

Accidental mechanical asphyxia of children in Germany between 2000 and 2008

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Abstract Accidents constitute one of the greatest risks to children, yet there are few medical reports that discuss the subject of accidental asphyxia. However, a systematic analysis of all documented cases in Germany over the years 2000–2008 has now been conducted, aiming at identifying patterns of accidental asphyxia, deducing findings, defining avoidance measures and recommending ways of increasing product safety and taking possible precautions. The analysis is based on a detailed retrospective analysis of all 91 relevant autopsy reports from 24 different German forensic institutes. A variety of demographic and morphological data was systematically collected and analysed. In 84 of the 91 cases, the sex of the victim was reported, resulting in a total of 57 boys (68 %) and 27 girls (32 %). The age spread ranged between 1 day and 14 years, with an average of 5.9 years. Most accidents occurred in the first year of life

(20 %) or between the ages of 1 and 2 years (13 %). In 46 % of cases, the cause of death was strangulation, with the majority occurring in the home environment. In 31 % of all cases, the cause of death was positional asphyxia, the majority resulting from chest compression. In 23 % of cases, the cause of death was aspiration, mainly of foreign bodies. Today, accidental asphyxiation is a rare cause of death in children in Germany. Nevertheless, the majority of cases could have been avoided. Future incidence can be reduced by implementing two major precautions: increasing product safety and educating parents of potentially fatal risks. Specific recommendations relate to children's beds, toys and food.

Keywords Asphyxia · Accidents · Suffocation · Strangulation · Chest compression · Aspiration · Precautions

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Introduction

With about 1.7 million cases per year, accidents are among the greatest health risks to children in Germany [1]. Though several cases relating to accidental asphyxia during childhood can be found in the scientific literature [2–6], only a small number of systematic analyses have been published [7, 8]. Even the official mortality statistics of the German Federal Bureau of Statistics [9] are not able to sufficiently answer all questions that may be of interest in these cases. The systematic analysis of accidental asphyxial deaths among children is of major importance for identifying potentially dangerous products such as children's toys, beds and food.

Only by undertaking a detailed risk assessment is there any chance of improving products and reducing their hazard potential. The aim of this analysis is to present the findings relating to the accidental asphyxial deaths among children up to the age of 14 years in Germany that occurred between 2000 and 2008. It also gives recommendations for increased product safety, along with possible precautions.

Materials and methods

All 32 institutes of legal medicine in Germany were asked to provide information on cases of accidental mechanical asphyxia in children during the above period. A detailed retrospective analysis of 91 relevant autopsy reports from 18 institutes was performed. However, six institutes reported that no autopsies relating to accidental asphyxia were performed during this time, while eight did not respond to the request.

A systematic questionnaire was developed to collect and analyse each autopsy report. A variety of demographic and morphological data was reviewed.

Results

A total of 91 autopsy reports were evaluated from 18 institutes. An average of 10 cases (a minimum of 5 and a maximum of 14) per year was investigated.

Most accidents occurred within the first year of life (18 cases=20 %) or between the ages of 1 and 2 years (12 cases=13 %), followed by children aged 13 (9 cases=10 %) and 12 years (7 cases=8 %). The average age throughout the period was 5.9 years (see Table 1). Out of the 91 cases, 84 reported the sex of the victim: 57 were boys (68 %) and 27 were girls (32 %).

Of the victims, 65.9 % died in their home environment; of these, 33 % were found in their bed. Seven deaths (7.7 %) occurred in day care units.

Table 1 Age of the victims

Age in years	Number of cases	%
0 to <1	18	20
1 to <2	12	13
2 to <3	6	7
3 to <4	6	7
4 to <5	3	3
5 to <6	5	6
6 to <7	0	0
7 to <8	4	4
8 to <9	6	7
9 to <10	3	3
10 to <11	2	2
11 to <12	6	7
12 to <13	7	8
13 to <14	9	10
14 to <15	4	<i>n</i>

Fourteen children were under the supervision of an adult when the accident happened (15.4 %). In 45 cases, there was no adult around when the accident happened. In a further 32 cases, it is unknown whether there was any adult supervision at the time of the accident. Strangulation was the most common cause of death (46 %) followed by positional asphyxia (31 %) and aspiration (23 %).

Strangulation (*N*=42)

All cases of strangulation were caused by accidental hanging. Analysis of the age structure shows two peaks in strangulation deaths in childhood. Toddlers aged 2 (17 %) and children aged 13 (12 %) and 14 years (17 %) suffered more frequently from strangulation than children of other ages. Strangulation resulted for example from home accessories, such as draw strings, clothing, e.g. jackets, belts, scarfs, ties and helmets, and items especially designed for children, like climbing frames, skipping ropes and children's drum cords.

Aspiration (*N*=21)

Aspiration can be divided into three main categories: aspiration of foreign bodies, aspiration of stomach contents and bolus death. The highest percentage was determined for foreign body aspiration (62 %). On closer inspection of the age pattern, it became obvious that the majority of aspirations were at the age of 1 (24 %), 3 (15 %) and 4 years (24 %). The frequency of aspiration decreases with advancing age. Products aspirated included grapes, nuts, pieces of meat or sausage, sweets and small toy parts.

Positional asphyxia (N=28)

This cause of death can be divided into three subcategories, the most common one being throat and chest compression (N=13; 46 %). There were 10 cases of entrapment (36 %) and 5 cases of overlaying (21 %). Children in the first year of life were the ones affected most frequently (N=12, 43 %). The item most commonly linked to such accidents is the child’s bed (N=16). Other cases involved a variety of items, including a stroller and an automatic car window lift.

Morphological findings

Petechial haemorrhages Sixty-seven autopsy reports mention petechial haemorrhages, either subpleural, subepicardial or in the thymus (positive or negative findings). In the majority of these cases, petechial haemorrhages were detected in at least one location (48 cases; 72 %). In 19 cases (28 %), petechial haemorrhages were not present (Fig. 1). Differences between groups are not statistically significant ($\chi^2=0.543$).

Petechial bleeding in the skin of the face was detected in 48 cases (72 %). In 19 cases (28 %), there was no congestive haemorrhaging. In 24 cases, no information was given relating to bleeding of this kind (Fig. 2). Again, differences between groups are not statistically significant ($\chi^2=0.9070$).

Spinal disc bleeding in strangulation In seven cases (23 %), spinal disc bleeding was detected. Of the 30 strangulation cases,

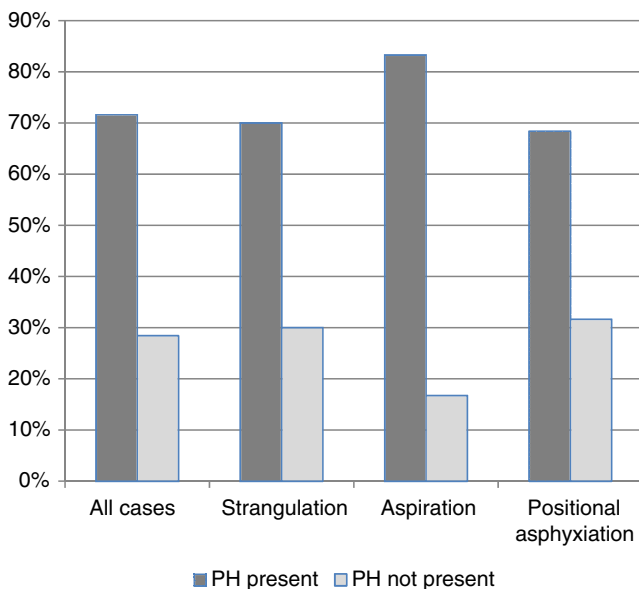


Fig. 1 Frequency of petechial haemorrhages (PH) associated with asphyxiation (location: subpleural, subepicardial and thymus) in different subgroups. Differences are not statistically significant

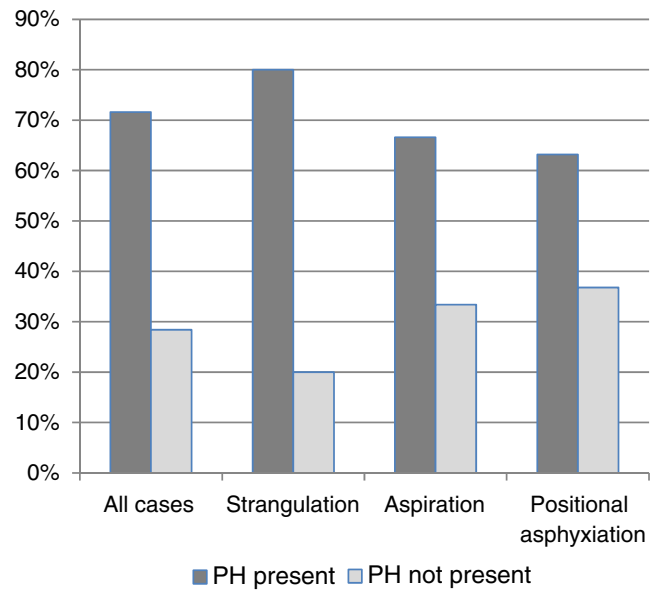


Fig. 2 Frequency of petechial haemorrhages (PH) in the skin of the face (caused by congestion) in various subgroups. Differences are not statistically significant

no spinal disc bleeding was detected in the majority (23 cases; 77 %). In 12 cases, there was no information available.

Muscle insertion bleedings in strangulation Thirty cases reported muscle insertion bleeding, which was detected in 17 cases (57 %). In 13 cases (43 %), it could not be found during autopsy. In 12 cases, there was no information concerning muscle insertion bleeding.

In 60 out of the total of 91 cases examined, the presence of liquid blood was mentioned. It was found in 59 cases (98 %). There was only one case (2 %) involving clotted blood.

Brain oedema was described in 48 (71.6 %) out of a total of 67 cases. In 19 cases, it was not detected (28.4 %). With respect to the different types of asphyxiation, it is found most frequently in cases of aspiration (88.9 %) followed by strangulation (58.6 %) and positional asphyxiation (63.1 %).

Discussion

The main aim of this analysis was to reflect the epidemiological situation in Germany with regard to accidental asphyxiation as precisely as possible and to identify specific recurring accident patterns in defined age groups. It is known from official mortality statistics that 445 cases of accidental asphyxiation occurred in Germany during the years 2000 and 2008 (International Classification of Diseases (ICD) codes W75–W80, Table 2) [9]. Of these cases, 91 were investigated in the present study. Considering the fact that about 60 % of the territory of Germany was

Table 2 Passage selected from the official mortality statistics of Germany for the years 2000–2008

ICD code	Number of cases in various age groups and years in Germany ($N=445$). Age groups: under 1 year/1 to 4 years/5 to 9 years/10 to 14 years									
	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total N
W 75	6/3/0/0	1/2/0/1	7/1/0/0	3/1/1/0	4/1/0/0	4/3/0/0	1/2/0/0	3/0/0/0	2/2/0/0	31/15/1/1
W 76	0/4/5/1	0/7/0/2	1/3/0/5	1/0/2/3	0/3/4/1	0/3/2/3	1/4/0/3	0/2/0/3	1/1/0/2	4/27/13/23
W 77	0/1/2/1	0/1/0/1	0/0/1/5	0/0/0/0	0/0/1/1	0/0/2/2	0/0/1/2	0/1/0/1	0/0/1/1	0/3/8/14
W 78	8/7/5/4	9/4/1/3	13/5/0/2	11/9/2/3	6/1/3/2	12/8/1/0	9/4/0/0	8/5/2/2	7/5/2/0	83/48/16/16
W 79	4/3/3/1	3/1/1/3	2/3/3/2	7/7/1/1	5/7/1/0	7/6/2/2	6/3/2/0	6/10/1/0	7/4/2/0	47/44/16/9
W 80	1/2/0/1	0/0/0/0	1/2/1/0	0/3/1/0	0/6/0/1	0/2/0/1	0/1/0/0	0/0/0/2	0/0/1/0	2/16/3/5
N in age groups	19/20/15/8	13/15/2/10	24/14/5/14	22/20/7/7	15/18/9/5	23/22/7/8	17/14/3/5	17/18/3/8	17/12/6/3	167/153/57/68
N in years	62	40	57	56	47	70	39	46	38	445

The number of deaths caused by accidental asphyxiation is given for various age groups

W 75 accidental strangulation, *W 76* other accidental hanging and strangulation, *W 77* threat to breathing due to cave-in, falling earth and other substances, *W 78* inhalation of gastric contents, *W 79* inhalation and ingestion of food causing obstruction of respiratory tract, *W 80* inhalation and ingestion of other objects causing obstruction of respiratory tract

included in this study (18 institutes out of a total of 33 because the institutes cover territories of different sizes), it has to be assumed that about one third of the cases in the study region were included. At present, it can only be speculated that this figure corresponds with the (low) autopsy rate in Germany (about 1 % of all deaths).

Death by accidental asphyxia is a high risk in children. As found by other reports, most accidents occur before the first birthday (20 %) or between the ages of 1 and 2 (13 %) [8, 10]. Furthermore, there was a predominance of males, representing 68 % of all cases.

Strangulation

The scientific literature contains a substantial number of reports of accidental lethal strangulation in childhood [2, 10–12]. Of the 91 cases analysed, strangulation as a cause of death represented the biggest group, with 42 cases (46 %). Analysis of the age patterns reveals two peaks for strangulation: toddlers and school-age children. The higher incidence of strangulation among toddlers is because although they are already quite mobile and free moving, they are not yet able to extricate themselves from all life-threatening situations [13]. They were often strangled by items that parents had employed with the intention of increasing the child's safety. An 18-month-old boy accidentally hanged himself in a strap that his parents had used to prevent the child from falling out of a rocking chair. An 18-month-old girl was strangled by a harness used by her mother to prevent her from falling out of bed. She had decided to use it because the child frequently attempted to stand up in her bed. Two boys, aged 4 and 8, were wearing a helmet, which became entangled in a climbing frame, resulting in strangulation by the chin strap.

Other objects responsible for accidental hanging were ordinary household items such as blind cords or hammocks. These findings match observations made by other authors [14–16]. But items designed especially for children, such as toys and clothing, also harbour a strangulation hazard. In the present study, strangulation was caused by a children's drum cord, a jacket and a skipping rope. Several authors have reported strangulation deaths related to child products [17–19].

A number of authors have examined cases of accidental strangulation among pubescent and pre-pubescent children [20–22]. In the present analysis, 71 % ($N=30$) of strangulation cases occurred with school-age children. In 12 of these cases, there was a mild suspicion of suicide with 11 boys and one girl, all aged between 9 and 14 years. These cases have not been eliminated from this analysis as the suspected suicide was not proven. In none of these cases was there an actual announcement of suicide or conflict immediately before the death. Nevertheless, the possibility of suicide cannot be totally excluded. On the whole, it is still generally assumed, however, that suicide among children under the age of 15 years is rare. It is even more probable that the deaths were due to play-related accidents [21, 22]. From the USA, it is known that the suicide rates of 5- to 14-year-old children increased from 0.4 per 100,000 in 1979 [23] to 1.2 per 100,000 in 1999 [24], while the average suicide rate in Austria was 1.4 per 100,000 (5- to 14-year-olds, 1970 to 2001) [25]. Dervic et al. [25] reported that hanging was the predominant method of suicide of children in Austria accounting for 62 % of all suicides in this age group. In the present study, strangulation resulted from ropes, dog leads, belts, scarfs, ties and bathrobe belts which worked as strangulation material. Deaths suspicious for autoerotic fatalities were not observed.

In this investigation, a significant relation was observed between death by strangulation and climbing frames. In five cases, children were strangled while playing on a climbing frame. Two boys aged 4 and 8 years were strangled by the chin straps of their helmets because the helmet entangled itself in the climbing scaffold. A 4-year-old girl was strangled by a scarf that became entangled in the climbing frame. The hood of a 7-year-old boy became caught on the edge of a climbing frame, resulting in strangulation by the collar of his jacket. Another girl was strangled while playing on a sport climbing frame.

Petruk et al. analysed deaths caused by strangulation involving children's clothing becoming entangled [18]. The authors recommended removing all cords, straps and knobs from children's clothing. Instead of neck scarfs, children should wear hat scarfs. Lullaby soft toys should possess all the mechanical components needed to activate the spring mechanism inside the toy.

Furthermore, to avoid strangulation deaths on playgrounds, it is of great importance to improve the design of the equipment and to perform regular service checks, with immediate repair where necessary. Furthermore, the information of parents can increase parental awareness of the risk of accidental strangulation [26].

Aspiration

Aspiration of all manner of foreign bodies of all kinds is a common hazard, especially among young children and older adults [27]. However, asphyxia caused by foreign body aspiration is largely due to accidents [4]. The number of childhood deaths caused by accidental asphyxia has decreased in the last couple of years, presumably because of improved bronchoscopy techniques and more effective first-aid measures. However, foreign body aspiration is still the most common cause of accidental death among children under the age of 1 year [27]. According to the official figures published by the German Federal Bureau of Statistics for the period 2000 to 2008, there were 49 deaths due to foreign body aspiration (ICD codes W79 and W80) in children under the age of 1 year (Table 2) [9]. Children aged 1 to 5 years were affected in 60 cases. There were 19 cases in the 5- to 10-year age group and 14 cases among children aged 10 to 15 years [9]. Such a large number of cases ($N=142$) is not found in the present study ($N=14$). This relevant discrepancy cannot be explained by the fact that only 60 % of the territory of Germany was included in this study. It must be assumed that no autopsy was performed in a significant number of these deaths. Nevertheless, the evaluation points out the prevalence of fatal foreign body aspiration in the first 5 years of life with the highest risk among children under the age of 1 year. Hard and round food items should be regarded as potential

aspiration hazards, e.g. boiled sweets, nuts, popcorn, carrots, grapes, sausages, seeds, peas and bread pieces. Coins, marbles, tablets and balloons and parts of toys can also lead to a fatal blocking of the upper airways [14, 28–32]. Besides radiography and bronchoscopy, a CT scan can be of special value to visualise the foreign body also post-mortem [33].

There are several precautions that can be taken to prevent such accidents. Parents, day carers, etc. must develop an understanding about which foodstuffs represent a potential hazard for children of certain age groups [28]. This can be achieved through parent education, e.g. in the paediatrician's practice during the child's regular medical check-up. Altmann et al. [29] also recommend printing warnings on dangerous foodstuffs for children in specific age groups. Byard [30] and Altmann et al. [29] pointed out that it is of utmost importance to supervise children during meals. However, in day care centres in particular, it is not possible to guarantee supervision for every single child at the same time [29, 30]. According to the American Academy of Pediatrics [31], prompt and effective first-aid measures can significantly decrease morbidity and mortality among children following aspiration. It would be desirable for paediatricians to encourage parents to take part in training to improve their first-aid skills; these are held regularly, e.g. by the Red Cross [31, 32]. Both Nixon et al. and Schöpfer et al. recommend that parents should be generally advised not to give nuts or similar food items to children under the age of 5 years and that all small items, such as small toy parts, marbles and coins must be strictly kept out of the reach of children [14, 32].

Positional asphyxiation

This type of asphyxiation is most relevant in infants within the first year of life. Death is often caused by chest or neck compression, as a result of becoming trapped between the bed and wall, bed and mattress or between the bars of a cot. While bed constructions are generally safe nowadays, such accidents occur when there are defects (bars missing) or the original conditions are altered (e.g. inappropriate size of mattress). Furthermore, it is known from investigations of SIDS cases that co-sleeping in the parental bed poses the risk of possible overlaying, leading to chest compression. But these facts are well-known and have been discussed in the literature. So far, the present investigation only serves to confirm previously obtained results [34–36]. Both situations require some attention and are easy to avoid.

Morphological findings

It is sometimes difficult to recognise the mechanism of death in cases of asphyxiation, in particular, if external conditions undergo atypical change or development. For

this reason, a number of morphological changes typical of asphyxiation have been analysed. Both internal and external petechial bleedings have been reported in 72 % of 67 analysable cases. The former is typically found in suffocation (*Tardieu* bleeding [37]). The latter is characteristic of increased pressure in the capillaries of the facial skin (as a result of neck and thoracic compression and increased intrathoracic pressure). The high frequency of such bleeding demonstrates that these findings are also important when diagnosing suffocation as a cause of death in children. The frequency of such bleeding is similar when various types of asphyxiation are compared. Furthermore, the results of the present study confirm previously obtained findings [38–40] and once again show that such bleeding is an important change indicating asphyxiation in infants and children. Although the pathogenesis of petechial bleedings is heterogeneous, most authors agree with the likelihood of a mechanical origin, as recently described in detail by Fracasso et al. [38] with regards to sudden and unexpected infant death. Spinal disc bleeding and muscle insertion bleeding are typical findings in strangulation and are hitherto well-documented with respect to adults. The frequencies found in the present study (23 and 57 % respectively) are similar to other reports [40].

In conclusion, most cases of accidental asphyxiation investigated in the present study could have been prevented, especially through continuous adult supervision [41]. It is important to conduct a detailed forensic investigation and just as important to integrate medical doctors and others working in the health sector in testing potentially dangerous goods. Parents should be informed about such hazards either by MDs or other employees in the health sector. By taking these measures, the incidence of accidental asphyxia can be considerably decreased. Furthermore, an increased autopsy frequency could help to immediately identify new products and/or new circumstances associated with risks to children.

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