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SHORT COMMUNICATION

# Effects of battery type and age on performance of rechargeable laryngoscopes

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**Abstract** Optimal visualization of the glottis can be crucial to successful laryngoscopy. Limited information has been published on the light intensity delivered from laryngoscopes powered by rechargeable batteries. In this study the laryngoscope light intensity delivered from 10 nickel metal hydride (NiMH), 7 nickel cadmium (NiCAD), and 2 lithium (LI) batteries with 3–5 or more years of clinical usage were tested in comparison to 5 new NiMH batteries. Each battery was charged in a new laryngoscope handle and recharging unit for 24 h before testing. Light intensity (lux) from the bulb in the laryngoscope handle was recorded at 3-min intervals under continuous loading until battery depletion. The mean times ±1 standard deviation (SD) to minimum acceptable light output (2,000 lux from the handle) were new NiMH 70 ± 1 min, 3-year-old NiMH 96 ± 2 min, 5+ year-old NiCAD 45 ± 22 min, and 5+ year-old LI 117 ± 4 min. There were significant differences in the time to minimum light intensity among all groups ($p = 0.00$–$0.04$). All new and used batteries exceeded the minimum ISO standard of light intensity for more than 10 min. These data demonstrate that rechargeable laryngoscope batteries can safely be used for several years before requiring replacement.

**Keywords** Battery · Laryngoscope · Rechargeable · Light intensity · Quality control

Optimal visualization of the glottis can be crucial to successful tracheal intubation, particularly in emergency situations. Adequate lighting is an integral component of direct laryngoscopy. Furthermore, the most recent standard from the International Organization for Standardization (ISO) on anesthetic equipment recommends a minimum light output of 500 lux delivered from the laryngoscope blade tip with 10 min of continuous usage [1].

Disposable alkaline and rechargeable batteries are often used to power the light sources in modern laryngoscopes. Three rechargeable battery types commonly used in laryngoscopes are lithium ion (LI), nickel cadmium (NiCAD), and nickel metal hydride (NiMH), each of which has different energy densities, service lives, and purchasing costs.

The shelf life of batteries can be affected by many factors including electrochemical design, temperature, depth of discharge, number of discharge cycles, recharging technique, length of storage, and initial battery formatting from the manufacturer. Battery performance is typically evaluated by application tests that replicate real-life usage, or through bench-top capacity tests. The life expectancy of batteries is difficult to accurately predict without exact usage data; thus, it is commonly estimated from a combination of real-world usage and laboratory testing or extrapolated from accelerated testing data [2].

The performance of batteries used in other medical devices such as defibrillators [3] and syringe pumps [4] has

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been previously characterized in the literature. However, limited data have been published on the performance of laryngoscope batteries. One previous study of light intensity delivered by laryngoscopes with disposable alkaline batteries demonstrated that replacement with new batteries can improve light output by 169 lux, or 27 % [5], and a small pilot study done at our institution demonstrated that new NiMH batteries can hold a single charge up to 180 days when used once daily for 30 s [6].

The purpose of this study was to examine the performance of rechargeable laryngoscope batteries after routine clinical usage in the operating room for 3–5 years or longer.

Our institutional research ethics board deemed approval as unnecessary for this bench-top quality control study of laryngoscope batteries. A total of 10 NiMH, 7 NiCAD, and 2 LI batteries in use from the operating room at our institution were tested in comparison to 5 new NiMH batteries (Heine, Herrsching, Germany). The total number of general anesthetics at our institution is approximately 15,000 per year, serviced by a fleet of 35 laryngoscopes. For the batteries that were in use, the number of years in service was tracked from the manufacturing date stamps on the side of each battery and purchasing invoices. Cumulative service life of the used batteries was separated into two nominal time periods for statistical purposes: 3 years of use (NiMH) or more than 5 years of use (5+) for NiCAD and LI. All batteries (3.5 V) were tested using a new Heine standard fiberoptic laryngoscope handle with a Xenon bulb (Heine) and were charged in a NT 200 laryngoscope charger (Heine) for 24 h before testing. Light output (lux) from the bulb in the laryngoscope handle was measured using a previously described light measurement apparatus [4] and digital light meter (Tenma 72-6693; MCM Electronics, Centreville, OH, USA; manufacturer's accuracy ±2.5 %). The light testing chamber was designed to test the light output directly from the laryngoscope handle (Fig. 1a) or the combined handle and blade set (Fig. 1b). For the purposes of this study we chose to measure light output directly from the laryngoscope handle (Fig. 1a). Light intensity measurements (lux) were recorded at 3-min time intervals under continuous usage until the battery was fully depleted such that the light intensity had reached zero. A previous pilot study demonstrated that rechargeable laryngoscope batteries can last up to 180 days with single daily usage; thus, we chose to test the batteries using an accelerated testing method under continuous depletion to assess lifespan within a feasible time frame. Futhermore, the ISO standard also recommends testing lighting conditions under continuous use for 10 min.

To determine the typical light transmission from the handle bulb to the tip of the blade and compare our handle data to the ISO standard, 16 matched sets of fully charged Heine handles and reusable stainless steel blades from our operating rooms were randomly selected for testing. The light output from both the tip of the blade and the handle was measured for each set to calculate the light transmission ratio (Fig. 1b versus Fig. 1a). These sets were "used" blades and handles and were chosen to represent the typical devices in clinical use at our institution. There were no data available on the number of uses or sterilizations each unit had undergone.

Data were expressed as mean and standard deviation. Time to minimum and zero light output was analyzed using Kaplan–Meier survival analysis and analysis of variance with Tukey's LSD post hoc comparisons. The level of significance was set at $p < 0.05$. Calculated times to minimum and zero output were rounded to 1-min intervals. All statistical calculations were performed using SPSS 14 (SPSS, Chicago, IL, USA).

The light output for each battery type under continuous discharge is shown in Fig. 2. There were significant

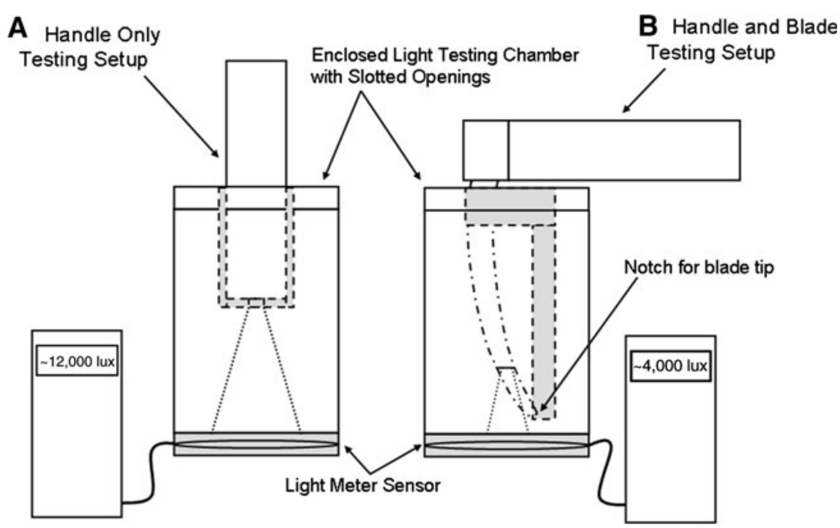


**Fig. 1** Laryngoscope light intensity measurement apparatus. A custom-fitted cap at the *top* of the enclosed chamber securely held the laryngoscope handle (**a**) or blade (**b**) in a reproducible manner, which ensured that the light emitted was centered on the light meter sensor. Distance from light source to sensor is 65 mm for the handle testing configuration (**a**) and 17 mm for the blade testing configuration (**b**)

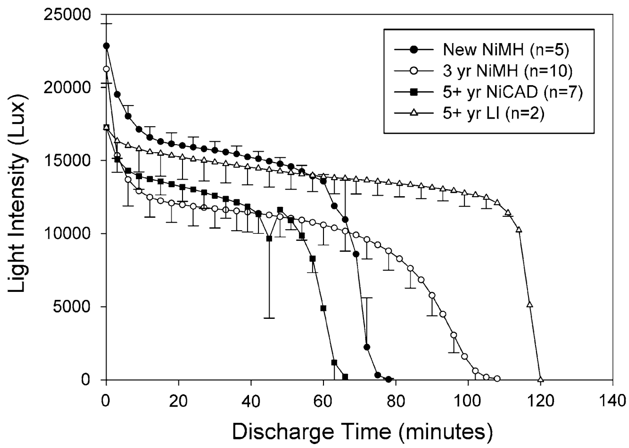


**Fig. 2** Laryngoscope handle light intensity under continuous usage for different rechargeable battery types and ages. Data points are mean ± 1 SD. *Error bars* are shown in one direction only for clarity. One battery in the 5+-year-old NiCAD group failed earlier than the other tested units, causing the variation at the 45-min mark. *NiMH* nickel metal hydride, *NiCAD* nickel cadmium, *LI* lithium

differences in time to zero light output for pairwise comparisons between all groups ($p \leq 0.01$), except between the 3-year-old NiMH and 5+-year-old LI batteries ($p = 0.14$). The new NiMH batteries demonstrated a higher initial light output but a shorter discharge time than the 3-year-old NiMH units.

The light output from the 16 randomly selected laryngoscope handle and blade sets in clinical usage was 19,825 ± 1,952 lux for the handles and 5,514 ± 728 lux for the output from the handle/blade sets, with an overall average ratio of 28 ± 2 % light transmission. A conservative ratio of 25 % was selected to calculate the equivalent minimum light delivered from the handle (as measured in our study), in comparison to the ISO standard of 500 lux from the blade tip. Based on this ratio, the times to minimum acceptable light output (defined as 2,000 lux from the handle) were as follows: new NiMH, 70 ± 1 min; 3-year-old NiMH, 96 ± 2 min; 5+-year-old NiCAD, 45 ± 22 min; and 5+-year-old LI. 117 ± 4 min. There were significant differences in the time to minimum acceptable light intensity for all pairwise comparisons between battery groups ($p \leq 0.01{-}0.04$).

This study was done at the time of a complete changeover of our fleet of laryngoscope batteries to NiMH batteries. Three years before then, we had undergone a partial changeover with a move toward NiMH batteries. For this study, we selected a random sample of ten of our 3-year-old NiMH batteries, and tested the only remaining NiCAD and LI batteries still in operation in our fleet. The average usage for each battery is estimated to be more than 400 uses per year based on our case volume and fleet size, but this figure may vary for different operating rooms depending on case load.

Previous research has shown that the light intensity from reusable laryngoscope blades significantly deteriorates with repeated sterilizations [7, 8]. We sought to eliminate this variable by measuring light output directly from the handle. The time to minimum acceptable light intensity was calculated using a conservative ratio of 25 % light transmission between the handle and blade, which would represent "used" laryngoscope blades in the clinical setting. Based on this calculation, all the new and used batteries tested in our study exceeded the minimum light intensity requirement (500 lux) for the 10-min period recommended by the ISO [1].

The new NiMH batteries were observed to deliver a higher light output but had a shorter discharge time than the used NiMH cells. Although not tested in our present study, we postulate that this may be the result of the battery initialization from the manufacturer or the differences in internal battery resistance between the new and used units [2].

The supplier of our laryngoscope batteries provides a 2-year replacement time period for any failed batteries; all the used batteries in our fleet were well past that age limit. Despite their increased age, the LI batteries exhibited a longer discharge time, whereas the aging NiCAD batteries had shorter discharge times.

There are several limitations to this study. We used the chronological age of each battery based on the manufacturing stamp and purchasing invoices as a surrogate marker of usage. We were unable to formally quantify the number of uses, recharges, or discharge patterns of each battery. In addition, the sample of LI units was limited to only two batteries and may not represent the true performance of these devices at the extremes of age.

In conclusion, we evaluated the performance of various rechargeable laryngoscope batteries types at different ages. All the batteries tested exceeded the ISO standard for light intensity despite multiple years of usage. However, anesthesiologists should still continue check the adequacy of each laryngoscope before its use.

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