Positional Asphyxia
Reflection on 2 Cases

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Abstract: Positional asphyxia, a fatal condition arising because of the adoption of particular body positions, causing mechanical interference with pulmonary ventilation, can occur in various circumstances that are likely to come under the observation of the specialist in legal medicine (work, car accidents, torture, kidnapping, etc.). It is difficult to diagnose the cause of death in such cases because they generally present with an aspecific anatomopathologic picture.

In some situations, positional asphyxia can be hard to distinguish from asphyxia because of chest compression. The main difference is in the way the event occurred: whether the particular position causing the asphyxia had been adopted by choice or by compulsion or necessity when an extrinsic mechanical action would result in traumatic asphyxia.

The diagnosis of positional asphyxia is essentially based on 3 criteria: the body position must obstruct normal gas exchange, it must be impossible to move to another position, and other causes of natural or violent death must be excluded.

To illustrate the main physiopathologic and diagnostic causes of positional asphyxia, the authors report 2 cases taken from the records of events that came under the observation of the Medico-Legal Sector of Bari University Hospital throughout the last 10 years.

Key Words: restraint asphyxia, positional asphyxia, head-down position, hogtying

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Positional asphyxia is caused by the adoption of particular positions in relation to unusual body posture (either induced or taken up independently) that mechanically interfere with pulmonary ventilation.

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In recent years, there have been various reports in the literature on this particular mode of asphyxiation, which is generally only briefly mentioned, if at all, in the classic and contemporary textbooks of forensic medicine.

In fact, a uniform approach to treatment is difficult, given the variety of situations that can lead to this mode of asphyxiation; according to the literature, there are a number of different positions and postures of the body that can cause positional asphyxia. For instance, the head-down position can occur in reverse suspension during accidents, especially sports accidents (alpinists, speleologists, parachutists), and in other analogous situations. Moreover, the head-down position can occur in other circumstances such as certain surgical operations (especially operations on the pelvis and lower abdomen) requiring the Trendelenburg position. In the literature, the possible negative effects of this position on coronary and cerebral circulation, especially in patients with antecedent disease, and on respiration are considered, such alterations being most noticeable (reduction of total pulmonary volume, residual functional capacity, and pulmonary compliance) in obese, elderly, or debilitated patients.[1]

There are also other possible causes of asphyxiation: physiologic positions (seated, lying down) when, for extrinsic reasons (placing of the body, limbs being tied) or intrinsic reasons (effect of drugs or alcohol), the position of certain parts of the body (for example, hyperflexion of the neck or trunk) impedes breathing. In this context, attention has been drawn to a coerced prone position with the wrists and ankles tied behind the back ("hog-tied restraint"), a maneuver that was used by the American police force to restrain subjects offering resistance and facilitate their custody and transport.[2]

Finally, cases of positional asphyxia[2,3] include those in which subjects fall into confined spaces and are unable to get out. Here, too, particular conditions making the victim less able to escape from the dangerous situation (drugs, alcohol, mental illness, etc.) must be taken into consideration. In such cases, differential diagnosis between positional asphyxia and the more familiar asphyxia caused by compression of the thorax (also called traumatic asphyxia) is more difficult.

In the 19th century, Ollivier and Tardieu[4,5] were the first to study traumatic asphyxia, an expression that indicates,

according to Carrara et al.,[6] "the compression and immobilization of the thorax or of the thorax and abdomen together, for an indeterminate length of time, until respiration ceases or becomes inefficacious". Borri et al.[7] coined the expression *indirect suffocation* to indicate the condition in which "the rib cage is reduced to a state of inertia by a peripheral obstacle which hinders its function." They did not, however, explicitly mention positional asphyxia.

In modes of asphyxiation by compression of the thorax, particular emphasis is placed on extrinsic mechanical action–generically known as *traumatic*, hence, the term *traumatic asphyxia* commonly used in the English language scientific literature–on the thorax or abdomen, which impedes normal breathing processes and has obvious repercussions on respiratory exchange phenomena at the pulmonary level, obstructing venous circulation from the vena cava to the right side of the heart, and in some cases blocking the heart action.

This type of compression of the thorax can occur in a great variety of situations, ranging from complete crushing of the thorax by heavy objects (landslides, buildings collapsing, vehicles overturning, etc.) to lesser causes, such as immobilization of the thorax through being crushed in a crowd.

As stated above, certain types of positional asphyxia can be difficult to distinguish from asphyxia by compression of the thorax; for example, when the body of the victim is trapped in a narrow space, with restriction or impediment of the respiratory activity of the rib cage. In this event, the difference with respect to asphyxia by thoracic compression will be largely caused by how the situation occurred: a particular position of the body (autonomous or induced) in the case of positional asphyxia or an extrinsic mechanical action in the case of traumatic asphyxia.

It is clear, therefore, that positional asphyxia can occur in various ways, some of which are better defined and more easily characterized from a pathophysiologic perspective (such as the head-down position), whereas in others, the forced position of the head, neck, or rib cage in restricted spaces can trigger asphyxiating mechanisms (blocking of the respiratory orifices, atypical compression of the neck, compression or immobilization of the thorax).

These complex situations in which it is difficult, if not impossible, to identify the precise mode of asphyxiation can be included among cases of positional asphyxia in the widest sense of the term.

In certain cases, these situations belong to the forensic medicine field: accidents at work, sports accidents, and death by torture or as a result of kidnapping. Often the cause of death in such cases is difficult to diagnose because of the paucity and aspecificity of the anatomic-pathologic findings.

Reported are 2 cases (occurring throughout the last decade) recorded in the archives of the Institute of Legal Medicine of Bari University Hospital. The main pathophysiologic and diagnostic aspects of positional asphyxia are outlined, and the criteria for including complex mechanical modes of asphyxiation under this heading are discussed.

CASE REPORTS

Case 1

A 30-year-old man died while operating a mechanical digger, when the vehicle fell over the edge into the quarry where he was working. A doctor certified death 20 minutes after the accident, while the body was still trapped in the cabin of the vehicle, lying upside down with the head facing the bottom of the quarry. Recovery of the body took a long time because of the difficulties caused by the position of the vehicle (Fig. 1).

External examination revealed localized hypostasis to the face, neck, and upper chest, with fine cutaneous petechiae of these regions and, bilaterally, of the conjunctiva. There were small wounds on the scalp, left eyebrow, left deltoid, left part of the chest, both forearms, right elbow, hands, and legs. The third distal region of the tongue was severed, having been bitten off.

Closer examination revealed, apart from slight hemorrhagic infiltration around the wounds observed during the external examination, blood congestion at the base of the tongue, epiglottis, and trachea. The brain showed significant congestion of the leptomeninges vessels, dura mater, and white substance; the lungs were heavy and dark red, and when incised, a frothy reddish liquid appeared. Samples taken from the remaining organs were not significant and no fractures were present. The alcohol test of the vitreous humor proved negative.

FIGURE 1. Case 1: The body was trapped upside down in the cabin of the excavator.

Histologic tests revealed edematous alterations of the brain tissue, associated with the vessel congestion. The lungs showed laceration of the interalveolar septum and conf1uence, with the presence of an amorphous acidophilic substance. Localized hemorrhage was evident around the liver area; a layer of red cells covered the mucous membrane of the tonsils.

The cause of death was deemed to be the result of asphyxia caused by the position of the victim after the vehicle overturned and the length of time spent upside down while trapped.

Case 2

A 45-year-old man, working as a guard in a security van, was trapped for an indefinite period (estimated to be several minutes at least) between the internal sliding security door and the door frame of the vehicle.

Once freed by his colleagues, he was immediately taken to the emergency department, where he arrived in a state of cardiac arrest, with no reflexes (superficial or deep; mydriatic pupils, without reflex) and with "mantle" edema and ecchymosis of the eyelids and neck, the upper chest region, the right armpit, and the forearm.

The victim was intubated and received external heart massage; after 5 minutes he was given electronic and mechanical cardiac stimulation. Assisted ventilation was set up with O_2 at 100% along with pharmacologic therapy (adrenergic drugs, bicarbonate, and antiedemas).

The lack of reflexes and bilateral mydriasis remained constant. The neurologic examination revealed anoxic ischemic encephalopathy caused by venous stasis (computed tomography scan evidence of cerebral venous stasis, widespread cerebral edema most evident in the midbrain pons). Throughout the following days, the neurologic condition remained severe, a diagnosis of irreversible coma was made, and death supervened after 6 days.

During the autopsy, internal examination revealed a fine linear abrasion (6 cm long) in the left sternocleidomastoid region, beneath which 4 other parallel abrasions were noted, the largest of which was situated proximally (8 cm long), whereas the others measured 3 cm each. A rounded abrasion (maximum diameter 2 cm) was located in the left subclavicular region above a greenish-yellow area of ecchymosis (Fig. 2). Petechiae were observed in the right chest region and the upper arms, with abrasions around the right armpit.

The autopsy revealed circumscribed infiltration in the right occipital bone area and the deep level of the scalp; examination of the meninges and brain showed abundant dark fluid blood in the superior longitudinal venous cavity, congested leptomeninges, f1attening of the cerebral convolutions, and surface sulcus.

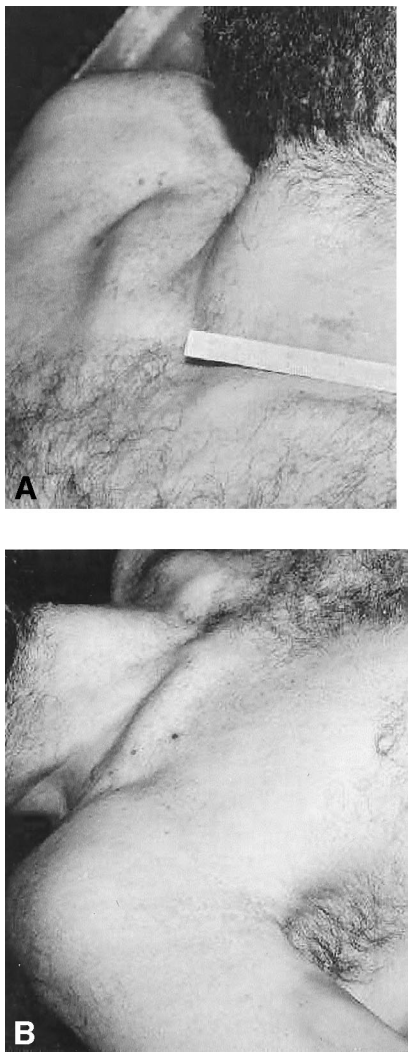

FIGURE 2. Case 2: Signs of bilateral compression of the neck and chest (arrows) caused by entrapment inside the sliding safety door.

Soft tissue sectioning of the neck revealed circumscribed hemorrhagic infiltration of the sternothyroid, thyrolegoid and left cricothyroid, the thyroid being unharmed. Further hemorrhage was noted in the deep muscles, close to the large and small cornu, to the left of the hyoid bone, whereas the carotid was intact with accessible lumen.

Deep hemorrhage was noted in the tongue muscles and the left periclavicular soft tissue. Fractures of the II, III, and IV right ribs along the hemiclavicle were observed.

Samples from the other organs and viscera yielded no significant findings, except for the lungs, which revealed macroscopic evidence of prevalently hypostatic bronchial pneumonia.

Microscopic examination of the brain showed evidence of edema and congestion of the encephalon and the cortical

vessels, with sporadic phenomena of homogenization of the cytoplasm of the nerve cells. At the pulmonary level, there was abundant phlogosis of the alveolar lumen, prevalently neutrophilic, tending to form microabscesses.

DISCUSSION

The 2 cases reported were caused by complex modes of mechanical asphyxiation, in which various factors could have interfered with normal pulmonary ventilation. The first case described undoubtedly comes under the heading of positional asphyxia, triggered by 2 possible mechanisms: the upside-down ("head-down") position of the body and entrapment in the cabin of an overturned vehicle.

The head-down position is a typical, if rare, event in which body position causes death. Madea[8] has indicated 2 typical cases of suspension in the head-down position, discussing 2 fatal processes: asphyxiation caused by blockage of the thorax, which limited the range of thoracic movement, and inadequate circulation. The second factor is generally considered prevalent in "pure" forms of reverse suspension, in which the subject remains suspended by the feet with the head down (Madea's first case,[8] cases reported by Purdue[9] and Marshall).[10]

In such cases there is complex hemodynamic malfunction caused by the following factors: (1) increase of hydrostatic pressure in the upper regions of the body (head, neck, and thorax) and blood stasis in areas of the body where the mechanisms of return blood flow to the heart are less efficient; (2) increase of transmural venous pressure in the brain; and (3) increase of static pressure in the carotid sinus and decrease of pressure in the arteries. The hemodynamic modifications caused by the head-down position must be taken into consideration, particularly from a clinical point of view, in view of the surgical operations carried out in the Trendelenburg position (for example, pelvic and submesocolic surgery). At angles between 15 and 30 degrees and in normal patients, however, there do not seem to be serious problems because the baroceptor reflex responds to the increase in central vein pressure and heart output, determining systemic vasodilation and bradycardia and thus reestablishing the hemodynamic equilibrium.

Particular problems can be caused by a further sudden increase of intracerebral pressure in hypertensive subjects with either heart or coronary disease, especially when there is alteration of the ejection fraction, because this increase can cause an uncompensated, and hence dangerous, increase in myocardial O_2 requirements.

In the head-down position, and especially when there is complete reverse suspension of the body, particularly unfavorable conditions are created, above all for respiratory dynamics, which reflects negatively on the hemodynamic picture.

Reporting a case of reverse suspension, Purdue[9] hypothesized that the traction effect tenses the abdominal muscles, blocking the thorax in the exhalation phase (whereas suspension in an upright position, with traction from above, would have the opposite effect of blocking the thorax in the inhalation phase). These processes have also been described in different forms of crucifixion.[8] Knight,[11] on the other hand, considers that the main factor impeding respiration in the head-down position is compression of the diaphragm by the abdominal viscera. Madea[8] stresses an alteration in the breathing process, especially the effects of a reduction of negative-positive venous pressure.

Recent experiments[12] seem to confirm the hypothesis that in the head-down position the abdominal viscera press down on the diaphragm, thereby prolonging the inhalation phase and impeding respiratory dynamics during this phase. Initially, in the head-down position respiratory frequency increases, probably to compensate blockage of inhalation, and there is a consequent increase of Pa_{O2}. Subsequently, it decreases because of a reduction in the range of respiratory movement because of respiratory muscle fatigue. In the terminal phase, there is severe hypoxia of the myocardium and, hence, cardiac arrest. The authors conclude that in the upside-down position of the body, death is caused by positional asphyxia as a result of respiratory muscle fatigue induced in the attempt to overcome the impediment to respiratory movement. In fact, in experiments carried out on animals, death occurred only after 12 hours.

In Case 1, it seems clear that, apart from the reverse body position, other factors contributed to the victim's rapid death: bodily entrapment in a confined space, which even in the absence of true compression of the thorax may be presumed to interfere with breathing dynamics and especially with the compensatory processes observed in experimental conditions. Moreover, these processes may be further hindered by flexion of certain body parts, especially the neck.

These situations are specifically recalled by Bell et al[3] as important factors in causing positional asphyxia. According to these authors, not only cases in which body posture leads to restricted or confined positions but also those in which it causes hyperflexion of the head and neck, with partial or complete obstruction of the respiratory tract, or atypical compression of the neck, must be included under the heading of positional asphyxia.

Despite the small number of cases published, it can be concluded that, in most cases of positional asphyxia, complex situations create a combination of various factors that impede the breathing process. Case 2 may be included among these: the victim was certainly trapped within a narrow space, but the exact position of the body cannot be deduced from anamnestic or circumstantial evidence, understandably, because he was rescued from an emergency situation and arrived at hospital still alive.

Nevertheless, according to the autopsy, because the subject's body was trapped between the sliding security door and jamb inside an armored vehicle, he sustained compression of the left side of the neck and right side of the thorax. One may also surmise that the restricted position within a narrow space led to anomalous lateral hyperflexion of the neck, causing obstruction of cerebral circulation and normal breathing dynamics. In this respect, the clinical admittance report (the subject reached the hospital in a state of cardiorespiratory arrest and survived for 6 days, albeit in a state of worsening coma) is interesting: it indicates mantlelike edema and widespread petechiae on the neck, upper thorax, and right armpit. Only after 5 minutes of cardiac massage were an adequate heart action and respiratory function restored. After the neurologic examination, anoxic ischemic encephalopathy caused by vein inactivity was hypothesized, and computed tomography examination revealed widespread cerebral edema, most evident at the midbrain pons level.

In the authors' opinion, this case shows how often the events causing death are less well-defined because various situations and body positions may be contributing factors, apart from head-down positions, which are perhaps better studied within a pathophysiologic framework, especially with reference to surgical patients (Trendelenburg).

Even in the various cases already published, the position of the body was not enough in itself to explain the fatal outcome, and so specific situations were adduced in each case, such as entrapment in narrow spaces, neck hyperflexion, facial compression against soft materials, and so on.

In these cases, the dividing line between positional asphyxia, asphyxia by immobilization of the thorax, and by suffocation is not clearly defined, and the only distinctive element is, in the final analysis, the impossibility of defining a single process of asphyxiation that goes with anomalous body position. This impossibility is the case in the controversial "hog-tied restraint," a form of immobilization previously used by the US police force to transport persons under arrest. Subjects were placed in a prone position with their wrists and ankles tied behind them.[13]

In reality, the effects of hog-tied restraint and its influence on respiratory muscles have still not been defined, even though any constraint that impedes a change of position can hinder respiration by impeding the use of accessory muscles. Furthermore, during the violent clashes that can occur in these circumstances, there is a major expenditure of muscle energy, and this energy is subtracted from the work of the respiratory muscles, with a consequent ventilation deficit. Other factors may also intervene, such as the position of the victim with his or her face on the pavement, possible occlusion of the respiratory orifices and further hindrance of chest movement, and use or abuse of drugs or alcohol[14].

To the coroner, these are typical cases in which the absolute relevance of circumstantial evidence and, above all, of an accurate on-the-spot investigation is clear[15]. In absence of the above data, the diagnostic difficulties are evident because in the majority of such cases, the autopsy gives only negative results or reveals only slight signs of generic, aspecific asphyxiation that are compatible with other, even natural, causes of death.

Even in cases of inverse suspension with increased pressure in the cephalic veins, the findings are of only slight significance. In the cases described by Marshall[10], Madea[8], and Purdue[9], postmortem examinations revealed mostly aspecific finds, such as congestion and edema of the conjunctiva and encephalic congestion. In the first case in the present study, there was also notable venous congestion around the epiglottis and at the base of the tongue. These findings can be difficult to interpret because of the presence of cephalic hypostasis in such cases. Even the presence of subcutaneous hemorrhage in the forearms[8] requires differential diagnosis with respect to hypostatic phenomena, although polymorphic cellular infiltration is found only in cases of prolonged survival.

In other cases in which positional asphyxia also includes obstruction of respiratory tracts (neck hyperflexion) or restriction and compression of the thorax and abdomen (prone position, torso hyperflexion, or contortion), more obvious signs may be present, such as hemorrhagic petechiae of the skin, conjunctiva, epicardium, larynx, epiglottis, and muscles (13 of 30 cases reported by Bell et al.).[3]

The formation of petechiae is directly proportional to the degree of vein occlusion and is in inverse relation to arterial compression above the heart. If return flow in the veins to the head is obstructed, but not arterial flow, there will be an increase of pressure in the veins, whereas if the force applied impedes arterial flow, there will be no stoppage of venous flow and no consequent rupture of small veins[16]

The presence of hemorrhagic infiltration in the chest and neck muscles is an important indication of asphyxia caused by obstruction of blood circulation, especially in circumstances in which there is no external pathognomonic lesion, because it indicates the rupture of muscular fascia as a result of strained respiratory movement in the attempt to overcome a constriction imposed by the position of the body.[11] The presence of these hemorrhages is thus a fundamental element in the diagnosis of asphyxia when no other specific external signs are present. According to Merli,[17] muscle hemorrhages are formed during the convulsive phase of asphyxia and may often be found in the armpit muscles, upper back muscles, and grand pectoral muscles, as well as in the periosteum of the clavicle at the juncture with the sternocleidomastoid muscle. These findings will be more obvious in cases with a certain degree of neck or thorax compression, as in Case 2.

In all cases, the exclusion of other causes of death is important, particularly death by poisoning (for example, carbon monoxide poisoning), as well as death by natural

causes (for example, coronary disease). Nevertheless, the latter may be a contributing factor, as in the case described by Madea[8] of the demise of a patient when in the Trendelenburg position.

Toxicologic examinations, too, can often clarify why a person may have taken up a particular position; for example, alcohol is a risk factor, as indicated by Bell et al.,[3] that can contribute to positional asphyxia, as can tranquillizers and sleeping pills. The effects of alcohol, in particular, cause a depression of the central nervous system and relaxation of the muscles that guarantee the perviousness of the respiratory tract during sleep, especially of the genioglossus, which pulls up the tongue during inhalation, pushing it against the back wall of the pharynx.

CONCLUSIONS

To conclude, positional asphyxia as a means of death must be taken into account in cases featuring the following conditions: the position of the body must hinder the normal exchange of respiratory gases; there must be a reason why it was impossible to change this position; other causes of natural or violent death must be excluded.

Positional asphyxia can explain the cause of death in various circumstances when autopsy does not reveal significant findings. It must be taken into account not only in suspected cases of death caused by alcohol or drug abuse or in subjects afflicted by psychiatric diseases but also in vehicle crashes and accidents at work. Moreover, its occurrence must be considered in persons subjected to torture (inverse suspension) and in some types of surgery (Trendelenburg position).

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