Original Article

Pulmonary edema caused by inhalation of vapors from water-soluble paint

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Aim: To report the effects of inhaling vapor from water-soluble paint after a recent encounter with 16 patients treated in our emergency department.

Methods: We examined a series of chest computed tomography (CT) images from the 16 affected patients. Computed tomography was carried out on days 1, 2, 5, and 19 after the inhalation event.

Results: Twelve of the patients were found to have pulmonary edema, based on their CT findings. Patients with pulmonary edema were classified as its persisted period. In the severe group, its pulmonary edema persisted over 5 days include, exacerbated edema, delayed-onset edema (during the follow-up), or edema amelioration. One patient had exacerbated edema, three patients had delayed-onset edema, and one patient experienced amelioration of their edema in the severe group. In all cases, the pulmonary edema had disappeared from the CT images by day 19 after the inhalation event. Thirteen of the 16 patients had a fever of ≥37°C. Three kinds of solutes (ethylene glycol, titanium dioxide, and silicon oxide) had been blended in the water-soluble paint. The titanium dioxide was considered the probable cause of the pulmonary edema.

Conclusion: Inhalation of vapors from water-soluble paints is considered relatively safe. However, our observations suggest that new lesions might develop and existing lesions could worsen, even if the edema is not severe immediately after the exposure. Thus, follow-up imaging is needed for approximately 2 weeks in such cases.

Key words: Inhalation of vapors, pulmonary edema, water-soluble paint

BACKGROUND

WATER-SOLUBLE PAINT IS considered safe and there are no reports of pulmonary edema caused by acute exposure to this type of paint vapor. Furthermore, it is clinically difficult to clarify the exposure time and concentration for substances that cause acute intoxication. We report our experience with multiple patients who developed pulmonary edema after inhaling vapors from water-soluble paint.

The exposure occurred during the filming of a commercial in an enclosed space (width, 17.8 m; length, 29.3 m; height, 7.4 m). A background had been painted with 10 L of white water-soluble paint at approximately 7:00 AM. After that, the studio was used for the filming between approximately 8:00 AM and 8:00 PM. During that time, 34 staff members continued to move in and out of the studio. None of these individuals immediately noticed the smell in the morning, although some individuals developed respiratory symptoms and arthralgia during the afternoon. Filming was continued because these symptoms were attributed to the common cold, although the individuals' symptoms worsened and one individual requested emergency assistance at 8:20 PM. A total of 16 patients were transported to our emergency department by the emergency medical service, which checked for gases in the studio but reported negative results. The present study examined background data regarding the patients' worksite, exposure time, and changes in the pulmonary edema lesions over time using serial computed tomography (CT) findings.

Through this study, our objective was to highlight the effects of vapor inhalation from water-soluble paint and to report on the measures to be undertaken when such situations are encountered.

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Table 1. Characteristics of patients who developed symptoms following exposure to water-soluble paint vapors (n = 16)

Profile			Exposure status		Vital signs in arrival				Symptoms and duration		Blood test results and edema severity		
Patient no.	Age (years)	Sex	Position relative to white screen	Time to onset (h)	Blood pressure (mmHg)	Temperature (°C)	Pulse (b.p.m.)	SpO_2 (%)	Symptom	Duration (days)	WBC count	Duration of high WBC (days)	Severity[†]
1	27	M	Inside	6	111/67	36.9	84	97	Arthralgia	3	17,000	3	Severe
2	41	M	Inside	6	126/79	37.8	85	98	Dyspnea	3	26,000	3	Severe
3	29	F	Inside	5	123/76	37.0	98	99	Cough	3	14,700	2	Moderate
4	29	M	Inside	4	104/52	37.1	59	98	Cough	4	14,000	3	Moderate
5	25	F	Inside	5	123/73	37.0	96	99	Dyspnea	2	18,900	3	Severe
6	23	M	Inside	5	120/70	37.5	87	97	Cough	3	17,100	3	Moderate
7	40	F	Outside	2	124/78	36.9	103	99	Dyspnea	3	12,400	1	Mild
8	29	M	Outside	10	125/88	37.4	103	98	Arthralgia	2	19,600	3	Moderate
9	29	F	Outside	5	130/77	37.2	89	99	Dyspnea	3	16,300	3	Mild
10	28	M	Outside	6	129/80	37.5	76	98	Dyspnea	1	13,600	1	Mild
11	31	M	Outside	8	116/75	37.0	75	99	Chest pain	3	15,900	2	Severe
12	30	F	Outside	5	110/63	37.0	68	99	Dyspnea	1	9,500	1	Moderate
13	33	F	Outside	2	122/85	37.1	90	99	Nausea	1	7,200	1	Moderate
14	26	M	Outside	5	106/60	37.0	60	99	Sore throat	1	10,800	1	Mild
15	29	F	Outside	6	96/62	37.9	82	99	Dyspnea	2	13,400	2	Severe
16	38	M	Outside	5	123/67	36.9	76	97	Dyspnea	2	18,000	3	Moderate

[†]Edema severity: mild, no findings on computed tomography (CT); moderate, CT findings persisted for ≤5 days; severe, CT findings persisted for >5 days. F, female; M, male.

METHODS

THE 16 PATIENTS underwent CT on days 1, 2, 5, and 19 after their exposure. Table 1 shows the patients' characteristics, including age, sex, distance to the painted screen, symptoms (with time to onset and duration), vital signs (blood pressure, mmHg; SpO_2, % : room air; temperature, °C; and heart rate, b.p.m.) blood test results, and edema severity. Time to onset means the duration from the beginning of the work until appearance of their symptoms. These durations were revealed by interviews with each patient. We divided severity into three levels: (i) severe, CT findings persisted for >5 days (Fig. 1; red circles, number indicates patient identifier; (ii) moderate, CT findings persisted for ≤5 days (Fig. 1; blue circles); and (iii) mild, no findings on CT (Fig. 1; white numbered circles) in this paper.

Five patients were classified with severe pulmonary edema, seven patients with moderate, and four patients with mild. Figure 1 shows the spatial positioning of these cases according to their severity and proximity to the painted background and U-shaped screen that enclosed the filming area. The changes in pulmonary edema were categorized as exacerbated lesions, delayed-onset lesions, and lesion amelioration (Figs. 2–4). All patients provided informed consent for their treatment and follow-up. The study's protocol was approved by our institutional ethics committee.

RESULTS

AS SHOWN IN Table 1, four patients had symptoms that resolved within 1 day, and these individuals worked outside the U-shaped screen that helped to enclose the filming area. Interestingly, individuals who worked inside the screen had a longer mean duration of symptoms, compared to individuals who worked outside the screen (3 days versus 2 days). Five patients had leukocytosis that disappeared within 1 day, and individuals who worked inside the screen had longer durations of leukocytosis, compared to individuals who worked outside the screen (2.8 days versus 1.8 days).

Figure 1 shows that patients 1–6 worked inside the screen, whereas the remaining 10 patients (patient nos. 7–16) worked outside the screen. Six of the nine individuals who worked inside the screen developed symptoms and were transferred to our emergency department. These patients had severe pulmonary edema (three cases) or moderate pulmonary edema (three cases). Ten of the 25 individuals who worked outside the screen (i.e., relatively distant from the painted back-screen) were transferred to our emergency department. These patients had severe pulmonary edema (two cases), moderate

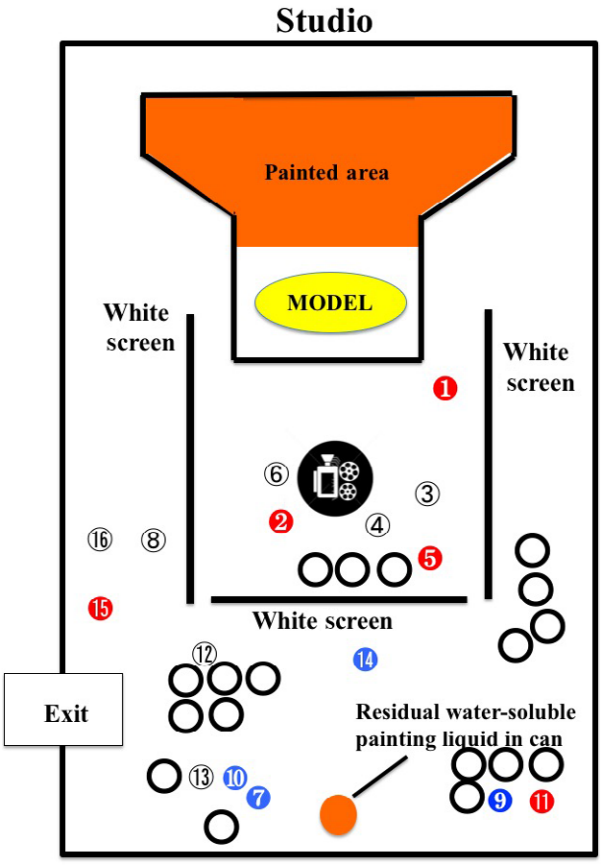

Fig. 1. Map of the studio (width, 17.8 m; length, 29.3 m; height, 7.4 m) in which water-soluble paint was used on a wall immediately before the filming of an advertisement. Multiple staff members developed pulmonary edema that was caused by inhaling paint vapors. There was a small window in the left upper wall, but it remained closed. Three large white screens had been placed in the middle of the studio, and the paint can have had been left behind in the studio. White circles indicate staff members who were not transported to the hospital because they did not experience symptoms.

pulmonary edema (four cases), and mild pulmonary edema (four cases), Thus, 12 of the 16 patients who received emergency transfer had pulmonary edema.

Ten people were hospitalized because of pulmonary edema and leukocytosis, although there was no relationship between the onset time and distance to the painted screen. At their admission, most of these patients had relatively normal vital signs, although 13 of the 16 patients had a fever of ≥37°C, which was determined by the tympanic route. None of the patients had a positive result from the quick Sequential Organ Failure Assessment score.[1] Fever severity was not related to inhalation time or distance from the painted background.

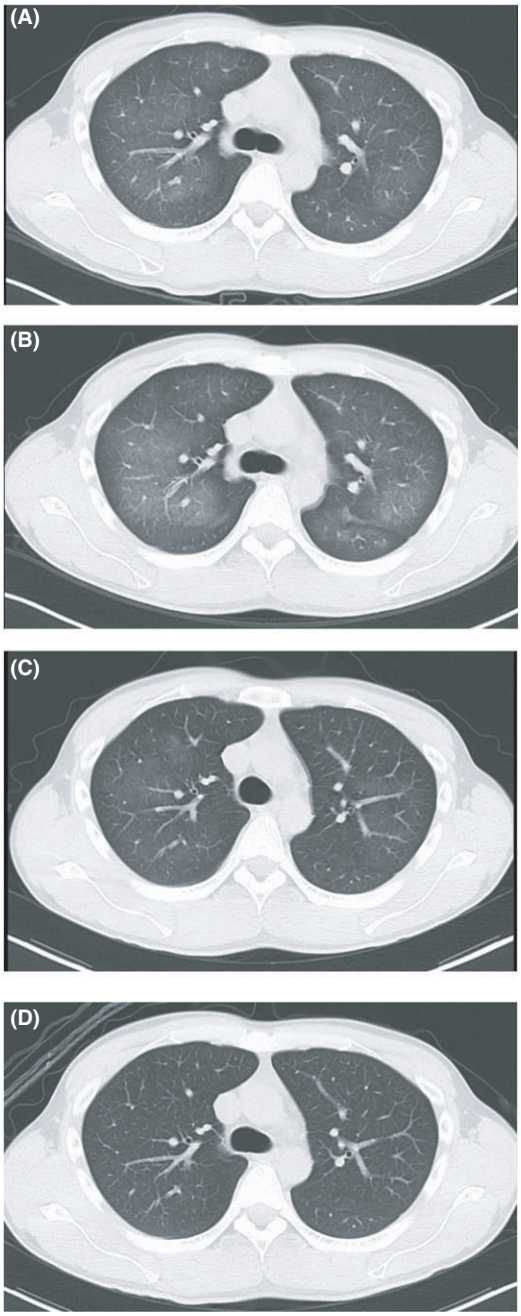

Fig. 2. Computed tomography (CT) imaging reveals exacerbation of pulmonary edema in patient 1 of a group of 16 individuals who developed symptoms following inhalation of water-soluble paint vapors. Patient 1 had been working nearest the painted wall. A, Day 1 of illness. CT shows the lightly increasing density of central distribution in both lungs, and pulmonary edema-like signs. B, Day 2 of illness. CT shows the increasing density of central distribution in both lungs. C, Day 5 of illness. CT shows decreasing density of central distribution in both lungs. D, Day 19 of illness. CT shows complete normalization of lungs.

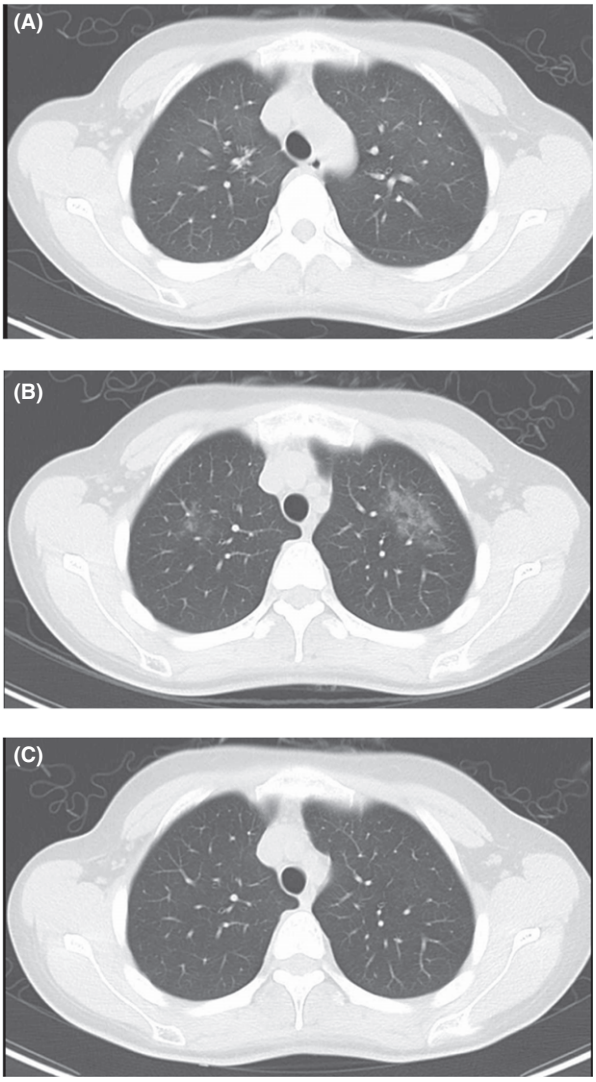

Fig. 3. Computed tomography (CT) imaging of a representative example of delayed lesions that developed in patient 5 of a group of 16 individuals who developed symptoms following inhalation of water-soluble paint vapors. These findings were observed over a period of 5 days. A, Day 1 of illness. CT shows lightly increasing density of central distribution in both lungs and pulmonary edema-like signs. B, Day 5 of illness. CT shows patchy areas of ground-glass attenuation. C, Day 19 of illness. CT shows complete normalization of lungs.

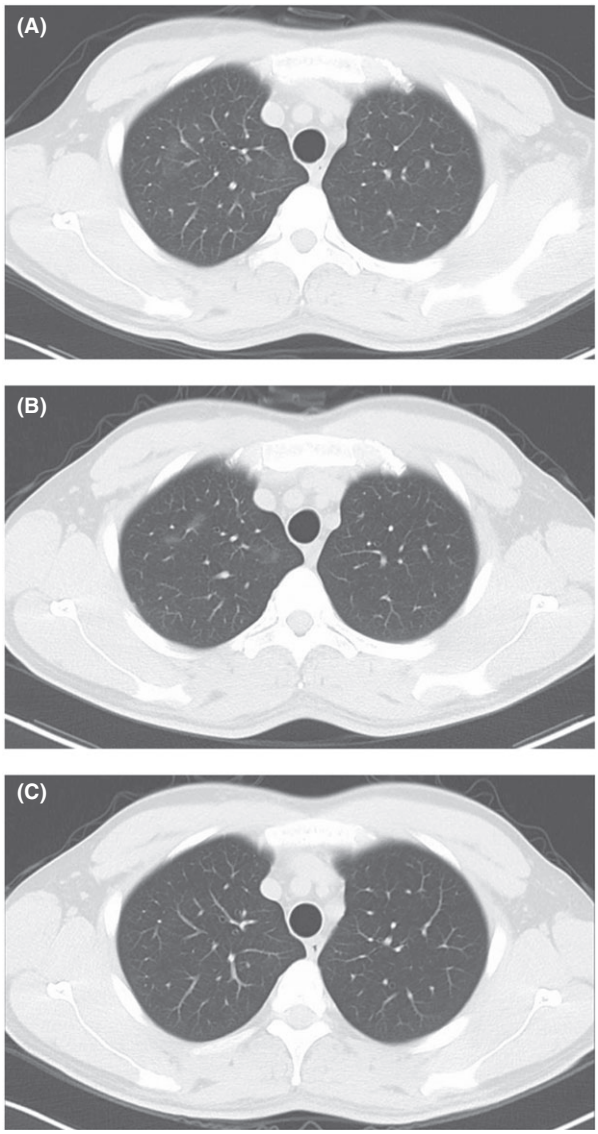

Fig. 4. Computed tomography (CT) imaging of pulmonary edema that gradually resolved over time in patient 11 of a group of 16 individuals who developed symptoms following inhalation of water-soluble paint vapors. A, Day 1 of illness. CT shows patchy areas of ground-glass attenuation. B, Day 5 of illness. CT shows patchy areas of ground-glass attenuation. C, Day 19 of illness. CT shows complete normalization of lungs.

Figures 2–4 show the serial changes in the CT findings. Patient 1 (Fig. 2), who was working nearest the painted wall, experienced exacerbation of the pulmonary edema. Patient 5 (Fig. 3) developed delayed-onset severe pulmonary edema that was detected on day 5 of their follow-up. Figure 4 shows that the pulmonary edema gradually resolved over time in patient 11. All patients showed complete elimination of pulmonary edema on day 19.

DISCUSSION

DURING THE DAY of filming, the staff had not opened windows for ventilation because of concerns

regarding premature release of the commercial. Thus, this incident highlights the importance of ventilating newly painted spaces in accordance with the paint manufacturer's instructions. The paint from this incident had three kinds of solutes: ethylene glycol, titanium dioxide (TiO_2), and silicon oxide. The Centers for Disease Control and Prevention's medical management guidelines[2] do not specify whether acute exposure to ethylene glycol vapor can induce pulmonary edema, although very high levels of inhaled ethylene glycol vapor can stimulate the upper respiratory tract and aspiration of ethylene glycol after massive ingestion may cause pulmonary edema.[3] Pneumoconiosis can also be caused by prolonged exposure to TiO_2,[4,5] and microparticles could cause inflammation during the acute phase.[6] Furthermore, pulmonary edema can be detected using radiography in cases of metal fume fever caused by titanium.[7] In the present incident, 13 of the 16 patients had a fever of ≥37°C, which has also been observed in combination with influenza-like symptoms in cases of metal fume fever. Interestingly, patient 1 did not have fever, although the pulmonary edema persisted, which suggests that the pulmonary edema was directly related to titanium microparticle-induced lung damage. Particulate matter containing silicon can also cause lung edema, even *in vivo*.[8] It appears that the signs and symptoms from the present cases were most likely attributable to TiO_2.

To the best of our knowledge, this is the first report of a multipatient incident that involved water-soluble paint. Interestingly, none of the 10 patients who were hospitalized required intubation, although microparticle-related inflammation causing pulmonary edema can be severe. In addition, as shown in Figure 3, it is unclear how the new lesions developed several days after the inhalation. Thus, given the delayed development of these lesions, we recommend careful follow-up for at least 2 weeks in similar cases of pulmonary edema. Moreover, it is possible that these cases involved exposure to microparticles from the paint for >10 h, and pulmonary edema is known to occur after exposure for ≥2 h. Nevertheless, it is impossible to quantify the inhalation, as we could not determine the exact activity time and intensity at the site. However, the aggravated lesions shown in Figure 2, and the delayed lesions shown in Figure 3, were detected in patients who were working relatively near the painted wall. Therefore, it is likely that these patients had greater exposure to the causative substance.

CONCLUSION

WE ENCOUNTERED MULTIPLE patients with pulmonary edema that was caused by inhaling vapor from a water-soluble paint. None of the patients required intubation, although it is possible that higher levels of the vapor could have led to more severe edema. Based on our findings, we recommend following patients with similar forms of pulmonary edema for at least 2 weeks, as well as appropriate ventilation of spaces where water-soluble paint is used.

DISCLOSURE

Approval of the research protocol: This study was approved by the clinical research committee of Shinyurigaoka General Hospital, Japan (20171127-2).
Informed consent: Oral informed consent was obtained from the patients for publication of this article.
Registry and the registration no. of the study/trial: N/A.
Conflict of interest: None.

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