Original Article

Precision in practice: An audit study on low-flow anesthesia techniques with desflurane and sevoflurane for cost-effective and sustainable care

ABSTRACT

Introduction: In the backdrop of escalating healthcare costs and an increasing focus on resource optimization, this audit study delves into the realm of anesthesia management, specifically exploring the application of low-flow anesthesia (LFA). The primary objective was to assess adherence to hospital standards and evaluate the economic implications of LFA (<1 L/min).

Materials and Methods: This retrospective audit focused on 700 adult patients undergoing elective surgeries with general anesthesia. Data sources included anesthesia records, electronic recording systems, and audits by a dedicated team. Fresh gas flow rates (FGFRs), minimum alveolar concentration (MAC), and volatile anesthetic consumption were analyzed. Cost comparisons between low-flow and high-flow anesthesia were conducted, employing specific cost per milliliter metrics.

Results: The average FGFR during the maintenance phase was found to be 0.45 ± 0.88 L/min. Adherence to hospital standards was notably high, with 94.29% of patients being maintained on low-flow gas rates. The differences in anesthetic consumption between low-flow and high-flow FGFR were statistically significant for both desflurane (12.17 ± 10.84 ml/MAC hour versus 43.12 ± 27.25 ml/MAC hour) and sevoflurane (3.48 ± 7.22 ml/MAC hour versus 5.20 ± 5.20 ml/MAC hour, $P < 0.001$). The calculated savings per patient with low-flow desflurane and sevoflurane anesthesia compared to high flow were found to be 109.25 AED and 6.74 AED, respectively.

Conclusion: This audit advocates for the widespread adoption of LFA as a standard practice. Beyond aligning with hospital standards, the study highlights the multi-faceted benefits of LFA, encompassing economic savings, environmental safety, and enhanced patient care.

Key words: Anesthesia management, cost analysis, desflurane, environmental impact, fresh gas flow rates, low-flow anesthesia, sevoflurane, volatile anesthetics

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Gopinath Kenkare Chowdappa, Svetoslav Ivanov Iolov, Khaled Saleh Abuamra, Prasad Padmakar Kulkarni, Jameelulla Aleemulla Shariff, Hatem Mohammed Khairy Abdelaziz, Justin Arun Kumar

Department of Anesthesia, Dubai Hospital, Al Baraha, Dubai, UAE

Address for correspondence: Dr. Gopinath Kenkare Chowdappa, Department of Anesthesia, Dubai Hospital, PO Box 7272, Al Baraha, Dubai, UAE.
E-mail: gopinathkc@dubaihealth.ae

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Introduction

The practice of anesthesia has evolved significantly in recent years, with an increasing focus on optimizing patient care, cost-effectiveness, and environmental sustainability. Within the realm of anesthesia, a promising avenue for potential cost reduction revolves around the administration of volatile anesthetics (VAs).[1] The notable advancement in this regard is the adoption of low fresh gas flow rates (FGFRs) during general anesthesia (GA). The classification of anesthesia circuits, as proposed by Baker, provides a systematic framework for understanding and implementing various flow rates.[2] This classification aids in tailoring anesthesia practices to individual patient needs and procedural requirements, enhancing the precision of anesthetic management. Despite the well-defined and specific classification, it is common for anesthesiologists in their routine clinical practice to perceive FGFR of 2–3 liters as indicative of low-flow anesthesia (LFA). Cultural and practical beliefs often lead many anesthesiologists to refrain from operating with an FGFR <1 L/min.[3]

Nevertheless, given the low blood-gas coefficients exhibited by current VA and the advancements in patient monitoring techniques, the adoption of LFA emerges as a viable strategy for minimizing the consumption of VA.[4-6] The safety profile associated with the implementation of LFA is widely recognized, and its advantages encompassing improved operational room conditions and substantial savings are universally acknowledged.[7-12] The conservation of anesthetic gases and the reduction of associated costs have been key motivators behind the adoption of LFA.[13] A study by Ryu HG *et al*.[1] demonstrated that the adoption of a low-FGFR policy showcased a remarkable decrease, approximately 40% in sevoflurane consumption.

In addition to low consumptions and economic benefits, the LFA technique contributes to environmental and ergonomic advantages, contributing to a noteworthy decrease in pollution within the operation theater attributed to anesthetic gases, fostering a safer workplace for healthcare professionals.[14] Furthermore, LFA has been shown to have favorable physiological effects on patients.[3,7,8] LFA has become not only safe and feasible but also a desirable practice in daily clinical settings.

In line with this, this audit endeavors to address two primary purposes in the context of anesthesia management. First, the aim is to ascertain the prevalence of patients subjected to low FGFR during the maintenance phase of GA with sevoflurane and desflurane, providing valuable insights into the current practices within our clinical setting and to compare it with established standards set by our hospital. By aligning our findings with these benchmarks, we aim to evaluate the adherence to institutional guidelines. Furthermore, a crucial aspect of this audit involves a comprehensive exploration of the cost-effectiveness associated with LFA compared to high flow.

Materials and Methods

The procedures followed in this clinical audit study were in accordance with ethical standards and with the Helsinki Declaration of 1975, as revised in 2000. The study was carried out as per the Institutional Clinical Audit Standards.

Study design

This audit study employed a retrospective observational design conducted at Department of Anesthesia over an 11-month period from February to December 2019. The primary objectives of the study were to calculate the percentage of patients anesthetized with a low FGFR <1 L/min, to compare them with the standards set by the Hospital, to estimate the average FGFR and average consumption of sevoflurane and desflurane during the maintenance phase of GA, and to compare the cost of low-flow versus high-flow anesthetic techniques. The auto control mode with a closed circuit was recommended during the maintenance phase. Switching to the fresh gas control mode was advised if FGFRs remained high on auto control for an extended period.

Inclusion and exclusion criteria

This clinical audit was carried out in adult patients undergoing elective surgery with GA in the main operation theater, who are intubated. Pediatric patients, cases involving laryngeal mask airway, and emergency cases were excluded from the study.

Data collection

Data were sourced from anesthesia records, anesthesia machine monitors, and the electronic recording system ‘Inovian’. We have chosen the maintenance phase of GA for our audit to be the period, starting 10 min after the mark ‘intubation’ and finishing 10 min before the mark ‘stop of anesthetics’. A designated audit team member collected the forms and cross-verified the data with anesthesia record forms. Random printouts from the electronic recording system were used for data confirmation. Average FGFRs at a temporal midpoint of the procedure and minimal alveolar concentration (MAC) were recorded for each of the anesthetic agents. The number of patients with the auto control mode chosen with a default closed circuit and switched to the fresh gas control mode were recorded in the audit tool form. To compare the consumption of VA in relation to the FGFRs used, we collected the MAC hour for desflurane and sevoflurane and then the VA consumption per MAC hour for each case was calculated and recorded in the audit tool form. MAC hour calculation involved multiplying MAC by the length of anesthesia. To compare anesthetic volume consumptions and cost comparison, anesthesia circuits were classified into low flow (FGFR 500–1000 ml/min), medium flow (FGFR 1–2 L/min), and high flow (FGFR 2–4 ml/min) based on the study by Baker.[2] The approximate cost per MAC hour (in AED) was considered as 3.53 AED/ml for desflurane and 3.31 AED/ml for sevoflurane. We conducted a cost analysis comparing low-flow with high-flow rates for desflurane and sevoflurane.

Statistical analysis

The statistical analysis was conducted using appropriate methods to assess the significance of observed differences and relationships within the study parameters. Descriptive statistics, including means and standard deviations, were calculated for continuous variables such as FGFR, MAC, MAC hour, and VA consumption. To compare the FGFR among different categories (low flow to high flow), analysis of variance (ANOVA) was employed. The independent *t*-test was used to compare the average consumption of desflurane and sevoflurane per MAC hour. In addition, comparisons of per patient costs between low-flow and high-flow anesthesia for both desflurane and sevoflurane were performed using the independent *t*-test. Statistical significance was set at a *P* value of < 0.05. All analyses were performed using SPSS version 25.0 (IBM Corp, Armonk, NY), and *P* values were interpreted to determine the significance of the observed differences.

Results

A total of 700 patients were included in this audit, with a mean duration of anesthesia recorded as 142.31 ± 68.66 minutes. The average FGFR during the maintenance phase was found to be 0.45 ± 0.88 L/min. Notably, the majority of patients, comprising 660 patients (94.29%), were maintained on low flow with FGFR <1 L/min. As shown in Figure 1, further categorization of patients on low gas flow rates revealed that 374 (53.43%) patients were on metabolic flow, 214 (30.57%) on minimal flow, and 72 (10.29%) on low flow with FGFR of 500–1000 ml/min.

During the maintenance phase of GA, the majority of patients, totaling 591 (84%), had the auto control mode chosen with the default Closed circuit option. However, in 22 cases (3.7%), the FGFRs on auto control mode persisted at very high levels for an extended period. Consequently, the system automatically switched to the fresh gas control mode, with low to moderate FGFRs (not exceeding 2 L/min), in adherence to the pre-defined protocol. The mean MAC was calculated as $0.75 \pm 0.30\%$, with a mean MAC hour of 2.02 ± 0.97.

Fresh gas flow rates and anesthetic consumption as per FGFR categorization

The average FGFR varied significantly among different FGFR categories. In patients with low-flow FGFR, the average FGFR was 0.70 ± 0.17 L/min, compared to 2.99 ± 0.56 L/min in patients with high-flow FGFR [Table 1]. Statistical analysis revealed a significant difference in FGFR among these categories ($P < 0.001$).

Volatile anesthetic consumption per MAC hour

Desflurane consumption totaled 15,538 ml, with a mean of 25.85 ± 30.30 ml, while the sevoflurane total consumption was 1989 ml, with a mean of 3.54 ± 7.19 ml. The calculated desflurane total consumption as per MAC was found to be 8,292 ml/MAC hour, and for sevoflurane, the total consumption as per MAC was 1,691 ml/MAC hour. The average consumption of the VA per MAC hour was 13.62 ± 14.71 mL/MAC hour for desflurane and 3.71 ± 7.21 mL/MAC hour for sevoflurane. A statistically

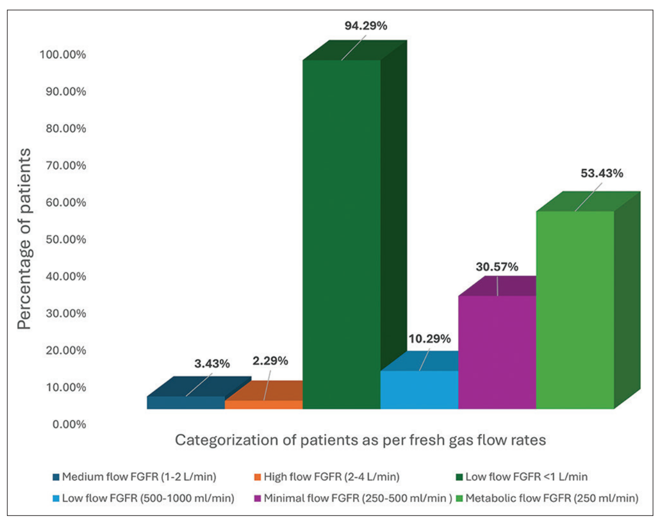

Figure 1: Categorization of audit patients as per Baker and Simionescu classification of anesthetic circuits

Table 1: FGFRs as per Baker classification of anesthetic circuits

Categories of Patients	FGFR (mean±SD)
Average FGFR (*n*=700)	0.45±0.88 L/min
Metabolic flow FGFR (250 ml/min) (*n*=374)	0.18±0.04 L/min
Minimal flow FGFR (250-500 ml/min) (*n*=214)	0.33±0.06 L/min
Low flow FGFR (500-1000 ml/min) (*n*=72)	0.70±0.17 L/min
Medium flow FGFR (1-2 L/min) (*n*=24)	1.54±0.29 L/min
High flow FGFR (2-4 L/min) (*n*=16)	2.99±0.56 L/min

significant difference was found between the two agents ($P < 0.001$).

Effect of fresh gas flow rates on anesthetic consumption

Desflurane total consumption as per MAC in patients on low flow FGFR (<1 L/min) was 6995 ml/MAC hour, with a mean of 12.17 ± 10.84 ml/MAC hour. Sevoflurane total consumption as per MAC in patients on low-flow FGFR was 1478 ml/MAC hour, with a mean of 3.48 ± 7.22 ml/MAC hour. In contrast, patients on high-flow FGFR (2–4 L/min) exhibited higher desflurane total consumption as per MAC (431.15 ml/MAC hour, mean: 43.12 ± 27.25 ml/MAC hour) and higher sevoflurane total consumption as per MAC (55.68 ml/MAC hour, mean: 5.20 ± 5.20 ml/MAC hour) [Figure 2]. The differences in anesthetic consumption between low and high flow rates were statistically significant for both desflurane and sevoflurane ($P < 0.001$).

Cost analysis

The total cost per year for total desflurane consumption, calculated at the rate of 3.53 AED/mL, was found to be 54,849.14 AED/year. Similarly, the total cost per year for sevoflurane consumption, at the rate of 3.31 AED/mL, was calculated as 6583.59 AED/year. The total cost for desflurane as per MAC was 29,270.76 AED, and for sevoflurane as per MAC, it was found to be 5,597.21 AED/year.

Comparison of costs between low-flow and high-flow FGFR

The total cost for desflurane as per MAC in patients on low-flow FGFR (<1 L/min) was 24,692.35 AED, while for patients with high-flow FGFR, it was 1,521.95 AED/year. Similarly, the total cost for sevoflurane as per MAC in patients on low-flow FGFR was 4,892.18 AED, while for patients with high flow FGFR, it was 184.30 AED/year.

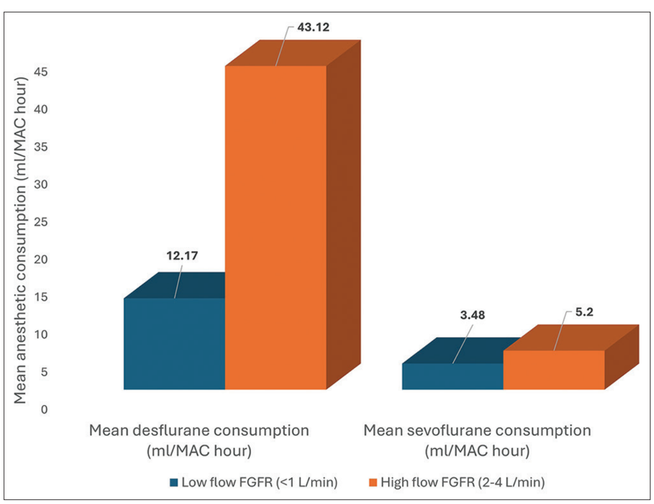

Figure 2: Average anesthetic consumption based on low- and high- flow fresh gas flow rates

Cost calculation per patient

For patients anesthetized with low-flow desflurane FGFR with a mean consumption of 12.17 ± 10.84 ml/MAC hour, the cost was 42.96 AED per patient. In contrast, for patients with high-flow desflurane FGFR with a mean consumption of 43.12 ± 27.25 ml/MAC hour, the cost was 152.21 AED per patient. Similarly, for patients anesthetized with low-flow sevoflurane FGFR, the cost was significantly higher in high-flow versus low-flow FGFR [Figure 3]. This difference between low-flow and high-flow groups was found to be statistically significant ($P < 0.001$) for both sevoflurane and desflurane.

Savings calculation

The calculated saving per patient with low-flow desflurane anesthesia compared to high-flow desflurane anesthesia was found to be 109.25 AED. Similarly, the saving per patient with low-flow sevoflurane anesthesia compared to high-flow sevoflurane anesthesia was 6.74 AED.

Discussion

The findings of this audit study shed light on several critical aspects of anesthesia management, particularly in the context of low-flow techniques with desflurane and sevoflurane. Our results indicate a high prevalence of patients anesthetized with low-flow FGFR, aligning with the established hospital standards. The high adherence to recommended FGFRs, coupled with favorable outcomes in terms of cost savings and resource efficiency, underscores the efficacy and feasibility of LFA in our clinical practice. The study emphasizes the need for ongoing monitoring and assessment of anesthesia practices to ensure optimal patient care, cost-effectiveness, and environmental responsibility.

The observed average FGFR of 0.45 L/min and the majority of patients falling within the low-flow category further support the contention that LFA is both feasible and widely adopted in our clinical setting. This echoes the sentiment expressed in the literature, advocating for the adoption of LFA to enhance patient outcomes.[4-7,15] The integration of LFA into routine practice has become increasingly prevalent, facilitated by advancements in modern anesthesia technology, including sophisticated machines, gas analyzer monitors, and precision vaporisers, coupled with the introduction of potent volatile agents.[15,16]

The substantial percentage of patients in our study (94.29%) receiving low FGFR (<1 L/min) during anesthesia maintenance highlights noteworthy adherence to hospital guidelines for low-flow FGFR and underscores the efficacy and acceptance of institutional policies. According to hospital guidelines, it

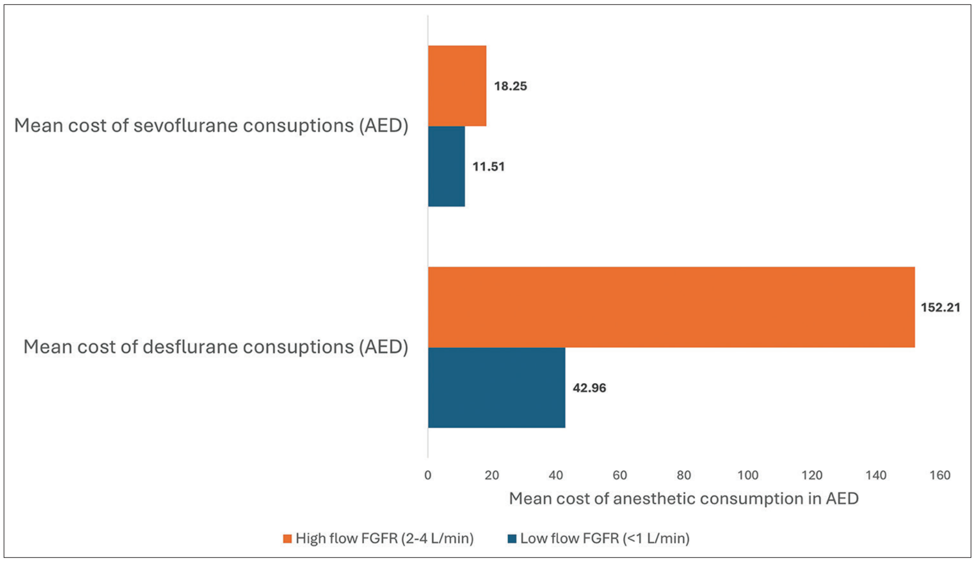

Figure 3: Cost comparison of anesthetic consumptions with low- flow FGFR versus high- flow FGFR anesthetic techniques

is recommended that in 80% of adult patients undergoing surgery lasting longer than 30 minutes under GA, the FGFR should not exceed 1 L/min. The high rate of adherence to this specific guideline is indicative of the anesthesiologists' commitment to maintaining optimal anesthesia practices.

A study conducted by Carter LA *et al*.[17] revealed a noteworthy trend toward the increased adoption of LFA practices within the department. This shift was accompanied by a substantial 25% reduction in the total departmental expenditure on volatile agents, despite an observed increase in theatre activity, all while maintaining the quality of patient care. The average MAC hour and VA consumption per MAC hour provide insights into the efficiency of anesthesia delivery with desflurane and sevoflurane.

The observed variations in VA consumption across different FGFR categories in our study shed light on the direct impact of flow rates on anesthetic agent utilization. Notably, patients on low-flow FGFR (<1 L/min) exhibited significantly lower desflurane consumption than patients on high-flow FGFR (2–4 L/min). Similarly, the findings for sevoflurane consumption reinforce the impact of FGFR on anesthetic agent usage. The statistically significant reduction in desflurane and sevoflurane consumption in the low-flow FGFR group substantiates the economic benefits of adopting low-flow techniques.

This substantial difference in anesthetic consumption aligns with established literature, emphasizing the inverse relationship between FGFR and VA consumption. In a study conducted by Cotter SM *et al.*,[5] comprehensive data were collected from 286 patients undergoing inhalational anesthesia for routine operative procedures. There was substantial reduction in the consumption of VA agents up to 56% with LFA. A study by Ryu HG *et al*. also demonstrated a remarkable reduction in VA consumption (approximately 40%) with the implementation of a low-FGFR policy.[1] In a study conducted by Shelgaonkar VC *et al*.,[18] it was observed that the consumption of sevoflurane was nearly 2.5 times lower in the LFA group compared to the high-flow group ($P < 0.001$). These findings provide valuable insights into the tangible benefits of adopting LFA practices, offering a data-driven perspective on the considerable reduction in VA consumption within a clinical setting and the potential for substantial cost savings by implementing LFA practices in routine clinical settings.

While the cost of anesthesia represents a relatively modest fraction of overall healthcare expenses, there has been a concerted effort to scrutinize anaesthetic drug expenditures as part of broader cost-containment initiatives. Given the extensive application of GA, with millions of patients undergoing GA annually, the adoption of cost-effective measures in anesthesia could yield considerable savings in drug expenditure without compromising patient comfort or increasing adverse events.[19]

The substantial cost disparities observed in our study between patients subjected to LFA and high-flow anesthesia techniques highlight the economic implications associated with FGFR management. For patients anesthetized with low-flow desflurane FGFR, the per-patient cost was notably lower at 42.96 AED. In stark contrast, patients with high-flow desflurane FGFR incurred a significantly higher per-patient cost of 152.21 AED. Similar patterns were observed for sevoflurane anesthesia (11.51 AED versus 18.25 AED). Calculating the savings per patient with low-flow desflurane and sevoflurane anesthesia revealed a substantial difference of 109.25 AED and 6.74 AED, respectively, compared to high-flow anesthesia.

The statistically significant differences in per-patient costs between the low-flow and high-flow groups reinforce the significant cost saving potential achievable through the strategic adoption of LFA practices. VA Utilization of LFA is linked to a substantial reduction in anesthesia costs, with estimates indicating a potential cost reduction of nearly 75%.[13] The simplicity and effectiveness of LFA position it as a viable and accessible method for cost reduction without sacrificing the paramount principles of patient well-being and safety.[19]

Furthermore, as the individuals making decisions regarding fresh gas flow, anesthesiologists bear a direct responsibility for the environmental consequences of anesthetic vapors and gases. The adoption of LFA emerges as a proactive measure to mitigate the environmental footprint associated with anesthesia practices. Literature suggests that each anesthesiologist, in the course of an average working day, administering N_2O or desflurane, may contribute to the CO_2 equivalent of over 1000 km of car driving.[20] Climatization thus emerges as an advantageous facet of LFA, particularly in settings where routine anesthesia practice lacks a heat and moisture exchanger. The use of low flows aids in maintaining humidity and moisture within the breathing circuit, contributing to a more favorable and controlled environment. Beyond these environmental and climatic benefits, LFA offers physiological advantages. It enhances the dynamics of inhaled gases, promoting improved mucociliary clearance and contributing to the maintenance of body temperature while minimizing fluid losses.[21-23] The substantial environmental impact of anesthetic gases in routine practice underscores the obligation for every anesthesiologist to conscientiously leverage available facilities and implement LFA.[24] This becomes not only a professional duty but also a crucial aspect of environmental stewardship.

Thus, employing LFA encompasses a spectrum of benefits, wherein it not only enhances economic efficiency by minimizing gas consumption but also contributes to environmental preservation. The symbiotic relationship between technological innovations and anesthesia protocols reflects the continual progress toward achieving safer, more cost-effective, and environmentally conscious healthcare practices.

Study limitations: it is crucial to acknowledge the limitations of our study, including its retrospective nature and the potential influence of various confounding factors on the observed outcomes. Future prospective studies could explore additional variables influencing VA consumption and provide a more comprehensive understanding of the practical implications of LFA.

Conclusion

The findings of this audit study underscore a commendable adherence to hospital standards for LFA. Patients on low flow demonstrated notably lower consumption of desflurane and sevoflurane per MAC hour, substantiating the cost-effective and resource-efficient nature of LFA practices. The calculated per-patient cost revealed a stark contrast between LFA and high flow, emphasizing the financial benefits of adopting LFA for both desflurane and sevoflurane anesthesia. As stewards of both patient care and environmental conservation, anesthesiologists play a pivotal role in shaping the trajectory of anesthesia practices toward sustainability. In light of these comprehensive findings, our study advocates for the continued integration of LFA as a standard practice.

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Conflicts of interest

There are no conflicts of interest.

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