

Technique Article

Anesthetic Vaporizer Mount Malfunction Resulting in Oxygenation Failure after Initiating Cardiopulmonary Bypass: Specific Recommendations for the Pre-Bypass Checklist

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Abstract: Modern technologic advances in medicine have allowed commonly used machines to perform safely with very low risk and a high degree of success. To detect or prevent potential malfunctions, professionals routinely perform pre-use checks for equipment such as anesthesia machines and cardiopulmonary bypass (CPB) machines. These machine checklists are not only critical for a safe operation but also have large impacts on outcomes. For example, when malfunctions are encountered that could have potential negative ramifications or adverse outcomes, multi-approach strategies should be used to identify

rectifiable causes and find solutions that are practical. This information can be used to promulgate safe practice guidelines. This case report identifies a machine-based contributing factor to precipitous hypoxia on initiation of bypass in one of our patients. After a detailed approach to identify preventable root causes, we made simple additions to our pre-bypass checklist and recommend these changes to other institutions. **Keywords:** cardiopulmonary bypass standards complications anesthesia inhalation equipment safety intraoperative complications. *JECT. 2009;41:183–186*

CASE REPORT

A 6-month-old, 6.2-kg infant with a diagnosis of large ventricular septal defect, atrial septal defect, and isolated left pulmonary artery stenosis was scheduled for patch closure of the ventricular septal defect and re-implantation of the left pulmonary artery. The cardiopulmonary bypass (CPB) machine (Sorin SIII Encore; Sorin Group USA, Arvada, CO) circuit was prepared in a routine fashion and checked using the American Society of Extra-Corporeal Technology (AmSECT, Herndon, VA) pre-bypass checklist (1). General endotracheal anesthesia was initiated, invasive hemodynamic monitoring lines were placed, and the surgical procedure began. The patient received heparin to

achieve an activated clotting time of 430 seconds. Arterial and venous cannulations were completed, an air-free connection was made to the CPB circuit, and CPB was initiated with adequate venous return and desired arterial flow rate. Within 5 minutes of initiation of CPB, the SVO₂ (continuous in-line blood gas monitoring with CDI 500; Terumo Cardiovascular, Ann Arbor, MI) dropped precipitously into the low 40s, with a concurrent drop of cerebral oximetry (INVOS, 5100B; Somanetics, Troy, MI) from a baseline of 60s to the low 30s. Visual inspection of the venous inflow and arterial outflow cannula showed blood similar in color, with progressively darkening arterial outflow. A quick check confirmed that the flow meter indicator was floating and indicated 1.0 L/m. No audible or tactile leaks were found in the gas flow tubing between the wall gas outlets and the oxygenator. While checking the gas lines, the perfusionist recalled that the last change made before the precipitous decline in blood oxygenation was the turning on of the isoflurane vaporizer (Isotec 4 Isoflurane vaporizer; Ohmeda, Madison, WI). The vaporizer was turned off and immediately removed from the system. Immediately, a dramatic

Received for publication March 27, 2009; accepted August 2, 2009.
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The senior author has stated that authors have reported no material, financial, or other relationship with any healthcare-related business or other entity whose products or services are discussed in this paper.

rise of SVO_2 and cerebral rSO_2 followed with a return of arteriovenous color differential. Anesthesia for the rest of CPB was accomplished with a propofol infusion, and the case proceeded without further incidents. The remainder of the post-operative course was uncomplicated.

Soon after the procedure, the CPB circuit and machine were re-evaluated with the vaporizer in place according to the modified AmSECT pre-bypass checklist (1), and again, no malfunctions were identified. However, further inspection showed that gas outflow at the distal end of tubing stopped when the vaporizer dial was activated. Subsequently, the vaporizer was disengaged from the mount and was replaced with another vaporizer of a similar make/model. After exchange of vaporizers, the same result was obtained; no gas flow with the vaporizer dial in the “on” position. The vaporizer mount was replaced, and gas flow to the distal end of the tubing was established with the vaporizer dial in the “on” position. Hence, the problem was isolated to a faulty vaporizer mount. The local service center evaluated the vaporizer mount and confirmed the malfunction to an internal part within the mount.

DISCUSSION

Multiple case reports exist describing similar malfunctions and/or leaks in anesthesia and CPB machines (2–6). However, recommendations for checking the CPB gas flow circuit are limited only to a tactile assessment of gas flow out at the distal end of the tubing (close to where it enters the oxygenator) and checks for audible leaks or grossly visible tubing/connector disconnections (4). The AmSECT Perfusion Quality Committee practice standards (1) recommend a pre-bypass checklist guideline that can be modified by perfusionist personnel to suit their institution practices and machines. This guideline does address a “debubble/leak free” tubing requirement but leaves it to the discretion or expertise of the personnel to choose a test for doing so.

The FDA and the Anesthesia Patient Safety Foundation issued a checkout procedure for anesthesia machines in 1986 (7). This checkout procedure has been updated and refined since its introduction, and it is now an accepted practice standard to check all anesthesia machines before use (8). The FDA anesthesia machine checkout includes simple tests to check for gas flow leaks in the low-pressure system (LPS) of the anesthesia machines. We modified these tests so that they could also be used to check for leaks in all components of the low-pressure oxygen/gas flow delivery system of the CPB machine. This low-pressure system (Figure 1) begins distal to the low-pressure side of the flow control devices (flowmeter knob), where the pressure is just slightly above atmospheric and varies with flow. This LPS includes all distal paths for gas flow including flow indicator, flow tubes, rotameters, gas flow tubing, connectors, vaporizer, vaporizer

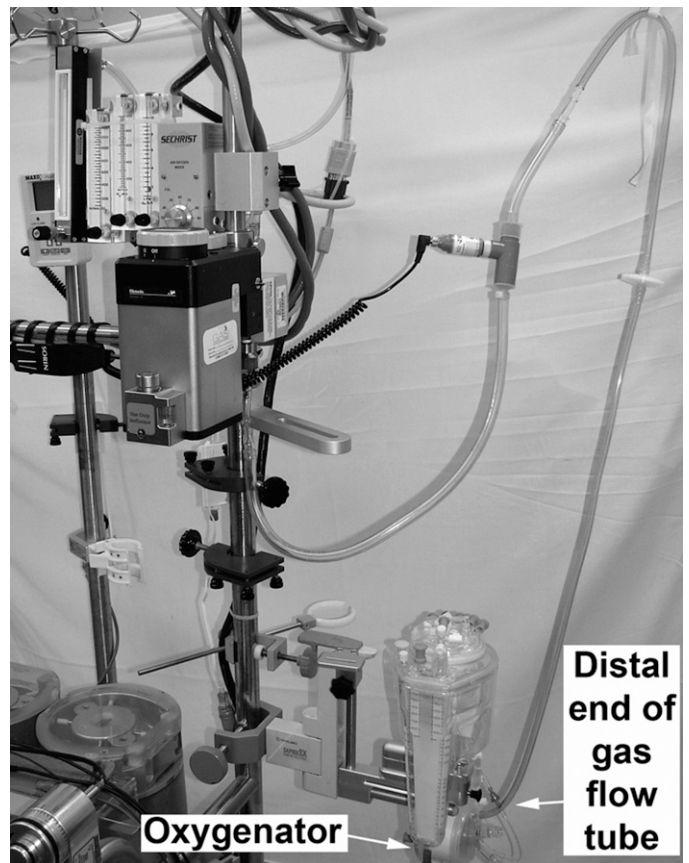


Figure 1. Low pressure system. The low pressure gas flow portion of cardiopulmonary bypass machine starts downstream of the flow control devices and extends up to the distal end of the gas flow tubing.

mounts, check valves, and hypoxia prevention devices such as oxygen analyzers. Our perfusionists require <1 minute to do these tests and ensure leak-free connections.

Based on this case report and its analysis, we recommend adding the following checks to the pre-bypass checklist for gas lines that included anesthetic vaporizers (8–12).

Negative Pressure Test

Attach a suction bulb (pre-manufactured or a standard sphygmomanometer bulb with the valve reversed) to the distal end of the fresh gas flow line of the CPB machine through a 5 in 1 Baxter connector (Figure 2). With gas flow off, squeeze the bulb to a deflated position to create a relative negative pressure. If the suction bulb remains collapsed for >10 seconds, assume no air is entrained to re-expand the bulb, and this confirms any significant circuit leaks up to the flowmeter. Repeat the test with the vaporizer turned on to check for a leak through the vaporizer. If a leak is detected, check the individual parts of the system upstream from the suction bulb by placing tubing clamp forceps, re-running the test, and identifying the faulty or leaking component.

The advantage of the negative pressure test is that it is easy and quick to perform and has a defined end point. The

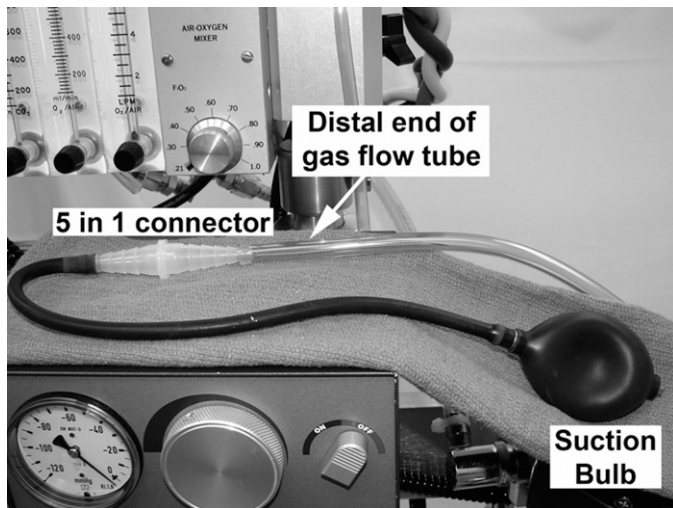


Figure 2. Negative pressure test. The suction bulb is attached to the distal end of the gas tubing and squeezed until it is collapsed. It should remain collapsed for 10 seconds. After this, the vaporizer should be turned on and the maneuver repeated.

presence or absence of check valves does not influence the test, and this test can be used on all low-pressure gas flow systems and hence it is also referred to as the universal leak test (9). Among the various leak tests mentioned in the anesthesia literature, the negative pressure leak test identified all the leaks and is the most sensitive at finding small leaks in the LPS (10–12). The suction device used for the test should be able to generate a sustained negative pressure of at least -65 mmHg for 60 seconds (11).

The drawback of the test is it cannot be performed once the procedure has started and hence the emphasis to add it to the pre-bypass checklist. The negative pressure test is purely a leak test and cannot identify obstructions to gas flow in the LPS. This inability to identify obstructions is not a disadvantage because, when a leak is found, tubing clamp forceps can be placed segmentally upstream from the distal end of the gas flow tubing and LPS can be tested again with the negative pressure test to identify the site of leak.

Fresh Gas Line Occlusion Test

Set flow to 5 L/min on the oxygen flowmeter in the CPB machine (Figure 3A). Occlude the distal fresh gas line (by clamping or kinking the tubing) for 1 second. The indicator in the flowmeter should move downward ($>.5$ L/min) in response to increased pressure downstream from the flowmeter (Figure 3B) and should return to the previous position when the occlusion is released. Float drop of $<.5$ L/min (5.0–4.5 L/min) indicates an unacceptable leak (11).

The fresh gas line occlusion test has its limitations in that it is insensitive to small leaks that may be clinically significant (10,12). However, it has the advantage of being able to detect large leaks if they were to appear during the procedure (e.g., if there were to be unintentional disconnections or loosely seated vaporizer liquid refill caps). This test also

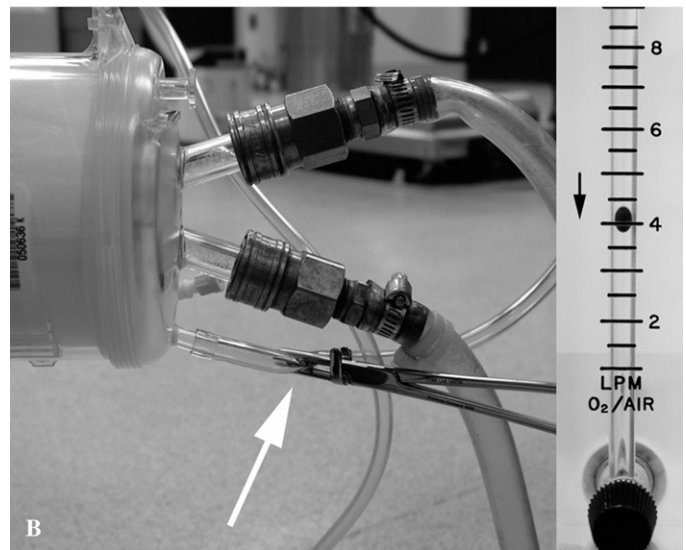
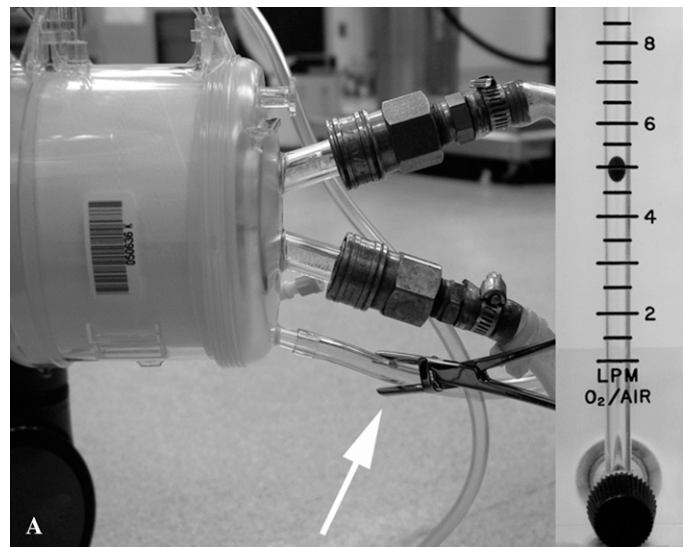


Figure 3. A, Fresh gas occlusion test. Oxygen flow is set to 5 L/min. Notice open jaws of the clamp at the distal end of the gas flow tube at the inlet to the oxygenator. B, The clamp is applied at the distal end of the gas flow tube for 1 second. Notice a drop in the float position in the flowmeter. A drop off $<.5$ L/min indicates an unacceptable leak.

has the advantage of identifying obstruction to gas flow in the LPS.

In addition to these tests, we also recommend that the AmSECT pre-bypass checklist include an alternative source of oxygen available with adequate and immediately available connectors as an emergency backup to the primary source of oxygen. Typically, the anesthesia machine has at least one oxygen E-cylinder as a backup in case of oxygen pipeline supply or bottled oxygen source failure.

CONCLUSION

Patient safety is dependent on reliable performance and operation of the CPB machine. The AmSECT pre-bypass

checklist is designed to encourage safe practice standards and prevent adverse events. Oxygenation failure is one such hazard that can result in serious sequelae if it goes undetected or cannot be immediately corrected. Checklists for commonly used critical machines with specific tests can help prevent a majority of these adverse events or failures. We recommend two inexpensive, brief, simple tests that check for LPS leaks that can prevent instances of oxygenation failure and provision of a ready alternative source of oxygen in case of failure of the primary oxygen source.

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