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Effects of pleasant olfactory mental imagery on the arterial oxygenation in patients with open heart surgery: A randomized controlled trial

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Background and purpose: Arterial hypoxemia is one of the most common respiratory complications following cardiac surgery. This study was intended to examine the effects of pleasant olfactory mental imagery on postoperative hypoxemia in patients undergoing open heart surgery.
Materials and methods: This is a randomized controlled clinical trial. The sample consisted of 80 patients who were randomly assigned to either practice olfactory mental imagery (experimental group) or receive routine care (control group). A card with the image of roses was given to patients and they were asked to look at the image, visualize the scent of roses in the mind, and then sniff as much as possible, hold their breath for 2 s and eventually exhale slowly through the nose. This procedure was consecutively repeated five times. After a fifteen-minute break, patients proceeded to practice olfactory mental imagery with other fruit images. The experimental group executed the olfactory mental imagery for two hours in the morning and two hours in the afternoon on postoperative days 1 and 2.
Results: No statistically significant differences were observed between the experimental and control groups regarding sociodemographic characteristics, medical and surgical information. This study also demonstrated that the mean Spao2 was significantly higher in the experimental group (97.400 ± 1.70) than the control group (96.465 ± 1.70) ($p = 0.015$).
Conclusion: The results of this study suggest that olfactory mental imagery can improve arterial oxygenation in patients with cardiac surgery.

1. Introduction

Early respiratory complications, including arterial hypoxemia, atelectasis, pneumonia, pleural effusion and respiratory distress syndrome, are common after cardiac surgery [1–3]. Arterial hypoxemia is one of the most common respiratory complications following cardiac surgery, which occurs in almost all patients postoperatively. Although a variety of conditions can lead to arterial hypoxemia, atelectasis appears to be the primary cause of an increased intrapulmonary shunt that results in arterial hypoxemia [4,5]. Due to external cardiopulmonary bypass, sedative medications, anesthesia, respiratory muscle dysfunction, pain from the sternotomy and chest drains, impaired phrenic nerve function and diaphragm dysfunction, cardiac surgical patients are subject to a reduction in lung volumes and serious pulmonary complications including nosocomial pneumonia [6–16], which can increase the length of hospital stay, health care costs, postoperative mortality and morbidity [1,17–19].

Despite the use of active (deep breathing along with coughing, incentive spirometry, frequent repositioning in the bed, and early ambulation) and passive (intermittent positive-pressure breathing, positive end expiratory pressure, and noninvasive positive-

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pressure ventilation) respiratory physiotherapy techniques following cardiac surgery [20], the incidence of post-surgical pulmonary complications is still considerable [21,22]. There is also insufficient evidence to support the effectiveness of respiratory physiotherapy techniques on the prevention of pulmonary complications after thoracic surgery [23–28].

Mental imagery is defined as the creation of a neural representation in the absence of an external stimulus or event [29,30]. Of various mental imageries (auditory, olfactory, visual, kinesthetic, and tactile), only olfactory imagery is accompanied by sniffing [30–33]. Although most people acknowledge that they have never experienced an olfactory mental imagery [34,35], there is still evidence to support human capacity for olfactory mental imagery [36].

Olfactory mental imagery is the ability to sense a smell in the absence of any olfactory stimulus and is actually a short memory of olfactory events with the mind's nose [33]. Similar to odor perception allowed by the sense of smell, olfactory mental imagery gives also rise to sniffing [33] which does not depend on the power of individuals' imagination [30,37]. Both olfactory perception and olfactory imagery may alter respiration [38]. Kleeman et al. found that “the changes in the breathing profile result from sniffing that accompanied both olfactory perception and olfactory imagery” (p.8). They also explored that respiratory minute volume and respiratory amplitude increase during pleasant olfactory imagery. This increase in respiratory parameters is brought about by the elevated tidal volume and the improved breathing pattern and is not associated with the respiratory rate [37]. A study revealed that odors associated with autobiographical pleasant memory can trigger a deep and slow breathing pattern [39].

Odor adaptation does not take place after olfactory imagery as the olfactory stimulus does not exist. Therefore, olfactory imagery can be used repeatedly in session. On the other hand, maximum sniffs occur when olfactory stimuli do not exist. This is because the cerebellum does not play its role of regulating the sniff volume inversely proportional to the odor concentration via a negative feedback mechanism [40–42]. Considering that nasal breathing (as opposed to mouth breathing) increases circulating blood oxygen and carbon dioxide levels, and improves overall lung volumes [43], it seems that pleasant olfactory mental imagery and resultant deep inspirations in the form of sniffing can become an easy part of respiratory exercise. The suggested mechanism is based on deep breathing caused by sniffing while trying to imagine smells and maintaining inspiratory volume in order to the expansion of collapsed alveoli.

To the best of our knowledge, no published study has explored the effect of pleasant olfactory mental imagery on the arterial oxygenation in patients after open heart surgery. Given the high incidence of hypoxemia following open heart surgery, despite active and passive breathing exercises, and the role of olfactory mental imagery in inducing deep breathing and the expansion of lung volumes, this study was intended to examine the effects of pleasant olfactory mental imagery on postoperative hypoxemia in patients undergoing open heart surgery.

2. Materials and methods

This is a randomized controlled clinical trial. The study population included all patients undergoing open heart surgery at a hospital affiliated to the Mazandaran University of Medical Sciences, Sari, Iran. This paper builds on a lager study entitled “effects of pleasant olfactory mental imagery on the incidence and extent of atelectasis in patients after open heart surgery”. The sample size for the original study was calculated as 30 patients for each group according to 95% confidence level, 90% statistical power, and 25% prevalence of atelectasis following cardiac surgery. With consideration of the likelihood of patient exclusion during the study, the final sample consisted of 40 patients in each group. The participating patients were randomly assigned to either practice olfactory mental imagery (experimental group) or receive routine care (control group) according to a computer generated randomization list (see Consort flow diagram, Fig. 1). The eligibility criteria included patients scheduled for elective, non-emergency, open heart surgery; age 18 years and older [44,45]; lack of mental impairment; lack of olfactory impairment (examined by a cotton ball soaked in alcohol); ejection fraction higher than 30 percent measured with echocardiography prior to cardiac surgery owing to its significant impact on the respiratory system [46]; no previous heart or lung surgery; lack of any chronic pulmonary diseases such as atelectasis and pneumonia according to treating doctors [15]; no previous severe head or nasal injuries; and no previous neurological disorders and recurrent sinus infections [30]. Patients were excluded from the study population if they had systolic blood pressure lower than 90 mmHg despite adequate fluid intake, arterial blood PH less than 7.30, partial pressure of arterial CO2 higher than 50 mmHg, arterial oxygen saturation less than 80% even with breathing supplemental oxygen, hemoglobin level less than 7 g/dL, serum creatinine level higher than 3.5 mg/dL, and a body mass index (BMI) of more than 40 kg/m^2 due to the increased risk of respiratory complications after surgery [47]. In addition, the exclusion criteria were a decision to withdraw from the study, postoperative hemodynamic instability (systolic blood pressure less than 80 mmHg) [21], postoperative bleeding more than 500 ml in the first postoperative hour [18], and the need for mechanical ventilator support for more than 15 h after surgical operation [48].

Four pleasant odors (roses, banana, apple and lemon) were used for mental imagery stimuli according to previous studies [30,37,39]. Pleasant olfactory stimuli were used as imagery-dependent sniffing functionally contribute to emotional tone [30] and interact with hedonics such that sniffs tend to be larger during imagery of pleasant odors than imagery of unpleasant odors as in real perception of odor [30,31,33,49]. Furthermore, pleasant odors induce a stronger breathing effect than unpleasant odors [32,37]. Visual images of odors are developed by the associations between vision and olfaction in human's daily lives and appropriate pictures for each odor evoke common mental images for odorous objects and these mental images cause humans to form expectations to the odors. Therefore, it is better to use visual images (e.g. pictures) instead of verbal cue to evoke the mental image when it is intended to induce more real images of odorous objects [50]. “In many experiments exploring phenomenal imagery, the cue to forming the image is the object's verbal referent— “imagine a lemon,” for example” (p.579) [51]. While this may be an effective way to recover a visual memory, it may not be an effective way to recover an olfactory memory [51].

All patients signed an informed consent form if agreed to participate in the study. To accustom participants to the experiment, patients in the experimental group underwent training for the olfactory mental imagery on the day before surgery. A card with the image of roses was given to patients and they were asked to look at the image, visualize the scent of roses in the mind, and then sniff as much as possible, hold their breath for 2 s and eventually exhale slowly through the nose. This procedure was repeated five times for the image of roses. After a fifteen-minute break, patients proceeded to practice olfactory mental imagery with other fruit images (banana, apple, and lemon) as similar as with the image of roses. In order to facilitate secretion clearance from the airways, patients were to be encouraged to have two effective coughs during exhalation following five consecutive olfactory mental imageries for each image. Each patient was expected to perform a total of twenty imagery tasks in an hour.