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# Prolonged "Phantom" Square Wave Capnograph Tracing after Patient Disconnection or Extubation

## Potential Hazard Associated with the Siemens Servo 900c Ventilator

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**Background:** The authors report on the appearance of misleading square wave "phantom" capnograph tracings for approximately 3 min after disconnection from the Siemens Servo 900c ventilator. A series of experiments are described to examine the mechanism of this phenomenon.

**Methods:** Patients were ventilated using the Siemens Servo 900c ventilator with the following settings: minute volume, 5 l/min; respiratory rate, 8 breaths/min; PEEP, 0 cm H<sub>2</sub>O; trigger sensitivity, 20 cm H<sub>2</sub>O. The ventilator was connected to the Siemens Servo Evac 180 evacuation system (25 l/min on evacuation flowmeter). Airway pressure and capnography were recorded at the Y piece during ventilation and after disconnection. A back-up ventilator was used to support the patient during disconnection of the ventilator being studied.

**Results:** Initially, the "phantom" capnograph tracing closely resembled the square wave capnograph tracing before disconnection, but the amplitude and shape of the waveform gradually decayed. Based on experiments described in this article, the authors show that the carbon dioxide for the "phantom" capnograph tracing comes from the gas exhaled by the patient in the last breaths before disconnection and which is present in both the expiratory tubing and in the evacuation system. The small pressure gradient between the exhaust reservoir and the atmosphere causes reverse flow of expired gas after disconnection, when both the nonreturn flap valve at the exhaust outlet is open (due to minimal valve incompetence) and when the expiratory servo valve is open (in the absence of positive end-expiratory pressure). This continuous reverse flow is detected by the capnograph but is interrupted intermit-

tently by each attempted positive pressure ventilation, thereby creating a "phantom" capnograph.

**Conclusions:** After accidental disconnection of the patient from the breathing system, or after accidental extubation of the trachea, the "phantom" capnograph is likely to confuse even an experienced anesthesiologist into the mistaken belief that his rapidly deteriorating patient is being ventilated adequately. Several potential mechanisms to eliminate this phenomenon are outlined, including the avoidance of zero positive end-expiratory pressure. "Phantom" capnography provides an illustration of the dangers of using monitoring techniques, however reliable, as a substitute for vigilant clinical observation. (Key words: Carbon dioxide. Complications. Monitoring. Ventilation, mechanical.)

ACCIDENTAL disconnection from mechanical ventilation is a frequent occurrence in the operating room or critical care setting.<sup>1-4</sup>† The most common site for disconnection is at the junction of the tracheal tube and the breathing system.<sup>2,3</sup> Unrecognized disconnection is a potentially catastrophic event and has been an important source of anesthetic morbidity and mortality.<sup>1</sup> Nevertheless, clinical concern has decreased in recent years with the widespread use of several monitors that help to readily diagnose patient disconnection. These monitors include low airway pressure alarms,<sup>5</sup> low tidal volume or minute volume ventilation alarms,<sup>5</sup> and capnography.<sup>6</sup> However, overreliance on these monitors may impair both clinical vigilance and the rapid diagnosis of disconnection if there is monitor dysfunction.<sup>7</sup>

We report on the reproducible appearance of misleading square wave "phantom" capnograph tracings for approximately 3 min after disconnection of a patient from the Siemens Servo 900c ventilator (Siemens-Elcoma AB, Sweden). We also describe a series of short experiments in which we were able to determine that this phenomenon is due to an inherent design fault that arises when using volume control or pressure control

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† Cooper JB, Couvillon LA Jr: Accidental breathing system disconnections. HHS Publication FDA 86-4205, U.S. Department of Health and Human Services: Public Health Services, Food and Drug Administration, 1986.



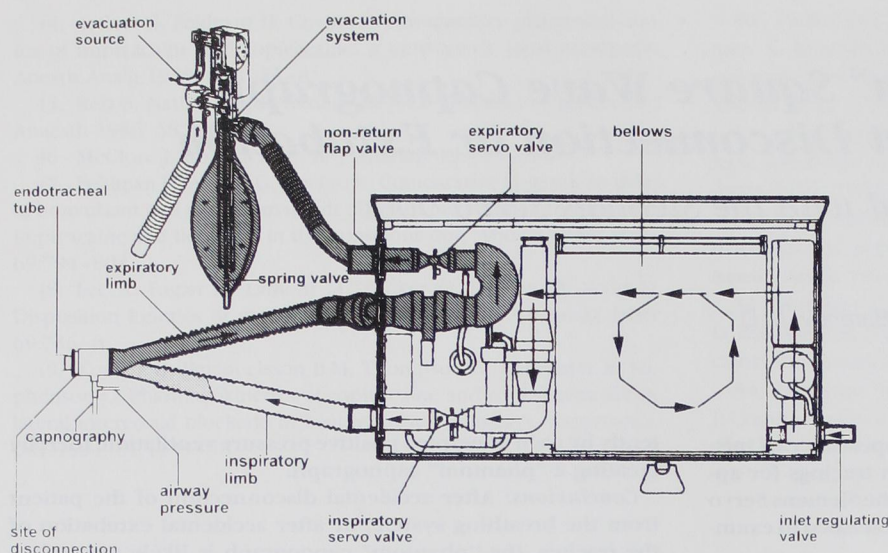


Fig. 1. The Siemens Servo 900c ventilator and the Siemens Servo Evac 180 evacuation system and the genesis of "phantom" capnography (see text for explanation) are shown. The dark shaded area is the carbon dioxide-containing gas within the expiratory limb and the evacuation system; the light shaded area is the carbon dioxide-containing gas within the portion of the inspiratory limb adjacent to the Y piece. The arrows show the flow of fresh and exhaled gas.

ventilation with the Siemens Servo 900c in the absence of positive end-expiratory pressure (PEEP) and when the ventilator is connected to an evacuation system based on noncontinuous suction of exhaust gases (Siemens Servo Evac 180). Finally, we have made some recommendations for simple design changes that would curtail this extremely dangerous phenomenon.

## Materials and Methods

In the following studies, two ventilators were in use at all times: (1) the Siemens Servo 900c ventilator under observation, which was disconnected during the conditions described in the experiments below (while connected to the carbon dioxide analyzer), and (2) a backup ventilator to maintain patient ventilation (and anesthetic delivery) after disconnection from the ventilator under investigation. The results presented were verified in three separate Siemens Servo 900c ventilators; "phantom" capnography was observed in all of them after disconnection of the breathing system.

The Siemens Servo 900c ventilator<sup>8,9,†</sup> is a pneumatically powered, electronically controlled, spring driven, bellows ventilator<sup>9</sup> (fig. 1). The force to expand the bellows is supplied by compressed gas that enters *via* a one-way gas inlet regulating valve. This force acts against a spring assembly, whose tension is adjustable

and is termed the preset working pressure. The ventilation cycle is controlled by two scissors valves, namely the inspiratory and expiratory servo valves. During inspiration, the inspiratory valve opens and the expiratory valve closes; this process is reversed during expiration. The degree to which these scissors valves open is governed by the feedback from the pressure and flow transducers on the inspiratory and expiratory limbs.

The Siemens Servo Evac 180 evacuation system<sup>§</sup> (Siemens-Elcoma AB, Sweden) (fig. 1) consists of a receiving unit connected to a suction source with an evacuation flowmeter that should display at least 25 l/min. The receiving unit continuously drains a reservoir tube that is open to room air. In addition, with upward displacement of a controlling valve, the receiving unit drains the evacuation bag. This valve is controlled by a long spiral spring that extends down to the bottom of the evacuation bag. When the patient exhales, the evacuation bag fills and the longitudinal bag length shortens, and so the valve spring is pushed upward, exposing the evacuation bag to suction from the receiving unit. When the evacuation bag is slack, the valve spring is not elevated and no suction is applied to the exhaust gases.

The capnography tracings presented were recorded using a sidestream analyzer (Datex AS3, Finland), although results were verified with a mainstream device (Hewlett Packard Model 66S, Andover, MA). The gas sampling rate of the Datex capnograph was 200 ml/min.

Airway pressure was recorded using a pressure trans-

† Siemens Servo Ventilator 900c Operating manual.

§ Siemens Servo Evac 180 Operating manual.



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ducer (Transpac I.V., Abbott Ireland Ltd., Sligo, Ireland) filled with air and connected to the breathing system. The transducer was connected to the invasive blood pressure port of the central monitoring processor (Datex AS3, Helsinki, Finland).

The plastic tubing to both the airway pressure transducer and the capnograph was connected to a three-way stopcock attached to the expiratory arm of the Y-piece. The tracheal tube was connected directly to the stem of the Y-piece; this was the site of disconnection used in all the experiments. The volume between the site of disconnection and the carbon dioxide sampling site was 3.5 ml.

The breathing tubing was 15-mm diameter corrugated tubing (Intersurgical, Wokingham, Berks, UK) with segment dividers that allowed the implantation of T-piece units with Luer lock fittings for the measurement of capnography and airway pressure at various locations within the inspiratory and expiratory limbs.

## Results

### *Demonstrating the "Phantom" Capnograph*

The patients' lungs were ventilated in the volume control mode (identical results were seen in the pressure control mode) with trigger sensitivity  $-20$  cm H<sub>2</sub>O, as recommended,<sup>‡</sup> with PEEP  $0$  cm H<sub>2</sub>O. The ventilator exhaust outlet was connected to the Siemens Servo Evac 180 evacuation system (with the evacuation flowmeter set at  $25$  l/min, as recommended<sup>§</sup>). After disconnection from ventilation, "phantom" capnograph tracings were observed. Initially, the "phantom" capnograph tracing closely resembled the square wave capnograph tracing before disconnection, both in amplitude and in shape (fig. 2A). No phase lag was observed in the capnograph tracing, suggesting that the carbon dioxide was still being detected in the expiratory phase of the ventilator cycle. Similar observations were made during ventilation through the carbon dioxide analyzer after extubation of the trachea at the end of surgery.

Maintaining mechanical ventilation past the carbon dioxide sampling site during these conditions led to persistent "phantom" capnograph tracings for approximately  $3$  min. The amplitude and shape of the waveform gradually decayed during this time (fig. 2B). The rate of this decay was not significantly affected by the following factors: the length of the expiratory limb from the patient to the machine outlet, the inspiratory mi-

nute volume setting, the rate of ventilation, the working pressure, and the method of capnography (sidestream or mainstream).

### *Determining the Source of the Carbon Dioxide for the "Phantom" Capnograph*

The obvious source of the carbon dioxide was the expiratory limb that contained the last exhaled breaths of the patient before disconnection. This could be demonstrated experimentally. First, by recording inspired carbon dioxide at a point halfway along the inspiratory limb, it was possible to show that no carbon dioxide was detected there, either during normal ventilation or during disconnection. This was consistent with the non-rebreathing design of the ventilator, as described earlier. In addition, by connecting a false lung (1-l breathing bag) to the Y-piece while maintaining ventilation after disconnection, the "phantom" capnograph tracing disappeared immediately and did not reappear, even after the false lung was disconnected (fig. 2C). This implied that the fresh gas "exhaled" by the false lung was able to wash out the source of the carbon dioxide from the expiratory limb. Finally, as will be described later, changes to the size of the carbon dioxide reservoir in the evacuation system led to direct corresponding changes in the rate of decay of the "phantom" capnograph.

### *Explaining Reverse Flow of Carbon Dioxide*

**The Force for Reverse Flow.** It seemed clear that intermittent reverse flow of exhaled carbon dioxide-containing gas within the expiratory limb was occurring during ventilation after disconnection. This could be explained by intermittent positive pressure in the evacuation system or by intermittent negative pressure exerted on the expiratory limb at the Y-piece.

Intermittent negative pressure exerted on the expiratory limb at the Y piece might have been caused by negative pressure within the inspiratory limb, or by a Venturi phenomenon at the Y piece. By measuring the inspired carbon dioxide at different points along the breathing system, we were able to demonstrate the presence of "phantom" capnography in the inspiratory limb as much as  $10$  cm from the Y piece. This is inconsistent with a Venturi effect, where low pressure gas is entrained in the stream of high pressure gas but never flows against it. By measuring airway pressure in the inspiratory limb adjacent to the machine outlet, we were able to demonstrate that, during ventilation after disconnection, there is a short, weak, negative pressure



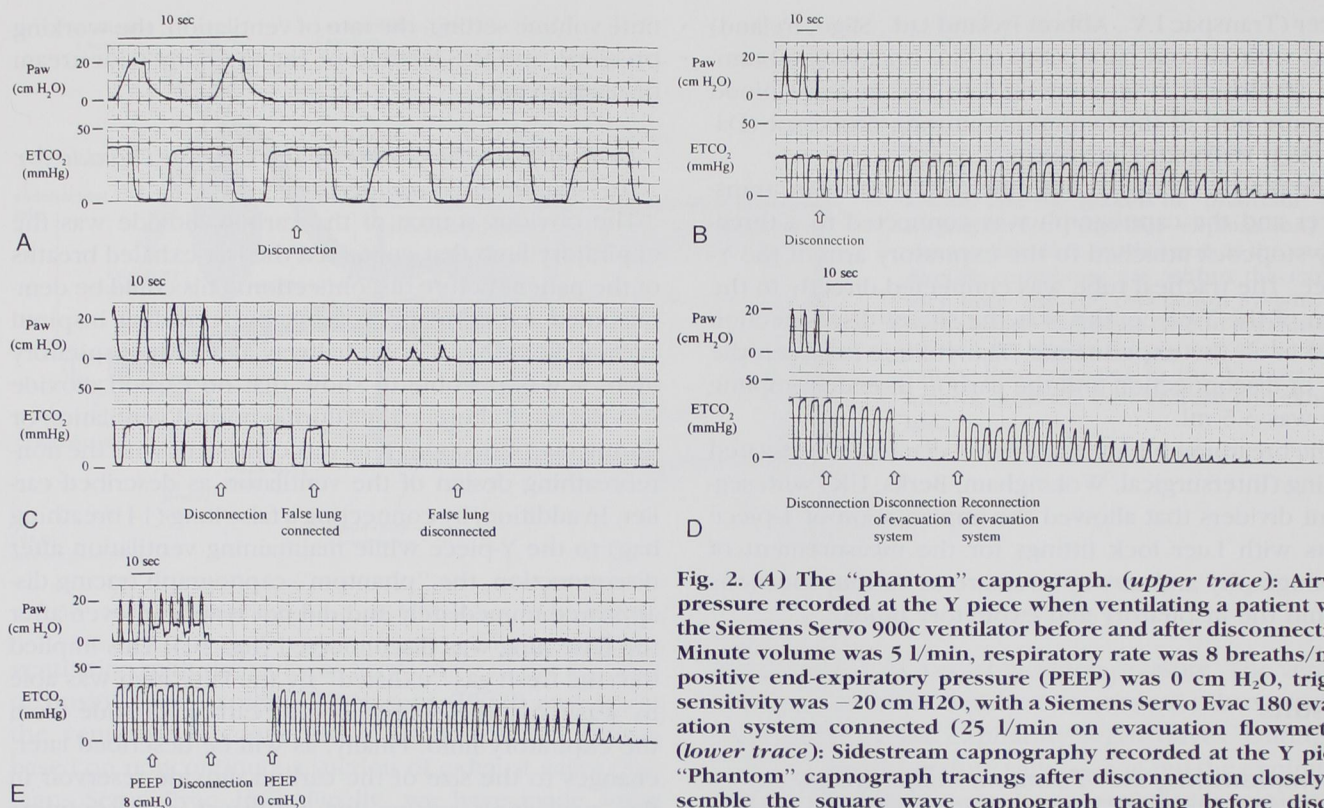


Fig. 2. (A) The "phantom" capnograph. (upper trace): Airway pressure recorded at the Y piece when ventilating a patient with the Siemens Servo 900c ventilator before and after disconnection. Minute volume was 5 l/min, respiratory rate was 8 breaths/min, positive end-expiratory pressure (PEEP) was 0 cm H<sub>2</sub>O, trigger sensitivity was -20 cm H<sub>2</sub>O, with a Siemens Servo Evac 180 evacuation system connected (25 l/min on evacuation flowmeter). (lower trace): Sidestream capnography recorded at the Y piece. "Phantom" capnograph tracings after disconnection closely resemble the square wave capnograph tracing before disconnection, both in amplitude and in shape. Note the slight blunting of the expiration portion of the "phantom" capnograph. (B) Decay of the "phantom" capnograph when ventilation is maintained under the conditions as outlined in figure 2 (A). Note that, although the shape and amplitude of the tracings decline over time, a recognizable waveform persists for more than 3 min. (C) Connection of a false lung (1-l breathing bag) to the Y piece while maintaining ventilation after disconnection (note the positive deflections on the airway pressure trace when ventilating the false lung). Conditions otherwise as described earlier. The "phantom" capnograph trace disappeared immediately and did not reappear, even after the false lung was disconnected. Conclusion: The expiratory limb was washed out by fresh gas "exhaled" by the false lung. The expiratory limb is the source of carbon dioxide for the "phantom" capnograph (see also fig. 2 [C]). (D) Disconnecting the evacuation system caused the "phantom" capnograph to disappear immediately. If the evacuation system had been covered and not allowed to void to the atmosphere, then reconnection led to an immediate return of the "phantom" waveform. No interruption in the "phantom" capnograph tracing was observed if the evacuation system was left connected to the exhaust outlet but the suction source was disconnected. Conclusion: A weak positive pressure gradient between the evacuation bag and the atmosphere creates the force for reverse flow in the expiratory system; remove the bag, eliminate the reverse flow. (E) PEEP setting and the "phantom" capnograph are shown. Setting PEEP (note the baseline airway pressure trace) before disconnection prevented the "phantom" capnograph. In addition, if, after an interval, the PEEP dial was then turned to 0 again, the "phantom" capnograph appeared. Conclusion: For reverse flow in the expiratory limb, the expiratory servo valve must be open, at least intermittently. Setting PEEP will force this valve to close in the presence of disconnection and, therefore, no "phantom" capnograph tracing will be seen.

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deflection immediately after inspiration. However, when analyzing data output from the highly sensitive flow oscillometer in the inspiratory limb, no reverse flow was detected, indicating that gas was not being sucked back into the inspiratory limb at any stage of the ventilatory cycle after disconnection (Siemens-Elcoma AB, personal communication).

Measuring airway pressure in the expiratory limb did not reveal intermittent positive pressure. However, if the Y piece was disconnected and the carbon dioxide

analyzer was attached separately to the expiratory tubing, a continuous plateau capnograph tracing was recorded, whose time to decay was approximately 3 min but which was not punctuated by the inspiratory phase of the "phantom" capnograph. This suggested that the force for reverse flow was provided by the weak positive pressure within the evacuation bag and that the "phantom" capnograph represented the intermittent interruption to this continuous reverse flow by positive pressure ventilation. This is consistent with the observa-



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tion that respiratory rate had no significant effect on the time to decay of the "phantom" capnograph; if reverse flow were due to negative pressure induced by the ventilation, then as ventilation rate increased, so the rate of depletion of the exhaust gas volume should increase. This was also consistent with the observation that disconnecting the evacuation system from the exhaust outlet caused the "phantom" capnograph to disappear immediately (fig. 2D). After reconnection of the evacuation system, the "phantom" capnograph reappeared as before (as long as the evacuation bag was not allowed to void to the atmosphere before reconnection). This illustrates that the pressure gradient between the evacuation bag and the atmosphere provides the force for reverse flow. Incidentally, this also showed that the entire expiratory limb, including the large 3-l evacuation bag, was providing the carbon dioxide reservoir for the "phantom" capnograph tracings. This explained why changes in the size of the expiratory limb tubing had no significant effect on the length of decay of the "phantom" capnograph (see earlier). Changing the capacity of the expiratory reservoir must affect the duration of the phenomenon but, clearly, even four-fold changes in the relatively low volume expiratory tubing was insignificant when compared with the large exhaust reservoir. Indeed, the addition of a second and then a third 3-l evacuation bag in series with the first caused predicted two-fold and three-fold prolongation of the "phantom" capnograph decay.

**Factors that Permit Reverse Flow in the Expiratory Limb.** Intermittent reverse flow was occurring in the expiratory limb during ventilation after disconnection, despite two mechanisms designed to prevent it in this ventilator. These mechanisms are the expiratory servo valve and the nonreturn flap valve at the exhaust outlet of the ventilator (fig. 1).

The expiratory servo valve normally closes in the inspiratory cycle and opens in the expiratory cycle. This valve is also programmed to generate PEEP, if set, and will tend to close so as to obstruct exhalation if expiratory airway pressure falls below the PEEP setting. In the event of disconnection, the expiratory valve will close entirely throughout the ventilatory cycle, because measured expiratory airway pressure (zero) is lower than the PEEP setting. This should prevent reverse flow and "phantom" capnography. However, if the PEEP setting is at zero, the expiratory valve remains open during the "exhalation" phase of the ventilator cycle, even after disconnection. Predictably, the act of setting PEEP before disconnection prevented the appearance

of the "phantom" capnograph tracing. In addition, if, after an interval, the PEEP dial was then turned to zero, the "phantom" capnograph appeared (fig. 2E). Clearly, the opening of the expiratory servo valve allowed expired gas to be removed from the expiratory limb by reverse flow, whereas closing the valve (by setting PEEP) created stasis in the expiratory limb.

Another potential objection to the concept of reverse flow was the presence of a nonreturn flap valve at the exhaust outlet of the ventilator. If the valve was open, it could only be due to valve incompetence or to an appropriate pressure gradient across the valve (positive pressure on the patient side or negative pressure on the evacuation side).

It was unlikely that the nonreturn flap valve was kept open by transmitted negative pressure from the evacuation system for two reasons: (1) because this would cause expulsion of expired gas into the evacuation system, which would also abolish "phantom" capnography (as was demonstrated after manual elevation of the valve spring in the evacuation bag after disconnection, which activated continuous suction on the exhaust reservoir and caused an immediate and irreversible cessation of the "phantom" capnograph tracing), and (2) in the presence of a disconnection, the evacuation bag is not filled, the valve spring is not elevated, and, therefore, transmitted negative pressure should not occur. We were able to demonstrate that negative pressure was not the mechanism for the opening of the flap valve; if the evacuation system was left attached to the exhaust outlet but was disconnected from the negative pressure suction source, then "phantom" capnography persisted.

It seems likely that some degree of minimal flap valve incompetence is responsible for allowing reverse flow in the expiratory limb, incompetence that the weak positive pressure in the evacuation bag is insufficient to obliterate. This could be demonstrated on a ventilator initially not demonstrating "phantom" capnography, by inducing severe incompetence in the flap valve (by inserting a matchstick into the valve) and then observing "phantom" capnography similar to that observed in our ventilators. Competence of the flap valve sufficient to obliterate the "phantom" capnograph has been encountered but seems to be a factor unrelated to age or maintenance of the valve; all the flap valves tested in our institution were sufficiently incompetent to cause "phantom" capnography, and a brand new flap valve supplied by Siemens gave results identical to our own.

It should be noted that the integrity of the flap valve



is critical to the sensitivity of the ventilator to patient triggering for the continuous positive airway pressure, synchronized intermittent mandatory ventilation, and pressure support modes of ventilatory support. However, with these conditions, negative pressure generated by the patient will tend to close the flap valve tighter and abolish minimal incompetence. Only more significant flap valve incompetence would be expected to adversely affect the trigger sensitivity and increase the patient work of breathing.

It should be noted that, when using an evacuation system of different design (Ohmeda Waste Gas Scavenging Interface Valve Assembly, Ohmeda, Madison, WI), also connected to a 3-l reservoir bag but based on continuous suction of exhaust gases, "phantom" capnography also was observed, but disappeared after one or two ventilations. When the Ohmeda evacuation system was disconnected from the suction source, the "phantom" capnograph after disconnection was identical to that seen in figure 2 (A,B). This demonstrates that the presence of noncontinuous suction on exhaled gases together with a large evacuation reservoir in this evacuation system provide the conditions that enable "phantom" capnography to persist.

## Discussion

We have presented a previously unreported observation that, with certain conditions, prolonged "phantom" capnograph tracings may occur after disconnection from the breathing system. We have explained this in relation to several features unique to the Siemens Servo 900c ventilator and the Siemens Evac 180 evacuation system (fig. 1). We have shown that the carbon dioxide for the "phantom" capnograph comes from the gas exhaled by the patient in the last breaths before disconnection and is present in both the expiratory tubing and in the exhaust system. We have suggested that the weak positive pressure gradient between the evacuation bag and the atmosphere forces the reverse flow of exhaled gases within the expiratory limb after disconnection. This only occurs when both the nonreturn flap valve at the exhaust outlet is open (due to mild valve incompetence) and when the expiratory servo valve is open (in the absence of PEEP). Despite the one-way flow within the normally functioning ventilator, the combination of these factors in the presence of a disconnection causes reverse flow of carbon dioxide-containing gas from the reservoir in the evacuation

system and expiratory limb to reach the carbon dioxide analyzer at the Y piece. This reverse flow is intermittently interrupted by each positive pressure ventilation, creating the "phantom" capnograph.

Several modifications could be envisaged that would abolish "phantom" capnograph tracings after disconnection from the Siemens Servo 900c ventilator: (1) a safety catch on the PEEP dial (at PEEP + 2 cm H<sub>2</sub>O) might prevent the unintentional administration of 0 PEEP. In these conditions, as described earlier, the expiratory servo valve would close after disconnection, and "phantom" capnography would be abolished. However, the imposition of even modest PEEP may not be desirable in all clinical conditions; (2) the use of the Siemens Servo 900c ventilator as part of a continuous flow breathing system has been described<sup>10,11</sup> and would, like in the circle absorber breathing system or in the Mapelson systems, prevent "phantom" capnography as expired gas is flushed out by fresh gas. Although these modifications may confer certain advantages in selected situations, they are not practical for all patients, they create a bypass of the low minute volume ventilation alarm,<sup>11</sup> and they are unjustified if used solely to prevent "phantom" capnography when much simpler alternatives are available; (3) the addition of an external low pressure disconnection alarm to the breathing circuit would certainly contribute to safety. In the Australian Incident Monitoring Study, it was recommended that critical areas be doubly or triply monitored.<sup>4</sup> It should be noted that in the volume control or pressure control modes of ventilation, the Siemens Servo 900c ventilator has no internal low pressure disconnection alarm (it has a low pressure alarm that records apnea only in synchronized intermittent mandatory ventilation, pressure support, or continuous positive airway pressure modes of ventilatory support). It should be stressed that there is a low minute volume ventilation alarm in the Siemens Servo 900c ventilator and that, in all the ventilators tested, this alarm was activated promptly after disconnection (the speed to activation being a function of the programmed lower alarm limit); (4) changing the evacuation system to one based on continuous suction of exhaust gases is impractical, because this may interfere with the low minute volume ventilation alarm and may lead to a negative pressure stress on the flap valve and impair trigger function. However, creating a more competent flap valve or possibly placing a second one-way valve at the inlet to the evacuation bag may be possible additional approaches to eliminate "phantom" capnography.



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The dangers of "phantom" capnography are self-evident. A "disconnection monitor" that does not function is worse than having no alarm at all.<sup>7</sup> However, more serious than the failure to respond is the continuous presence of inappropriately reassuring signals from the monitor. The implication of this phenomenon for clinical monitoring is more important than the precise mechanism of "phantom" capnography or of any technical modification that may be adopted to curtail it. The demonstration of these dangerously misleading tracings revives the need to stress, again, the proper role of monitors (however reliable) as aids to vigilant, clinical observation of the patient. After accidental disconnection of the endotracheal tube from the breathing system, or after accidental extubation of the trachea, the "phantom" capnograph is likely to confuse even an experienced anesthesiologist into the mistaken belief that the lungs of his/her rapidly deteriorating patient are being ventilated adequately.

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## References

1. Adams AP: Breathing system disconnections. *Br J Anaesth* 1994; 73:46-54
2. Neufeld PD, Johnson DL: Survey report: Results of the Canadian Anaesthetists' Society opinion survey on anaesthetic equipment. *Can Anaesth Soc J* 1983; 30:646-52
3. Neufeld PD, Walker EA, Johnson DL: Survey on breathing system disconnections. *Anaesthesia* 1986; 41:438-9
4. Russell WJ, Webb RK, Van der Walt JH, Runciman WB: The Australian Incident Monitoring Study. Problems with ventilation: An analysis of 2000 incident reports. *Anaesth Intensive Care* 1993; 21:617-20
5. Branson RD: Monitoring ventilator function. *Crit Care Clin* 1995; 11:127-43
6. Murray IP, Modell JH: Early detection of endotracheal tube accidents by monitoring carbon dioxide concentration in respiratory gas. *ANESTHESIOLOGY* 1983; 59:344-6
7. Pryn SJ, Crosse MM: Ventilator disconnection alarm failures: The role of ventilator and breathing accessories. *Anaesthesia* 1989; 44:978-81
8. Kacmarek RM, Meklaus GJ: The new generation of mechanical ventilators. *Crit Care Clin* 1990; 6:551-65
9. McPherson SP: *Respiratory Therapy Equipment*. 4th edition. St. Louis, Mosby, 1990
10. Radermacher P, Breulmann M, Felber HJ, Santak B: CPAP with a Siemens Servo 900c ventilator during weaning in infants. *Int Care Med* 1991; 17:189
11. Swegarden JL: Continuous flow modification for Siemens Servo 900c ventilator. *Int Care Med* 1992; 18:443-4