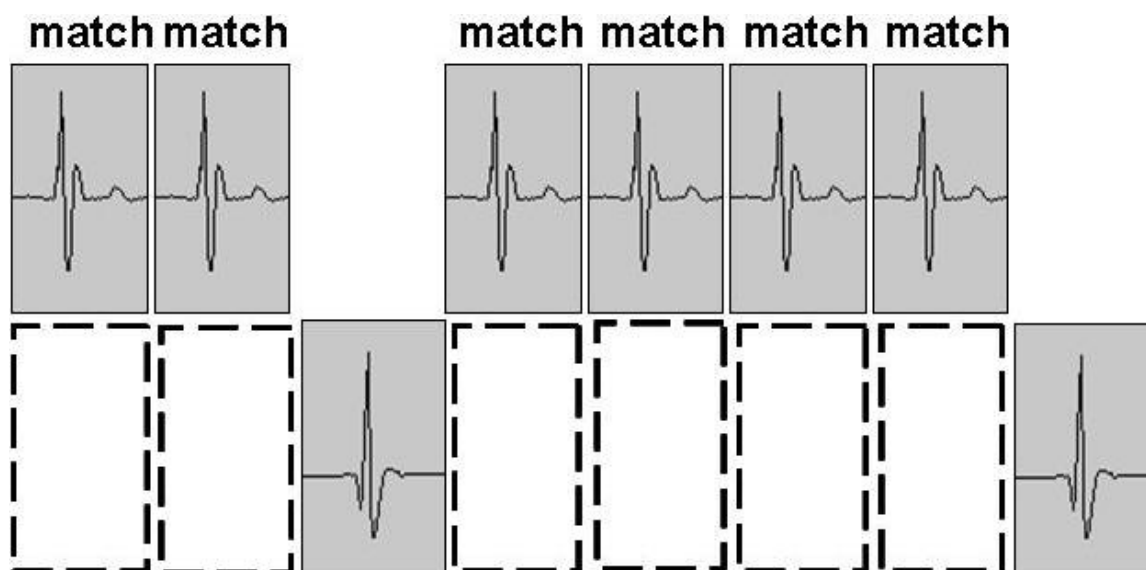

Figure 13. Demonstration of morphology score calculation: match or not match based on percentage template match threshold measurement by St. Jude Medical window detection algorithm. In this case of 6 matches from 8 the algorithm votes for SVT [75%].
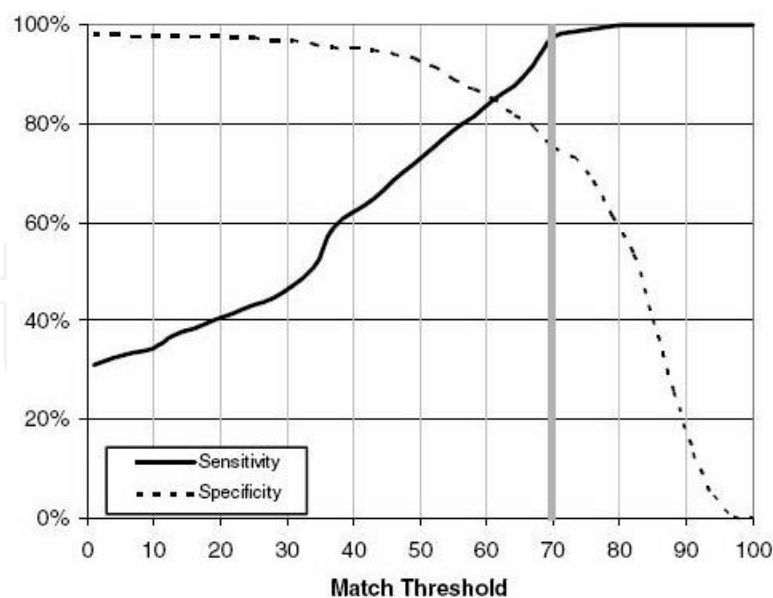
Figure 14. Demonstration of sensitivity and specify of the Medtronic Wavelet™ algorithm to differentiate between SVT and VT by Klein et al [24]. As recommendation a value of 70% match is standard by Medtronic devices.
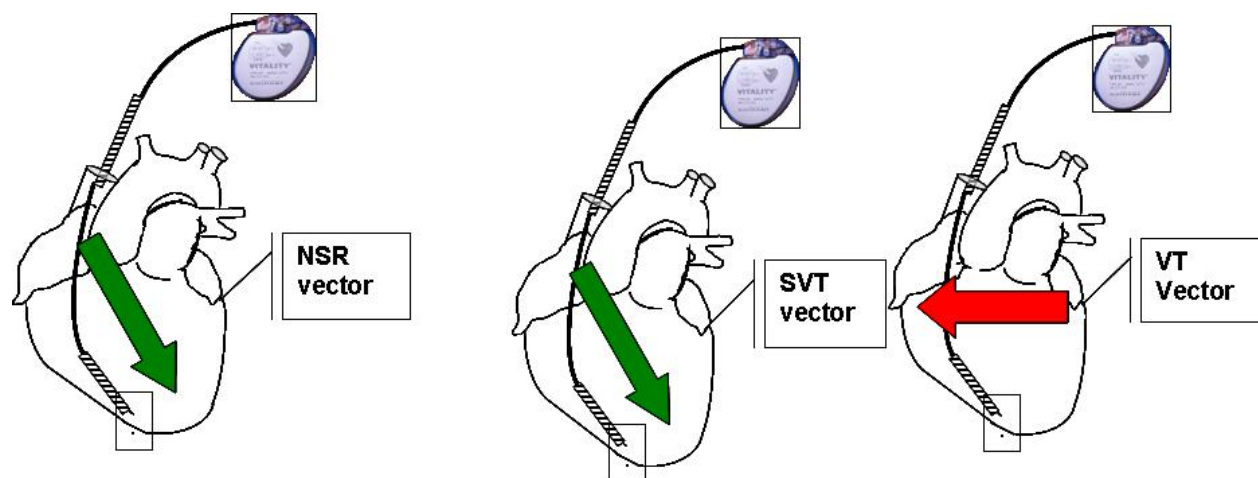

Figure 15. Demonstration of the Rhythm ID™ discrimination algorithm: discrimination between sinus rhythm and SVT with "normal" vector (green) to a potential VT vector (red). This algorithm is not based on EGM signal but on an internal ECG electrode from device can to RV shock coil and the vena cava shock coil.

11. SVT/VT discrimination algorithms in single chamber devices

In the programming of single chamber ICD the three most important discrimination criteria are stability, morphology and sudden onset. However, it should be defined whether a single criterion or only matching of all three criteria should rule out a VT. Currently, if all three criteria are active, it is recommended to rule out VT in case of 2 out of 3 votes for SVT. If

only two criteria are active (standard), stability and morphology are recommended, and 1 out 2 votes is required for the diagnosis of SVT. Anyway, differentiation between SVT and VT in single as well as dual chamber ICD remains difficult and should be carefully checked by the physician at each follow-up visit (figure 16a-b).
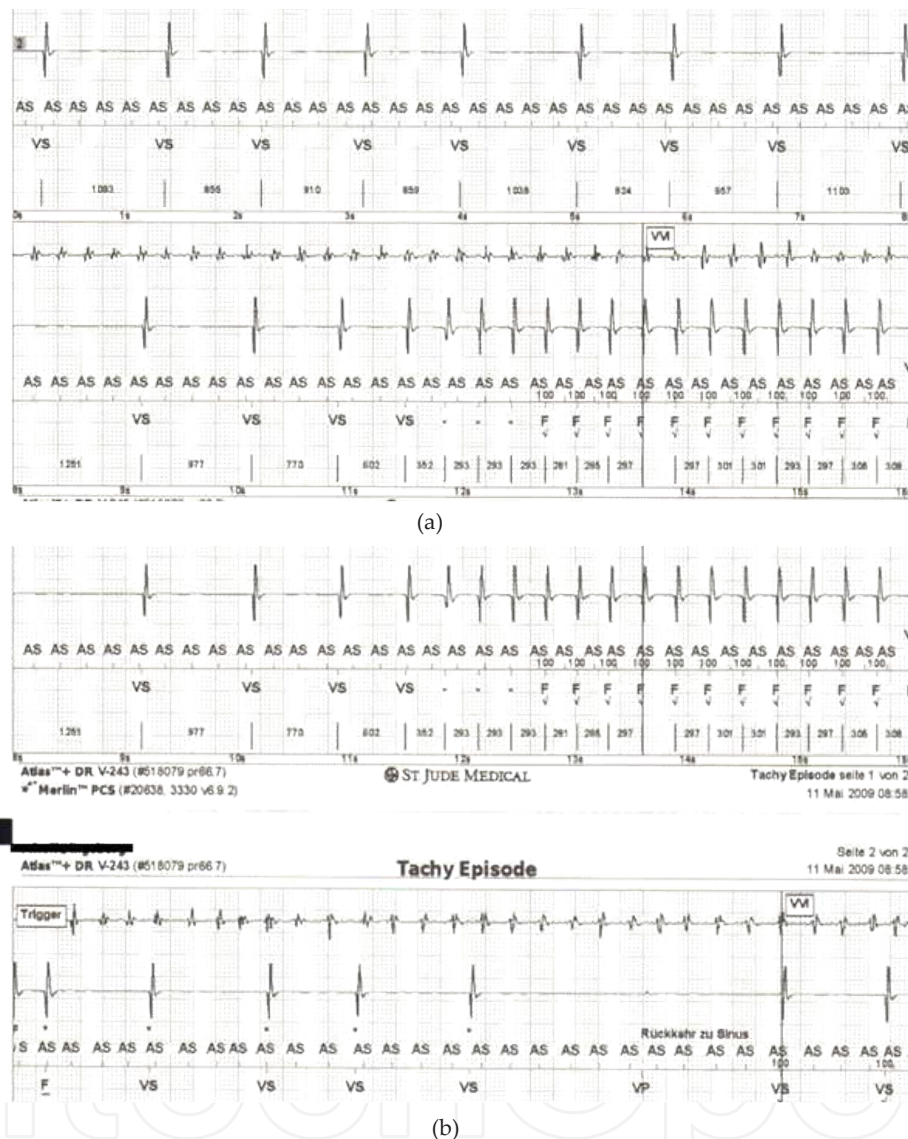

(a)

(b)

Figure 16. a: This episode of a dual chamber tachycardia detection (Atlas DR St. Jude Medical) with A>V during AF with a CL around 100ms demonstrates the hardly difficult decision-making in spite of all common discrimination algorithms. The ventricular EGM shows a fast stable tachycardia with a CL of around 300ms and sudden onset as well as nearly same EGM signal like intrinsic activation before. This tachycardia falls in VF zone and the morphology criteria founds a match to intrinsic activation of stored template. Although morphology votes for SVT, stability outvote for VT <40ms (sudden onset not active), but anyway the CL falls in VF zone in this case without active SVT discrimination algorithm the device detected this episode as VF and start charging shock therapy (*). b: The same episode stopped spontaneously without any therapy and the shock is aborted by the device. The example underlined the importance of long detection intervals (TDI 18-24 not 12 like in this case), the need of competent discrimination algorithm also in short CL under 300ms and the difficult interpretation of an episode not only by the device but also by physicians in decision making SVT or VT.

12. SVT/VT discrimination algorithms in dual chamber devices

Detection and diagnose of arrhythmias in dual chamber devices is more complex, and the mechanism of decision making is harder to demonstrate. Discrimination algorithms are still based on the principles explained above. Significant addition is the comparison of atrial (A) and ventricular (V) frequency (figure 17). In case of V>A VT therapy is initiated directly. For cases with V=A or V<A further discrimination algorithms are used to differentiate between SVT and VT. For V<A programming of morphology and stability criteria is recommended. For V=A programming of morphology criterion may be sufficient. In addition for V<A episodes measurement of the A-V-A intervals may differentiate SVTs with 2:1 activation from VTs with VA dissociation during AF/Aflut. Measurement of A-V-A intervals by St. Jude Medical devices (AV Detection Enhance™) is illustrated in figure 18a-b. This algorithm counts the last 12 AV intervals and calculates the difference between the second longest and second shortest AV interval; difference < 40ms suggests association between A and V and decides for SVT. A comparable algorithm based on pattern recognition typical for Aflut or SVT with 1:1 AV-conduction is used by Medtronic called PR-Logic™ and by Biotronik called SMART™. Sorin use an algorithm more orientated to CL stability called PARAD(+)™[9].
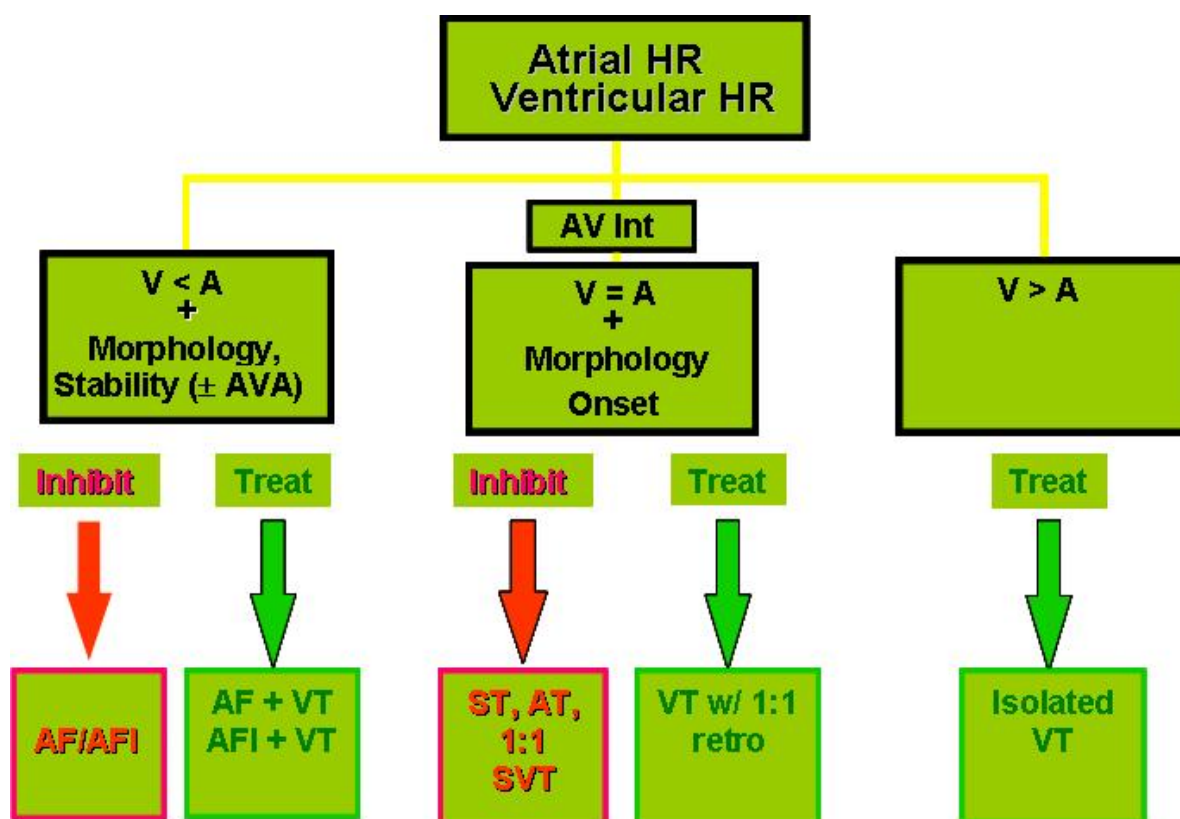

Figure 17. The rate branch differentiates between V<A, V=A and V>A. For VA dissociation a VT will therapies by ICD directly. In case of V=A a sinus tachycardia or other 1:1 SVT should inhibited by ICD and in case of retrograde activation of a VT the ICD should delivered therapy. For V<A and AF/AFl therapy should inhibited and V<A with VT and current AF/AFl therapy should delivered.
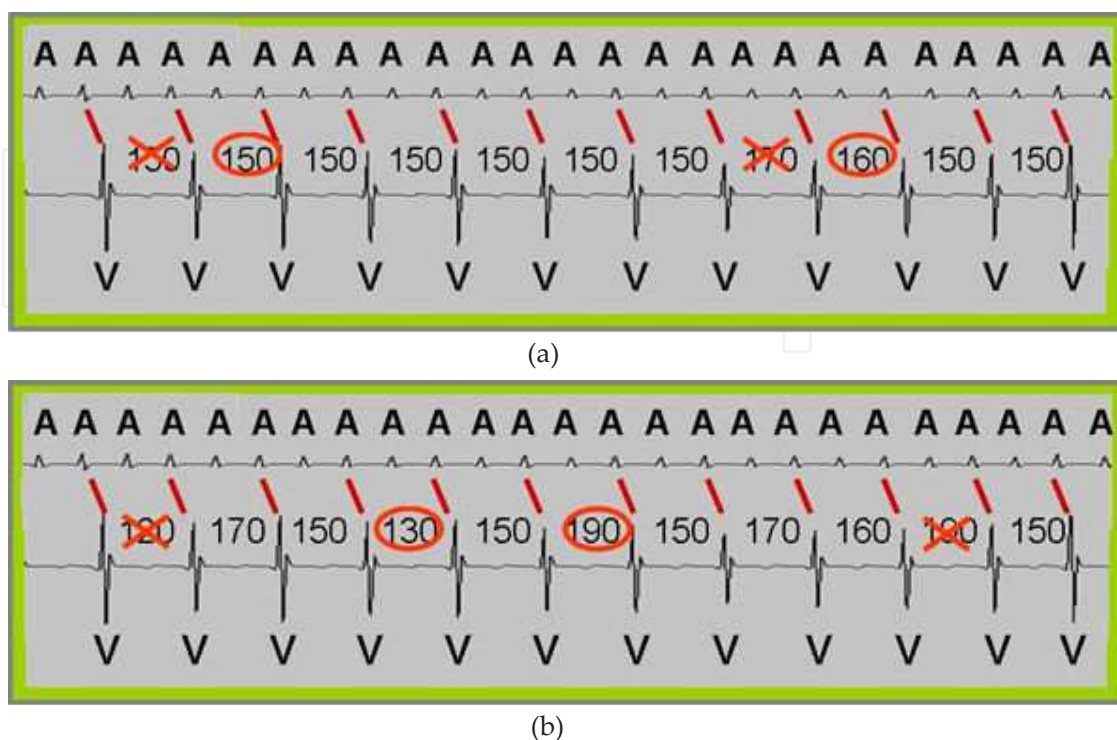
(a)

(b)

Figure 18. a: This is an example for measurement AV association during AFl with 2:1 activation. Although stability says stable CL <40ms there is an association between A and V. 160-150ms = 10ms for AVA interval (standard < 40ms for SVT) indicate association with RA. The algorithm vote for SVT and AVA interval outvotes stability. b: This is an example for measurement AV dissociation during AFl and VT. The second longest minus second shortest AV interval (190ms-130ms=60ms) is voted by delta >40ms for dissociation and VT.

13. Tachy/Sinus ratio

Tachy/Sinus ratio counter is an algorithm from St. Jude Medical to avoid oversensing bigeminy during sinus tachycardia, t-wave oversensing or cluster caused by lead fracture. In figure 19 calculation of CL ratio of 2.5 (500ms/200ms) over the last 12 sinus beats is illustrated. For every ratio of 2.5 the algorithm counts -1, and for counter <3 over the last 12 beats the algorithm votes for bigeminy and for >3 for VT. Medtronic has developed an algorithm called Lead Integrity Alert™; a short RR counter combined with daily lead impedance monitoring as early warning system for lead fracture. These algorithms have growing importance due to the rising number of lead fracture problems over the last years. Biotronik also developed its t-wave detection protection algorithm. Furthermore, all manufacturers use an automatic gain control as dynamic sense control to avoid t-wave oversensing.
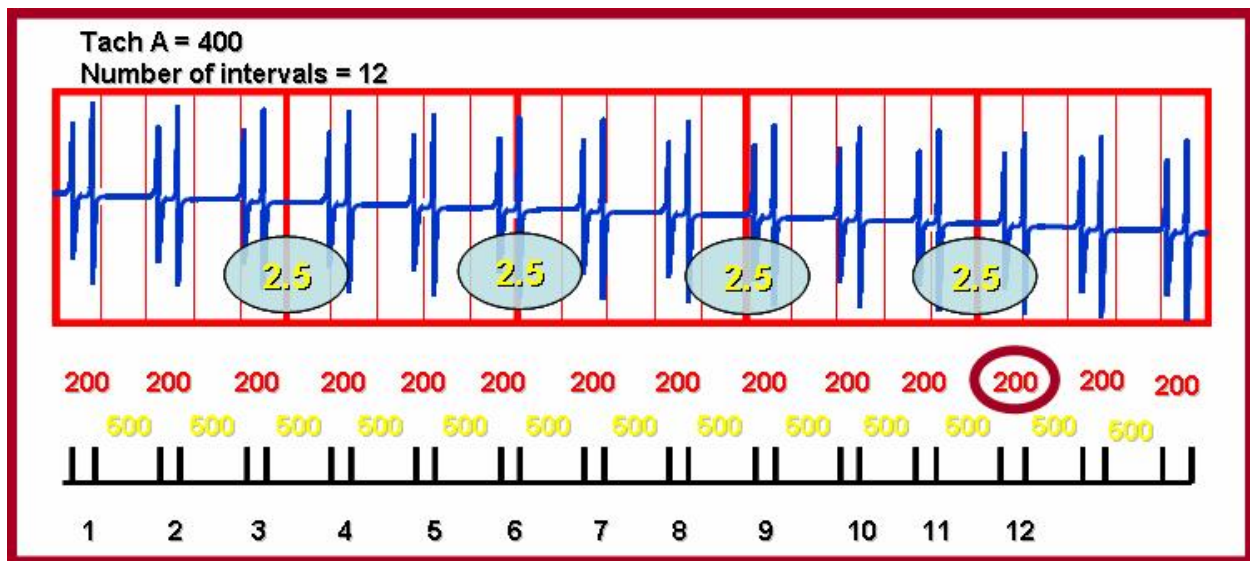
Figure 19. This is an example for measurement Tachy/Sinus ratio. Over the last 12 interval the ratio 500/200 turns out 2.5. For this value the algorithm counts -1 and calculate this over the last 12 beats. For a value <3 SVT and >3 VT is assumed.

14. Decision making for single or dual chamber ICD

In the last decade the issue of implanting single or dual chamber ICD was thoroughly discussed. The negative influence of ventricular pacing in DAVID I trial [10] could be avoided in the DAVID II trial [11], which demonstrated similar prognoses in single and dual chamber patients for freedom of unfavourable ventricular pacing. The 1&1 trail of Bansch et al [9] failed (p=0.08) to demonstrate superiority of dual chamber devices to prevent inappropriate therapy in ICD patients. Also in MADIT II no benefit for dual chamber ICD patients could be confirmed [4]. The Detect SVT study by Friedman et al [12] could show a significant decrease of inappropriate therapy in dual chamber patients (with 30.9% in 1,090 episodes versus 39.5% in 1,253 episodes in single chamber ICD patients (p=0,03, see figure 20). Superiority was reported in the diagnose of AF, Aflut and atrial tachycardia (figure 21). No benefit could be demonstrated in sinus tachycardia, lead dysfunction and t-wave oversensing. Still, even dual chamber ICDs may fail to discriminate appropriately (figure 22a-f). This figure also may help to explain why inappropriate ICD therapy could have a negative effect on mortality in ICD patients. An recently, not jet published abstract of HRS congress 2012 of Friedman et al. of a prospective randomized trail of dual chamber versus single chamber ICD to minimize shocks in optimally programmed devices with optimal 30/40 detection of Medtronic devices no significant superiority of dual chamber devices could measure in attention to inappropriate therapies. Significant more AF was detected in the dual chamber device group. Generally, the choice of single or dual chamber does not depend on the intention of a better SVT discrimination (e.g. patients with paroxysmal AF). Main indication for dual chamber ICD is the necessity of atrial pacing.
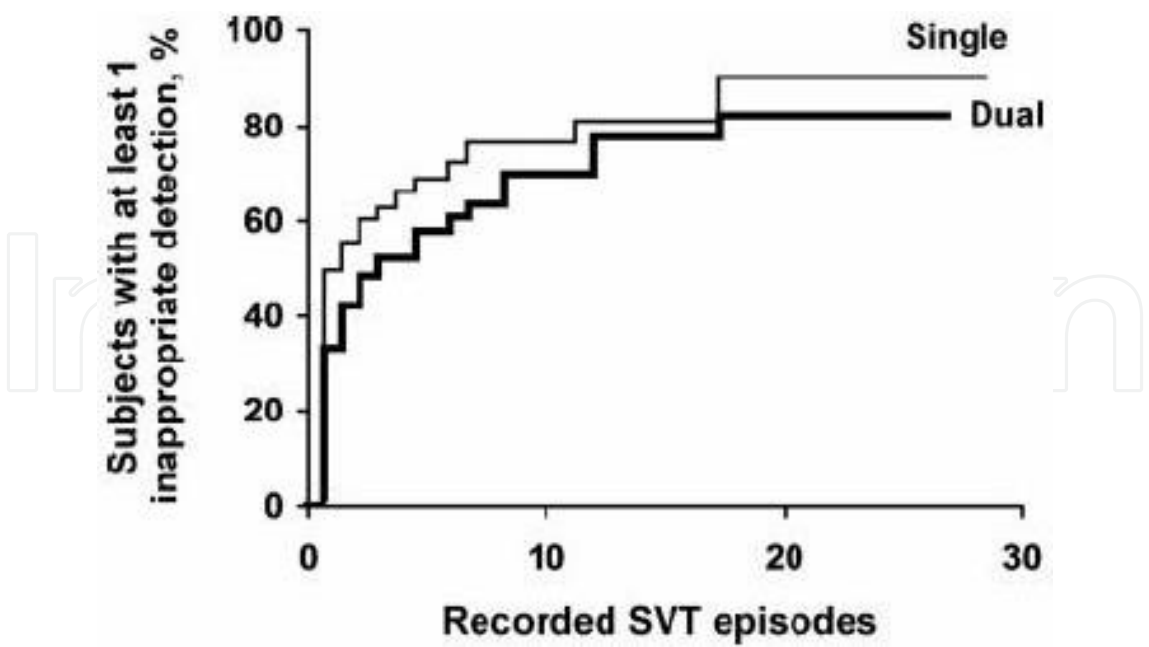
Figure 20. Comparison of inappropriate SVT detection in single and dual chamber ICDs. Notice 30.9% inappropriate SVT detection in 1,090 episodes in dual chamber versus 39.5% in 1,253 episodes in single chamber ICD patients (p=0.03) [12].
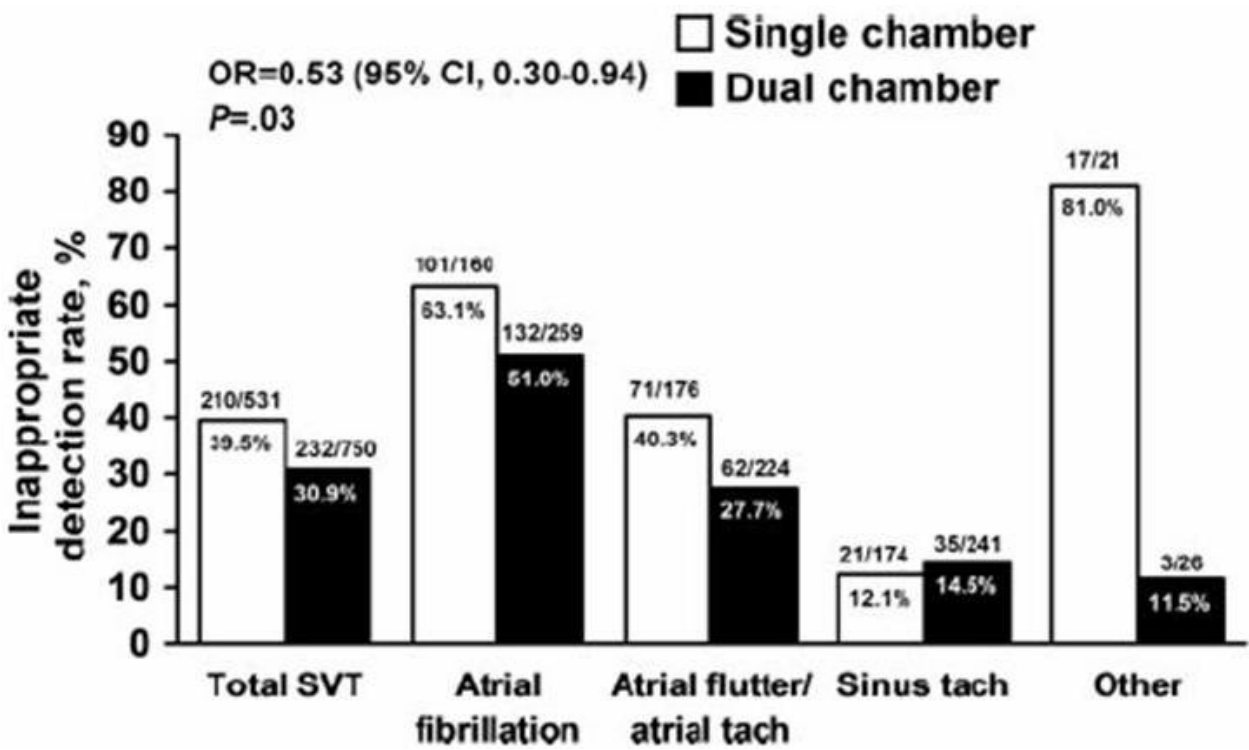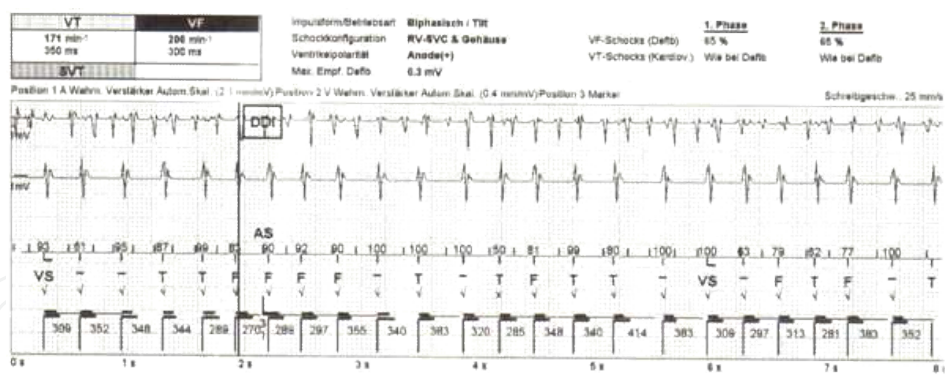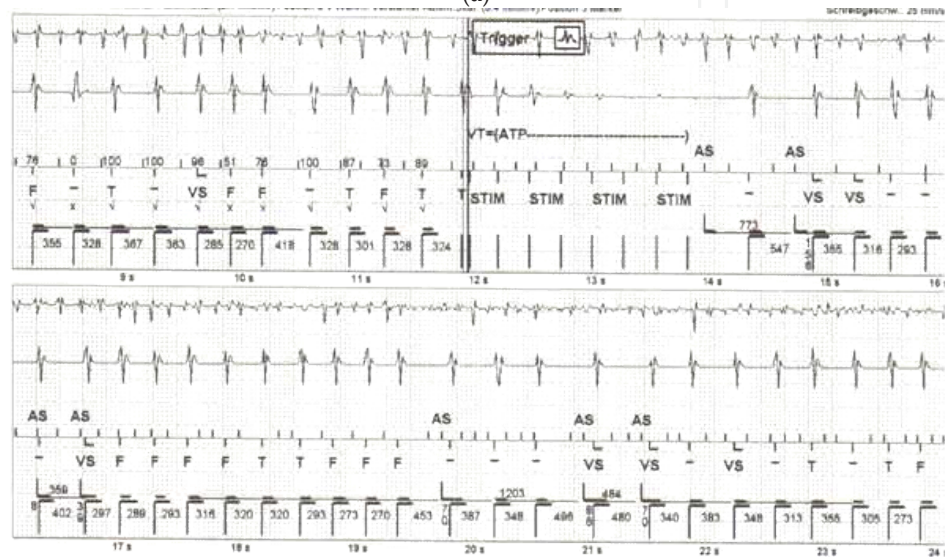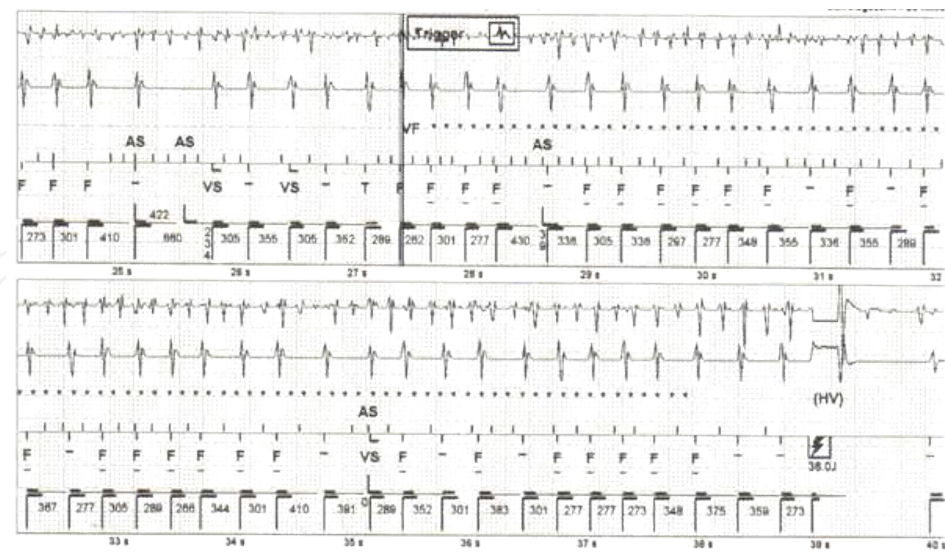

Figure 21. Comparison of inappropriate SVT detection in single and dual chamber ICDs. A trend for superiority was estimated in AF, AFl and atrial tachycardia in the Detect SVT study [12].

(a)

(b)

(c)

(d)

(e)

(f)
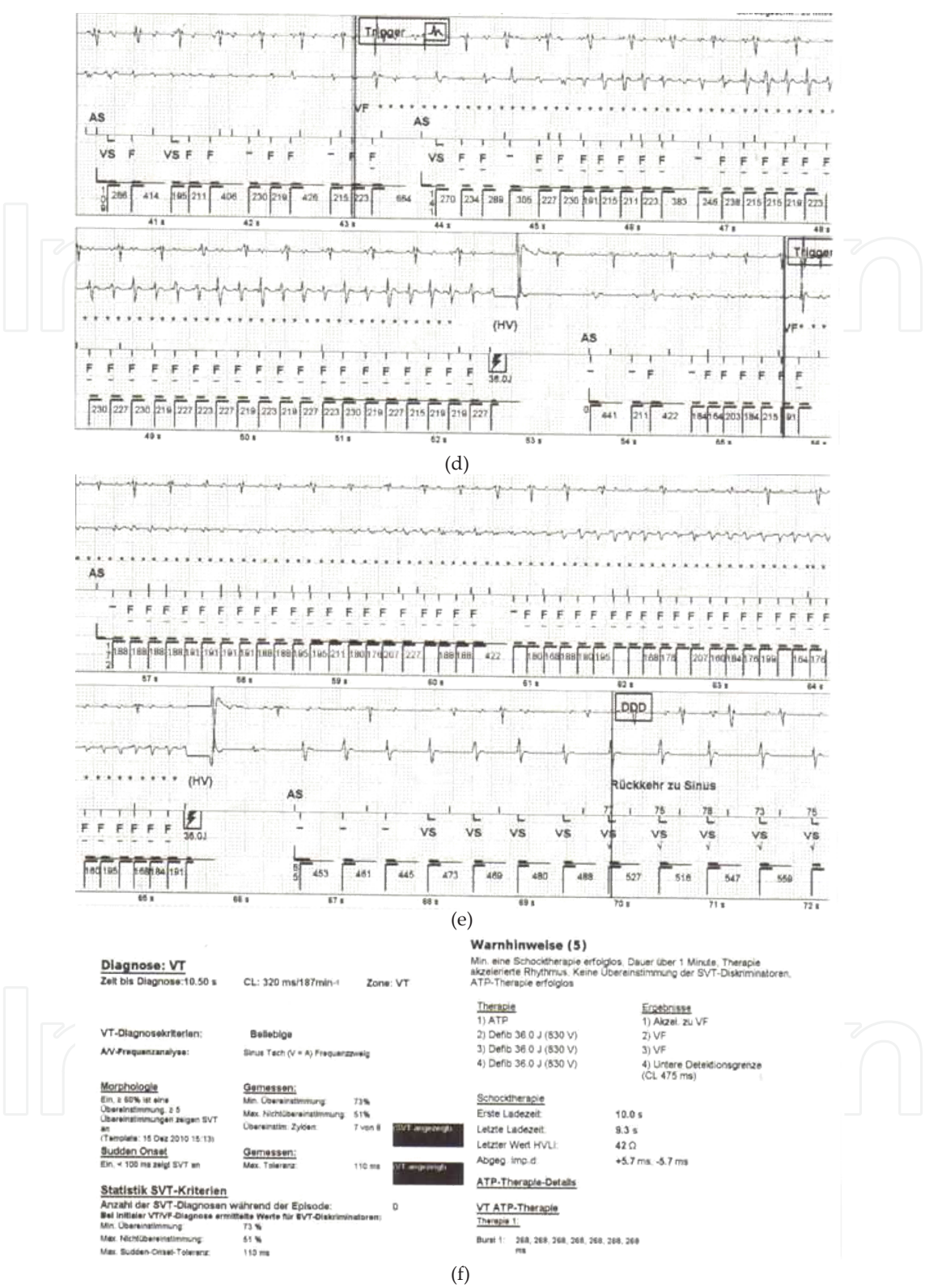
Figure 22. a: Demonstration of an AF episode in a CRT-D device with dual chamber detection (Promote St. Jude Medical) A>V with CL around 344 to 270ms. Depending of CL the device counts VT (T) and VF (F) beats for detection. In this device no SVT discrimination algorithms are allowed in VF zone. b: Same episode 12 seconds later. After detection VT episode (NID 12] first VT therapy (ATP) is given. c: Same episode 27 seconds later. After acceleration of AF a VF episode

is detected (NID 12] and the first shock is delivered. d: Same episode 43 seconds later. After the first shock ventricular fibrillation with syncope of patient is following, second shock (ineffective) at second 52 of episode is delivered. e: Same episode 65 seconds later. The third shock, now effective, is delivered during ventricular fibrillation and episode ends with sinus rhythm.f: This picture of the same episode turns out reasons for detection of AF in the VT zone. A temporary AF undersensing in RA rolls this episode in V=A branch. Generally based from 1:1 tachycardia in this branch stability is not sensible and programmed in this branch. In this case there are morphology and sudden onset discrimination active. For understandable reasons morphology votes for SVT and sudden onset for VT and resulting VT therapy starts. As previously described sudden onset criteria is not recommended in this branch and an always problematic discrimination algorithm.

15. Summary/Conclusion

Avoiding of inappropriate therapy delivery is one of the major issues in ICD therapy. In the last decade several new algorithms were developed to improve sensitivity and specificity of tachycardia detection. Current recommendation for primary prevention patients is the programming of a fast VT zone from 187 to 250 bpm with long NID or DT [30/40] for Medtronic, 12 seconds for Boston, 18/24 for St. Jude Medical and Biotronik), is ATP prior or during charging followed by shock therapy. For devices that not allow SVT discrimination in this zone a separate VF zone above 250 bpm should be programmed to make SVT discrimination possible in a VT zone of 187 to 250 bpm. If a second VT zone around 150-187 bpm is programmed, a long NID (minimum 25 beats or 60 seconds) with stability and morphology discrimination algorithm without time out rule is recommended. Algorithms for early detection of lead fracture, sinus/tachy ratio and impedance monitoring are recommended when available. In patients with long QT syndrome or other risk for primary VF a single zone over 220 bpm is recommended. In dual chamber ICDs stability, morphology and A-V-A (or equivalent) SVT discrimination algorithms are recommended in the analysis of V=A and V<A tachycardias. Implantation of dual chamber ICD for better SVT/VT discrimination only is not indicated by currently available studies.

No algorithm is sensitive or specific enough to substitute the individual adaptation of ICD detection and therapy for every patient. Detailed knowledge of ICD algorithms may provide the necessary basis for the cardiologist to program devices individualized for each patient. Stored episodes should be carefully evaluated at every follow-up visit to further improve discrimination of SVTs and VTs.

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