Impact of high-pass filtering on ECG quality and clinical interpretation: a comparison between 40 Hz and 150 Hz cutoff in an outpatient population

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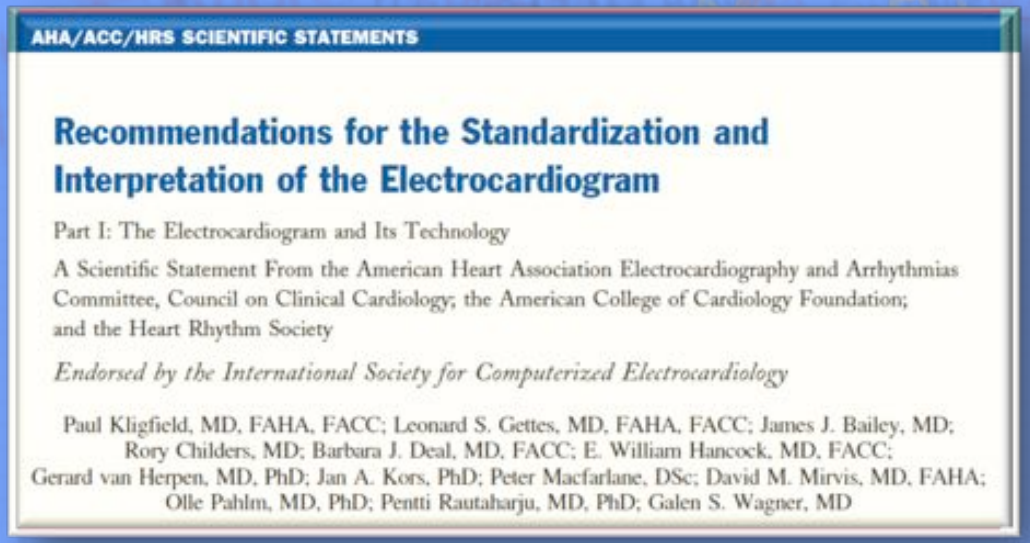
Background

- In the preoperative evaluation, patients are often screened only on the basis of an ECG
- The American Heart Association in 2007 established a standard 0.05 to 150 Hz bandwidth for the routine recording of 12-lead ECGs.
- The bandwidth of an electrocardiograph influences the fidelity of electrocardiographic waveforms, including the amplitudes used for the diagnosis of ventricular hypertrophy, the accuracy of the magnitudes of ST-segment modifications and Q-wave measurements



AHA/ACC/HRS SCIENTIFIC STATEMENTS

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

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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

of heart disease (49–51). 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. 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 (52).

[49]Goldberger AL et al. Circulation 1981
[50]Pettersson J, et al. J Electrocardiol 1995
[51]Pettersson J,et al. Am Heart J 2000;
[52]Garson A Jr.et al. Am Heart J 1987

Previous studies have indicated, in everyday clinical practice, a very high prevalence of settings deviations from the recommended standards mainly because of improved tracing appearance

High- and low-filter bandwidth governs the fidelity of electrocardiographic waveforms, including the durations used in established criteria for infarction, the amplitudes used for the diagnosis of ventricular hypertrophy, and the accuracy of the magnitudes of ST-segment elevation and depression. Electrocardiographs allow users to reset high- and low-filter settings for special electrocardiographic applications, but these may be used inappropriately. To examine the prevalence of standard and nonstandard electrocardiographic filtering at 1 general medical community, 256 consecutive outpatient electrocardiograms (ECGs) submitted in advance of ambulatory or same-day admission surgery during a 3-week period were examined. ECGs were considered to meet standards for low-frequency cutoff when equal to 0.05 Hz and to meet standards for high-frequency cutoff when equal to 100 Hz, according to American Heart Association recommendations established in 1975. 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. In conclusion, improper electrocardiographic filtering, with potentially adverse clinical consequences, is highly prevalent at 1 large general medical community and is likely a generalized problem. This problem should be resolvable by targeted educational efforts to reinforce technical standards in electrocardiography.

Kligfield P, Okin PM. Am J Cardiol. 2007

Methods

- This prospective observational study enrolled consecutive adult outpatients undergoing routine preoperative ECG in our institution between October and December 2014
- Nurses were trained to print-out two standard 12-lead ECG tracings for each patient: one with a high-frequency cutoff of 40 Hz and another with a high-frequency cutoff of 150 Hz. The low-frequency cutoff was set at 0.05 Hz
- Two blinded cardiologists reviewed and interpreted all the ECG tracings

The following parameters were considered and compared

PR segment and ST-T wave abnormalities
Q-wave > 1 mm or suggestive of myocardial necrosis
QRS amplitude measured in the precordial leads
Left ventricular hypertrophy (LVH) was assessed using the Sokolow-Lyon criteria
Pacemaker spikes
J-point elevation
Delta-wave and Epsilon-wave

The operators were also asked to evaluate the traces with an arbitrary score, ranging from 1 to 3, ***where 1 indicated a poor quality trace, 2 indicated an average quality and 3 an optimal quality*** *for clinical interpretation. Score 1 ECGs were also discerned as interpretable or non-interpretable, thus requiring ECG re-tracing.*

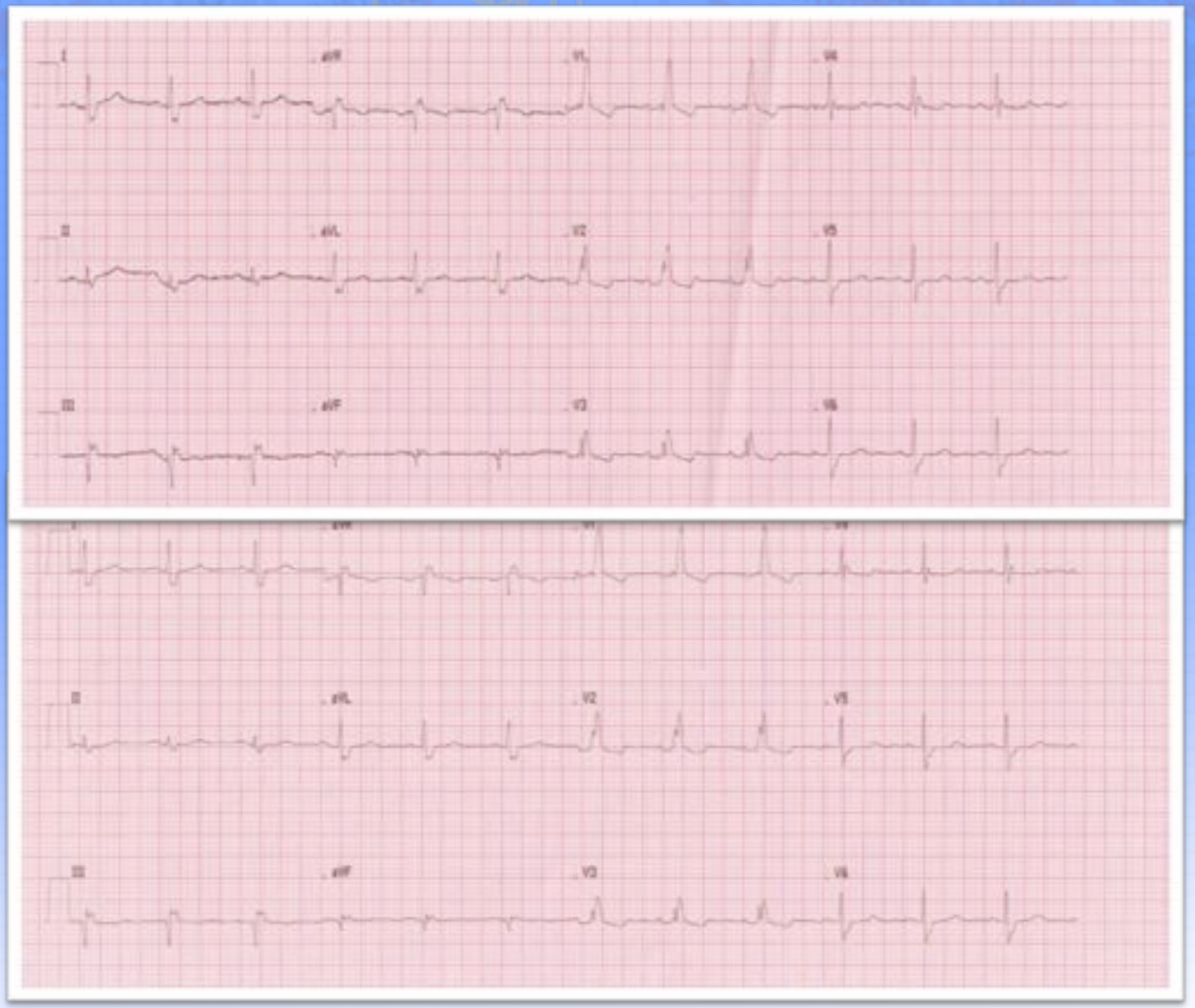
Baseline Characteristics

Characteristics	Study population (N=1582)
Age (yrs)	57.8 ± 16.9
Male sex	660 (41.7%)
Sinus rhythm	1542 (97.5%)
Atrial fibrillation	35 (2.2%)
Supraventricular extrasystoles	55 (3.5%)
Ventricular extrasystoles	35 (2.2%)
Heart rate (bpm)	68.2 ± 11.5
PR interval (ms)	161.8 ± 29.6
QRS complex (ms)	98.6 ± 18.8
QT interval (ms)	393.2 ± 31.6
QT_c interval (ms)	407.7 ± 24.0
Right bundle branch block	117 (7.4%)
Left bundle branch block	39 (2.5%)

Results

	40 Hz high-frequency cutoff	150 Hz high-frequency cutoff	p value
PR abnormalities	5 (0.3%)	7 (0.4%)	0.500
ST abnormalities	481 (30.4%)	476 (30.1%)	0.267
T-wave abnormalities	446 (28.2%)	448 (28.3%)	0.791
Q-wave > 1 mm	183 (11.6%)	144 (9.1%)	0.804
Significant Q-wave*	79 (5.0%)	69 (4.4%)	1.000
J-point elevation	166 (10.5%)	152 (9.6%)	0.007
ε-wave	-	-	-
δ-wave	-	-	-
Pacemaker spikes	16 (1.0%)	15 (0.9%)	1.000
QRS amplitude (mV)	21.1±7.4	23.1±7.6	< 0.001
Left ventricular hypertrophy	86 (5.4%)	117 (7.4%)	< 0.001

* Suggestive of myocardial necrosis


I
aVR
V1
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II
aVL
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III
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II
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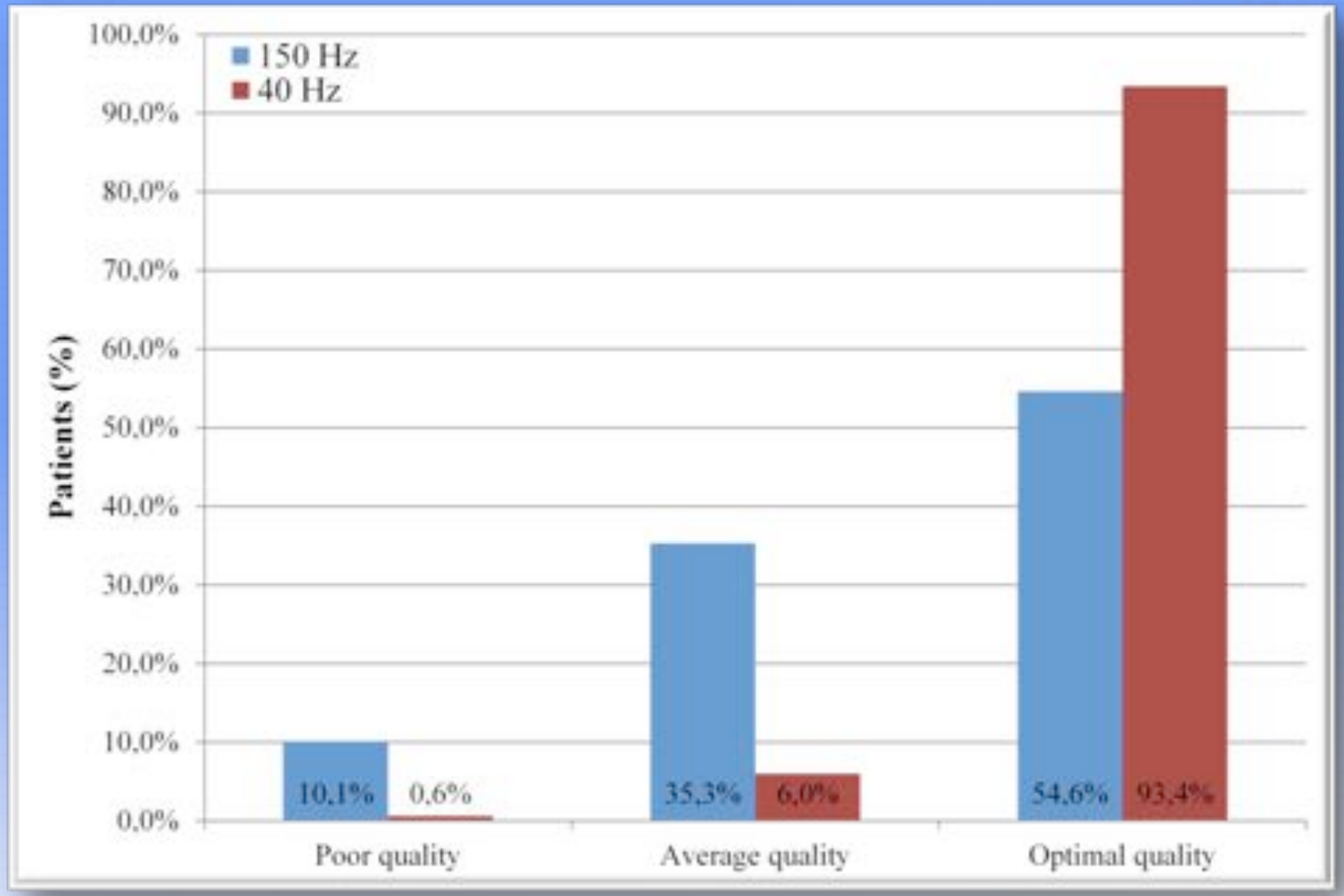
III
aVF
V3
V6

Results


100,0%
90,0%
80,0%
70,0%
60,0%
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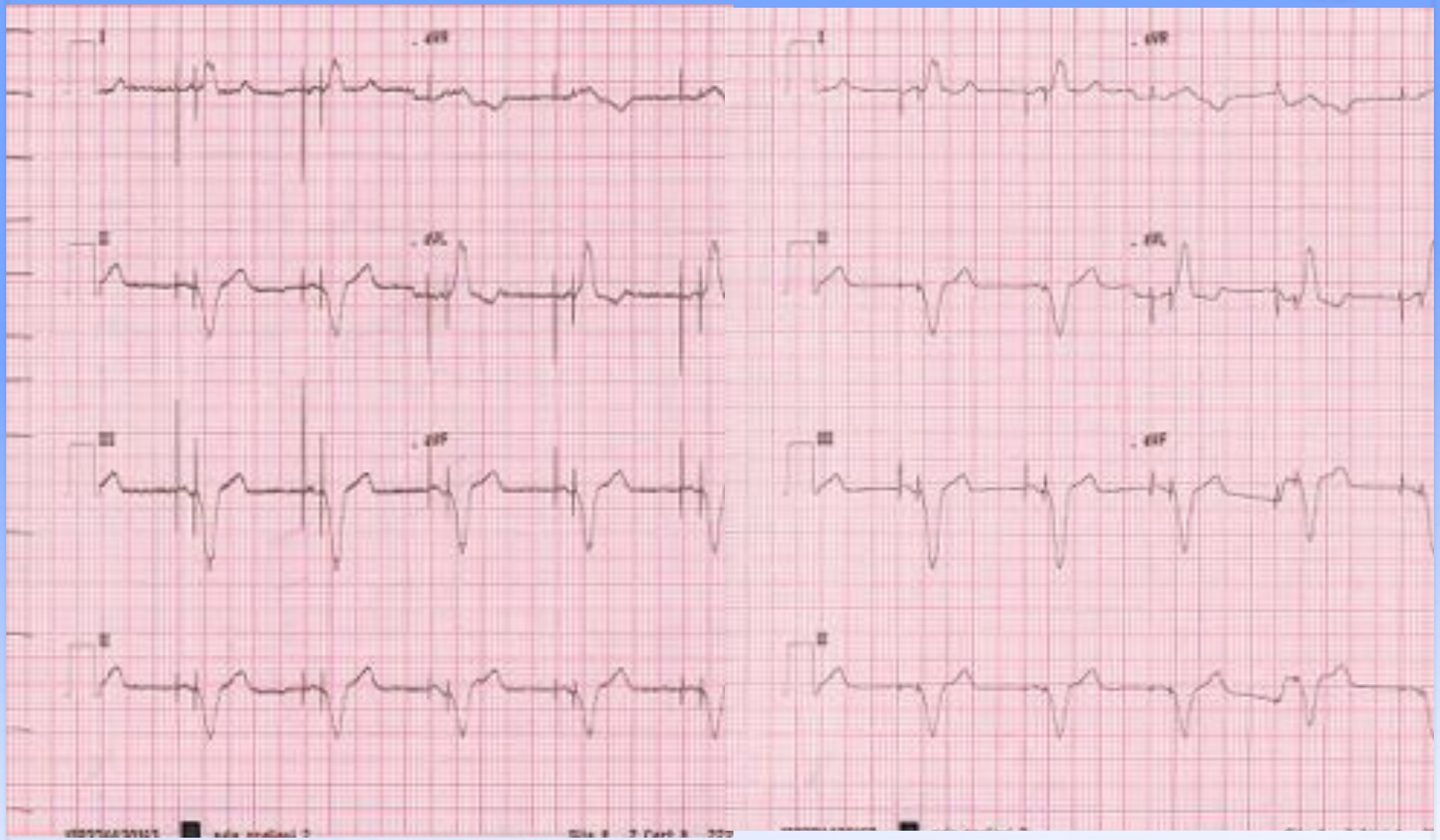
40,0%
30,0%
20,0%
10,0%
0,0%
Patients (%)
150 Hz
40 Hz
10,1%
0,6%
35,3%
6,0%
54,6%
93,4%
Poor quality
Average quality
Optimal quality



Results

The QRS amplitude significantly differs between the two cutoffs, resulting in a higher rate of LVH detected with the 150 Hz.

This difference comprises only the individuals with borderline QRS amplitudes (between 3.3 and 3.7 mV), a minor part of the population evaluated (1.9% of the entire study population)

Conclusions

The elimination of the bands between 40 Hz and 150 Hz does not substantially affect ECG interpretation in the pre-operative setting

Our study is the first to demonstrate a better perceived quality of 40 Hz traces compared to 150 Hz high-bandwidth filtering, with a lower rate of ECGs judged as non-interpretable

The clinical impact of the differences in LVH diagnosis is minimal, because it has been demonstrated already that LVH diagnosis should not be solely based on a pure measurement of QRS amplitude and that ECG has a low sensitivity in the diagnosis of LVH

Key Messages

This study demonstrates that, with newer ECG machines, the standardization of a high-pass 40 Hz filtering improves the quality of a 12-lead ECG without significant impact on the diagnostic potentiality of this invaluable cardiologic tool.

Future researches in ECG filtering and analysis methods will clarify the optimal setting of the machines for a safe and comprehensive ECG evaluation.

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