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ORIGINAL ARTICLE

Bowel wall hemorrhage after death by hanging

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Abstract We describe and discuss autopsy findings of bowel wall hemorrhage in a study population comprising cases of suicidal death by hanging. Intramural hemorrhages were seen in approximately 12% of the cases examined; no preexisting bowel diseases were found. In hanging deaths with a longer agonal phase, we opine that abdominal congestion during the hanging process provides a viable pathophysiological explanation for bowel wall hemorrhage. Though we are not dealing here with obligatory autopsy findings, the detection of bowel wall hemorrhage might be used as another sign of vital hanging after considering differential diagnostic aspects.

Keywords Bowel wall hemorrhage · Vital signs · Hanging · Suicide · Autopsy

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Introduction

Within the context of classifying the manner and cause of death and excluding external events, the medicolegal autopsy of a person found in a hanging position will have to clarify whether the person hanged himself or was hanged while alive or whether he was placed in a hanging position as a corpse—in order to cover up a homicide, for example. Apart from the evidence available at the scene of corpse discovery and the lack of defensive wounds, the so-called postmortem signs of vitality may be useful here.

Vital reactions are generally divided into local lesions (injuries of the laryngeal framework and hyoid bone as well as around the ligature mark), systemic reactions (signs of congestion in the head and neck region and systemic signs in the histomorphological analysis of lung tissue), and indirect lesions (strain-induced bleeding in the sternocleidomastoid muscles and hemorrhages beneath the anterior longitudinal ligament, so-called Simon's hemorrhages) [1, 2]. Findings used as evidence of vital hanging include a double zone of hyperemia above and below the ligature mark, congestive hemorrhages above the ligature mark, a positive phosphatide sample [3], pulmonary dystelectasis and the pulmonary microembolism syndrome [4], as well as occasional pulmonary embolism and signs of aspiration [3, 5, 6]. However, single morphological findings are nonspecific [7–9] and may not necessarily be of vital origin or can also be provoked postmortem [3, 10]. Thus, it is important to apply as many signs of vitality as possible in order to classify the manner and cause of death and exclude postmortem hanging to cover up a homicide in the synopsis of

the criminal investigation, the inspection of the scene of corpse discovery, and the medicolegal autopsy.

After observing segmental bowel wall hemorrhage at the autopsy of a hanged person, the first author performed a literature search to explore such phenomena. It yielded only one study from 1993. Here Maxeiner described bowel wall hemorrhage after death by strangulation or throttling [11] but attributed these findings to mechanical trauma, since the study involved only homicide victims and the perpetrator "threw" himself on the recumbent victim during the homicidal act in at least some of the cases investigated.

The first author was subsequently able to observe additional cases of bowel wall hemorrhage at autopsies of hanged persons performed by various medical examiners. The repeated observation of bowel wall hemorrhage gave rise to a retrospective analysis that yielded a total of nine cases of small or large bowel hemorrhage after death by hanging (2005–2009).

It was not possible to retrospectively answer the question regarding a possible "dark figure" of bowel wall hemorrhage diagnosed at postmortem examination but not recorded in the autopsy protocol. The question as to pathophysiological connections in the development of bowel wall hemorrhage and its possible classification as another sign of vitality in hanging death cases prompted the authors to conduct this retrospective study.

Material and methods

Based on the respective autopsy protocols and investigation files, all hanging death cases submitted to postmortem examination at the Institute of Legal Medicine, University of Hamburg, from 2005 to 2009 were retrospectively collected and evaluated with regard to gender, age, height, weight, postmortem interval, putrefactive changes, manner of hanging, signs of congestion in the head and neck region, severity and localization of bowel wall hemorrhage, hemorrhages in the auxiliary respiratory muscles, Simon's hemorrhages, preexisting diseases, and alcohol level or toxicologically relevant influence at the time of death. Corpses in an advanced state of putrefaction were excluded from the study because of highly limited assessment; those with incipient putrefactive changes in terms of green discoloration of the abdominal walls were included in the study. The hanging death cases were further classified into: (a) a study group with bowel wall hemorrhage described in the autopsy protocol and (b) a control group without bowel wall hemorrhage described in the autopsy protocol.

In cases of bowel wall hemorrhage after death by hanging, the complete histological examination results were included for further evaluation; in this connection, areas of macroscopic hemorrhage were evaluated as well as adjacent parts of the bowel that appeared normal to the naked eye at autopsy. In the control group, a histological workup was not done if bowel walls were described as normal at autopsy, this was mainly due to the fact that, because of the normal macroscopic findings, no tissue sections were stored for later histological processing.

Statistic evaluation

For examination of statistic significances concerning differences of the frequency between groups, the two-sided *t* test was used [12].

Results

The total study population ($n=74$) consisted of 58 men and 16 women. All suicide cases classified as vital hanging based on the autopsy findings. They had a median age of 46 years (±16.4 SD), a median height of 175 cm (±7.8 SD), and a median body weight of 72.5 kg (±13.5 SD); the median body mass index (BMI) was thus 23.6 kg/m^2 (±3.3 SD). Sixty hours (±34.4 SD) had elapsed between the time of death and the autopsy (as far as reconstructible). Twenty-seven of the cases showed incipient putrefactive changes in terms of green discoloration of the abdominal walls, while 47 exhibited no signs of putrefaction at autopsy. In 40 cases, death was due to typical hanging (free suspension without ground contact), while 34 of the hanged persons had ground contact. Signs of congestion in the head and neck region were seen in 23 cases. In 18 cases, autopsy disclosed hemorrhages in the auxiliary respiratory muscles, mostly in the scapular region (indicative of maximum strain on the auxiliary respiratory muscles [13, 14]). Thirty-six of the cases showed hemorrhages beneath the anterior longitudinal ligament (so-called Simon's hemorrhages). Preexisting diseases were found in 33 cases, but none of them involved the gastrointestinal tract. Alcoholization was seen in 24 cases with high levels in some of them (between 0.05‰ and 2.76‰). Toxicologically relevant findings were detected in only two cases: one with combined nonlethal methadone and diazepam intoxication and the other with an overdose of nonsteroidal anti-inflammatory drugs.

Nine of the retrospectively examined hanging death cases (12.1%) had bowel findings indicative of hemorrhage according to data contained in the respective autopsy protocols. In another 65 hanging death cases (87.9%), the autopsy protocols yielded no data suggestive of bowel hemorrhage.

Table 1 shows findings of bowel wall hemorrhage in the study population. Table 2 provides a survey of all parameters collected in the study population and the control group, as exemplified by the study group. All data are also available as electronic supplemental material (ESM).

Table 1 Bowel wall hemorrhage in the study population

No.	Gender	Age (years)	. interval (h)	Small bowel	Large bowel
1	F	32	36	Normal	Transverse colon: multiple, small/large patchy, sharply delimited wall hemorrhages
2	M	46	72	Terminal ileum: 2×1.5-cm wall hemorrhage	Ascending/transverse colon: diffuse patchy wall hemorrhages
3	M	31	60	Terminal ileum: 0.5–3-cm irregularly distributed, sharply delimited wall hemorrhages	Normal
4	M	41	9	Terminal ileum: max. 2-cm patchy wall hemorrhages	Normal
5	M	47	60	Segmental patchy wall hemorrhages	Normal
6	M	23	84	Duodenum: segmental patchy wall hemorrhages	Normal
7	F	35	36	Terminal ileum: 2×1.5-cm wall hemorrhage	Normal
8	F	17	60	Entire small bowel: marked congestion, focal with hemorrhages	Normal
9	M	43	2	Terminal ileum: 2×3-cm-large wall hemorrhages, bowel markedly bloated	Normal

Study group

The study group consisted of six men and three women with a median age of 35 years (±10.4 SD), a median height of 175 cm (±7.3 SD), and a median body weight of 68 kg (±15.4 SD); their median BMI was thus 22.7 kg/m^2 (±4.3 SD). Sixty hours (±27.9 SD) had elapsed between the time of death and the autopsy (as far as reconstructible). Four of the cases showed incipient putrefactive changes in terms of green discoloration of the abdominal walls, while five exhibited no signs of putrefaction at autopsy. In three cases, death was due to typical hanging (free suspension without ground contact), while six of the hanged persons had ground contact. Signs of congestion in the head and neck region were found in only one case.

In eight of the nine cases, multiple hemorrhages were detected in the bowel wall by macroscopic and histological examination. They tended to be small patches with an expansion of 0.5–3 cm and were localized in the following bowel segments: the entire small bowel (n=1), the duodenum (n=1), the terminal ileum (n=6), the ascending colon (n=1), and the transverse colon (n=2).

Hemorrhages were seen in the small bowel in eight cases and in the large bowel walls in two cases. One case exhibited hemorrhages in both the small and large bowel walls; it was the only one with petechial hemorrhages in the skin and mucosa of the head and neck region. All bowel hemorrhages were macroscopically detectable (Figs. 1 and 2).

All vessels histologically showed strong dilatation (congestion)—decreasing toward hemorrhage-free areas—and were engorged with erythrocytes. Strong, fresh, variously sized hemorrhages without cellular reactions were found largely in the submucosa but focally also in the muscularis and extending to the serosa (Figs. 3 and 4). In another case, the primary finding was marked congestion, particularly of the submucosa (precursor of bowel wall hemorrhage). There were no hemorrhages into the autolyzed bowel mucosa or blood-tinged contents in the bowel lumen. The histological examination yielded no indications of microthrombosis in the affected afferent or efferent vessels. No edematous mucosa was detected.

The histological workup of adjacent hemorrhage-free bowel segments did not yield pathological findings in any of the cases—apart from foci of mild congestion.

An exception was a case of hanging survived for 3 days. Here platelet aggregates and fibrin were histologically detected in the submucosal vessels; the mucosa and submucosa showed slight to moderate lymphocyte and granulocyte infiltration. Only this case also showed mild hemorrhages into the bowel mucosa (Fig. 5).

No preexisting bowel diseases were found in any of the cases.

In two cases, autopsy and histology disclosed hemorrhages beneath the muscles in the scapular region. Five of the nine cases showed hemorrhages beneath the anterior longitudinal ligament. Hepatic steatosis was seen in two cases; no other preexisting diseases were found. Alcoholization was seen in five cases with high levels in some of them (between 0.63‰ and 2.29‰); all other toxicological examinations remained negative despite a reported history of diazepam abuse in one case.

Some cases showed content-related pulmonary vascular changes in the form of platelet aggregates, which were detected in combination with myeloid cells of varying maturity in one case [4]. The histological examination did not disclose pulmonary fat embolism in any of the cases.

Table 2 All parameters collected in the study population and the control group, as exemplified by the study group

No.	Gender	Age (years)	Height (cm)	Weight (kg)	BMI (kg/m^2)	P.M. interval (h)	Putrefaction	Manner of hanging	Congestion in the head and neck region	Small bowel	Large bowel	Muscle hemorrhages	Simon's hemorrhages	Preexisting diseases	BAC/Toxicology
1	F	32	170	58.4	20.21	36	Green putrefaction, lower abdomen	Freely suspended	−	Normal	Transverse colon: multiple, small/large patchy, sharply delimited wall hemorrhages	–	+	–	1.30‰, history of diazepam abuse
2	M	46	174	98.4	32.50	72	No signs of putrefaction	Sitting	+	Terminal ileum: 2×1.5-cm wall hemorrhage	Ascending colon/transverse colon: diffuse patchy wall hemorrhages	Scapulae	−	–	1.64‰
3	M	31	182	83.7	25.27	60	Green putrefaction, lower abdomen	Standing	−	Terminal ileum: 0.5–3-cm, irregularly distributed, sharply delimited wall hemorrhages	Normal	–	+	Hepatic steatosis	1.80‰
4	M	41	178	72	22.72	9	No signs of putrefaction	Freely suspended	−	Terminal ileum: max. 2-cm patchy wall hemorrhages	Normal	–	+	–	0.63‰
5	M	47	175	63.1	20.60	60	Green putrefaction, lower abdomen	Standing	−	Segmental patchy wall hemorrhages	Normal	Scapulae	−	–	–
6	M	23	183	67.5	20.16	84	Green putrefaction, lower abdomen	Standing	−	Duodenum: segmental patchy wall hemorrhages	Normal	–	+	–	–
7	F	35	167	68	24.38	36	No signs of putrefaction	Sitting	−	Terminal ileum: 2×1.5-cm wall hemorrhage	Normal	–	−	–	2.29‰
8	F	17	162	53	20.20	60	No signs of putrefaction	Freely suspended	−	Entire small bowel: marked congestion, focal with hemorrhages	Normal	–	+	Hepatic steatosis	–
9	M	43	182	92	27.77	2	No signs of putrefaction	Squatting/survived for 3 days	−	Terminal ileum: 2×3-cm wall hemorrhages, bowel markedly bloated	Normal	–	−	–	–

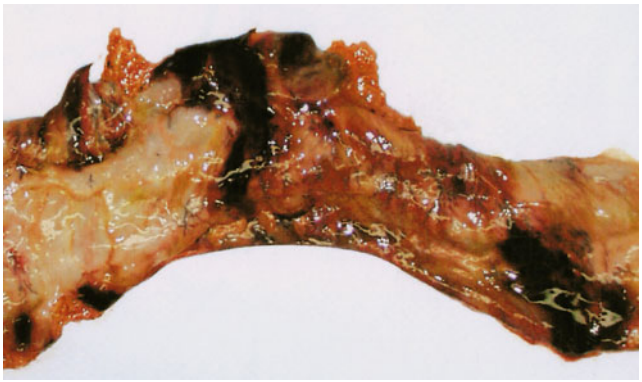

Fig. 1 Macroscopic findings: multiple, small/large patchy, sharply delimited wall hemorrhages in the terminal ileum

Control group

The 65 hanging death cases consisted of 52 men and 13 women with a median age of 50 years (±16.6 SD), a median height of 175 cm (±7.9 SD), and a median body weight of 73 kg (±13.3 SD); the median BMI was thus 23.7 kg/m^2 (±3.2 SD). Sixty hours (±34.5 SD) had elapsed between the time of death and the autopsy (as far as reconstructible). Twenty-three of the cases showed putrefactive changes in terms of green discoloration of the abdominal walls, while 42 exhibited no signs of putrefaction at autopsy. In 37 cases, death was due to typical hanging (free suspension without ground contact), while 28 of the hanged persons had ground contact. Signs of congestion in the head and neck region were seen in 22 cases. There were hemorrhages beneath the scapular muscles in 16 cases and beneath the anterior longitudinal ligament in 31. Thirty-one cases had preexisting diseases affecting the cardiovascular system (24 cases) as well as the respiratory system (7 cases). Other preexisting diseases, e.g., diabetes mellitus, were not found in any of the cases, especially not of the gastrointestinal tract.

Fig. 2 Macroscopic findings: multiple, small/large patchy, sharply delimited wall hemorrhages in the transverse colon

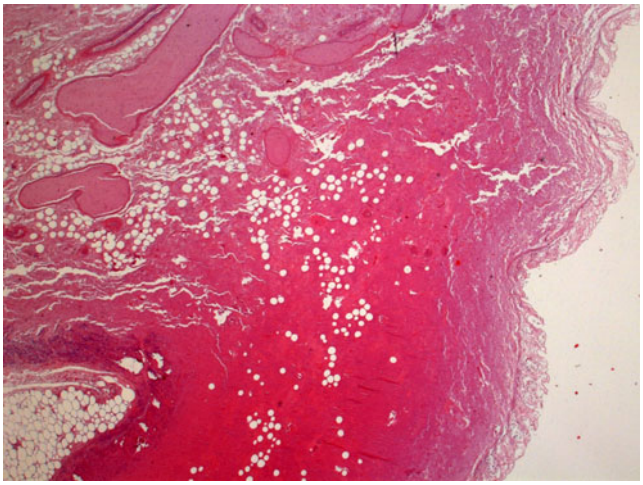

Fig. 3 Histological findings: transverse colon—strong fresh hemorrhages mainly in the submucosa, focally also in the muscularis and extending to the serosa without cellular reaction. No vessel wall alterations. Strong dilatation of the bowel wall vessels engorged with erythrocytes. Autolyzed mucosa without hemorrhage. Hematoxylin–eosin staining ×12.5

Alcoholization was seen in 19 cases with high levels in some of them (between 0.05‰ and 2.76‰). As stated above, toxicologically relevant findings were detected in only two cases. A histological workup of bowel segments was not done.

Statistic results

A significant connection between the occurrence of bowel wall hemorrhage and the other parameters recorded in both

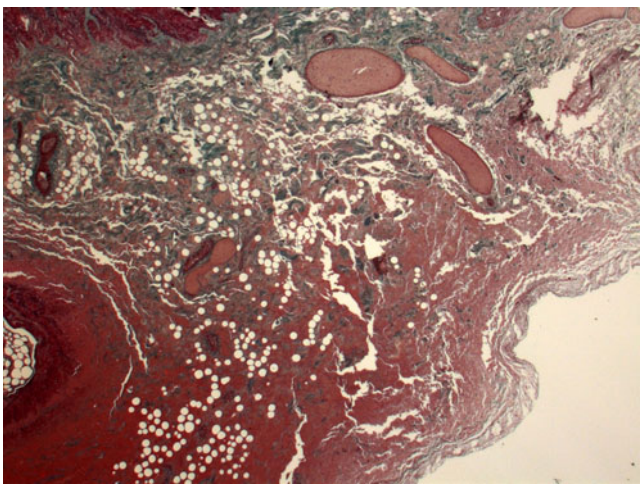

Fig. 4 Histological findings: transverse colon—strong fresh hemorrhages mainly in the submucosa, focally also in the muscularis and extending to the serosa without cellular reaction. No vessel wall alterations. Strong dilatation of the bowel wall vessels engorged with erythrocytes. Autolyzed mucosa without hemorrhage. Masson–Goldner staining ×12.5

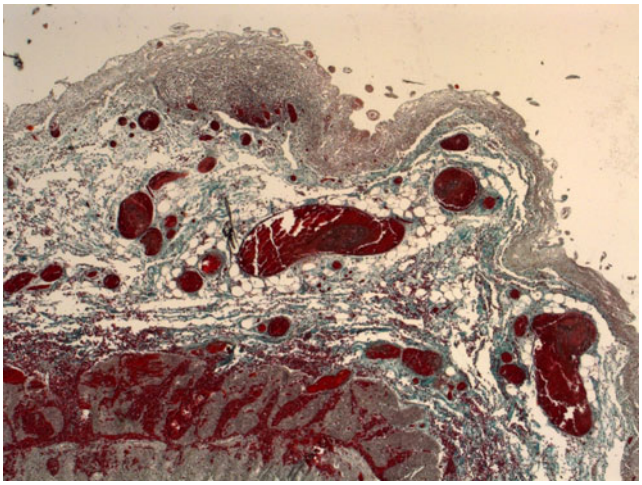

Fig. 5 Histological findings: terminal ileum—hemorrhages in the submucosa and particularly in the muscularis. Focal platelet aggregates and fibrin in the vessels filled with erythrocytes. Circumscribed mucosal hemorrhages. Slight to moderate infiltration of the mucosa and submucosa with lymphocytes and granulocytes (hanging survived for 3 days, Masson–Goldner staining ×25)

groups was found for the median age (two-sided *t* test, $p=0.029$). No other statistically significant differences were found between the study and the control group for the other parameters evaluated.

Discussion

The autopsy diagnosis of "bowel wall hemorrhage" initially implies several differential diagnostic considerations on the part of the medical examiner. Apart from autolysis and artifacts of putrefaction, these also include mechanical trauma or so-called shock bowel with impaired microcirculation and microthrombi or hypoperfusion-related hemorrhages in terms of abdominal angina or mesenteric infarction; secondary hemorrhages can then occur in the areas of ischemic mucosal damage [15]. It must also be taken into account that segmental bowel wall hemorrhage may be triggered by diapedetic hemorrhages in diseases like congenital or acquired clotting disorders (related, for example, to disseminated intravascular coagulation or sepsis) [16, 17]. The gastrointestinal tract can also be altered by patchy or punctiform (mucosal) hemorrhages in conjunction with hypothermic processes [18].

Artifacts of putrefaction could be excluded as a cause of segmental bowel wall hemorrhage in our study population; just mild putrefactive changes were seen in only four of the nine cases. The traumatic mechanical cause of bowel wall hemorrhage postulated by Maxeiner could not be confirmed in our study population [11]. There were no indications of hypothermia at the time of death. Moreover, no relevant preexisting diseases, particularly none affecting the gastrointestinal tract, were found in any of the studied cases.

Further differential diagnostic considerations were thus necessary: conceivable in hanging death cases are signs of abdominal congestion in conjunction with acute circulatory dysregulation, which can in places lead to hemorrhagic infarction of bowel wall layers without (ischemic) hemorrhage into the mucosa [19]. Primary ischemic lesions with secondary hemorrhagic infarction of the bowel wall did not seem plausible—they would manifest earliest in the mucosa [20]. In the cases we examined, however, the inner lining of the bowel was histologically normal with no hemorrhage. Since intramural hemorrhages were found in all cases except the one in which hanging was survived for 3 days, acute enteral congestion was assumed to be the cause of bowel wall hemorrhage. The bowel mucosal hemorrhage in the 3-day survival case may have been due to shock bowel or stress hemorrhage occurring in conjunction with protracted multiple organ failure and hypoxic brain damage in the course of intensive care therapy.

In cases of typical hanging, peracute anoxia with carotid occlusion leads to an interruption of respiratory center perfusion; this prevents the rise in systemic carbon dioxide that triggers respiration. An immediate effect is strong respiratory suppression. A loss of consciousness also occurs within a few seconds [3, 21, 22]. However, cardiac action has been found to persist considerably longer: Agonal phases of 7–20 min (even longer in some cases) have been described for executions by hanging [23–26]. Initial bradycardia and forceful heart beats (with possible congestion proximal to the right heart) are observed initially, followed by tachyarrhythmia and ultimate cardiac arrest [3, 27]. Atypical hanging additionally results in signs of congestion in the head and neck region due to the initially incomplete interruption of intracranial arterial perfusion in conjunction with ligature-induced interruption of venous drainage. Another consideration being discussed is mechanical irritation of the carotid sinus by ligature traction with resultant systemic blood pressure decoupling and additional hypoxemia-induced alteration of the autonomic nervous system. On the whole, the pathophysiological processes are heterogeneous in hanging death cases [28]. In summary, acute hypoxemic and vegetative circulatory dysregulation with fluctuations of blood pressure and heart rate is currently assumed to occur during the long agonal phase.

Congestion of the splanchnic area seems plausible to us—a sign of abdominal congestion is the acute congestion of parenchymal abdominal organs (except the spleen) regularly seen at the autopsy of hanged persons.

On the whole, the abdominal viscera are extremely well-perfused; blood flow is precisely regulated: 28% of the stroke volume is taken up by visceral perfusion; there is a

high pressure gradient between the arterial and venous beds (approx. 1:10), and the blood supply is regulated by vasomotor reactions of the small arteries under sympathetic and parasympathetic influence [20]. The mesenteric circulation and peristalsis are thus regulated very sensitively by the autonomic nervous system. In conjunction with a postulated postcapillary congestion, bowel wall spasms due to vegetative decoupling of the autonomic nervous system during the hanging process could explain the segmental manifestation of hemorrhages. Catecholaminemia has also been observed in conjunction with hanging [29]; this could induce systemic hypertension and cause enteral congestion in the presence of concomitant bradycardia with high pulse pressure, resultant heart failure, and a longer agonal phase. Even the heart itself can be affected by increased catecholamine secretion; a recent report describes catecholaminemia-related left ventricular dysfunction in a case of survival after attempted suicide by hanging [30].

Systemic hypertension through increased catecholamine secretion in hanging death cases with concomitant anoxic decoupling of the right and left heart in the course of acute circulatory dysregulation could thus explain the above-described hemorrhagic enteropathy due to postcapillary congestion with increased visceral perfusion.

As mentioned, the only statistically significant connection between the occurrence of bowel wall hemorrhage and the other parameters evaluated was found for the median age (two-sided t test, $p=0.029$): the difference determined—a markedly higher age in the control than in the study group (50±16.6 SD as opposed to 35±10.4 SD)—could be due to the fact that older people had already developed relevant cardiovascular diseases that can limit the duration of the agonal phase and thus also the occurrence of bowel wall hemorrhage.

The small bowel seems to be more susceptible than the large bowel to intramural hemorrhages with enteral congestion—we have no explanation for this at present. It also remains unclear whether the approximately 12% incidence detected in our study corresponds to the actual occurrence of the enteropathies. It is conceivable that more cases of bowel wall hemorrhage after death by hanging could have occurred but were regarded as an unimportant secondary finding and therefore not recorded.

To further validate the pathophysiological interrelationships we have postulated here, it will be necessary in the future to also consistently examine and assess enteral congestion and bowel wall hemorrhage in a larger study population of hanging death cases.

Conclusions of practical interest

To clarify whether a person hanged himself or was hanged while alive or whether he was placed in a hanging position as a corpse (to cover up a homicide, for example), it is important to look for postmortem signs of vitality, which can also be manifested as visceral congestion, depending on the biomechanical conditions as well as the duration of the agonal phase and the complex pathophysiological processes. The detection of hemorrhages in the small and large bowel walls can be used as another sign of vital hanging after considering differential diagnostic aspects of abdominal congestion.

Conflict of interest There is no conflict of interest. The corresponding author affirms that he has no relationships with a company whose product is mentioned in the article or with one that sells a competitive product. The presentation is impartial, and the content is independent of commercial influence.

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