# Troubleshooting implantable cardioverter-defibrillator related problems

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Since its introduction, now more than 20 years ago, the implantable cardioverter-defibrillator (ICD) has evolved from a non-programmable (committed) device into a sophisticated multi-programmable, multi-functional device with extensive diagnostic and therapeutic options. The more recent combination with cardiac resynchronisation therapy (CRT) further expanded its use to selected patients with severe symptoms of heart failure and left ventricular dyssynchrony at risk of sudden cardiac death.

Whereas ICD technology developed rapidly, endocardial ICD leads, consisting of an integrated pace/sense and shock electrode positioned in the right ventricle, remained essentially unchanged after their introduction in the late 1980s, aside from a reduction in diameter.

In the early years, ICD implantation was a major surgical procedure associated with significant morbidity and mortality, necessitating a thoracotomy to place the epicardial leads and patches and an abdominal incision to insert the bulky first generation device. With the introduction of endocardial shock electrodes and the significant reduction in size and weight of the devices, the complexity of the implantation procedure was reduced significantly and currently most systems can be implanted in the catheterisation laboratory by the electrophysiologist under local anaesthesia.

However, compared to the relative ease of the current implantation procedure, follow-up and troubleshooting of ICD patients has become a much more complicated and challenging process, demanding extensive knowledge of cardiac electrophysiology as well as a thorough understanding of the different features and algorithms incorporated in modern (CRT) ICDs. Combined with the increasing number of ICD patients, troubleshooting of ICD related problems has become a challenging task. In this overview some of the most important device related problems will be discussed.

## TROUBLESHOOTING POLICY

Device related problems in ICD patients may vary from relatively simple sensing or pacing problems to life threatening episodes of inappropriate shocks or failure of shock delivery. In analysing and solving ICD related problems, it is important to maintain a structured approach towards every patient presenting with possible device related issues.

ICD troubleshooting starts either when a patient with a device presents at the hospital with a possible device related complaint or when a regular technical follow-up reveals a possible device deviation. In order to identify and solve the problem, the device should be interrogated extensively and the retrieved data should be stored on disc to allow offline analysis and comparison with historical data.

After identification of the problem, the possible cause is analysed. Different methods of evaluation may be needed, such as manipulation of the device, observing the effect of postural changes and deep inspiration and expiration, 12 lead electrocardiography, a chest *x* ray, and 24 h Holter monitoring.

Patients with an ICD related problem present with complaints which generally fall into one of the following four categories:

- Shocks (appropriate, inappropriate or failure to deliver therapy)
- Dizziness/fainting
- Palpitations
- Alerts (audible beeps or sensed vibrations originating from the ICD).

## SHOCKS

Whereas ICD therapy improves survival of selected patient groups and patients may have the feeling of being protected, the actual delivery of shocks, both appropriate and inappropriate, may have significant psycho-sociological consequences. Several studies have demonstrated that the occurrence of ICD shocks negatively influences patients' subjective feeling of physical and mental wellbeing.[1 2] This is caused by the fact that shock delivery is a traumatic physical experience and because of the psychological effect of confronting the patient with his/her compromised physical status or with his/her risk of developing life threatening arrhythmias.

In general, most single shocks are appropriately (and successfully) delivered to terminate an episode of ventricular tachycardia/fibrillation, and because the ICD worked properly the patient may even be reassured.

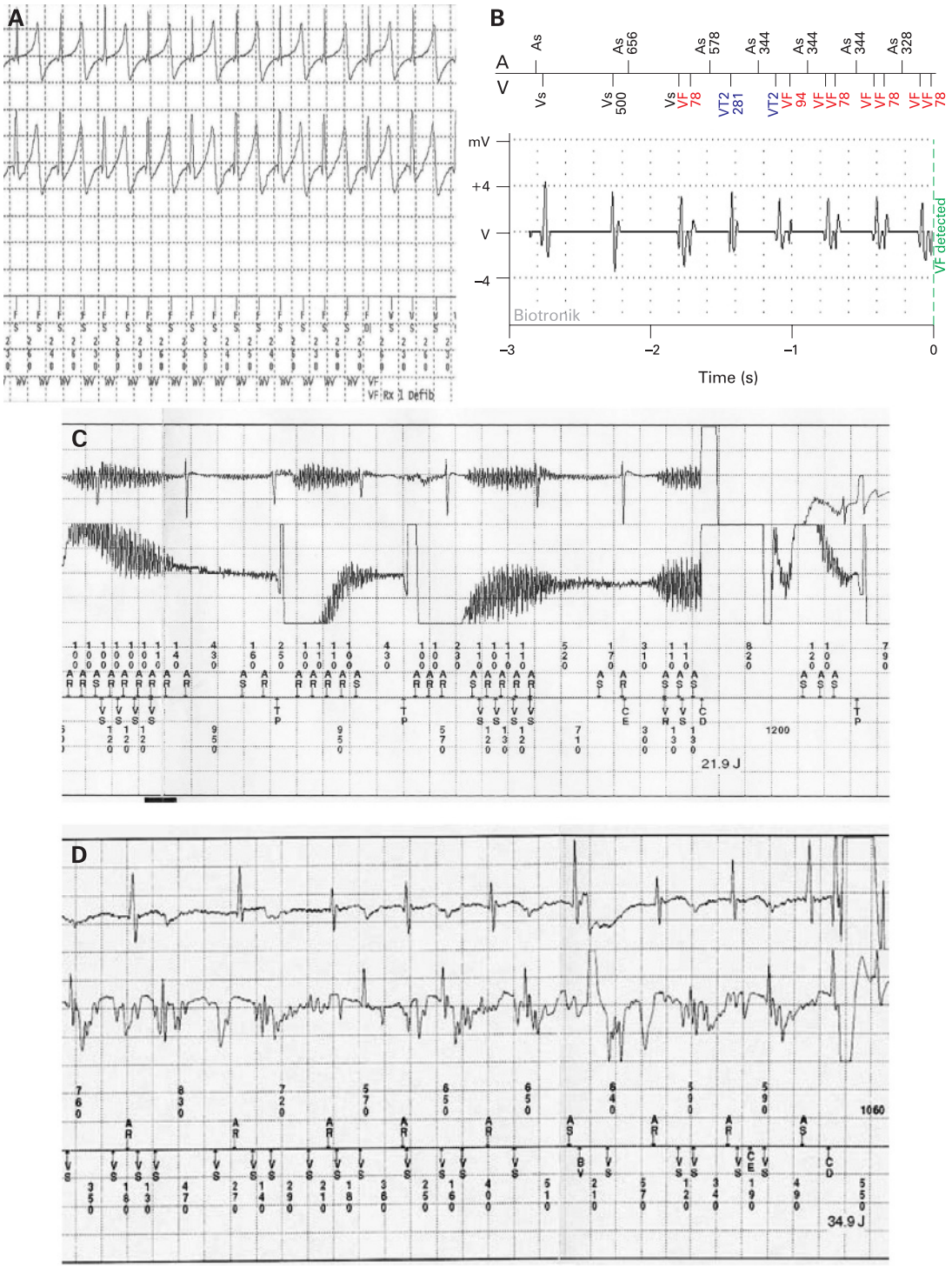


**Figure 1** Causes for inappropriate shocks with typical examples. (A) Non-tachycardia: Oversensing of P- or T-waves may result in shock delivery. In this example oversensing caused the sensing of giant T-waves, and as a consequence the device is activated. (B) Double-counting of R waves starts with the appearance of frequency dependent bundle branch block, resulting in incorrect ventricular fibrillation (VF) detection. (C) Lead or connector problems may cause electrical noise resulting in device activation. (D) Source of electromagnetic interference (EMI) outside the body (the patient was installing a pump in a pool). EMI may cause therapy delivery. However, EMI may also cause inhibition of a pacemaker.

On the other hand, multiple shocks are more often classified as inappropriate. The experience of receiving multiple shocks during consciousness is extremely distressing for both patients and witnesses, and warrants extensive clinical evaluation to reveal the possible cause and to reprogram the device or take other necessary measures to prevent future inappropriate shock episodes. Therefore, patients presenting after multiple shocks should always be advised to have their ICD interrogated, whereas patients who received a single shock can generally be reassured.

### How does the ICD decide to deliver a shock?

All devices use the signal rate recorded by the right ventricular lead as the first detection criterion. In order to be declared an arrhythmia, a specified number or percentage of sensed events must occur at a rate higher than the programmed cut-off rate. These sensed events may originate from a real

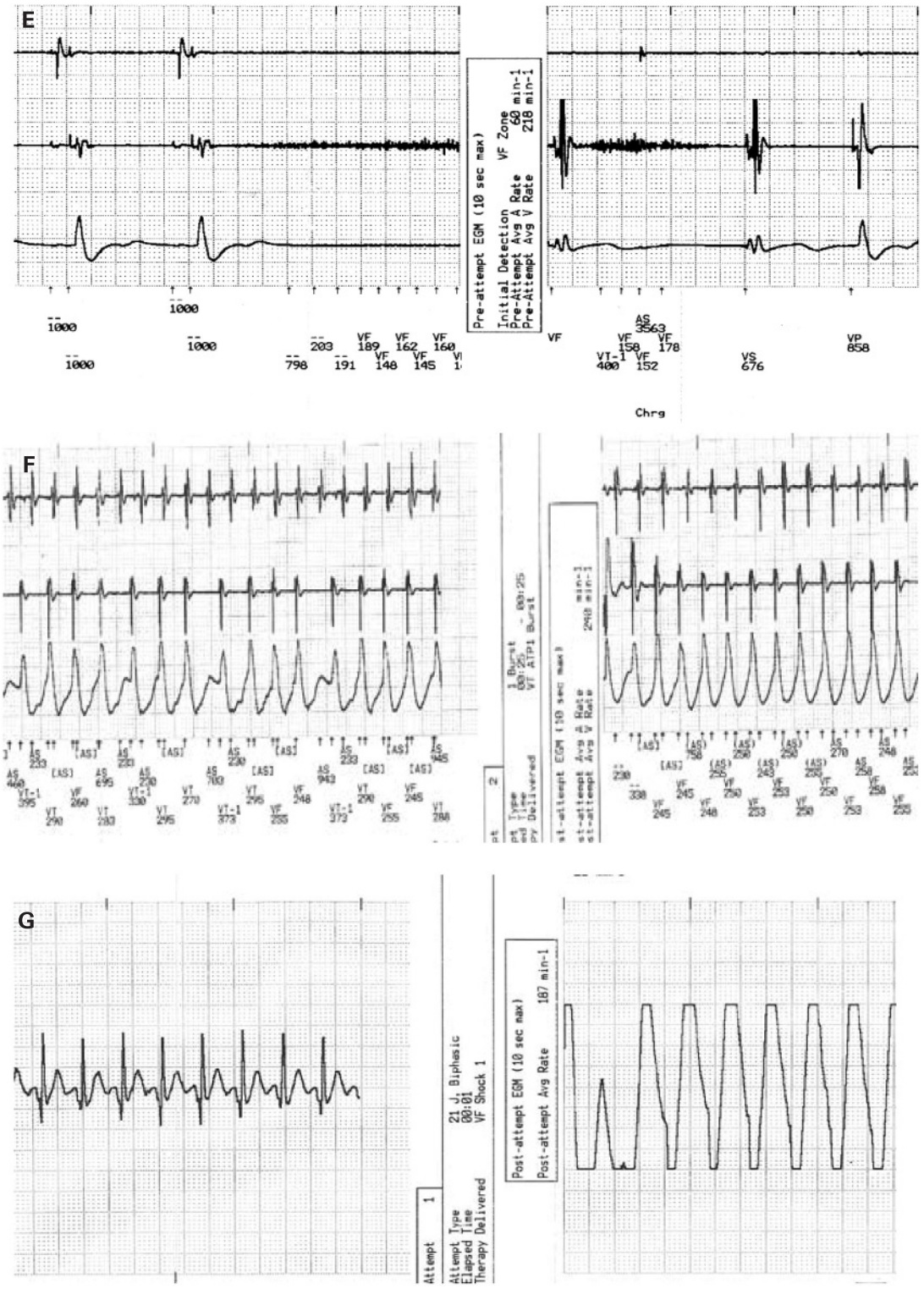


**Figure 2** Causes for inappropriate shocks with typical examples (continued). (E) Source of electromagnetic interference (EMI) inside the body: oversensing of diaphragmatic potentials. The implantable cardioverter-defibrillator (ICD) criteria for initial ventricular fibrillation (VF) detection are met (8 out of 10 intervals classified as fast), but VF is not reconfirmed as the diaphragm potentials cease and the "Duration" is not met (Duration is programmed to 1 s). VF therapy is not delivered. Note that after the first intrinsic beat (arrow) the sensing of noise is reduced, due to the auto gain sensitivity (see text for details). (F) Atrial arrhythmia with fast conduction (but initially not 1:1) and a ventricular rate fulfilling the detection criteria followed by antitachycardia pacing. Thereafter, the atrial arrhythmia is conducted 1:1. (G) Shock delivered during sinus tachycardia just above the cut-off rate for VF (188 beats/min), resulting in a ventricular tachycardia.

tachycardia, either supraventricular tachycardia (SVT) or ventricular tachycardia (VT), but also from signals originating from another source (figs 1 and 2).

To discriminate between SVTs and VTs, various algorithms have been developed with the intention to improve specificity for discrimination of VT from SVT without compromising the sensitivity for detection and treatment of VTs.[3–5] Current ICDs can be programmed into three different cycle length (CL) related zones and the detection algorithms are programmable in the two lowest zones (in case of programming three different zones). The highest programmable zone is meant to detect fast VT or VF without any further discrimination to avoid unnecessary therapy delivery delay.

Available algorithms include sudden onset, sustained high rate duration, rate stability, and morphology/wavelet/rhythm ID capabilities for single and dual chamber devices, whereas dual chamber devices can use additional information retrieved from the atrial lead, like atrial to ventricular timing relationships. All currently available algorithms have known limitations (table 1). By combining some of these algorithms the amount of inappropriate inhibition or therapy delivery can be further reduced.

It is important to have knowledge and understanding of the incorporated automatic algorithms for discrimination of arrhythmias in order to apply them effectively.

### Sudden onset

The intended use of this algorithm is to discriminate sinus tachycardia from VT. With the onset of a VT, there is usually a sudden increase in ventricular rate (as opposed to, for example, an exercise induced sinus tachycardia). The sudden onset criteria is effective in discriminating VT from sinus rhythm except in the case of only a minimal CL difference when, for example, during sinus tachycardia a VT is initiated, or in case of slow VT. This algorithm may lead to false positive as well as false negative therapy delivery decisions. Patient tailored programming is thus mandatory to improve both sensitivity and specificity. To reduce the chance of a VT going untreated, a specified acceptance time for a sustained high ventricular rate can be programmed as an overriding algorithm (sustained high ventricular rate). However, this feature in itself has disadvantages since it can lead to inappropriate shocks—for example, an appropriately withheld shock during sinus tachycardia will be delivered after expiration of the preset time interval. On the other hand, sustained high rate duration can also (when a long duration has been programmed) result in a potentially dangerous delay of therapy delivery.

**Table 1** Detection algorithms in implantable cardioverter-defibrillators: intended use and weaknesses

| | Discrimination | Algorithm weakness |
|---|---|---|
| **Single and dual chamber device** | | |
| Sudden onset | Sinus rhythm vs VT | VT starting during sinus tachycardia |
| | | VT below cut-off that accelerates |
| Rate stability | AF vs VT | Unstable VT |
| | | Stable conducted AF |
| Morphology/Wavelet/Rhythm ID | All SVT vs VT | Aberrant conduction |
| | | Mismatching with template |
| **Dual chamber device** | | |
| Atrial: ventricular rate | V>A with VT | Atrial undersensing with AT with 1:1 AV relationship |
| | | "Double tachycardia": concurrent atrial and ventricular tachycardia |
| | | Misinterpretation of AV and VA relationship |

AF, atrial fibrillation; AT, atrial tachycardia; AV, atrioventricular; SVT, supraventricular tachycardia; VA, ventriculoatrial; VT, ventricular tachycardia.

### Stability

This algorithm is intended for discrimination of fast conducted atrial fibrillation/flutter from VT. It is an effective discriminator, except in the case of a relatively stable ventricular rate during atrial fibrillation, which occurs more often at higher ventricular rates (due to a limited absolute variation in RR intervals). As with the onset algorithm, stability may lead to both false positive and false negative declarations. During atrial fibrillation with relatively stable RR intervals, inappropriate therapy can be delivered (false negative) and with relatively unstable VTs, therapy may inadvertently be inhibited (false positive). In this case, an overriding algorithm using the elapse of time is useful to overcome the inappropriately inhibited therapy for unstable VT, but will lead to more inappropriate therapy in the case of atrial fibrillation.

### Electrogram morphology

Morphology (St Jude Medical, St Paul, Minnesota, USA), Wavelet (Medtronic, Minneapolis, Minnesota, USA) single chamber ICD, and Rhythm ID (Boston Scientific, Natick, Massachusetts, USA) are features incorporated into the different devices to discriminate an SVT from a VT, especially in single chamber devices that lack additional information retrieved from the atrial lead. These algorithms are based on retrieving a template of the electrogram during baseline rhythm. Morphology uses the near-field rate electrogram derived from the small intracardiac bipole; Wavelet uses the far-field shock electrogram, analysing the electrical activity between a shock electrode and the intracardiac electrode, and taking the electrical axis into account; Rhythm ID uses the far-field shock electrogram aligned in time to the rate electrogram, combining electrical axis and timing. When an event is detected in the applied zone, the morphology of each electrogram is compared to the baseline template and the percentage of match or mismatch is calculated. The advantage of these algorithms is the independence of the atrioventricular (AV) sequence and timing relationship. No comparative studies on efficacy are, however, available.

### Atrioventricular (AV) sequence/timing algorithms

Dual chamber devices enable the use of information provided by the atrial lead. If the ventricular rate exceeds the atrial rate (V>A), the diagnosis is VT. Comparison of atrial and ventricular rate during tachycardia can be used as an initial step in the decision tree or as an "overrider" after other algorithms have been applied by the device. This information can also be used in combination with the above mentioned algorithms to enhance sensitivity and specificity of arrhythmia discrimination, or it can be used for separate AV time relationship algorithms. Weaknesses with these AV sequence/time algorithms are 1:1 conducted atrial



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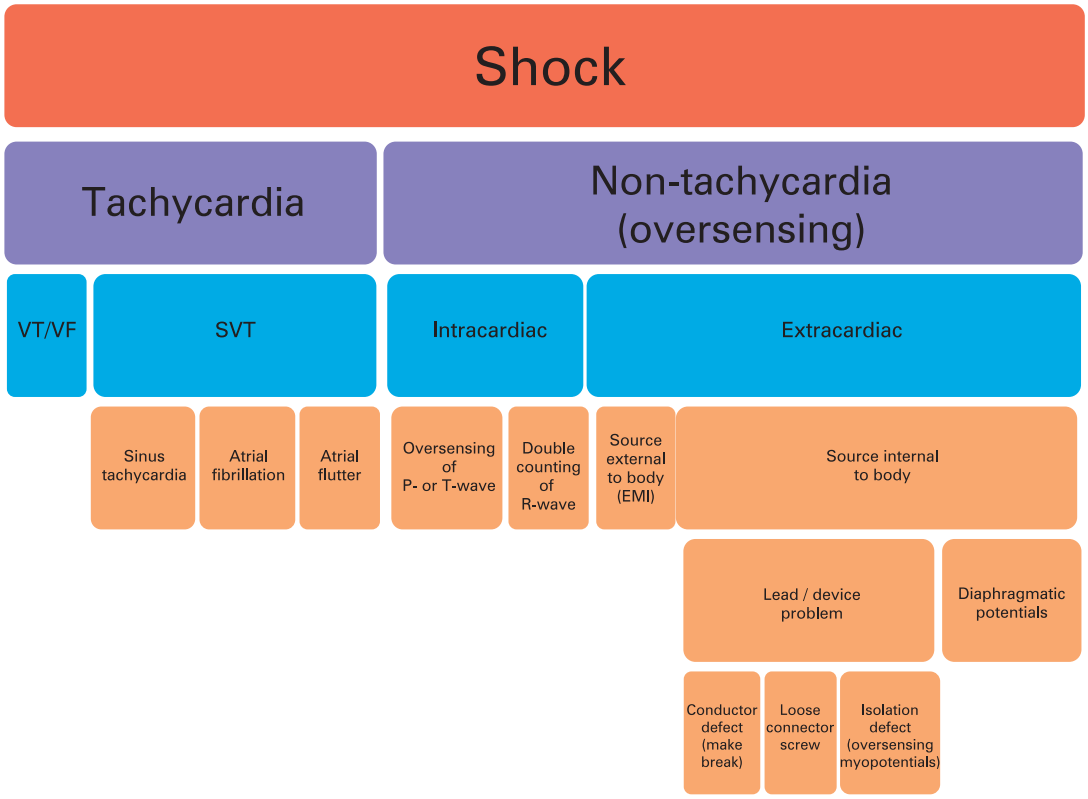



**Figure 3** Schematic representation of the possible causes of shock delivery. Shocks can be either delivered because of a tachycardia (ventricular: appropriate, or supraventricular: inappropriate) or because of oversensing problems (all inappropriate). SVT, supraventricular tachycardia; VF, ventricular fibrillation; VT, ventricular tachycardia.

tachycardias with prolonged AV time and VTs with 1:1 retrograde conduction. Although no studies have been conducted to support this statement, the value of the atrial lead information for the human interpretation of stored electrograms is significant, particularly during the onset of the arrhythmia which device based algorithms currently do not take into account.

### How to evaluate the appropriateness of a delivered shock?

ICDs are not perfect in their judgment of the perceived signals. The annotated interval markers and other markers provide information and insight into the decision making process of the ICD. However, a careful review of stored electrograms is often mandatory to verify appropriateness and efficacy of therapy delivery. The stored episode electrograms retrieved from a far-field dipole are in general helpful for analysis, especially when it is possible to compare these electrograms with a real time reference electrogram. Furthermore, stored electrograms can be used to analyse A–V sequence and timing.

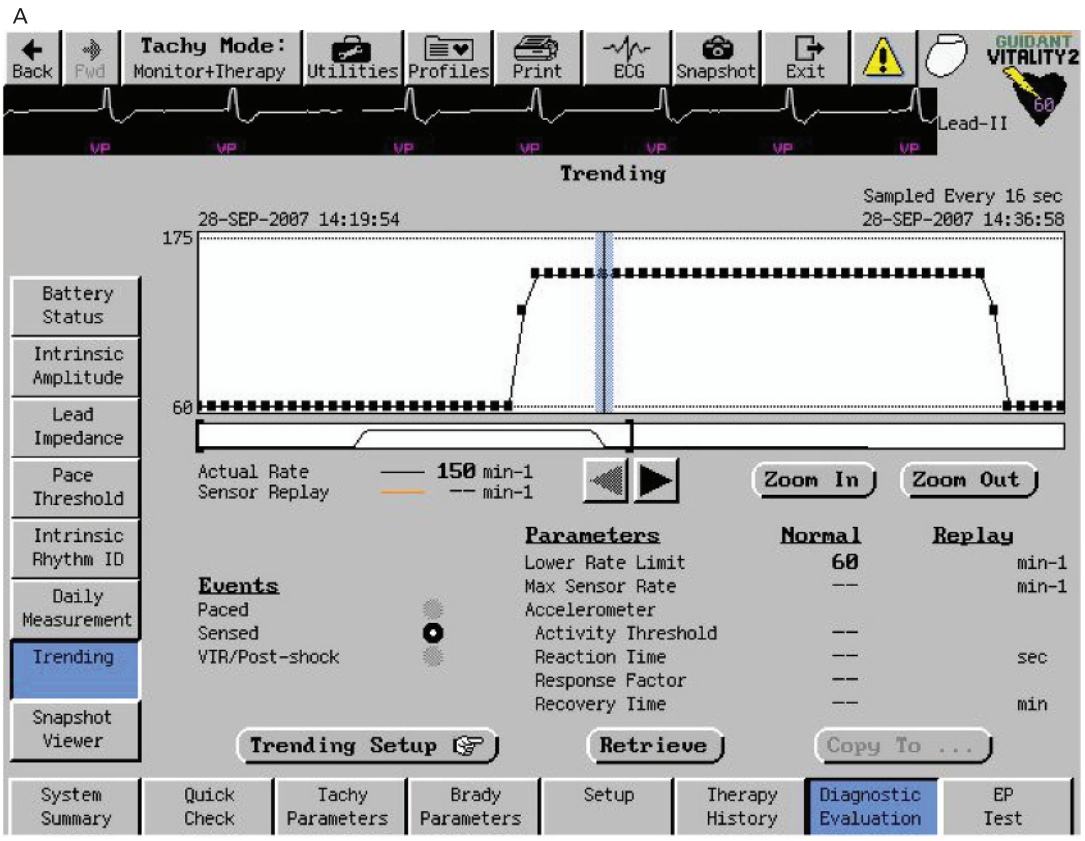
The first step in analysing a possible arrhythmic episode is to differentiate a real tachycardia (SVT or VT) from a device interpreted tachycardia (figs 1 and 2). This is essentially carried out by analysis of stored episode signals and comparing these with the information as it is perceived by the ICD which is represented by the annotation markers. A decision tree is shown in fig 3.

### Inappropriately device interpreted tachycardia

When the stored electrograms do not show a real tachycardia but the markers reveal that the device interpreted the signals as tachycardia, the next step is to trace back the origin of the signals as intra- or extracardiac (figs 1 and 2).[6]

Intracardiac signals that may cause oversensing and false arrhythmia detection are usually the T-wave or (infrequently) the P-wave (fig 1, panel A). In both cases, VT/VF detection criteria are already met at relatively low heart rates since each heart cycle leads to two sensed signals. T-wave oversensing occurs more frequently during exercise. Another phenomenon, which occurs infrequently in the current generation of ICDs, is double counting of the R-wave (fig 1, panel B).

Oversensing of extracardiac signals can be easily recognised as high frequency, low amplitude signals that are not related to the intrinsic electrical activity of the heart. Electromagnetic interference from an external source, such as a power drill (fig 1, panel C), usually has a more continuous character, may be visible on several channels and can generally be tracked back by careful history taking. Internal sources causing oversensing are signals produced in case of lead or connector related make-break contacts (fig 1, panel D). Since these phenomena may occur intermittently, impedance, threshold and sensing parameters may be normal at the time of examination. However, pocket manipulation or postural changes may reveal changes in these parameters or may show "noise" on the real time intracardiac electrogram.



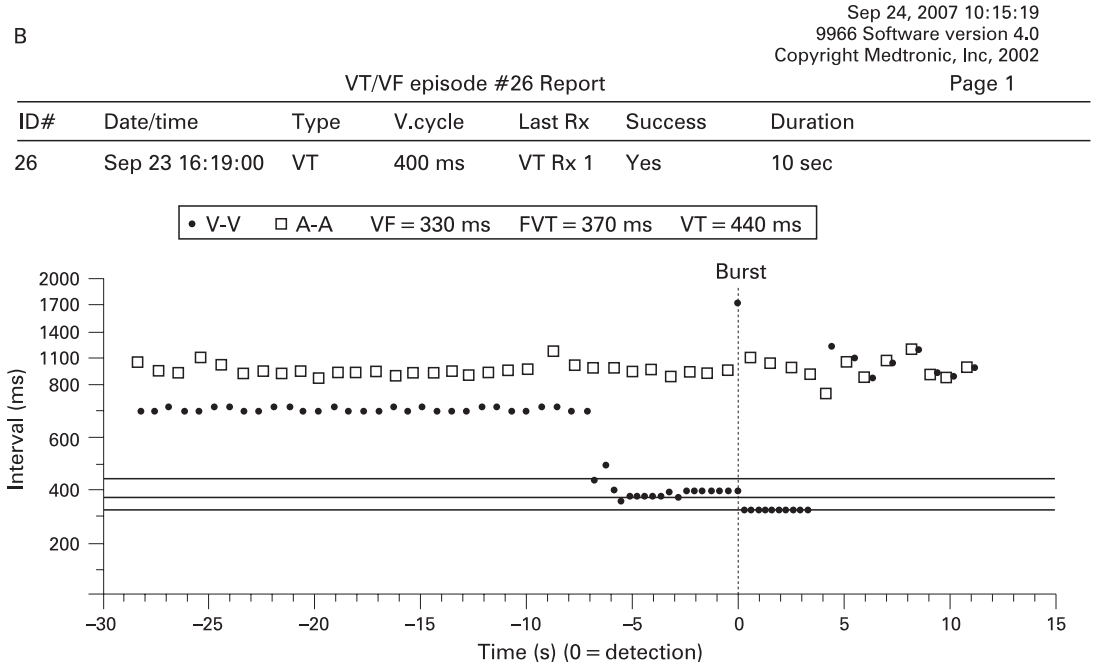




**Figure 4** (A) "Trending" (Boston Scientific) or (B) "Cardiac flash back" (Medtronic) revealing a ventricular rate under the detection zones.

These high frequency signals typically start to show some time after an intrinsic or paced beat. The algorithm of increasing sensitivity which is typical for ICDs ("auto gain sensitivity") allows sensing of the low amplitude signals from the diaphragm. This will lead to VF detection (and therapy delivery) unless the sensing level is suddenly reduced with a subsequent intrinsic beat or by release of the diaphragm. As these myopotential related signals may also inhibit pacing, when no intrinsic beat occurs—as in patients with no or slow intrinsic rhythms—a shock may follow. Fortunately, most patients relax at an earlier moment and the diaphragmatic potentials cease. Myopotentials originating from the pectoral muscle may be sensed in case of an isolation defect of the pace/sense lead part of the ICD electrode.

### Appropriately device interpreted tachycardia

When, after an episode, the retrieved signals are judged not to be due to oversensing but to an actual tachycardia, further evaluation of the arrhythmia has to be performed to verify appropriateness of the shock since SVT–VT discrimination algorithms are not always perfect. This evaluation essentially follows the same algorithms that are described above. However, whereas the ICD starts applying the algorithm formulas after the criteria for initial detection are met, the human interpretation has a wider scope and can start at the actual onset of the arrhythmia. In certain ICDs (Medtronic, Boston Scientific) this extra information is graphically represented as the interval cycle length versus the time elapsed since the onset of the episode (fig 4). Other information can be retrieved by comparing the episode electrograms and annotations with data obtained at device examination. For example, the similarity of the morphology of an isolated ventricular extrasystole recorded by the shock electrode and the morphology during VT may lead to the diagnosis. Also, the absence of retrograde conduction during ventricular pacing may help to reject the diagnosis of ventricular tachycardia when during tachycardia a 1:1 AV relation exist.

High ventricular rates during atrial fibrillation or atrial flutter are the most frequent cause of inappropriate detection and therapy (fig 2, panel F). Atrial fibrillation causes typically an unstable ventricular rate (although this becomes less at higher ventricular rates as mentioned earlier) but usually does not fulfil the sudden onset criterion. Atrial flutter also results in unstable ventricular rates and is often clearly distinguishable in a dual chamber device unless 1:1 AV conduction occurs. Sinus tachycardia (fig 2, panel G) is sometimes hard to differentiate from 1:1 conducted atrial tachycardia, except for the gradual onset seen in sinus tachycardia. The Flashback memory (Medtronic) or Trending feature (Boston Scientific) may provide helpful information to discriminate between the different supraventricular arrhythmias. To distinguish a VT with 1:1 retrograde conduction from a supraventricular tachycardia with 1:1 AV conduction, both onset of the tachycardia and the morphology recorded with the far-field dipole may be of help.

Lastly, after a first unsuccessful shock in case of concurrent termination of the episode of VT, SVT or device interpreted tachycardia, an inappropriate second shock may be delivered. This second shock is so-called "committed", meaning that it is delivered without further pre-evaluation, for reasons of safety to prevent underdetection and undertreatment of arrhythmias. Commitment also starts when the first therapy of an episode has been diverted but the arrhythmia restarts before the episode has ended.

**Box 1: Causes of dizziness, syncope and palpitations. Most causes for dizziness and syncope may also give rise to palpitations**

- Causes of dizziness and syncope
  - undersensing of ventricular arrhythmias
  - polymorphic ventricular tachycardia (VT)
  - unstable VT around cut-off rate
  - VT below cut-off rate
  - non-effective therapy
  - non-sustained VT
- Causes of palpitations
  - atrial tachyarrhythmias
  - frequent premature ventricular contractions (PVCs)
  - ventricular pacing

### How to reduce the chance of delivering inappropriate shocks

Since most inappropriate shocks are delivered for supraventricular arrhythmia, and shocks have an important negative effect on the quality of life of patients, all efforts should be undertaken to reduce the chance of inappropriate shock delivery.

Awareness of risk factors for inappropriate shocks can help to prevent them by customising the programming of the ICD at implant.[7] For example, a history of atrial fibrillation is associated with an increased risk for inappropriate shocks. Also, especially in young patients, sinus rates during exercise may reach the arrhythmia detection zones easily and it is therefore important to adjust settings if necessary.

Theoretically, the most effective way to avoid inappropriate shocks in these patients would be to program the ICD as a single zone device with a high rate cut-off, but obviously this is undesirable for safety reasons since ventricular arrhythmias may be missed. However, lowering the VF zone cut-off rate will increase the number of inappropriate shocks. Therefore, the best solution in patients with paroxysmal atrial tachycardia or expected fast sinus rates is multiple zone programming with implementation of discriminators in the lower two zones, thereby allowing to program the cut-off rate for the VF zone relatively high (210–220 beats/min). Delivery of shocks for non-sustained VT or SVT can be delayed or even prevented by prolonging the programmed time for the device to detect. However, it is important to realise that after the first shock, the following shock(s) within a single episode, when becoming committed, cannot be avoided.

### Inappropriate shocks for other reasons than tachycardia

**T-wave oversensing** as a cause of inappropriate shocks is an important issue. ICD specific characteristics such as filter settings may make some patients more vulnerable to T-wave oversensing and inappropriate shocks. Patient characteristics like a high T-wave amplitude, a low R-wave and younger age may contribute to this phenomenon.[8] T-wave oversensing can be prevented by

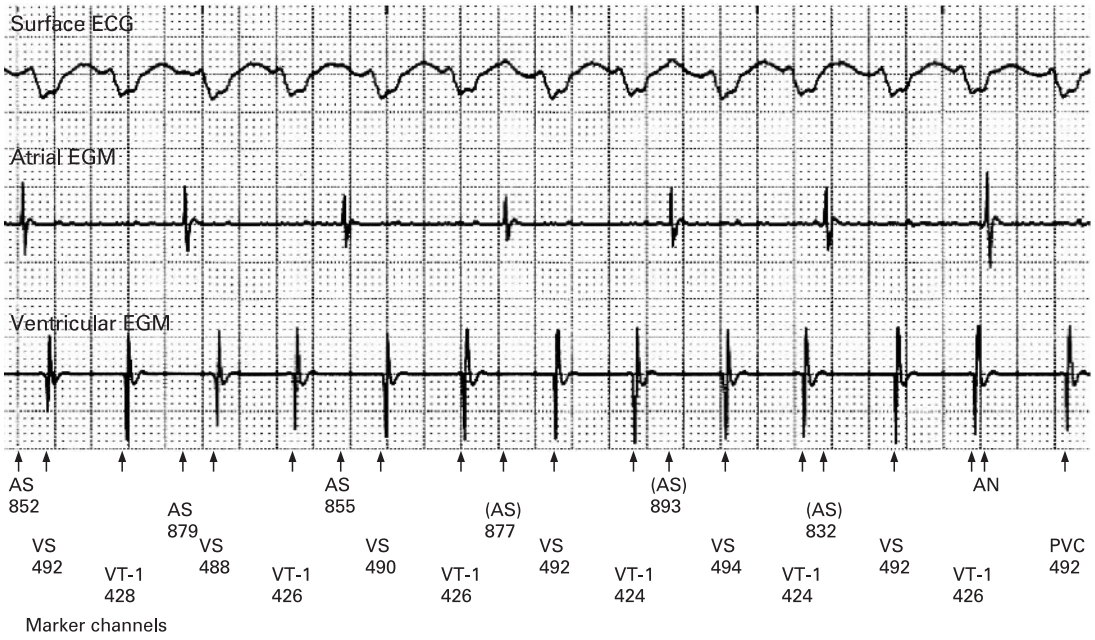



**Figure 5** Ventricular tachycardia. The ventricular egrams (lower channel) are clearly faster than the atrial egrams (middle channel). There is an alternating ventricular cycle length with the cycle length of each second cycle falling below the cut-off zone ("VS") leading to non-diagnosis of ventricular tachycardia. Symptoms of dizziness or syncope may be the effect.

programming the sensitivity level of the automatic gain control to a less sensitive level (this however may increase the risk of underdetection of or delayed therapy for VF). When T-wave oversensing is unmanageable, the only solution may be changing the device to another brand with more specific filtering to reject T-waves.

**R-wave double-counting**, another cause of inappropriate detection and therapy, can be managed by either reprogramming the ventricular blanking period, or by reducing the minimum sensitivity level or, when the other options fail, by lead revision (change of lead position).

**Electromagnetic interference (EMI)**: The potential sources of EMI are ubiquitous, especially in the hospital (for example, electrocautery, magnetic resonance imaging, lithotripsy) but also at work (for example, welding, high voltage power source, electric motors) and in daily life (for example, metal detectors, electronic article surveillance devices, cellular telephone).[9] The most frequent responses to EMI are inappropriate inhibition or triggering of pacemaker stimuli and spurious ICD tachycardia detection and inappropriate therapy. The effects of EMI on pacemakers and ICDs depend on the intensity of the electromagnetic field, the frequency of the signal, the distance and orientation of the device relative to the source, device characteristics and patient factors. Measures have been taken to make ICDs less susceptible—for example, by incorporating a filter. The fear for EMI is high compared to the real clinical problem. In fact, EMI is only rarely a cause of inappropriate shocks.[10] The best way to avoid EMI related shocks/device inhibition is to keep a sufficient distance from the EMI emitting source. Good advice is essential and, when indicated, a field evaluation may be necessary to identify possible hazards. However, testing for EMI is not 100% conclusive.

**Sensing of diaphragmatic potentials** infrequently results in shock delivery. In case of diaphragmatic potential sensing, setting the sensitivity level at the lowest level can be helpful but, as with T-wave oversensing, may compromise VF detection (and appropriate therapy delivery). Therefore, increasing the mandatory detection time seems to be more logical advice. If, despite reprogramming, the problem of oversensing diaphragmatic potentials is unsolvable, lead repositioning may be a reasonable alternative.

**Lead/device related problems** are frequent and may cause all kind of phenomena. Lead fracture or connector problems give rise to make-break contacts, leading to intermittent high frequency signals, sometimes associated with postural changes and limited to the sensing electrogram. Impedance may be within normal limits. Shocks may ensue, often multiple. Isolation defects may lead to oversensing of signals and inappropriate therapy.

All extracardiac sources of oversensing in pacing dependent patients lead to the additional problem of pacing inhibition. Special noise reduction modes implemented in modern devices are not always helpful in this respect.

In case of a pace/sense problem, implantation of an additional pace/sense lead may overcome these problems. In case of a structural problem of the lead, lead replacement may become necessary.

## How to reduce the number of appropriate shocks?

The delivery of appropriate shocks can, in the case of a VT, be reduced by programming antitachycardia pacing (ATP) modes in different zones. ATP has been shown to be very effective in terminating ventricular arrhythmias, even in the cases of high ventricular rates.[11 12] Empirical programming (for example, 8 pulses at 88% of the VT cycle length)

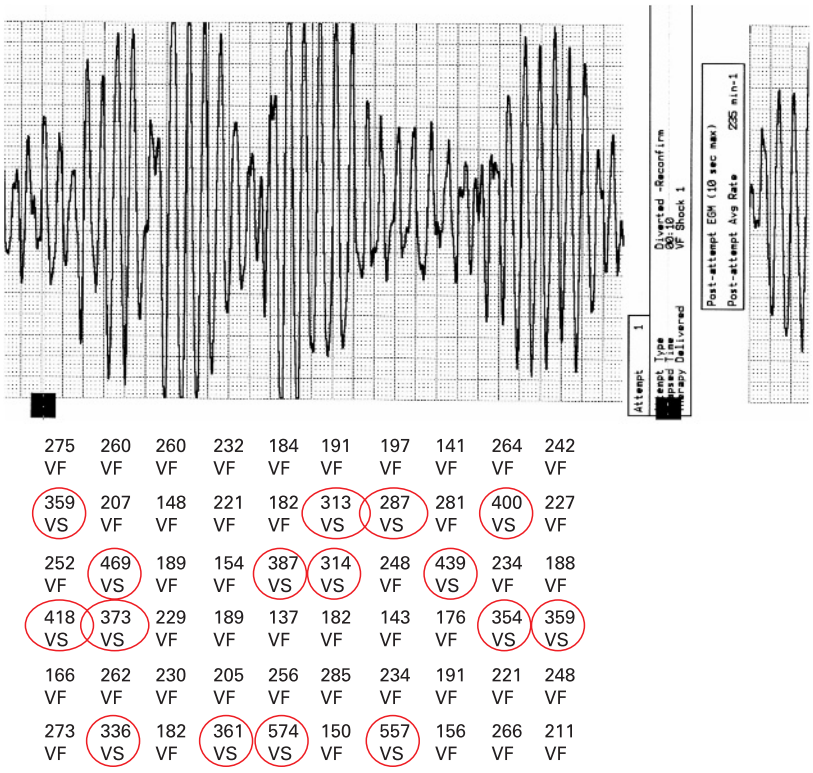



**Figure 6** Underdetection of polymorphic ventricular tachycardia due to rarely occurring rapid changes in intrinsic amplitude. The sensitivity level auto-adjusts but not fast enough, resulting in underdetection of intrinsic events; consequently intervals fall in a lower zone ("VS"). Thus, the device is not coming to detection and does not deliver therapy ("divert-reconfirm").

without tailoring of the ATP sequences has been shown to be safe and effective. Therefore, ATP should be programmed "on", even if its efficacy in the individual patient has not been assessed yet.

Further reduction of the number of shocks can be achieved by other measures.[13–15] β-blockers, sotalol and amiodarone and other antiarrhythmic drugs are usually helpful although side effects may limit their use. Azimilide was shown to be effective but is not clinically available yet.[16] In general, it is of course important that in ICD patients with a low left ventricular ejection fraction, other drugs such as angiotensin converting enzyme (ACE) inhibitors and diuretics are given.

In patients with recurrent VTs for which ICD therapy is delivered, radiofrequency catheter ablation may be an effective approach to reduce or abolish the number of VT episodes and ICD discharges acutely and in the long term. If refractory to other treatment options, surgical elimination of arrhythmogenic foci may be performed usually in combination with other operative goals such as revascularisation, surgical ventricular reconstruction and valvular repair.

### How to deal with multiple shocks?

The first objective in the management of a patient receiving multiple shocks is to avoid delivery of further shocks while conscious. Thus, depending on the haemodynamic and mental state of the patient, the heart rhythm and the cause of the shocks, sedation of the patient is usually helpful in achieving stress reduction.

If the patient's rhythm is supraventricular in origin, it is sound to switch the ICD off either by using a programmer or a magnet. The same holds true for all non-tachycardia causes of shocks. If necessary, while the ICD is switched off, shocks can still be delivered by the ICD using the emergency button present on the programmers of all manufacturers or by removing the magnet.

Management of the patient is more difficult when the patient's rhythm is ventricular in origin or when recurrent episodes of ventricular arrhythmias occur. The shocks are appropriate but at the same time a disruptive experience for the patient if conscious. In the acute situation, antiarrhythmic drug therapy can be effective, such as the intravenous administration of amiodarone or procainamide. β-blocker treatment has been shown to be valuable as well. When VTs still recur, (manual) overpacing may be helpful. Furthermore, suppression of VT can be achieved in some patients by increasing the lower rate of the pacemaker. Longer term management includes evaluation and treatment of the underlying cause, such as worsening heart failure symptoms or ischaemia or more general causes such as hyperthyroidism or a systemic infection.[14 17]

**Box 2: Events eliciting alerts in ICDs (list not complete)**

- Battery voltage low
- Prolonged charge time
- Magnet applied or in neighbourhood
- Ventricular fibrillation (VF) detection off
- VF therapy partially programmed
- Electrical reset of system
- Lead impedance out of range
  - pacing
  - high voltage
- Pacing programmed to fixed rate
- Intrathoracic impedance change

## DIZZINESS AND SYNCOPE

Dizziness is a well known, frequently occurring, symptom in patients with an impaired left ventricular function (as in the majority of ICD patients). Mild heart failure is associated with autonomic derangement, especially weakening of the arterial baroreflex sensitivity with permanent activation of the sympathetic nervous system. Dizziness is often distinct in these patients in whom the autonomic nervous system is further affected by heart failure medication. History taking is helpful in differentiating this form of dizziness from other causes for dizziness and syncope in ICD patients (box 1). To reveal a non-arrhythmogenic origin of dizziness or syncope, interrogation of the

device may be helpful as these symptoms may be caused by arrhythmias also. Dizziness or even syncope may also be caused by underdetection of ventricular arrhythmias. Underdetection may occur when there is a variation in cycle length during VT and the cycle length alternates around the cut-off rate of the detection zone (fig 5). This may be solved by lowering the cut-off rate. It may also be caused by a variation in amplitude of the intracardiac signals as may occur during a polymorphic VT or VF (fig 6). Committed shock delivery, still a feature in modern ICDs, may be used to solve this issue. Adjustment of the sensitivity level or shortening of the detection time, if possible, may also be helpful to solve these problems.

Another reason for dizziness may be the occurrence of non-sustained VTs that do produce symptoms but do not continue long enough to meet the programmed detection criteria of the device. In the case of non-sustained VT, antiarrhythmic drugs may help to lower the number of episodes.

Whereas the aforementioned arrhythmias will be apparent at interrogation of the device, a VT with a cycle length below the cut-off rate, unless ongoing during clinical evaluation, is less easily detectable since the detection criteria have not been met and no episodes will be stored. However, clues hidden in the Cardiac flash back (Medtronic) or the Trending (Boston Scientific) (fig 4) help to reveal the arrhythmia. Such relatively slow VTs particularly occur in patients with jeopardised myocardium using amiodarone to treat faster ventricular arrhythmias. Although in general these problems can be solved by lowering the cut-off rate, in cases of extremely slow ventricular arrhythmias reprogramming is often not possible due to overlap with brady pacing settings or because the lowest programmable cut-off rate is reached (Boston Scientific 90 beats/min, Medtronic and Biotronik 100 beats/min, St Jude 102 beats/min). In that case additional antiarrhythmic drugs or ablation may be reasonable alternatives.

Rapidly conducted but well-discriminated atrial arrhythmias may cause dizziness as well, particularly in patients with reduced left ventricular ejection fraction. Drug therapy or His bundle ablation may resolve this issue.

Dizziness or even syncope may also occur in the ICD patient who is pacemaker dependent when the pacemaker is erroneously inhibited. Treatment is guided by the cause of inhibition (see sections above).

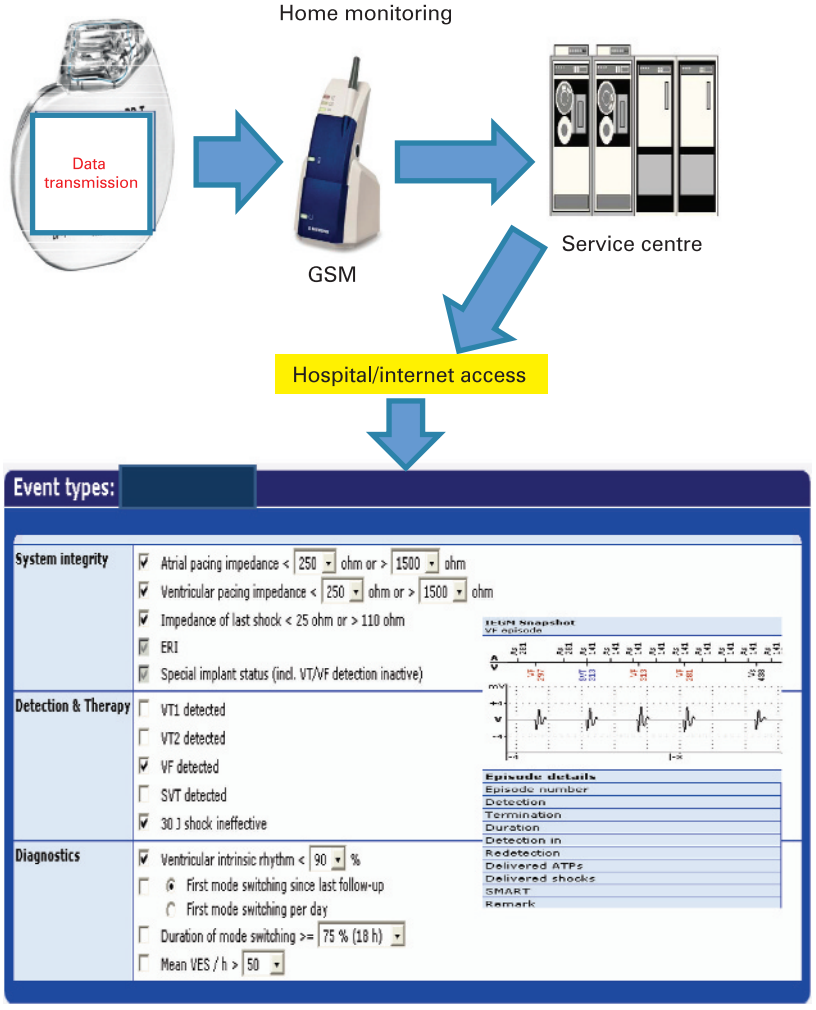



**Figure 7** Example of a telemonitoring system (Homemonitoring, Biotronik). The unit transmits data to a receiver which sends the data to a service centre (through the GSM network). From the service centre, alerts (in the case of preprogrammed deviations (device or arrhythmias)) are sent to the treating physician who can access the data through the internet. GSM, global system for mobile communications.

## PALPITATIONS

Although patients do not usually present complaining of palpitations in an emergency setting (like those with shocks, dizziness and/or syncope), palpitations are a frequent complaint at regular ICD follow-up. Palpitations can be due to several reasons, overlapping with those causing dizziness or syncope (box 1). ICD interrogation will give more insight into the underlying cause since it may reveal the occurrence of irregular or fast atrial arrhythmias, ventricular extrasystole or non-sustained VTs. Sustained VTs with a cycle length below the cut-off rate are especially difficult to diagnose when the VT is not ongoing during follow-up. The already mentioned Trending feature (Boston Scientific) may be helpful in revealing the arrhythmia. The Flashback memory (Medtronic) stores the egrams preceding an episode or preceding interrogation. If history is pointing in this direction, the monitor zone can be adjusted to store these arrhythmias. Particularly patients with single chamber ICDs may complain of palpitations at rest, at times keeping them from their sleep, caused by lower rate pacing. Decreasing the lower rate of the pacemaker or lowering the β-blocker dosage may resolve these complaints.

## Troubleshooting ICD related problems: key points

- Implantable cardioverter-defibrillator (ICD) troubleshooting starts when a patient presents with a possible device related problem or when technical follow-up reveals a possible problem. ICD troubleshooting should be performed in a structured manner following interrogation of the device and examining the patient. Important issues include:
  - complaints of patient related to device activity?
  - device activity: arrhythmia related or caused by malfunction of device, or lead (or both) or related to an external source?
  - device activity: caused by supraventricular or ventricular arrhythmia?
  - device activity: appropriate or inappropriate?
  - device activity: adjustment of settings necessary?
- Patients with an ICD related problem present with complaints which generally fall into one of the following four categories:
  - shocks (appropriate, inappropriate or failure to deliver therapy)
  - dizziness/fainting
  - palpitations
  - alerts (audible beeps or sensed vibrations originating from the ICD)

### ALERTS

Most ICDs have alerts that notify the patient of undesired settings or electrical events of the ICD and/or leads.[18–20] Recently, Medtronic has introduced a diagnostic feature intended to predict a forthcoming episode of heart failure (box 2).[21 22] The alerts produce audible signals (Medtronic, Boston Scientific) or a vibrational sensation (St Jude). Alerts are repetitive, discontinuous signals that can be programmed to a specified time. Most alerts are programmable (on/off), except "system alerts" that convey debilitated functioning with respect to proper treatment of tachycardia. The system alerts the patient with the intention that he/she should contact the physician in case the programmed parameters are undesirable or the measured parameters are not within normal limits. The time and character of the alerts and interval between alerts inform the physician or technician about its cause, without interrogation of the device. Instruction may be helpful and relatively easy. Although the alerting systems have been shown to be valuable in many cases, the sensitivity is limited.[20] Furthermore, the alerts have an underestimated distressing effect on patients, who generally feel well at the moment of the alert and do not anticipate being alerted. Instruction does not eliminate all of the confusion and inconvenience coinciding with an alert. Thus, efforts should be made to avoid false negative alerts, and when programming the alerts it is important to be aware of this effect and ensure the patient is well informed.

Presently, remote monitoring systems are becoming available for evaluation of ICD/lead systems which may replace the necessity of alerts in the future. Monitoring systems allow system integrity checks, usually on a daily basis. Furthermore, these systems allow continuous following of the clinical status of the patient which may help (in the near future) to prevent deterioration of the clinical status by timely interventions. In fig 7, a schematic example of one of these systems (Home-monitoring, Biotronik, Erlangen, Germany) is given. At this time all telemonitoring systems provide a one way dataflow (from patient to the hospital) and it is not possible to program devices using the telemonitoring system.

### PATIENTS WITH A DEVICE OR LEAD UNDER "RECALL"

In recent years a significant number of so-called "dear doctor" letters concerning a possible device or lead malfunction have been issued by almost all device companies. To handle such a situation (depending on the seriousness of the warning) may be a challenging task as, although these letters describe a potentially dangerous situation, the resulting advice to the clinician is not always straightforward. In the recent past this has resulted in large numbers of devices being replaced worldwide, whereas (in retrospect) it may have been sufficient to intensify follow-up; such large scale replacements may even have caused serious complications.[23]

To help the clinician, among others, the Heart Rhythm Society (HRS) and the European Heart Rhythm Association (EHRA) installed device committees which should issue a clinical advice in case of a device recall.

In general, to deal with such a situation a few things are important for every implanting centre:

- Keep track of the device patients implanted at the centre. An up-to-date patient database will ensure patients involved in a recall are informed quickly. Furthermore an up-to-date database will make it easy to follow the performance of implanted devices and leads. Preferably a nationwide database should be available.

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- Follow the initial guidance of the company and adjust according to the final guidance by HRS or EHRA.
- If a patient with a device or lead under recall presents with problems (for example, shocks) investigate if the problem is related to the recall.
- In the case of an unexpected death of a patient, try to retrieve information from the device to establish the cause of death.
- Inform the company that a device or lead related problem occurred. This is the only way to obtain a reliable picture.

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