

Effects of different respiratory expansion methods



INTRODUCTION

A pneumothorax is defined as a collapse of lung due to air in the pleural space. A pneumothorax without secondary causes, such as trauma or surgical intervention, is classified as a spontaneous pneumothorax.

Treatment options for a pneumothorax include medical follow-up, fine-needle aspiration, percutaneous catheter drainage, tube thoracostomy, video-assisted thoracoscopic surgery (VATS), and thoracostomy (1, 2).

Pneumothoraces assessed radiologically that occupy 20% of the lung will require a tube thoracostomy. During follow-up, re-expansion of the lung is achieved by the removal of the air from the pleural space through the drainage system via a number of methods, including forced coughing, triflow, inflating a balloon, straining exercises, walking, pursed lip breathing, and climbing up the stairs (1). In this study, we investigated the effects of different respiratory expansion methods, assessing forced coughing, triflow exercise, balloon inflating, and walking on respiratory function tests including pulse rate, time to complete pulmonary expansion, and time to remove the chest tube among patients with PSP.

MATERIAL AND METHODS

Subjects with PSP, which occupied more than 20% of the lungs and had a chest tube fitted, were enrolled in the study. All subjects had a chest tube fitted between the midaxillary line and the 6th or 7th intercostal space under local anesthesia using 5–10 cc lidocaine hydrochloride solution (2 mL/20 mg) accordingly. All patients were administered equal doses of intravenous paracetamol relative to body weight to keep pain under control postoperatively. Different respiratory training methods were applied to

obtain pulmonary expansion and adherence of parietal and visceral pleural layers. For this purpose, 40 consecutive subjects aged 16 to 60 years with PSP were prospectively included. Following detailed radiological evaluation, the patients diagnosed with secondary pneumothorax or significant lesions on computed tomography (CT) were excluded. The eligible subjects were randomly assigned to one of four groups (10 subjects per group) as follows: forced coughing plus the triflow exercise with same-brand and functionality triflow (the triflow group); forced coughing plus inflating-balloon exercise with standardized, same-stiffness, and same-feature balloons (the balloon group); forced coughing plus exercise on a treadmill with determined distance and duration (the treadmill group); and forced coughing (the control group). All respiratory training methods were applied in accordance with patients' ability at maximum. Age, gender, weight, height, body mass index (BMI), and which lung had a pneumothorax were recorded. After insertion of the chest tube, each patient was followed to determine when complete pulmonary expansion occurred by chest X-ray. Further measurements included air leakage, FEV1 values on day 1 after application of the chest tube and day of discharge, follow-up oxygen saturation, and pulse rate values. A number of subjects also had VATS performed due to prolonged air leakage. The subjects with prolonged air leakage, defined as failure to stop air leakage at the end of a 10-day respiratory training, underwent surgical treatment. Thus data collection of the subjects was limited to the initial 10 days after application of the chest tube. Informed consent of each subject and approval of the local ethics committee were obtained for the study.

Statistical analysis

Statistical analyses were performed using the SPSS software version 18.

Continuous variables are expressed as means \pm SD, while categorical variables are presented as frequencies (%). Spearman tests were used for correlation analyses and the Kruskal-Wallis test was used to identify significant differences between the groups. The Wilcoxon signed rank test was used to compare changes in FEV1, oxygen saturation, and the pulse rate between day 1 after application of the chest tube and the day of discharge. Categorical variables of the groups were compared using the chi-square test. A p value of less than 0.05 was considered to show a statistically significant result.

RESULTS

In total, 40 subjects were included in the study. The four groups were statistically similar in respect to age, gender, weight, height, BMI, and side of pneumothorax. FEV1 and oxygen saturation values on day 1 after application of the chest tube and on the day of discharge were statistically nonsignificant across the groups. The groups had a similar average time to complete pulmonary expansion and duration of air leakage. The difference in the FEV1 values on day 1 after application of the chest tube and on the day of discharge was defined as Δ FEV1. The groups had similar Δ FEV1 values. In separate analyses of the groups, each group showed a significant change in FEV1 from day 1 after chest tube application compared to the day of discharge ($p < 0.01$ for all groups). VATS was the method of choice for all subjects indicated for surgery. Using VATS, the subjects underwent apical wedge resection and pleurectomy. The frequency of application of VATS was

similar across the groups. The average day 1 oxygen saturation values of each group did not differ from the day of discharge (p values for balloon, triflow, treadmill and control groups = 0. 103, 0. 085, 0. 063, and 0. 076, respectively, using the Wilcoxon test). There was a positive correlation between the time to complete the pulmonary expansion and the duration of air leakage ($r = 0. 800$, $p < 0. 001$). We did not find any correlation between the duration of air leakage and day 1 FEV1 ($r = -0. 022$, $p = 0. 892$) or day 1 oxygen saturation ($r = -0. 128$, $p = 0. 432$).

Discussion

We found that respiratory expansion methods such as forced coughing, triflow exercise, balloon inflating, and walking had similar effects on clinical parameters such as respiratory function tests, pulse rate, time to complete pulmonary expansion, and time to removal of the chest tube among patients with PSP.

PSP is defined as cases without any detectable underlying causes while secondary pneumothorax has an underlying cause, with the biggest cause being chronic obstructive pulmonary disease (2). Thorax CT is the most useful and demonstrative tool for differentiating primary and secondary cases. PSP was encountered mostly between 20 and 40 years old and was observed six times more frequently among males than females.

Asymptomatic subjects suffering a small PSP can be followed medically without the need of any intervention. If the PSP under medical follow-up is bigger or there is the presence of a tension pneumothorax, a contralateral lung lesion or difficulty in pulmonary expansion exists at the follow-up, tube thoracostomy is indicated for treatment (3).

Following tube thoracostomy, pulmonary expansion is rapidly achieved in most of the patients and usually air leakage ceases within 48 h. Prolonged air leakage is defined as continuation of air bubbles for greater than 48 h after the insertion of a chest tube. Tube thoracostomies are radiologically followed with chest X-ray to control the presence of pulmonary expansion. Subjects with resistive air leakage of more than 10 days, recurrent pneumothorax, pneumothorax of bilateral lung involvement, or a first pneumothorax attack following pneumonectomy are directly indicated for surgical treatment. Patients with permanent air leakage or failure of re-expansion of the lung must be rapidly referred for surgical intervention (2–4). Of the 40 patients, only six were referred for surgery due to air leakage that continued for more than 10 days. Bullae-bleb resection, together with apical pleural abrasion or apical/total pleurectomy, are the standard surgical treatment methods for patients with PSP. Currently, uniportal or multiportal VATS is frequently performed for suitable candidates. Usually it is applied via axillary thoracotomy and/or lateral thoracotomy (5). We performed apical wedge resection and pleurectomy for all six patients via uniport VATS using the drainage passage as the entry port. The frequency of VATS application was statistically similar for the groups.

All of the patients were advised to perform respiratory exercises such as forced coughing, triflow, balloon inflating, walking, and climbing up stairs to increase pulmonary capacity, to prevent atelectasis, to strengthen their respiratory muscles (which are weakened following anesthesia during the surgery), and finally to reduce the incidence of complications (3, 5). The basic defensive mechanism of the respiratory system is cough. This is the

one of the most effective methods to remove secretions and foreign bodies from the respiratory tract. Deep breathing via the triflow exercise allows a high amount of air intake into the lungs. The pulmonary capacity improves, and as a result the oxygen intake increases. If triflow is not available, inflating a balloon and walking exercises are the other effective respiratory exercise methods used frequently to reduce postoperative complications (6, 7). All of the methods are clinically effective; however, there are no studies in the literature that have compared the effectiveness of these respiratory exercise methods among patients who received chest tubes or thoracic surgery.

Whether spirometric exercises are useful methods for chest physiotherapy in low- and high-risk patients has been researched, and there's evidence that they are not beneficial in low-risk patients such as individuals using colostomy (8). Row et al. (9) compared the effectiveness of spirometric and respiratory physiotherapies in 185 patients that had undergone high-risk coronary bypass surgery. They did not find any difference between the groups in respect to atelectasis, oxygen saturation, pulmonary infection, and duration of index hospitalization. They reported that spirometric exercise plus respiratory physiotherapy was not superior over respiratory physiotherapy alone. Celli et al. (10) compared the efficiencies of deep breathing, spirometry, and intermittent positive pressure breathing exercises for reducing pulmonary complications. However, they did not find any differences between the methods except shorter duration of hospitalization in the spirometry group. Similarly, Gosselink et al. (7) included 44 patients with pulmonary surgery and 30 patients with esophageal surgery and

compared the effectiveness of respiratory physiotherapy and spirometry exercises. Pulmonary function, body temperature, chest X-ray, complete blood counts, and duration of hospitalization including within the intensive care unit of all subjects were recorded. The groups did not differ significantly in respect to these parameters and they had similar incidences of atelectasis when assessed radiologically. The addition of spirometric exercises on top of regular respiratory physiotherapy did not shorten the duration of index hospitalization or the stay in intensive care. The groups did not show any differences related to BMI. However, having a BMI of $> 27 \text{ kg/m}^2$ was an independent risk factor for pulmonary complications in patients that had undergone abdominal surgery. In the present study, BMI was not significantly related with index hospitalization ($p = 0.385$). Issa et al. (11) reported a 60% complication rate among a group that had undergone respiratory physiotherapy, while there was a 13% complication rate among groups that had undergone endotracheal aspiration via minithoracotomy.

In the present study, time to complete pulmonary expansion and duration of air leakage were similar across the groups. Average ΔFEV1 values were also similar for the groups. All of these findings indicate that there was not any significant difference between respiratory exercises in respect to clinical outcomes. When analyzing each group separately, we found that FEV1 from day 1 of all subjects had increased significantly by the day of discharge. This may be due to the contribution of the non-functional pneumothorax space into functional respiration following complete expansion. However, the day 1 oxygen saturation of the subjects did not differ significantly from the postoperative values (p values for balloon, trifold, treadmill, and control

groups = 0.103, 0.085, 0.063, and 0.076, respectively, using the Wilcoxon test). These findings imply that the collapsed lung tissue due to the pneumothorax did not impair oxygen saturation following the application of a chest tube.

There was a positive correlation between the time to complete pulmonary expansion and the duration of the air leakage, indicating that the air leakage stopped earlier, leading to complete pulmonary expansion on the chest X-ray. The duration of the air leakage did not have any significant correlation either with the FEV1 or oxygen saturation on day 1 after the application of the chest tube. This suggests that prolonged air leakage did not impair the respiration mechanism. Thus, we confirmed that air leakage of 7–10 days in duration might not deteriorate a patient's clinical status until the decision for surgery is made. This finding is consistent with the literature.

In parallel with the literature, this study confirms that respiratory exercise methods, added to forced coughing, are not superior over forced coughing alone, and forced coughing itself is enough to provide sufficient respiratory exercise. Similarly, the trifold, balloon, and treadmill groups, in respect to clinical outcomes, indicate that deep breathing exercises such as inflating a balloon or walking are as effective as trifold, which thus can be replaced if unavailable.