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The effect of pleasant olfactory mental imagery on the incidence and extent of atelectasis in patients after open heart surgery

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Highlights

- **Groups did not differ significantly for incidence of atelectasis 2-hr after surgery.**
- **The incidence of atelectasis in the test group was significantly lower on day 2.**
- **Olfactory imagery can reduce the risk of atelectasis in heart surgery patients.**

Abstract

Background and purpose: Atelectasis is the most common pulmonary complication after open heart surgery. This study was intended to examine the effects of pleasant olfactory mental imagery on postoperative atelectasis 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 (test 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 seconds 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 (banana, apple, and lemon). The test group executed the olfactory mental imagery for two hours in the morning and two hour in the afternoon on postoperative days 1 and 2. The control group received the routine ICU care. A questionnaire collected information on sociodemographic characteristics and clinical parameters. Chest radiographs were used to diagnose atelectasis, which were evaluated by the hospital radiologist.

Results: No statistically significant differences were observed between the two groups regarding sociodemographic, medical and surgical information. The incidence of atelectasis in the test group (40%, n = 16) was significantly lower than in the control group (67.5%, n = 27) on postoperative day 2 (p=0.02).
Conclusion: Our findings suggest that olfactory mental imagery can improve respiratory function and reduce the risk of atelectasis in patients with cardiac surgery.
Keywords: mental imagery, olfactory imagery, atelectasis, heart surgery.

Introduction

Early pulmonary complications are common after cardiac surgery,[1-3] such complications include atelectasis, pneumonia, pleural effusion, and acute respiratory distress syndrome.[4, 5] Atelectasis is the most common pulmonary complication after open heart surgery[5] with the incidence of 15-98% after heart and thoracic surgeries.[6] In Iran, the incidence of atelectasis has been reported to be as high as 75% and 56.7% following thoracic[7] and coronary artery bypass surgeries[8], respectively. Atelectasis is the collapse of a group of alveoli, a small lobule or larger lung units, which can be caused by a variety of factors following surgery (specifically thoracic surgery) including external cardiopulmonary bypass, sedative medications[9, 10], anesthesia[3, 10, 11], respiratory muscle dysfunction[11-13], pain from the sternotomy, pain from the chest drains[10, 14-16], impaired phrenic nerve function, and diaphragmatic dysfunction.[5, 11, 17, 18] There may be no significant clinical symptoms of post-surgical atelectasis. However, post-surgical atelectasis has a progressive process and may contribute to serious pulmonary complications including nosocomial pneumonia, which can increase the length of hospital stay and health care costs.[1, 19-21]

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, noninvasive positive-pressure ventilation) respiratory physiotherapy techniques following cardiac surgery[22], the incidence of post-surgical atelectasis is still considerable.[7, 23] There is also insufficient evidence to support the effectiveness of respiratory physiotherapy techniques on the prevention of pulmonary complications after thoracic surgery.[6, 24-28]

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.[29] Olfactory mental imagery is thought to involve the same brain areas as olfactory perception.[30-32] Similar to odor perception allowed by the sense of smell, olfactory mental imagery gives also rise to sniffing[31], which does not depend on the power of individuals' imagination.[33, 34] Several studies indicated that pleasant odors are sniffed stronger and longer than unpleasant odors.[34-36] One of the characteristics of the olfactory system is its close connection with the respiratory system.[36, 37] Kleeman et al. found that "changes in the breathing profile result from sniffing that accompanied both olfactory perception and olfactory imagery". They also explored that respiratory minute volume and respiratory amplitude increase during pleasant olfactory imagery in comparison to baseline. 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.[33] There are two assumptions about the improvement of respiratory function following olfactory mental imagery. The first one is that breathing pattern is often slow and deep with the least rate during the feelings of comfortableness and pleasantness. In other words, deep breathing and pleasantness mutually affect each other. Pleasant olfactory mental imagery contributes to increased feelings of pleasantness and comfortableness, leading to deep breathing and reduced respiratory rate.[38] The second hypothesis suggests that there is a deep synchronization between the brain's slow-wave (alpha waves) across the entire cortical mantle and slow and deep breathing pattern during sleep. "Humans have learned, through the conscious control of slow breathing, to induce a level of whole-brain synchronization that is naturally found only during slow-wave sleep. However, when induced in the active state, the synchronization occurs at the higher frequencies associated with controlled mentation" (p.435).[39] Pleasant olfactory mental imagery can also stimulate lung baroreceptors through deep breathing caused by the sniff reflex. Stimulating these receptors leads to an increase in the frequency and duration of inhibitory neural impulses, resulting in parasympathetic dominance. Alpha waves are also synchronized through enhanced activation of the parasympathetic system.[40] Thus, deep breathing and alpha waves mutually affect each other, which facilitates deep breathing pattern.

It has been shown that odor-evoked autobiographical pleasant memory retrieval may extend the inspiratory and expiratory time (particularly the expiratory time) through pleasantness of the memory or increased parasympathetic tone, resulting in deep breathing and reduced respiratory rate.[38] This respiratory pattern is not only controlled by voluntary deep breathing and changes in metabolic demand, but also it is affected by olfactory-related brain regions.[41] Prolonged expiration triggered by olfactory imagery[38] increases intra-thoracic pressure,[42] which pushes more blood into the heart with a subsequent increase in stroke volume. Baroreceptors in aortic arch receive more pressure caused by the increased stroke volume, which inhibits the tonic activity in vasoconstrictor fibers and excites the vagal innervations of the heart with resultant vasodilatation, a decrease in blood pressure and bradycardia.[40, 42] Vagal cardiac and pulmonary mechanisms are linked, thereby the changes in the cardiovascular system may have effects on the respiratory system.[38] Therefore, an increase in pulmonary vagal tone leads to slow and deep breathing pattern.

Odor adaptation does not take place after olfactory imagery as the physical odor stimulus does not exist. Therefore, olfactory imagery can be used repeatedly in session. On the other hand, given that the cerebellum regulates inversely the sniff volume in relation to odor concentration,[33, 43] maximum sniffs occur during olfactory imagery with physically absent odors. Considering that nasal deep breathing more than oral deep breathing can improve respiratory function,[44] it seems that pleasant olfactory mental imagery and resultant deep inspirations in the form of sniffing can become an easy part of respiratory exercise.

To the best of our knowledge, no published study has explored the effect of pleasant olfactory mental imagery on postoperative atelectasis in patients undergoing open heart surgery. Given the high incidence of atelectasis 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 atelectasis in patients undergoing open heart surgery.

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. The sample consisted of 80 patients who were consecutively enrolled and randomly assigned to either practice olfactory mental imagery (test group) or receive routine care (control group) according to a computer-generated randomization list**.** The eligibility criteria included patients scheduled for elective, non-emergency, open heart surgery; age 18 years and older;[45, 46] lack of mental impairment, ejection fraction higher than 30 percent measured with echocardiography prior to cardiac surgery owing to its significant impact on the respiratory system;[47] no previous heart or lung surgery, lack of any chronic pulmonary diseases such as atelectasis and pneumonia according to treating doctors;[17] no previous severe head or nasal injuries, and no previous neurological disorders and recurrent sinus infections.[34] In addition patients were not enrolled in the study 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.[48] , The exclusion criteria were a decision to withdraw from the study, postoperative hemodynamic instability (systolic blood pressure less than 80 mmHg),[7] postoperative bleeding more than 500 ml in the first postoperative hour,[20] and the need for mechanical ventilatory support for more than 15 hours after surgical operation.[2]

All patients signed an informed consent form if agreed to participate in the study. To accustom participants to the experiment, patients in the test 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 seconds and eventually exhale slowly through the nose. This procedure was repeated five times for 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.

After the training session, the test group executed the olfactory mental imagery for two hours in the morning and two hours in the afternoon on postoperative days 1 and 2. The control group received the routine ICU care. A questionnaire collected information on sociodemographic characteristics and clinical parameters including age, sex, and marital status, highest level of educational attainment, smoking status and BMI. The questionnaire also recorded information on type of heart surgery (vessels, valves), number of arteries bypassed, number of chest tubes inserted, duration of surgery, duration of cardiopulmonary bypass, overall intubation duration, and duration of mechanical ventilation.

Chest radiographs were used to diagnose atelectasis, which were evaluated by the hospital radiologist. Data were analyzed with SPSS (Statistical Package for Social Science, version16.0) using descriptive statistics (mean, standard deviation, and percentage) and analytical tests (Chisquare, t-test, and McNemar's test). An alpha level of 0.05 or less was set as the criterion for significance.

Results

A total of 80 patients, including 40 males and 40 females, were investigated. No statistically significant differences were observed between the test and control groups in terms of age, gender, smoking history, marital status, highest level of educational attainment, and BMI (Table1). The statistical analysis showed no significant differences in type of surgery, number of arteries bypassed, duration of cardiopulmonary bypass, duration of surgery, number of chest tubes inserted, duration of mechanical ventilation and overall intubation duration between the two groups (Table2). Chest radiograph findings confirmed all detected atelectasis were sub segmental. In addition, there was no statistically significant difference between two groups in the extent of atelectasis. The two groups did not differ significantly for the incidence of atelectasis 2 hours after surgery in the ICU (test group: 32.5%; n=13 *vs* control group: 35%; n=14). The incidence of atelectasis in the test group (40%, n=16) was significantly lower than in the control group (67.5%, n=27) on postoperative day 2 (p=0.02). Table 3 depicts the incidence and extent of atelectasis 2 hours and 48 hours after cardiac surgery.

The statistical analysis showed no significant difference in the incidence changes of atelectasis between postoperative day 2 (40%, n=16) with 11 new cases and 8 improved cases of atelectasis and two hours after surgery (32.5%, n=13) in the test group (p=0.648). On the contrary, the changes in the incidence of atelectasis between postoperative day 2 (67.5%, n=27) with 16 new cases and 3 improved cases of atelectasis was significantly different from those in two hours after surgery (35%, n=14) (p=0.004) in the control group (Table 4).

Discussion

The aim of present study was to explore the effects of pleasant olfactory mental imagery on postoperative atelectasis in patients undergoing open heart surgery. The study results confirmed our hypothesis, indicating that the incidence of atelectasis was significantly lower in the test group, suggesting that olfactory mental imagery can improve respiratory function and reduce the risk of atelectasis in patients with heart surgery. Improvements in respiratory function following olfactory imagery have also been documented by other researchers. Several studies have indicated that sniff volume capacity is significantly increased when imaging pleasant odors.[35, 36, 49] In another study, it was shown that olfactory mental imagery of pleasant odors can increase respiratory amplitude and respiratory minute volume only by increasing tidal volume and improving the breathing pattern without any changes in the respiratory rate, resulting in an improvement in the respiratory function.[33] In addition, Masaoka (2012) found that the pleasantness toward the odor evoked by autobiographical memory is associated with increased a slow and deep breathing pattern.[38] In addition, a systematic literature review of the effects of olfactory mental imagery on respiratory function deduced that this type of imagery can effectively improve respiratory function.[50]

All research studies of olfactory imagery have included healthy subjects, while patients with cardiac surgery were investigated in the present study. Studies of breathing exercises on the prevention of pulmonary complications following cardiac surgery have reported conflicting results. However, postoperative breathing exercises are routinely performed for patients with cardiac surgery.[51-53] Studies have reported that active breathing exercises such as deep breathing along with directed coughing and incentive spirometry can prevent or reduce atelectasis after heart and thoracic surgeries[7, 8, 53, 54] which is consistent with the results of the present study. However, several studies have claimed that there is no sufficient credible evidence establishing a connection between breathing exercises and decreased pulmonary complications after heart and thoracic surgeries.[6, 24-26] Therefore, further research is needed to confirm available study results. Our study demonstrated that breathing exercises through olfactory mental imagery improves the respiratory function and thereby reduces the incidence of postoperative atelectasis in patients with cardiac surgery. Other studies have examined the beneficial effect of active breathing exercises (such as deep breathing, directed coughing and incentive spirometry) on postoperative pulmonary complications in patients with heart and thoracic surgeries, while deep breathing was performed with olfactory mental imagery and the resultant sniff reflex activation in the present study. Deep breathing exercises help reinflate collapsed alveoli, improving respiratory function and preventing atelectasis. Olfactory mental imagery enhances ventilation efficiency for oxygen as well as respiratory muscle performance by means of deep breathing.

The accuracy and interpretation of our findings may be limited by several uncontrolled confounding variables, including routine breathing exercises (performed by the test group), anxiety, and pain. These variables may have partly affected the study results. There is a need to match patients for the pharmacological management of pain and anxiety in the postoperative period and to have a larger sample to ensure the identification of best matching variables in future studies. In addition, the encouragement of patients to perform olfactory mental imagery may also have had an impact on the patients' mental function and consequently the findings of the study, which can be eliminated in future research.

Conclusion

Our findings suggest that olfactory mental imagery can improve respiratory function and reduce the risk of atelectasis in patients with cardiac surgery. It is recommended that mental imagery is to be incorporated into an existing preventive practice for respiratory complications following cardiac surgery, given its benefits of being non-invasive and safe, being easy to learn and administer, and being cost-effective.

Conflict of interest statement

There is no conflict of interest to declare.

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Table 1. Sociodemographic and clinical parameters of participants*

Variables	Groups		*P value*
	Test (n=40)	Control (n=40)	
Age (years)	63.20±7.99	61.55±10.32	0.42
Gender			
Male	23(57.5)	17(42.5)	0.26
Female	17(42.5)	23(57.5)	
Marital status			
Single	2(5)	1(2.5)	0.55
Married	38(95)	39(97.5)	
Highest level of educational attainment			
Illiterate	25(62.5)	27(67.5)	
Primary/secondary school	9(22.5)	6(15)	0.88
Diploma	2(5)	2(5)	
University graduate	4(10)	5(12.5)	
Current smoker			
Yes	6(15)	1(2.5)	0.48
No	34(85)	39(97.5)	
BMI (kg/m2)	27.33±4.86	27.64±4.53	0.76

*Data are presented as number (%) or mean ± standard deviation.

Table 2. Comparison of surgical data between two groups*

Variables	Groups		*P value*
	Test (n=40)	Control (n=40)	
Type of surgery			
CABG	33(82.5)	35(87.5)	0.58
VS	3(7.5)	1(2.5)	
VS+CABG	4(10)	4(10)	
Duration of surgery (h)	3.88±0.67	4.03±1.13	0.48
Duration of CPB (min)	73.77±22.40	78.4±43.05	0.54
Number of arteries bypassed	2.81±0.46	2.85±0.42	0.7
Number of chest tubes inserted	2.07±0.47	2.27±0.45	0.057
Duration of intubation postoperatively (h)	12.68±4.21	13.46±4.94	0.44
Duration of mechanical ventilation postoperatively (h)	5.99±3.16	7.37±4.38	0.11

*****Data are presented as n (%) or mean ± standard deviation.
CABG: coronary artery bypass graft; VS: valve surgery; CPB: cardiopulmonary bypass.

Table 3. Incidence and extent of atelectasis within 2 and 48 hours postoperatively*

Time & Groups	Atelectasis			Atelectasis-free lungs	*P value*
	Segmental & subsegmental	Lobar	Entire lung		
2 hours after surgery					
Groups	13(32.5)	------	------	27(67.5)	1

Test (n=40)	14(35)	------	------	26(65)	
Control (n=40) Total	27(33.7)	------	------	53(66.3)	
48 hours after surgery					
Groups					
Test (n=40)	16(40)	------	------	24(60)	0.02
Control (n=40)	27(67.5)	------	------	13(32.5)	
Total	43(53.8)	------	------	37(46.2)	

*Data are presented as n (%).

Table 4. Incidence changes of atelectasis within 2 hours and 48 hours after surgery*

Groups &Time	48 hours after surgery		Total	*P value* McNemar
	Segmental & subsegmental	atelectasis-free lungs		
Test				
2 hours after surgery				
Segmental & subsegmental	5 (31.3)	8(33.3)	13(32.5)	0.648
atelectasis-free lungs	11 (68.7)	16(66.7)	27(67.5)	
Total	16 (100)	24(100)	40(100)	
Control				
2 hours after surgery				
Segmental & subsegmental	11 (40.7)	3(23.1)	14(35)	0.004
atelectasis-free lungs	16 (59.3)	10(76.9)	26(65)	
Total	27 (100)	13(100)	40(100)	

*Data are presented as n (%).