Best Data Collection Methods and
Best Universal Data Formats:

Clinical Perspective

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Questions

- What do we need to do to make sure to collect data suitable for clinical research?
- Is it just a matter of format?
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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Abstract—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. *(J Am Coll Cardiol 2007;49:1109–27)*
So, before the format...

- Summarize things that matter:
  - (which) waveforms to acquire/store
  - Bandwidth
  - Sampling rate

*keeping in mind that we’re talking about the young*
Even more important...

- What is the scientific goal of the screening project?
  - Qualitative storage of data?
  - Assessing basic measurements (QT/QTc)
  - Performing more sophisticated analyses?

- What is the price if we plan to use digitized ECG?
Define quality waveforms

- **Display quality waveform**
  - When we want to retrieve and simply display an ECG, and can be happy with qualitative assessment and a few “simple” measurements.

- **Research quality waveform**
  - When we want to perform full reanalysis of the ECG data.
(which) waveforms?

- simultaneously acquired (synchronous) waveforms
- 10 seconds
- Standard leads
The fundamental frequency for the QRS complex at the body surface is $\approx 10$ 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 (35). The
Bandwidth

LF

HF

Bandwidth

\[ f_1 \quad f_c \quad f_2 \]
Bandwidth

LF  $f_c$  HF

-3 dB
Example of HF cutoff on an adult ECG
Minimum Bandwidth Requirements for Recording of Pediatric Electrocardiograms

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Background—Previous studies that determined the frequency content of the pediatric ECG had their limitations: the study population was small or the sampling frequency used by the recording system was low. Therefore, current bandwidth recommendations for recording pediatric ECGs are not well founded. We wanted to establish minimum bandwidth requirements using a large set of pediatric ECGs recorded at a high sampling rate.

Methods and Results—For 2169 children aged 1 day to 16 years, a 12-lead ECG was recorded at a sampling rate of 1200 Hz. The averaged beats of each ECG were passed through digital filters with different cut off points (50 to 300 Hz in 25-Hz steps). We measured the absolute errors in maximum QRS amplitude for each simulated bandwidth and determined the percentage of records with an error >25 µV. We found that in any lead, a bandwidth of 250 Hz yields amplitude errors <25 µV in >95% of the children <1 year. For older children, a gradual decrease in ECG frequency content was demonstrated.

Conclusions—We recommend a minimum bandwidth of 250 Hz to record pediatric ECGs. This bandwidth is considerably higher than the previous recommendation of 150 Hz from the American Heart Association. (Circulation. 2001;104: 3087-3090.)

Key Words: electrocardiography ■ pediatrics ■ bandwidth
<table>
<thead>
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<th>Age</th>
<th>Total</th>
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<tr>
<td>0 to 3 months</td>
<td>606</td>
</tr>
<tr>
<td>3 to 6 months</td>
<td>226</td>
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<td>6 to 12 months</td>
<td>213</td>
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<td>240</td>
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<tr>
<td>5 to 8 years</td>
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<td>8 to 12 years</td>
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<td>12 to 16 years</td>
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<td>2169</td>
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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
Bandwith

- For adults: 150Hz
- For pediatrics: 250Hz
- For older kids (>12): 150Hz may be ok
Sampling rate

\[ s.f. = \frac{1}{T} \]
Sampling rate

an infinite sampling interval, the 1990 AHA report recommended sampling rates at 2 or 3 times the theoretical minimum (23). A series of studies have now indicated that 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 \( \approx 1\% \) in adults (43,44). Greater bandwidth may be required for accurate determination of amplitudes in infants (35,45,46). The Euro-

Adults BW 150Hz  \( \rightarrow \) sampling rate 500Hz ok
Pediatric BW 250Hz  \( \rightarrow \) sampling rate 500Hz not ok
1000Hz is surely better (non redundant…….)
ECGScan: a method for conversion of paper electrocardiographic printouts to digital electrocardiographic files

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Digital vs. Digitized
Digital vs. Digitized

*the price paid:*

- Original bandwidth is gone already on the paper ECG (for a number of reasons).
- Original sampling rate is gone (same as above).
- Some data is not even there……
- Only good for some basic measurements and for storage/review.
Digital vs. Digitized

- R wave: 10% reduction
- Q wave: 25% reduction
Table 2
Summary of test 2 results

<table>
<thead>
<tr>
<th></th>
<th>QT original</th>
<th>QT derived</th>
<th>ΔQT (dev)</th>
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<tbody>
<tr>
<td>n = 144</td>
<td>404</td>
<td>405</td>
<td>0.755</td>
</tr>
<tr>
<td>Mean</td>
<td>55.7</td>
<td>56</td>
<td>5.41</td>
</tr>
<tr>
<td>SD</td>
<td>292</td>
<td>288</td>
<td>-12</td>
</tr>
<tr>
<td>Minimum</td>
<td>612</td>
<td>604</td>
<td>12</td>
</tr>
<tr>
<td>Maximum</td>
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Conclusions

- Act accordingly to the scope of the screening project.

- But make sure to properly report:
  - Sampling rate / amplitude resolution
  - Bandwidth
  - Digitized data (it that was used)