Follow-Up of Blebs and Bullae in Pilots 40 Years and Older Using CT

Sangheum Bang; Solmon Yang; Seong Whi Cho; Dong Hyeon Kim; Hohyung Kang

BACKGROUND: Preventive treatment for incidentally detected blebs or bullae is required for fast jet pilots, but their aeromedical risk is not clearly proven.

METHODS: This is a retrospective study and includes 46 pilots 40 yr and older with incidentally detected emphysema-like changes (ELCs) comprising blebs or bullae in low-dose chest CT (LDCT) during health screening. Two radiologists retrospectively reviewed imaging features. Statistical analysis was done using independent *t*-tests and bivariate analysis.

RESULTS: Among 46 pilots, 39 pilots flew fast jet aircraft and 7 pilots flew nonfast jet aircraft. The mean follow-up period was 1531 d and the LDCT follow-up interval mean period was 424.4 d. There was no evidence of rupture in incidentally detected ELCs during the follow-up period. The mean size of the ELCs was 19.15 mm. There were five cases showing changes in size. There was a statistically significant correlation between the size of ELCs and height. There were no statistically significant differences in the size or number of ELCs relating to smoking status or aircraft type, and there were no statistically significant correlations between the size or number of ELCs and multiple factors, including smoking quantity, flight time, age, BMI, and weight.

CONCLUSION: This study demonstrates the aeromedical safety of incidentally detected ELCs in pilots 40 yr and older without underlying lung disease. The results indicate no need for recommending preventive treatment for ELCs in pilots 40 yr and older, even those flying fast jet aircraft, as a requisite to continue their flight duties.

KEYWORDS: bleb, bulla, pilot, CT.

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Spontaneous pneumothorax can be classified as either primary or secondary based on cause.[26] Primary spontaneous pneumothorax (PSP) is defined as a pneumothorax without underlying lung disease and predominantly occurs in young and thin men.[4,16,22] PSP has an age-adjusted annual incidence of 7.4 to 18 cases per 100,000 men, and 1.2 to 6 cases per 100,000 women.[3,16] Secondary spontaneous pneumothorax is defined as a pneumothorax secondary to underlying pulmonary disease and predominantly occurs in older individuals.[14,26] Only PSP was considered for this study.

The aeromedical concern in pilots due to incidentally detected blebs or bullae (hereafter referred to as emphysema-like changes or ELCs) includes rupture during flight, which can be incapacitating because of chest pain, dyspnea, and other symptoms.[29,32] Further, according to Boyle's Law, gas expansion at high altitudes can occur in untreated pneumothorax in pilots.[25] The aeromedical disposition depends on the aircraft type (fast jet vs. nonfast jet) where fast jet aircraft are defined as capable of high gravitational force for maneuverability, and nonfast jet aircraft are defined as limited to low gravitational force and primarily function as transport/cargo aircraft. In fast jet pilots, resection of ELCs with pleurodesis is recommended for continuing flight duties.[5] Because fast jet aircraft are often single-seaters with the pilot being responsible for all routine and emergency duties during flight, such pilots undergo higher physical stress and antigravity straining maneuvers due to exposure to higher gravitational forces compared to pilots of

From the Aerospace Medical Center, Republic of Korea Air Force, Cheongju-si, Chungcheongbuk-do, Republic of Korea.

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Address correspondence to: Sangheum Bang, M.D., Aerospace Medicine, Aerospace Medical Center, Republic of Korea Air Force, #635 Danjae-ro, Namil-myeon, Sangdang-gu, Cheongju-si, Chungcheongbuk-do 363-849, Republic of Korea; bangzzang@gmail.com.

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nonfast jet aircraft.[24] However, PSP rarely occurs in civilian individuals over the age of 40 and the exact role of ELCs in the occurrence of PSP is controversial.[19,22] To the best of our knowledge, there is no published literature reporting long-term follow-up studies of ELCs in pilots. The purpose of this study was to determine the aeromedical safety of untreated ELCs in pilots 40 yr and older.

METHODS

Subjects

The study was approved by our institutional review board and informed consent was not required. All pilots 40 yr and older in the Republic of Korea Air Force (ROKAF) undergo low-dose chest CT (LDCT) scans for health screening in the aerospace medical center and 56 pilots had ELCs incidentally detected in their LDCT scans between May 2009 and February 2016. Among the 56 pilots, 7 pilots who had a history of surgical treatment, pleurodesis due to ELCs, or spontaneous pneumothorax, 1 pilot who had a misinterpreted CT scan, and 2 pilots who were under 40 yr old were all excluded. Each of them showed normal results on pulmonary function tests. Subsequently, 46 pilots 40 yr and older who had incidentally detected ELCs without a history of treatment or spontaneous pneumothorax were included in the retrospective study.

Equipment

All LDCT scans were obtained with a 128-MDCT scanner (Ingenuity CT, Philips Healthcare). The scanning parameters for the MDCT scanner were as follows: tube current, 30 mAs; voltage, 100 kVp; detector configuration, 64×0.625 mm; slice thickness and reconstruction interval, 3 mm; table feed speed, $81.2\ mm \cdot s^{-1}$; pitch, 1.015; and gantry rotation time, 0.5 s. Coronal reformation images with a 3-mm reconstruction interval were constructed by our expert technician.

Procedures

Two radiologists reviewed all LDCT images and arrived at a consensus. The diagnostic definition of ELCs such as blebs and bullae on LDCT scans were based on their appearance as focal lucencies with thin walls; a bulla is defined as ≥1 cm in diameter and a bleb <1 cm in diameter.[8] Size measurements were performed on the axial and coronal planes to determine diameter, and the definition of size difference between interval LDCT scans was a difference of >3 mm in diameter. For the number of ELCs, up to three ELCs were counted in each case and cases with ≥ four ELCs were considered as having multiple lesions.

Statistical Analysis

The independent *t*-test was used to compare the difference of the size or number of ELCs relating to smoking status and types of aircraft. Bivariate correlation using Pearson's correlation was performed to evaluate the correlation between the size or number of ELCs and multiple factors such as smoking quantity, flight time, age, BMI, and weight. The height of the pilots was classified into five grades (grade 1: $160.0 < N \leq 165.0$ cm; grade 2: $165.0 < N \leq 170.0$ cm; grade 3: $170.0 < N \leq 175.0$ cm; grade 4: $175.0 < N \leq 180.0$ cm; grade 5: $180.0 < N \leq 185.0$ cm) and the correlation between the size or number of ELCs and height grade was also evaluated using bivariate correlation with Spearman's correlation. All statistical analyses were performed with commercially available statistical software (SPSS version 18.0 for Microsoft Windows, IBM, New York, NY, USA). $P < 0.05$ was considered a statistically significant difference.

RESULTS

Basic information about the pilots is shown in **Table I**. Their mean age at the time of detection on LDCT scanning was 43.6 yr (SD, 3.39; range, 40–54 yr) and they were all men. Of the pilots, 37 were smokers (80.4%) with a mean smoking quantity of 12 pack-years (SD, 7.5; range, 2–30 pack-years), and 9 were nonsmokers (19.6%). There were 39 pilots who flew fast jet aircraft (85%) and 7 pilots who flew nonfast jet aircraft (15%). ROKAF policy changed to discontinue the follow-up exam in pilots flying nonfast jets because of lower aeromedical concerns due to ELCs and weak justification of CT radiation exposure, so the number of these subjects is small in this study.[18] Mean flight time was 2466 h (SD, 1128.8; range, 626–5600 h). Mean BMI of the pilots was $24.4\ kg \cdot m^{-2}$ (SD, 2; range, $19.4–29.4\ kg \cdot m^{-2}$), their mean height was 173.7 cm (SD, 4.67; range, 162.8–181.8 cm), and their mean weight was 73.5 kg (SD, 6.74; range, 57.3–85.3 kg). The mean total follow-up period was 1531 d (SD, 373; range, 699–2253 d), the mean LDCT follow-up interval period was 424.4 d (SD, 93.2; range, 302–691 d), and the mean number of LDCT scans was 4.7 (SD, 0.89; range, 3–7).

There was no evidence of rupture in incidentally detected ELCs during the follow-up period. The mean ELC size (diameter) was 19.15 mm (SD, 12.8; range, 6–78 mm). There was no change in size in 41 cases during the follow-up period (**Fig. 1**). Five cases showed size differences between interval LDCT scans (size increase, $N = 1$; size decrease, $N = 4$) (**Fig. 2** and **Fig. 3**).

Table I. The Basic Description of Pilots Included in This Study.

CHARACTERISTICS	PILOTS ($N = 46$)
Age (years)	43.6 ± 3.39 (40 ∼54)
Height (cm)	173.7 ± 4.67 (162.8 ∼181.8)
Weight (kg)	73.5 ± 6.74 (57.3 ∼85.3)
Body Mass Index (BMI) ($kg \cdot m^{-2}$)	24.4 ± 2 (19.4 ∼29.4)
Smoking status	
Smoker	$N = 37$
Nonsmoker	$N = 9$
Quantification of smoking (pack-year)	12 ± 7.5 (2 ∼30)
Types of aircraft	
Fast jet aircraft	$N = 39$
Nonfast jet aircraft	$N = 7$
Flight time hours	2466 ± 1128.8 (626 ∼5600)
Low dose chest CT scan	
Total follow-up period (days)	1531 ± 373 (699 ∼2253)
Interval scan period (days)	424.4 ± 93.2 (302 ∼691)
Total scans number	4.7 ± 0.89 (3 ∼7)

Data are presented as mean ± SD and parentheses indicate range values.

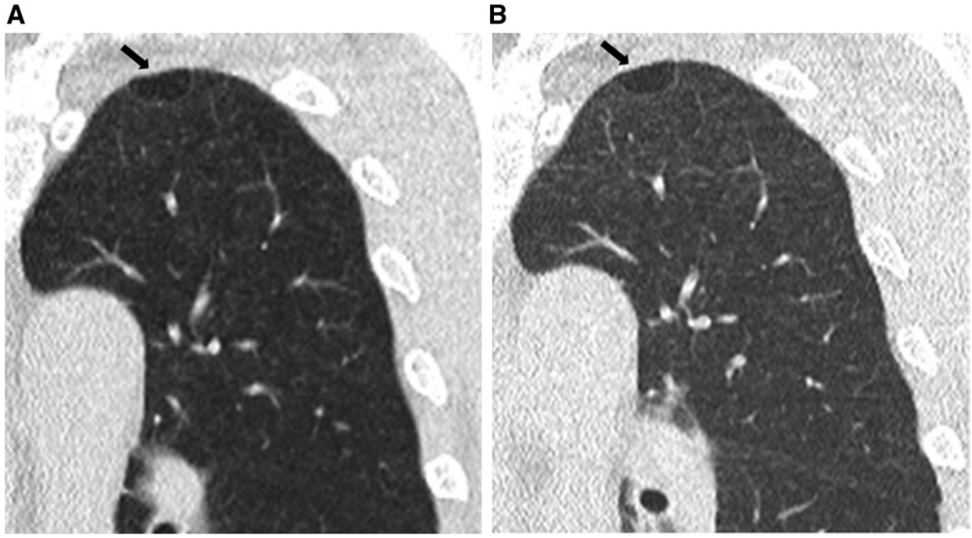

Fig. 1. Coronal CT images in a 45-yr-old pilot of fast jet aircraft showed no interval change of a 20-mm sized bulla (arrows) at the left apex between two scans (A, taken on 2010-12-01; B, taken on 2014-10-07).

Despite the change in ELC size, all pilots were granted a waiver disposition, meaning that they continued their flight duties with active medical surveillance. The number of ELCs in the pilots was as follows: one, $N = 14$; two, $N = 5$; three, $N = 2$; multiple, $N = 25$. The results of statistical analysis are shown in **Table II** and **Table III**. There were no statistically significant differences in the size or number of ELCs relating to smoking status and aircraft type.

Further, there was no statistically significant correlation between the size or number of ELCs and factors studied—smoking quantity, flight time, age, BMI, or weight. A statistically significant correlation was found between ELC size and height grade ($P = 0.048$), although the correlation coefficient, Spearman's rho (r_s), was low ($r_s = 0.3$).

DISCUSSION

There is controversy regarding whether ELCs are a cause of spontaneous pneumothorax.[9,17,30] Although a few cases of spontaneous pneumothorax were reported in USAF pilots older than 40 yr, there was no mention of ELCs in such cases.[32] In the present study, there was no evidence of spontaneous pneumothorax from ELCs in ROKAF pilots 40 yr and older. The reasons for no ELC ruptures seen in the present study may be that: 1) the number of subjects was small and the population group may have been skewed considering the incidence of spontaneous pneumothorax in the general population; and 2) ELCs may not be a cause of spontaneous pneumothorax.

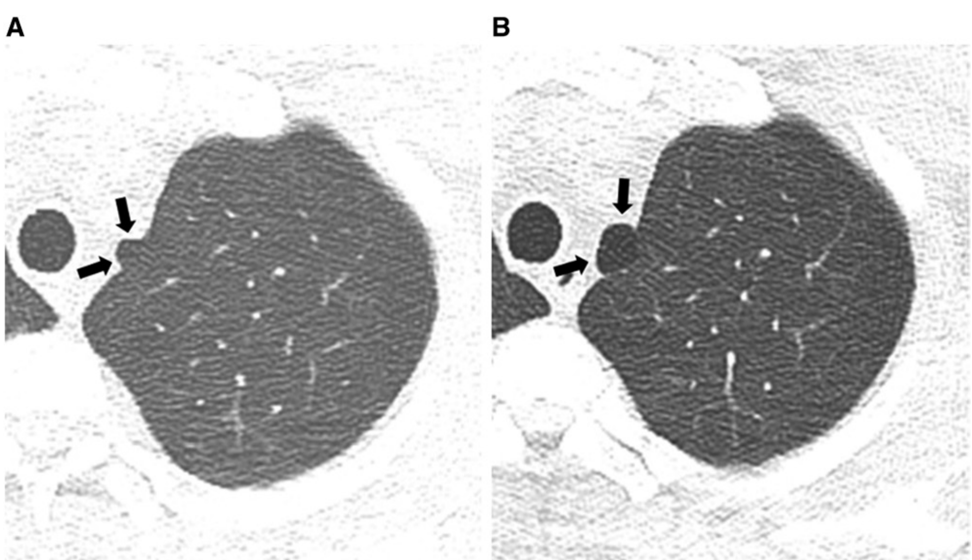

Fig. 2. Axial CT images in a 42-yr-old pilot of fast jet aircraft demonstrated increasing size of a bulla (arrows) from 9 mm to 15 mm at the left upper lobe between two scans (A, taken on 2009-12-10; B, taken on 2014-10-24).

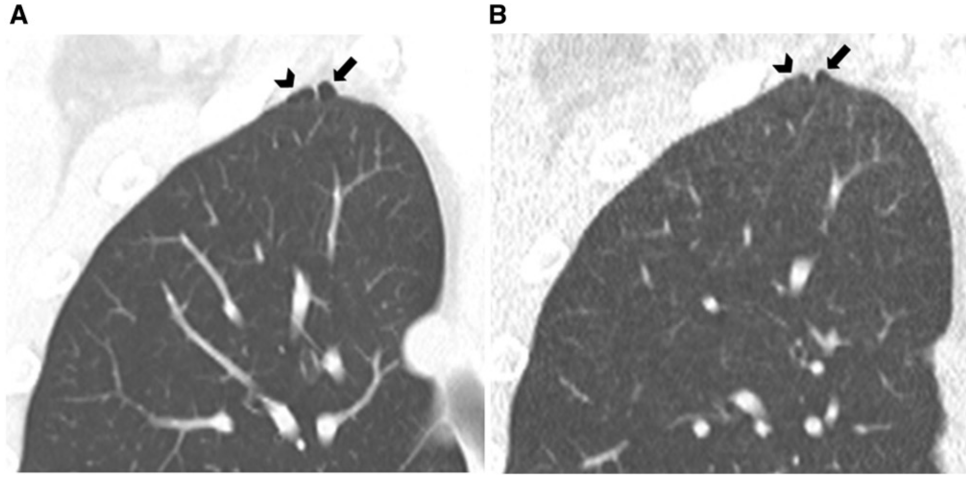

Fig. 3. Coronal CT images in a 43-yr-old pilot of nonfast jet aircraft showed a bleb (arrows, medial side of two blebs) with decreasing size from 9 mm to 5 mm at the right apex between two scans (A, taken on 2011-02-21; B, taken on 2014-07-11). There was another bleb (arrowheads, lateral side of two blebs) with no definite evidence of size change at the right apex.

There are several etiologies of the pathogenesis of ELCs related to smoking, morphometric, genetic, and atmospheric conditions.[13,28] Among them, intrathoracic pressure as a result of rapid growth in terms of morphometric conditions is known to drive ELC formation.[7,33] In this study there was a statistically significant positive correlation between ELC size and height grade, which may indicate ELCs are more likely to form when negative pressure at the apex of the lung occurs in those with larger thoracic vertical dimensions, although the correlation coefficient was low.

There was no statistically significant association of the size or number of ELCs based on smoking status and smoking quantity. However, smoking prevalence in the study sample was 80.4% ($N = 37$), which was much higher than that in the general pilot population (15%), which may suggest a relationship between ELC pathogenesis and smoking.[2,10,12]

There has been a hypothesis linking the possible risk of accelerating ELC expansion with repeated exposure to the increased shear stresses of radial accelerative forces in fast jet aircraft.[5] However, we found no statistically significant difference in the size or number of ELCs based on aircraft type and flight duration. This suggests that high gravitational forces in flight are not relevant to accelerating ELC expansion.

According to previously reported literature,[27] decrease in ELC size rarely occurs, but there were four cases (8.7%) showing size decrease in our study. This may have been because: 1) in contrast to the previous report, image analysis in our study was performed using LDCT with 3-mm slice sections, enabling accurate diagnosis and detection of subtle changes; or 2) ELCs may communicate with the airways to a greater extent than expected[15,31] and intermittent, repetitive exposure to the flight environment may inhibit formation of check-valves, leading to noncommunicating ELCs in small airways due to increased air flow via gas expansion per Boyles law.[1,25]

There were several limitations to the present study. First, the study focused only on ROKAF pilots. Such pilots are strictly required to maintain a physical state suitable for flight duty; they represent a group selected through several physical examinations, beginning flight duties after their mid-20s. This is a significantly different setting compared to that of the general population in terms of spontaneous pneumothorax incidence. Second, the study included a small group ($N = 46$) and a specific age group ($\geq$40 yr), and the group may not represent all pilots. Third, because civilian pilots currently tend to perform flight duties into older ages with extension of retirement, more long-term follow-up studies are required to assess the aeromedical safety of ELCs in pilots.

Considering the flight environment and the importance of pilots, a safe and cautious approach is needed to deal with ELCs in pilots, although it is unclear whether ELCs are causes of spontaneous pneumothorax. Further, according to published literature, flight conditions such as accelerative forces, oxygen breathing, and altitude changes may result in susceptibility to spontaneous pneumothorax.[6,23,34] It seems appropriate to have a conventional policy recommending preventive treatment for ELCs, especially in pilots younger than 40 yr flying fast jet aircraft.[5] However, ELCs rarely occur in the general population older than 40 yr and there was no evidence of ELC ruptures

Table II. Statistical Analysis of ELCs Relating to Smoking Status and Types of Aircraft.

	SMOKING STATUS	TYPES OF AIRCRAFT
PARAMETER	SMOKER ($N = 37$) / NONSMOKER ($N = 9$) [P-VALUE]	FAST JET ($N = 39$) / NONFAST JET ($N = 7$) [P-VALUE]
Size of ELCs (mm)	18.76 ± 12.9 / 20.78 ± 12.6 [0.676]	19.21 ± 13.5 / 18.86 ± 8.7 [0.948]
Number of ELCs	2.95 ± 1.3 / 2.33 ± 1.6 [0.233]	2.74 ± 1.4 / 3.29 ± 1.3 [0.341]

Data are presented as mean ± SD.

Table III. Statistical Analysis for the Correlation Between ELCs and Factors Studied.

FACTORS	SIZE OF ELCS (*P*-VALUE)	NUMBER OF ELCS (*P*-VALUE)
Quantification of smoking	0.486	0.176
Flight time	0.787	0.702
Body mass index (BMI)	0.230	0.370
Weight	0.837	0.624
Height grade	0.048*	0.112

* There was statistical significance between the size of ELCs and height grade, although the correlation coefficient (r_s) was low, $r_s = 0.3$.

during the follow-up period in the present study. This indicates that it may not be appropriate to recommend preventive treatment of ELCs (such as resection with pleurodesis) in pilots 40 yr and older flying fast jet aircraft as a requisite to continue their flight duties considering the cost and side effects of such treatment.[11,20,21] In conclusion, it does not seem necessary to perform preventive treatment of ELCs in pilots 40 yr and older with no underlying lung disease, even those flying fast jet aircraft, as a requisite to continue their flight duties.

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Authors and affiliations: Sangheum Bang, M.D., Solmon Yang, M.D., and Hohyung Kang, M.D., Aerospace Medical Center, Republic of Korea Air Force, Cheongju-si, Chungcheongbuk-do, Republic of Korea; Seong Whi Cho, Ph.D., M.D., Kangwon National University Hospital, Chuncheon-si, Gangwon-do, Republic of Korea; and Dong Hyeon Kim, M.D., Seoul National University Hospital, Seoul, Republic of Korea.

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