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PAPER

PATHOLOGY/BIOLOGY

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Cervical Soft Tissue Emphysema in Hanging—A Prospective Autopsy Study*

ABSTRACT: The underlying mechanism of cervical soft tissue emphysema (CSTE) in hanging remains unclear. The aim of this study was to determine the frequency of CSTE in cases of hanging. The sample included 83 deceased persons, average age 55.3 ± 17.9 years. CSTE was established in 44 cases. CSTE is presented as frothy air, soap bubble-like formations in superficial and/or deep connective tissue between the neck muscles up to the ligature mark, visible during gross neck examination, using special neck autopsy technique—preparation of the neck organs in layers. The interpretation of positive CSTE must be taken with caution: it could be an antemortem phenomenon possibly because of either Macklin Effect or direct or indirect trauma to the cervical airways, as well as an ante- or postmortem artifact.

KEYWORDS: forensic science, forensic pathology, hanging, cervical soft tissue emphysema, Macklin Effect, cervical airways trauma

Hanging is a form of strangulation in which the pressure on the neck is applied by a constricting band tightened by gravitational weight of the body or the part of the body (1). A furrow is the hanging ligature mark on the skin, usually localized above the larynx, which is initially a slightly yellow parchment-like area that becomes brownish with suspension time (2). Other typical autopsy findings in cases of hanging include throat-skeleton fractures often accompanied by hemorrhaging of soft tissues, as well as the congestive hemorrhaging in the conjunctiva and buccal mucosa (2,3).

Using postmortem imaging, in cases of hanging, it was possible to detect and document gas collections within the soft tissues of the mediastinum and neck, which follow the visceral space around structures, such as the trachea, esophagus, and large vessels of the neck, with the structures serving as guides for the spread of air. However, soft tissue emphysema was usually not found in autopsy dissection (4).

The aim of this study was to determine the frequency of cervical soft tissue emphysema (CSTE) at autopsy in cases of hanging.

Materials and Methods

A prospective autopsy study included selected cases of suicidal hanging. The cases were determined to be suicides through police investigations, specific circumstances of death, suicide notes, previous suicide attempts, and heteroanamnestic or medical data about the presence of mental disorders and various other medical conditions as a suicidal motivation, etc.

The sample consisted of cases with full suspension hanging, as well as incomplete hangings in a standing position without the drop effect. We did not analyze the incomplete hangings in kneeling, sitting, lying, or other positions. To make the sample as homogenous as possible, we considered only cases where the position of the ligature knot or point of suspension was in the posterior part of the neck.

All subjects included in the analyzed sample died at the scene without an outliving period and without any cardiopulmonary resuscitation.

The time passed from death to autopsy was in the range from 12 to 36 h. We excluded all cases in which a period of 36 h was exceeded to avoid the possibility of the CSTE being misinterpreted as bubble gas formation because of putrefaction. In all selected cases, there were no visible signs of initial putrefaction changes, such as discoloration of the lower abdominal wall, marbling of the skin because of initial putrefaction, or postmortal reddishness and swelling of the tissues (especially the wall of the blood vessels).

The cases included in the study were only those in which ethanol was not detected in the blood samples taken from the femoral vein (headspace gas chromatography, limit of ethanol detection 0.01 g/dL, and limit of ethanol quantitation 0.03 g/dL). This was performed to exclude all cases where there was a possibility of endogenous alcohol formation because of putrefaction.

The technique performed in each case of hanging in our institution includes all soft and solid neck structures prepared by layers, as well as their thorough examination. In this way, we selected only those cases with hemorrhages of the cervical soft tissue beneath and around the ligature mark—hemorrhages in subcutaneous adipose tissue, muscles and/or cervical connective tissue, and/or hemorrhages within the point of the sternocleidomastoid muscles' attachment. These hemorrhages suggest that strangulation,

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and therefore the eventual appearance of CSTE, was premortem in origin.

During a gross examination of the neck region and the preparation of structures by layers, CSTE is presented as frothy air, soap bubble-like formations in superficial and/or deep connective tissue between the neck muscles. In each case, two observers during the autopsy confirmed the presence or absence of CSTE independently, without grading its intensity; we considered that the CSTE was present if both of the observers confirmed its presence.

We formed a control group of nonhanging cases without any neck injuries according to previously listed criteria in hanging cases (the subjects died at the scene without an outliving period and without any cardiopulmonary resuscitation, the time passed from death to autopsy was within the range of 12–36 h, with no visible signs of initial putrefaction changes, and ethanol was not detected in the blood samples taken from the femoral vein). The same technique of all soft and solid neck structures prepared by layers was performed to establish the presence of soft tissue emphysema (also confirmed by two independent observers), as well as the frequency of this phenomenon, and compare it with hanging cases.

The sample was analyzed concerning the occurrence of CSTE, Simon's bleedings, and throat-skeleton fracture accompanied by hemorrhaging. The sample was analyzed with regard to gender and the age of the deceased, as well. The obtained data were statistically analyzed using Pearson's chi-square test, Fisher's exact test, Student's *t*-test (with Mann–Whitney sum ranks test when necessary) for estimating the differences, and multiple regression for estimating the relationships. A p-value < 0.05 was considered significant.

Results

The sample included 83 deceased persons who fulfilled the previously listed criteria: 59 men and 24 women (gender ratio 2.5:1; $\chi^2 = 14.76$, $p < 0.001$), with an average age of 55.3 ± 17.9 years (range from 19 to 93 years)—men 53.1 ± 17.8 years and women 60.6 ± 17.2 years of age ($t = 1.765$, df = 81, $p = 0.081$).

Table 1 shows the sample distribution with regard to the occurrence of CSTE, as well as Simon's bleedings and throat-skeleton fractures, and the age of the deceased.

CSTE was established in 44 cases. In 27 cases, this phenomenon was present concomitant with Simon's bleedings, and in 25 cases, CSTE was accompanied by throat-skeleton fractures. In 16 observed subjects, CSTE was accompanied by both throat-skeleton fractures and Simon's bleedings.

The control group included 26 deceased persons who fulfilled the previously listed criteria: 20 men and six women (gender ratio 3.3:1; $\chi^2 = 7.54$, $p = 0.006$), with an average age of 65.0 ± 16.6 years (range from 33 to 89 years). Subjects in the control group were gender matched to the subjects in the sample (Mann–Whitney $U = 1016.00$, $p = 0.563$), but also somewhat older ($t = 2.463$, df = 24, $p = 0.012$). All the subjects in the control group died of natural causes: 22 died from cardiac diseases (ischemic heart disease, cardiomyopathy, or myocarditis), two died from intracranial bleeding, one from gastrointestinal bleeding, and one from liver cirrhosis. In only two out of 26 cases in control group, both observers confirmed the presence of CSTE.

Discussion

First observation of CSTE in cases of attempted strangulation was made clinically (5). While this phenomenon was also radiologically documented in cases of near hanging (4,6), it was not described in forensic autopsy cases of strangulation without an outliving period: the lack of appropriate neck autopsy technique was probably the reason. Unlike postmortem imaging, standard autopsy tecnique does not allow for the exact detection of gas propagation along neck organs in such cases. A kind of frothy air, soap bubble-like formation in cervical soft tissue could be a phenomenon resulting from the stretching and exenterating of the neck organs during autopsy. To avoid this and differentiate it from CSTE in cases of hanging, we applied a special autopsy technique of neck dissection in all observed cases. In our institution, this type of technique is performed in all cases with neck injuries, such as hanging. This special technique implies the preparation of all neck organs in separate layers: the first longitudinal neck incision is followed by the preparation and removal of the skin and platysma, so that the sternocleidomastoid muscles can be seen and examined clearly. This is followed by the preparation of these muscles, cutting their bone attachments, and then removing them: if there were any of the frothy air, soap bubble-like formations, that is, CSTE, they would be visible on the dorsal side of these muscles. After removing the sternocleidomastoid muscles in this way, the omohyoid muscles are clearly visible. After the preparation of these muscles, the great cervical vessels and nerves are visible and can be examined properly. By applying this technique, we avoid stretching the neck organs and tissues during autopsy and prevent artificial postmortal CSTE because of the exenterating of the neck organs during autopsy. Applying this special neck autopsy technique, consisting in preparation of the neck structures in layers, we make the CSTE more visible. Applying the classical neck autopsy technique in cases of hanging could lead to overlooking and misinterpreting the CSTE, and this phenomenon is frequently missed during autopsy. However, even in our study with preparation of the neck structures in layers, in some cases there were inter-observer discrepancies in intrepretation of soft tissue emphysema, so such cases were excluded from the study.

To make CSTE as visible as possible, we selected only the cases where the position of ligature knot or point of suspension was in the posterior part of the neck, as well as the cases with clearly

TABLE 1—*Sample distribution with regard to cervical soft tissue emphysema occurrence, as well as Simon's bleeding and throat-skeleton fractures, and age of deceased.*

		Age (Years)									
		≤20	21–30	31–40	41–50	51–60	61–70	71–80	>80	Total	Average Age
Cevical soft tissue emphysema	Yes	1	2	8	5	12	8	6	2	44	54.6 ± 17.0
	No	0	4	5	8	8	2	8	4	39	56.0 ± 19.0
Simon's bleedings	Yes	1	3	10	10	15	4	3	0	46	48.9 ± 13.9
	No	0	3	3	3	5	6	11	6	37	63.2 ± 19.2
Throat-skeleton fracture	Yes	0	2	11	12	12	6	7	5	55	55.8 ± 19.0
	No	1	4	2	1	8	4	7	1	28	55.0 ± 17.4

visible skin ligature mark. This way we made it easier to observe these frothy, soap bubble-like formations (Figs 1 and 2). These formations could reach the cervical connective tissue up to ligature mark: the ligature stops them from reaching the submental region. The ligature pressure on the cervical skin makes a kind of bind toward upper parts of the neck, making CSTE more evident: air bubbles accumulate in parts below the ligature. This way, we unintentionally might have excluded hanging cases of supple, soft, and large ligatures.

The underlying mechanism of CSTE in hanging remains unclear. There is probably an increase in thoracic pressure provoked by expiration movements against a closed glottis during the hanging. This could result in the occurrence of CSTE as a continuum of interstitial lung emphysema and pneumomediastinum following the visceral space around the trachea, esophagus, and large vessels of the neck. However, CSTE could be the result of direct or indirect trauma to the cervical airways, that is, a traumatic tear or rupture of the lower or upper airways because of either ligature pressure or stretching (4). In 1930, Joannides and Tsoulos (7) stated that the causes of interstitial lung emphysema in general included a sudden increase in the intrapulmonary air pressure resulting from physical straining (coughing, childbirth), or an obstruction of the air passage by the aspiration of foreign material, which acts as a ball valve during unaided forceful respiration against the obstruction. This proposed etiology of pulmonary interstitial emphysema was confirmed by Macklin and Macklin (8,9): a rupture of terminal alveoli caused by elevated intrathoracic pressure and a subsequent dissection of air along the perivascular and peribronchial fascial sheaths into the mediastinum and/or connective tissue of the neck and subcutaneous tissue. Today, this is known as the Macklin Effect (10). Pneumomediastinum and CSTE arise in various conditions because of the Macklin Effect, as a result of an alveolar rupture secondary to high intra-alveolar pressure (11,12).

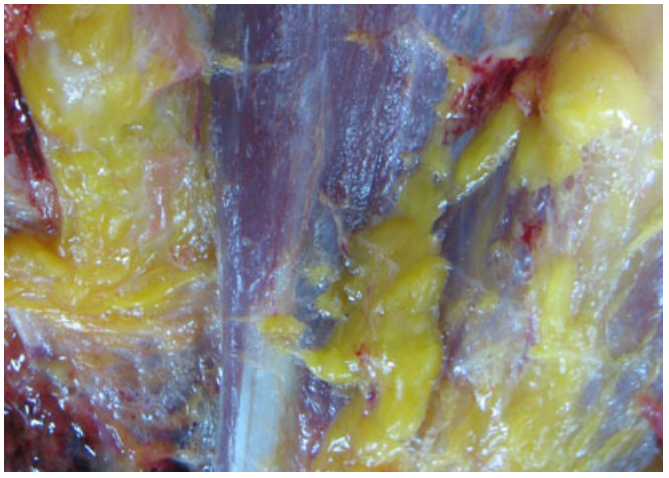

FIG. 1—*Soft tissue emphysema with soap bubble-like air formations in superficial cervical connective tissue near the lower attachment of left sternocleidomastoid muscle—"in situ" (woman, 57 years old).*

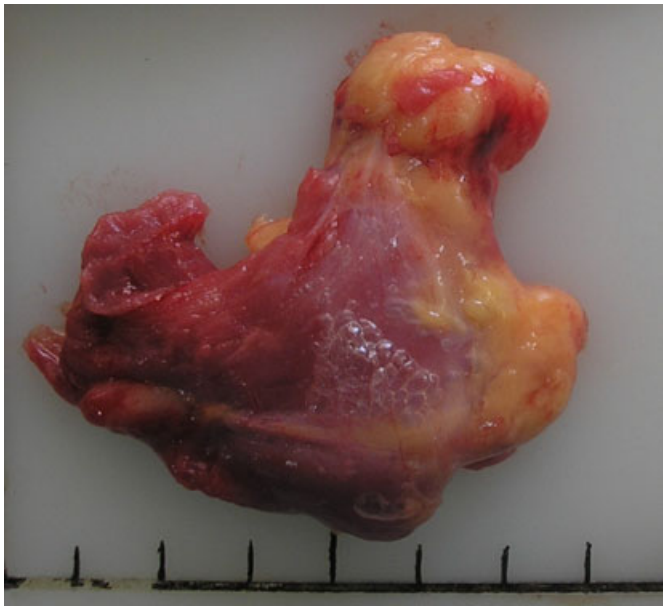

FIG. 2—*Soft tissue emphysema with soap bubble-like air formation on the back side of sternocleidomastoid muscle (man, 33 years old).*

In our sample, CSTE was present in about 53% of cases of hanging, compared to only 7% in nonhanging cases in the control group (two out of 26, Mann–Whitney $U = 590.00$, $p = 0.000$). In forming the control group, observers disagreed in two additional cases, which were excluded from the analysis. There was no correlation between the occurrence of throat-skeleton fractures (hyoid and/or thyroid fractures) and CSTE (Mantel–Haenzel $\chi^2 = 2.893$, $p = 0.089$). This result suggests that the Macklin Effect could be a more probable cause of CSTE rather than direct or indirect trauma to the cervical airways. However, recent studies on filmed hangings have suggested that there might not even be fatal airway obstruction in hanging (13), and therefore no increased intrathoracic pressure, which undermines the Macklin Effect as a potential mechanism. Unlike postmortem imaging, autopsy does not allow for the exact detection of gas propagation along chest and neck organs in such cases. Soft and solid neck structures preparation by layers only allows for the visualization of CSTE, but does not explain its origin clearly. Therefore, the pathophysiology of the finding remains unclear at this time. This phenomenon could also be a postmortem artifact caused by cardiopulmonary resuscitation or inappropriate autopsy technique and also could be misinterpreted with putrefaction gas.

In the observed sample, there were no statistically significant differences in the average age between the groups with and without throat-skeleton fractures ($t = 0.201$, df = 81, $p = 0.841$), although these injuries were more frequent in subjects older than 30 years (Fisher's exact test value $p = 0.040$). The rate of throat-skeleton fractures in cases of hanging increases with the age of the deceased (14), and this could be explained by a greater rigidity of the entire throat complex because of the ossification of laryngeal cartilage being completed at around 30–40 years of age (15,16). Testing a multiple regression model for correlation of the age of the deceased with the presence of a throat-skeleton fracture, the occurrence of Simon's bleeding and CSTE was significant for the whole model ($F = 5.105$, $p = 0.003$). However, there was no correlation between the occurrence of throat-skeleton fracture and the age of the deceased ($B = 1.278$, $p = 0.751$). On the other hand, there was a statistically significant difference in average age between the groups with and without Simon's bleedings ($t = 3.946$, df = 81, $p = 0.000$). Multiple regression analysis showed that the probability of a person having Simon's bleedings decreased with the age of the deceased ($B = -14.852$, $p = 0.000$). The discovery of these bleedings in the lumbar part of the spinal column in younger persons could be considered as a vital sign of hanging (17,18). Hence, throat-skeleton fractures could more frequently be found in older

subjects who committed suicide by hanging, but Simon's bleedings could be more frequent in younger subjects. There was no statistically significant difference in average age between the groups with and without CSTE ($t = 0.375$, df = 81, $p = 0.708$), and multiple regression showed that there was no correlation between the occurrence of this phenomenon and the age of the deceased ($B = 0.618$, $p = 0.871$). This means that unlike Simon's bleeding and throat-skeleton fractures, which are specific for certain age groups, CSTE could be observed regardless of the age of the deceased.

So far, our work is the first prospective autopsy study, which points out the frequency of CSTE in cases of hanging. Numerous local vitality reactions have been associated with hanging: direct—hemorrhages into the skin between two strangulation marks in the case of several loops; or indirect—hemorrhages within the point of the sternocleidomastoid muscles' attachment, in the auxiliary inspiratory muscles and trunk muscles, as well as Simon's bleedings. The same value can be attributed to hemorrhaging accompanying throat-skeleton fractures, as well as to the congestive hemorrhaging in the conjunctiva, at the root of the tongue, in the pharynx, of the laryngeal mucosa, of the salivary glands, the galea, and the temporal muscles. These vital reactions are not compulsory in hanging, and they can also be produced postmortem (19,20). Some authors suggested some new vital signs in cases of hanging, which are controversial or of uncertain significance (21–25). Although the underlying mechanism of CSTE occurrence in hanging remains unclear, our study suggests that this phenomenon could be considered as a vital sign in cases of hanging. This possible new vital sign is easy to recognize: during gross examination of the neck region and preparation of structures by layers, CSTE is presented as frothy air, soap bubble-like formations in superficial and/or deep connective tissue between the neck muscles up to the ligature mark. This special neck preparation autopsy technique is cheap, simple, and easy to apply, especially in institutions where there is no possibility to perform postmortem imaging. Additionally, in cases of smothering, choking, soft ligature hangings etc., with an absence of obvious neck injuries and other vital signs (local tears, soft tissue hemorrhages, throat-skeleton fractures, etc.), CSTE, as a possible vital sign, could point out premortal fatal airway obstruction as well as the pathophysiology of the fatal event.

The interpretation of positive cervical soft tissue emphysema must be taken with caution, because the underlying mechanism in hanging remains unclear: it could be an antemortem phenomenon possibly because of either Macklin Effect or direct or indirect trauma to the cervical airways, as well as an ante- or postmortem artifact.

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