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**Case report of an autopsy of a child who died in a drum-type washing machine tub:
pathophysiology resulting in death and assessment of previous literature**

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Abstract

The patient was a 5-year-old boy who was found in a state of cardiorespiratory arrest in the tub of a washing machine without water with the door closed. The autopsy findings included severe facial congestion and petechiae of the facial skin and palpebral conjunctiva. Several organs exhibited congestion. Hemorrhagic spots were seen on the serous membranes of various organs, with particularly marked hemorrhagic spots seen on the lungs. The heart contained fluid blood without soft clots. There were no findings indicative of marked trauma, intoxication, or hyperthermia. The examination results suggested that asphyxia had occurred in this case. However, there were no findings indicative of cervical compression, oronasal obstruction, or the presence of a foreign body in the respiratory tract. Image analysis showed the child could make postural changes inside the washing machine tub. Consequently, impaired thoracic movement and postural asphyxia were considered unlikely to have occurred. The results of blood gas analysis showed no evidence of marked hypercapnia. We therefore concluded that the cause of the child's death was asphyxia due to hypoxia caused by being in a closed space, i.e., a washing machine tub.

Keywords: Drum-type washing machine; Asphyxia; Hypoxia; Autopsy; Forensic

Introduction

Accidents involving children have been reported on the Internet to have occurred in many countries as a result of the use of drum-type washing machines. Until recently, pulsator-type washing machines have been the most common type in Japan. However, as drum-type washing machines have become more popular, attention has been drawn to accidents in which children have become trapped in the tubs of the machines. Because the door of the drum-type washing machine is located low on the front of the machine, it is easy for a child to enter it. Consequently, many drum-type washing machines are equipped with child locks to prevent children from becoming trapped in the washing machine tub. However, the many reports of accidents involving children on the Internet indicate that the child-lock feature is not being used. Drum-type washing machines are highly airtight to prevent water leakage, and are therefore poorly ventilated. Consequently, if a child becomes trapped inside, he or she may be deprived of oxygen. To our knowledge, there have been few medical reports of accidents in which children have become trapped in drum-type washing machines.^{1,2} In previous reports of accidents occurring in small, closed spaces other than washing machine tubs, deaths have been attributed to factors such as hypoxia or hypercapnia caused by oxygen deficiency.³⁻⁷ In a recent report, however, positional asphyxia resulting from cervical hyperflexion was raised as a possible cause of death.⁸ In addition to asphyxia, a report has indicated that attention should be

given to hyperthermia (heat stroke).⁹ Thus, positional asphyxia and hyperthermia have been surmised as being possible causes of death in drum-type washing machine tubs. However, due to the lack of cases reported in international medical journals, the pathophysiological mechanisms resulting in death have not been adequately investigated. We autopsied a child who died in a drum-type washing machine tub and examined the pathophysiology involved. Through this case report, we note the need for an examination of strict measures to prevent future accidents involving children in drum-type washing machine tubs.

Case report

Case history

The patient was a 5-year-old boy reported to have a mild intellectual disability, the details of which were unspecified. One morning in January, the boy and his father played in a park, then returned home at about 11:30. The boy subsequently ate lunch with his father, who then went to sleep in bed at around 13:00. What the child did while his father was asleep is not known. The father awoke at around 15:00 and searched for the boy. The father found the boy in a state of cardiorespiratory arrest inside the tub of their washing machine (opening diameter, 60 cm; washing machine tub volume, 82 L; depth, 29 cm; Fig. 1a) without water with the door closed. The father became panicked, and accurate details regarding position of the boy when his father

found him are therefore not available. The boy was immediately transported to a hospital, where cardiopulmonary resuscitation was performed. However, the boy's cardiorespiratory function was not restored, and death was confirmed at 16:14. The father had been asleep for approximately 2 h. The boy had no severe injuries that could be considered directly related to his death. A forensic autopsy was performed approximately 2 days after he died.

Postmortem imaging

Computerized axial tomography (CT) images obtained after the boy's death were analyzed, and the volume of the washing machine tub and the boy's body volume were compared. The volume of the washing machine tub, 82,000 cm³, was approximately four times greater than the boy's body volume, 19,329 cm³. Based on the configuration of the washing machine tub, it was surmised that the boy had been in a sitting position with his knees bent (Fig. 1b and 1c). The length from the tip of the boy's coccyx to the top of his head was 61.27 cm. Image analysis showed the child could make postural changes inside the washing machine tub. Postmortem CT imaging of the boy's lung fields showed the presence of severe pulmonary edema (Fig. 2a and 2b).¹⁰

Autopsy findings

The boy measured 118 cm in length and weighed 20.0 kg (the averages for 5-year-old Japanese

children are 110 cm and 19 kg, respectively). The autopsy was essentially unremarkable, failing to uncover any signs of trauma or natural disease. The only abnormal findings consisted of cerebral edema and scattered petechial hemorrhages affecting the face, conjunctivae, thymus, lungs, and kidneys. Toxicological tests for drugs and toxic substances, including stimulants and psychotropic drugs, performed by immunochromatography and gas chromatography were also negative.^{11, 12} In the absence of trauma, natural disease, etc. and given the circumstances of the case, the cause of death was determined to be asphyxia from entrapment with oxygen deprivation.

Discussion

The values published in the literature indicate that the volume of oxygen consumed by a typical 5-year-old Japanese boy is 6.931 mL/kg/min,^{13, 14} and the child in this case weighed 20 kg. Therefore, the volume of oxygen consumed was calculated to be 138.62 mL/min (volume consumed while child in the closed space \times weight: 6.931 mL/min \times 20 kg = 138.62 mL/min). The volume of oxygen consumed until respiration stopped was calculated as follows to be 10,027.36 mL: (volume of washing machine tub – body volume of boy) \times atmospheric oxygen concentration (21%) – oxygen concentration at which respiration arrest occurs (5%), or $(82,000 - 19,329) \times (0.21 - 0.05) = 10,027.36$ mL. The time until respiration stopped was then theoretically calculated to be 72.3 min as follows: volume of oxygen consumed until

respiratory arrest / oxygen consumed by the patient, or $10,027.36 / 138.631 = 72.3$ min. Thus, based on these theoretical values, the time from when the child became trapped in the tub of the drum-type washing machine until respiration stopped was calculated to be 72.3 min (approximately 1 h).

There have been very few reports of detailed investigations regarding the pathophysiology of deaths occurring in drum-type washing machine tubs. Of the cases that have been reported, one resulted clinical case from an accident. In that case, a 2-year-old girl had been put into the rotating drum of a domestic washing machine by her 8-year-old sister and was pulled out by her mother after probably less than 1 min. There was a marked petechial rash on the right side of her face, neck, and shoulders and a less distinct but similar rash on her right trunk, pelvis, and thigh. A blood gas sample showed a metabolic acidosis, while a chest radiograph showed a left pneumomediastinum. She demonstrated many of the features of traumatic asphyxia syndrome. It was reported that the mechanism of chest compression was presumably positional owing to the body being forced in a hyperflexed attitude into a confined space.¹ In another case, a 7-month-old girl was put in a washing machine along with the laundry by her mother with depression. The baby was found in a turned on washing machine by her father, and her father pulled her out. Her clothes were soaked in cold, soapy water, and there was a folded handkerchief in her mouth. On autopsy, no other causes of death were evident, and typical signs of asphyxia, such as epicardial and pleural petechiae, were present. Therefore, the cause

of death in this case was acute asphyxia. As the cause of asphyxia, it was reported that drowning was at least partially involved, because the entering of water into the upper airways was inevitable.² The cause of death in these two cases was related to asphyxia, but the mechanism of death was different in each case. From the present case and previous reports, it appears that various factors such as asphyxiation, drowning, and trauma can occur as causes of a child's death in drum-type washing machines. The present report is useful for understanding the mechanism of death of a child who died in a drum-type washing machine tub.

The investigation concluded that the cause of the child's death was hypoxemia resulting from oxygen deficiency. However, household matters are private, and it is difficult to distinguish between abuse, accidents, homicide, and suicide based on autopsy findings alone. Therefore, no categorical conclusion can be drawn regarding the manner of death. A cause contributing to the incident in this case was that although the drum-type washing machine was equipped with a child lock, it was not being used.

To prevent such incidents from occurring in homes, households with children should be given a clear explanation of the risks involved in using drum-type washing machines, and appropriate precautions should be taken.

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Figure legends

Fig. 1 Depiction of the drum-type washing machine involved in this case **(a)**, depiction of the posture of the boy in the tub of the drum-type washing machine (pictured from the front side) **(b)**, **(c)** same as **(b)** (pictured from the left side)

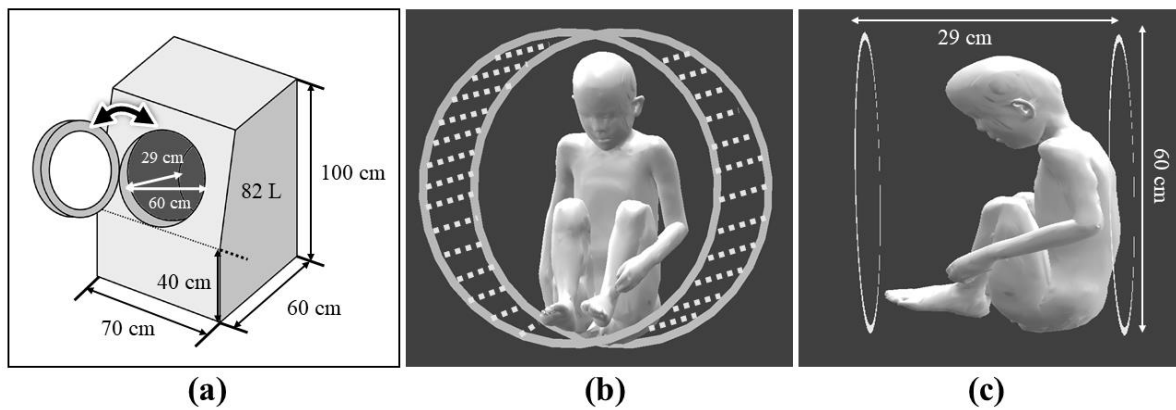


Fig. 2 Postmortem computed tomography images. Bilateral lung fields (a), parts of bilateral lung fields with pulmonary edema (Risk Pointer[®], Hitachi Medical Co., Ltd., Tokyo, Japan) (b).

> -2000, < -400 Hounsfield units (HUs) in yellow; > -399, < -50 HUs in light blue; > -49, < 50 HUs in blue; > 51 HUs in white. Light blue and blue regions indicate edematous areas

