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Potential Pulmonary Barotrauma When Venting Anesthetic Gases to Suction

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Routine scavenging from anesthesia machines has been advocated to decrease health hazards arising from trace concentrations of anesthetic gases.[1] Scavenger systems utilizing wall suction require an air inlet to prevent subatmospheric pressure from being applied to the valve outlet. If the air inlet is occluded, subatmospheric pressure develops at the valve exhaust, with malfunction of the valve. To study this potential anesthetic hazard we examined the behaviors of three commercially available scavenger valves with the air inlet to the scavenger system occluded.

METHODS

An anesthesia circle system incorporating a carbon dioxide absorber was assembled using Ohio disposable corrugated tubing, Y-piece and reservoir bag. A Dupaco valve or one of two Ohio gas-evacuator relief valves (henceforth called Ohio diaphragm‡ and Ohio popoff valves§) was installed and a T-piece scavenger system attached. Pressure transducers (Sanborn 267B) were employed to measure circuit and suction pressures, which were recorded on a Sanborn 350 oscillograph at a paper speed of 5 mm/sec. Flow through the valve was measured using a Fleisch pneumotachograph placed on the circuit side of each valve. When entry of room air through the open end of the T-piece was prevented, wall suction generated subatmospheric pressures at the exhaust side of the scavenger valve. Maximum pressure changes in the anesthesia circuit and scavenger system were measured at different valve adjustments using inflow rates of oxygen to the anesthesia circuit of 2.5, 5, or 7.5 l/min. Finally, an inlet relief valve was inserted between the suction and scavenger valve and measurements repeated. The wall suction used had a recorded flow of 0.67 l/sec and generated a static subatmospheric pressure of 440 torr.

RESULTS

When suction was applied to the exhaust side of these scavenger valves, by occluding the open end of the T-piece, several patterns of gas flow across the valves were observed (fig. 1). The Ohio diaphragm valve prevented suction from evacuating the anesthesia circuit, whereas both the Dupaco and Ohio popoff valves permitted significant flows across the valves until they were almost closed.

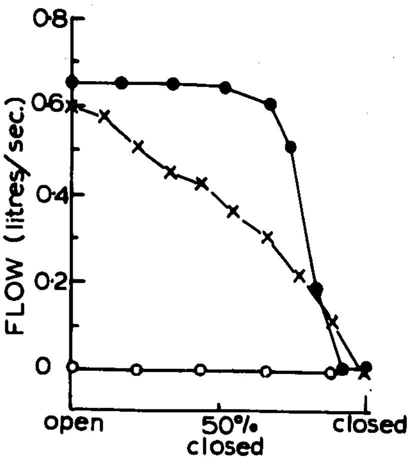

FIG. 1. Effects of wall suction on flows through each valve at various adjustments. O = Ohio diaphragm; ● = Dupaco; × Ohio popoff.

Table 1 lists pressures recorded within the anesthesia circuit (potentially applied to patients' airways) when wall suction was applied directly to the exhaust sides of the Dupaco and Ohio valves. Subatmospheric pressures within the anesthesia circuit were as high as 380 torr using the Dupaco valve, and 70 torr with the Ohio popoff. In both valves, subatmospheric pressure developed within the circuit until the valve was completely closed. Thus, if subatmospheric pressures are applied directly to the exhaust ports of these scavenger valves, potentially dangerous subatmospheric pressures may develop in the anesthesia circuit, at settings clinically used for spontaneous or manually controlled ventilation.

Subatmospheric pressures applied directly to the exhaust port of the Ohio diaphragm valve suck the valve disc onto the seat, preventing egress of gas from the anesthesia circuit. Circuit pressure subsequently increases (with 5 l/min flowing into the circuit) until the valve opens and circuit pressure falls (fig. 2). The peak pressures recorded within the anesthesia circuit are directly related to the magnitude of subatmospheric pressure applied to the outlet port (table 2). When full suction is applied directly to the outlet, the diaphragm valve becomes effectively closed and it is impossible to empty the circuit by squeezing the reservoir bag.

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§ Stock No. 216-6414-880.

TABLE 1. Peak Subatmospheric Circuit Pressures (torr) Recorded with Wall Suction Applied to the Outlets of Dupaco and Ohio Popoff Valves at Three Rates of Gas Inflow

	Ohio Popoff Valve				Dupaco Popoff Valve		
	2.5 l/min	5 l/min	7.5 l/min		2.5 l/min	5 l/min	7.5 l/min
Valve setting				Valve setting			
Open	35	32	28	Open (0°)	370	350	320
¼ rotation	54	48	43	30°	380	335	335
½ rotation	60	53	46	60°	380	355	350
¾ rotation	61	53	45	90°	375	350	350
1 rotation	52	45	39	120°	365	330	320
1¼ rotation	45	37	32	135°	290	240	135
1½ rotation	40	30	21	150°	0	0	0
1¾ rotation	33	23	16	180°	0	0	0
2 rotation	30	21	14	Closed	0	0	0
Closed	0	0	0				

Figures 2 and 3 illustrate the effects of a negative-pressure relief valve inserted anywhere in the outlet tubing of the scavenger system. If pressure in the scavenger system falls to 2 torr subatmospheric, room air is sucked into the system through the inlet relief valve. This prevents the application of subatmospheric pressure greater than 2 torr to the outlet port of the scavenger valve. Suction pressure applied directly to the exhaust port of an open Dupaco valve results in identical subatmospheric pressure within the anesthesia circuit (fig. 3), as there is little resistance to flow across the valve when open. After introduction of the negative-pressure relief valve, circuit pressure declined only 2 torr in spite of total occlusion of the open end of the T-piece (fig. 3, *C* and *D*), a maneuver that would otherwise result in 380 torr subatmospheric pressure in the circuit (table 1). A similar beneficial effect was seen when the relief valve was used in conjunction with the Ohio diaphragm valve; no increase in circuit pressure occurred in spite of total occlusion of the open end of the T-piece (fig. 2, *C–E*). However, when the open end of the relief valve was also occluded, circuit pressure rose as the circuit was filled by inflowing gas (fig. 2, *E* and *F*).

DISCUSSION

The use of equipment to scavenge waste anesthetic gases has introduced yet another potential hazard for the patient and the anesthesiologist. We have shown that each scavenger valve tested failed to function safely when wall suction was applied directly to the exhaust port. (This may easily happen in practice if the air-entrainment port is obstructed.) Two of the valves tested enabled suction to evacuate the anesthesia circuit so that subatmospheric pressures ranging from 20 to 380 torr were recorded within the circuit. A third valve was effectively sealed by the application of subatmospheric pressure to its outlet, resulting in positive pressure within the circuit. Such subatmospheric pressures may induce pulmonary edema[2] or atelectasis,[3] and the positive airway pressures recorded could result in cardiovascular collapse[4] or trauma to pulmonary parenchyma.

Whitcher *et al.* evaluated several modes of scavenging anesthetic gases.[5] They preferred to vent gases to the outlet port of a nonrecirculating air-conditioning system, but considered wall suction to be a suitable alternative. Because atelectasis was a potential hazard, they advocated an "interfacing device" (such as a negative-pressure relief valve) to prevent development of large subatmospheric circuit pressures. Our data confirm their fears and extend their observations on the possible consequences of venting gases to suction. The inclusion of a pressure relief valve may be mandatory to prevent inadvertent subatmospheric circuit pressures. However, these valves, too, may malfunction by becoming occluded (fig. 2). Therefore, the function of such valves should be periodically checked and the possibility of occlusion of the outlet prevented.

All of the valves tested are differently designed. The Dupaco has a variable orifice with no mechanism to prevent suction from evacuating the cir-

TABLE 2. Peak Circuit Pressures Recorded in the Anesthesia Circuit with Various Suction Pressures Applied to the Exhaust of the Ohio Diaphragm Valve at 5 l/Min Gas Inflow

	Circuit Pressure (torr)				
	Position of Control				
	5*	4	3	2	1
Suction pressure (torr subatmospheric)					
0	1.5	8	19	33	41
12	4	13	24	36	45
26	9	19	29	40	48
46	14	25	34	45	53
61	20	29	42	54	

* Number of rings remaining visible on the control knob.

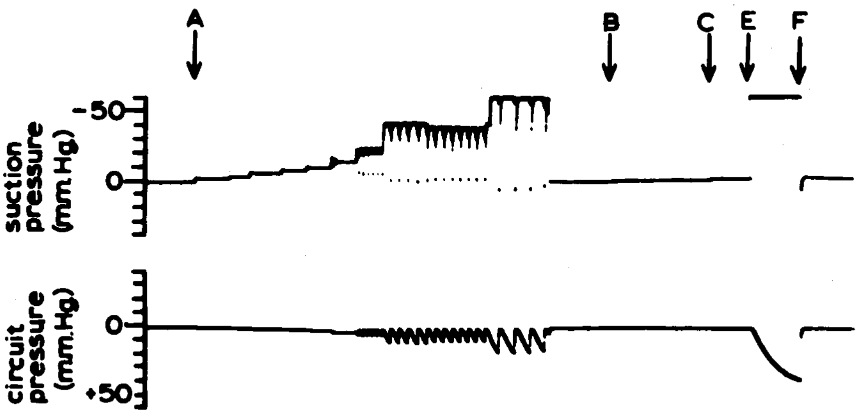

FIG. 2. The effect of increasing suction pressure on circuit pressure using the Ohio diaphragm valve when open. *A* negative-pressure relief valve is incorporated into the circuit at *B*, full wall suction applied at *C*, the inlet to the negative-pressure relief valve is occluded at *E* and released at *F*.

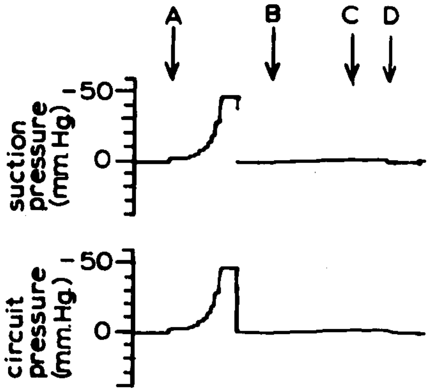

FIG. 3. The effect of increasing suction pressure on circuit pressure, using the Dupaco valve in the open circuit with 51 flowing into the anesthetic circuit (*A*). An inlet relief valve is incorporated (*B*). Full wall suction is applied at *C* and released at *D*.

cuit. The Ohio diaphragm valve is designed so that it closes when subatmospheric pressure is applied to its exhaust port. This prevents the occurrence of subatmospheric circuit pressure, but results in accumulation of gases and positive pressure within the anesthesia circuit. The design of the Ohio popoff valve enables room air to be entrained through orifices around the valve itself when subatmospheric pressure develops at its outflow port. However, this measure is inadequate and pressures as high as 70 torr subatmospheric were recorded within the circuit using this valve. Thus, specific features designed to avert subatmospheric circuit pressures appear either to be ineffective (Ohio popoff) or to result in positive circuit pressure (Ohio diaphragm). A negative-pressure relief valve inserted in the outlet system is more effective in preventing abnormal circuit pressures than any of these commercial valves *per se*.

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