Maximizing interpretable heart sounds in the Emergency Department using digital auscultation and computerized analysis

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Introduction

The third heart sound (S3) has been associated with left ventricular dysfunction and acute heart failure syndrome (AHFS). Recent efforts to use stethoscope-based digital phonocardiography for detection of the third heart sound (S3) in suspected Emergency Department (ED) AHFS patients have been limited by the high noise/signal ratio (NSR) of recordings.

Objectives

We sought to systematically lower the noise-signal ratio (NSR) of digital heart sound recordings in the ED. Specifically, we sought to find an optimal combination of three modifiable variables capable of minimizing the NSR of heart sound recordings in the ED environment: (1) auscultation location, (2) stethoscope type, and (3) patient position.

Methods

Three trained operators recorded heart sounds on a convenience sample of healthy volunteers in a tertiary care ED from June-August 2007. Eight 15-second recordings were obtained on each volunteer in an ED room or ED hallway using a digital stethoscope with a line-in connection to a laptop computer running Phonocardiograph software (Biosignetics Co., Exeter, NH). The 8 recordings represented all possible permutations of the three main dependent variable categories. These recordings included: (1) two auscultation locations - mitral and pulmonic, (2) two digital stethoscopes - ThinkLabs ds32a and WelchAllyn Meditron, and (3) two patient positions - patient lying in left lateral decubittus (LLDC) and patient lying in bed with the head of the bed elevated to 45 degrees (semi-supine). Prior to analysis, each recording was digitally filtered using Phonocardiograph software to progressively remove all sounds having a frequency lower than 40 Hz or higher than 400 Hz. The primary outcome measures were the “subjective” operator ratings of sound quality (ORSQ) and “objective” noise-signal ratios (NSR). Univariate and multivariate analyses based on repeated measures ANOVA were used with $p < 0.05$ considered significant.

Operator ratings of sound quality (ORSQ)
Upon completing each recording, the operator rated the quality of the sound heard on a 1-4 scale, with 1 representing "distant and unclear" and 4 "loud and clear."

Noise-Signal ratio (NSR) calculation
Once the recordings were obtained and rated by operators, a trained analyst (YB) listened to every heart sound recording and visually examined each corresponding tracing using Phonocardiograph software (Biosignetics, Exeter, NH). Based on this examination, the analyst then identified three representative heart sound intervals within each recording for analysis. For each of the intervals, the analyst obtained software-assisted measurements of the peak-to-peak noise and software-generated measurements of the peak-to-peak signal. For each interval, the NSR (%) was calculated as follows:

$$\text{NSR}\ (\%) = \frac{\text{Peak - to - peak noise}}{\text{Peak - to - peak signal}} \times 100\%$$

The NSR for each recording represents the average NSR of the three intervals measured for that recording.

Results

Heart sound recordings were performed on 33 subjects, with 8 recordings per subject for a total of 264 recordings. The mean age was 31 years (SD±12) and 16 were male.

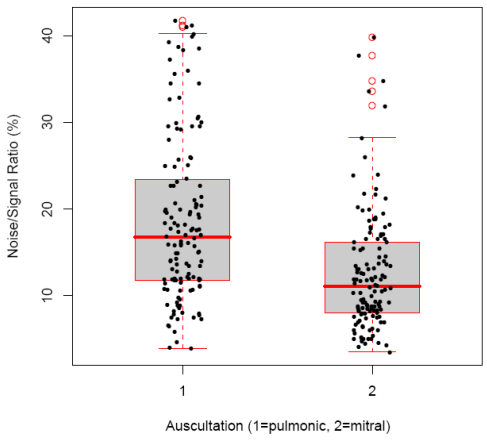
Results of univariate analysis (summarized in Table 1):
-Auscultation location: the mitral position produced recordings with lower NSR (NSR = 12.6% vs. 18.7%, $p < 0.001$) and better operator ratings of sound quality (ORSQ) than the pulmonic ($p < 0.001$).
-Stethoscope type: the ThinkLabs ds32a produced recordings with lower NSR than the WelchAllyn Meditron (NSR = 13.8% vs. 17.5%, $p < 0.001$), but there was no significant difference in ORSQ between the two stethoscopes ($p = 0.156$).
-Patient position: there was no difference in NSR between the semi-supine and LLDC positions (16.1% vs. 15.1%, $p = 0.940$), although operators rated the recordings obtained in the LLDC position as sounding better than those obtained in the semi-supine ($p = 0.006$).
-Inter-operator variability ($p = 0.164$) and recording location ($p = 0.934$) did not significantly affect NSR.

Graphs 1-6 demonstrate the effect of each of the three main dependent variables on NSR and ORSQ based on univariate analysis. A multivariate analysis that examined jointly all major and minor dependent variables produced results consistent with the univariate analysis.

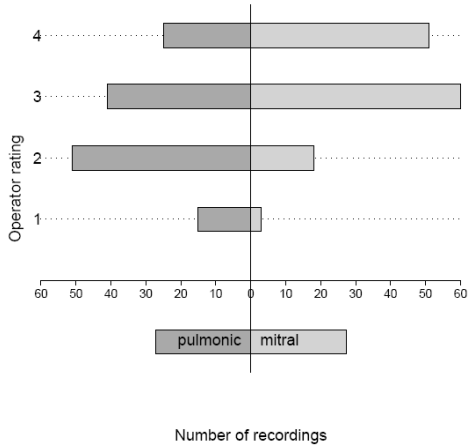
Table 1: Effect of major dependent variables on measures of recording quality

Variable		*NSR (%)*	*p Value*	*OSQR*	*p Value*
Auscultation location	Pulmonic	18.7	p < 0.001	2.58	p < 0.001
	Mitral	12.6		3.21	
Stethoscope type	ThinkLabs	13.8	p < 0.001	2.83	NS
	WelchAllyn	17.5		2.96	
Patient position	Semi-supine	16.1	NS	2.77	p = 0.006
	LLDC	15.1		3.02	

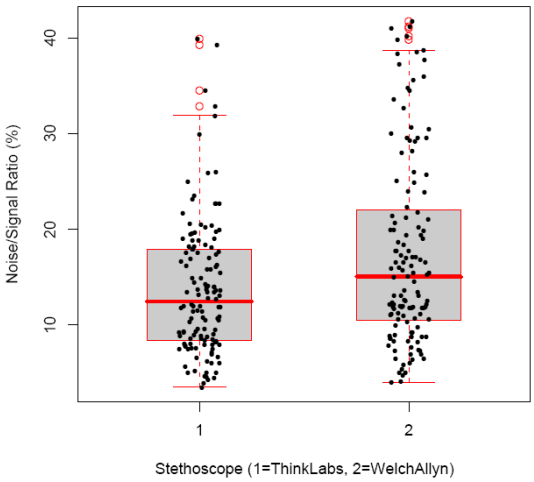
NSR (%), Noise Signal Ratio documented as a percentage
ORSQ, Operator Ratings of Sound Quality
NS, not significant



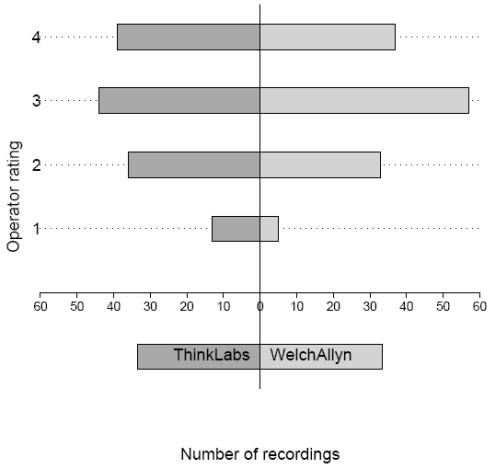
Graph 1: Effect of auscultation location on noise-signal ratio (%).



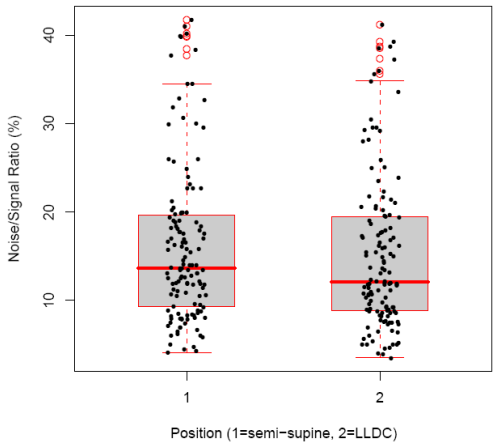
Graph 2: Effect of auscultation location on operator ratings of sound quality.



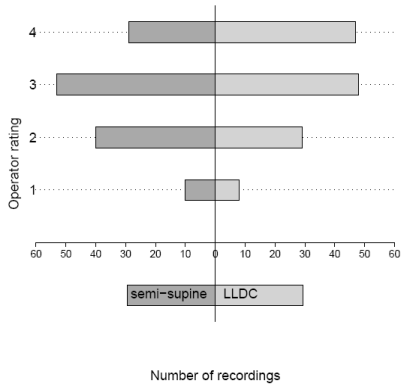
Graph 3: Effect of stethoscope type on noise-signal ratio (%).



Graph 4: Effect of stethoscope type on operator ratings of sound quality.



Graph 5: Effect of patient position on noise-signal ratio (%).



Graph 6: Effect of patient position on operator ratings of sound quality.

Conclusions

The ThinkLabs ds32a stethoscope in the mitral position produced recordings with the lowest noise-signal ratio (NSR). The study corroborated the conventional wisdom that placing a person in left lateral decubitus position enhances the subjective amplitude and clarity of heart sounds as heard by the human ear. However, the study also showed that, objectively, there was no significant difference in NSR between recordings taken at the left lateral and semi-supine positions. The discordance between objective and subjective measures of sound quality for stethoscope and subject position suggests that observations obtained through traditional cardio-auscultation might not generalize predictably to the emerging field of digital phonocardiography. Alternatively, the difference in NSR between recordings taken at the two patient positions may not have reached significance simply because of the small sample size of the study. Further experiments are needed to verify this provocative finding.

Limitations

-Small study population of healthy volunteers – generalizability
-Noise measurements analyst-dependent (non-automated)

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