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CASE REPORT

Fatal outcome of a sand aspiration

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Abstract Although extensive deep aspiration of sand, gravel, or dirt is a very rare incident, its consequences may be severe ranging from the necessity of immediate intensive care to death. Cases reported so far were due to external causes such as cave-ins, near drowning, or being buried under sand masses. We report a case of a 2 1/2-year-old boy who ingested sand while playing in a sandbox with his older brother. Despite early resuscitation and endotracheal intubation efforts, he died subsequently showing clinical signs of asphyxia due to airway obstruction. Autopsy revealed sand masses obstructing the trachea and lobar bronchi of both lungs as well as brain *edema*, while no signs of blunt trauma, forced sand ingestion, or preexisting medical conditions were found. This case demonstrates that fatal self-administered sand aspiration may occur in early childhood. The pathophysiology of the lethal outcome with regard to the physical properties of sand and implications for the clinical assessment of emergency situations are discussed.

Keywords Sand aspiration · Asphyxia · Emergency medicine · Obstruction of airways

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Introduction

Sand, gravel, or dirt aspirations are rare but potentially lethal incidents in emergency medicine. Most of the few cases reported so far share the common mechanism of being buried accidentally under sand, dirt, or gravel masses at construction sites [1–4], as the result of the collapse of sand tunnels [5, 6], sand castles [7], and sand piles [1, 8] or in the course of a vehicle accident [9, 10]. Single cases of sand aspiration during drownings and near drownings have also been described [11, 12]. Furthermore, sand may be deposited postmortem in the deep respiratory passages in immersion deaths, e.g., if the body has been rolled by the waves on a beach [13] Fortunately, many of the accidental aspirations, notably those of children being buried under sand masses, were survived after successful bronchoscopy treatment [5, 7, 8, 11, 14] or application of bronchodilators and postural drainage alone [2]. In a number of cases, sand aspiration was due to the deposition of sand masses on the head of homicide victims [1]. In conclusion, the fatalities due to sand aspiration reported so far were ascribed to extraneous causes.

In contrast, deliberate ingestion of sand is a phenomenon that is frequently found in children playing in sandboxes or at the beach. Nevertheless, to the best of our knowledge, fatalities due to deliberate sand ingestion have never been reported before.

Here, the fatality of a 2 1/2-year-old boy is reported, who apparently tried to eat sand and subsequently died of asphyxia due to sand aspiration and airway obstruction after unsuccessful resuscitation and treatment efforts.

Particular consideration is given to the pathophysiology of the lethal outcome as determined by the physical properties of sand, and conclusions for the clinical assessment of the emergency situation are presented.

Case

A 2 1/2-year-old boy with no previous medical history was playing with his 4-year-old brother in a sandbox in the backyard of his parents' house. Shortly (approximately 10 min) after his mother had left the balcony (from where she had watched the children playing in the sandbox) to do some house cleaning, the brother walked in and told her, that the brother "had gone to sleep." On arrival at the sandbox, she noted that her son was not breathing anymore. She called for an ambulance which arrived within 6 min after the emergency call. Upon arrival of the emergency team, the boy presented with fixed pupils and no discernible spontaneous cardiopulmonary activity. Resuscitation efforts were started immediately. Obstructing sand masses were removed from the oral cavity and larynx. Upon endotracheal intubation, only small remains of sand were seen on the tongue and laryngeal mucosa. Since a substantive increase of arterial oxygen saturation (60% before and 80% after endotracheal intubation) was measured during the first minutes after endotracheal intubation and adequate chest movements were noted initially, correct positioning of the tubus was assumed. Resuscitation efforts by the emergency team continued until admission to the emergency care unit of a pediatric hospital. Spontaneous cardiopulmonary activity was not reestablished and the pupils remained fixed. After administration of epinephrine (3×1.5 ml; 1:10,000), atropine (1×0.25 mg), and sodium bicarbonate (1×15 mval), defibrillation was performed in ascending doses (2×50, 3×100, 1×200 J). Nevertheless, no spontaneous cardiac activity was achieved and resuscitation efforts were terminated unsuccessfully after 45 min.

Prior to the autopsy, radiographs of the skull, chest, and abdomen were carried out. The chest radiograph showed slightly radio-opaque material in the lower parts of the trachea and both main stem bronchi.

Upon external examination, sand grains were noted only in both groins. The close-cut fingernails as well as the palms of both hands were devoid of sand grains (as they had been cleaned by the emergency staff).

Medicolegal autopsy revealed a massive aspiration of sand that obstructed the airways beginning 1.5 cm below voice chord level and extending to the lobar bronchi (Fig. 1). Sand was also found in the larynx as well as the oral cavity and esophagus to a minor nonobstructing degree. Only few grains of sand were detected in the stomach and none in more aboral parts of the digestive tract. On examination of the brain, morphological findings of elevated intracranial pressure such as effacement of cortical sulci and a massive cerebellar tonsillar herniation were noted. The conjunctivae and skin showed no signs of congestion, e.g., petechiae.

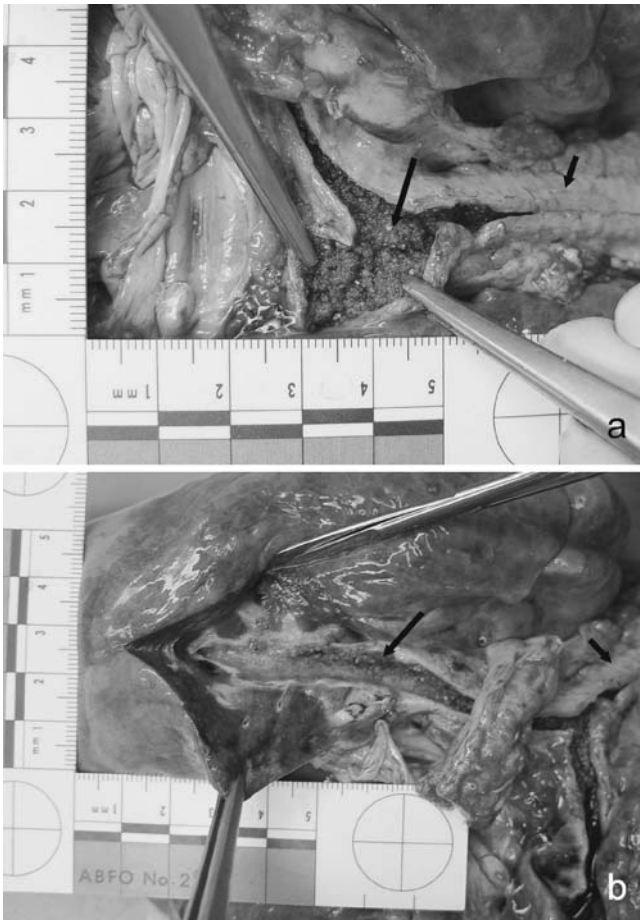

Fig. 1 **a** Sand masses obstructing the trachea at the bifurcation level (*long arrow*), **b** sand masses obstructing the right bronchus (*long arrow*) reaching to the lobar bronchi (**a** + **b**: *short arrows* marking the trachea)

No evidence of blunt trauma indicating a forced ingestion was detected.

Histological examination showed marked emphysema in both lungs. As the clotted sand masses had not proceeded further than the lobar bronchi, no aspired material was detected in smaller air passages or alveoli. A preexisting medical condition that might have contributed to death was not found.

Discussion

In the present case, the cause of death was unequivocally determined to be asphyxia due to an obstruction of the airways by the aspiration of sand. The police investigations in connection with the medicolegal examination discerning no injury suggesting a forced ingestion of sand indicate a deliberate "sand eating" resulting in accidental aspiration.

To the best of our knowledge, the cases of sand aspiration reported up to now in the literature [1–3, 5–12, 14] involved accidents such as cave-ins, drownings, near drownings, and

vehicle accidents on the one hand and homicides on the other hand. Therefore, they share the common feature of an underlying extraneous cause.

Nevertheless, most of the sand aspirations caused by accidental cave-ins and near drownings, markedly those of children, were survived.

The lethal outcome in the present case is particularly astonishing since "sand eating" is a phenomenon commonly observed in children playing in sandboxes or at the beach. This fatality may be at least partly attributed to the physical properties of sand.

From a geological point of view, sand is particulate rock as a result of weathering processes. Sand originating from natural deposits usually displays grain diameters ranging between 0.063 and 2 mm (grain diameters above 2 mm are defined as grit or gravel). Aspired sand grains in this case had a mean diameter of 0.35 mm (SD 0.085 mm) and were thus categorized as medium sand using the Wentworth scale [15] (mean particle size 0.25–0.5 mm). The analyzed portion of sand showed a medium degree of contamination with botanical material and dust particles.

Weather records for the respective suburban area showed approximately 13.5 h of sunshine on average with a mean temperature of 19.5°C (24 h) for the preceding 7 days. Furthermore, no rain at all was recorded during the relevant time period which suggests that the aspired sand had been dry at the time of aspiration.

From a physical point of view, granular materials like sand show a wide variety of behaviors (such as gas, liquid, solid, plastic flow, and glassy behavior) [16]. Due to differing physical behaviors, a distinction has to be made between wet and dry sand masses. Wet sand masses normally act as a solid, e.g., forming a sandcastle, and tend to form adhesive conglomerates of sand grains. The anatomy of the larynx and trachea as well as the cough reflex usually prevent bigger solid items such as these grain conglomerates from being aspired. However, due to a smaller diameter of aspired items, aspiration of dry sand masses is only restricted to a lesser degree by these physiological mechanisms. Once dry sand has entered the bronchial system, it tends to follow granular gas [17, 18] or liquid-like flow principles as in a sandglass (although sandglasses show liquid-like flow only in the middle section and also display some solid properties, e.g., supporting a weight on the sand surface). This gas-fluidized sand (glass beads) bed has also been described as a "weak" solid [19]. During the aspiration process, a layer of dry sand covers the tracheal and bronchial mucosa forming a centripetally growing tubular to cylindric hollow body. Experiments using spheres of defined diameters have shown that within dry gas-fluidized (in this case breathing and coughing efforts) sand masses simulating a fluidized sand bed the spheres (clustering of sand grains due to contact with oral and pharyngeal mucosa) sink inside a sand-filled glass tube depending on the gas flow rate [17]. This shows that even the physiological mechanisms directed against aspiration (breathing and coughing efforts) lead to a fatal aggravation of the situation as sand masses advance within the respiratory system. Furthermore, Lohse et al. [20] showed that even after stopping the air stream in a gas-fluidized sand bed the loosely packed sand cannot support objects of higher density (e.g., a ping-pong ball filled with bronze grains) calling it a dry variety of quicksand. Although these experimental setups cannot be exactly equated with the respiratory system, they help to understand the physical mechanisms underlying sand aspiration.

In consideration of an unknown amount of sand in the oral cavity and adjacent parts of the larynx and known dimensions of the trachea, a volume of approximately 28 cm^3 of sand intermingled with mucus was needed to tamponade the respiratory system at the tracheal level in the documented manner. This volume was estimated assuming a cone-shaped cylindric tracheal form:

$$V=\left((R\times r)+R^2+r^2\right)\pi\times(L/3)$$

(where V volume, R greatest lumen radius in millimeter, r smallest lumen radius in millimeter, L length of cylinder in millimeter).

This volume is in relatively good accordance with the capacity of a child's palm and is thus consistent with the idea of self-ingestion.

In synopsis, this fatality illustrates the challenge of assessing unnatural causes of death and distinguishing between accidental and deliberately inflicted trauma frequently faced by forensic pathologists when examining injuries or fatalities in infants [21, 22].

As far as the initial assessment of the emergency situation is concerned, the present observation underlines that even after successful removal of the sand obstructing the mouth and pharynx a persistent obstruction of the deeper airways due to the physical properties of dry sand must be included in the diagnostic and therapeutic considerations.

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