Can ExSpiron®, a Non-invasive Respiratory Volume Monitor, detect diaphragmatic dysfunction?

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Background: Diaphragmatic dysfunction is a common side effect of brachial plexus blocks (BPB), but a systematic assessment of the dysfunction is an uncommon practice. Spirometry, maximum inspiratory and expiratory pressures, chest x-rays, and ultrasound have been used to evaluate phrenic nerve dysfunction[1,2]. Non-invasive respiratory volume monitor (RVM) ExSpiron® uses bioelectrical impedance and correlates to lung volumes. The objective of this study was to evaluate if RVM could detect diaphragmatic dysfunction and correlate the changes in minute ventilation (MV) to inspiratory flow and airway pressures.

Methods: With IRB approval, adult English-speaking patients without known muscular or nerve disorders or pre-existing phrenic nerve or diaphragm pathology, scheduled to undergo BPB for upper extremity surgery, were evaluated for recruitment. After informed consent, ExSpiron® sensor was applied to the right side of the chest only (manufacturer recommendations) and patients were instructed on how to use an incentive spirometer (IS) connected to a pressure transducer. A pulse oximeter was applied to the respective extremity. Real-time respiratory measurements were recorded prior to sedation, after sedation, and 15-30 minutes after nerve block placement. Patient demographics, MV, maximum negative inspiratory pressure, flows and photoplethysmographic (PPG) amplitude, and peak area were collected. Data was entered into Excel® and pressure waveforms were analyzed in LabChart. T test was used to compare negative pressures before and after BPB and a value of $p<0.01$ was considered statistically significant.

Results: Thirty-four patients were approached for participation from June to October 2022. Two patients declined to participate, and five had incomplete data sets due to technical difficulties. A total of 27 patients were included in the analysis. Demographically, the mean age was 55 years, and 52% were women. Average respiratory metrics are shown in Figure 1A. After right-sided brachial plexus block, the average change in TV increased by 20% during spontaneous ventilation, and it reduced by 26% during organized deep breathing (with IS). Average percentage change in negative pressure decreased by 65% with reduction in airflow on IS (average number of balls decreased from 3 to 2). After left-sided BPB, average percentage change in TV reduced by 28% and 42% during spontaneous and organized deep breathing, respectively. Average percentage change in negative pressures decreased by 44% with reduction in air flow on IS (average number of balls decreased from 2.5 to 2). There was a significant decrease in negative inspiratory pressure before and after BPB ($p<0.00005$).

Conclusion: The objective of this study was to evaluate if RVM could detect diaphragmatic dysfunction. To the best of our knowledge, this is the first study to objectively assess MV changes after BPB. A trend was seen on the RVM with reduction in average percentage change in TV during organized deep breathing, as expected after BPB. However, the ExSpiron® showed a 20% increase in TV after right sided BPB. We think this result is due to ExSpiron® sensor placement as well as the irregularity in the depths of breaths during spontaneous ventilation. The IS showed consistent readings with significant reduction in negative pressures and flows after BPB bilaterally. There was a consistent increase in both PPG amplitude and peak area indicating sympathectomy and successful BPB placement[3,4]. In conclusion, RVMs are not ideal monitors to detect diaphragmatic dysfunction after BPB but flow measurements with IS might be clinically applicable. Moreover, IS has been shown to improve pulmonary function postoperatively so their use could be beneficial in two meaningful ways[5]. Systematic assessment of diaphragmatic dysfunction could contribute to an improved practice to optimize patients´ post-operative management and outcomes. Further research is needed to establish the changes in IS in relation to different approaches of BPB.

Figure 1-A

			TV (mL)	MV (L/min)	RR	negative pressure mmHg	#balls on IS	PPG amplitude	PPG peak area
RIGHT BPB	Spontaneous breaths	Pre PNB	398.6	5.2	13.0				
n=10	Spontaneous breaths	Post PNB	417.6	6.1	14.5				
	Incentive breaths	Pre PNB	776.9	10.7	15.3	-24.0	3	6.1	2.0
	Incentive breaths	Post PNB	683.3	10.8	17.2	-18.0	2	9.2	2.6
LEFT BPB	Spontaneous breaths	Pre PNB	436.5	7.0	16.0				
n=17	Spontaneous breaths	Post PNB	363.2	6.1	17.1				
	Incentive breaths	Pre PNB	754.0	10.3	14.6	-19.9	2.5	3.1	1.0
	Incentive breaths	Post PNB	567.9	9.6	17.7	-15.3	2	7.6	2.3

Figure 1-B

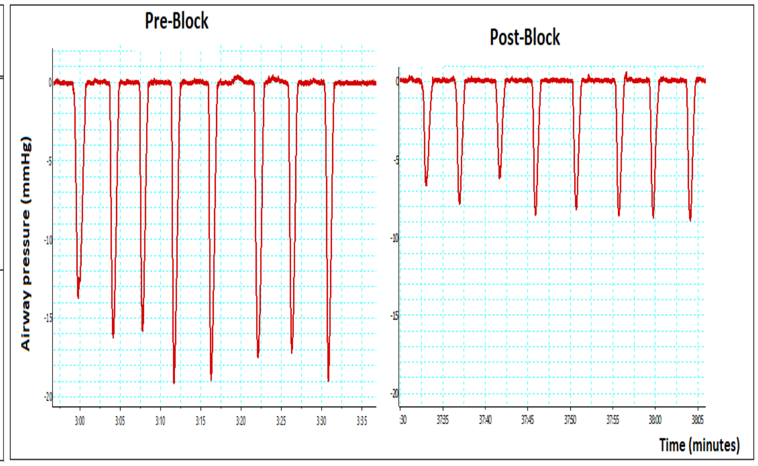

Figure 1-C

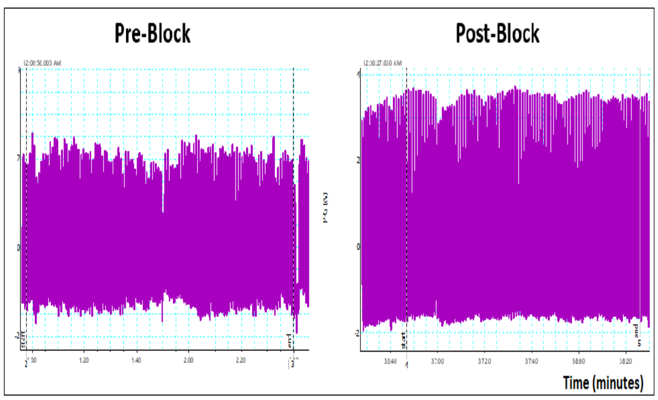

Figure 1. **A**: Average respiratory metrics categorized by right sided and left sided brachial plexus blocks. **B**: Negative pressure waveforms before and after BPB with spontaneous and organized deep breathing with IS as analyzed in LabChart. **C**: Changes in photoplethysmographic (PPG) amplitude and peak area before and after BPB.

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