Sudden Death Caused by Positional Asphyxia Related to Forensic and Clinical Medicine

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Abstract: Positional asphyxia refers to a special type of mechanical asphyxia, which can lead to death under severe circumstances. It can be found in clinical practice and medico-legal expertise such as sudden infant death syndrome (SIDS) in the sleeping, unexplained sudden death in alcoholics and seniors of weak physiques, as well as violence-related sudden death in special physical position. However, the death cases of positional asphyxia were failed to be given more focuses in clinical practice. Most of the cases associated with positional asphyxia are mainly subject to forensic medical identification, and the death mechanism and the expertise standard have been discussion in forensic medicine. But both clinical medicine or forensic medicine, positional asphyxia can be classified into violence and non-violence, having some associated high-risk factors such as age, temulence, heart disease etc. Therefore, it is very important to correctly identify the causes and related risk factors of positional asphyxia and to make scientific clinical diagnosis and correct forensic experts opinions for correctly judging the cause of death of victims.
***Keywords*:** positional asphyxia, forensic pathology, clinical medicine, sudden death

Introduction

Positional asphyxia (or posture asphyxia) is defined as special form of asphyxia that the individual was restricted in an abnormal body position for a long time and cannot be freed from it due to special reasons, leading to the consequence that the airway is compressed and blocked or the respiratory movement is obstructed and the venous return is blocked[1-4]. Although the concept of positional asphyxia was first proposed by McNie in the chapter on asphyxia in the monograph "Forensic Pathology" published by Fisher in 1970s[1], such cases were frequently encountered in the practice of forensic medicine in the past. There are still not attention to related deaths caused by positional asphyxia. In particular, the risk of positional asphyxia has not been properly evaluated in the cases of death in the state of high alcohol intoxication, in the death of the weak seniors as well as in sudden death syndrome in infants[5-7]. It is necessary to discuss the characteristics and forensic identification of positional asphyxia as more and more cases of positional asphyxia have been reported in clinical and forensic literature in recent years.

1. General data on positional asphyxia

There are few systematic studies on the incidence of positional asphyxia, and most of them are case reports or cases rarely reported in the literature. Based on the retrospective investigation conducted by Bell et al.[2], the Florida Medical Examation Office, which was responsible for the judicial autopsy of about three million people in Broward and Dade Counties, conducted autopsy for 4500 victims caused by non-motor vehicle accident during a nine-year period from Jan. 1981 to Dec. 1990. Among them, six per cent (270 cases) died of suffocation. Among these asphyxia deaths, 30 were positional asphyxia, accounting for 11.11% of the total number of asphyxia deaths, 0.67% of the total number of non-motor vehicle accidents, and 0.01% of the general population.

The incidence of positional asphyxia proves to be relatively high in young adults and the seniors. Data from Bell et al suggest that the average age of the victims was 50.6. Based on various literatures, the incidence of positional asphyxia in young adults is 55%, and 27.5% in the senior. Table 1 shows the age distribution of the victims. Although the ratio of male to female victims of positional asphyxia was 2:1, there was no statistically significant difference in sex when analyzing the total number of anatomical cases. It should be pointed out that the death cases of positional asphyxia in infants' sleep or in children's car chairs have aroused people's concern.

The common venues where positional asphyxia occurs can be frequently seen in bedroom, car, bathroom and others. Bell et al.'s statistics show that positional asphyxia in bedroom takes up 36.7%, 16.7% in automobiles, 13.3% in bathrooms,

and 10% in other places such as indoor, outdoor and stairs. This statistical result is generally similar to case reports in the literature.

Table 1. Age distribution of victims of positional asphyxia

Age	Number of cases						
	Bell[2]	Reay[4]	Brogan[8]	Aoki[10]	Yukama[9]	Nagasaki[11]	Wan[12]
＜ 20	1		2				1
21~30	6	2		1			
31~40	5	1		1	1	1	
41~50	5						
51~60	2						
61~70	5						
71~80	4						
81~90	2						

2. Positional characteristics of the classification of positional asphyxia

positional asphyxia can be divided into non-violent positional asphyxia and violent positional asphyxia by analyzing the causes and positional asphyxia. The characteristics of non-violent asphyxia are that the victims did not encounter violence before their death, but under the sole or combined action of factors such as drunkenness and disease attack, the victims fell into a state of consciousness disorder and were in a position that obstructed breathing movement, resulting in death. Violent positional asphyxia refers to the death of a victim who is unconscious and unable to free himself or herself from a position in which the body is forced to stay in a position that prevents breathing.

The reports of non-violent asphyxia are more frequently seen in Europe and America. In 1992, Bell et al. Initially observed the positional characteristics of 30 cases of positional asphyxia. The results showed that the majority of deaths were caused by pressure on the windpipe while the neck was in an over-flexion position (also known as the head-down position). The causes of over-flexion of the neck are not only caused by narrow space and physical constraint, but also by over-flexion due to excessive low-hanging of the neck in the sitting position. In addition, they observed posture of face downward with congestion of the nose and mouth and supine position of upper body falling over the edge of the bed. Brogan et al.[8] reported three victims of cerebral palsy, two of whom were in the abdominal position with their upper body hanging down under the bed edge, and one of whom had their head and neck trapped in the mattress and bed rails.

In Japan, Yukawa et al. [9] was reported a case in which the upper body threw itself against the wall in a narrow corridor, resulting in the death of the trachea occlusion caused by excessive extension of the neck. Aoki et al. [10] reported two cases of neck compression caused by reclining on the back of the adjacent chair after being drunk in the sitting position and mouth and nose compression caused by prone position. Nagasaki et al. [11] witnessed a controversial case in which the victim's body position was leaning forward with his head in contact with the ground.

As for the posture of violent positional asphyxia, Reay et al. [4] described three cases of hog-tied position placed horizontally on the back seat of a car in the prone position. One patient died of ventricular rest due to high abdominal obesity and subcutaneous fat pressing into the abdominal cavity during abdominal lying, resulting in limitation of chest and abdominal breathing movement. The other two patients died of ventricular death due to constriction of thoracic and abdominal breathing movement caused by the abdominal bulge below. Since then, this kind of anti-bundle asphyxia has been reported in the European and American literature. On the contrary, there are few reported cases of anti-binding posture in China. Wang Zhanyong et al.[12] reported a case of suspension of both legs (upside down: After forensic medical identification of supraventricular death caused by upside down with limbs binding position, related cases of positional death caused by upside down limbs binding position have been reported continuously. Table 2 shows the summary of postures reported in relevant literature.

Table 2. Position status of victims of positional asphyxia

Position		Cases		Literature
Neck hyper-flexion and hyper-extension due to the environment	Confined space or narrow space in a vehicle	(13)	16	2
	Body hyper-stretch in fall against the wall	(1)		9
	Body hyper-flexion when upper body fell under the bed	(2)		8
Oral and nose blockage by prone position		8		2) 8)
Restricted thoracic or diaphragm movement by prone position	Compress the abdomen by protrusions such as the rim of the bathtub	(4)	8	2
	Wrists and ankles "Hog-tied" behind the back	(3)		4
Hyper-flexion or hyper-compressed in Sitting position	Head-down position in sitting	(1)	5	11
	Occlusion of tracheotomy or compression of enlarged thyroid	(4)		2
	Neck down on the back edge of an adjacent chair in sitting position	(1)		10
Neck compression from collar and wheelchair trip wire during fall-down		2		2
Foot suspension in upside-down position with limbs Hog-tied		1		12

3. Cadaveric signs of positional asphyxia

The classical signs of asphyxia mentioned (petechial hemorrhages of the conjunctiva, viscera and/or skin, cerebral and/or pulmonary edema, visceral congestion, the fluidity of the blood) have been used in the diagnosis of asphyxial death for many years. The past-view was that these autopsy findings are known to be nonspecific and can appear in various other causes of death. Thus, an assured conclusion mostly depends on the circumstances of the incident, especially in the case of positional asphyxia. However, for the current clinical data analysis, whether non-violent positional asphyxia mostly have obvious physical signs and in vivo signs of asphyxiation death.

The appearance of lividity is closely related to body position in cadaveric signs. Although the head position in most victims of positional asphyxia was not in the lowest position, obvious livor mortis could still be observed on the face, indicating that the blood vessels in the neck were blocked. Besides, hemorrhagic sites with a high incidence proves to be of particular value for academic reference (Petechiae). In the early Bell data[2], 7 cases were found in the skin, 6 cases in the conjunctiva, and 6 cases in the body. Reay et al.[4] observed hemorrhagic spots in conjunctiva in 2 of the 3 cases. In two of the three cases reported by Brogan et al.[8], hemorrhagic spots were observed in facial livor mortis and in internal lung tissues respectively. Three of the four cases reported by Japanese scholars[9-11] had obvious hemorrhagic spots in the conjunctiva.

In all cases of positional asphyxia, there were obvious pulmonary congestion and edema, and the bulk and weight of the lung were increased, and the section of the lung contained a lot of foamed

dark red liquid. Among the anatomical data available, Bell et al. found that lung weights ranged from 770 to 2110 grams. Yukawa et al. recorded 710 g left lung and 820 g right lung (Normal Figures in Japan, Left Lung: 480+176 g, Right Lung: 555+197 g). Two cases by Aoki were (1) that the left lung weighed 750g, and right lung 850g; (2) Left lung weighted 740 grams and right lung 850 grams. In addition, most autopsy data of positional asphyxia revealed flowing dark-red heart blood, Tardieu spots appear in serosa and submucosa, and congestion of liver, kidney and brain. In recent clinical studies, the above characteristics of cadaver signs were also found.

In an examination of death from asphyxiation in an hyper-extended position of the neck, Yukawa et al found hemorrhage in the inferior attachment of the sternocleidomastoid muscle of the neck muscle group and in the anterior longitudinal ligament of the 5th to 6th cervical vertebrae. They hypothesized that when the neck is suddenly hyper-extended, anterior muscles such as the sternocleidomastoid first absorb the extension force of the neck. As the extension force extends upward, the force is transmitted to the anterior longitudinal ligament and intervertebral lamina fibers located in front of the cervical spine. If the extension force exceeds the limits of muscle and fiber extension, these soft tissues can be broken. This is consistent with other literature indicating that the most common site of cervical hyperextension injury is in the lower cervical spine. All three cases reported by Reay et al. had cervical hyper-extension, so an examination of the cervical muscles and soft tissues surrounding the lower cervical spine can be helpful in determining posture.

4. Pathophysiological changes and mechanisms of death caused by positional asphyxia

positional asphyxia is insufficient intake of oxygen as a result of body position that interferes with one's ability to breathe; Restraint asphyxia is a form of positional asphyxia that occurs during the process of subduing and restraining an individual in a manner causing ventilation compromise[13]; As a consequence of the restraint application, respiration is compromised causing insufficient oxygen in the blood to meet the body's oxygen needs or demands (hypoxia) which then results in a disturbed heart rhythm (cardiac arrhythmia).

The cause of in-custody deaths of individuals placed into the Hog-Tied position following vigorous combat has been a subject of great controversy. Many Coroner or Medical Examiners have ascribed these deaths as being due to cardiac arrhythmias or the effects of drugs and alcohol, while others have concluded that positional asphyxia was the cause of death in these situations. Dr. Reay, a Medical Examiner for Seattle/ King County, was one of the first physicians to consider respiratory mechanisms to explain deaths occurring in individuals that had experienced great physical exertion combating police, then being placed into a Hog-Tied prone position and dying in transport. Dr. Reay explained[14] the cause of these deaths as being due to low oxygen levels and physical exhaustion following extreme exertion plus the added effects of hyper-metabolic states caused by drugs, alcohol and altered mental states. He studied 10 normal individuals in good health in both the sitting and "Hog-tied" positions following modest exercise (on a Nordic Track until heart rate exceeded 120 beats/ min). He noted drops in oxygen saturation as measured by an oximeter and prolonged recovery times for the heart rate to return to less than 100 beats/min in individuals placed in the 'hog-tied' position as compared to the resting seated position. He concluded that positional restraint does have measurable physiologic effects and must be considered in ascribing cause of death

At other study by Dr. MacDannald[15], it was demonstrated that there is increased work of breathing in health care workers when placed into the Hog-Tie position as compared to sitting comfortably in a chair(9 men and 1 woman, age 28 to 59; Body Mass Index 28.7 to 49.2 kg/m2). There was a 23% mean increase in oxygen consumption. Also noted was a 25% mean increase in carbon dioxide production, 44% increase in respiratory rate and 29% mean increase in minute ventilation. There was a 2% mean decrease in oximeter oxygen saturation and 7% mean decrease in tidal volume.

This head-down position and outside-down position have a strong negative outcome on the body's hemodynamics.[16] The movement of the diaphragm increases pleural and intrathoracic pressures, which raises the systemic and pulmonary vascular resistance, while lowering the flow in the inferior vena cava and venous return to the heart. Thus, due to an increase of the afterload, a decrease of the preload and an initiated arterial reflex — cardiac output falls.[17] The inversion also causes an increase in hydrostatic pressure of the venous systems of the head, neck, and chest, as well as an increased static pressure in the carotid sinus. The increased intrathoracic pressure, the decreased venous return and the provoked carotid sinus reflex are known factors, capable of affecting heart contractility and invoking bradycardia.[18] Whereas the venous retention in the extremities due to gravity can lead up to a 20% loss of circulating blood volume, causing relative hypovolemia, further venous return reduction.[19] Therefore, it seems that the increased blood volume in the upper half of the body induces negative cardiovascular effect through multiple interacting processes, leading to inadequate circulation and oxygen distribution.

It should be pointed out that there are ethical and logistical difficulties to laboratory studies of respiratory muscle fatigue and positional asphyxia. It is not possible to re-create the extreme combative conditions and exhaustion that some individuals experience before being placed in the Hog-tie restrained position. This is especially true when the individual may be under the influence of delirium, drugs or alcohol and may have been sustained the weight of multiple police personnel bearing their collective weight on the individual. Study groups of individuals usually consist of healthy volunteers who are not greatly stressed physically and are under no influences of altered mental or metabolic conditions of delirium, drugs or alcohol.

5. Risk factors for inducing positional asphyxia

For non-violent positional asphyxia, alcohol, drug or drug abuse, heart disease and brain degeneration were listed as risk factors. Drunkenness has been recognized as the most important and frequently occurring risk factor for positional asphyxia, especially in young adults. Of the 30 cases reported by Bell et al., 22 (73.4%) tested positive for blood alcohol at blood concentrations ranging from 0.01 to 0.48%, with an average of 0.24%. The four cases reported by three Japanese scholars were positional asphyxia after drinking alcohol, and the blood ethanol concentration ranged from 0.47 mg/ml to 5.7mg/ml. Even moderate levels of drunkenness are thought to increase blood carbon dioxide levels and inhibit central ventilation. In high intoxication, the relaxation of peripheral muscles caused by the inhibitory effect of second intoxication on central

nervous system can easily lead to trachea occlusion and respiratory movement inhibition. In addition, the inhibitory effect of ethanol on the central consciousness is also an important factor that the victims cannot extricate themselves from the dyspnea position.

Drug or drug abuse is a risk factor that cannot be ignored. Long-term use of antipsychotic drugs such as diazepam, phenobaprenoids, etc., can make individuals more likely to fall into or lead to consciousness disorders, positional asphyxia. It should be emphasized that it should be differentiated from the so-called Neuroleptic Maligarant Syndrom (NMS). NMS is common in patients taking antipsychotic medications and is characterized by high fever, low muscle tone, and mood swings caused by autonomic nervous system instability. The patient may die suddenly due to exhaustion, dehydration, loss of consciousness, etc. Due to the lack of specific diagnostic basis, it is sometimes difficult to distinguish it from positional asphyxia. Reay et al. suggested that sometimes there could be both. Sudden death from drugs, especially cocaine and methamphetamine, has been noted, and Wetli and Fishbain[20] observed that some addicts die in a bad position that interferes with breathing.

The heart disease of victims, especially ischemic cardiomyopathy, is an important risk factor for positional asphyxia. It is well known that sudden cardiac death is most common in sudden deaths of natural causes, even in the absence of significant cardiac pathophysiology. Most of the direct causes of sudden cardiac death are arrhythmias, which are closely related to physical and mental pressure. In response to physical and/or mental stress, coronary blood flow may be low, myocardial ischemia may induce arrhythmias. Moreover, when alcohol is ingested, the heart rate increases and the oxygen consumption of the myocardium increases, which increases the risk of myocardial ischemia. Kapoor, known as an authoritative scholar on loss of consciousness, pointed out [21] that most of the loss of consciousness in patients with heart disease is caused by cardiogenic arrhythmia, which is characterized by acute onset and often accompanied by trauma.

Among the four cases of positional asphyxia reported by Japanese scholars, two cases were closely related to cardiac arrhythmia. They think that, a case of a life in a series of irregular and long time business services during orthostatic choke after drinking in) induced arrhythmia because of the physical and mental pressure (one in high drunk and family after violent quarrel orthostatic suffocation, leading to the victims in a loss of consciousness, developed acute cardiac insufficiency. And the victim cannot free himself from the fatal position.

Recently, cases of positional asphyxia deaths among infants and young children have attracted significant attention. Infantile asphyxia is common in slings Carriers or car seats[22]. Clinical observations found that postnatal immature newborns, low birth weight newborns and younger infants who were immobilized in a car seat for more than one hour were at greater risk of postnatal asphyxia. Through further studies, it has been confirmed that when the straps of car child seat are loose, infants may fall and lead to positional asphyxia or strangulation [23]. A study at 2015 showed that 69% of newborn families had car seat belts that were too loose [24].

Therefore, child car seat and carrier of braces have become the safety products of concern. A study by Batra et al. [25] found that among 47 infant deaths, 31 cases (66%) occurred in child car seats and 5 cases (11%) occurred in braces, and all of them were positional deaths. Medical studies suggest that infants under 4 months of age do not have proper head and neck control. If the airway is compromised, infants are unable to move their head should airways become compromised. Their small airways may be inhibited simply by the tilt of their head (e.g., as their chin is resting on their chest).

The mechanism of infant positional asphyxia may be caused by a variety of factors, including the blockage of respiratory tract by sleeping position, the accumulation and re-inhalation of carbon dioxide in the narrow space formed by bedding (pillows, mattresses, pads, etc.), and the immature development of respiratory organs (including poor diaphragm function) [26]. If this continues, oxygen levels will drop to dangerously low levels and carbon dioxide levels will rise to dangerously high levels. The baby's low oxygen levels actually further impair the baby's ability to respond to the condition, creating a vicious cycle that, if continued, can lead to death.

6. Identification of positional asphyxia

Bell et al were the first to use the term "Postional asphyxia", along with certain criteria that could assist with the complicated diagnosis. Reay et al suggested that the following aspects should be considered in the diagnosis of positional asphyxia-death: (1) The victim was in a breathing restricted position at the scene of death; (2) Medical history indicates that the victim had signs of "dyspnea" or abnormal physiological symptoms of breathing, such as cyanosis or gasping, or other physiological abnormalities with evidence of respiratory depression prior to death; (3) The absence of obvious or meaningful pathological changes by autopsy such as intracranial hemorrhage, old myocardial infarction rupture and other fatal events; (4) Exclude toxins (such as CO poisoning, chloride poisoning) or other lethal concentrations of drugs, drugs and chemicals. Even though some of the criteria have been challenged by more recent publications, such as the requirement that the human

body cannot be forced into the abnormal position, the majority of authors still rely heavily on the main assessments made. These criteria essentially can be summarized into the following[27-28]. (1) Negative autopsy or some signs of asphyxia; (2) The body position must interfere with normal gas exchange; (3) It must be impossible for the subject to move to another position; (4) Other causes of death (natural and unnatural) must be excluded.

There are two different views on how to analyze the cause of death in positional asphyxia in which the victim has significant cardiac disease. Bell et al. suggested that such cases with significant heart disease should be excluded from the category of positional asphyxia. In light of this, diagnosis must be made on the basis of active exclusion of other causes of death since positional asphyxia lacks a characteristic autopsy. From the standpoint of forensic pathology, positional asphyxia is an exclusive diagnosis. On the other hand, Reay et al. argued that the possibility of positional asphyxia should be taken into consideration first, rather than relying solely on the appearance and autopsy results of a suspected case of positional asphyxia.

Their claims reflect that the criteria for determining positional asphyxia and death from natural causes, especially sudden cardiac death, are not always clearly defined. In their case, although one showed moderate focal coronary atherosclerosis and increased heart weight (410g), they made a diagnosis of positional asphyxia based on site conditions.

Japanese scholars believe that the heart disease can not be purely excluded or included into the category of asphyxia. The role of cardiac disease and positional asphyxia in the cause of death should be carefully analyzed in combination with the situation at the scene. Yukawa et al. identified a case of cardiogenic loss of consciousness and falling into positional asphyxia as an opportunity. The victim's heart enlarged (440g) and focal moderate stenosis of coronary arteries. In pulmonary histological examination, besides congestion and edema, there were more macrophages in the alveoli, indicating the early state of left heart dysfunction.

Based on the field situation, the victims of recently life and work, and a post-mortem histological result, their analysis showed that the victims because in days of irregular life, and mental stress and physical fatigue accumulated by long-term business labor in high intensity, developed cardiac arrhythmia, cardiac loss of consciousness, as a result, the victims fall into positional asphyxia state.

Their conclusion was that the cause of death was arrhythmia, classic karoshi (a typical over-work death). Similarly, Qingmu et al. performed an autopsy on a case of positional asphyxia with abdominal supine sleep and mouth and nose blocked by pillows after heavy drinking, and found that the victim's heart weight was 680 grams, focal coronary stenosis reached 60%, and lung tissue examination was characterized with chronic congestion and heart failure cells. Based on a comprehensive analysis, they concluded that the cause of death was cardiac failure due to coronary artery sclerosis, although the role of respiratory tract occlusion in the cause of death could not be excluded.

Recently, Chittaranjan Behera and Karthik Krishna reported one case of fatal positional asphyxia following a fall in bathroom[29]. The victim is an 27-year-old female student, and she was found dead inside the bathroom of her university hostel. The body was in a prone position with her neck over-flexed on to her trunk. The medico-legal autopsy found features of asphyxia. Multiple lacerated wounds were present on the occipital region of scalp. The cause of death was opined as positional asphyxia following an accidental fall and blunt trauma to the head. In this case, concussion due to blunt trauma to the head may have precluded any self-rescue efforts by the victim from the floor leading to positional asphyxia.

The above clinical practice reveals that, for the diagnosis of positional asphyxia, there is no doubt that information about the body position at the time of finding the victim is indispensable, especially the photo of the scene before the body is moved. In the diagnosis of positional asphyxia, the pre-death condition and pathological examination results of the victims should be fully taken into consideration.

Conclusion

In the previous studies, positional asphyxia mainly occurred in the process of law enforcement of special mechanical asphyxia death cases. However, in recent clinical and forensic studies, positional asphyxia has gradually become a cause of death that must be considered or excluded in neonates, the seniors and people under the influence of alcohol, as well as people working in special environments. Therefore, the expertise of forensic medicine and clinical diagnosis of positional asphyxia are of great importance. To improve the understanding of positional asphyxia is conducive to improving the nursing of newborn babies, the management of infants on buses, the care of frail elderly and the improvement of working safety environment.

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