I filtri: istruzioni per l'uso corretto

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OSPEDALE SAN CARLO BORROMEO AZIENDA OSPEDALIERA

Sistema Sanitario Regione Lombardia


CARDIOLINE


PHILIPS

Il filtro


BIT
NOISE FILTER
CN1-F60
2×3300 pF(Y)
0.1 µF(×2)MKT - P
2×2.1mH
-25/+55°C/HPF
250V~6A 50/60Hz
T.V. 1500V~1MIN.
MADE IN KOREA
0301 1703
LR65729
565-3

I Filtri

- **L’ECG è la registrazione, nel tempo, dell’attività elettrica del cuore.**
- **La sequenza cardiaca ha una natura elettrica ed è possibile misurare questa azione elettro-chimica direttamente sulla superficie corporea (visto che il corpo è conduttivo).**
- **Durante la propagazione dell’impulso nelle diverse parti del cuore, i fenomeni di depolarizzazione e ripolarizzazione generano campi elettrici che si estendono alla superficie del corpo.**

I filtri

- **Le variazioni istantanee di grandezza e direzione di questi campi elettrici si rispecchiano in variazioni delle differenze di potenziale, che possono essere misurate tra punti diversi della superficie corporea.**
- **Un potenziale elettrico all’incirca di 1mV si sviluppa tra diversi punti della superficie corporea, ed è possibile misurarlo posizionando degli elettrodi direttamente a contatto con la pelle**

I filtri: problemi tecnici

- **Correnti a livello dell'interfaccia elettrodo esplorante/cute, corrente di alimentazione, correnti del sistema di amplificazione del segnale**
- **Una regola fondamentale nella misurazione è non permettere che uno strumento di misura influenzi il segnale sotto osservazione. Un amplificatore dovrebbe esibire un'alta impedenza di ingresso per far si che non vengano attenuati i segnali fisiologici che si stanno misurando.**
- **Nel caso del segnale elettrocardiografico, l'elettrodo stesso dell'ECG ha una bassa impedenza, ma l'impedenza della pelle, può variare da 100Ω ad 1 MΩ. Le correnti d'ingresso dell'amplificatore generano potenziali ai capi dell'impedenza della pelle, che sono amplificate dal guadagno dell'amplificatore, causando elevati offset in DC nell'uscita dell'amplificatore.**

I filtri: problemi tecnici

- Il problema diventa grave quando i biopotenziali, che vogliamo monitorare, hanno un'energia utile che assume valori in un intervallo di 50/60 Hz.
- Rumore e deriva.

Sono i segnali indesiderati che contaminano le misurazioni fisiologiche, il rumore prodotto all'interno della circuiteria dell'amplificatore è di solito definito, come quel segnale con componenti al di sopra di 0,1 Hz, mentre deriva si riferisce alle variazioni della linea di base (baseline) al di sotto di 0.1 Hz

I filtri

- **La larghezza di banda di un amplificatore fisiologico dovrebbe essere in grado di amplificare correttamente tutte le frequenze significative nel segnale, mentre dovrebbe reiettare quei segnali fuori dalla banda d’interesse.**
- **La larghezza di banda è definita come la differenza tra la frequenza di taglio inferiore e la frequenza di taglio superiore.**

I filtri

Grandezze tipiche ECG

Amplificazione di un fattore all'incirca 1000 (60db) solo nella banda utile (il segnale originale ECG è dell'ordine di circa 1-5 mV)

- Per il monitoraggio freq. comprese 0.05 – 50 Hz
- Per la diagnostica freq. fino al 1KHz

Alta impedenza d'ingresso per evitare che l'impedenza incognita dell'elettrodo possa creare una partizione del segnale, attenuandolo

Deve reiettare un forte disturbo della rete (50Hz) di ampiezza paragonabile al segnale (filtro Notch)

A norma di legge la corrente che circola sul paziente deve essere inferiore a 10µA (correnti superiori aumentano l'incidenza di Fibrillazione)

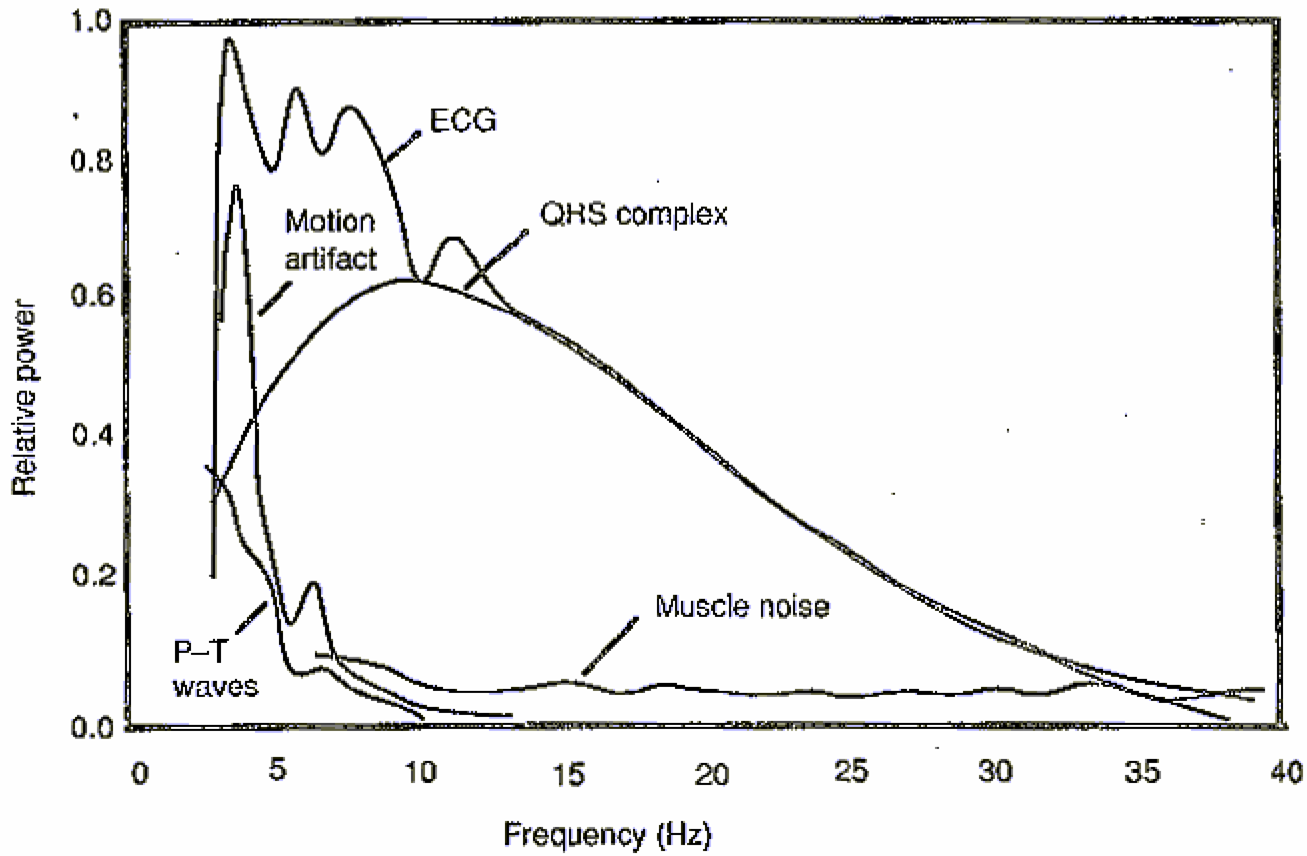
I filtri

- **il QRS ha un contenuto in freq. più alto (picco 10-15 Hz) rispetto alle onde P e T (4-5 Hz)**
- **artefatti da movimento (contatti elettrodi) sono a bassa frequenza**
- **Molti segnali dell'attività fisiologica hanno ampiezze piccole e devono essere amplificati e processati prima che possano essere considerati in maniera significativa con l'utilizzo di amplificatori biopotenziali**

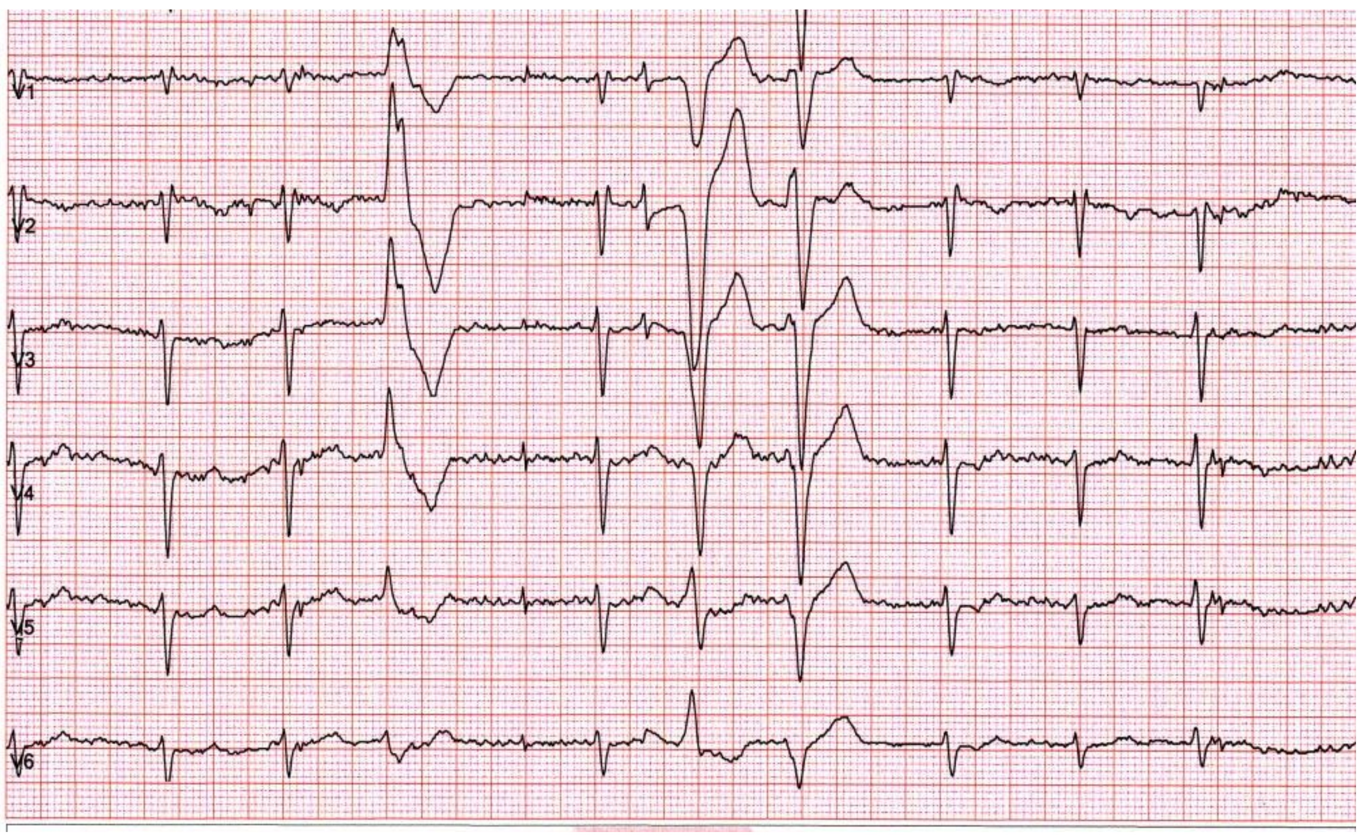
I filtri: problemi tecnici

- Il complesso QRS può oscillare tra 400µV a 2,5mV, e richiede un guadagno in tensione che va da 100 a 1000. La banda dell'ECG è stata standardizzata per rendere uniforme l'interpretazione dei risultati. Vengono usati due filtri con banda a -3 dB (guadagno), un filtro passa alto a 0.05 Hz e un filtro passa basso a 150 Hz. Risposta in frequenza
- Ci sono molti altri potenziali che sono inavvertitamente amplificati usando elettrodi per monitorare l'ECG. La potenza condotta produce un alto livello di interferenze elettromagnetiche (EM), che devono essere accuratamente eliminate. Il corpo umano è una buona antenna
- Altre fonti di radiazioni EM sono le stazioni radio, cellulari, telefoni portatili, sorgenti a microonde, computer.

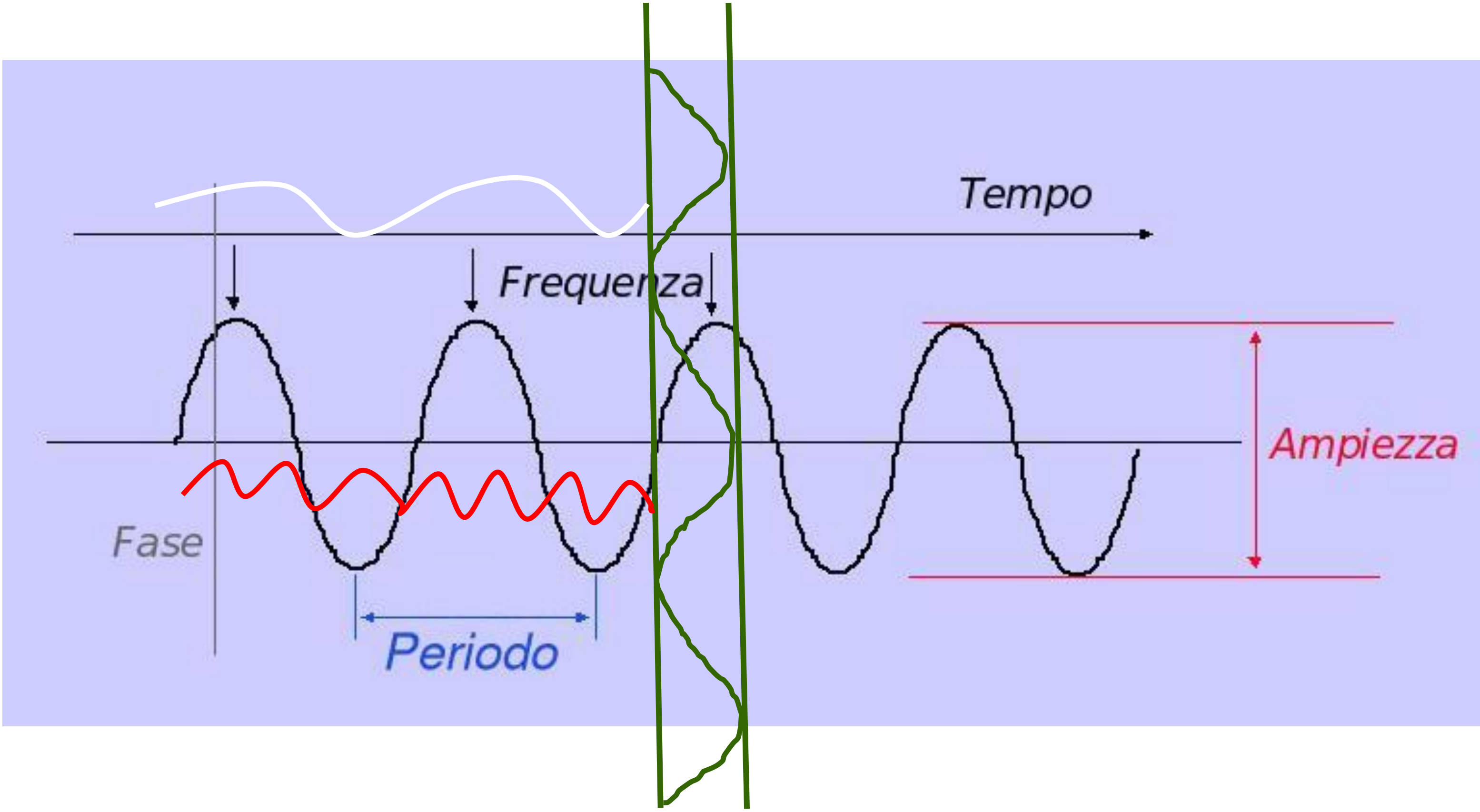
I filtri



ECG
QRS complex
Motion artifact
P–T waves
Muscle noise
Relative power
Frequency (Hz)
1.0
0.8
0.6
0.4
0.2
0.0
0
5
10
15
20
25
30
35
40

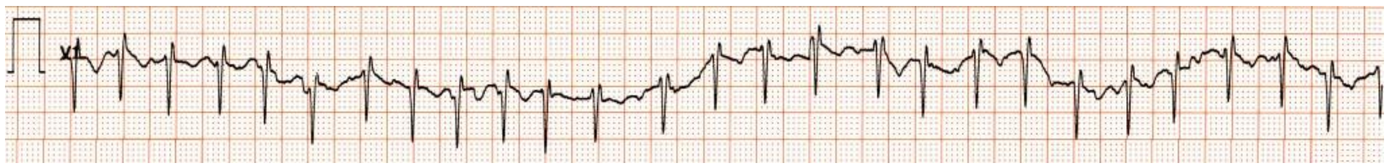

V1
V2
V3
V4
V5
V6

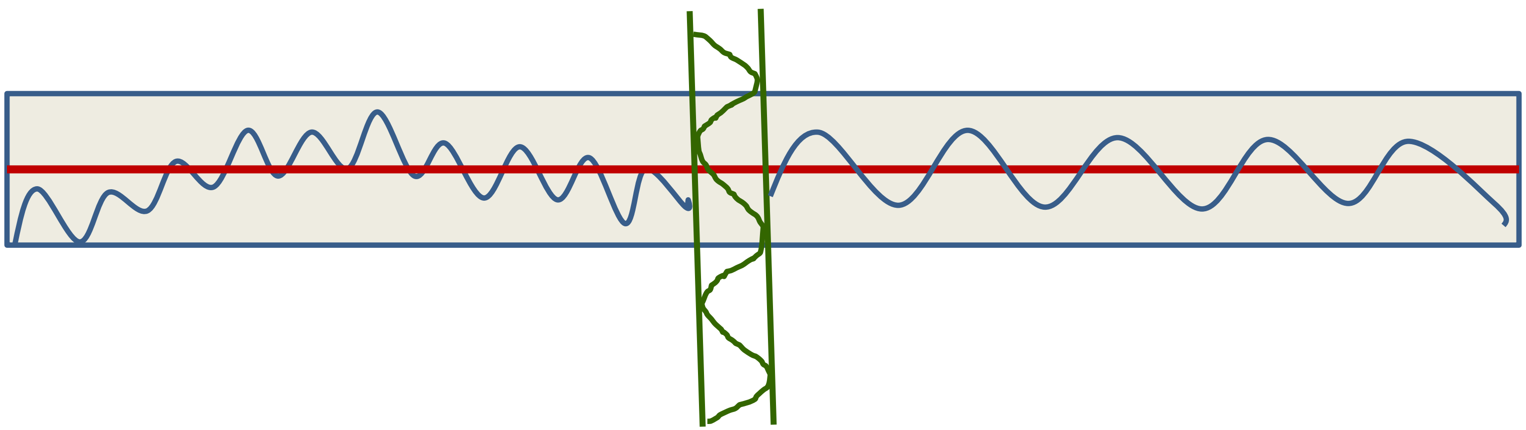
Perché Il filtro



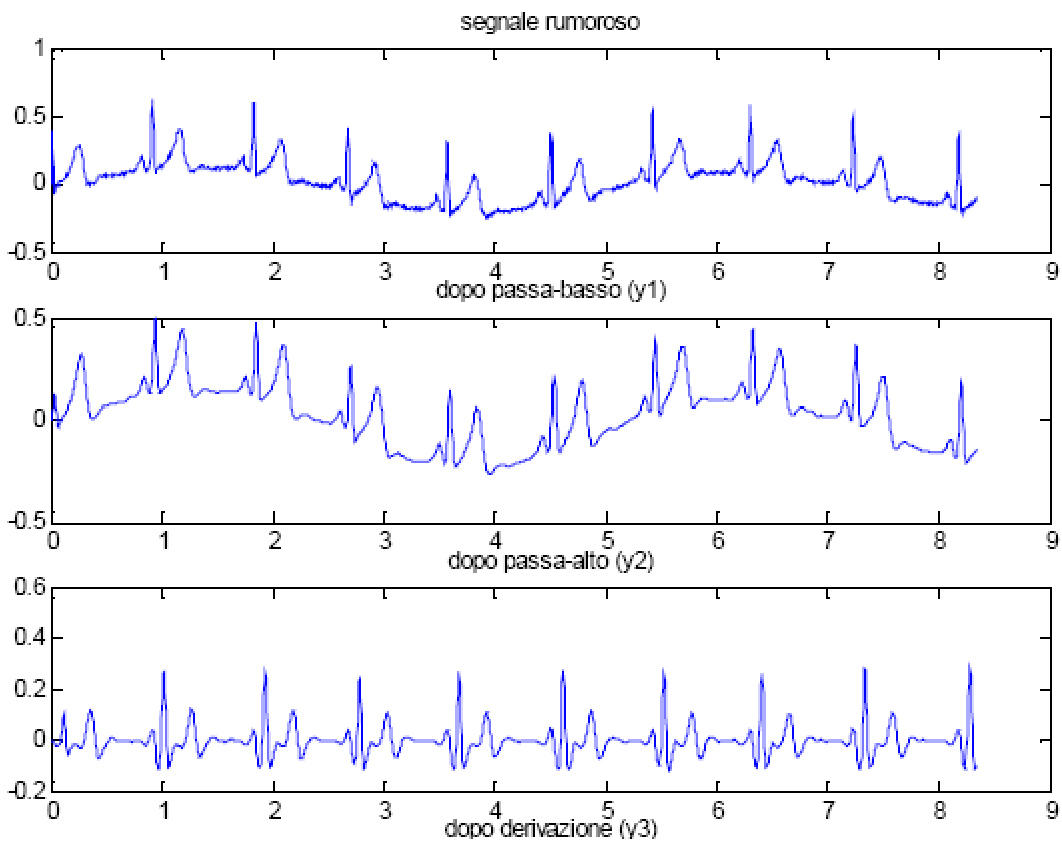
L'elettrocardiografo è in grado di registrare tutte le correnti generate alla superficie del corpo, non solo quella dell'attività elettrica del cuore

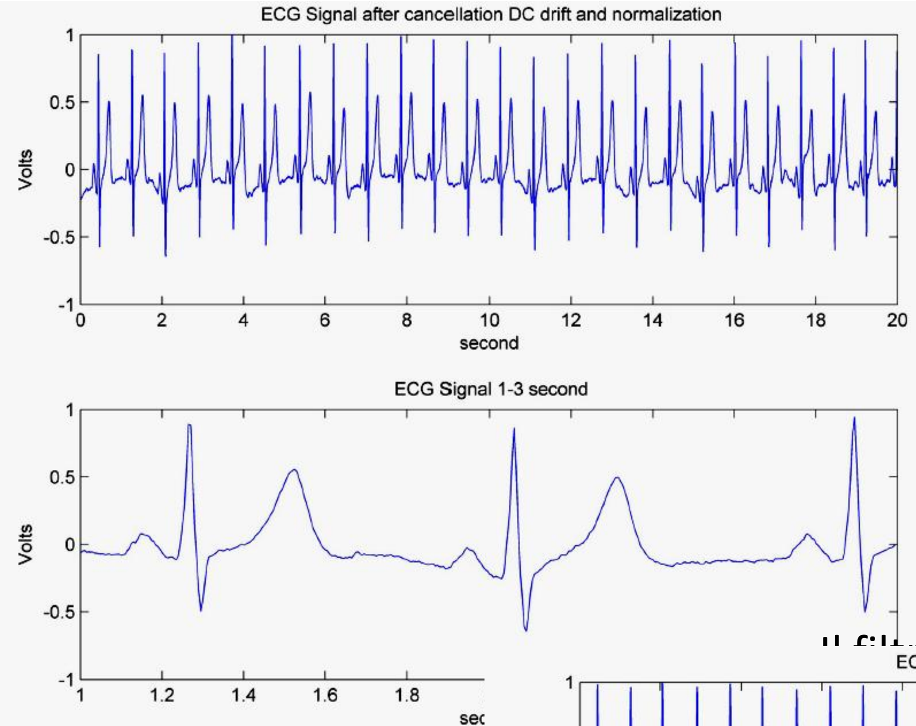
Perché Il filtro

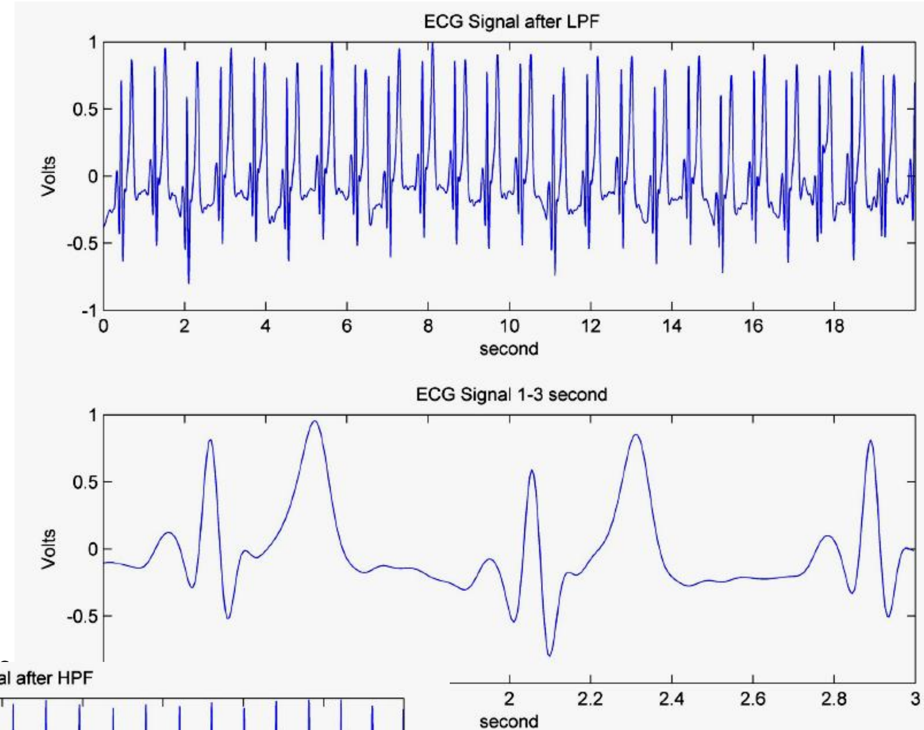


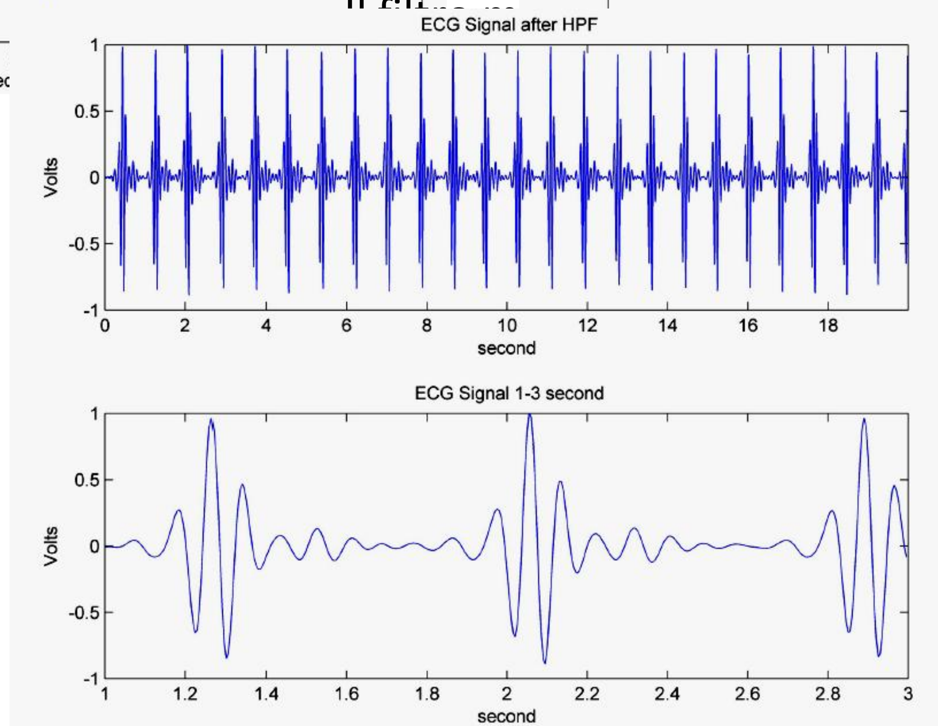


L'elettrocardiografo è in grado di registrare anche le oscillazioni rispetto alla linea di base legate alla instabilità del segnale (wandering, tipicamente legato al respiro)


segnale rumoroso
dopo passa-basso (y1)
dopo passa-alto (y2)
dopo derivazione (y3)
1
0.5
0
-0.5
0.6
0.4
0.2
-0.2
0 1 2 3 4 5 6 7 8 9


ECG Signal after cancellation DC drift and normalization
Volts
second
ECG Signal 1-3 second
Volts


ECG Signal after LPF
Volts
second
ECG Signal 1-3 second
Volts
second


ECG Signal after HPF
Volts
second
ECG Signal 1-3 second
Volts
second

Prevalence and Clinical Implications of Improper Filter Settings in Routine Electrocardiography

Only 25% of ECGs (65 of 256) conformed to recommended standards; 75% of ECGs (191 of 254) did not.
The most prevalent deviation from standard was reduced high-frequency cutoff, which was present in 96% of tracings with nonstandard bandwidth (most commonly 40 Hz).
Increased low-frequency cutoff was present in 62% of ECGs in which it was documented

Am J Cardiol 2007;99:711–713

Recommendations for the Standardization and Interpretation of the Electrocardiogram

Part I: The Electrocardiogram and Its Technology

A Scientific Statement From the American Heart Association Electrocardiography and Arrhythmias Committee, Council on Clinical Cardiology; the American College of Cardiology Foundation; and the Heart Rhythm Society

Endorsed by the International Society for Computerized Electrocardiology

This statement examines the relation of the resting ECG to its technology. Its purpose is to foster understanding of how the modern ECG is derived and displayed and to establish standards that will improve the accuracy and usefulness of the ECG in practice. Derivation of representative waveforms and measurements based on global intervals are described. Special emphasis is placed on digital signal acquisition and computer-based signal processing, which provide automated measurements that lead to computer-generated diagnostic statements. Lead placement, recording methods, and waveform presentation are reviewed. Throughout the statement, recommendations for ECG standards are placed in context of the clinical implications of evolving ECG technology.

Circulation 2007;115:1306-1324;

Recommendations for the Standardization and Interpretation……………

- The fundamental frequency for the QRS complex at the body surface is ≈10 Hz, and most of the diagnostic information is contained below 100 Hz in adults, although low-amplitude, high-frequency components as high as 500 Hz have been detected and studied.
- The QRS of infants often contains important components as high as 250 Hz. The fundamental frequency of T waves is approximately 1 to 2Hz.

Recommendations for the Standardization and Interpretation……………

- **Filtering of the ECG signal to within the band between 1 to 30 Hz produces a stable ECG that is generally free of artifact, but this bandwidth is unacceptable for diagnostic recording because it produces distortions of both high- and low-frequency components of the signal.**

- **The high-frequency components of the ECG signal define the most rapidly changing parts of the signal, including Q waves and notched components within the QRS complex. Because QRS amplitude measurement depends on accurate detection of the peak of an R wave, an inadequate high-frequency response results in systematic underestimation of signal amplitude and in smoothing of notches and Q waves.**

I filtri: problemi tecnici

Low-Frequency Filtering

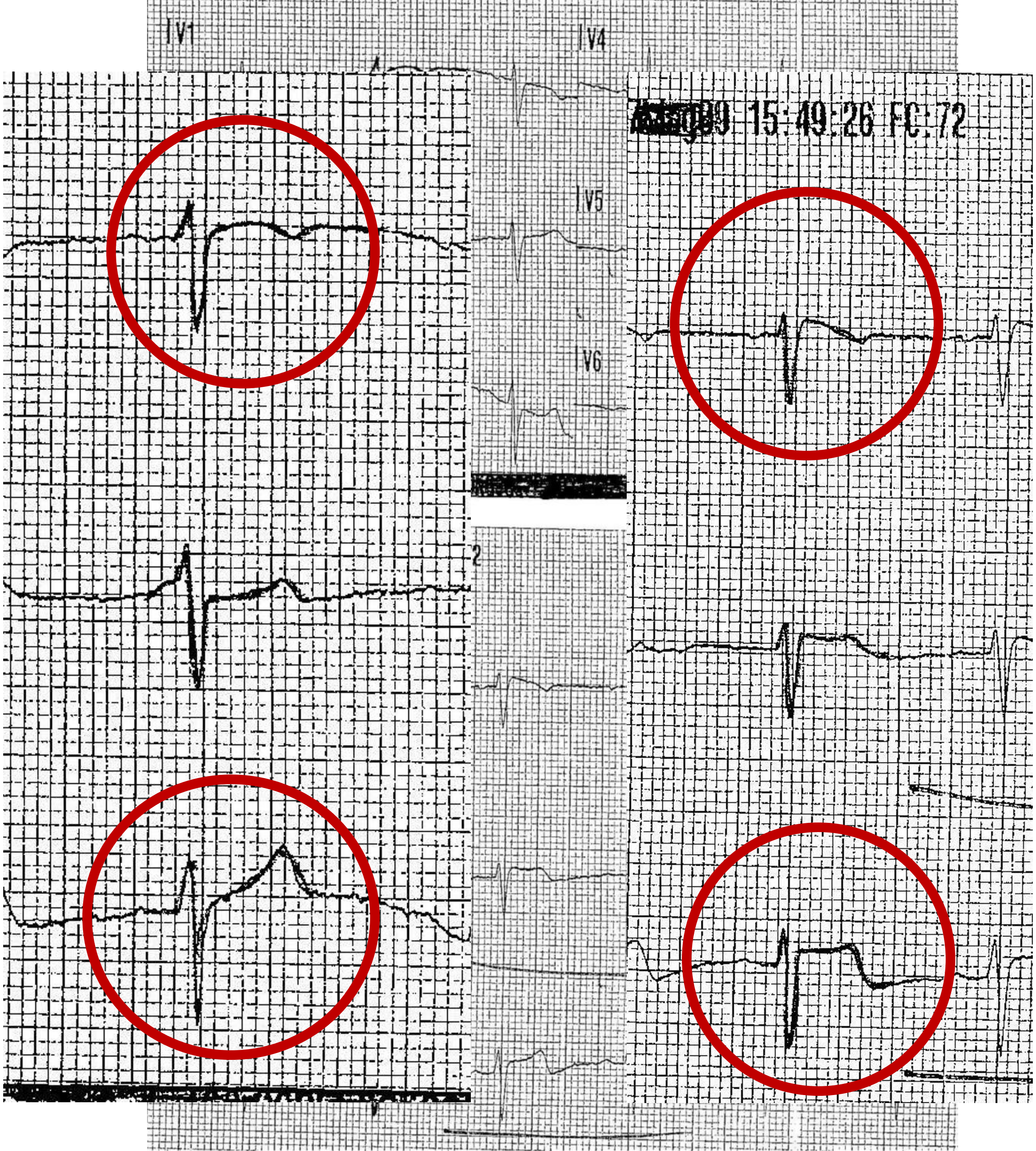
The heart rate, in beats (cycles) per minute (bpm), when divided by 60 (seconds per minute) forms a lower bound for the frequency content in Hertz (Hz, cycles per second) In practice, this is unlikely to be lower than 0.5 Hz, which corresponds to a heart rate of 30 bpm; heart rates below 40 bpm (0.67 Hz) are uncommon in practice. However, with traditional analog filtering, a 0.5-Hz low-frequency cutoff introduces considerable distortion into the ECG, particularly with respect to the level of the ST segment

I filtri: problemi tecnici

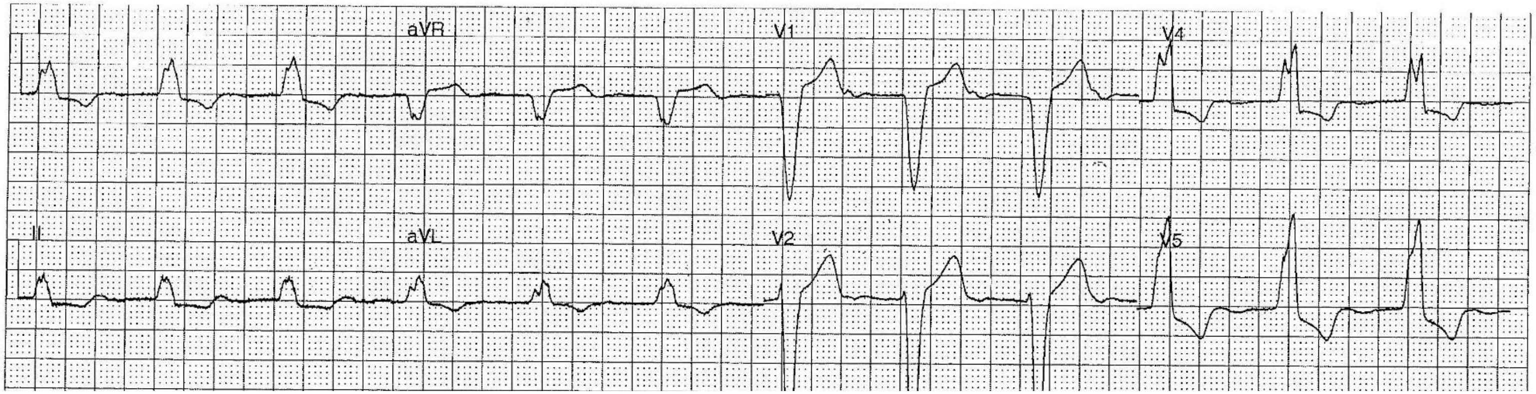
- **This distortion results from phase nonlinearities that occur in areas of the ECG signal where frequency content and wave amplitude change abruptly, as occurs where the end of the QRS complex meets the ST segment. Digital filtering provides methods for increasing the low-frequency cutoff without the introduction of phase distortion.**

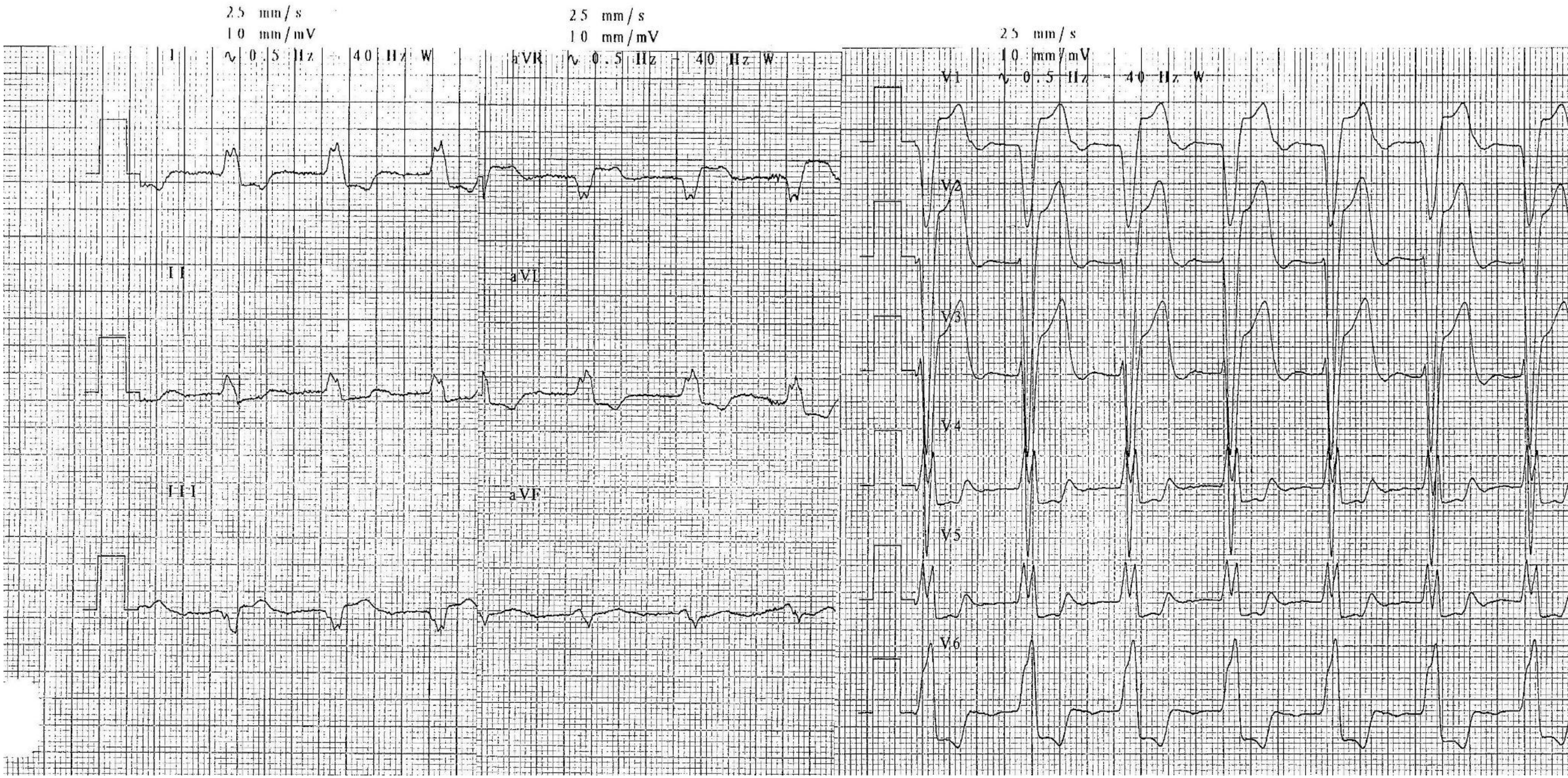
Recommendations for the Standardization and Interpretation…………..

- **On the other hand, an inadequate low-frequency response can result in important distortions of repolarization. Accordingly, the transfer functions of the filtering algorithms of analog and digital electrocardiographs have a major effect on the resulting ECG.**
- **the digital ECG must eliminate or suppress low-frequency noise that results from baseline wander, movement, and respiration and higher-frequency noise that results from muscle artifact and power-line or radiated electromagnetic interference**

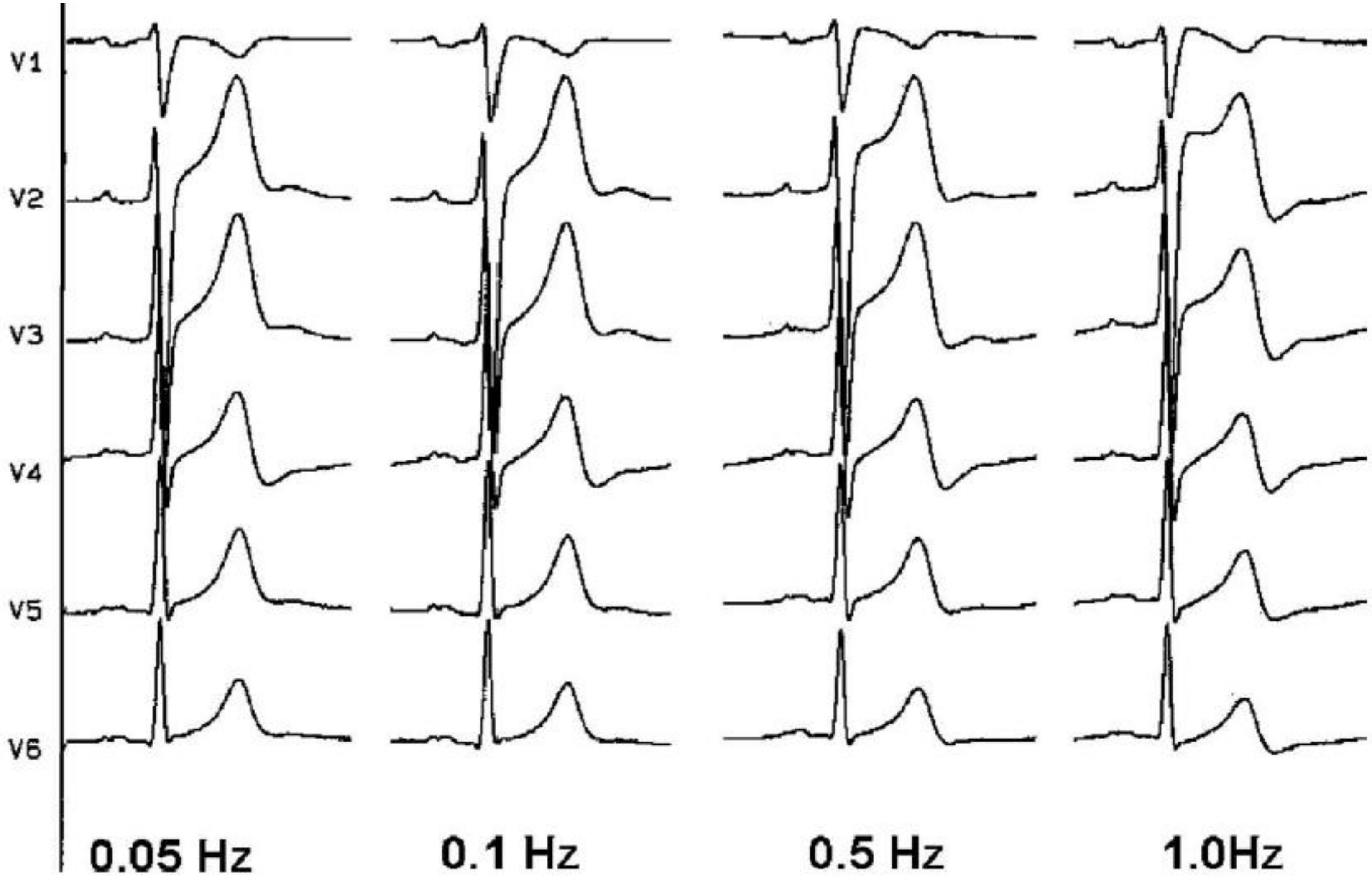

V1
V4
V5
V6
15:49:26 FC:72
2

Inform./Tecnico:





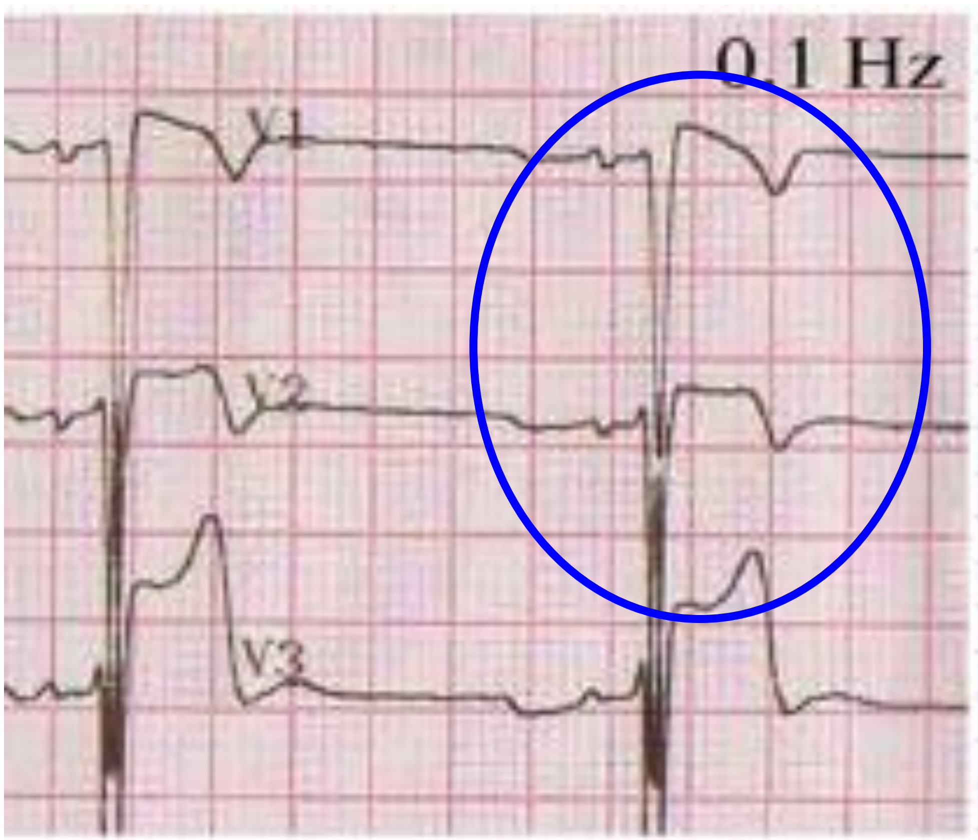
Simulation of anteroseptal myocardial infarction by electrocardiographic filters



Journal of Electrocardiology 39 (2006) 253– 258

Brugada electrocardiographic pattern: Reality or fiction?

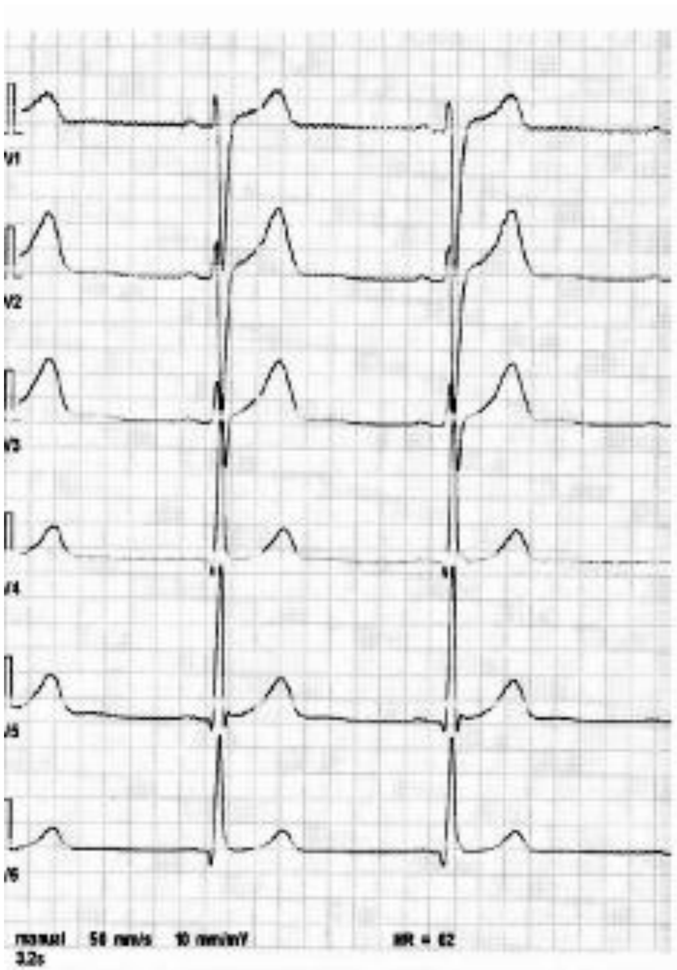
Javier García-Niebla, RN,[a,*] Guillem Serra-Autonell, MD,[b]
Miquel Fiol, MD, PhD,[c] Antonio Bayés de Luna, MD, PhD[d]

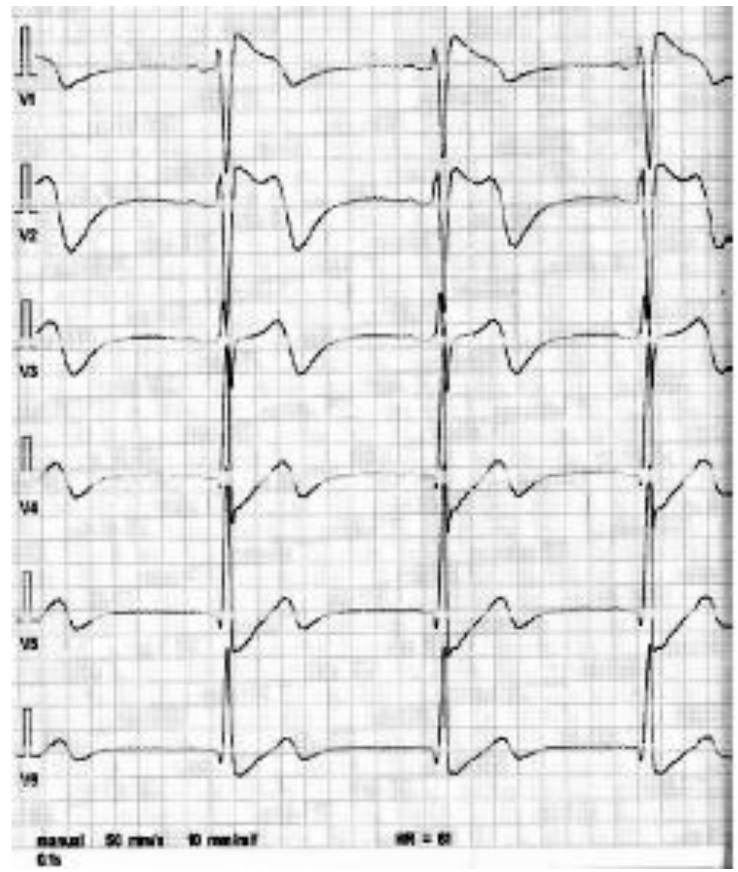


Journal of Electrocardiology 2014; 47:362

Nieprawidłowe ustawienie filtrów czy zespół Brugadów?

Abnormal filter setting or Brugada syndrome?





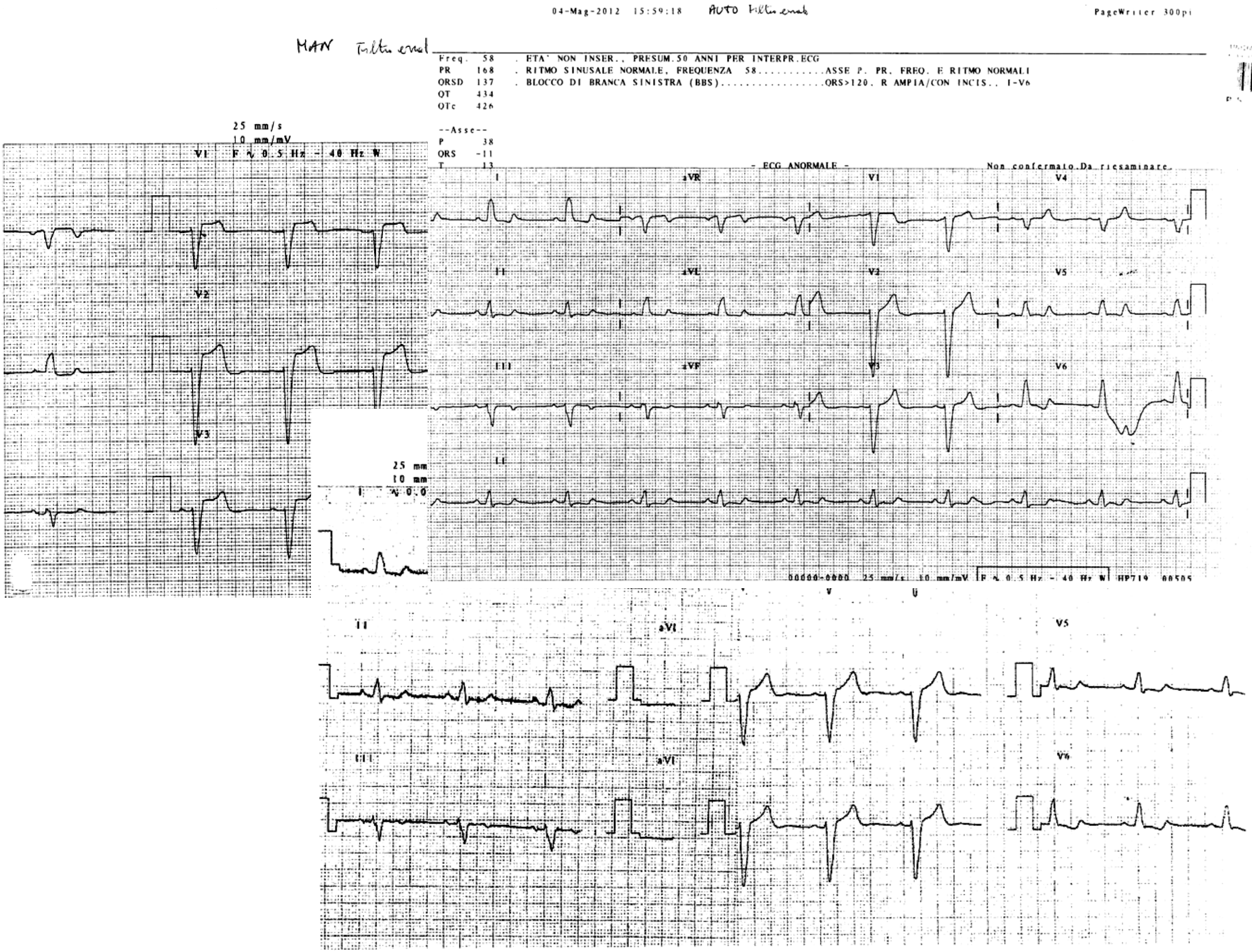
Kardiologia Polska 2013; 71, 11: 1192

I filtri: problemi tecnici

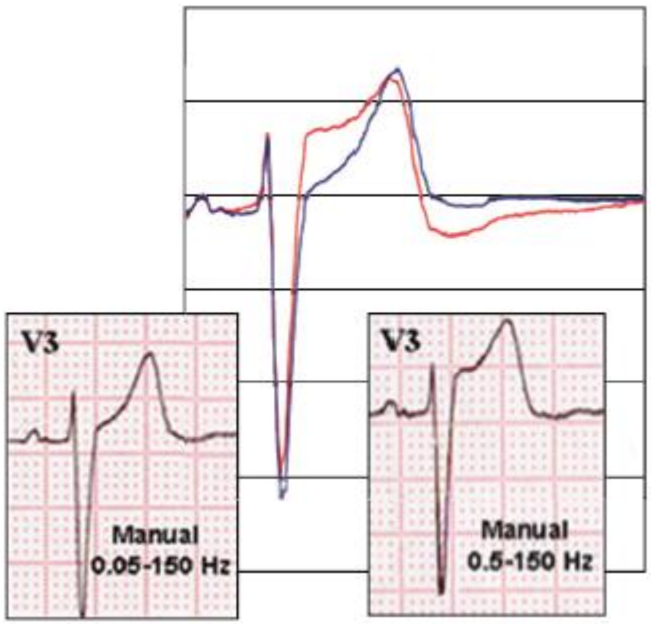
- **This distortion results from phase nonlinearities that occur in areas of the ECG signal where frequency content and wave amplitude change abruptly, as occurs where the end of the QRS complex meets the ST segment. Digital filtering provides methods for increasing the low-frequency cutoff without the introduction of phase distortion.**

I filtri: problemi tecnici

- **This can be accomplished with a bidirectional filter by a second filtering pass that is applied in reverse time, that is, from the end of the T wave to the onset of the P wave.**
- **This approach can be applied to ECG signals that are stored in computer memory, but it is not possible to achieve continuous real-time monitoring without a time lag.**


04-Mag-2012 15:59:18
AUTO Filtro
PageWriter 300pi
MAN Filtro
Freq. 58
PR 168
QRSD 137
QT 434
QTc 426
--Asse--
P 38
QRS -11
T 13
. ETA' NON INSER., PRESUM.50 ANNI PER INTERPR.ECG
. RITMO SINUSALE NORMALE, FREQUENZA 58..........ASSE P. PR. FREQ. E RITMO NORMALI
. BLOCCO DI BRANCA SINISTRA (BBS)................QRS>120. R AMPIA/CON INCIS., I-V6
- ECG ANORMALE -
Non confermato.Da riesaminare.
25 mm/s
10 mm/mV
F ~ 0.5 Hz - 40 Hz W
I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
00000-0000 25 mm/s 10 mm/mV F ~ 0.5 Hz - 40 Hz W HP719 00505

High-Bandpass Filters in Electrocardiography: Source of Error in the Interpretation of the ST Segment



International Scholarly Research Network
ISRN Cardiology
Volume 2012, Article ID 706217, 10 pages
doi:10.5402/2012/706217

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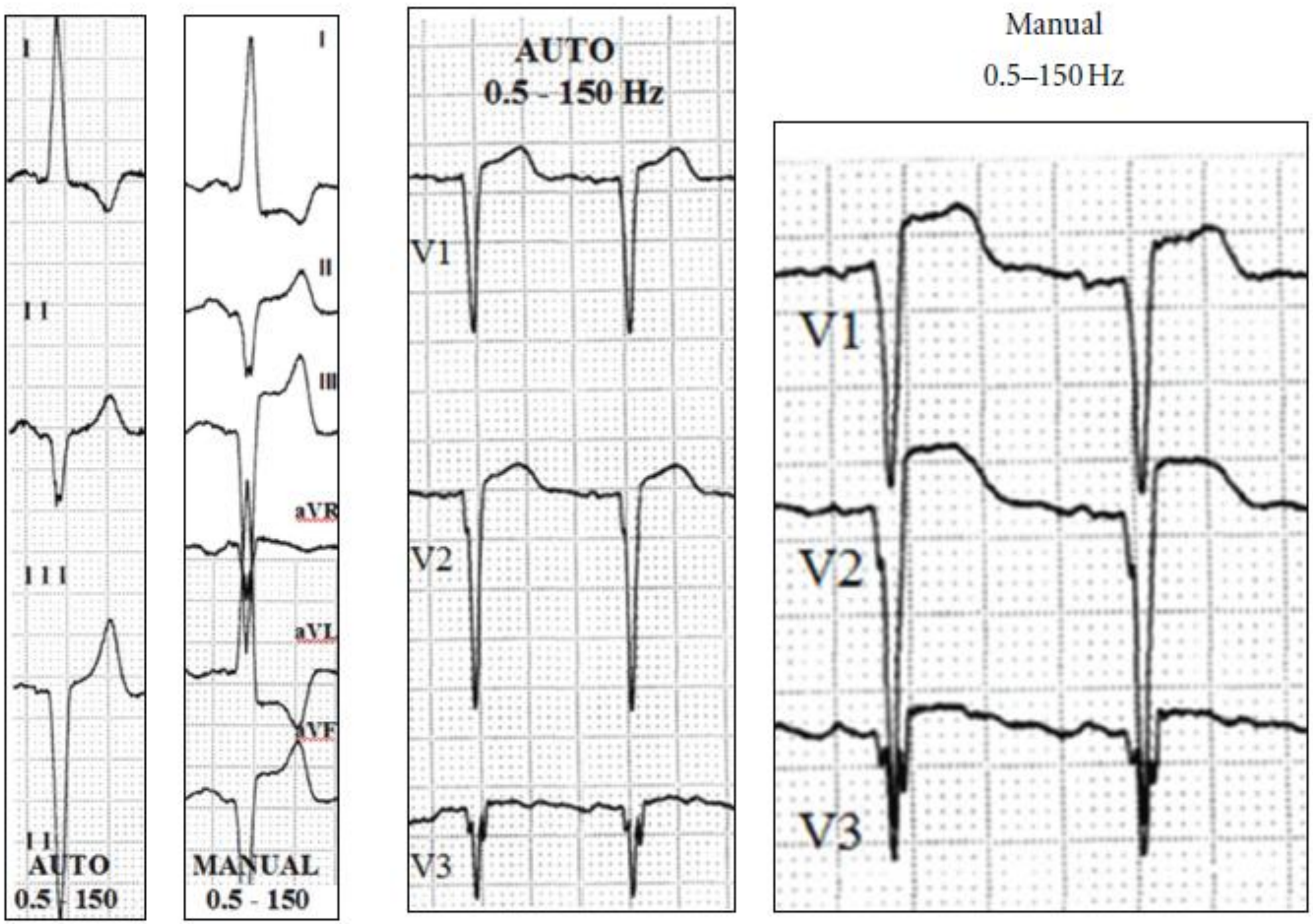

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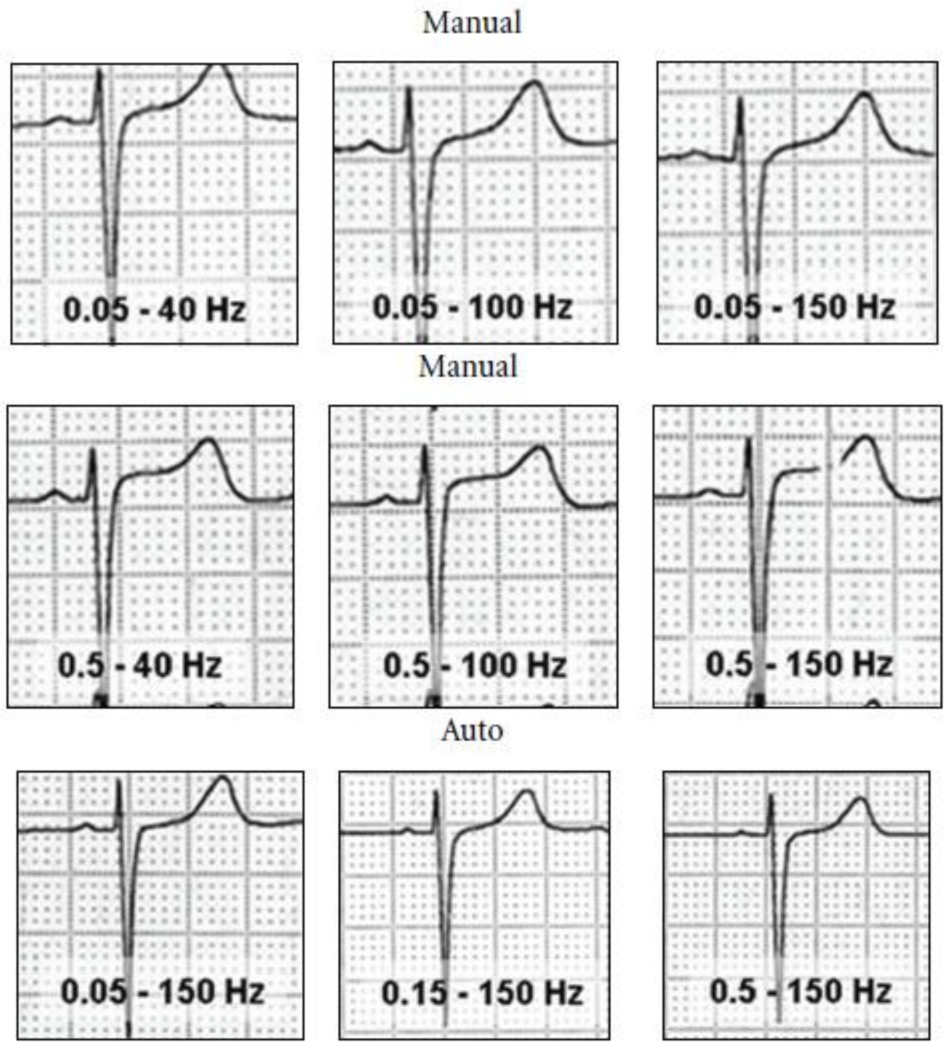
High-Bandpass Filters in Electrocardiography: Source of Error in the Interpretation of the ST Segment



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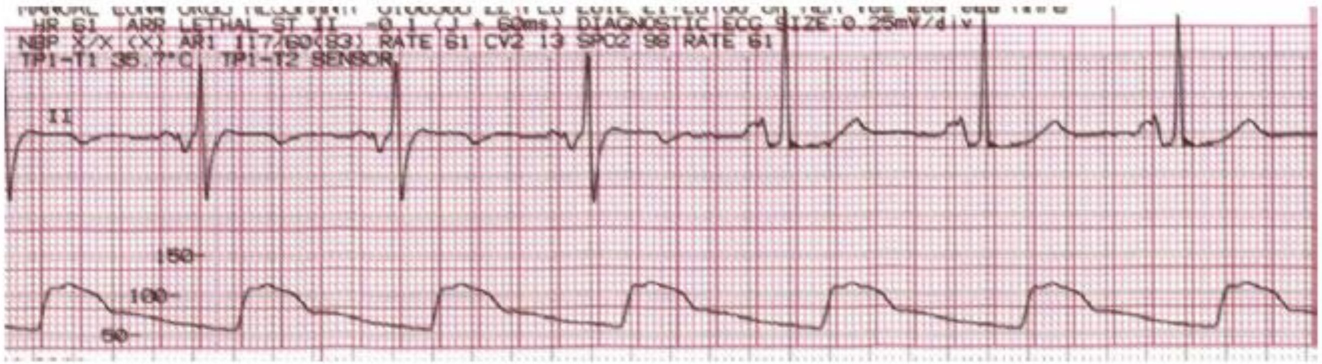
doi:10.5402/2012/706217

I Filtri

- **Low-frequency noise, such as that produced by respiration, causes the tracing to wander above and below the baseline. A low-frequency cutoff at 0.5 Hz, which was once widely used in ECG rhythm monitors, reduces baseline drift due to the generally lower frequency of respiratory motion but can result in marked distortion of repolarization that may produce artifactual ST-segment deviation.**

Reflections on an Electrocardiogram: Inverted T Waves



J Cardiothor Vasc Anesth, 2013;27:819-820

Recommendations for the Standardization and Interpretation……………

High-Frequency Filtering

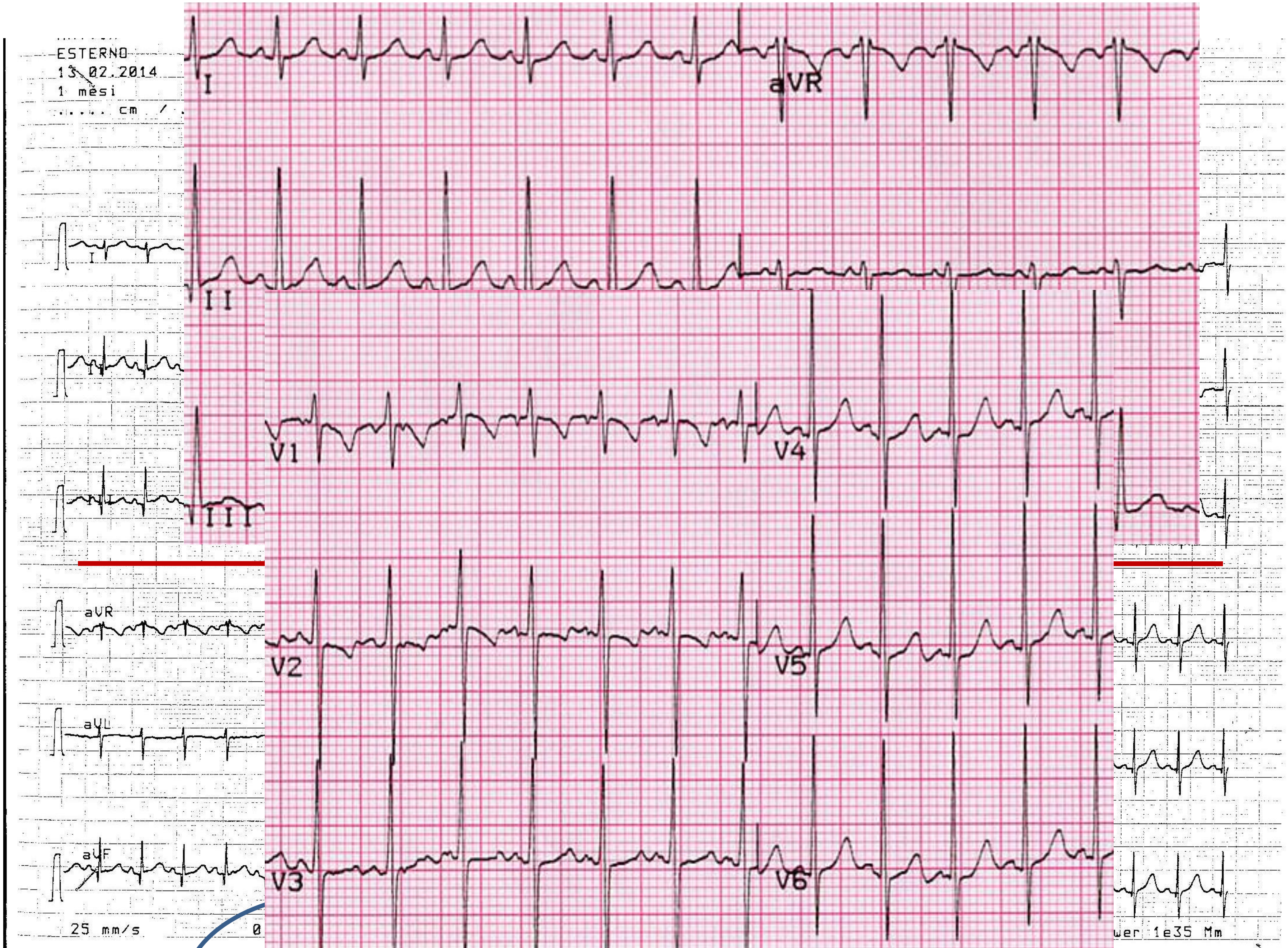
digital sampling must be performed at twice the rate of the desired high-frequency cutoff.

Because this theorem is valid only for an infinite sampling interval, the 1990 AHA report recommended sampling rates at 2 or 3 times the theoretical minimum.

Data at 500 samples per second are needed to allow the 150 Hz high-frequency digital filter cutoff that is required to reduce amplitude error measurements to circa 1% in adults

Recommendations for the Standardization and Interpretation……………

- The higher the frequencies contained in the filtered signal, the more accurate will be the measurement of rapid upstroke velocity, peak amplitude, and waves of small duration.
- Inadequate high-frequency response reduces the amplitude of QRS measurements and the ability to detect small deflections.
- A high-frequency cutoff of 100 Hz was considered adequate by the AHA in 1975 to maintain diagnostic accuracy during visual inspection of direct-writing tracings by electrocardiographers.



ESTERNO
13.02.2014
1 mesi
I
aVR
II
III
V1
V2
V3
V4
V5
V6
aVL
aVF
25 mm/s

0.05 -35 Hz

Recommendations for the Standardization and Interpretation……………

- An obvious consequence of these high-frequency recommendations is that reduction of noise by setting the high-frequency cutoff of a standard or monitoring ECG to 40 Hz will **invalidate any amplitude measurements used for diagnostic classification.**
- The standard of 1991, reaffirmed in 2001, recommended a high-frequency cutoff of at least 150 Hz for all standard 12-lead ECGs

Table 1 ECG Criteria

Model (Ref. #)	Criteria	
Sokolow-Lyon voltage (17)	$SV_1 + RV_5/V_6 \geq 3.5$ mV and/or $RaVL \geq 1.1$ mV	
Sex-specific Cornell voltage (18)	$SV_3 + RaVL > 2.8$ mV (for men) and > 2.0 mV (for women)	
Romhilt-Estes point score (19)	Diagnostic ≥ 5 points and probable ≥ 4 points	
	Criteria	**Points**
	Voltage criteria	
	R or S wave in limb leads ≥ 20 mm	3
	S wave in V_1 or V_2 ≥ 30 mm	3
	R wave in V_5 or V_6 ≥ 30 mm	3
	ST-T wave abnormality	
	ST-T vector opposite to QRS complex without digitalis	3
	ST-T vector opposite to QRS complex with digitalis	1
	Negative terminal P mode in V_1 1 mm in depth and 0.04 s in duration	3
	Left axis deviation	2
	QRS duration ≥ 0.09 s	1
	Delayed intrinsicoid deflection in V_5 or V_6 (>0.05 s)	1
Perugia score (20)	Positivity of ≥ 1 of the following 3 criteria: $SV_3 + RaVL > 2.4$ mV (men) or > 2.0 mV (women), left ventricular strain, or Romhilt-Estes score ≥ 5	
Perugia 2 score (21)	Positivity of ≥ 1 of the following 2 criteria: $SV_3 + RaVL > 2.4$ mV (men) or > 2.0 mV (women), or left ventricular strain	
Minnesota code 3.1 (22)	$RV_5/V_6 > 2.6$ mV or $RI/II/III/aVF > 2$ mV or $RaVL > 1.2$ mV	
Lewis index (23)	$[(RI + SIII) - (RIII + SI)] > 1.7$ mV	
Framingham-adjusted Cornell voltage (24)	men: $[RaVL + SV_3 + 0.0174 \times (age - 49) + 0.191 \times (BMI - 26.5)] \geq 2.8$ mV; women: $[RaVL + SV_3 + 0.0387 \times (age - 50) + 0.212 \times (BMI - 24.9)] \geq 2.0$ mV	
Cornell voltage product (25)	$([RaVL + SV_3] \times \text{QRS duration}) \geq 243{,}600$ µVms	
Sokolow-Lyon voltage product (25)	$(SV_1 + RV_5/RV_6) \times \text{QRS duration} \geq 371{,}000$ µVms	
Gubner and Ungerleider voltage (26)	$RI + SIII \geq 2.2$ mV	

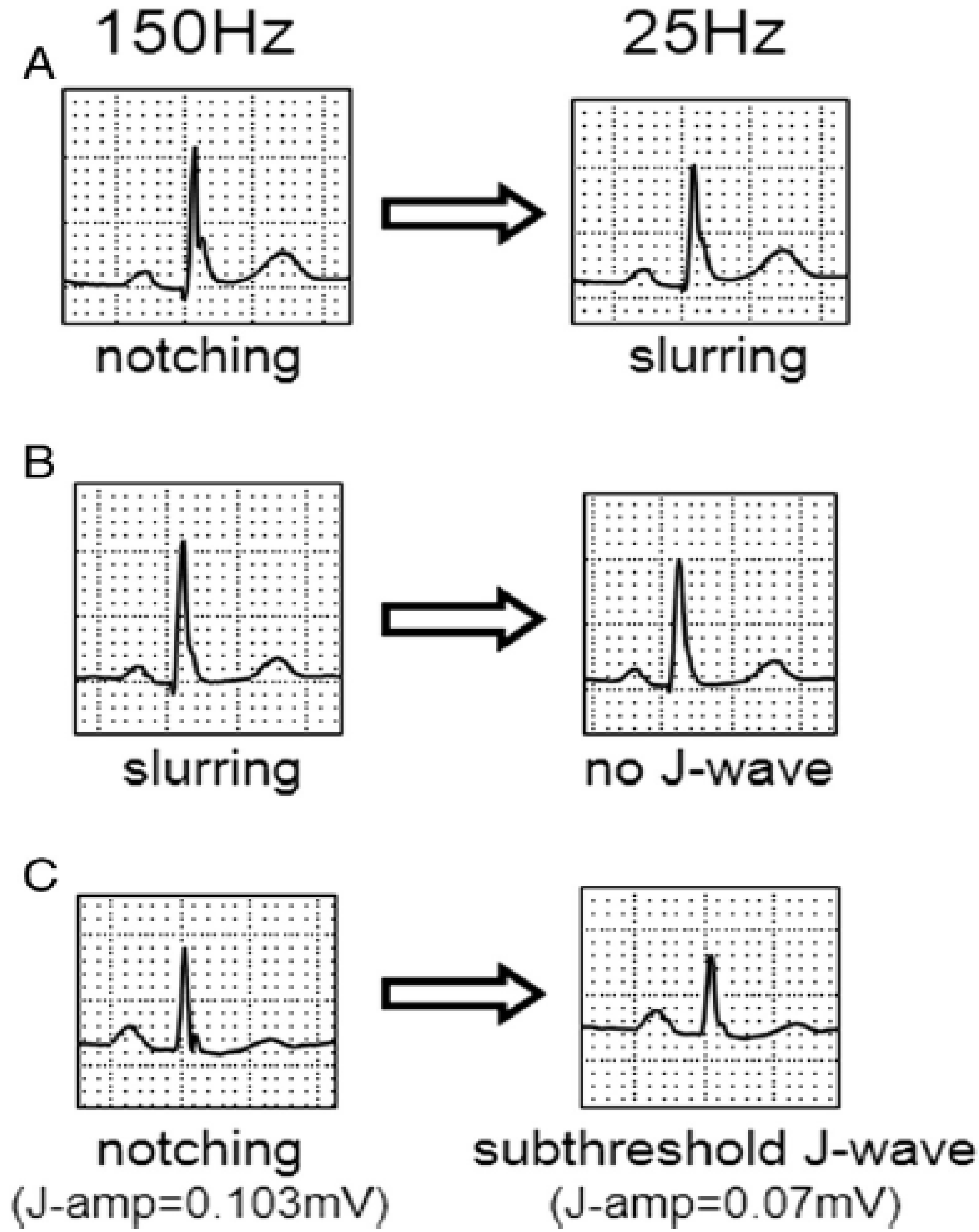
Recommendations for the Standardization and Interpretation……………

- Greater bandwidth may be required for accurate determination of amplitudes in infants.
- The European CSE group recommended that waveforms should be recognized if they have amplitudes of at least 20μV and durations of at least 6 ms.
- This implies a high-frequency response in the range of 150 Hz. A 2001 Dutch report showed that in order to keep amplitude errors ≈25 μV in >95% of the cases, a bandwidth up to 250 Hz is needed for pediatric cases and up to 150 Hz for adolescents

Recommendations for the Standardization and Interpretation……………

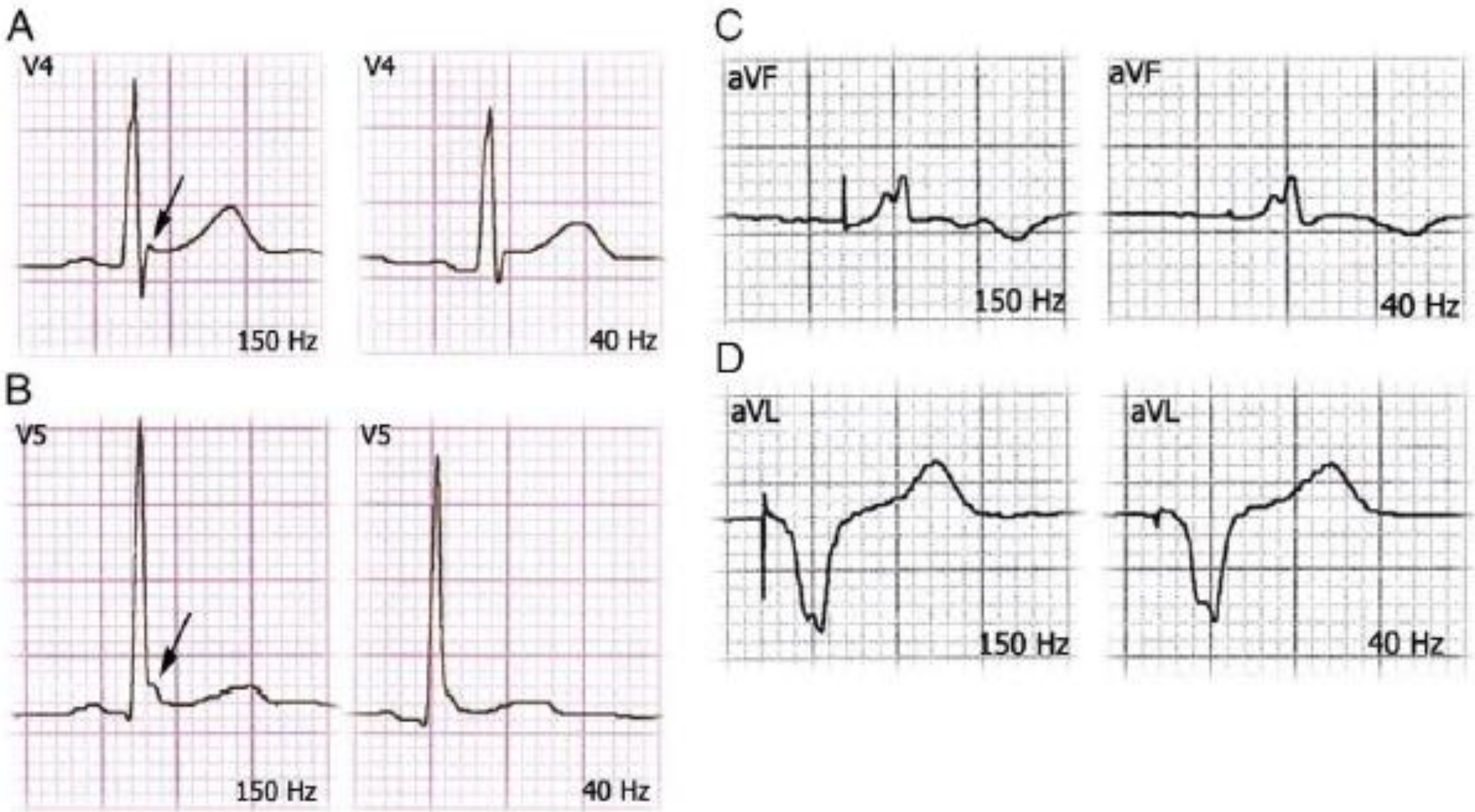
- Even so, it has long been recognized that higher-frequency components of the QRS complex are present and that these components may have clinical significance in patients with various forms of heart disease.
- To measure routine durations and amplitudes accurately in adults, adolescents, and children, an upper frequency cutoff of at least 150 Hz is required; an upper frequency cutoff of 250 Hz is more appropriate for infants

Effect of ECG filter settings on J-waves



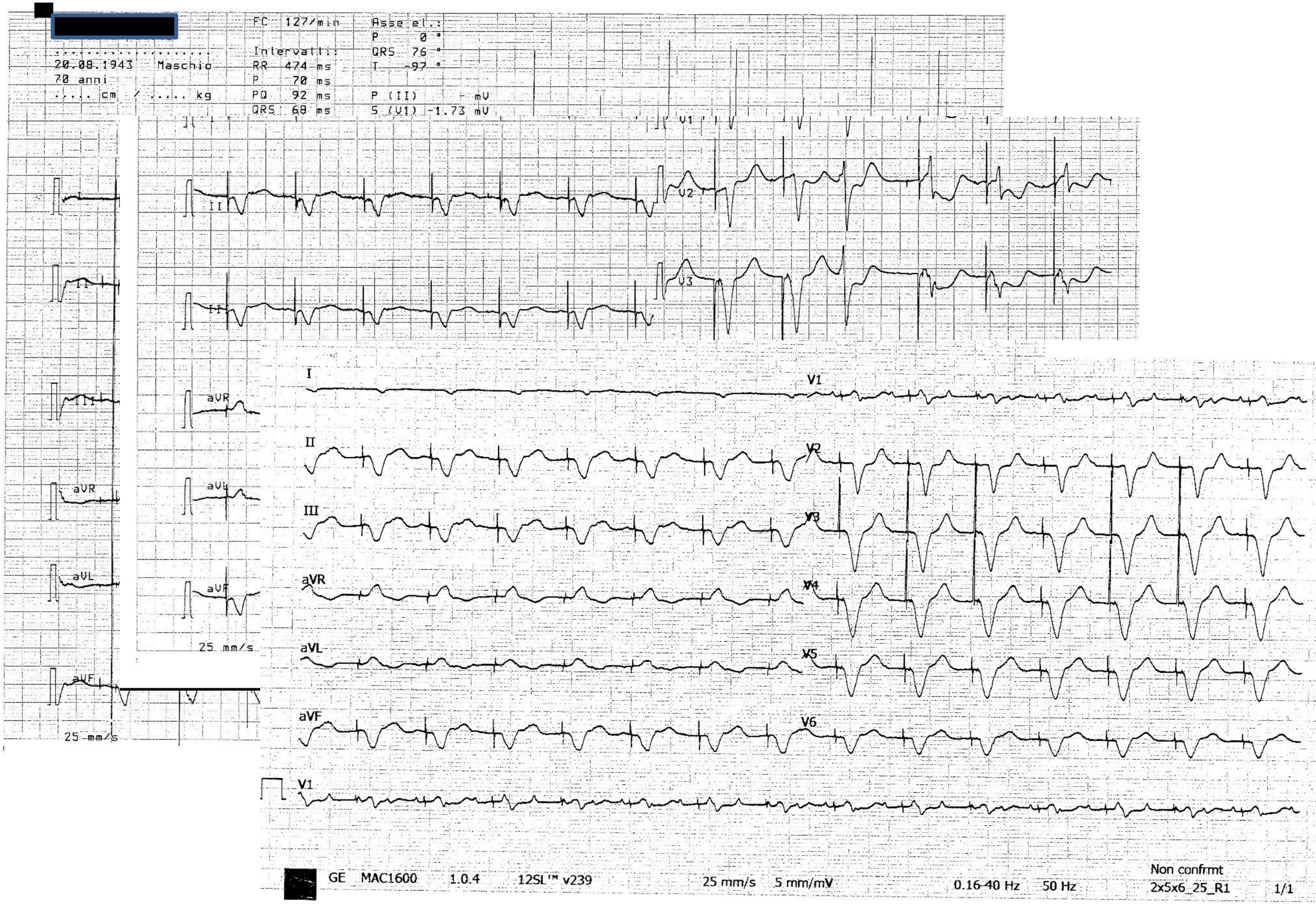
Journal of Electrocardiology 47 (2014) 7–11

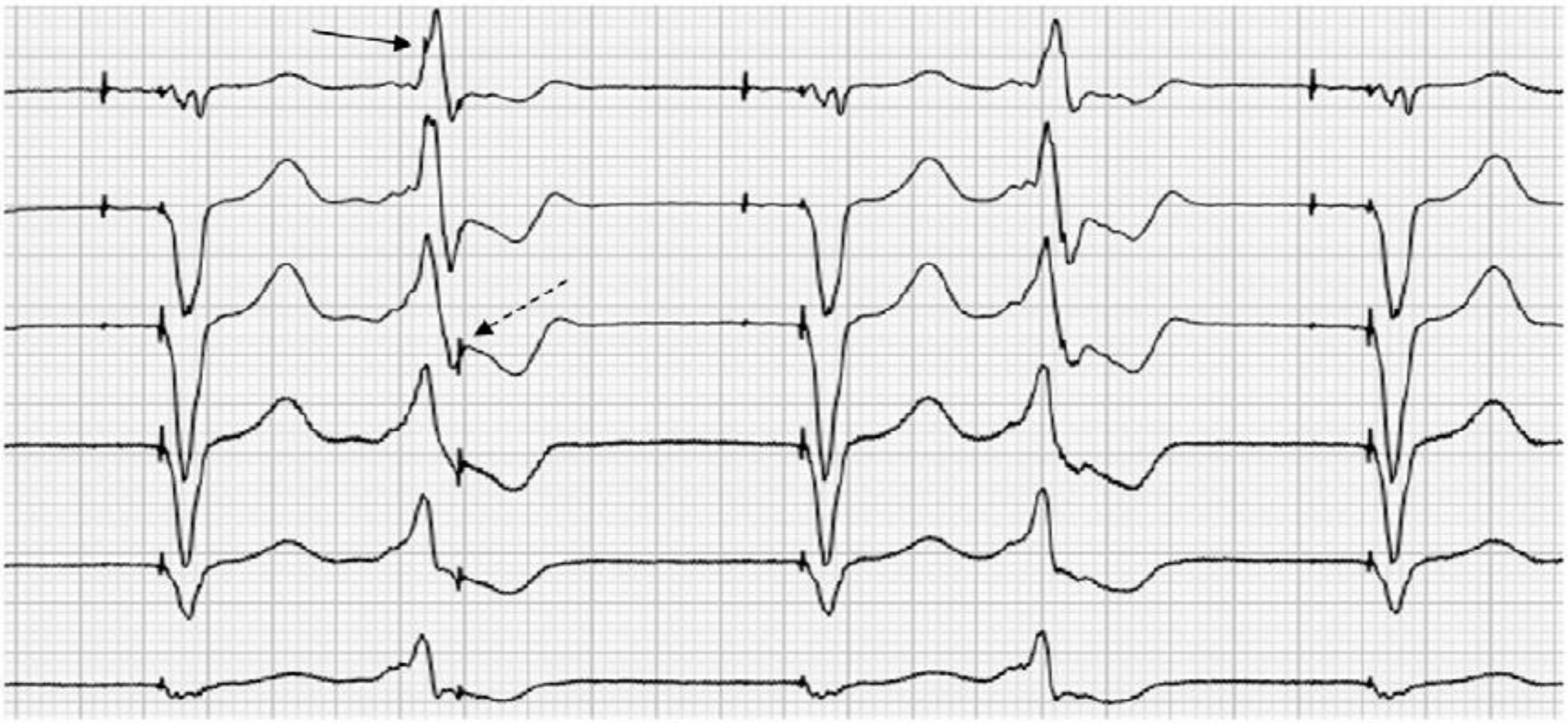
Effects of inadequate low-pass filter application



Journal of Electrocardiology 42 (2009) 303–304

- Oversampling was originally introduced to detect and represent pacemaker stimulus outputs, which are generally circa 0.5 ms in duration. Front-end sampling has been performed at rates from 1000 to 2000 per second, but newer converterscan routinely sample at 10 000 to 15 000 per second or even higher;


[redacted]
FC 127/min
Asse el.:
P 0 °
QRS 76 °
T -97 °
Intervalli:
20.08.1943 Maschio
RR 474 ms
70 anni
P 70 ms
..... cm / ..... kg
PQ 92 ms
P (II) - mV
QRS 68 ms
S (V1) -1.73 mV
I
II
III
aVR
aVL
aVF
V1
V2
V3
V4
V5
V6
25 mm/s
GE MAC1600 1.0.4 12SL™ v239
25 mm/s 5 mm/mV
0.16-40 Hz 50 Hz
Non confrmt
2x5x6_25_R1
1/1



Impact of Pacing and High-Pass Filter Settings on Ventricular Bipolar Electrograms in Implantable Cardioverter Defibrillator Systems

– Implication of Predictors for Inappropriate Therapy Caused by Oversensing of Repolarization Electrograms –

The R wave amplitude during DDD was significantly lower as compared to that during the other conditions in all high-pass filter settings.

The existence of Brugada syndrome and T/R ratio during the AAI with a high-pass filter setting of 10/20 Hz was an excellent predictor of T wave oversensing in the follow-up period.

DDD had a significant impact on the R wave amplitude reduction and the T/R ratio during AAI can be predictors of T wave oversensing. These findings have important implications for inappropriate shocks due to T wave oversensing.

Circ J 2011; 75: 2095 – 2104

Recommendations for the Standardization and Interpretation……………

- **The 1975 AHA recommendations included a 0.05-Hz low-frequency cutoff for diagnostic electrocardiography. This recommendation preserves the fidelity of repolarization, but it does not eliminate the problem of baseline drift.**
- **To reduce artifactual distortion of the ST segment, the 1990 AHA document recommended that the low-frequency cutoff be 0.05 Hz for routine filters but that this requirement could be relaxed to 0.67 Hz or below for linear digital filters with zero phase distortion.**
- **These standards continue to be recommended.**

- **These most recent limits continue to be recommended for adolescents and for adults, with extension of the high-frequency cutoff to 250 Hz in children.**
- **Electrocardiographs should automatically alert the user when a suboptimal high-frequency cutoff, such as 40 Hz, is used, and a proper high-frequency cutoff should automatically be restored between routine standard ECG recordings.**

THE SOCIETY FOR
CARDIOLOGICAL SCIENCE & TECHNOLOGY

Clinical Guidelines by Consensus

Recording a standard 12-lead electrocardiogram

An Approved Methodology

British Cardiovascular Society

February 2010
Review Date: February 2013

Appendix C: AUDIT CHECKLIST

Filter Settings

1. In 'Auto' mode is the machine preset to a recording bandwidth of either: *0.05Hz – 100Hz* or *0.5Hz – 100Hz*?

   ☐ Yes ☐ No

2. In 'Manual' or 'real time mode' is the machine preset to a recording bandwidth of *0.05Hz – 100Hz?*

   ☐ Yes ☐ No

3. Is the mains filter (50Hz) set to 'off'?

   ☐ Yes ☐ No

Training

1. Has the person performing the ECG recording been appropriately assessed in this technique?

   ☐ Yes ☐ No

Recording

1. Are the patient details present and correct?
   ☐ Yes ☐ No

2. Is the ECG free of artefact?
   ☐ Yes ☐ No

3. If artefact is present has an explanation been written on the ECG?
   ☐ Yes ☐ No ☐ N/A

4. Has the mains filter been used?
   ☐ Yes ☐ No

5. If the front panel 'filter' has been selected has an explanation been written on the ECG?
   ☐ Yes ☐ No ☐ N/A

6. Have the appropriate gain settings been used?
   ☐ Yes ☐ No

7. If the rhythm is irregular has an additional rhythm strip been recorded?
   ☐ Yes ☐ No ☐ N/A

Guidelines for recording a standard 12-lead electrocardiogram

Equipment

- Electrocardiograph that meets or exceeds the requirements of IEC 60601-2-51 (2003)*.

  The device should be pre-programmed in accordance with American

* IEC 60601-2-51 (2003) - *Particular requirements for safety, including essential performance, of recording and analysing single channel and multichannel electrocardiographs.* This document establishes minimum safety and performance requirements for electrocardiographic (ECG) systems that are intended for use in the analysis of rhythm and of detailed morphology of complex cardiac complexes.

** Digital filter design allows for the low-frequency filter to be raised to **0.5Hz** when recording in 'auto' mode. However, ST-segment distortion may occur when this setting is used in 'manual' mode. Fixing the low-frequency setting at **0.05Hz** in the pre-set should prevent this error occurring[3].

*** AAMI EC12-00 (2000) - This standard establishes minimum labeling, safety, and performance requirements for disposable electrodes used for diagnostic electrocardiography.

'Manual' or 'real time' mode 0.05 Hz – 40 Hz

- Disposable tab electrodes that meet or exceed the requirements of AAMI EC12-00 (2000) ***
- Skin preparation equipment (for example, razor, abrasive tape)