Influence of tracer gas delay-time on FRC and Lung Clearance Index from multi-breath nitrogen washout

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Aim of the study

The measurement of Functional Residual Capacity (FRC) and Lung Clearance Index (LCI) based on multiple-breath gas washout is increasingly used for diagnostic purposes. Precise flow and gas sensors are mandatory for this measurement; in addition the time-alignment of gas and flow signals has great influence on FRC and LCI.

The delay-times between flow and gas signals depend on the gas transport-times from the main-stream flow sensor near the patients mouth to the side-stream gas analyzer(s) as well as on the response-times of the gas analyzers. We investigated the influence of varying ‘main-stream flow’ to ‘side-stream gas signal’ delay-times on FRC and LCI.

Methods

For this study an EasyOne Pro LAB system (ndd Medical Technologies, Switzerland) with ultrasonic flow and motar mass sensor was used. The EasyOne Pro LAB system is a compact and portable device for spirometry, single-breath DLCO and portable device for spirometry, single-breath DLCO and CO2 выводs with CF; 44% female) were analyzed. Patient age ranged from 7 to 49 years. The raw data files from the multiple-breath N2 washout tests contain flow, main-stream MM, and side-stream MM and CO2 signals, all recorded with a sampling rate of 200 Hz.

The delay-time for each data file was determined by the cross-correlation of the side-stream gas sensor signals (MM and CO2) with the main-stream MM signal. Starting from this reference the delay-time was varied from -50 to +50 ms in steps of 10 ms; FRC and LCI were computed for each delay-time and compared to the reference values. The following schematic illustrates the system setup. The delay-sampling time causing the delay-time between main- and side-stream sensors is highlighted in red color.

The N2 multiple-breath washout measurement for FRC and LCI determination is based on a side-stream molar mass (MM) sensor combined with an infrared CO2 sensor. A total of 27 raw data files from 9 patients (6 healthy, 3 patients with CF; 44% female) were analyzed. Patient age ranged from 7 to 49 years. The raw data files from the multiple-breath N2 washout tests contain flow, main-stream MM, and side-stream MM and CO2 signals, all recorded with a sampling rate of 200 Hz.

For each data file the reference delay-time was determined by cross-correlation of the side-stream gas sensor signals (MM and CO2) with the main-stream MM signal. Starting from this reference the delay-time was varied from -50 to +50 ms in steps of 10 ms; FRC and LCI were computed for each delay-time and compared to the reference values. The following schematic illustrates the system setup. The delay-sampling time causing the delay-time between main- and side-stream sensors is highlighted in red color.

For each multiple-breath washout file analyzed the computed reference delay-time was determined by cross-correlation of the side-stream gas sensor signals (MM and CO2) with the main-stream MM signal. Starting from this reference the delay-time was varied from -50 to +50 ms in steps of 10 ms; FRC and LCI were computed for each delay-time and compared to the reference values.

Results

The FRC values varied from 0.8 to 4.51 (mean 2.33, sd 0.99 l), LCI varied from 5.5 to 9.9 (mean 7.0, sd 1.1).

As expected an increasing delay-time decreased the LCI (Cumulative Expired Volume divided by FRC), see Figure 2a. The change in the computed LCI also depends on the breathing frequency (R² = 0.63), see Figure 2b.

The FRC increased almost linearly over the -50 to +50 ms delay-time change (Figure 1a); mean reference delay-time was 1107 ms (sd 26 ms).


tation of the delay-time will significantly alter results. We recommend that the delay-time is determined with an accuracy of at least 10 ms, this is extremely true when analyzing files of patients with high respiratory rates (e.g. small children). Sampling rate of flow and gas signals should therefore be at least 100 Hz (200 Hz preferred).

Conclusion

For accurate FRC and LCI measurements precise determination of the delay-time is essential and should be reported. Mis-calculation of the delay-time will significantly alter results. We recommend that the delay-time is determined with an accuracy of at least 10 ms, this is especially true when analyzing files of patients with high respiratory rates (e.g. small children). Sampling rate of flow and gas signals should therefore be at least 100 Hz (200 Hz preferred).