Automatic QRS Selvester Scoring in Patients with Left Bundle Branch Block

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I. Background:

The Selvester QRS scoring (SQRS) system uses standard 12-lead ECG to estimate the myocardial scar size in the absence or presence of various QRS complex abnormalities, including left bundle branch block (LBBB). This multi-criteria method requires a thorough review of the QRS patterns of the ECG. Manual measurements for computing the SQRS is a very lengthy process.

II. Aims:

The objective of this study is to develop a set of algorithms to automatically measure the SQRS score for LBBB with the presence of the new strict criteria. Automation will enable consistency of measurements and streamline the SQRS analysis. We call this software tool the "QUantitative and Automatic REport of Selvester Score (QuAReSS)".

III. Methods:

Study Population

This study involved the ECG recordings from patients enrolled in MADIT-CRT. A total of 220 ECGs recorded prior to implantation were used from patients with LBBB based on new strict criteria. Forty ECGs were randomly selected from this pool to be used as a learning set while the remaining 180 ECGs were used as a validation set. The 12-lead high-resolution Holter ECGs were recorded with 1000 Hz sampling frequency and 3.75μV amplitude resolution (Mortara H12+).

Design strategy

Two experts (BW, DS) in manual application of SQRS scored the training set of recordings in order to design and train automatic algorithms. Next, a group of three experts (BW, DS, GW) reviewed and discussed the discordant scoring to eliminate the discrepancies and clarify the detection and recognition rules.

Automatic Selvester Scoring

A set of algorithms were developed to compute the Selvester Score:

- **QRS boundaries**: The QRS detection was based on the technique developed for normal QRS with adjustments to optimize the location of boundaries for wider QRS in LBBB.
- **QRS morphology characterization**: we automatically classified QRS patterns in identifying the presence of Q, R, S, R prime, and S prime.
- **Waves location and interval**: measurements of ratios of wave amplitudes and the durations of the waves were implemented.
- **Subtle QRS patterns**: algorithms for notch and slur detection were developed and applied to measure the subtle patterns required in Selvester Score so-called the "NchInit40", R/R' and S/S' patterns.

Figure 1: Algorithm Flow – Automatic scoring system

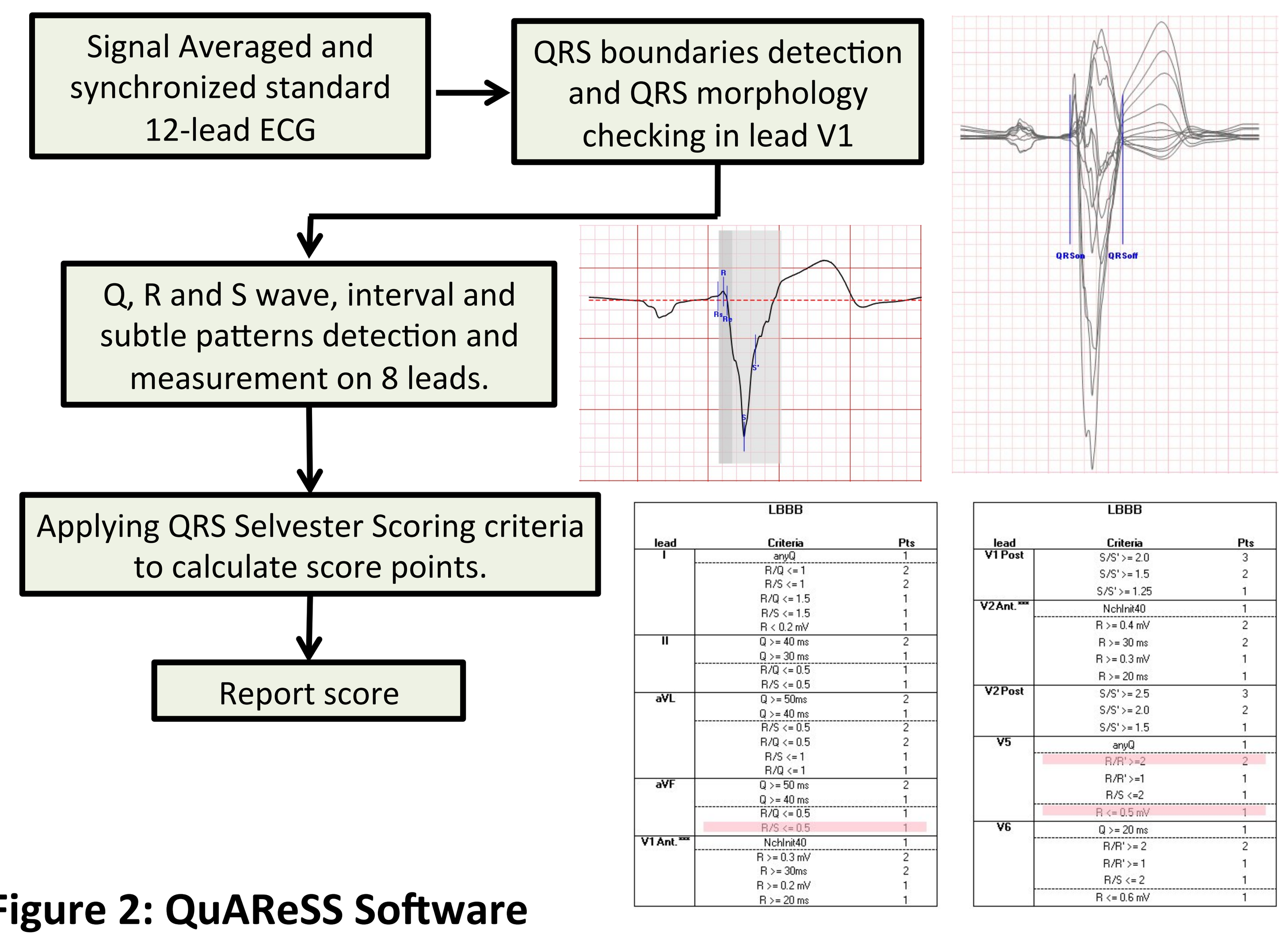
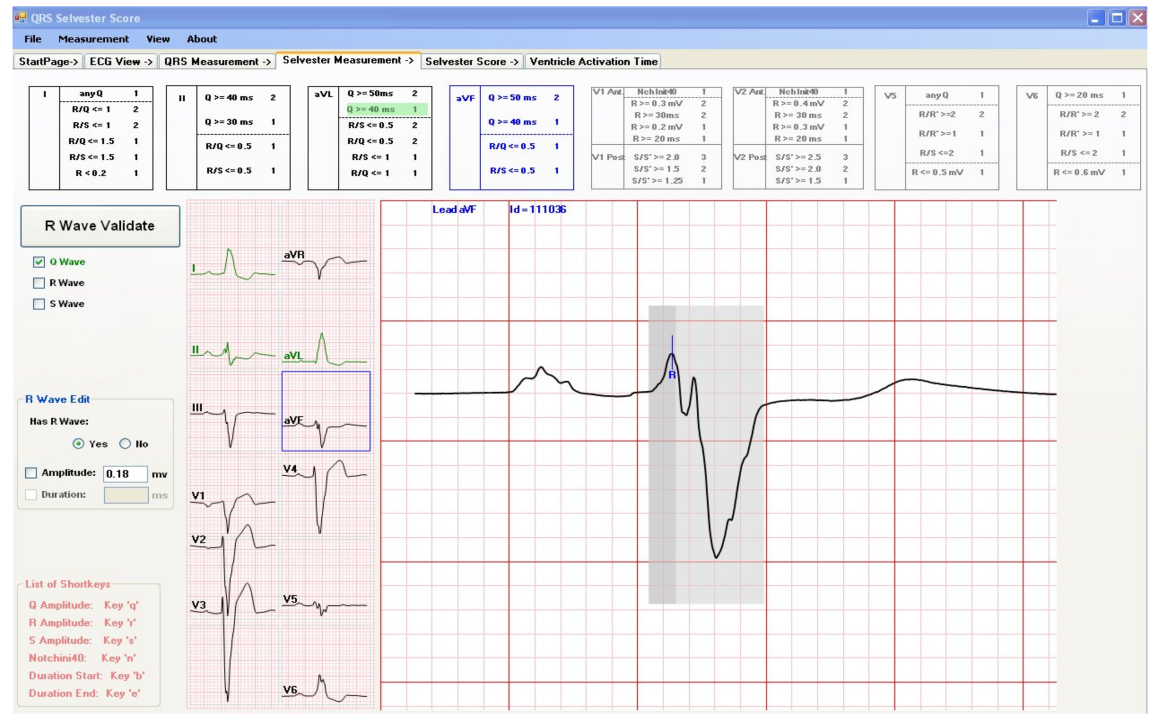


Figure 2: QuAReSS Software



The QuAReSS was developed for windows platform using Microsoft .NET framework 3.5. The software provides detail and visual guides to facilitate the manual adjudication of the automatic results.

V. Results:

The validity of the automated measurements was visually assessed on a validation set by one of the experts (BW).

Signal Averaging

Figure 3: Noise level in function of number of beats considered in the averaging process.

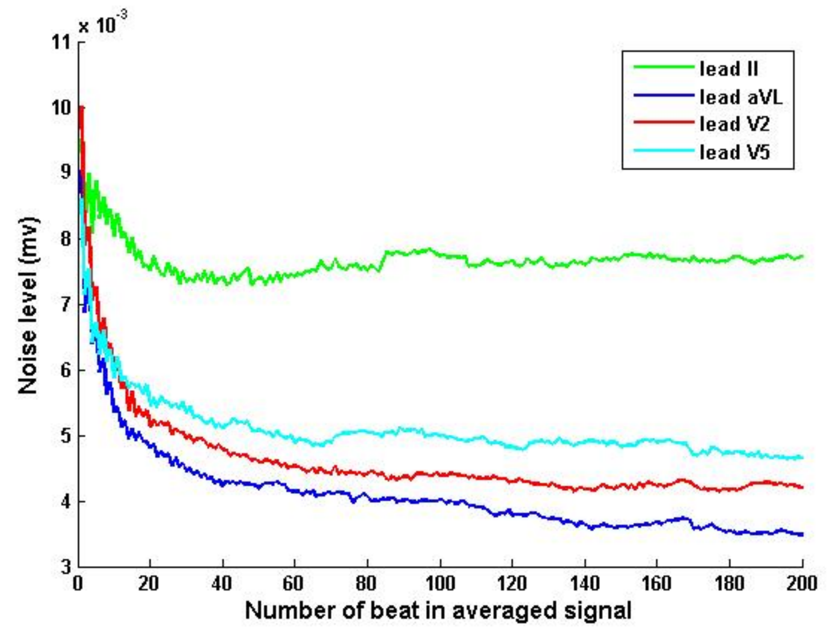


Figure 3 is based on 220 ECGs. We evaluated the number of beats to be included in the signal averaging process to reach a plateau.
A noise level below 8μV was reached in all 12-lead signal average ECG signals.
The lowest noise level (3.5 ± 6.3μV) was observed in lead aVL and the highest in lead II (7 ± 8.9μV).

QRS boundaries

Table 1. Validation of automatic QRS onset, offset, and duration using adjudicated results performed on 180 ECGs.

QRS onset (ms)	QRS offset (ms)	QRS duration (ms)
-1.4±4.7	-4.0±5.0	-2.6±7.0

Selvester Score

Table 2: Results for waves and subtle pattern detection .

	Number of measurements	Sensitivity	Specificity
Q wave	1080	85%	100%
R wave	1440	100%	81%
S Wave	1440	99%	100%
R Prime	360	76%	92%
S Prime	360	86%	99%
NchInit40	360	74%	100%

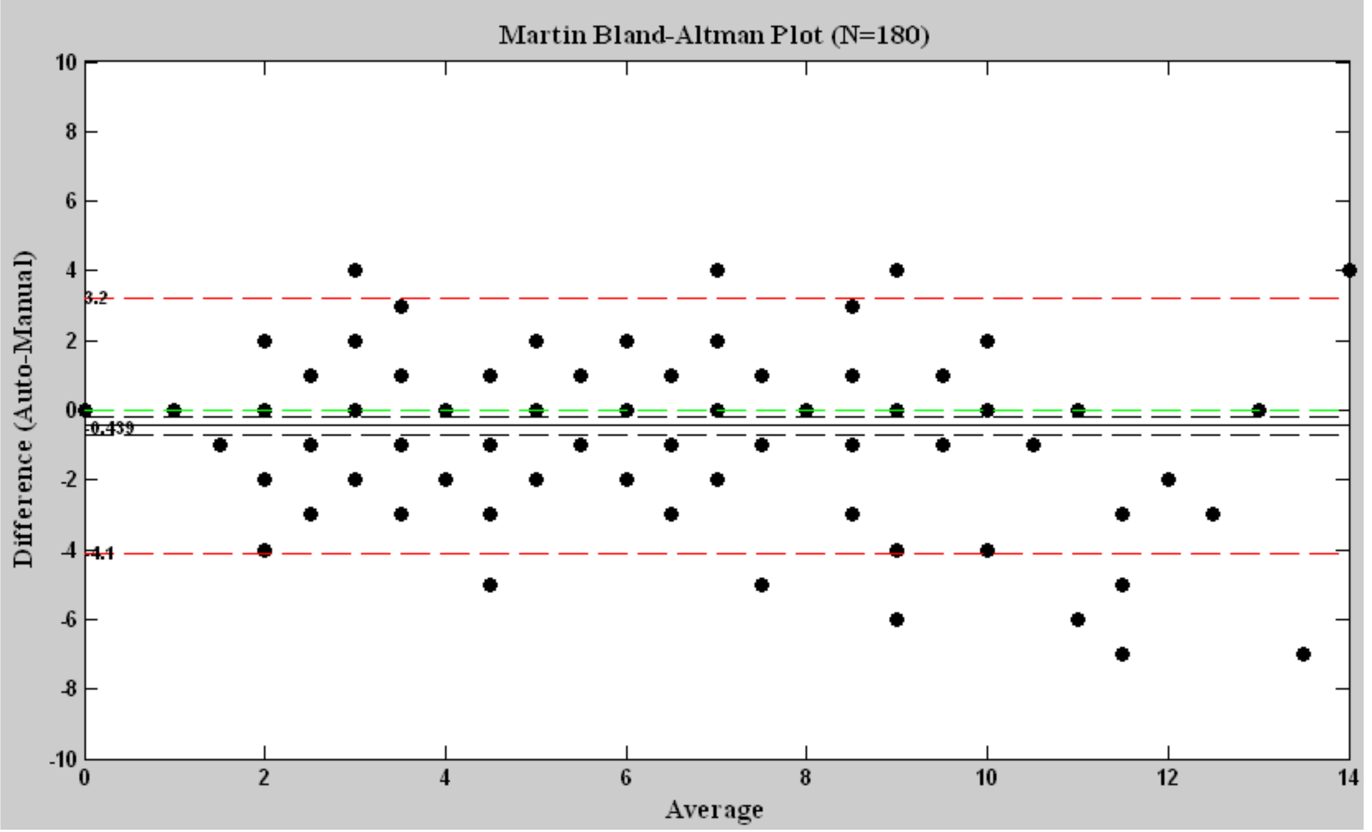
Table 3. Agreement between automatic and adjudicated measurements on wave duration, locations, peak, onset, offset and other subtle patterns.

	Difference (ms) auto vs. manual	N
Q Duration	1.9 ± 4.2	98
R Duration	4.8 ± 19.9	285
Q offset	0.2 ± 1.3	98
R Peak	0 ± 11.2	1362
R Prime	-1.8 ± 8.5	141
S Peak	-0.2 ± 5.3	1013
S Prime	-5.7 ± 14.5	121

N: number of measurement.

The average of difference and absolute difference between automatic and adjudicate calculated Selvester score are -0.4 ± 1.8 and 1.2 ± 1.5 points in 180 ECGs .

Figure 4: Level of agreement between automatic and manual Selvester scoring.



VI. Conclusions:

We have developed a method to enable automatic Selvester scoring of standard 12-lead ECGs with adjudication. We estimate that the use of the software enable a 5-15x time gain in computing the score depending on manual observer's experience. Our next step is to generalize the computation of the score to patients with other conduction abnormalities.