Aging of the respiratory system

Seung Hun Lee, Su Jin Yim, Ho Cheol Kim

Department of Internal Medicine, Gyeongsang National University School of Medicine, Jinju-si, Gyeongsangnam-do, Korea

Changes in the respiratory system caused by aging generally include structural changes in the thoracic cage and lung parenchyma, abnormal findings on lung function tests, ventilation and gas exchange abnormalities, decreased exercise capacity, and reduced respiratory muscle strength. Decreased respiratory system compliance caused by reduced elastic recoil of the lung parenchyma and thoracic cage is related to decreased energy expenditure by the respiratory system. Lung function, as measured by 1-second forced expiratory volume and forced vital capacity (FVC), decreases with age, whereas total lung capacity remains unchanged. FVC decreases because of increased residual volume and diffusion capacity also decreases. Increased physiological dead space and ventilation/perfusion imbalance may reduce blood oxygen levels and increase the alveolar-arterial oxygen difference. More than 20% decrease in diaphragm strength is thought to be associated with aging-related muscle atrophy. Ventilation per minute remains unchanged, and blood carbon dioxide concentration does not increase with aging. However, responses to hypoxia and hypercapnia are decreased. Exercise capacity also decreases, and maximum oxygen consumption decreases by >1%/year. Consequence of these changes, many respiratory diseases occur with aging. Thus, it is important to recognize these aging-related respiratory system changes.

Key Words: Aging, Respiratory system

The worldwide aging population is rapidly increasing and Korea also expects to become an ultra-aging society as elderly individuals aged 65 years or older will comprise more than 25% of its total population by 2025.1

The human body undergoes a variety of aging-related changes including changes in the respiratory system. However, normal variations of such changes may not be easily distinguishable from pathological changes because of marked interindividual differences.2 Changes in the respiratory system with aging do not cause serious problems such as airway obstruction or parenchymal lung disease in healthy people because they have reserve lung capacity. However, when the affected person has comorbid underlying lung disease due to previous infections or smoking, the reserve is reduced, and therefore, lung problems can arise more easily. The changes in the respiratory system caused by aging generally include structural changes in the thoracic cage and lung paren-
chyma, abnormal findings on pulmonary function tests, ventilation and gas exchange abnormality, reduced respiratory muscle strength, and decreased exercise capacity. In this review, the authors intend to present the physiological alterations caused by aging such as changes in respiratory system dynamics, gas exchange abnormalities, and changes in exercise capacity and respiratory muscle strength.

**Changes in respiratory system structures and dynamics**

Structural changes induce an increase in the anterior and posterior diameters of thoracic cage, causing it to assume a round shape. Increased stiffness and reduced compliance of the thoracic wall is induced by aging-related calcification of the joint cartilage of the thorax and spinal scoliosis caused by osteoporotic changes. A study that measured the compliance of the thoracic wall in 61 healthy adults ranging from 24 to 75 years old, reported that the thoracic compliance was reduced according to the participants' age. Reduced compliance of the thorax causes a reduction of energy efficiency increasing the effort required for breathing. Additional aging-related changes include periphery airway calcification, reduction of elasticity due to changes in elastic fibers of small airways (reduction by about 0.1~0.2 cm H2O each year), reduction in the proportion of lung parenchyma versus the lung volume, and mucous gland hypertrophy in addition to structural changes in lung parenchyma.

**Change in Lung Function**

Aging-induced changes in the respiratory system, such as reduction of compliance and of respiratory muscle strength, result in changes in the results of pulmonary function tests. Lung function reaches its peak when individuals are in their early 20s, is maintained for some time, and then decreases normally with aging. In general, it is known that 1-second forced expiratory volume (FEV1) reduces by about 20 mL/year up to the age of 25~39 years, whereas it reduces by 35 mL/year in those over 65 years of age. The reduction rates of forced vital capacity (FVC) and FEV1 increase with increasing age, but they do not display a linear reduction and the reduction rates are faster in men than in women.

Total lung capacity (TLC) does not change or slightly reduces during aging, but residual volume (RV) is increased and vital capacity (VC) is reduced. Compared to a 20-year-old person, the
residual volume increases by about 50% and vital capacity reduces by 75% in a 70-year-old person. Therefore, the ratio of RV/TLC increases with age, and this increase is considered to be due to reduced lung elasticity and thoracic wall compliance, weakened expiratory muscle strength, and increased closing lung volume.\(^6\)\(^{14}\)

The peak expiratory flow rate (PEFR) reaches its peak at the age of approximately 30~35 years and subsequently declines, particularly after the age of 45. After the age of 50, PEFR reduces at the rate of 4 L/min/year in men and 2.5 L/min/year in women. These reductions indicate small airway disease based on the flow rate-volume curve.\(^14\)

Small changes in airway resistance occur during aging, which can be explained by a reduction in the diameter of the peripheral airway; however, the diameter of the central airway is increased with aging and this offsets the effects of increased peripheral airway resistance,\(^15\) which comprises only 10% of the total airway resistance.

The diffusion capacity for carbon monoxide (DLCO) also decreases with age by 0.2 mLCO/min/mmHg/year in men and by 0.15 mLCO/min/mmHg/year in women. The degree of decreases in women is reported to be lesser than that in men, possibly due to the influence of estrogen, which maintains integrity of the blood vessel. A study by Stam et al. reported a decrease in the diffusing capacity of 55 healthy persons compared with aged ≥70 years, even after adjusting for the dimension of the alveoli. This decrease in diffusing capacity may likely be caused by aging-induced changes in the alveolar-capillary membrane.\(^16\)

With aging-induced ventilation/perfusion imbalance, physiological dead space increases. At the age ranged 15 to 20 years old, the dead space is about 13% of alveolar ventilation, but it increases to 32% at the age ranged from 61 to 75 years.\(^17\) In study of Miller et al., it was reported that the physiological dead space in old healthy person was about 235 ± 67.5 ml and it showed it was increased by more than 50% compared to young healthy person whose physiological dead space was 150 ml.\(^18\) With the increase of dead space, the normal arterial oxygen's partial pressure in the elderly people is lowered than in younger people while the differences in the concentrations of alveolar arterial oxygen, that is, (Aa) DO\(_2\), is increased. However, the minute ventilation is not decreased and there is no occurrence of the carbon dioxide exchange impairment by aging, therefore, the occurrence of respiratory acidosis should be considered as pathological in old ages as well.
Changes in the respiratory muscle strength

Decreased muscle strength is a general consequence of aging, and affects the respiratory muscles as well.\textsuperscript{19,20} Respiratory muscle strength can be determined by measuring various parameters such as the maximum trans-diaphragmatic pressure (Pdi max), maximal voluntary ventilation (MVV), and maximal inspiratory pressure (MIP). All these parameters have been found to be decreased in elderly people.\textsuperscript{21,22}

In a study that measured the muscle strength of the diaphragm, it was found that elderly people (65 to 75 years old) show a decrease of approximately 25% in the Pdi max compared to young adults (19 to 28 years old).\textsuperscript{19} A study by Polkey et al. also showed similar results,\textsuperscript{23} and the MIP was 30% higher in men than in women irrespective of age. The change in H\textsubscript{2}O/year in men ranging from 65 to 85 years old was found to be 0.8–2.7 cm.

The reduced strength of the diaphragm with aging is associated with muscle atrophy and with decrease of fast fibers that create a higher level of tension. Reduction of diaphragmatic muscle strength increases the respiratory rate in the elderly, which results in fatigue to the diaphragm, and may eventually cause ventilatory failure. Thus, the reduction of respiratory muscle strength due to aging may not be a serious problem in healthy individuals, but if the ventilation demands are increased due to pulmonary disease, it can be a major problem resulting in respiratory failure.

The cross-sectional area of the intercostal muscles is slightly reduced, while that of the expiratory muscles is reduced to a much greater extent, at the age of 50 years or higher.\textsuperscript{24} In contrast, no change in the thickness the diaphragm occurs during aging. However, the reduction of compliance in the chest wall results in a reduction in the curvature causing a reduction in Pdi max.

Reduction in respiratory muscle strength in the elderly has shown to be associated with nutritional status, and BMI has been reported to have a significant correlation with the MIP as well as with the maximal expiratory pressure.\textsuperscript{25}

Responses to hypoxia and hypercapnia

Minute ventilation remains the same between the younger and the older age groups. Although the tidal volume is reduced with age, the minute ventilation is maintained by increasing the respiration rate. However, the ventilator response to hypoxemia or to increased carbon dioxide concentration may be inadequate in the elderly.\textsuperscript{26}

A study conducted by Kronenberg and Drage.
in 8 healthy young and 8 healthy elderly participants, revealed that the response to hypoxia was reduced by 50% and the response to hypercapnia was also reduced by 40% in the elderly individuals. Although the mechanism is unclear, these changes might have been caused by dysfunction of chemosensory receptors and by structural changes in the lung and thoracic cage. Poulin et al. reported that the ventilation demands for the generation of carbon dioxide were increased during aging in 224 healthy persons aged between 56 and 85 years old. This change was considered to be caused by aging-induced increases in the end expiratory-arterial carbon dioxide concentration and the ventilation/perfusion imbalance.

Changes in cough reflex

The cough reflex weakens with aging. This change may be attributed to the decrease in cough sensation, increased activation threshold of the vagus and occipital nerves, decreased tension of smooth muscles, and reduction of cognitive capacity. Respiratory muscle strength also decreases so that coughing cannot adequately remove a foreign material or secretion. Such weakening of the cough reflex contributes to the increase in the incidence of aspiratory pneumonia in elderly individuals.

Changes in exercise capacity

The maximal oxygen consumption (VO$_2$max) which is an indicator of exercise capacity, reaches its peak level when individuals are between the ages of 20 and 30 years and then decreases by approximately 1% every year depending on the individual capacity of physical activity. Generally, VO$_2$max decreases at a rate of 32 mL/min/year in men and at a rate of 14 mL/min/year in women after the age of 20-30 years. In a longitudinal study on the effects of aging on lung function at rest and during exercise in healthy older people, McClaran et al. confirmed that VO$_2$max decreased by 11% over 6 years.

Conclusion

The various changes that occur in the respiratory system of elderly individuals result in an increased risk for a variety of respiratory diseases. In order to understand respiratory diseases that occur in elderly individuals, it is important to recognize aging-related changes in the respiratory system. Based on a thorough understanding of these changes, it might be possible
to take appropriate steps to protect elderly individuals against respiratory diseases and to manage these diseases adequately when they occur.

REFERENCES


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Lung function, as measured by 1-second forced expiratory volume and forced vital capacity (FVC), decreases with age, whereas total lung capacity remains unchanged. FVC decreases because of increased residual volume and diffusion capacity also decreases. Increased physiological dead space and ventilation/perfusion imbalance may reduce blood oxygen levels and increase the alveolar-arterial oxygen difference. If we make understand the changes in respiratory function that occur with increasing age, there is meaningful results in maintaining a healthy life.

(Editorial Board)