Effect of deep breathing exercises on oxygenation after major head and neck surgery

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OBJECTIVES: To investigate respiratory and hemodynamic responses to deep breathing exercise (DBE) during the follow-up period in the intensive care unit after major head and neck surgery.

STUDY DESIGN: Prospective study.

SUBJECTS AND METHODS: Thirty-five patients were instructed to perform DBE every hour for 3 consecutive hours during the first postoperative day. The ratio of the partial pressure of arterial oxygen to the fraction of inspired oxygen (PaO2/FiO2), oxygen saturation (SpO2), respiratory rate (RR), heart rate (HR), and mean arterial pressure (MAP) was recorded.

RESULTS: DBE increased the PaO2/FiO2 ratio from 416.7 ± 143.6 to 453.4 ± 110.0 mm Hg and increased SpO2 from 97.4 ± 1.9 to 99.2 ± 0.9. DBE decreased the RR from 24.1 ± 3.3 to 21.8 ± 2.9 breaths/min (P < 0.05). No statistically significant difference in HR or MAP was observed after DBE (P > 0.05).

CONCLUSION: DBE improves oxygenation after major head and neck surgery, without causing additional harmful hemodynamic effects.

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The location of the primary tumor was the larynx in 18 patients, the oral cavity in six patients, the tonsils in three patients, the hypopharynx and skin in two patients, and the parotid gland in one patient. Three patients had metastatic neck masses from an unknown primary tumor. Appropriate surgical treatment was performed for the primary lesion as dictated by tumor site and stage. All patients underwent neck dissections: unilaterally in 26 patients and bilaterally in nine patients. Nineteen radical, five modified radical, and 20 selective neck dissections were performed, and a pectoralis major myocutaneous flap was used to reconstruct a tongue cancer resection defect in one patient.

All patients were extubated the day after surgery in the ICU. DBE was initiated approximately 30 minutes after extubation. While resting in a semi-recumbent position, the patients were instructed to inhale as slowly and deeply as possible, hold their breath for 3 seconds, and then exhale in a relaxed manner. With the help of a physiotherapist using proprioceptive input, the patients were encouraged to make each subsequent breath deeper than the previous breath for five to 10 breaths. This period was followed by a rest period (ie, normal breathing), and the cycle was repeated four times per hour for 3 consecutive hours. Before and immediately after DBE, hemodynamic parameters, including HR and MAP, and respiratory parameters, including the respiratory rate (RR) and oxygen saturation (SpO2), were recorded with monitoring equipment (Draeger Medical Systems, Inc. Danvers, MA). The ratio of the partial pressure of arterial oxygen to fraction of inspired oxygen (PaO2/FiO2) was also calculated from arterial blood samples taken before and 30 minutes after the intervention. Because all patients received oxygen therapy to prevent desaturation (SpO2 < 90%), FiO2 values were recorded, and the PaO2/FiO2 ratio was calculated to determine pulmonary gas exchange.

All patients were successfully weaned from the ventilator and then transferred to the Department of Otorhinolaryngology–Head and Neck Surgery on the day after surgery.

**Statistical Analysis**

Data were analyzed with the Statistical Package for the Social Sciences for Windows, version 11.0 (SPSS Inc, Chicago, IL). Hemodynamic and respiratory parameters before and after DBE were compared by repeated measures of analysis of variance. When a significant time effect was found, paired sample *t* tests with Bonferroni correction were used to detect significantly different time periods. Changes in arterial blood gas were analyzed by dependent sample *t* tests. Differences in hemodynamic and respiratory parameters between smokers and nonsmokers were compared by Mann-Whitney *U* tests. A *P* value of 0.05 was considered statistically significant.

### RESULTS

**Effect of DBE on Respiratory Parameters**

DBE resulted in a statistically significant increase in the PaO2/FiO2 ratio by a mean value of 36.6 ± 50.1 mm Hg (8.7%) compared with pretreatment baseline values (*P* < 0.05). DBE also resulted in a statistically significant increase in SpO2 by a mean value of 1.8 ± 1.4 (1.9%), and a statistically significant decrease in the RR by a mean value of 2.2 ± 2.9 breaths per minute (9.2%) compared with pretreatment values (*P* < 0.05; Table 1).

No statistically significant differences were observed between smokers and nonsmokers in comparisons of the effects of DBE on respiratory parameters (*P* > 0.05; Table 2). In addition, none of our patients experienced postoperative pulmonary complications while hospitalized.

**Effect of DBE on Hemodynamic Parameters**

No statistically significant differences were observed in hemodynamic parameters after DBE compared with pretreatment resting values (*P* > 0.05). Compared with pretreatment values, a slight increase in HR (1.4 ± 5.9 beats/min, or 1.8%) and a slight decrease in MAP (0.8 ± 5.7 mm Hg, or 0.9%) were observed, but these difference were not statistically significant (*P* > 0.05; Table 1).

No statistically significant differences were observed between smokers and nonsmokers in comparisons of the effect of DBE on hemodynamic parameters (*P* > 0.05; Table 2).

### DISCUSSION

Pulmonary complications contribute to morbidity, mortality, and increased treatment costs as a result of prolonged hospitalization following major head and neck surgery. The reported rates for pulmonary complications after head and neck cancer surgery are 2% for adult respiratory distress syndrome, 3% for failure to wean, and 4% to 15% for
pneumonia. Even in a case series reporting a relatively low incidence of pneumonia (3.26%), the mortality rate for this morbidity approached 10.94%. Thus, every effort to improve ventilation capacity, which in turn should decrease postoperative pulmonary complications, is invaluable.

Risk factors and avoidance strategies for postoperative pulmonary complications after major surgeries have been discussed in various studies, but the majority of these investigations focused on thoracic and abdominal surgery. These types of surgeries directly interfere with pulmonary function by invading the pleural space or transgressing the respiratory muscles with the surgical incision. However, this is rarely the case in head and neck surgery patients. Instead, respiratory dysfunction in this group may be the result of phrenic nerve inhibition by a reflex mechanism or postoperative pain, both of which may lead to reduced tidal volume, vital capacity, total lung capacity, and, subsequently, insufficient cough. The inability to cough effectively may cause atelectasis in the basal lung segments and a decrease in functional residual capacity (FRC), which in turn negatively affects the gas exchange properties of the lung by increasing the ventilation/perfusion mismatch.

In a comparison of upper abdominal surgery with head and neck surgery, Campbell et al found a similar pattern of change in vital capacity, but a much greater decrease in patients undergoing major head and neck surgery. Hypoxemia was at its worst on the first or second day after surgery and then began to recover. After both surgeries, arterial $\text{PaO}_2$ decreased on the first postoperative day. However, although $\text{PaO}_2$ started to recover by the seventh postoperative day after upper abdominal surgery, $\text{PaO}_2$ did not improve during the same period in head and neck surgery patients. Although the definitive etiology was unclear, poor oxygenation in the head and neck group was attributed to the greater extent of surgery and the need to perform a tracheotomy. Tracheotomy, and the subsequent inhalation of dry air, was thought to decrease FRC by stimulating bronchial secretion and increasing bronchomotor tone. The patients described here also had major surgeries and prolonged operative times, with a mean anesthesia duration of 8.41 hours. Twenty-six of 35 patients also required a tracheotomy.

As a method of increasing FRC and preventing respiratory complications, DBE, incentive spirometer (IS), continuous positive airway pressure, intermittent positive pressure breathing (IPPB), and early mobilization are performed during the postoperative period. Physiotherapists have successfully used DBE to increase tidal volume and prevent pulmonary complications during the postoperative period in upper abdominal and cardiac surgery patients. Westerdahl et al found a significant reduction in atelectatic lung area and improved oxygenation after DBE in coronary artery bypass surgery patients. Jenkins et al found IS and DBE to be superior to mobilization alone after upper abdominal surgery. Celli et al compared an untreated control group with treatment with IPBB, DBE, or IS in a series of 172 patients undergoing elective abdominal surgery. All treatment groups had positive benefits in terms of respiratory parameters compared with the control group. No difference was found among treatment groups in terms of treatment efficacy. To our knowledge, only one study has evaluated the effects of postoperative chest physiotherapy in head and neck surgery patients. Tan reported a positive effect of IS on postoperative forced vital capacity and oxygenation in patients undergoing major head and neck surgery.

Lederer et al reported that hourly regular coaching during DBE is more important than the use of any specific device. Patient collaboration and motivation are essential factors in any treatment, and the assistance of a physiotherapist is important in helping patients perform their best. For this reason, we performed DBE with proprioceptive input with the help of a physiotherapist and encouraged patients to make each breath deeper than the previous one. Because oxygenation, gas exchange, and FRC improve in the semirecumbent position, we also used this position in a standardized manner in all interventions.

Significant volume displacement occurs between the thoracic and abdominal cavities during surgery, both as a result of placing patients in a supine position and by the admin-

### Table 2

Comparison of hemodynamic and respiratory parameter changes before and after DBE between the smoker and nonsmoker groups (mean ± SD)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Smokers (n = 30)</th>
<th>Nonsmokers (n = 5)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BDBE</td>
<td>ADBE</td>
<td>BDBE</td>
</tr>
<tr>
<td>HR (bpm)</td>
<td>79.2 ± 13.2</td>
<td>81.4 ± 13.0</td>
<td>87.0 ± 6.2</td>
</tr>
<tr>
<td>MAP (mm Hg)</td>
<td>90.4 ± 15.8</td>
<td>89.8 ± 15.2</td>
<td>79.0 ± 9.1</td>
</tr>
<tr>
<td>$\text{PaO}_2$/FiO$_2$ (mm Hg)</td>
<td>418.3 ± 146.0</td>
<td>452.0 ± 143.0</td>
<td>407.0 ± 143.4</td>
</tr>
<tr>
<td>$\text{SpO}_2$ (%)</td>
<td>97.4 ± 1.7</td>
<td>99.2 ± 1.0</td>
<td>97.4 ± 3.2</td>
</tr>
<tr>
<td>RR (breaths/min)</td>
<td>24.1 ± 3.5</td>
<td>21.8 ± 3.0</td>
<td>24.0 ± 2.8</td>
</tr>
</tbody>
</table>

BDBE, Before deep breathing exercises; ADBE, after deep breathing exercises; HR, heart rate; bpm, beats per minute; MAP, mean arterial pressure; $\text{PaO}_2$/FiO$_2$, ratio of partial pressure of arterial oxygen to fraction of inspired oxygen; $\text{SpO}_2$, oxygen saturation; RR, respiratory rate.
istration of general anesthesia. These volume changes affect the curvature of the diaphragm, moving it up from its natural resting position, which decreases the diaphragm’s efficiency as a pressure generator, as reflected by a decrease in FRC from 200 to 300 mL. Consequently, patients’ lungs and chest wall become stiffer after surgery and more energy is required to expand the lungs and chest wall. Patients must then increase their RR to maintain minute ventilation in the postoperative period. Such an increase in RR may be more easily achieved than an increase in tidal volume. DBE helps to remove secretions and relax the patients, and also increases chest wall mobility and promotes surfactant production. As lung compliance improves, alveolar ventilation and oxygenation increase and the work of breathing decreases. The improvement in gas exchange and the reduction in the RR after DBE were both statistically significant in our study. Our results are likely related to an increase in tidal volume and chest mobility, as well as a decrease in the work of breathing. Because we demonstrated that improved ventilation is reflected clinically in a decreased RR, we hypothesize that responses to DBE can be easily monitored by checking only the RR.

DBE improved ventilation to a similar degree in both smokers and nonsmokers. This is particularly important because most head and neck cancer patients are smokers. Thus, DBE can be used without any restriction regarding smoking history.

Physiotherapy may cause hemodynamic instability by precipitating alterations in cardiovascular parameters, such as blood pressure, HR, or intracranial pressure. Stiller recommended that hemodynamic status be carefully monitored during physiotherapy to prevent detrimental effects. In our study, we observed no significant hemodynamic side effects as a result of DBE, suggesting that this therapy is safe for head and neck surgery patients when performed in an appropriate manner.

CONCLUSION

Our findings suggest that performing DBE has beneficial effects in the treatment of postoperative hypoxemia after major head and neck surgery. Physiotherapy can be initiated safely in the ICU on the first postoperative day, and physiotherapists should be considered an essential part of the postoperative patient care team. Because all patients are instructed to perform DBE while staying in the ICU at our institution, including a nontreatment group in this study was ethically impossible. Therefore, studying the effects of DBE on patients who are extubated immediately after surgery and sent directly to inpatient departments would also be desirable. Because pulmonary physiotherapy is not routinely performed in this group of patients, including a nontreatment group to compare treatment efficacy or possible postoperative pulmonary complications would not present an ethical conflict.

REFERENCES


