



ORIGINAL ARTICLE

**Assessment of the light intensity of otoscopes utilized in teaching hospitals**<sup>☆,☆☆</sup>



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**KEYWORDS**

Otoscopy;  
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**Abstract**

*Introduction:* To attain an accurate otoscopic diagnosis, a functioning device with adequate capacity must be used.

*Objective:* Evaluate the light intensity of otoscopes, comparing it utilizing the batteries present at the moment of calibration and after new batteries were supplied.

*Methods:* Cross-sectional study of a historical cohort, which assessed 38 otoscopes, measuring the light intensity with the batteries present at the moment of assessment compared to the intensity with new batteries, as well as charge of the test batteries and the new batteries.

*Results:* The mean of the sum of new batteries' charge was 3.19V, and of the test batteries was 2.70V, representing a decrease of 18.02% in charge. The mean luminosity with the new batteries was 366.89 lumens, whereas in the test batteries it was 188.32 lumens, representing a decrease of 83.75% in the light intensity. Student's *t*-test was applied for data comparison, showing a statistical difference between the light intensity with the original batteries and the new batteries ( $p=0.0001$ ; CI=0.95).

*Conclusion:* There was a statistically significant difference between the proportions of light intensity in the otoscopes. A small variation in battery charge results in a great variation in light.

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**PALAVRAS-CHAVE**

Otoscópios;  
Otoscopia;  
Luz

**Avaliação da intensidade da luz dos otoscópios em hospitais-escola****Resumo**

**Introdução:** Para a realização de um diagnóstico otoscópico preciso deve-se utilizar um aparelho funcionando com uma capacidade adequada.

**Objetivo:** Avaliar a intensidade luminosa dos otoscópios comparando a intensidade da luz com as pilhas encontradas no momento da aferição e com pilhas novas.

**Método:** Estudo de coorte histórica com corte transversal, onde foram analisados 38 otoscópios, sendo realizada a aferição da qualidade luminosa com a pilha utilizada e comparado com uma pilha nova, e a aferição da carga das pilhas novas e em utilização no momento do exame.

**Resultados:** A média da soma das cargas das pilhas novas foi de 3,19 V, e a das pilhas testes foi de 2,70 V, representando decréscimo de 18,02% na carga das pilhas. A média da luminosidade com as pilhas novas foi de 366.89 lúmens, e com a pilha teste foi de 188.32 lúmens, representando decréscimo de 83,75% na intensidade luminosa. Foi aplicado o teste T para comparação entre os dados, onde percebe-se diferença estatística entre a intensidade luminosa com pilhas testes e novas ( $p = 0,0000$ ;  $IC = 0,95$ ).

**Conclusão:** Houve diferença estatisticamente significativa entre a proporção de intensidade da luz dos otoscópios. Uma pequena variação da pilha proporciona uma grande variação na luz.

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**Introduction**

The otoscope is a medical device commonly used in both primary care and hospitals.<sup>1</sup> The first otoscopes were designed for viewing the ear canal, as a pair of tweezers, similar to current rhinoscopes.<sup>1</sup>

Otoscopy is the main focus of the otological physical examination and should be performed with an appropriate otoscope that offers a good light source, preferably with halogen light (white) so as not interfere with the normal color of the outer ear and the middle ear structures.<sup>2</sup> It should be attached to a disposable or sanitized otoscope speculum and be of an appropriate size for the ear conduit to be assessed.<sup>2</sup>

Adequate illumination of the tympanic membrane requires special equipment and an open and clean ear canal, but the circumstances are rarely optimal.<sup>3</sup> Approximately one-third of physicians exchange the otoscope bulbs less often than recommended, and one-third of otoscopes do not have adequate lighting capacity.<sup>3</sup>

There are insufficient studies in the literature that have evaluated the ideal luminosity for good diagnostic accuracy or that have assessed the influence of battery power on the quality of light. There is only the study by Barriga et al., carried out in 1986, which evaluated the intensity of light of otoscopes, taking into account lamp replacement frequency.<sup>4</sup>

The present study aimed to evaluate the light intensity of otoscopes in outpatient clinics, offices, and emergency wards of teaching hospitals, by comparing the intensity of light with batteries found at the moment of measurement and with fully charged batteries.

**Methods**

The study was carried out with the authorization of Hospital da Cruz Vermelha (Paraná, Brazil) and Hospital Pequeno

Príncipe, where data collection was conducted from June, 2013, to January, 2014. It was a historical cohort study with cross-sectional design, and as it did not involve human beings, approval from the research ethics committee was not necessary.

**Selection of study site and the types of otoscopes**

Two school hospitals were chosen to assess the quality of light of otoscopes in places with situations believed to be close to the ideal for symptomatic patient assessment.

This study evaluated not only the otoscopes of the institutions, but also those belonging to the physicians who agreed to participate in the study after a brief explanation of the study objectives.

The sample collection sites for assessment were: general outpatient clinic, emergency, otorhinolaryngology clinic, otorhinolaryngology offices, infirmary, and academic outpatient clinic of both hospitals.

The inclusion criteria were assessed otoscopes with halogen light, light-emitting diodes (LED), common lamp bulb, or optical fiber, powered by energy supplied by conventional batteries.

The exclusion criteria included otoscopes powered by electricity or power supply provided by rechargeable batteries, or those whose owners refused to participate.

A total of 38 otoscopes were assessed, of five different brands, Welch Allyn®, Missouri®, Piko®, Omni® and Mikatos®, of which six belonged to Hospital da Cruz Vermelha (Paraná, Brazil), with the remainder belonging to the service providers of the institutions.

**Otoscope luminosity and battery intensity assessment**

Test batteries were those found in the otoscopes at the time of assessment; new batteries consisted of Duracell® AA or C



Figure 1 Dark box.

batteries bought by the researchers, depending on the type of otoscope, with charge > 1.5 V.

The charge of the test batteries of the otoscopes to be assessed was evaluated before the measurement of light intensity through a calibrated voltmeter to determine the charge level. Additionally, the new batteries with charge > 1.5 V were assessed, so that they could be verified as fully charged.

A dark box was constructed (Fig. 1), which did not allow light to enter after being closed, so that the otoscope light intensity assessment could be standardized without the influence of external light.

An Icel® light meter, calibrated to a 2000 lux sensitivity factor, had its photometer affixed to one of the box walls; the photometer was mobile and could be moved upward or downward, as it was fixed by Velcro® strips. Thus, it could be placed perpendicularly to the otoscope light extremity at the time of measurement.

The otoscopes were mounted on a holder prepared to keep it standing at 4 cm from the basis and perpendicular to the photometer central point with a 3-mm mean speculum opening, according to the otoscope model (Fig. 2).

After the otoscope was positioned, it was turned on and the box was closed, after which the light intensity was measured by the light meter. The maximum measured light intensity was recorded.

This procedure was first performed with otoscopes with the test batteries and then with the new batteries, to determine the proportion in percentage of light intensity in the otoscopes with the test batteries, considering 100% light intensity found with the new batteries for each tested otoscope. Data were collected by two researchers, who were together during all measurements, which were entered into a spreadsheet and submitted to statistical analysis.

**Statistical analysis**

The charge intensity of the test and new batteries and the proportion of light intensity of the otoscopes were compared



Figure 2 Otoscope fixed at the base at a 4-cm distance and light source directed to the central point of the photometer.

using the Student’s *t*-test for paired data, as they were compared with the results of the same otoscope, but with the different batteries, with a *p*-value < 0.05 considered statistically significant.

**Results**

All otoscopes assessed in this study used two non-rechargeable batteries for their operation. The mean of the sum of the charges of the two new batteries was 3.19 V, whereas the two test batteries had a mean value of 2.70 V. This represented an 18.02% decrease in the mean charge of the two batteries (Table 1).

The maximum light capacity in each otoscope was individually assessed and the value measured with the new batteries considered to be 100%. The mean intensity of the 38 assessed otoscopes was 366.89 lumens. The mean intensity achieved with the test batteries was 188.32 lumens, which shows that on average, the otoscopes functioned at 54.42% of their potential (Table 2).

Table 1 Mean and standard deviation of the total charge of batteries, and test battery charge ratio in relation to the new batteries.

	Mean	Standard deviation
Full charge of test batteries (V)	2.70	0.32
Full charge of new batteries (V)	3.19	0.02
Test charge ratio (%)	84.73	10.31
New charge ratio (%)	100	0

**Table 2** Mean and standard deviation of light intensity, and test battery light intensity ratio in relation to new batteries.

	Mean	Standard deviation
Test light intensity (lumens)	188.32	114.783
New light intensity (lumens)	366.89	238.272
Test light intensity ratio (%)	54.42	17.33
New light intensity ratio (%)	100	0

Otoscope 1 had the lowest battery power; it originally had only 40.9% of the maximum voltage and battery replacement generated a 100% improvement in light intensity (Tables 3 and 4).

A mean increase of only 18.02% in battery power results in an increase of 83.75% in light intensity. When assessing the 38 otoscopes by Student's *t*-test for data comparison, it can be observed that there was a significant difference between light intensity with test batteries and new ones ( $p = 0.0000$ ;  $CI = 0.95$ ).

## Discussion

Medical practice demonstrates that otoscope illumination is critical for adequate patient otological assessment, and this examination is essential for the diagnosis and monitoring of otological pathologies.<sup>5</sup>

The otoscopes assessed in this study used non-rechargeable alkaline batteries, which, when new, have a total charge of 1.5V each. If the voltage is below 0.8V, the

**Table 3** Full battery charge and test battery ratio in relation to the new batteries of each otoscope.

	Sum of charge of test batteries (V)	Sum of charge of new batteries (V)	Test battery ratio (%)	New battery ratio (%)
Otoscope 1	1.30	3.18	40.9	100
Otoscope 2	2.62	3.18	82.4	100
Otoscope 3	1.30	3.19	40.7	100
Otoscope 4	2.34	3.16	74	100
Otoscope 5	2.70	3.18	84.9	100
Otoscope 6	3.00	3.16	94.9	100
Otoscope 7	2.73	3.18	85.8	100
Otoscope 8	2.38	3.22	73.9	100
Otoscope 9	2.49	3.22	77.3	100
Otoscope 10	2.60	3.23	80.5	100
Otoscope 11	2.67	3.21	83.2	100
Otoscope 12	2.84	3.22	88.2	100
Otoscope 13	2.73	3.21	85	100
Otoscope 14	2.64	3.22	82	100
Otoscope 15	2.87	3.21	89.4	100
Otoscope 16	2.43	3.21	75.7	100
Otoscope 17	2.63	3.20	82.2	100
Otoscope 18	2.77	3.21	86.3	100
Otoscope 19	2.68	3.19	84	100
Otoscope 20	2.38	3.20	74.4	100
Otoscope 21	2.82	3.20	88.1	100
Otoscope 22	2.74	3.19	85.9	100
Otoscope 23	2.64	3.19	82.7	100
Otoscope 24	2.85	3.18	89.6	100
Otoscope 25	2.53	3.18	79.5	100
Otoscope 26	2.87	3.18	90.2	100
Otoscope 27	2.72	3.16	86	100
Otoscope 28	3.04	3.16	96.2	100
Otoscope 29	2.98	3.18	93.7	100
Otoscope 30	2.94	3.18	92.4	100
Otoscope 31	3.00	3.18	94.3	100
Otoscope 32	3.08	3.18	96.8	100
Otoscope 33	2.76	3.18	86.8	100
Otoscope 34	3.00	3.16	94.9	100
Otoscope 35	3.03	3.18	95.3	100
Otoscope 36	3.00	3.11	96.5	100
Otoscope 37	3.04	3.14	96.8	100
Otoscope 38	2.42	3.16	76.1	100

**Table 4** Light intensity and test battery light ratio in relation to the new batteries in each otoscope.

	Test battery light intensity (lumens)	New battery light intensity (lumens)	Test light ratio (%)	New light ratio (%)
Otoscope 1	80	160	50	100
Otoscope 2	183	264	69.3	100
Otoscope 3	12	211	5.7	100
Otoscope 4	256	656	39	100
Otoscope 5	220	421	52.2	100
Otoscope 6	168	362	46.4	100
Otoscope 7	226	440	51.3	100
Otoscope 8	177	398	44.4	100
Otoscope 9	198	371	53.3	100
Otoscope 10	234	487	48	100
Otoscope 11	254	498	51	100
Otoscope 12	290	497	58.3	100
Otoscope 13	232	467	49.6	100
Otoscope 14	211	401	52.6	100
Otoscope 15	299	512	58.4	100
Otoscope 16	179	399	44.8	100
Otoscope 17	207	429	48.2	100
Otoscope 18	243	432	56.2	100
Otoscope 19	219	401	54.6	100
Otoscope 20	188	359	52.3	100
Otoscope 21	279	438	63.7	100
Otoscope 22	226	430	52.5	100
Otoscope 23	257	593	43.3	100
Otoscope 24	265	575	46	100
Otoscope 25	92	197	46.7	100
Otoscope 26	96	169	56.8	100
Otoscope 27	46	157	29.3	100
Otoscope 28	96	145	66	100
Otoscope 29	121	269	45	100
Otoscope 30	231	341	67.7	100
Otoscope 31	9	10	90	100
Otoscope 32	10	11	90.9	100
Otoscope 33	63	114	55.2	100
Otoscope 34	370	393	94.1	100
Otoscope 35	610	1420	42.9	100
Otoscope 36	204	233	87.5	100
Otoscope 37	38	51	74.5	100
Otoscope 38	67	231	29	100

battery is surely exhausted; for voltages between 0.8 and 1.3 V, the result is a weak unit; with voltages above 1.3 V, the battery can be considered good.<sup>6</sup> The mean charge of each analyzed battery was 1.35 V, which is considered good, and even then, replacing it by a new battery offers a significant gain regarding light intensity. This can be clearly observed when shown in percentages, as an increase of at least 20% of battery charge results in an increase of over 80% in light intensity.

When comparing the increases in light intensity, it was not possible to perceive any rules on light intensity improvement. This fact is due to the difference in the lamps used in the otoscopes and the variety of assessed brands. As an example, consider otoscopes 1 and 3. Otoscope 1 showed a 100% increase in light intensity with an increase of 144%

of battery power, while otoscope 3, with the same 144% increase in the battery power, showed an increase of approximately 1700% in luminosity.

In the study by Barriga et al., the authors assessed otoscopes located in 96 medical offices.<sup>4</sup> The light output was measured in each otoscope and reassessed with a new lamp, and when possible, a new battery was placed in the unit.<sup>4</sup>

In approximately one-third of the otoscopes, the light output was suboptimal.<sup>4</sup> Lamp replacement provided adequate illumination for 80% of the otoscopes.<sup>4</sup> Barriga et al. observed that one-third of physicians change otoscope lamps annually, and less than two-thirds do so every two years (as recommended).<sup>4</sup> In that study, almost half of rechargeable batteries were discharged.<sup>4</sup> It was observed that lamp bulb replacement was more significant than replacing the battery

to provide better luminous quality.<sup>4</sup> As the lamp replacement would require a standardization of brand and type of lamp bulb (LED or halogen light), this study chose to evaluate only the influence of battery power on otoscope light.

One of the difficulties in performing this study was having access to otoscopes at the designated sites, as they were always being utilized for diagnosis. It was observed that the available otoscope in the study sites was not always that of the institution, which makes battery charge control difficult, as when the professional himself is the owner of otoscope, he/she is responsible for replacing batteries. In the Emergency Department of the Hospital da Cruz Vermelha (Paraná, Brazil) otoscopes are electric, which provides maximum luminosity, with the state of the lamp bulb representing the only influencing factor.

Regarding the methodology, the researchers had difficulty with the luminosity measurement method standardization, as many items can influence it, such as ambient light, the light direction in relation to the light meter, time of measurement, and the speculum size. The completion of the assessment in a controlled environment (dark box) with the light directed to the center of the light meter (perpendicularly), the use of a standard speculum opening (3.00 mm), with the otoscope positioned on a flat surface and the possibility of changing the light meter height, allowed the standardization of the measurement methodology.

The authors propose other studies, comparing the influence of the battery power intensity and the exchange of the equipment lamps associated to a questionnaire directed to the assessing physician on the influence of the otoscope light intensity on the diagnosis of ear pathologies.

## Conclusion

There was a statistically significant difference between the proportion of light intensity of assessed otoscopes when evaluated with the batteries used at the time of assessment and with new, fully charged batteries.

To carry out a more precise otoscopic diagnosis, attention should be paid to the importance of the maintenance of a well-functioning device, with the capacity close to the maximum, as a small variation in battery charge results in a much greater variation in light intensity.

## Conflicts of interest

The authors declare no conflicts of interest.

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