Using a mathematical model of oxygen transport to monitor pulmonary function following surgery.

S Kjærgaard, SE Rees , J Grønlund , JA Nielsen , M Freundlich , P Thorgaard , E Toft , S Andreassen .

Abstract. *Introduction*: Late postoperative hypoxaemia is common after major surgery, and may be a contributing factor leading to complications. Procedures to identify and monitor the pulmonary abnormalities leading to hypoxaemia range from the use of multicompartmental models and tracers to the estimate of a single effective shunt parameter. We have studied hypoxaemia following coronary artery bypass surgery (CABG) and gynecological laparotomy, and estimated two parameters of a mathematical model of oxygen transport (1) describing pulmonary dysfunction, pulmonary shunt (shunt) and alveolar lung capillary diffusion resistance (Rdiff).

Methods: Patients undergoing CABG surgery were studied 2-4 hours, one, two and seven days after surgery. Patients scheduled for gynecological laparotomy were studied the day before surgery and 2, 8 and 48 hours postoperatively. On each occasion inspired oxygen fraction (FIO_2) was varied in 4 to 6 steps in order to achieve oxygen saturations (SaO_2) in the range of 90 to 100%. Measurements were taken at each inspired oxygen fraction and included: minute volume, respiratory frequency, arterial oxygen saturation (blood samples or pulse oximetry) and end-tidal gases.These measurements were used to estimate shunt and Rdiff.

Results:

Figure 1

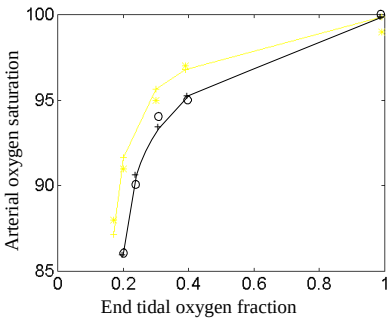
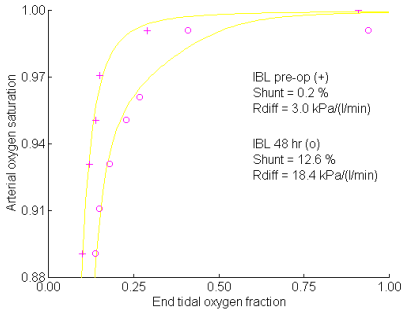


Figure 2.



Figures 1 and 2 illustrate end tidal oxygen fraction plotted against SaO_2 and model fitted curves to these data from one patient HAB 2 (o) and 7 (*) days after CABG (fig. 1), and from one patient IBL before and 8 hours after hysterectomy (fig. 2). For the CABG patient oxygenation is improved from day 2 to day 7. This is illustrated as a shift of the FEO_2/SaO_2 curve to the left. The FEO_2/SaO_2 curves for the hysterectomy patient illustrates the effects of surgery upon oxygenation, i.e. the curve is shifted to the right postoperatively. These lateral displacements of the FEO_2/SaO_2 can be quantified by changes in Rdiff.

Model estimates of “shunt” and “Rdiff” for the two patients were:

	CABG patient		Hysterectomy patient	
	2 day postoperative	7 days postoperative	Preoperative	8 hours postoperative
Shunt (%)	12.8	7.8	0.2	12.6
Rdiff (kPa/(l/min))	205	10.7	3.0	18.4

CONCLUSIONS: Pulmonary dysfunction is often present following surgery. These abnormalities can be described by performing an oxygen titration experiment and estimating two parameters describing pulmonary function shunt and Rdiff. The experiment can be automatically performed by a computerized system. By following these parameters over time it is possible to monitor the improvement or deterioration of lung function following surgery.

1. Andreassen S, Rees S, Kjærgaard S, Winter SM, Morgan CJ, Alstrup P, Thorgaard P, Toft E. Hypoxemia following coronary bypass surgery modeled by resistance to oxygen diffusion. Crit Care Med. In press.