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Optimization of an Automated Algorithm for Analysis of Spontaneous Rhythmic Bladder Contractions During Urodynamics Testing

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OPTIMIZATION OF AN AUTOMATED ALGORITHM FOR ANALYSIS OF SPONTAENEOUS RHYTHMIC BLADDER CONTRACTIONS DURING URODYNAMICS TESTING

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INTRODUCTION

Overactive Bladder is a common problem characterized by urgency to empty the bladder

Detrusor Overactivity (DO):

- Involuntary contractions of the bladder (detrusor) muscle during bladder filling
- DO is one cause of overactive bladder
- DO is visually identified during clinical urodynamics (UD) testing

Spontaneous Rhythmic Contractions (SRC):

- A type of periodic DO

Previous Work (Cullingsworth et al.):

- A Fast Fourier Transform (FFT) algorithm was developed to quantify the amplitude and frequency of DO
- The algorithm provides the physician with a quantitative model of any DO identified

Objective:

- Optimize algorithm parameters to maximize DO detection

METHODS

- Participants recruited for urodynamics studies
- Vesical (Pves) and abdominal (Pabd) pressures were recorded throughout filling
- Physician used UD data to diagnose DO
- Previously developed algorithm was adapted and used to identify and quantify DO (Figure 1.)
  - Algorithm tests to determine if any activity in Pves is significant (Are the contractions large enough to be more than noise?)
  - Algorithm tests to determine if activity in Pves is independent of Pabd (Are they caused by the bladder or the gut?)
- Multiple parameters were adjusted to optimize the algorithm
- ROC curves were developed to determine optimal values for selected variables, in this case, variables include an independence variable (indVar) and x variable

SRC ALGORITHM

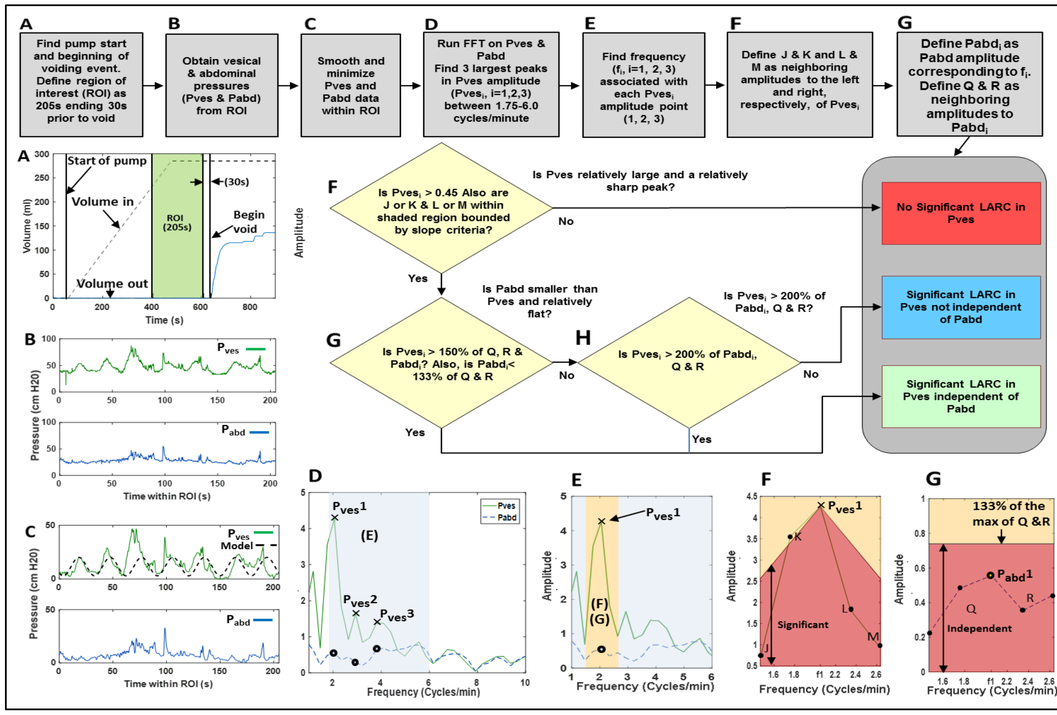

Figure 1. Flowchart for the FFT LARC algorithm. (A) UDS volume data showing time ROI. (B & C) raw and smoothed P_{ves} and P_{abd} data from the time ROI. (C dashed) Model of an ideal sine wave with a frequency of 2.05 cycles/min and a peak-to-peak amplitude of 17.12 cm-H2O, derived from the FFT results in panel F. The model peak-to-peak amplitude is 4 times the FFT output amplitude due to a factor of 2 from the FFT windowing and factor of 2 due to the two halves of the sine wave. (D) FFT of P_{ves} and P_{abd} from the ROI with the 1.75–6 cycle/min frequency range of interest shaded. (E) gray shaded region from panel D for $P_{ves}1$ with range of neighboring points shaded orange. (F) Significance test: $P_{ves}1$ is a sharp "significant" peak if J and/or K, and L and/or M are within the red region and if $P_{ves}1$ > 0.45. (G) Independence test: a significant $P_{ves}1$ peak is "independent" of $P_{abd}1$ if $P_{abd}1$ is relatively flat compared to points Q & R (within the red region below 133% of the max of Q & R) and if $P_{ves}1$ > 150% of $P_{abd}1$ (F & G).

PARTICIPANTS

- 136 participants included
  - 45 participants diagnosed with DO by physician
  - 91 participants without DO

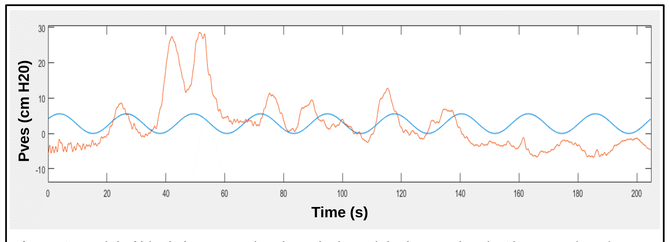

Figure 2. Model of ideal sine wave signal overlaying original Pves signal. Sine wave has the frequency and amplitude identified by the algorithm. Physician can visualize the model and compare it with the original signal.

MODEL VARIABLES AND PARAMETERS

Variable/ Method	Units	Original Value	Optimized Value	Maximized Sensitivity
Filter Type	N/A	average moving	lowpass	lowpass
Hanning Window	N/A	On	Off	Off
Frequency Area of Interest (AOI)	cycles/ minute	1.75-6	1.0-6	1.0-6
Significance Variable (Fig 1. F)	N/A	0.45	0.26	0.26
Slope Variable (Fig 1. F)	% Pves/ freq. step	0.2	0.1	0.1
Independence Variable X (Fig 1. G)	N/A	1.5	2.1	0.6
Independence Variable (indVar) (Fig 1. G)	N/A	1.33	1.4	1.3
Independence Variable 2 (Fig 1. H)	N/A	2	2.5	2.5

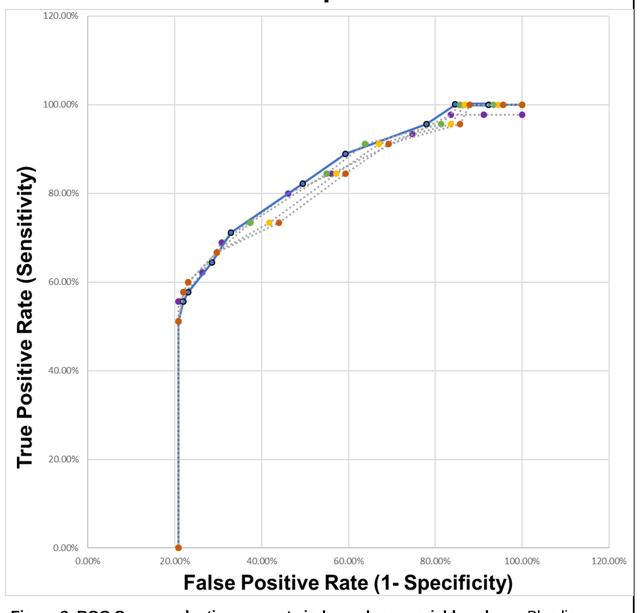

Figure 3. ROC Curve evaluating separate independence variable values. Blue line represents indVar value of 1.3 which has highest AUC and therefore most optimal parameter.

OPTIMIZED RESULTS

Original Values

	Detected DO	Detected NonDO	Total		
Diagnosed DO	16	29	45	35.56%	Sensitivity
Diagnosed NonDO	15	76	91	83.52%	Specificity
Total	99	37	136		
	16.16%	78.37%		67.64%	Overall
	True Positive	False Negative			

Optimized Values

	Detected DO	Detected NonDO	Total		
Diagnosed DO	27	18	45	60.00%	Sensitivity
Diagnosed NonDO	21	70	91	76.92%	Specificity
Total	99	37	136		
	27.27%	48.65%		71.32%	Overall
	True Positive	False Negative			

Maximized Sensitivity

	Detected DO	Detected NonDO	Total		
Diagnosed DO	45	0	45	100.00%	Sensitivity
Diagnosed NonDO	77	14	91	15.39%	Specificity
Total	99	37	136		
	45.45%	0.00%		43.38%	Overall
	True Positive	False Negative			

CONCLUSIONS

Improved algorithm provides objective quantification of SRC

- Quantifies SRC frequency and amplitude throughout filling
- Provides a model for visual confirmation of SRC

Clinical implementation is feasible

- Automated for real-time analysis (< 5 seconds)
- Uses UDS data already being collected

Two sets of parameters were identified

- One set maximizes overall performance (71.32% correct)
- Other set maximizes sensitivity (100%) and develops a model for all likely participants with DO

Potential clinical applications

- Provides new quantitative data to help physicians diagnose DO
- Could be used for quantification of the effects of treatments on SRC

REFERENCES

Cullingsworth, Z., Kelly, B., Deebel, N., Colhoun, A., Nagle, A., Klausner, A. and Speich, J. (2018) "Automated Quantification of Low Amplitude Rhythmic Contractions (LARC) During Real-World Urodynamics Identifies a Potential Detrusor Overactivity Subgroup," PLoS ONE 13(8): e0201594, DOI: 10.1371/journal.pone.0201594.

ACKNOWLEDGEMENTS

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