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The Effects of Ultrasonic Aerosols on the Total Respiratory Resistance of the Intubated Patient

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Ultrasonically-produced aerosols of water or saline solution cause considerable increases in airway resistance when inhaled for 15 minutes through the mouth by patients with chronic obstructive airway disease, but produce no significant changes in normal subjects.[1] Because ultrasonic aerosols frequently are used to humidify the airways of patients with tracheostomies, we were interested to see if an ultrasonically-generated aerosol delivered directly to the tracheobronchial tree via endotracheal tube, bypassing the larynx, affected respiratory resistance.

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MATERIALS AND METHODS

We studied 18 patients without histories suggestive of chronic bronchitis or asthma and one patient who had historical and diagnostic evidence of chronic obstructive and restrictive pulmonary disease. All patients were in an intensive care unit and each had either a tracheostomy or an endotracheal tube in place to facilitate continuous artificial ventilation and/or tracheobronchial toilet. Prior to study all

TABLE 1. Total Respiratory Resistance (R_T) before and after 15-minute Inhalation of an Ultrasonically-produced Aerosol of One-half Physiologic Saline Solution*

Patient	Age (years)	Sex	Diagnosis	Total Respiratory Resistance (cm H_2O/l/sec)	
				Control	After 15-min Aerosol Inhalation
1	54	M	Mitral valve replacement	1.8	2.4
2	44	F	Postoperative bowel resection; generalized angiitis	4.2	4.6
3	28	M	Polio	1.0	1.0
4	65	F	Cerebral injury 2° to cardiac arrest	2.4	2.4
5	19	M	Traumatic brain injury	2.2	2.3
6	39	F	Flail chest	5.2	4.4
7	58	M	Traumatic brain injury	1.2	1.9
8	64	M	Mitral valve repair	1.8	2.7
MEAN				2.5 ± 1.5	2.7 ± 1.2†

* Each patient had a tracheostomy or endotracheal tube in place.
† $P > 0.1$.

patients were inhaling heated mist for humidification of the inhaled air.

The patients without obstructive airway disease were divided into two groups to investigate the effect of duration of inhalation of the ultrasonic aerosol. In eight patients measurements of total respiratory resistance (R_T) were made before and after 15 minutes of inhalation of a mist of one-half physiologic saline solution produced by an ultrasonic nebulizer * set to deliver 3.0 ml water/min. Ten patients inhaled the same mist for two hours; their R_T values were measured every 30 minutes. The patient with proven obstructive airway disease also inhaled the aerosol for two hours.

Total respiratory resistance (resistance of airways, lung, and chest wall) was measured with the forced-oscillation technique [2] during apnea at end-tidal exhalation (functional residual capacity). A small-amplitude 3-cycle/sec pressure oscillation was applied to the trachea via the endotracheal tube. The pressure difference between peak inflation and deflation flows produced by the 3-cycle/sec oscillation was divided by the amplitude of the resultant flow transient to give the value for R_T

$$(R_T = \frac{\text{amplitude of pressure at peak flow } (cmH_2O)}{\text{amplitude of oscillating flow } (l/sec)}).$$

To minimize possible effects of hypoxia, volume history, and secretions on R_T, endotracheal suction followed by several hyperinflations with 100 per cent O_2 was carried out prior to each measurement.

Results

There were no changes in R_T in the eight patients who inhaled the ultrasonic mist for 15 minutes (table 1). In the ten patients who inhaled the mist for two hours there were small but significant increases in R_T over control values at 30, 90 and 120 minutes (table 2). There was, on the average, no tendency for R_T to increase with duration of exposure. The patient with obstructive lung disease had a progressive increase in R_T to a value of more than 100 per cent of control at 120 minutes (table 3).

* DeVilbiss Model 880.

Table 2. R_T before and after Every 30 Minutes of Two-hour Inhalation of an Ultrasonically-produced Aerosol of One-half Physiologic Saline Solution*

Patient	Age (Years)	Sex	Diagnosis	Total Respiratory Resistance (cm H_2O/l/sec)				
				Control	30 Min.	60 Min.	90 Min.	120 Min.
9	73	M	Cerebrovascular accident	2.3	4.2	3.0	4.0	3.0
10	62	F	Mitral valve replacement	4.0	7.2	—	5.8	6.1
11	40	F	Aspiration pneumonitis, peritonitis	6.5	6.6	8.2	6.3	6.6
12	62	M	Heart failure, renal failure	3.1	4.3	3.3	5.0	6.1
13	44	M	Tuberculous meningoencephalitis	3.5	3.4	3.4	2.0	2.1
14	47	M	Aortic valve replacement	5.0	5.6	3.4	6.4	5.5
15	25	M	Crushed chest	3.4	3.4	3.4	4.0	4.3
16	63	M	Rib fractures	2.8	3.8	4.6	4.5	5.0
17	24	M	Crushed chest	3.3	3.8	5.2	4.0	4.3
18	18	M	Traumatic brain injury	2.5	2.4	3.1	2.5	3.0
MEAN				3.6 ± 1.3	4.5 ± 1.5	4.2 ± 1.7	4.7 ± 1.5	4.6 ± 1.5
					$P < 0.05$	$P > 0.1$	$P < 0.05$	$P < 0.05$

* All patients had tracheostomy or endotracheal tubes in place. The mean values at each time are compared with control values.

TABLE 3. R_T in a Patient with Chronic Obstructive and Restrictive Airway Disease and a Tracheostomy during Two-hour Inhalation of an Ultrasonic Aerosol of One-half Physiologic Saline Solution

Patient	Age (years)	Sex	Diagnosis	Total Respiratory Resistance (cm H_2O/l/sec)				
				Control	30 Min.	60 Min.	90 Min.	120 Min.
19	62	M	Heart failure, obstructive airway disease, pulmonary fibrosis	3.6	6.1	7.7	7.2	8.8

DISCUSSION

The respiratory oscillation technique is useful because it permits this type of study of patients in an intensive care ward without causing them discomfort or interrupting their treatment. However, the method does not monitor lung volume. Some or all of the patients may have had some increases in airway resistance which were masked by increases in their functional residual capacity. Our data from a previous study[1] indicate that patients with obstructive airway disease have increases of about 100 per cent in airway resistance (corrected for changes in lung volume as measured in the body plethysmograph) after inhalation of ultrasonic aerosols for 15 minutes. Such changes are unlikely to be completely masked by increases in lung volume. In addition, the marked increase in R_T in patient 19 indicates that the method will show major increases in airway resistance.

There was a statistically significant increase in R_T in these patients without preoperative evidence of obstructive airway disease when the ultrasonic aerosol was inhaled through a tube directly into the airway for 30 minutes or more. This change would increase the work of breathing only slightly. No increase in R_T was evident after 15 minutes. None of the 18 patients showed any clinical evidence of respiratory distress except coughing during inhalation of the aerosol.

The cause of the increase in R_T when an ultrasonic aerosol is inhaled is the subject of speculation. If it is due to an accumulation of fluid blocking small airways, then R_T should have increased progressively with the time of inhalation of the mist; this did not happen. The increase in resistance can be prevented or treated with bronchodilator (isoproterenol) aerosols, suggesting that bronchospasm may play a part.[1] The present study suggests that a bronchoconstrictor reflex from the larynx[3] is not necessary for the response. The larynx was bypassed, and yet slight increases in resistance were found in patients whose airways presumably were normal and a dramatic increase in R_T was found in the patient with obstructive airway disease.

REFERENCES

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