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Pro-Con Debate for Thenar Tissue Oxygenation in Prone Position during Lumbar Discectomy

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ABSTRACT

AIM: To compare the regional tissue oxygen saturation under general, spinal, and epidural anesthesias during the posterior lumbar discectomy procedures performed in the prone position.

MATERIAL and METHODS: A total of 90 patients with an American Society of Anesthesiologists score I-III were evaluated. Using the research randomizer program, the patients were split into three groups: group of general anesthesia (GA, Group I), group of spinal anesthesia (SA, Group II), and group of epidural anesthesia (EA, Group III). Each patient received non-invasive peripheral arterial oxygen saturation (SpO_2), three-lead electrocardiography, non-invasive mean arterial blood pressure (MAP), and the in Spectra TM StO_2 Spot Check device with near-infrared spectroscopy (NIRS) technology. The group GA also received end-tidal CO_2 monitoring and tissue hemoglobin index (THI), and StO_2 monitoring.

RESULTS: The data of 90 patients showed that age, weight, height, American Society of Anesthesiologists score, amount of bleeding, duration of surgery, and anesthesia were not statistically significant. Tissue oxygen saturations were detected between groups at the 15th, 30th, 45th, and 60th minutes. The values of group EA at the 15th, 30th, and 45th minutes were higher than group SA ($p=0.001$; $p<0.05$).

CONCLUSION: This study shows that general anesthesia, as opposed to spinal and epidural anesthesia, offers superior thenar tissue oxygenation in a prone position during posterior lumbar discectomy surgery, despite the ongoing debate over the pros and cons of this position.

KEYWORDS: General anesthesia, Prone position, Spinal anesthesia, Tissue oxygen saturation

ABBREVIATIONS: EA: Epidural anesthesia, **GA:** General anesthesia, **NA:** Neuraxial anesthesia, **NIRS:** Near-infrared spectroscopy, **SA:** Spinal anesthesia

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INTRODUCTION

To meet the many obstacles presented in the perioperative treatment of patients for neurosurgical procedures, the field of neuroanesthesia has grown dramatically in recent years. The frequency of surgeries performed under regional anesthetia has significantly increased in recent years. Patients are generally placed in a prone posture during spinal procedures. Changes in this position can significantly affect the physiology of the patient. Maintaining oxygen homeostasis is a crucial objective of anesthesiologists when managing patients in the prone position. One of the most common causes for lower back pain is degenerative disc disease. Lumbar discectomy is a frequent spinal surgical procedure used for patients with lumbar disc herniation who do not improve with conventional therapy (2,3,6). During lumbar disc surgery, general anesthesia (GA) or neuraxial anesthesia (NA) can be used. In spinal anesthesia (SA) and epidural anesthesia (EA), the sympathetic nervous system is blocked, so the microcirculatory dynamics around the surgical field can be different from the circulatory dynamics. The field of anesthesia has grown significantly over the last few decades. The importance of fluids and vasopressors in maintaining tissue oxygenation through appropriate cardiac output and perfusion pressure has become increasingly evident. In order to maintain organ function, microcirculatory homeostasis must be maintained. Regional oxygen saturation (rSO_2) is measured in real time using a technique called near-infrared spectroscopy (NIRS), which decodes oxy- and deoxyhemoglobin signals. NIRS is a low-cost, simple, and non-invasive technique that has been shown to be safe and feasible for use during surgery. Compared to a single venous saturation measurement, it reveals hemodynamic changes earlier, but the effects of the prone position on tissue oxygenation have not been studied well. Annually, the number of spine surgeries performed globally is increasing at an astounding rate. Despite advances in technology (8), the effects of tissue oxygenation have not been studied well during lumbar discectomy in the prone position, under general or SA. The Pro-Con debate of the issue still continues. We investigated the effects of GA, SA and EA on tissue oxygenation in patients who would be operated on in a prone position during the lumbar discectomy procedure.

MATERIAL and METHODS

Ethical approval for this study was provided by the Ethical Committee of Recep Tayyip Erdogan University (2021/129; July 14th, 2021). Volunteer patients were determined with American Society of Anesthesiologists (ASA) classifications 1-3 between the ages of 18 and 65 who were operated on electively for lumbar disc herniation between July 2021 and December 2022. The patients were divided into three groups as Group GA (Group I), Group SA (Group II), and Group EA (Group III) through the research randomizer program. Demographic data such as age, gender, weight, height, duration of anesthesia and surgery, and operative data such as the amount of intraoperative bleeding were recorded. Each patient underwent non-invasive mean arterial blood pressure (MAP), three-lead electrocardiography, peripheral arterial oxygen saturation (SpO_2), and in Spectra TM StO_2 Spot Check Model 300 (Hutchinson Technology Inc, Hutchinson, MN, USA) device with near-Infrared Spectroscopy (NIRS) technology over a probe placed in the left-hand thenar region, receiving StO_2 and tissue hemoglobin index (THI) monitoring and end-tidal CO_2 monitoring to the group GA.

All patients were premedicated with 0.02 mg/kg midazolam. In Group I patients, after preoxygenation and denitrogenation with 100% oxygen for 3 minutes (min) after premedication, endotracheal intubation was performed with 1 µg/kg fentanyl, 2 mg/kg propofol, and 0.6 mg/kg rocuronium with an intravenous (iv) induction spiral tube. In volume-controlled mode after endotracheal intubation, a mixture of oxygen (40%) and air (60%) was applied for an ideal body weight of 6 ml/kg tidal volume, 5 cmH_2O positive end-expiratory pressure, and oxygenation. The respiratory frequency of $EtCO_2$ was adjusted to 35-40 mmHg. Anesthesia was maintained as an IV infusion with desflurane at a minimum alveolar concentration of 4-5 and remifentanil at 0.1-0.3 µg/kg/min.

In Groups II and III, O_2 was administered with a 5 L/min nasal cannula to patients undergoing neuraxial anesthesia. After premedication, the patient was given 15-17.5 mg hyperbaric bupivacaine in a seated position with a 25-G Quincke-tipped needle for SA after obtaining appropriate antisepsis from one or two levels above the level of disc herniation. For EA, an 18-G Tuohy needle was administered, the epidural interval was determined using the resistance loss method, and a test dose was performed with 3 cc of 2% lidocaine and 0.15 µg of adrenaline. After that, 75 µg of fentanyl and 0.05% bupivacaine were injected at the dose calculated according to the patient's height. After a neuraxial block, patients were followed up in a supine position for 10 min, and patients with sufficient block were taken to the prone position. A headrest foam pillow was used to position and keep the patient's head in a neutral position. The breathing circuit was reconnected, and a recruiting maneuver was carried out. The knees and hips of the legs were padded, and they were slightly flexed. The patient's abdomen was examined for any unusual pressure. Periodically, the airway, face, and eyes were also examined. Each patient underwent maintenance intravenous fluid therapy by the intraoperative 4-2-1 rule (4 mL for the first 10 kilos, 2 mL for the second 10 kilos, and 1 mL for every subsequent 10 kilos) by taking into account the fasting period.

Intraoperative heart rate (HR), MAP, $EtCO_2$, SpO_2, StO_2, THI data of the patients who were supine at 0 minutes (S0) and 10 minutes (S10) and prone at 15 minutes (P15), 30 minutes (P30), 45 minutes (P45), 60 minutes (P60), and postoperative (PPOSTOP) were recorded in the supine position after extubation.

At the end of the surgical procedures, patients who underwent GA underwent decurarization with 0.02 mg/kg IV atropine and 0.04 mg/kg IV neostigmine. Patients with spontaneous breathing, return of protective reflexes, and the ability to hold the head in the air for 5 seconds were extubated.

IV ephedrine was administered to patients with intraoperative MAP basal blood pressure decreases of more than 25%, and patients in need of vasopressors were excluded from the study. Intraoperative complications were recorded.

Statistical Analysis

The statistical analysis was performed using the Number Cruncher Statistical System (NCSS) (2007, Kaysville, Utah, USA) application. The Shapiro-Wilk test was used to assess the distribution of the study data as well as the descriptive statistical methods (mean, standard deviation, median, frequency, ratio, minimum, and maximum). When comparing three or more groups of quantitative data without a normal distribution, the Kruskal-Wallis test is used; when a normal distribution is present, ANOVA is used; and the Mann-Whitney U test is used for the comparison of the two groups that could not show a normal distribution and the Student's t-test is used for the normal distribution. To determine the relationship between the quantitative data, Pearson correlation analysis was used when it showed a normal distribution, and Spearman correlation analysis was used when it did not show a normal distribution. Significance was accepted as $p<0.01$ and $p<0.05$.

A power analysis was performed. As for the percentage measurement values of the methods, the effect size was 0.4, and the power was 80%. The margin of error was 0.05, and the total sample size found using the G-POWER program was n=66.

RESULTS

A total of 115 patients were included in this study, and the data of 90 patients, 30 in each group, were evaluated. There was no significant difference between demographic data such as age, weight, height, and gender in all three groups (Table I) ($p>0.05$). The flowchart is seen in Figure 1. When the effects

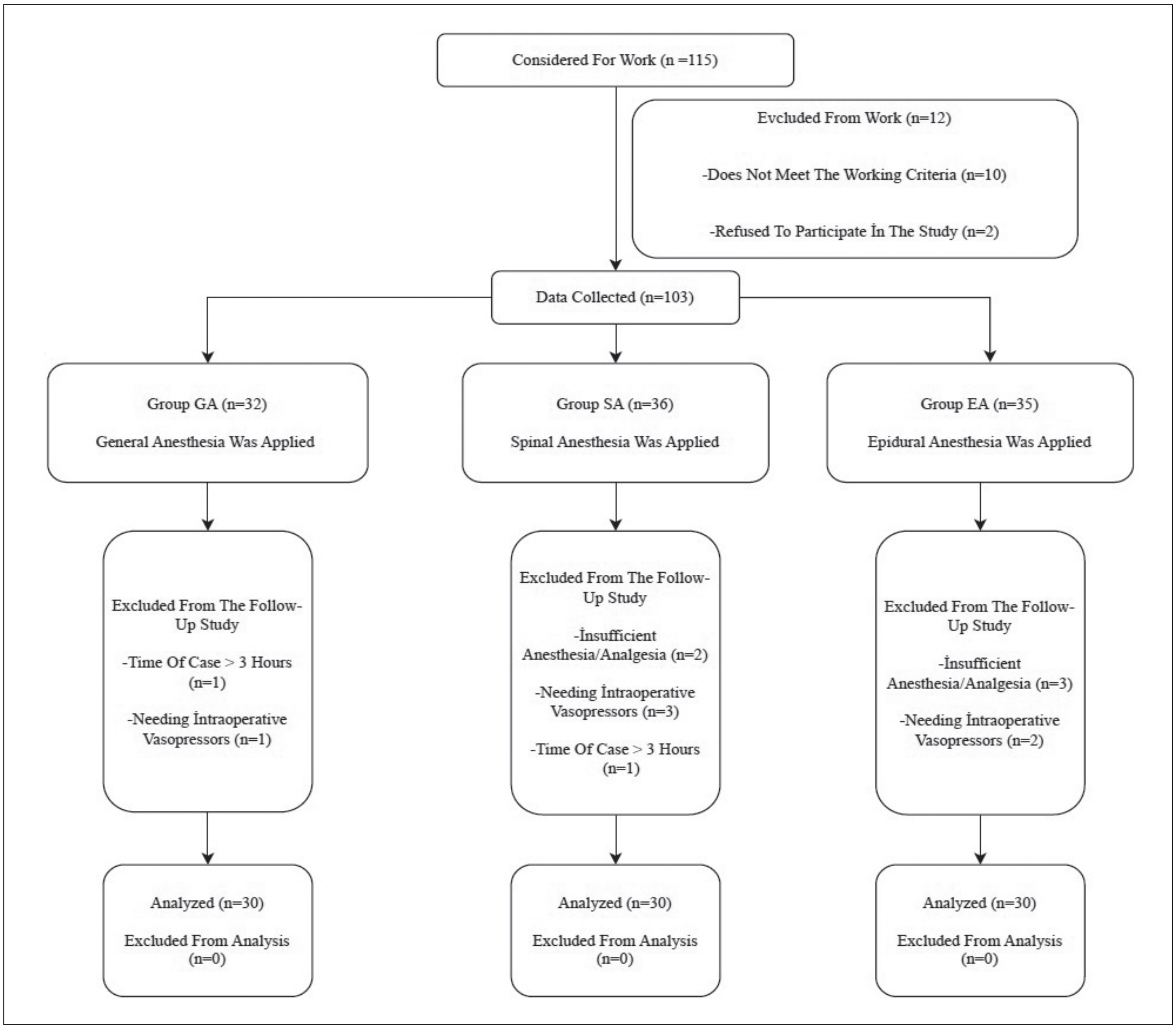

Figure 1: The flowchart of the study.

Table I: Demographic Data

	Group GA (n=30)	Group SA (n=30)	Group EA (n=30)	p-value
Age (years) (mean±SD)	47.1±11.3	50.43±10.49	44.83±11.05	0.107
Weight (kg) (mean±SD)	81.13±12.28	83.2±12.02	80.93±11.58	0.767
Height (m) (mean±SD)	1.69±0.09	1.68±0.09	1.73±0.08	0.094
Female/Male, n	13/17	15/15	8/22	0,164
ASA 1/2/3, n	5/23/2	5/19/6	1/26/3	

***GA:** General anesthesia, **SA:** Spinal anesthesia, **EA:** Epidural anesthesia, **ASA:** American Society of Anesthesiologists*

Table II: Intraoperative StO_2 Values (mean ± standard deviation)

	Group GA (n=30)	Group SA (n=30)	Group EA (n=30)	p-value
0 min	83.17±6.1	82.2±6.78	84.03±6.84	0.556
10 min	86±6.04	83.97±5.74	89±5.29	**0.005**
15 min	89.17±4.62	76.57±9.22	83.93±7.75	**0.001**
30 min	88.07±5.73	76.57±8.29	82.3±8.63	**0.001**
45 min	88±5.94	74.57±9.93	81.2±9.45	**0.001**
60 min	87.23±6.94	75.23±7.2	78.93±8.65	**0.001**
Postoperative	80.57±8.6	77.13±6.17	79.13±7.71	0.236

***min:** Minutes, **StO_2:** Tissue oxygen saturation, **GA:** General anesthesia, **SA:** Spinal anesthesia, **EA:** Epidural anesthesia*

of the anesthesia method on tissue oxygenation were evaluated by StO_2 from the thenar region, it was found that the StO_2 values of Group GA were higher than those of Group SA and Group EA at 15th, 30th, 45th, and 60th minutes in the prone position ($p=0.001$; $p<0.05$) (Table II, Figure 2). When neuraxial anesthesia methods were compared among themselves, StO_2 data of Group EA were significantly higher in the prone 15th, 30th, and 45th minutes than in Group SA ($p=0.001$; $p<0.05$). The results of the study are presented in the graphical abstract (Figure 3).

DISCUSSION

Main Results

To the best of our knowledge, this study represents the first research to determine the effects of GA, SA, and EA on tissue oxygenation in prone patients undergoing spinal surgery. This study indicates that GA provides better tissue oxygenation than SA and EA in a prone position during posterior lumbar discectomy surgery.

Interpretation

A sufficient oxygen supply is important to support proper cellular metabolism (7). The hypothesis of this study is that hemodynamics and respiratory complications for patients in prone or supine positions are not the same. Patients are more likely to have tracheal discomfort and cough when they are moved from the prone position to the supine position (5). Both physiological function and cellular signaling depend on oxidative stress. Oxidative stress, which is linked to disruptions in reduction/oxidation (redox) regulation, cellular malfunction, organ failure, and illness, is caused by an imbalance between the generation of reactive oxygen species and antioxidant defense. Anesthesia, surgery, and the patient all play a part in the complicated reaction known as perioperative oxidative stress. Surgery is an acute event that causes systemic dysfunction in addition to localized tissue damage. Providing tissues and organs with an appropriate supply and delivery of oxygen is a major goal in perioperative settings.

In the supine posture, the dorsal alveoli are more likely to experience atelectasis, and the ventral alveoli are more likely to experience over-inflation because the dorsal transpulmonary pressure (airway opening pressure minus pleural pressure) is higher than the ventral transpulmonary pressure.

Pro: GA in the prone position

Pressure on the intra-abdominal organs in the prone position, especially during thoracic procedures, can impact the hemodynamics and lung mechanics because of surgical compression (1). The dynamic lung compliance decreases when a patient under GA is placed in the prone position because there are no unrestricted movements of the chest wall or abdomen (1). A higher airway pressure is necessary to provide proper breathing when lung compliance is decreased (1). These patients need methods aimed at enhancing oxygenation, such as the prone posture (4). Healthcare providers must take precautions against endotracheal tube dislodgement, hemodynamic compromise, line disconnection, eye and pressure injuries,

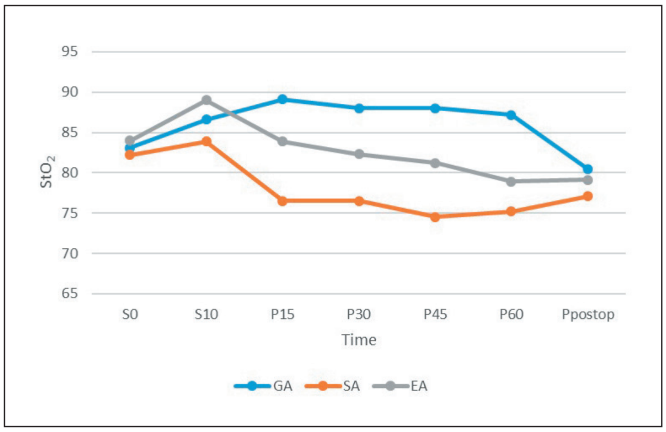

Figure 2: StO_2 graph of all patients over time.

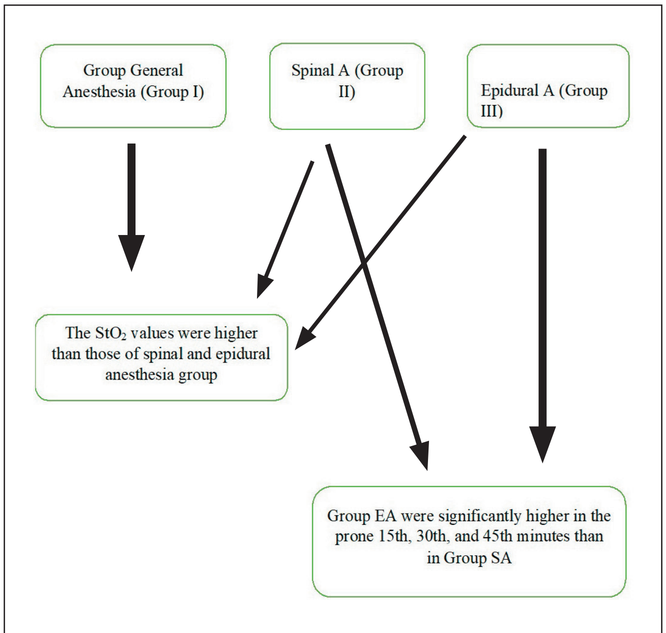

Figure 3: The study's findings are summarized in the graphical abstract.

and maintain access to the chest, central lines, arterial lines, and urinary catheters, even though the clinical advantages of proning greatly exceed any potential negative event (4).

Con: EA or SA under the prone position: Can it be a panacea?

Previous studies have shown that the prone posture improves oxygenation in a number of cases of acute lung damage, or ARDS (1). The prone position is frequently used to enhance oxygenation in patients with acute respiratory distress syndrome who are on mechanical ventilation and during specific surgical operations. Compared to the supine position, the prone posture produces more uniform ventilation, lung aeration, and strain distribution because the difference between the dorsal and ventral transpulmonary pressures is reduced. Increased oxygenation is a result of opening the collapsed dorsal lung sections, boosting homogenous ventilation, improving ventilation/perfusion ratios, decreasing alveolar shunt volume, raising functional residual capacity, and enabling secretion clearance (1). By improving lung circulation, decreasing dorsal lung compression, and adjusting the ventral-dorsal transpulmonary pressure gradient, the prone posture enhances gaseous exchange. In the prone position, there was an increase in functional residual capacity (1). There is little information available regarding the effects of the prone position on healthy lungs under GA, SA, or EA, despite the anesthesiologists' familiarity with its effects on damaged lungs. We hypothesized that tissue microcirculation can be impaired in the prone position. Tissue hypoperfusion may lead to numerous complications. Because arterial hyperoxemia increases the production of free oxygen radicals, it may result in end-organ damage. Follow-up of tissue perfusion and early detection of insufficiency allow early diagnosis and management of organ damage. In this study, microperfusion alterations of tissue were assessed by NIRS. We evaluated the effect of the anesthesia method on tissue oxygenation and microcirculation of patients undergoing lumbar discectomy in a prone position, with the measurement of StO_2 from the thenar region to observe changes in microcirculation. A null hypothesis, which is commonly used in statistical testing, asserts that certain outcomes (9) (such as the same StO_2 values under SA or GA in the prone position of lumbar discectomy surgery) are affected by methods (such as general versus spinal epidural anesthesia in this study) in the same way; however, in the prone position, Group GA's StO_2 values were higher than those of Group SA and Group EA when the effects of the anesthetic technique on tissue oxygenation were assessed using StO_2 from the thenar region ($p=0.001$; $p<0.05$).

The tissue oxygenation differences between the groups in this investigation were statistically significant, and the values were reasonably close to one another. Since compromised tissue oxygenation during surgery is linked to higher rates of postoperative mortality and morbidity, we believe that those little variations have a therapeutic significance. It has been demonstrated that tissue oxygenation monitoring during surgery is crucial for minimizing and preventing somatic damage, postoperative mortality, and morbidity.

Limitations

The study is single-centered with a relatively small sample size (n=30 per group) and lacks blinding, which may introduce bias. Furthermore, the exclusion of patients requiring vasopressor support may limit the generalizability of the findings to real-world surgical populations. There is no doubt that there are many parameters that affect blood oxygen parameters, such as patients' internal diseases. It can be better to include it and perform another multivariate analysis. Furthermore, the preoperative values of the patients can be compared with each other, and the statistical significance of the change can be evaluated. Therefore, these parameters can be considered as insufficient. These points are other limitations of the present study.

CONCLUSION

Although both SA and GA have been utilized in lumbar disc herniation procedures, GA is today utilized nearly exclusively (10). In this study, we compared the anesthesia methods and found that tissue oxygenation was better in the group where GA was applied than in the group treated with SA or EA. When neuraxial anesthesia methods were compared among themselves, it was found that tissue oxygenation was higher in EA application. Although there is ongoing debate on the pros and cons of prone positioning during lumbar discectomy, this study suggests that GA, as opposed to SA and EA, offers superior oxygenation of the thenar tissue during posterior lumbar discectomy surgery. Given the recent increase in the use of SA and EA in spinal surgery, neurosurgeons may find this study to be of interest. The findings of the study might serve as a caution that spinal anesthetics should not be used while a patient is prone, particularly if they have tissue oxygenation issues. More comprehensive studies are required.

Declarations

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Availability of data and materials: No new data were created or analysed during this study. Data sharing is not applicable to this article.

Disclosure: The authors declare that there are no conflicts of interest related to this study.

AUTHORSHIP CONTRIBUTION

Study conception and design: MNS
Data collection: MNS
Analysis and interpretation of results: LK
Draft manuscript preparation: SB
Critical revision of the article: AK
Other (study supervision, fundings, materials, etc...): OS
All authors (MNS, LK, SB, OS, AK) reviewed the results and approved the final version of the manuscript.

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