

Title: PRESSURE-VOLUME CURVES OF THE TOTAL RESPIRATORY SYSTEM IN ANESTHETIZED AND PARALYZED CHILDREN

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Introduction: The respiratory system changes considerably in size and composition with growth but there are few studies of the mechanical consequences of these changes. In order to gain some knowledge in this respect we measured the pressure volume relations of the total respiratory system in healthy young children during anesthesia.

Methods: 12 children, 6 months-11 years of age, were studied prior to surgery. Informed consent was obtained from the parents and the study was approved by the local Human Studies Committee. Monitoring was with ECG, BP, and pulse oximetry. Anesthesia was induced with i v thiopental (5-8 mg/kg), succinylcholine (1-2 mg/kg) was given, and the trachea was intubated with a cuffed endotracheal tube. Anesthesia was maintained with 1% halothane in air-oxygen ($FiO_2=0.6$). Vecuronium (0.1 mg/kg) was given immediately before measurements. Functional residual capacity (FRC) was determined with a multiple breath tracer gas washout technique. The pressure-volume measurements were done as follows: The lungs were inflated by a supersyringe to an airway pressure of +25 or +30 cmH_2O , the lower pressure being used in children less than 1 year of age. During the following slow deflation to -20 cmH_2O , the expired flow was interrupted for 0.1 s every 0.4 s by an electro-magnetic occluder placed close to the tracheal tube. The airway pressure at the end of each occlusion (P_{occl}) was measured. Airway flow was measured by a pneumotachograph placed close to the tracheal tube. The signals were recorded by a computer. The volume changes between occlusions were obtained by integration of the flow signal. The volume exhaled between maximum insufflation and the point where P_{occl} was zero (V-exh) was noted. The insufflation-deflation maneuver was repeated with slightly increased maximal pressures so that a satisfactory insufflation plateau was obtained. The resulting lung volume (=TLC) was calculated by adding FRC and V-exh. All volumes were corrected for apparatus deadspace and converted to BTPS conditions. Maximal lung-thorax compliance (C_{LT}) was obtained as the steepest slope of the PV curve. The pressures at 60 and 90 percent of TLC, $P_{60\%}$ and $P_{90\%}$ respectively, were noted. Regression lines and correlation coefficients were obtained by the method of least squares.

Results: The values for TLC, C_{LT} , $P_{60\%}$, and $P_{90\%}$ are shown in the table. PV curves representing patients from four different age groups are shown in the figure. In the six oldest children in whom normal values for TLC were available, measured TLC was $98\pm 13\%$ of predicted¹. FRC and residual volume expressed in % of TLC was 28 ± 4 and $13\pm 5\%$, respectively, and neither changed significantly with growth. C_{LT} increased with the weight of the child: $C_{LT}(\text{ml}/\text{cmH}_2\text{O}) = 2.67 \times \text{Weight (kg)} + 1.07$, $r=0.95$. The corresponding relation for TLC was: $\text{TLC (ml)} = 97.3 \times \text{Weight (kg)} - 243$, $r=0.97$. C_{LT}/TLC decreased with increasing weight ($r=-0.78$) and age ($r=-0.85$). The airway pressures obtained at 60 and

90 percent of TLC were low in the two infants but changed little with age in older children (table).

Discussion: C_{LT} and TLC both increased with age in a regular manner, but the increases were not proportional: C_{LT}/TLC decreased, and the pressures needed to expand the lungs to TLC (fig.) tended to increase with growth. The finding could be explained by increasing muscle support and ossification, and does not necessarily imply a change in the relation between lung compliance and lung volume.

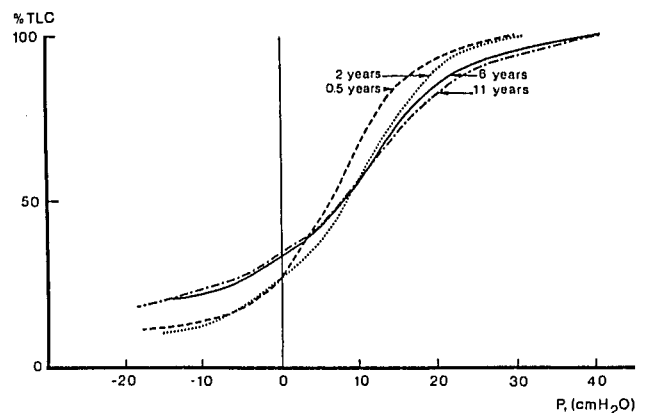


Fig. Effect of age on pressure-volume curve of the total respiratory system. Ordinate, volume in percent TLC; abscissa, tracheal pressure.

TABLE

Pat no	Age yrs	Weight kg	TLC ml	FRC ml (TLC%)	C_{LT} ml/cmH ₂ O	$P_{60\%}$ cmH ₂ O	$P_{90\%}$ cmH ₂ O
1*	0.5	7.0	355	96 (27)	15.7	8.4	18
2	0.6	8.3	391	132 (34)	16.4	7.9	17
3	1.2	10	713	194 (27)	26.8	12	24
4	1.3	10	692	167 (24)	25.6	12	22
5*	1.9	11	831	211 (25)	31.9	11	20
6	2.4	10	954	231 (24)	34.7	12	23
7	4.5	22	1714	359 (21)	65.3	14	23
8	5.2	17	1278	360 (28)	46.4	10	21
9*	5.8	19	2135	702 (33)	68.5	11	23
10	6.4	21	1709	557 (33)	46.4	11	23
11	9.2	32	2714	726 (27)	83.3	14	27
12*	11.3	30	2746	931 (34)	78.5	11	25

* the corresponding PV curve is shown in the figure.

Reference:

- Helliesen PJ, Cook CD, Friedlander L, Agathon Studies of respiratory physiology in children. Pediatrics 22:80-90, 1958