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Clinical and imaging characteristics of hematologic disease complicated by air leak syndrome

A STROBE-compliment observational study

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Abstract

There are limited systematic studies on hematologic disease complicated by air leak syndrome (ALS). Physicians in radiology departments and hematology departments have a limited awareness of ALS.

The aim of this study was to explore the similarities and differences in clinical data between the clinical group and imaging group in patients with hematologic disease complicated by ALS.

Clinical and CT data for 59 patients with hematologic disease complicated by ALS in our hospital were retrospectively reviewed. Patients were assessed by clinical grouping and image grouping. Data were compared between groups, and $P < .05$ was considered statistically significant.

Dyspnea occurred more often in the allo-HSCT (allogeneic hematopoietic stem cell transplantation) group than that in the non–allo-HSCT group (68.8% vs 4.7%, $P < .001$), there were statistically significant differences in inducing factors between groups, and differences in other aspects were not statistically significant. Chest tightness and dyspnea occurred more often in the allo-HSCT with BO/BOOP (bronchiolitis Obliteran/bronchiolitis obliterans organizing pneumonia) group than those in the allo-HSCT without BO/BOOP group (80.0% vs 9.1%, $P = .013$), and differences in other aspects were not statistically significant. Chest pain occurred more often in the HPT (hydropneumothorax) group than that in the other 3 groups (pure pneumothorax [PT], pulmonary interstitial emphysema [PIE], complex ALS) (71.4% vs 11.1%, 0.0%, and 26.5%, $P = .005$); ALS thickness in the HPT group was greater than that in the other 2 groups (PIE and complex ALS) (19.7 vs 3.5 cm and 9.5 cm, $P = .001$); catheter drainage occurred more often in the HPT group than that in the other three groups (PT, PIE, complexALS) (64.3% vs 22.2%, 0.0%, and 2.9%, $P = .001$).

ALS is a high risk in male patients who have a low BMI, have leukemia as a basic disease, and have basic lung diseases (eg, BO/BOOP). CT types are mainly complex ALS, HPT, and pure PT. In addition, clinical symptoms for patients in the HPT group are severe, and there is a high prevalence of catheter drainage.

Abbreviations: allo-HSCT = allogeneic hematopoietic stem cell transplantation, ALS = air leak syndrome, BO/BOOP = bronchiolitis obliteran /bronchiolitis obliterans organizing pneumonia, CT = computed tomography, DIPI = drug-induced pulmonary injury, GVHD = graft-versus-host disease, HPT = hydropneumothorax, HRCT = high-resolution CT, IPS = interstitial pulmonary syndrome, MPR = multi-planar reconstruction, PIE = pulmonary interstitial emphysema, PM = pneumomediastinum, PT = pneumothorax.

Keywords: air leak syndrome, allogeneic hematopoietic stem cell transplantation, computed tomography, hematopathy

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1. Introduction

Air leak syndrome (ALS) is a general term for pulmonary interstitial emphysema (PIE), pneumomediastinum (PM), and pneumothorax (PT). Hematologic disease is a group of diseases that originate or affect the hematopoietic system and blood; it includes leukemia, lymphoma, aplastic anemia, myeloma, thrombocytopenia, among others. Patients with hematologic disease complicated by ALS were first reported in 2007.[1] ALS is rare, in patients with hematopathy after allogeneic hematopoietic stem cell transplantation (allo-HSCT), the incidence is approximately 0.8% to 2.3%.[2] Some cases of patients with allo-HSCT complicated by ALS have been reported worldwide in recent years, and patient overall prognosis is poor.[3–9] However, there are limited systematic studies on hematologic disease complicated by ALS. Physicians in radiology departments and hematology departments have a limited awareness of ALS. To systematically understand hematologic disease complicated by ALS, data from 59 patients with hematologic diseases complicated by ALS were retrospectively reviewed. These patients were divided in accordance with clinical methods and imaging, and statistical comparisons were performed.

2. Methods

2.1. Study objectives and materials

The inclusion criterion was that hospitalized patients were diagnosed with hematologic disease (leukemia, lymphoma, aplastic anemia, myeloma, thrombocytopenia, hemophilia, pernicious anemia, and myelodysplastic syndrome) complicated by ALS. The exclusion criteria were patients who were diagnosed with primary pulmonary diseases (such as asthma, tuberculosis, and chronic obstructive pulmonary disease) before hematopathy, and mechanical ventilation, trauma, atrogenic trauma, esophageal rupture/perforation, and mediastinal infection caused byacrogenic bacteria before ALS.

This study was conducted at Institute of Hematology and Blood Diseases Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College, and it was approved by the ethics committee of this hospital. All the patients in our study had been informed consent. The recorded data of 59 patients in our hospital from January 2014 to December 2018 were retrospectively analyzed, including clinical data (age, sex, height, weight, basic hematologic disease, numbers of basic treatment, symptoms, basic lung disease, inducing factors, history of allo-HSCT, ALS treatment methods, duration, and survival) and CT data (CT images, ALS type, and ALS thickness).

2.2. CT examination and scanning

All patients were scanned with the 64 Slice multidetector CT Scanner (Brilliance, Philips Medical Systems, Germany). Scanning range: the superior thoracic aperture to the adrenal gland. Scanning parameters: 120 kV, 180 to 200 mA, 1.5 mm average layer thickness, processing with a layer spacing of 1.5 mm for thin layer reconstruction and multi-planar reconstruction (MPR) image. The ALS thickness was the sum of the thicknesses of PIE, PM and PT. The PT thickness referred to the maximum vertical thickness of the pulmonary hilum to the pleural pneumatosis. The PM and PIE thicknesses were both the maximum thickness of pneumatosis. The average of all values was used after the double-blind measurement by 2 deputy chief physicians.

2.3. Statistical methods

SPSS22.0 (Chicago, IL) statistical software was used for data analysis. Measurement data were expressed as $\overline{x} \pm s$. Data between groups were compared using t tests. Data between multiple groups were analyzed using variance. The least significant difference test was utilized to compare 2 groups. Data without a normal distribution were expressed by M (IQR). The rank sum test was used for comparison between groups. The count data were expressed by constituent ratios or rates, and the χ^2 test or Fisher exact test was used for the comparison between groups. The test level $P < .05$ was regarded as a statistically significant difference.

3. Results

A total of 59 patients with hematologic disease complicated by ALS in our hospital from January 2014 to December 2018 were included. During this time, a total of 54,986 patients were admitted to the hospital, which included a total of 807 patients received allo-HSCT and 28 patients complicated by bronchiolitis obliteran/bronchiolitis obliterans organizing pneumonia (BO/BOOP) with allo-HSCT; therefore, the total incidence of hematologic disease complicated by ALS was 0.011% (59/54986). No deaths occurred in 59 patients with ALS. In addition, ALS disappeared after conservative/catheter drainage therapy for all the 59 patients.

3.1. Baseline data comparison in the allo-HSCT and non–allo-HSCT groups

A total of 59 patients were divided into the allo-HSCT group (n = 16) and the non–allo-HSCT group (n = 43) in accordance with the significant difference in the clinical status between the conventional treatment and allo-HSCT patients. The incidence of ALS in the allo-HSCT group and the non-HSCT group was 2.0% versus 0.1%, ($P < .001$). Baseline data comparison between the 2 groups is shown in Table 1. The number of treatment courses in the allo-HSCT group was higher than that in the non-allo-HSCT group (4 vs. 1, $P = .005$). The incidence of dyspnea in the allo-HSCT group was higher than that in the non–allo-HSCT group (68.8% vs 4.7%, $P < .001$). There was no statistically significant difference in chest tightness, chest pain, and without symptom between the 2 groups. The incidence of BO/BOOP in basic lung diseases in the allo-HSCT and non–allo-HSCT groups was 31.3% vs 0.0% ($P = .001$), respectively; the number of patients without lung diseases in the non–allo-HSCT group was greater than that in the allo-HSCT group (51.2% vs 12.5%, $P = .007$); there was no statistically significant difference in lung infection and IPS (interstitial pulmonary syndrome) between the 2 groups. There was a statistically significant difference in inducing factors between the 2 groups; cough was the primary cause of ALS in the allo-HSCT group, accounting for nearly 62.5%. Meanwhile, the rate of cough was 27.9% in the non–allo-HSCT group, and there was no distinct cause of ALS in 69.8% of patients. There was no statistically significant difference in other factors between the 2 groups, including age, sex, BMI, basic hematologic diseases, CT type, ALS thickness, treatment methods, and ALS duration.

3.2. Comparison between allo-HSCT with BO/BOOP and without BO/BOOP

Sixteen patients in the allo-HSCT groups were divided into the allo-HSCT with BO/BOOP group (n = 5) and without BO/BOOP group (n = 11). The incidence of ALS in the allo-HSCT with BO/

Table 1

Baseline data comparison in the allo-HSCT and non-allo-HSCT groups.

	Allo-HSCT (n = 16)	Non–allo-HSCT (n = 43)	$\chi^2/t/z$	*P*
Age	33.8 ± 15.1	26.6 ± 19.9	1.316	.193
Sex (male), n (%)	11 (68.8)	27 (62.8)		
BMI	19.4 ± 4.3	19.5 ± 3.5	0.102	.919
Basic hematologic disease, n (%)			0.146	.703
Leukemia	13 (81.3)	31 (72.1)		
Other*	3 (18.8)	12 (27.9)		
Numbers of basic treatment	4 (2, 6.5)	1 (1, 3)	2.788	.005
Symptoms, n (%)				
Chest pain	3 (18.8)	17 (39.5)	2.248	.134
Chest distress	5 (31.3)	6 (14.0)	1.301	.254
Dyspnea	11 (68.8)	2 (4.7)	24.283	.000
Without symptoms	4 (25.0)	18 (41.9)	1.418	.234
Basic lung disease, n (%)				
Infection	5 (31.3)	19 (44.2)	0.809	.369
BO/BOOP	5 (31.3)	0 (0)	10.929	.001
IPS	4 (25.0)	4 (9.3)	1.295	.255
Without lung diseases	2 (12.5)	22 (51.2)	7.223	.007
Inducing factors, n (%)			5.904	.041
Without inducing factors	6 (37.5)	30 (69.8)		
Emesis	0 (0.0)	1 (2.3)		
Cough	10 (62.5)	12 (27.9)		
CT types, n (%)			1.330	.416
PT	5 (31.3)	18 (41.9)		
PIE	1 (6.3)	1 (2.3)		
Complex ALS	10 (62.5)	24 (55.8)		
ALS thickness, cm	14.9 (7.3, 20.7)	12.5 (6.0, 21.0)	0.290	.772
Treatment methods, n (%)			0.304	.583
Conservative treatment	14 (87.5)	33 (76.7)		
Catheter drainage	2 (12.5)	10 (23.3)		
ALS duration, (days)	15 (6.0, 30.5)	9 (7.0, 19.0)	0.628	.530

allo-HSCT = allogeneic hematopoietic stem cell transplantation, ALS = air leak syndrome, BMI = body mass index, BO = bronchiolitis obliterans, BOOP = bronchiolitis obliterans organizing pneumonia, IPS = interstitial pneumonia syndrome, PIE = pulmonary interstitial emphysema, PT = pneumothorax.

* lymphoma aplastic, anemia, multiple myeloma, myelodysplastic syndrome.

BOOP group and without BO/BOOP group was 17.9% versus 1.4% ($P < .001$), respectively. The data comparison results between the 2 groups are shown in Table 2. The clinical symptoms of chest tightness and dyspnea in the allo-HSCT with BO/BOOP group occurred more often than those in the allo-HSCT without BO/BOOP group, with differences of 80.0% versus 9.1% ($P = .013$) and 100.0% vs 54.5% ($P = .019$), respectively. There was no statistically significant difference in chest pain and without symptoms between the 2 groups. Differences in CT type, ALS thickness, treatment methods, and

Table 2

Comparison between allo-HSCT with BO/BOOP and without BO/BOOP.

	With BO/BOOP (n = 11)	Without BO/BOOP (n = 5)	χ^2/z	*P*
Symptoms, n (%)				
Chest pain	2 (18.2)	1 (20.0)	—	1.000
Chest distress	1 (9.1)	4 (80.0)	—	.013
Dyspnea	6 (54.5)	5 (100.0)	—	.019
Without symptoms	4 (36.4)	0 (0.0)	—	.245
CT types, n (%)			—	.725
PT	4 (36.4)	1 (20.0)		
PIE	1 (9.1)	0 (0.0)		
Complex ALS	6 (54.5)	4 (80.0)		
ALS thickness, cm	11 (7.0, 22.6)	17.4 (12.5, 18.0)	0.170	.865
Treatment methods, n (%)			—	1.000
Conservative treatment	9 (81.8)	5 (100.0)		
Catheter drainage	2 (18.2)	0 (0.0)		
ALS duration, days	15 (7, 26)	30 (5, 33)	0.512	.608

— = no exact value, allo-HSCT = allogeneic hematopoietic stem cell transplantation, ALS = air leak syndrome, BO = bronchiolitis Obliterans, BOOP = bronchiolitis obliterans organizing pneumonia, CT = computed tomography, PIE = pulmonary interstitial emphysema, PT = pneumothorax.

Table 3

Comparison between image groups.

	PT (n = 23)					
	Pure PT (n = 9)	HPT (n = 14)	PIE (n = 2)	Complex ALS (n = 34)	χ^2/H	*P*
Symptoms, n (%)						
Chest pain	1 (11.1)	10 (71.4)*	0 (0.0)†	9 (26.5)†	12.749	.005
Chest distress	0 (0.0)	4 (28.6)	0 (0.0)	7 (20.6)	3.067	.369
Dyspnea	1 (11.1)	1 (7.1)	0 (0.0)	11 (32.4)	4.234	.195
Without symptoms	5 (55.6)	4 (28.6)	2 (100.0)	11 (32.4)	4.898	.149
ALS thickness, cm	12.5 (11, 23.9)	19.7 (12.8, 40.4)	3.5 (3, 4)†	9.5 (5, 18)†	15.687	.001
Treatment methods, n (%)					25.510	.001
Conservative treatment	7 (77.8)	5 (35.7)*	2 (100.0)†	33 (97.1)†		
Catheter drainage	2 (22.2)	9 (64.3)*	0 (0.0)†	1 (2.9)†		
ALS duration, days	9 (7, 15)	19 (7, 33)	7.5 (5, 10)	9 (7, 19)	2.617	.455

* The comparison with pure PT, $P < .05$.

† The comparison with HPT, $P < .05$.

ALS = air leak syndrome, HPT = hydropneumothorax, PIE = pulmonary interstitial emphysema, PT = pneumothorax.

ALS duration between the 2 groups were not statistically significant.

3.3. Comparison between imaging groups

In accordance with the difference in CT manifestation, 59 patients were divided into the PT group (n = 23), the PIE group (n = 2), and the complex ALS group (n = 34); among the PT group, 23 patients were divided into the pure PT group (n = 9) and the hydropneumothorax (HPT) group (n = 14). Patients with PM with/without PIE and PT were included in the complex ALS group. The clinical data comparison results between multiple groups are shown in Table 3, and CT images are shown in Figures 1–6. The incidence of the clinical symptom of chest pain in the HPT group was greater than that in the other 3 groups (71.4% versus 11.1%, 0.0%, and 26.5%, $P = .005$). There was no statistically significant difference in chest tightness, dyspnea, and without symptoms. ALS thickness in the HPT group was greater than that in the other 3 groups, with a median of 19.7 cm. In addition, the difference was statistically significant in the HPT group compared with that in the PIE group and the complex ALS group but was not statistically significant compared with that in the PT group. The use of catheter drainage as a treatment method in the HPT group occurred more often than that in the other 3 groups, with proportions of 64.3% versus 22.2%, 0.0%, and 2.9% ($P = .001$). There was no statistically significant difference in terms of ALS duration in each group.

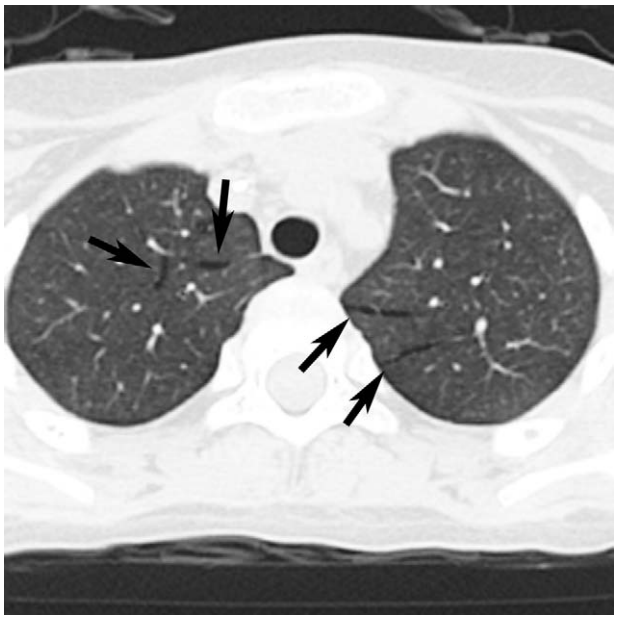

Figure 1. PIE (interlobular septal type) on CT in an 8-year-old female patient with aplastic anemia, with a history of allo-HSCT, and with a conservative treatment duration of 4 days. PIE—linear air around interlobular septal (black arrow). CT = computed tomography, PIE = pulmonary interstitial emphysema.

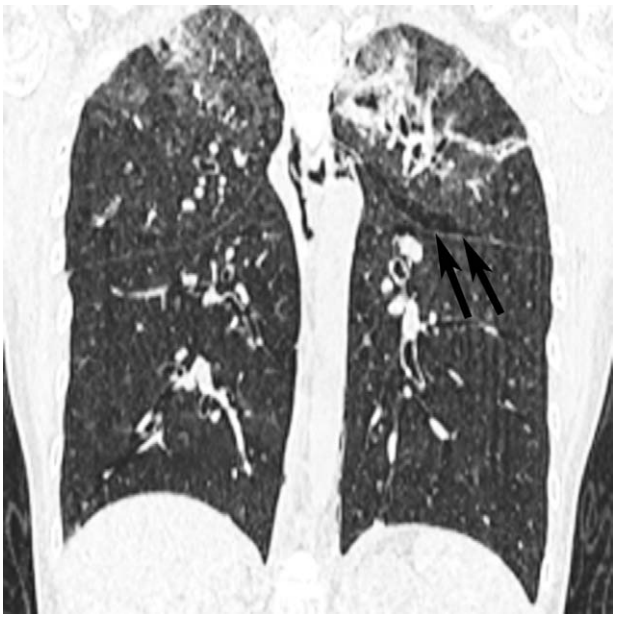

Figure 2. PIE (subpleural type) on CT (MPR-coronal) in a 17-year-old female patient with acute myelogenous leukemia with a history of allo-HSCT, and with a conservative treatment duration of 33 days. PIE—banded air in subpleural in the left upper lobe (black arrow). With cGVHD-related IPS in the upper lobe. CT = computed tomography, PIE = pulmonary interstitial emphysema. cGVHD = chronic graft-versus-host disease, IPS = interstitial pulmonary syndrome.

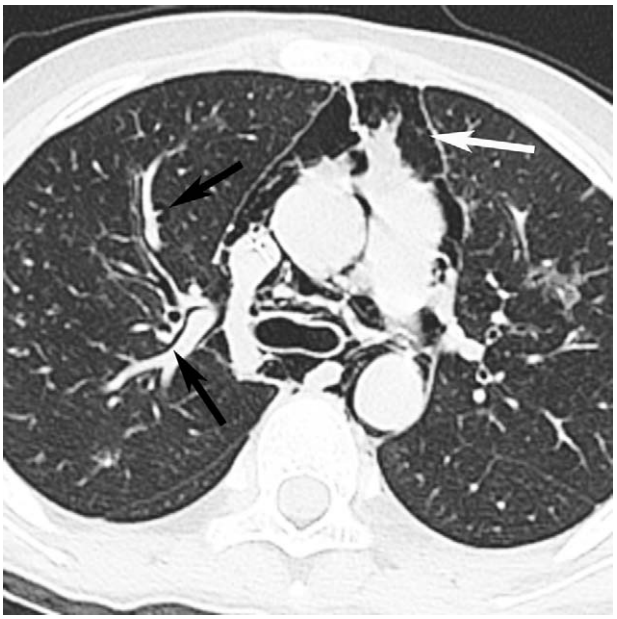

Figure 3. Complex ALS on CT in a 11-year-old male patient with acute lymphoblastic leukemia with a history of allo-HSCT, and with a conservative treatment duration of 33 days. PIE—linear air shadow around bronchial vascular bundles (black arrow), PM- gas in mediastinal (white arrow). With BOOP in both lungs. Allo-HSCT = allogenic hematopoietic stem cell transplantation, ALS = air leak syndrome, BOOP = bronchiolitis obliterans organizing pneumonia, CT = computed tomography, PIE = pulmonary interstitial emphysema, PM = pneumomediastinum.

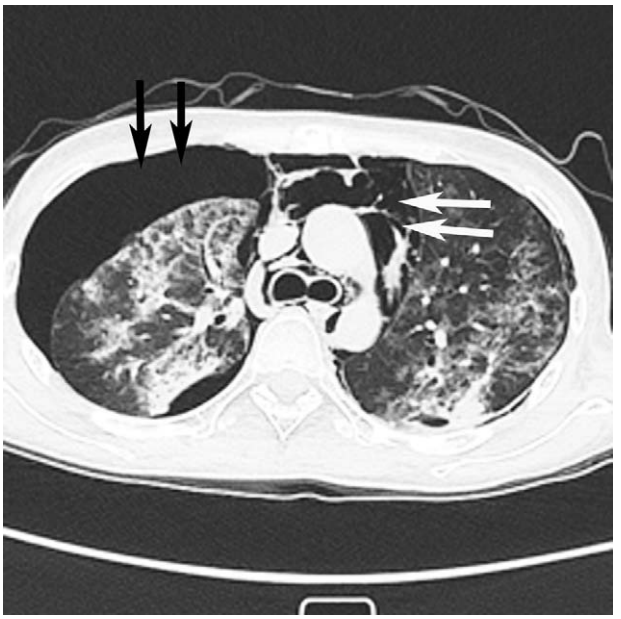

Figure 4. Complex ALS on CT in a 32-year-old female patient with acute lymphoblastic leukemia with a history of allo-HSCT, and with a conservative treatment duration of 26 days. PM—gas in mediastinal (white arrow), PT- gas in the right pleural cavity (black arrow). With BOOP in both lungs. Allo-HSCT = allogenic hematopoietic stem cell transplantation, ALS = air leak syndrome, BOOP = bronchiolitis obliterans organizing pneumonia, CT = computed tomography, PM = pneumomediastinum, PT = pneumothorax.

4. Discussion

Hematologic disease complicated by ALS was first reported in 2007, and it is the general term used for PIE, PM, and PT. It can be divided into primary and secondary ALS.[1] The pathogenesis of PIE, PM, and partial PT was first introduced by Macklin and Macklin in 1944.[10] PIE is mainly caused by the rupture of alveoli around the bronchial vascular bundle, which is related to the generation of transpulmonary pressure and the toughness of the alveolar wall. The generation of transpulmonary pressure is characterized by excessive alveolar expansion, increased alveolar pressure, and decreased blood volume in the pulmonary vessels. Researchers[11] further described the mechanism of interlobular septal and subpleural PIE and suggested that PIE in this region may indicate the rupture of terminal alveoli in the adjacent region. Part of the primary PT mechanism is still unknown. However, researchers[12] believe that PT is caused by the rupture of the subpleural pulmonary bullae or pneumatocele.

ALS is a rare disease, the incidence of patients with ALS in this group was 0.1% in the non–allo-HSCT group (no literature report), 2.0% in the allo-HSCT group (0.83%–2.3%[3,8,9] in the literature), and 17.9% in the group with allo-HSCT and BO/BOOP (20% in the literature[9]), which was substantially higher than that in the average population (<1/44,000).[2] Patients with hematological disease receive multiple drug treatments and have immune reactions. Drug-induced pulmonary injury (DIPI), pulmonary edema, and interstitial pneumonia are easily induced, leading to a more fragile alveolar wall and decreased lung compliance. These patients have a higher incidence of ALS than the general population. However, patients with allo-HSCT require pretreatment before transplantation, and graft-versus-host disease (GVHD) is prone to develop, with further aggravated lung injury, the number of courses of basic treatment in the allo-HSCT group was higher than that in the non-allo-HSCT group (4 vs 1, $P < .05$). Researchers[8] found that chronic graft-versus-host disease

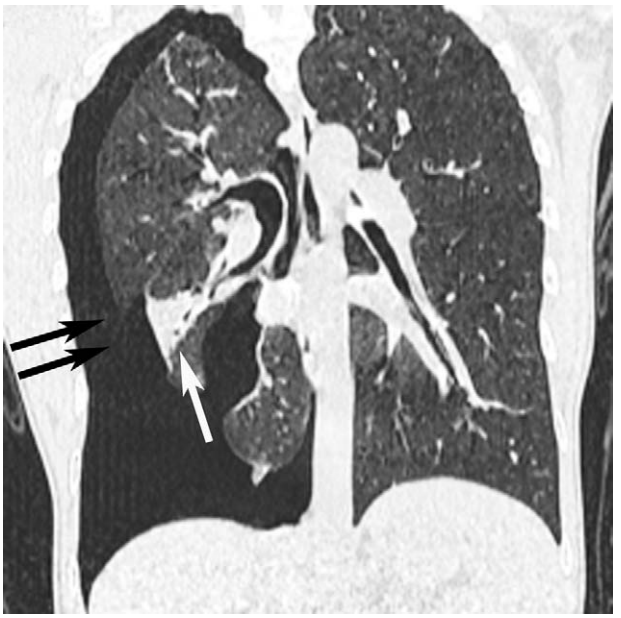

Figure 5. PT on CT in a 23-year-old male patient with aplastic anemia, and with a duration of 4 days after catheter drainage. PT—gas in right pleural cavity (black arrow). With an infectious lesion in the lower right lobe with the pleura involved (white arrow). CT = computed tomography, PM = pneumomediastinum, PT = pneumothorax.

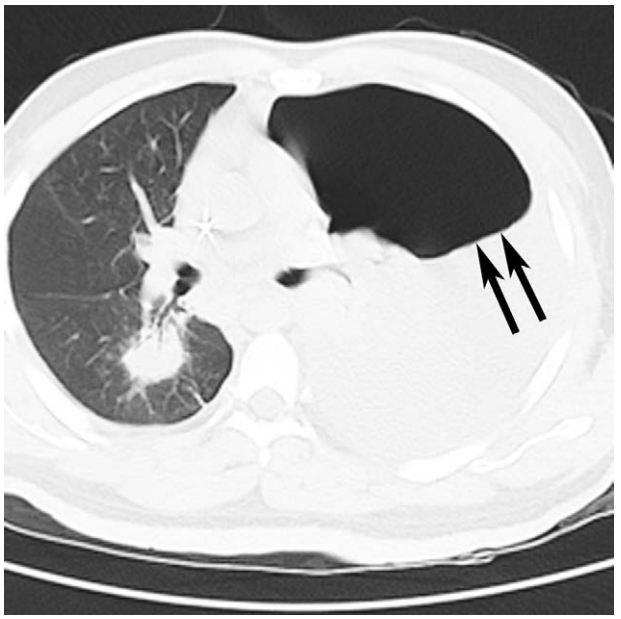

Figure 6. HPT on CT in a 31-year-old male patient with acute myelogenous leukemia, and with a conservative treatment duration of 90 days. HPT—gas–fluid level in left pleural cavity (black arrow), and the left lung presented atelectatic. With an infectious lesion in the lower right lobe. CT = computed tomography, HPT = hydropneumothorax.

(cGVHD) is the most relevant risk factor for the incidence of ALS in patients with hematologic disease complicated by allo-HSCT (odds ratio, 13.48). BO/BOOP is a cGVHD-related small airway disease, where the alveolar is more easily ruptured because of terminal alveolar air retention and excessive expansion.

The incidence of ALS is high in young males with a low BMI[12](easy to generate trans-pulmonary pressure in respiration dynamics[14]). Patients in the allo-HSCT group and the non–allo-HSCT group had an average age of 33.8 and 22.6, with a mean BMI of 19.4 and 19.5 and a male ratio of 68.8% and 62.8%, respectively. The difference between the groups was not statistically significant, and the difference was relatively the same as that reported in the literature.[13,15] Of a total of 59 patients, 44 patients had leukemia as the basic blood disease, which is consistent with the literature,[1,5,6] and the cause is unclear so far. A valsalva maneuver is the most common inducing factor of ALS.[1,10] The most common inducing factor in the included patients was cough, with rates of 62.5% and 27.9% in the allo-HSCT group and the non–allo-HSCT group, respectively. In the non–allo-HSCT group, 69.8% of patients had no precise inducing factor of ALS.

Chest tightness, chest pain, and dyspnea are the most common symptoms of ALS, mainly caused by lung tissue damage, inflammatory reactions, and the pressure of free air to the cardiopulmonary vessels (air-block effect).[10,15,16] Chest tightness and dyspnea in the allo-HSCT group occurred more often than in the non–allo-HSCT group (31.3% vs 14.0%, 68.8% vs 4.7%); these symptoms in the allo-HSCT with BO/BOOP group occurred more often than those in the allo-HSCT without BO/BOOP group (80.0% vs 9.1%, 100.0% vs 54.5%). The author considers that the symptoms of some patients with ALS are caused by lung diseases (especially BO/BOOP[17]). Symptoms of chest pain were most common in the HPT group (with an incidence of 10/14), which is associated with greater injury and inflammatory responses in the pleural and lung tissues of patients with HPT as well as the thickness of ALS.[18]

CT is the criterion standard for the diagnosis of ALS.[11] In particular, the application of thin-layer high-resolution CT and MPR has improved the detection rate of PIE. Furthermore, PIE is the basis of PM pathogenesis, which can be divided into 3 types according to CT imaging: interlobular septal type (Fig. 1), subpleural type (Fig. 2), and bronchial vascular bundle type (Fig. 3). After the occurrence of PIE, free air is generated along the bronchial vascular bundle (mainly around the pulmonary vein) to the hilum region under the pressure gradient and with respiratory movement (ie, Macklin effect[10]), and it enters the mediastinal space to form PM (Fig. 4); free air can enter the neck subcutaneously upward and/or downward into the peritoneum. If the pericardium is ruptured, a pneumopericardium is formed; if the pleura is damaged, PT is generated (Fig. 4). HPT is generated under the condition of PT with pleural effusion/hemorrhage (Figs. 5 and 6). In this study, complex ALS was most common (34/59), followed by HPT (14/59) and PT (9/59). ALS thickness in the HPT and PT group was higher than in the other groups, the average thickness was 12.5 cm and 19.7 cm, respectively; this result may be related to the lack of passage in the pleural cavity.

Conservative treatment (staying in bed, oxygen uptake, and antibiotics) is commonly used in the treatment of hematologic disease complicated by ALS.[1,8,9] Among the 59 patients in this study, 47 patients received conservative treatment, and 12 patients needed catheter drainage. Of these, catheter drainage for patients with HPT had the highest rate (9/12). Patients with hematologic disease are prone to low blood pressure, bleeding, and low immunity; therefore, these serious traumatic treatment methods such as puncture or catheter drainage should be used more carefully. The median duration of ALS in the allo-HSCT and non-allo-HSCT groups was 15 days (slightly less than the 16.3 days reported in the literature[9]) and 9 days, respectively. The longest duration was 30 days in the allo-HSCT and BO/BOOP groups, and the shortest duration was 7.5 days in the PIE group.

The overall prognosis of hematologic disease complicated by ALS is poor, especially in patients with ALS complicated by BO/BOOP. Researchers[9] reported that there were 6 deaths in 18 patients with ALS complicated by BO/BOOP, and there were no deaths in these 59 patients during the duration of ALS. This result may be related to physicians' awareness of the improvement of ALS. Researchers[8] found that the 1-year and 3-year overall survival rates of patients with hematologic diseases complicated by ALS with allo-HSCT were much lower than those of patients without ALS. Many researchers[1,9] suggest that the incidence of ALS is an early warning sign for greater lung injury in patients.

In summary, hematologic disease complicated by ALS is prone to occur in young males with a low BMI and patients with leukemia as the basic disease, especially in patients with BO/BOOP complicated by allo-HSCT. Chest tightness, chest pain, and dyspnea are common symptoms, and cough is the most common cause of ALS. The CT types that are mainly present are complex ALS, HPT, and PT. Moreover, the overall clinical symptoms of patients with HPT are severe, and the proportion of catheter drainage is high.

5. Limitations

The number of patients in this study is still not large, and further multicenter studies are needed. The influence of other variables

was not excluded. Multivariate logistic regression analysis for independent risk factors is still required.

Author contributions

Conceptualization: Kemin Zhang, Bing Shi, Qiang Zhai.
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Formal analysis: Bing Shi, Qiang Zhai, Shan Jiang.
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