

# Effect of Mechanical Stimulation of the Lower Airway on Respiratory Mechanics in Apneic Anesthetized Man

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In 6 apneic anesthetized patients, mechanical irritation of the lower airway was produced by means of a polyethylene catheter. While vigorous coughing was provoked, there was no change in the mechanical properties of the total respiratory system once apnea was re-instituted, when compared with the control period prior to stimulation.

It has been demonstrated that mechanical irritation of the lower respiratory tract of anesthetized cats results in a decrease in dynamic compliance of the lung.<sup>1</sup> In conscious man, inhalation of inert dust particles<sup>2</sup> and cigarette smoke<sup>3</sup> produce an increase in airway resistance. In patients anesthetized with sodium thiopental and made apneic by hyperventilation, insufflation of ether vapor produced a decrease in total static compliance which was not returned to control levels following the administration of intravenous succinylcholine.<sup>4</sup> It was the purpose of our study to investigate changes in total respiratory mechanics following mechanical irritation of the lower respiratory tract in anesthetized man.

## Method

Six patients were investigated. They were free from disease of the respiratory and cardiovascular systems, as judged by clinical examination. Their physical data are given in table 1.

The method of measurement of the mechanics of respiration has been previously described.<sup>5</sup> In summary, this consists of the introduction into the lungs of the apneic anes-

thetized patient of gas at a known, constant flow rate for a known time and concurrent measurement of the changes in endotracheal pressure. A gas cylinder containing a mixture of 75 per cent nitrous oxide and 25 per cent oxygen was used. A reducing valve on this cylinder was adjusted so that when a solenoid valve was opened, a flow rate of 1 liter per second occurred. The gas was led, via a four-way connector, into the endotracheal tube of the patient. The solenoid valve was electrically operated and could be opened for intervals of from 0.1 to 2.0 seconds. As the pressure at which the reducing valve delivered a flow of 1 liter per second was approximately 50 pounds per square inch, it is evident that the flow rate was essentially constant, with the back pressures observed.

Pressures were sensed in the distal part of the endotracheal tube by means of an open-ended polyethylene catheter (internal diameter 1.37 mm.) which was inserted through the four-way connector. The end of this catheter reached to within 2 to 3 cm. of the end of the endotracheal tube. A series of 9 spirally arranged holes were made at 1.5 cm. intervals from the tip of the sensing catheter. The proximal end of the catheter was connected to a Sanborn physiological pressure transducer (model 267A). The output of the transducer was amplified and recorded on a Sanborn recorder (model 150, 100B) calibrated so that 1 mm. deflection was equivalent to 1 cm. of water pressure change.

To make a measurement of the mechanics of ventilation, the recorder paper was run at 100 mm./second. The recording was continued for 5 to 6 seconds after flow ceased.

From the pressure tracing so produced (fig. 1) we calculated total flow resistance (gas flow plus lung and chest wall viscous resist-

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Received from the Wellcome Research Department of Anaesthesia, McGill University, Montreal, and the Queen Elizabeth Hospital, Montreal, Canada; accepted for publication January 3, 1966.

TABLE 1. Physical Characteristics and Results for Patients Studied, to Show the Effect of Mechanical Stimulation of the Lower Respiratory Tract

Pt.	Sex	Age (yrs.)	Height (cm.)	Weight (kg.)	Total Flow Resistance (cm. H <sub>2</sub> O/l./sec.)		Total Static Compliance (ml./cm. H <sub>2</sub> O)		Pressure Stress Relaxation (mm. H <sub>2</sub> O/cm. H <sub>2</sub> O)	
					Control	After Stimulation	Control	After Stimulation	Control	After Stimulation
1	M	47	176	70.5	8.6 (3)	8.8 (4)	84.9 (3)	81.1 (3)	2.6 (3)	2.5 (3)
2	M	38	180	91.8	6.1 (4)	6.1 (4)	84.6 (4)	81.6 (4)	2.1 (4)	2.3 (4)
3	F	49	158	61.4	3.9 (5)	5.2 (4)	82.4 (5)	89.6 (4)	2.1 (5)	2.6 (4)
4	F	38	152	43.2	5.8 (5)	6.9 (3)	69.4 (5)	64.1 (3)	1.8 (5)	1.9 (3)
5	F	32	163	50.9	6.2 (5)	5.8 (5)	100.3 (5)	98.7 (5)	2.1 (5)	2.4 (5)
6	F	44	170	48.2	5.1 (4)	5.5 (4)	86.2 (4)	76.4 (4)	2.4 (4)	2.2 (4)
Mean difference					+0.4 (±0.27)		-2.7 (±2.3)		0.1 (±0.1)	
<i>P</i>					0.2 0.1		0.3 0.2		0.3 0.2	

The figures are the arithmetic means with, in parentheses, the number of individual readings. The control readings were made for 5-7 minutes before stimulation of the lower respiratory tract with a polyethylene catheter. The readings after stimulation were completed within 5-7 minutes of re-instituting apnea.

The mean difference is the mean of the differences for each patient, and the standard error of the mean is also given. The *P* value is the probability that this mean difference arose by chance alone.

ance), total static compliance and total pressure stress relaxation. It should be noted that the initial pressure rise,  $P_2 - P_1$ , included the resistance of that part of the endotracheal tube distal to the pressure sensing device; in the cases reported here no subtraction was made for this as it remained a constant factor throughout the experiment.

Procedure

Premedication was accomplished with intramuscular pentobarbitone, 100 mg. given approximately 90 minutes prior to induction of anesthesia which was as follows. An injection of 3 ml. 4 per cent lidocaine was made through the crico-thyroid membrane. The tongue and posterior pharynx were anesthetized with 0.5

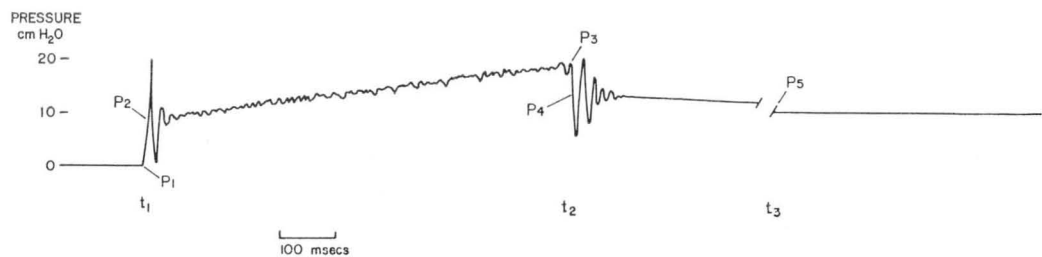


FIG. 1. Reproduction of the pressure within the trachea during constant flow rate of 1 liter/second. Zero pressure equals atmospheric pressure. Flow occurs between  $t_1$  and  $t_2$ . Static conditions are established at  $t_3$ .  $P_2$  is measured at the intersection of a line projected backwards from the slope of the uniform rise in pressure ( $P_2$  to  $P_3$ ) and a line vertical to  $P_1$ .  $P_4$  is measured where a projection backwards from the slow decline in pressure ( $P_4$  to  $P_5$ ) meets a vertical line from  $P_3$ .  $P_5$  is measured when the pressure has become approximately stable, not varying more than 0.5 cm. of water in 2-3 seconds.

The calculations from this tracing are, if *V* is volume introduced: (1) Total flow resistance =  $P_2 - P_1$  cm. of water/liter/second. (2) Total static compliance =  $V/P_5 - P_1$  ml./cm. of water. (3) Total kinetic compliance =  $V/P_4 - P_1$  ml./cm. of water. (4) Pressure stress relaxation =  $P_4 - P_5/P_4 - P_1 \times 10$  mm. of water/cm. of water. (5) Mean rate of stress relaxation =  $P_4 - P_5/t_3 - t_2$  cm. of water/second.

ml. 4 per cent lidocaine. Sodium thiopental in 2 per cent solution was then administered in a dosage of 5 mg./kg. body weight, over 20 seconds. Apnea usually occurred, and if not, it was instituted by controlled ventilation. A Macintosh laryngoscope was gently inserted and a further 0.5 ml. 4 per cent lidocaine was applied to the superior surface of the vocal cords.

The trachea was intubated with either a 34 F, or 36 F, cuffed portex tube, depending on the size of the patient. The cuff was gently inflated until no gas leak occurred, and ventilation maintained with a Bennett ventilator, using a gas mixture of nitrous oxide 6 liters/minute and oxygen 2 liters/minute. If at any time during the maneuvers of the induction—except of course the initial transcrico-thyroid injection—any untoward reaction such as hiccuping or coughing occurred, the patient was not included in the series. This accounts for the small number of cases reported.

Three to five control measurements of total flow resistance, total static compliance and pressure stress relaxation were then made over approximately seven minutes. A polyethylene catheter was next inserted through the endotracheal tube, and the lower trachea and bronchi irritated. This usually provoked a vigorous cough from the patient. If no reaction occurred the case was rejected from the series. Apnea was re-instituted by gentle assistance of ventilation. Three to five sets of measurements were then performed, over approximately five minutes. The first measurement was made within 30 seconds of the re-institution of apnea.

All measurements were completed before operation, with the patient in the supine position. Before each measurement, 3 or 4 manual hyperinflations of the lungs to 30–40 cm. water were performed to maintain a uniform inflation history.

### Results

The results are shown in table 1. In the following summary, the mean difference with the standard error is given, and the probability ( $P$ ) that this difference arose by chance alone.

The total flow resistance (lower airway plus lung and chest wall viscous resistance, plus the distal part of the endotracheal tube) showed a mean value of 6.0 cm. of water/liter/second in the control period. Following stimulation, there was a mean difference of  $+0.4 \pm 0.27$  cm. of water/liter/second ( $P = 0.2 - 0.1$ ).

The mean total static compliance in the control period was 84.6 ml./cm. of water. Following stimulation, there was a mean decrease of  $2.7 \pm 2.3$  ml./cm. of water ( $P = 0.3 - 0.2$ ).

The mean total pressure stress relaxation<sup>5</sup> in the control period was 2.2 mm. of water/cm. of water. Following stimulation there was a mean increase of  $0.1 (\pm 0.1)$  mm. of water/cm. of water ( $P = 0.3 - 0.2$ ).

### Discussion

The results suggest that mechanical irritation of the lower respiratory tract of apneic anesthetized man does not result in any significant change in the mechanical properties of the lungs and chest wall which can be measured once apnea has been re-instituted.

It is possible that the procedure of induction and intubation had already produced reflex alterations in lung mechanics, which prevented any further change following stimulation with a polyethylene catheter. Values for the total flow resistance (*i.e.*, upper and lower airway and lung and chest wall tissue resistance) vary. Using the tank respirator method, mean values of 5.0 cm. of water/liter/second<sup>6</sup> and 4.8 cm. of water/liter/second<sup>7</sup> have been found. From passive expiration in seated subjects, the mean value was 5.3 cm. of water/liter/second.<sup>8</sup> Measurements with the method of rapid oscillations of mouth pressure provided mean values of 1.78 cm. of water/liter/second,<sup>9</sup> and 1.9 cm. of water/liter/second.<sup>7</sup> Upper airway resistance probably accounts for approximately 30 per cent of the total.<sup>9</sup> Our mean figure of 6.0 cm. of water/liter/second is for lower airway and lung plus chest wall tissue resistance, and also includes the distal part of the endotracheal tube. The latter resistance was not measured but would be approximately 2 cm. of water/liter/second. It is impossible, therefore, to draw any firm con-

clusions as to whether any significant change in flow resistance had occurred with the method of induction and intubation, but it is perhaps unlikely as our results differ little from those obtained at more normal frequencies. It should be mentioned that it is not necessary for there to be any visible sign—coughing or movement—for changes in airway diameters to occur.<sup>10</sup>

It is also possible that failure to demonstrate any changes following stimulation was because the response was transient and had returned to control values before the first measurement was made. Nadel and Widdicombe<sup>11</sup> demonstrated that mechanical irritation of the larynx of anesthetized cats produced an increase in total lung resistance which returned to control levels within one minute. Our first measurement was made within 30 seconds of re-instituting apnea, but there was a longer time interval from the time of stimulation.

The reported fall in total static compliance following insufflation of ether into apneic anesthetized man was not restored to control levels following the intravenous administration of succinylcholine.<sup>4</sup> If the same were found following mechanical stimulation of the airway, it would suggest that stimulation during intubation of the trachea, for example, would result in a fall in static compliance which would not be reversed by the intravenous injection of muscle relaxants. However, we did not observe any significant change in total static compliance following mechanical stimulation.

The difference between the result of stimulation by ether when compared to mechanical irritation might be explained by a difference in the site of action. It has been postulated that these types of stimuli act on different receptors<sup>12</sup> and hence the reflex effect of each may be different.

### Summary

In 6 anesthetized patients, mechanical irritation of the lower respiratory tract provoked coughing. However, once apnea had been re-

instituted there was no significant difference in the mechanical properties of the lungs and chest wall when compared with the control period prior to irritation.

We are grateful to Dr. W. G. Cullen and the members of his department for their full cooperation during the course of this investigation and to the surgeons of the Queen Elizabeth Hospital who gave much of their valuable time.

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