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SPECIAL ARTICLE

Tsunami lung

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Abstract We encountered three cases of lung disorders caused by drowning in the recent large tsunami that struck following the Great East Japan Earthquake. All three were females, and two of them were old elderly. All segments of both lungs were involved in all the three patients, necessitating ICU admission and endotracheal intubation and mechanical ventilation. All three died within 3 weeks. In at least two cases, misswallowing of oil was suspected from the features noted at the time of the detection. Sputum culture for bacteria yielded isolation of *Stenotrophomonas maltophilia, Legionella pneumophila*, *Burkholderia cepacia*, and *Pseudomonas aeruginosa*. The cause of tsunami lung may be a combination of chemical induced pneumonia and bacterial pneumonia.

Keywords Tsunami · Drowning · Pneumonia

Introduction

The great earthquake with a magnitude of 9.0 on the Richter scale that shook the Pacific coast of the East Japan at 2:46 p.m. on March 11, 2011, caused a giant tsunami which hit the East Japan facing the Pacific Ocean. It killed more than 20000 individuals and caused catastrophic damage to thousands of buildings and natural environments. The energy of this earthquake was about 45 times as high as the energy of the Great Kanto Earthquake of 1923 and about 1450 times as high that of the Great Hanshin-Awaji Earthquake of 1995, and was ranked forth in terms of the energy level among the earthquakes recorded around the world since 1900. Many of the victims died of drowning in the tsunami rather than due to being trapped under the debris of collapsed buildings, which was the major cause of death in the Great Hanshin-Awaji Earthquake. The tsunami was incredibly powerful. Most of the individuals who failed to escape from the approaching tsunami lost their lives. Even the individuals who could fortunately be rescued developed serious lung disorders due to drowning (so-called "tsunami lung"). In this paper, we describe the characteristics of the "tsunami lung," points that need to be paid attention to in its treatment and so on, on the basis of our experience of caring for three such cases.

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Cases outlined

All of the three cases encountered by us who were rescued after being struck by the tsunami were females, aged 87, 86 and 33 years old, respectively. Because they had severe respiratory distress, they were transported by helicopter to our critical care center (located inland) on the morning after the earthquake. The consciousness level upon arrival at our center varied among the three patients, and all of them were admitted to the ICU and judged as needing endotracheal intubation and mechanical ventilation. One patient showed aggravation of the respiratory failure, without any signs of improvement, and died on the day after the admission. The remaining two patients showed transient improvement, but their conditions also worsened again, and they died 15 and 18 days after admission,

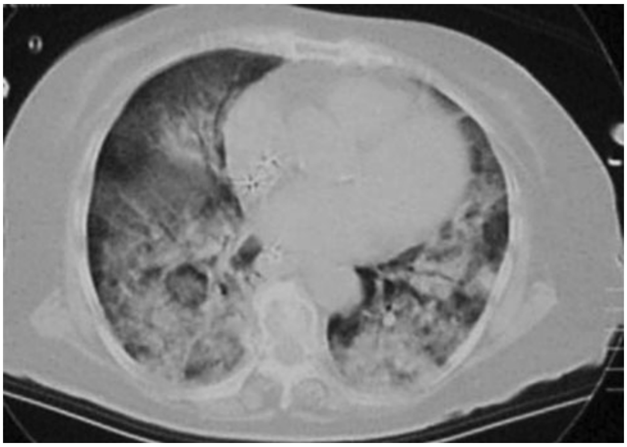

Fig. 1 Lung CT of Case 1 on admission

respectively. The antibiotic used was piperacillin (PIPC) for Case 1, doripenem (DRPM) [switched to ciprofloxacin (CPFX) 3 days before death] for Case 2, and meropenem (MEPM) [switched to pazufloxacin (PZFX) and minocycline (MINO) 5 days before death] for Case 3. Sputum culture for bacteria yielded isolation of *Stenotrophomonas maltophilia* from Case 2 and *Stenotrophomonas maltophilia, Legionella pneumophila, Burkholderia cepacia* and *Pseudomonas aeruginosa* from Case 3 (bacterial culture was not possible for Case 1 who died on the day after admission). Figures 1, 2 and 3 show the chest CT images and X-rays of each case obtained at the time of arrival at our center. All patients showed involvement of almost all segments of both lungs.

Tsunami caused by the Great East Japan Earthquake

The Great East Japan Earthquake, which occurred on March 11, 2011, had a magnitude of 9.0 on the Richter scale, and was the fourth strongest earthquake recorded around the world since 1900. In Japan, this earthquake is often compared with the Great Hanshin-Awaji Earthquake which took place in 1995. The energy level of the Great East Japan Earthquake is said to be about 1450 times as high as that of the Great Hanshin-Awaji Earthquake, indicating that this earthquake came with a power beyond our imagination. Because the Great Hanshin-Awaji Earthquake struck before dawn in the middle of the winter season, i.e., at a time when most people were sleeping, about 80% of the 6434 documented deaths were caused by crushing of the individuals under the debris of collapsed houses or buildings. In contrast, more than 80% of the deaths that followed the Great East Japan Earthquake were caused by drowning in the large tsunami triggered by the earthquake.

Fig. 2 Chest X-ray of Case 2 on admission

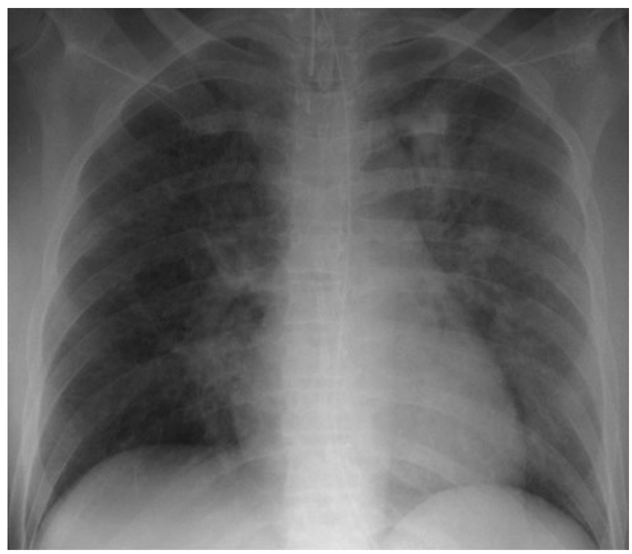

Fig. 3 Chest X-ray of Case 3 on admission

The height of a tsunami is measured either in terms of the height of the tide in meters or the run-up height of the wave on the land. During this last tsunami, the tide level gauges installed along the coast were destroyed, and it was difficult to determine the peak height of the tsunami. However, in the Taro Area of Miyako City, Iwate Prefecture, the tsunami easily crossed the 10-m high tide embankment, to cause an enormous amount of damage; thus, the height of the tidal wave was judged to be well over 10 m. The run-up height in the same Taro Area was 37.9 m, according to the results of the survey conducted by the Earthquake Research Institute, University of Tokyo.

This run-up height was close to the maximum height recorded in the domestic history of earthquakes, being comparable to the maximum height of 38.2 m recorded by the Meiji Sanriku Tsunami that struck Ofunato City of Iwate Prefecture during the Meiji Era.

The velocity of tsunamis increases as the depth of the sea increases. At a sea depth of 4000 m, tsunamis have a very high velocity (ca. 200 m/s and around 10 m/s near the seashore), equivalent to 36 km/h. Tsunamis striking at this velocity, equivalent to a speed of 100 m/10 s), can easily get ahead of humans running ahead of the tsunami. Furthermore, unlike the ordinary waves seen on the sea surface, tsunamis involve movement of all the layers of seawater from the bottom of the sea to the surface, and have very high energy levels. Tsunamis with a height of over 2 m have the power to destroy wooden houses almost completely. Therefore, it is easy to conceive the enormous energy level of the recent East Japan Tsunami, whose height was estimated as being in excess of 10 m. Such large tsunamis, therefore, leave no scope for humans to escape and will inevitably be associated with a high death toll. Excluding those who died from fires that occurred after the tsunami, the inhabitants of the tsunami-hit areas can be roughly divided into two groups: those that successfully escaped from the approaching tsunami and those that failed to escape and died; the number of individuals rescued after having drowned in the tsunami was very small.

Features of tsunami lung

Drowning has traditionally been divided into freshwater drowning (in rivers, lakes, swimming pools, baths, etc.) and seawater drowning (in sea). These two types of drowning have been considered to differ from each other, due mainly to the difference in the osmotic pressure between seawater containing salts and freshwater. However, according to the view that has prevailed in recent years, there is little difference between freshwater drowning and seawater drowning, because water rarely enters the lungs in volumes large enough to cause electrolyte abnormalities in the living body [1, 2]. Lung disorders caused by drowning affect the entire lung, unlike segmental pneumonia or lobar pneumonia (community-acquired pneumonia, aspiration pneumonia, etc.), because drowning involves entry of water into the lungs during respiration movements.

Drowning in a tsunami is considered to differ markedly from drowning in normal seawater. This is because the seawater making landfall during a tsunami carries various objects along with it (e.g., soil, sand, buildings, vehicles, dust/wastes, oil and so on). As a result, the seawater entering the lungs of tsunami victims contains various substances, making the lung damage more complex. Of these substances, oil seems to be most often involved in the development of the “tsunami lung.” Oil includes heating oil used in households, gasoline and light oil used for automobiles and ships, and heavy oil used for ships and factories. In addition, there are also oil pooling facilities along the coast. All of these various types of oil come to cover the sea surface during a tsunami. Humans caught in a tsunami will attempt to ascend to the sea surface to breathe (or will remain floating on the sea surface because of the specific gravity of seawater). At this time, they are at a high risk of aspirating the oil floating on sea surface. The lung invaded by oil develops serious chemical-induced pneumonia affecting most segments. The condition of such victims is probably aggravated by the complication of infective pneumonia caused by the dirty seawater. All of the three cases encountered by us were female, and the findings at the time of their detection suggest that at least two of these females had swallowed the oil. In other words, tsunami lung may represent a combination of chemical-induced pneumonia and bacterial pneumonia affecting the entire lung.

Frequently isolated pathogens from cases of bacterial pneumonia associated with drowning include the *Aeromonas* species, *Burkholderia pseudomallei* and so on, in cases of freshwater drowning, and *Francisella philomiragia* in cases of seawater drowning (*Pseudallescheria boydii, Pseudomonas aeruginosa*, etc. in cases of drowning in polluted water) [3]. There is one report of a case of drowning whose life could be successfully saved following the tsunami at Okushiri Island in 1994 [4]. *Legionella pneumophila* isolated from Case 3 herein is known to cause Legionella pneumonia. This bacterium is a constituent of the indigenous flora of the soil and is a facultative intracellular parasite. It can proliferate within macrophages. It is known that Legionella pneumonia develops in circulating baths and spas due to its propensity to proliferate within facilities for pooling and circulation of massive volumes of water. This bacterium often produces beta-lactamase and is resistant to penicillins, cefems, carbapenems and so on. *Stenotrophomonas maltophilia* was isolated from two of the three cases reported herein. This is a glucose non-fermenting Gram-negative bacilli (formerly called *Xanthomonas maltophilia*), which is widely distributed in nature, and is resistant to multiple drugs and disinfective agents. Because this bacterium produces metallo-beta-lactamase in a chromosome-dependent manner, it shows natural resistance to carbapenems, cephamycins and so on. The antibiotic used for our two cases was a carbapenem. It seems therefore likely that aggravation of infection with drug-resistant bacteria (*Stenotrophomonas maltophilia, Legionella pneumophila*, etc.) developing as a result of microbial substitution following the use of carbapenem was one of the factors responsible for the deterioration of the respiratory status after a transient improvement in these patients, who eventually died.

Conclusion

In this paper, we have presented the characteristics of the "tsunami lung" based on our experience of caring for three cases of lung disorders caused by drowning in the tsunami. "Tsunami lung" may be considered as a condition representing a combination of chemical-induced pneumonia (due to oil, soil sand, etc.) and bacterial pneumonia affecting the entire lung. Because bacterial pneumonia in such cases can be caused by diverse bacteria, it is advisable to also consider measures to deal with carbapenem-resistant bacteria.

References

1. Ganaha H. Drowning. Jpn J Pediatr Med. 2011;43(1):123–5.
2. Imaizumi H, Masuda Y. Lung disorders due to drowning. Jpn J Clin Med. New specialty-wise syndrome series No. 9:203–9, Nippon Rinsho Co., Ltd., Tokyo, 2009.
3. Ender PT, Dolan MJ. Pneumonia associated with near-drowning. Clin Infect Dis. 1997;25:896–907.
4. Yoshikawa O, Akinori K, Takashi H, Naoko T, Izumi Y. Four cases of near-drowning in tsunami. Jpn J Intensive Care Med. 1994;18:1187–92.