the single-sensor scheme is simpler, easier to implement and less susceptible to signal distortion due to the movements of the soft abdominal tissues.

Compared to RIP, the most commonly used competitive method, our method performs better in two important aspects, accuracy and drift. Firstly, the studies of RIP performed under the same conditions as the study described here, that also use the calibration method not requiring subject cooperation, report the maximum tidal volume error round −24% (Fig. 6 in [30]) (with the mean error of −6.39%) on a set of 7 healthy volunteers [30] and the maximal tidal volume error of 24% on a set of 10 healthy volunteers [19]. The maximum tidal volume error on a set of 18 volunteers reported here was 17% (with the mean error of 0.4%). Secondly, unlike RIP, our method does not suffer from high and unpredictable baseline drift. Although a weak drift in the light source intensity is present, it is much slower than a respiratory cycle and does not introduce errors in tidal and minute volume measurements.

Finally, we note that the heart-beat signal that contaminates the useful signal and thus limits the measurement accuracy can be removed by one of the known signal-separation techniques, such as those applied in the separation of electrocardiographic from electromyographic and electroencephalographic signals [31,32]. On the other hand, the simultaneous detection of the respiratory and cardio signals by a single sensor opens the door to the development of sophisticated multi-parameter monitoring schemes.

5. Conclusion

We have presented and validated a measurement method and optical fiber-grating sensing scheme that permits monitoring of lung volume through a real-time measurement of tidal and minute volumes. The novelty of the proposed method is that it is based on a correlation between the change in local torso curvature and the change in lung volume. In the paper we report on the study that proves this correlation by applying a two-step calibration-test procedure to a series of healthy volunteers and show that it is linear for clinically relevant breathing patterns. The technical novelty of our work lies in facts that we use a single fiber-grating sensor and a monochromatic measurement scheme that requires only a photodiode as a detector. A good agreement of tidal and minute volumes measured simultaneously by sensors and spirometer as a reference, proves sensor accuracy and consistency in time. An LPG was a sensor of choice since it has a greater sensitivity to bending than an FBG. The proposed single-sensor scheme is non-invasive, simple, low-cost and easy to implement. Furthermore, the sensing system can be made compact and easy to implement as a part of the mechanical ventilators but also can be a standalone device, potentially opening up the possibility of long term and ambulatory monitoring and home care applications. Moreover the proposed method can be implemented on both male and female patients with comparable accuracy and the calibration does not require patient cooperation. Importantly, it does not suffer from the flaws of air-flow measurements associated with the leaks from oronasal masks and is also more convenient for patients. The presented LPG sensor completely eliminates the need for chest movement observation by clinicians. These preliminary results are promising and indicate that the method proposed here could be used in NIV. Future work will be directed towards compensation of bodily movements, optimization of the working point, higher-order corrections to the calibration curve and on-line data analysis.

Acknowledgments

We acknowledge support of the Ministry of Education and Science and Technological Development of Serbia (Project III45010).

#201903 - $15.00 USD Received 25 Nov 2013; revised 18 Jan 2014; accepted 19 Feb 2014; published 12 Mar 2014