JOURNAL OF FORENSIC SCIENCES

J Forensic Sci, 2010
doi: 10.1111/j.1556-4029.2010.01434.x
Available online at: interscience.wiley.com

PAPER

PATHOLOGY AND BIOLOGY

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Agonal Sequences in Eight Filmed Hangings: Analysis of Respiratory and Movement Responses to Asphyxia by Hanging*

ABSTRACT: It has been proposed that filmed hangings may hold the key to a better understanding of human asphyxia, and The Working Group on Human Asphyxia was formed to systematically review and compare these video recordings. This study analyzed eight filmed hangings. Considering time 0 to represent the onset of the final hanging, rapid loss of consciousness was observed (at 8–18 sec), closely followed by convulsions (at 10–19 sec). A complex pattern of decerebrate rigidity and decorticate rigidity then followed. Between 1 min 38 sec and 2 min 15 sec, muscle tone seemed to be lost, the body becoming progressively flaccid. From then on, isolated body movements were observed from time to time, the last one occurring between 1 min 2 sec and 7 min 31 sec. As for the respiratory responses, all cases presented deep rhythmic abdominal respiratory movements (last one between 1 min 2 sec and 2 min 5 sec).

KEYWORDS: forensic science, hanging, asphyxia, video recording, pathophysiology, human

Hanging is a form of asphyxia secondary to compression or constriction of the neck structures by a noose or other constricting band tightened by the weight of the body (1). Hanging can be either incomplete (partial suspension) or complete (full suspension), depending on whether or not parts of the body touch the ground (e.g., toes, feet, knees, or buttocks) (1). Death is caused by closure of the blood vessels and/or air passages of the neck, with insufficient oxygen reaching the brain (1). A reflex vagal inhibition by stimulation of the baroreceptors in the carotid sinuses and the carotid body may also play a role. Although theses generalities are found in all forensic textbooks (1–3), further description of the pathophysiology of hanging is very limited. This situation is not surprising considering the paucity of available research: apart from a few animal studies (4), most of our contemporary body of knowledge is in fact based on old writings from the end of the 19th century and beginning of the 20th (5). Judicial hangings (executions) can still be witnessed nowadays in a few countries, but those deaths are very different in nature from typical hangings, death being caused by fracture dislocation of the upper cervical vertebrae with transection of the cord rather than asphyxia by compression of neck structures.

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*Presented at the 61st Annual Meeting of the American Academy of Forensic Sciences, February 16–21, 2009, in Denver, CO.

Received 31 Mar. 2009; and in revised form 3 Aug. 2009; accepted 8 Aug. 2009.

It is known, however, that some hanging victims film their hangings, mainly in an autoerotic context. It has been proposed that these filmed hangings may hold the key to a better understanding of human asphyxia. The Working Group on Human Asphyxia (WGHA) was formed to systematically review and compare these video recordings (6,7). Each scientist who has such a video or who has access to such a video is welcome to join this group and the video will be added to the ongoing study.

This study by the WGHA described the agonal sequences observed in eight filmed hangings.

Material and Methods

A total of eight filmed hangings were analyzed: six autoerotic accidents and two suicides. All victims were adult white men.

In the first recording, a man recorded his suicide with a video camera. He tied his neck with a padded rope fixed on the rail system of an electric garage door and used the remote control to close the door, therefore hanging himself. His feet were fixed in ski boots, tied with chains to a metal platform. In the second recording, a man masked with woman's underwear hanged himself in his garage, using a traditional hangman's noose made out of thick rope. A large white sheet was spread on the back wall. He hanged himself from a standing position, his knees slightly bent, and his feet touching the floor. In the third recording, a man dressed in a cowboy costume hanged himself in a basement trap by letting go of the nearby ladder (free hanging with a ligature that seems to be a rope). The fourth recording was of a suicide in custody, filmed by a surveillance camera. The victim was kneeling on the ground, a cloth band tied to the cell bars adjacent to the decedent. These first four videos were previously reported (6,7). The fifth video was

filmed in an autoerotic context: the nude man hanged himself almost completely lying down in a prone position, with a rope. On the sixth recording, a man hanged himself with a cloth band, in a standing position with feet on the ground. His face is covered by a hood. In this video, the victim hangs himself on and off several times, applying intermittent neck compression for several minutes before the final fatal hanging. The seventh video shows the autoerotic accidental hanging of a man in a standing position, feet on the ground, with a rope. As for the eighth recording, an autoerotic accident as well, it illustrated the hanging of a nude man with an electric cord, in a standing position in the hallway, feet on the ground.

For each video, we evaluated the time frame of body responses: loss of consciousness, convulsions, decorticate rigidity, decerebrate rigidity, loss of muscle tone, last muscle movement, and respiratory responses. All recording were evaluated jointly by at least two judges, one of the judges having seen all the videos.

Results

The agonal sequences observed in the eight filmed hangings are presented in Table 1. Considering time 0 to represent the onset of the final hanging, rapid loss of consciousness was observed (at 8–18 sec). Loss of consciousness was largely assessed by a close examination of the victim's face, voluntary movements, and body tonus. In two cases (cases 2 and 4), loss of consciousness was not possible to evaluate: in case 2, the victim's face was masked with underwear and in case 4, image quality from the surveillance camera was not optimal enough to estimate this issue adequately.

Loss of consciousness was closely followed by mild convulsions in all cases (at 10–19 sec). Convulsions were generalized, of the tonic-clonic type.

A complex pattern of decerebrate rigidity and decorticate rigidity then followed: decerebrate rigidity is characterized by a full extension of both upper and lower limbs, whereas decorticate rigidity is associated with flexion of the upper limbs combined with extension of lower limbs and trunk. In all cases but one (case 5), the decerebrate rigidity was first noted (at 11–31 sec), followed in most cases by two separates phases of decorticate rigidity. The first phase of decorticate rigidity was relatively sudden and quick (at around 21 sec–1 min 8 sec). In the second phase, the decorticate rigidity developed slowly and was more sustained (at around 34 sec–1 min 32 sec). It should be mentioned that the time of decerebrate rigidity in case 1 presented here is different from that previously reported (6,7): as the judges gain experience in analyzing the agonal sequences of hanging, it was noted that the true decerebrate rigidity in case 1 was missed in the earlier viewing because it was off field.

Between 1 min 38 sec and 2 min 15 sec, muscle tone seemed to be lost, the body becoming progressively flaccid. From then on, isolated body movements were observed from time to time, the last one occurring between 1 min 2 sec and 7 min 31 sec. In cases 7 and 8, we did not have the original recording, and unfortunately the recording was cut too early to allow evaluation of these late responses.

As for the respiratory responses, all cases presented deep rhythmic abdominal respiratory movements. These respiratory movements started between 13 and 24 sec and stopped between 1 min 2 sec and 2 min 5 sec. It is worth emphasizing that these respiratory movements were not only seen but also heard, confirming the passage of air in the airways despite the hanging process.

Discussion

Loss of Consciousness and Convulsions

The rapid loss of consciousness (in 8–18 sec) observed in this study supports the general affirmation found in forensic textbooks that hanging causes unconsciousness in an average of 10 sec (2,3). It is also in keeping with an old study by Rossen et al. (8): inflation of a pressure cuff on the neck of 85 male volunteers caused loss of consciousness in 5–11 sec. Two other filmed hangings are reported in the literature, one also presenting an early loss of consciousness at 10 sec (9), whereas in the other the loss of consciousness is delayed at 55 sec (10).

Loss of consciousness was closely followed by generalized tonic-clonic convulsions (10–19 sec). This correlates with the same type of convulsions observed in the study on male volunteers (8) and in one of the previous filmed hanging (10). However, the other filmed hanging reported fine twitches but no clonic and tonic spasms (9).

Decerebrate Rigidity and Decorticate Rigidity

Decerebrate rigidity indicates lesions of the brainstem caudal to the red nucleus and rostral to the vestibular nuclei (11). The upper and lower limbs are fully extended, with an extension of hips and knees, plantar flexion of feet and toes, internal rotation of the shoulders, extension of the elbows, hyperpronation of the distal parts of the upper limbs with finger extension at the metacarpophalangeal joints and flexion at the interphalangeal joints (11). Decorticate rigidity on the other hand points toward a cerebral cortex

TABLE 1—*Agonal sequences in eight filmed hangings.*

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8
Movement responses								
Loss of consciousness	13 sec	nd	18 sec	nd	10 sec	8 sec	10 sec	12 sec
Convulsions	15 sec	14 sec	19 sec	18 sec	13 sec	11 sec	10 sec	14 sec
Decerebrate rigidity	19 sec	19 sec	21 sec	nd	1 min 19 sec	31 sec	11 sec	20 sec
Decorticate rigidity (stage 1)	21 sec	1 min 8 sec	1 min	nd	59 sec	33 sec	26 sec	31 sec
Decorticate rigidity (stage 2)	1 min 11 sec	1 min 32 sec	1 min 4 sec	nd	–	–	34 sec	–
Loss of muscle tone	1 min 38 sec	2 min 15 sec	2 min 4 sec	nd	1 min 52 sec	–	nd	nd
Last muscle movement	4 min 10 sec	2 min 47 sec	3 min 1 sec	nd	7 min 31 sec	1 min 2 sec	nd	nd
Respiratory responses—very deep respiratory attempts								
Start	20 sec	21 sec	22 sec	24 sec	13 sec	19 sec	13 sec	16 sec
End	2 min	2 min 3 sec	2 min 4 sec	nd	2 min 5 sec	1 min 2 sec	nd	nd

nd, no data; –, not observed.

impairment and is characterized by flexion of the upper limb combined with extension of the lower limb (11). Despite the term rigidity, decorticate rigidity is more closely related to spasticity: lesions of the premotor areas are associated with an increased muscle tone, more obvious in the extensor muscles of the legs and flexors of the arms.

In all but one case, decerebrate rigidity was observed first, followed by decorticate rigidity. At the present time, there is neither obvious explanation nor hypothesis to explain this fact.

Jugular veins and carotid arteries are more prone to occlusion by neck compression than the more deeply located vertebral arteries. Considering that the brainstem is vascularized by tributaries of the vertebral arteries whereas the premotor areas are vascularized by tributaries from the carotid, it could have been assumed that decerebrate rigidity would appear first. However, this is not the case.

Time Delay of Agonal Responses in Incomplete and Complete Hangings

It is generally thought in the forensic community that the time delay to agonal responses will vary depending on the type of hanging, hangings with complete suspension of the body leading to death more quickly than hangings in which the body is partially supported (e.g., feet or knees on the floor). This indeed would seem logical. However, this study does not support this assumption. As a matter of fact, agonal responses in complete hanging (case 3) appeared no sooner than in incomplete hangings with feet or knees on the ground (cases 1–2, 4, 6–8) or even incomplete hangings lying down (case 5).

The fastest agonal responses were observed in case 6. Interestingly, the decedent in this case intermittently applied the neck compression longer than the other decedents. This may have resulted in an ultimately more rapid hypoxia leading to earlier observed physiologic distress with the final compression.

Respiratory Responses

All cases demonstrated deep rhythmic abdominal respiratory movements. These respiratory movements were not only visualized but were also clearly audible. This fact strongly supports the notion that vascular occlusion is the major component of the pathophysiology of hanging. It should be pointed out that this last assertion is controversial and further studies are needed before concluding this old debate on the relative contribution of the three main possible mechanisms to death by hanging (occlusion of the airways, occlusion of the neck vessels, and vagal inhibition). It may be argued that the diaphragm and chest wall appear to move as if the person is breathing, without air actually entering or exiting the lungs. The fact that abdominal ''breathing'' movements are visualized does not mean that air exchange is occurring. However, the breathing movements were not only seen but also heard. It could also be argued that hearing breath sounds does not eliminate the possibility of significant airway obstruction. For example, many choking deaths with airway obstruction by food or foreign objects present with partial pathway for air to move around the obstruction, yet these people still presumably die from airway obstruction. Similarly, if the trachea is compressed by a noose around the neck, there may be substantial narrowing of the lumen but some air could theoretically continue to pass by the area of compression, thus accounting for some degree of actual air passage. Therefore, the mere fact that you can hear breath sounds does not definitely rule out respiratory obstruction as a mechanism of death in these cases. Ultimately, this study strongly supports the idea that tracheal occlusion is not complete in some types of hanging, but it would be premature to totally exclude some implication of partial airways obstruction in the mechanism of death by hanging.

Nevertheless, the presence of clear audible respiration confirming the absence of total airways obstruction in several of these hangings is particularly interesting. For example, case 1 will be further analyzed. In this filmed hanging, the victim is an adult man of 148 pounds (67.3 kg). The hanging is incomplete, with the victim standing, feet on the ground. The amount of body weight involved tightening the ligature in relation to the hanging position can be evaluated by using results from a previous study by Khokhlov (12): more than 65% for a hanging in a standing position feet flat. In case 1, 65% of body weight is about 96 pounds (44 kg). This pressure around the neck is highly superior to the weight of 33 pounds (15 kg) mentioned in textbooks as the pressure necessary to occlude the trachea (1,13). Nevertheless, filmed hanging #1 was clearly associated with audible respiration. The explanation is probably that one important factor is often overlooked: the angle of the pressure on the structures of the neck. As a matter of fact, the weight necessary to occlude the various structures of the neck seems to have been studied with pressure vectors applied relatively perpendicularly to these structures compare to a true typical hanging. Pressure vectors in real life are more diagonal, with a greater angle to the neck structures. Furthermore, another factor may have been underestimated: the level of the ligature on the neck (across the trachea, the larynx, or above the larynx).

Conclusion

Despite differences in the types of hanging in these eight films, similarities in the agonal responses to hanging are striking. Filmed hangings seem to be one key to a better understanding of human asphyxia, and the WGHA will continue to add new cases in the following years.

References

1. DiMaio VJ, DiMaio D. Asphyxia. Forensic pathology, 2nd edn. Boca Raton, FL: CRC Press, 2001;229–77.
2. Spitz WU. Asphyxia. In: Spitz WU, Spitz DJ, editors. Spitz and Fisher's medicolegal investigation of death: guidelines for the application of pathology to crime investigation, 4th edn. Springfield, IL: Charles C Thomas Publisher LTD, 2006;783–845.
3. Saukko P, Knight B. Suffocation and 'asphyxia'. In: Ueberberg A, project editor. Knight's forensic pathology, 3rd edn. London: Arnold Publishers, 2004;352–67.
4. Boghossian E, Clement R, Sauvageau A. Respiratory, circulatory and neurological responses to asphyxia by hanging: a review of animal models. J Forensic Sci. E-pub ahead of print. DOI: 10.1111/j.1556-4029.2010.01436.x.
5. Clement R, Redpath M, Sauvageau A. Cause of death in hanging: a historical review of the evolution of pathophysiological hypotheses. J Forensic Sci. E-pub ahead of print. DOI: 10.1111/j.1556-4029.2010.01435.x.
6. Sauvageau A, Racette S. Agonal sequences in a filmed suicidal hangings: analysis of respiratory and movement responses to asphyxia by hanging. J Forensic Sci 2007;52(4):957–9.
7. Sauvageau A. Agonal sequences in four filmed hangings: analysis of respiratory and movement responses to asphyxia by hanging. J Forensic Sci 2009;54(1):192–4.
8. Rossen R, Kabat H, Anderson JP. Acute arrest of cerebral circulation in man. Arch Neurol Psychiatry 1943;50:510–28.
9. Yamasaki S, Kobayashi AK, Nishi K. Evaluation of suicide by hanging from the video recording. Forensic Sci Med Pathol 2007;3(1):45–51.

10. Risse M, Weiler G. Agonale und supravitale bewegungsabläufe beim erhängen. Beitr Gerichtl Med 1989;47:243–6.
11. Ghez C. Posture. In: Kandel E, Schwartz JH, Jessel TM, editors. Principles of neural science, 3rd edn. Norwalk, CT: Appleton & Lange, 1991;596–607.
12. Khokhlov VD. Calculation of tension exerted on a ligature in incomplete hanging. Forensic Med Pathol 2001;123:172–7.
13. Shkrum M, Ramsay DA. Asphyxia. In: Karch SB, series editor. Forensic pathology of trauma: common problems for the pathologist, 1st edn. Totowa, NJ: Humana Press, 2007;65–179.

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