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A comparison between low-flow leak test and oxygen flush leak test

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Abstract
Purpose. The clinical efficacy of two methods of preanesthetic leak test,namely the oxygen flush leak test (OFLT) and the low-flow leak test (LFLT), was compared regarding their ability to detect leakage in the anesthesia circuit and their accuracy.
Methods. Examinees comprised 16 staff anesthesiologists and 7 physicians undergoing anesthesia training at our institution. They performed the two leak tests on anesthesia machines with some intentional leaks (0.1–$1.0\,l\cdot min^{-1}$). The leakage detection rates (LDR) were analyzed by the χ^2-test. The ability to detect leaks was measured by recording how many leaks were detected by 50% (LDR_{50}) and 95% (LDR_{95}) of the examinees.
Results. The LDRs in the two tests were significantly different (χ^2- analysis, $P < 0.0001$). Both LDR_{50} and LDR_{95} for the LFLT (0.23 and $0.41\,l\cdot min^{-1}$, respectively) were smaller than the values for the OFLT (0.37 and $0.82\,l\cdot min^{-1}$, respectively). The sensitivity and specificity of the LFLT (0.97 and 0.84, respectively) were higher than those of the OFLT (0.78 and 0.80, respectively).
Conclusion. The LFLT was found to be superior to the OFLT regarding leak detection and reliability. We therefore recommend the LFLT for preanesthetic leak testing.

Key words Oxygen flush leak test · Low-flow leak test · Preanesthetic inspection

Introduction

Anesthesia circuit leakage which is detectable at preanesthetic inspection could come from either of two different circuits, i.e., machine gas piping circuits from flowmeters to common gas outlets, or patient breathing circuits, which are defined as being the section from the common gas outlets to the patient's connection ports, including the canister and reservoir bag.

A leak test on the machine gas piping circuit must be performed to avoid hypoxia or patient awareness during anesthesia [1–3], and also to maintain environmental hygiene in the operating theater. The low-pressure leak test is considered to be a particularly important preanesthetic inspection [1–3]. Several different methods have been used to check leaks in machine gas piping circuits [1,2]. Usually, these leak tests required special instruments to conduct the procedures, such as a manometer or a suction-bulb device. Most such tests are both time-consuming and complicated, with the exception of the Food and Drug Administration (FDA) universal negative-pressure leak test (FDAT) [1,2,4]. As a result, such leak tests tend to be used for periodic inspections rather than for daily preanesthetic inspections.

The FDAT has been reported to be superior to other leak tests because it can be used regardless of design differences in machines. It is especially useful when the check valve is located between the flowmeter and the common gas outlet [1,2,4]. However, the FDAT needs an additional test to check the patient's breathing circuit, because it detects leakage in the machine gas piping circuits only. However, the oxygen flush leak test (OFLT) can examine the entire anesthesia circuit.

In 1994, the Japan Society of Anesthesiology recommended a new leak test, called the low-flow leak test (LFLT) [5], that can also test the entire anesthesia circuit. A major advantage of this test is that it could be performed on anesthesia machines with a check valve.

The goal of this study was to compare the clinical efficacy of two different leak tests, namely the OFLT and the LFLT, for use in preanesthetic inspections regarding both their ability to detect leakage and their accuracy.

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Materials and methods

Sixteen anesthesiologists and seven physicians undergoing anesthesia training at our institution performed the leak tests. They (the examinees) tested anesthesia machines which had some artificial leakage in their anesthesia circuits, to determine the existence of any leaks. Leakage was produced by leakage devices that had leakage of 0, 0.1, 0.2, 0.3, 0.5, or 1.0 l·min^{-1} at a pressure of 30 cmH_2O. The examiners connected the leakage devices to an anesthesia circuit at the interconnection between the canister and the inspiratory corrugated tube before the leak tests. The blindfold examinees then tested the circuit for any leaks. The leak flows were randomly chosen by the examiner. The test was done only once with each device. The leakage device was a plastic tube penetrated by a small steel tube from the inner to the outer surface. This steel tube, with an inner diameter of about 0.3 mm, was pinched with pliers to produce the desired leakage. Before the examinees performed the leak test, the examiner demonstrated it according to the procedures described by the manufacture.

The OFLT [1] was carried out under the following conditions. (1) All gas flows were set at zero (or at the minimal basal flow). (2) The APL (adjustable pressure limiting) valve was closed and the Y-piece was occluded. (3) The pressurized breathing system was set at about 30 cmH_2O with an O_2 flush. (4) The pressure was checked to determine whether it remained fixed for at least 10 s.

The LFLT [5] was carried out under the following conditions. (1) The tube end of the Y-piece was connected to the breathing bag with a short I-shaped corrugated tube. (2) The oxygen flow was set at 0.1 l·min^{-1} (or at the minimal basal flow). (3) The manometer on the machine was carefully monitored to ensure that the pressure in the breathing circuit reached 30 cmH_2O. (4) When the pressure reached 30 cmH_2O, then no leak could be larger than 0.1 l·min^{-1}.

While the examinees were performing the leak test, the examiner watched their procedures to make sure they were using the right methods. The anesthesia machines used were the Excel 210 SE (Ohmeda, WI, USA), which has no check valves and has a minimal basal flow of 0.2 l·min^{-1}. As a result, the examinee had to perform the leak tests under a basal flow of 0.2 l·min^{-1} during a normal inspection.

Before the tests, the usual periodic inspection of the anesthesia machine was performed to confirm the absence of leakage. A new breathing bag and corrugated tube, with no leaks, were used in all of the tests. Each examinee performed all of the tests under all of the conditions described above.

Regression lines were obtained based on the results of leakage detection. (The regression lines for the LFLT were calculated from the results of leakage detection by eliminating values obtained after reaching 100% leak detection.)

Both the sensitivity and specificity were calculated based on the fact that under a basal flow of 0.2 l·min^{-1}, a leak of 0.2 l·min^{-1} cannot be detected because of the counterbalancing effect of the basal flow and the leakage. Therefore, when an examinee detected a leak of 0.2 l·min^{-1} under the basal flow, the finding was judged to be false-positive.

χ^2 analysis was used to compare the results of leak detection between the OFLT and the LFLT. A statistical analysis was performed to determine the suitability of a simple regression of the results of leak detection. These data were considered to be statistically significant when the P value was <0.05.

Results

The leakage detection rates are shown in Fig. 1. The leakages detected in the two tests were significantly different (χ^2 analysis, $P < 0.0001$). Moreover, there were significant differences in the leakage rates of 0.3 and 0.5 l·min^{-1} ($P < 0.05$). Regression lines were determined based on the results of leak detection. These lines showed a good statistical adaptation ($P < 0.05$). From the lines, we calculated the leakage values correspond-

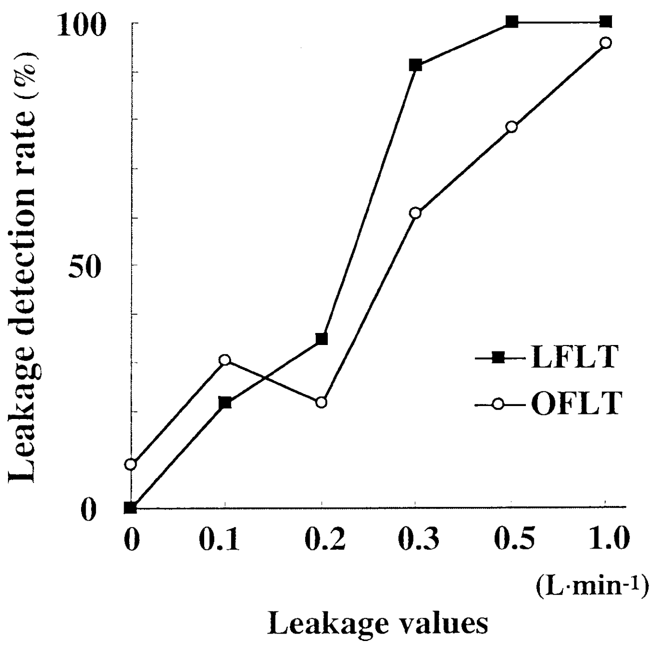

Fig. 1. Leakage detection. The ordinate represents the percentage of examinees who identified leaks versus the total number of examinees (23). The abscissa represents the leak values obtained by the leak-producing devices

ing to a 50% detection rate (LDR_{50}) and a 95% detection rate (LDR_{95}). The values of LDR_{50} in the OFLT and the LFLT were 0.37 and $0.23\,l\cdot min^{-1}$, respectively. The values of LDR_{95} in the OFLT and the LFLT were 0.82 and $0.41\,l\cdot min^{-1}$, respectively.

The sensitivities of the OFLT and the LFLT were 0.78 and 0.97, respectively. The specificities of the OFLT and the LFLT were 0.80 and 0.84, respectively.

Discussion

The values of both LDR_{50} and LDR_{95} for the LFLT were smaller than the values for the OFLT. Furthermore, the sensitivity and specificity of the LFLT were higher than those of the OFLT. As a result, the LFLT is considered to be superior to the OFLT for leakage detection and reliability.

Theoretically, the LFLT could detect leakage of over $0.1\,l\cdot min^{-1}$. The reason why several physicians were unable to detect any large leakage by the LFLT was thought to be due to mistakes produced by ending the procedure prematurely before the test was finished. The LFLT is usually very time-consuming. Furthermore, if there is an extremely large amount of leakage, the procedure cannot be completed. We therefore propose a modified technique for the LFLT: (1) increase the O_2 flow until it reaches a pressure of $30\,cmH_2O$; (2) decrease the O_2 flow to $0.1\,l\cdot min^{-1}$. This technique helps to shorten the procedure, but still allows machines with check valves to be adequately tested.

LFLT can also be used to measure the leakage values by another modified technique [6]. If the anesthesia machine has a large leak, then the manometer cannot reach a pressure of $30\,cmH_2O$. In such a case the O_2 flow should be increased until the manometer reaches $30\,cmH_2O$, and thereafter should be maintained at that pressure. This O_2 flow allows the leakage value to be kept at a pressure of $30\,cmH_2O$. We previously reported that the average leakage found during such testing was $0.97\,l\cdot min^{-1}$ after investigating 66 anesthesia machines using the LFLT [6]. We speculated that the reason for the presence of large leakage in clinical situations was primarily related to the ease of leakage detection by the OFLT.

We thus concluded that the LFLT was superior to the OFLT for leak detection and reliability. We therefore recommend the use of the LFLT for preanesthetic leak testing.

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