Title: AN AUTOMATED SULFUR HEXAFLOURIDE WASHOUT FRC MEASUREMENT SYSTEM FOR ANY MODE OF MECHANICAL VENTILATION AS WELL AS SPONTANEOUS RESPIRATION

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Introduction. Function residual capacity (FRC) is a parameter of interest in a variety of pulmonary pathologies. A sulfur hexaflouride (SF6) washout FRC measurement system has been previously described which automatically measures FRC in patients who are mechanically ventilated[1,2]. This system has a significant advantage since it does not require alteration of FiO2 and is fully automated. The use of this system during anesthesia was severly limited because it required a known constant inspiratory flow. This restricted its use to patients on assist control mechanical ventilation with a constant inspiratory flow pattern. An automated SF6 washout system for use with any type of inspiratory flow pattern has been developed. The accuracy and precision of this system was tested both in normal volunteers and in patients with ARDS.

Methods. The SF6 FRC measurement system consisted of a Siemens (Solna, Sweden) 900i servo ventilator, an IBM PC/AT computer, a Siemens prototype infrared SF6 analyzer, and a computer controllable SF6 delivery system. The SF6 delivery system guaranteed that the inspired concentration of SF6 remains constant at 0.5% no matter what the inspiratory flow. It consisted of a small prototype Siemens piezo-electric valve which is switched on and off at a high frequency. The cycle time of the valve was varied in direct proportion to the instantaneous inspiratory airway flow. The result was that the flow of SF6 was in proportion to the inspiratory flow. The computer started the measurement by turning on SF6 delivery to the patient. The mixed expired SF6 concentration was monitored until three sequential breaths had concentrations within 0.001% of one another. The SF6 delivery was stopped and washout occured. FRC was then calculated by the computer. This system was evaluated in two different human studies. Both studies were approved by our Human Subjects Committee and informed consent was obtained. The accuracy and precision of the system was compared with two conventional clinical techniques for measuring FRC in 12 spontaneously breathing normal subjects. FRC was measured using the SF6 washout system, a Collins helium dilution system, and a Gould body plethysmograph. For each FRC measurement technique, measurements were made until three FRCs were obtained which were within 10% of each other. The sequence of the measurement techniques was randomized. The patients were in the same sitting position for all three techniques. A mixed model analysis of variance was used to test for differences between measurement techniques. The precision of the system was tested in twelve patients who had ARDS and were being mechanically ventilated with PEEP. All care proceeded as normal with the exception that FRC was measured every 30 minutes. The patients were monitored for at least 24 hours and for no more than 96 hours. The patients were not paralyzed and had some spontaneous respiratory effort. As long as PEEP was the same, the patient was considered to have a 'stable' FRC for the purposes of this study. The mean and standard deviation of the FRC values during these 'stable' periods was calculated to determine the precision of the technique.

Results. The absolute and percentage differences between the three FRC measurement techniques used in the 12 normal subjects are summarized in the following table: (Mean ± SEM)

SF6-Helium	SF6-Body Pleth	Helium-Body Pleth	
-20±60	-39±100	-18±108	ml
0.2±1.9	-1.1±2.7	-1.3±3.2	%

There was no significant difference between the three measurement techniques ($F(2,87) = 0.44$, $p = 0.65$). There was no difference in precision between SF6 and helium ($p = 0.35$), SF6 and body plethysmography ($p = 0.66$), or between helium and body plethysmography ($p = 0.94$). There were a total of 1424 FRC measurements made on the 12 ARDS patients. The number of FRC measurements per patient was 105 ± 55.3 (Mean ± SD). The 'stable' periods were 14 ± 15 hours long and ranged from 60 minutes to 63.5 hours. The standard deviation of the FRC measurements during the 'stable' periods was 10.7% ± 1.0% (Mean ± SEM) indicating good precision. In all cases steady state washin of SF6 was achieved within 7 minutes.

Conclusion. The SF6 FRC measurement system for spontaneous respiration was accurate and precise in normal subjects. The precision of the technique was excellent in patients with ARDS considering all of the other factors which effected FRC during some of the long periods over which we assumed FRC to be stable. Since a good steady state washin was achieved in all ARDS cases it does not appear that there was incomplete gas mixing occuring in these patients. This system will provide fully automated accurate FRC measurements during spontaneous respiration as well as SIMV, Pressure Support, CPAP and manual modes of mechanical ventilation. This will make it much more applicable to studies done during anesthesia when patients are rarely ventilated throughout the entire case with assist control mechanical ventilation and a constant inspiratory flow profile.

References.

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2. Jonmaker C, Castor R, Drefeldt B, et al: Measurement of functional residual capacity by sulfur hexaflouride washout. Anesthesiology 63:89-95, 1985

Supported by Siemens-Elema Corp (Solna, Sweden)