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AUTONOMOUS NERVOUS SYSTEM-RELATED VITAL REACTIONS IN SHORT DROP HANGINGS

VITALNE REAKCIJE U VEZI SA AUTONOMNIM NERVNIM SISTEMOM KOD VEŠANJA SA KRATKIM ZAMAHOM

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Abstract

There are numerous anatomopathological signs forensic pathologists take into account in autopsy evaluation of deaths by hangings, having in mind one of the most important tasks: to prove the person was alive at the moment of suspension. Forensic medicine textbooks describe in detail many routinely observed findings, but some phenomena were not of particular interest. This may be due to the unreliability or impracticability of the findings interpretation. Nevertheless, some signs of vitality that may be related to the autonomous nervous system (ANS) in hangings could be useful. These can be considered as general ANS-related vitality phenomena associated with the agonal sequence, and those directly associated with the specific neck region injury by the ligature. The former is primarily the non-specific increase in blood catecholamine levels and the hypersalivation with saliva dropping on the facial skin from the lips' angles, associated with agonal convulsions and deep terminal "abdominal" respirations. The latter, probably more interesting, is the so-called *faciès sympathique*: the lesion of the sympathetic fibers in the neck region may lead to myosis and partial upper eyelid ptosis on the side of the lesion. However, this reaction/sign was not of great research interest and remained incompletely understood regarding the interpretation of postmortem appearance. This demands further studies, but if properly analyzed, it may prove useful as a proof of vitality and for reconstructing the event, too, in case the other findings are subtle or absent.

Keywords:
hanging,
autopsy,
forensic pathology,
vital reaction,
faciès sympathique

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Sažetak

Prilikom obdukcije tela vešanika obducent razmatra veći broj anatomopatoloških fenomena, imajući pritom u vidu jedan od najvažnijih zadataka: da dokaže da je osoba bila živa u trenutku vešanja. U udžbenicima iz oblasti sudske medicine detaljno su opisani mnogi obdukcioni nalazi u vezi sa ovim, ali određenim fenomenima nije dat veliki značaj. Razlog je činjenica da su određene vitalne reakcije, tj. znaci nepouzdani ili da njihovo utvrđivanje i interpretacija tokom obdukcije nisu praktični. Ipak, neke vitalne reakcije kod vešanja, koje su u vezi sa funkcijom autonomnog nervnog sistema (ANS), mogle bi da budu i korisne. Ove fenomene možemo da posmatramo kao opšte, u vezi sa karakterističnim agonalnim pojavama ili kao one koji su u vezi sa konkretnom povredom vrata omčom. Prvu grupu prevashodno predstavljaju nespecifični porast koncentracija kateholamina u krvi, kao i hipersalivacija i slivanje pljuvačke iz uglova usana niz kožu lica, što je uzrokovano agonalnim konvulzijama i dubokim „abdominalnim" agonalnim respiracijama. Drugu, verovatno interesantniju grupu, predstavlja tzv. „simpatički facijes" (*faciès sympathique*): povreda simpatičkih vlakana u vratu može da uzrokuje miozu i delimičnu ptozu gornjeg očnog kapka na strani na kojoj je i povreda. Ova pojava, međutim, nije bila interesantna ni naročito istraživana, te je njeno razumevanje i interpretacija kao postmortalnog nalaza vrlo ograničena. Neophodno je sprovesti dodatna istraživanja – ispravno protumačen obdukcioni nalaz mogao bi da bude vrlo koristan dokaz zaživotnosti (vitalne reakcije), ali bi ujedno mogao i da pomogne u rekonstrukciji položaja čvora omče u slučaju da ostali obdukcioni nalaz nije od koristi.

Ključne reči:
vešanje,
obdukcija,
sudska medicina,
vitalna reakcija,
Faciès sympathique

Introduction

Hanging, or suspension, is a mechanical asphyxia, a form of strangulation in which a constricting band applies pressure on the neck, tightened solely by the gravitational drag of the hung body or part of the hung body (1, 2). An important distinction that must be made immediately is the difference between the so-called *long* and *short drop* hangings. The former are usually seen in jurisdictional death penalty executions (the person is dropped from a significant height, which leads to traumatic neck-spine injury, not to asphyxia). The latter are the typical suicidal hangings (1-4). A short drop means that the distance a body falls before the noose and rope is tightened around the neck is no more than c. 1-2 m, or there is no drop at all (remember that hanging may occur while the person kneels, sits, or even lies down) (3-6). In this paper, it is referred exclusively to short drop hangings.

Cases of death by hanging are frequent in the autopsy rooms (1, 7-11). Many pathomorphological autopsy findings, general and local, all broadly described in reference forensic pathology textbooks, are used to reconstruct the event (e.g., a ligature mark can point to the knot position) and, more importantly, to determine if the person was alive when suspension occurred (1-3, 5, 12-18). The latter phenomena are so-called *vital reactions* (12). In hangings, they are either directly related to the mechanical neck trauma – for example, hemorrhages in the neck soft tissues, especially of sternocleidomastoid muscles, and soft tissues surrounding fractured horns of the hyoid bone and thyroid cartilage, or the reactions/signs are related to the mechanisms of death by hanging and can be distant from the neck structures (e.g., interstitial bleeding in the anterior longitudinal ligament covering thoracolumbar intervertebral discs – Simon's hemorrhages), such as the characteristic but non-specific general findings of deaths by asphyxia (1, 2, 5, 12, 19, 20). In routine autopsy practice and the literature, attention is paid more to some vital reactions than others because the certainty with which they suggest the vitality of hanging differs, and some can easily be misinterpreted due to artifacts and rapid taphonomy alteration (by putrefaction), or due to a low occurrence frequency of some. The vital reactions that can be related to the nervous system, particularly the autonomous part (ANS, sympathetic, and parasympathetic), arerarely considered topics (12, 21-23). Didactically, these phenomena are also considered to be:

- General ANS-related vital reactions – *related to the agonal sequence*.
- Local ANS-related vital reactions – *related to the specific neck injury*.

Agonal sequence and general autonomous nervous system-related vital reactions

For a long time, a lot has been speculated about the mechanisms of death occurrence in hangings. The three main pathophysiology concepts, not mutually exclusive, are 1. mechanical airway obstruction due to *tamponada oris*, a mechanical occlusion of the upper airway by ligature pushing the base of the tongue upwards and posteriorly; 2. a mechanical compression of the neck vascular structures, the carotid arteries and/or internal jugular veins, and 3. a vagal reflex and cardiac arrest (1-3, 5, 19, 24, 25). In fact, many evidence-based conclusions on the mechanism of death and agonal sequence stem from an analysis of cases of suicidal hangings that were video-recorded (26-28) and recent work on this issue of the Working Group on Human Asphyxia (24). The hanged person typically

becomes unconscious after about 10 seconds and then develops generalized tonic-clonic convulsions, followed by decerebrate and decorticate rigidity, with the last observable movement about 4 minutes after the hanging. There are also periods of deep rhythmic abdominal respiratory movements throughout the first two minutes (19,24). The general nervous system-related vital reactions may stem from this evident non-specific general neuronal discharge and convulsions due to brain anoxia upon neck compression.

Increase in blood catecholamine levels

So, undoubtedly, there is general neuronal activation due to anoxia just preceding the onset of death. This nervous system activation may lead to a surge of circulating catecholamines, adrenaline, and noradrenaline released from the adrenals. In addition, the person preparing to commit suicide may have this surge initiated just before hanging due to the perception of an imminent death (12). But as we may expect, a fight-or-flight response can be triggered in any situation where the threat of injury and violent death is perceived. The question of whether the postmortem concentrations of blood catecholamine levels may be useful regarding this was raised many decades ago (12, 29, 30). The first studies reflected on strangulation deaths, where higher levels existed compared to reflex deaths, and also suggested that this increase correlates with the duration of terminal episodes (29-31). Animal experiments showed a manifold increase in circulating catecholamines following fatal strangulation compared to controls (12, 32). More recently, Wilke et al. showed that postmortem catecholamine levels and adrenaline/noradrenaline ratios in various body fluids do not permit any conclusions regarding the cause of death and length of the agony period in individual cases, including hangings (33). Madea et al., in the recent comprehensive review on vital reactions, however, do consider increased catecholamine levels as a significant vital parameter in asphyxia deaths in general (12).

Salivation

In some hangings, saliva pouring from the subject's mouth can be observed at the scene, running from the angle of the lips down the skin of the face, depending on the head position (3, 12). During an autopsy of such cases, the dried saliva mark on the skin can usually be observed (**Figure 1**).

This is considered a vital reaction (3, 12). The position of the dried mark may be useful in reconstructing the position of the head, as this "drooling" is gravity-dependent. Finally, this may aid in reconstructing the knot position, particularly in so-called lateral hangings (the knot is on the left or right side of the head): the head may be tilted contrary to the knot position, but this should be confirmed in future studies. The appearance of this sign may stem from the combination of hypersalivation and whisking of this saliva in the mouth and throat during convulsions, a known ictal phenomenon in epileptology (34-36), and, later, deep agonal respirations. The additional explanation for the increased saliva production may be the mechanical stimulation of the glossopharyngeal nerve upon ligature neck compression (3), as well as the general congestion of the head above the level of the noose that occurs in many cases (12). Agonal convulsions *per se* may cause the appearance of interstitial bleeding in the anterior longitudinal ligament covering thoracolumbar intervertebral discs, Simon's hemorrhages (1, 2, 6, 12), but this is not considered to be related to the activity of ANS and is out of the scope of this paper.

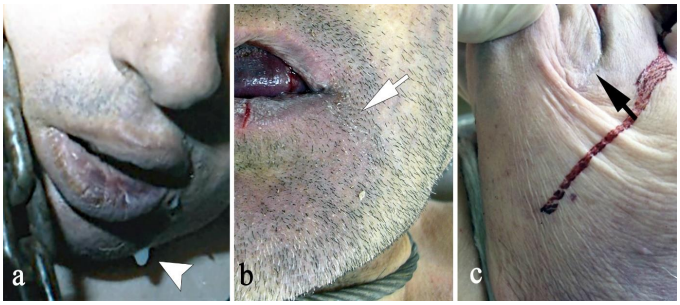

Figure 1. Hypersalivation and running saliva as vital reactions and sign in hanging

a) The saliva dropping from the left lip angle of a hung person (finding at the scene) b) and c) On autopsy, the mark of the dropping saliva is dried and can be subtle (white and black arrows). Note the dried blood running down the face in the third picture, which can also be a vital phenomenon but should not be confused with the previous observation. The cases are from the authors' medicolegal autopsy practice. The first photograph (a) was previously published by Nikolić and Živković (6). Source: Institute of Forensic Medicine, University of Belgrade – Faculty of Medicine, Belgrade, Serbia

Local autonomous nervous system-related vital reactions

The term *local* in this context is used to point out these vital reactions related to the ANS directly result from the local neck injury – the mechanical compression of the neck structures, particularly the nerve structures in the neck, and not the mechanism of death in general. Other than that, the ANS signs of this injury are mostly appreciated remotely from the site of mechanical compression.

Parasympathetic nervous system phenomena

As already mentioned, one of the postulated mechanisms of death in hanging is the vagal reflex and consequent cardiac arrest (3, 24, 25, 37, 38). When the ligature tightens around the neck, the carotid sinus and vagal nerve injury in the carotid sheet may occur. The mechanical stimulation of baroreceptors and nerve endings in the carotid sinus, located in the tunica adventitia of the internal carotid artery just distal from its origin, triggers the cardioinhibitory reflex (37, 38). From the sinus, the afferent impulses are transmitted via the sensory fibers of the carotid sinus nerve (Hering's nerve), the branch of the glossopharyngeal nerve. These afferent fibers terminate in the *nucleus tractus solitarii* in the *medulla oblongata*, while the efferent impulses traverse through the *n. vagus* (37-39). So, it is probably not the direct trauma to the vagal nerve

in the neck responsible for this reflex. Locally, however, the pathologists may not see any signs of vitality, and histology analysis should be performed to detect potential hemorrhage in the artery wall in the carotid sinus region and adjacent soft tissue (37, 38). It should be noted that in addition to the vagal inhibition, other mentioned mechanisms may interplay in death onset in these cases, and other common vital reactions of asphyxia must always be sought.

Sympathetic nervous system phenomena

Probably the most interesting finding related to the ANS vitality reactions in hangings is a manifestation of injury to the sympathetic portion of the autonomous nervous system in the neck region. However, this phenomenon is rarely reported in forensic pathology literature, with ambiguous interpretations and a lack of studies that will enable a straightforward interpretation. Only recently have Marchetti et al. brought it back to broader attention, suggesting further research on this topic is necessary (21).

The finding was first described by Etienne Martin (1871 - 1949) in 1899 in two cases of lateral hangings, where he had noted unilateral myosis and partial ptosis of the upper eyelid (the latter only in one case) (21, 40). He termed the appearance *le faciès sympathique* (**Figure 2**) because these features strongly resembled findings in patients with goiter who underwent sympathectomy for exophthalmos (21). Nowadays, appearance is probably better recognized as two out of three Horner syndrome features (23, 41).

In both cases, Etienne reported the myosis occurred on the site opposing the knot position, where the pressure a noose (loop) applies to the neck is greatest (21). Minovici later reported the broader case series, but this finding was seen only in some cases, and he even considered the results

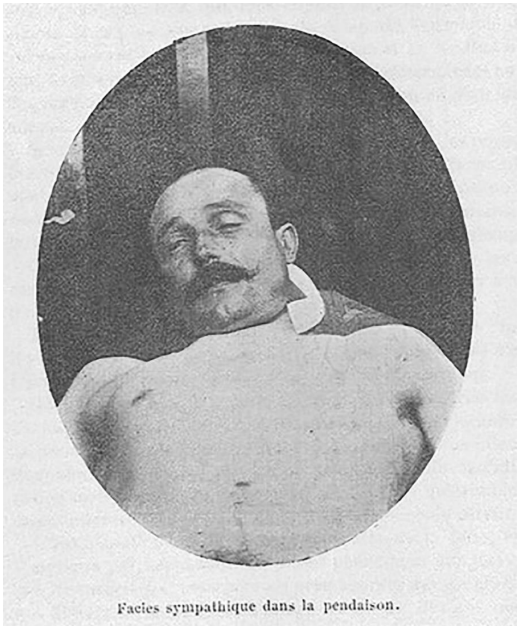

Figure 2. The original photograph from Martine Etienne's report "Le faciès sympathique des pendus," dating from 1899

Archives de l'anthropologie criminelle (vol. 14; 1899, Page 178), Source: Musée Criminocorpus (40), available at: https://criminocorpus.org/en/library/page/9565. The figure was recently also published by Marchetti et al. (21)

contrary to Etienne's (21, 42). Nevertheless, only Etienne offered an explanation for the underlying pathophysiology. According to Marchetti et al., he postulated that "compression and/or stimulation by stretching of the cervical sympathetic trunk" causes the observed anisocoria and ptosis (21). Later, Polson et al. also reported a case of anisocoria and unilateral ptosis on the side of the knot (22, 23).

The cervical sympathetic trunk, and more specifically for the issue considered, the upper part of it – the superior cervical sympathetic ganglion is located in front of the transverse processes of the 2nd and 3rd cervical vertebrae (43). This is where some of the preganglionic fibers of the thoracolumbar sympathetic centers in the medulla spinalis make synapses. From there, unmyelinated postsynaptic fibers arise, follow, and traverse around carotid arteries (forming so-called plexuses) and their branches, some to eventually innervate the dilator muscle of the pupil (*m. dilatator pupillae*), and the smooth muscle of the upper eyelid (*m. tarsalis*), whose tonus normally prevents the ptosis (41, 43).

The disruption of these fibers (or ganglion itself) causes ptosis and leaves the parasympathetic tonus to the pupil (*m. constrictor pupillae*) unopposed, which causes myosis (41). So, it was postulated that this could be due to compression of the sympathetic chain at the level of the bifurcation of the common carotid artery and the angle of the jaw or compression of the carotid sympathetic plexuses (21-23). In subjects with dissection of the carotid artery Horner's syndrome is often the presenting sign alongside cerebral ischemia (44, 45). What is known about electrical excitability, stretching, and compression of large peripheral nerves (in the 19th century, a therapeutic nerve stretching procedure neurectasy was proposed) is, for example, that if the mechanical stimulation of limited force is applied to the nerve (i.e., stretching), it may cause increased excitability, while more significant force would lead to complete loss of excitability and action potential transmission (46). So, Martin's rationale for explaining signs of *faciès sympathique* to occur on the site where the noose applies the greatest pressure (opposite to the knot) is straightforward. It can only be speculated, but Minovici reported signs of anisocoria and not myosis but mydriasis (21) – could this be the case of moderate nerve stretching and hyperexcitability on the site of the knot (where the pressure is limited, but the neck is stretched)? Furthermore, could there be a symmetrical bilateral finding of Etienne Martin's sign in evenly distributed pressure on these nerve structures, as in typical hangings (the knot is located around the occiput)? Moreover, can we draw any conclusion in a case presenting mixed findings (e.g., ptosis and contralateral miosis, **Figure 3**)?

Of course, the most obvious problem of this discussion will be faced on the first pages of many reference forensic pathology textbooks: the rigor mortis and putrefactive changes that affect the muscles, including the smooth muscles of upper eyelid and eyes, make the interpretation of such findings very questionable, uncertain, and often impossible (1, 2, 5, 20). Therefore, in future studies,

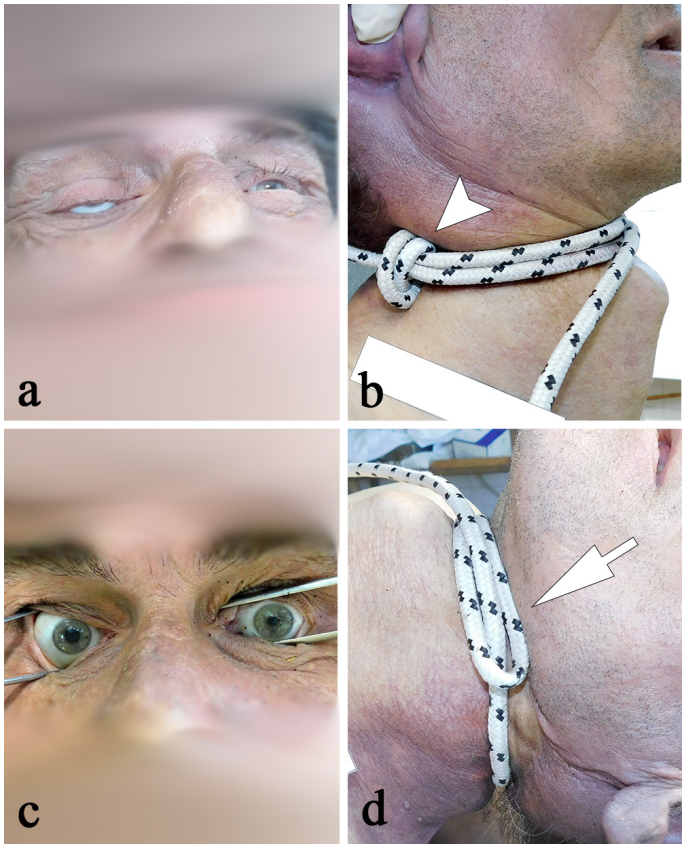

Figure 3. The autopsy case of left lateral hanging with ambiguous mixed findings: a) the upper eyelid ptosis on the right eye; b) the site with the greatest pressure on the right side of the neck but with the additional knot in the loop (white arrowhead); c) the marked anisocoria, note the left eye miosis; and d) the sliding knot of the noose on the left lateral side of the neck (white arrow). The usefulness of this finding should be further researched. Postmortem period c. 24-48 h.

The case is from the authors' medicolegal autopsy practice. Source: Institute of Forensic Medicine, University of Belgrade – Faculty of Medicine, Belgrade, Serbia

attention should be paid to exact postmortem periods, keeping in mind the supravital period of the iris muscles that remain pharmacologically excitable for significantly more time than others (response to some medicaments for up to 46 hours) (2, 47). Potential analysis in non-fatal neck strangulation would also be helpful (21, 23). Ultimately, proper expert opinions regarding the interpretation of the *faciès sympathique* sign may aid in reconstructing the hanging event – the position of the knot in a noose.

The *faciès sympathique* should not be confused with "another" Etienne Martin's sign in hanging, which is a hemorrhagic infiltration in the adventitial wall of the carotid artery due to rupture of the vasa vasorum (48). Therefore, the former term should be preferred to avoid confusion.

Conclusion

There are several vitality phenomena in hangings related to the activity of the autonomous nervous system. These are either the consequence of the specific agonal sequence or directly related to the neck injury and lesion of the sympathetic fibers in this region. On autopsy, the readily appreciable signs may be of agonal hypersalivation with saliva drooping and *faciès sympathique*, which may be called Etienne Martin's sign. Additionally, tanatochemical investigation may detect increased blood catecholamine levels, but this is a non-specific finding. However, the ANS-related vital reactions are not unambiguous and must be interpreted with caution. Findings such as the *faciès sympathique* have been neglected in forensic literature, and further research on ANS-related vitality phenomena in hangings is to be conducted for better conclusions to be made and for reliable direct application in daily autopsy practice.

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