

Simon's bleedings: a possible mechanism of appearance and forensic importance—a prospective autopsy study

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Abstract Simon's bleedings are stripe-like hemorrhages on the ventral surface of the intervertebral disks of the lumbar part of the spinal column. The aims of this study were to determine the appearance frequency of Simon's bleedings in cases of hanging and in other cases of asphyxiations and to determine if the age of the deceased was in correlation with the occurrence of Simon's bleedings. A prospective autopsic study included 147 cases of hanging, 39 other asphyxiation deaths, and 461 deaths other than asphyxiation (blunt trauma, natural deaths, etc.). Simon's bleedings were present in 62.8% cases of hanging and in 61.5% cases of other types of asphyxiations. Simon's bleedings are not specific for hanging ($\chi^2=0.022$, $p>0.05$). Simon's bleedings were less frequent in other cases. It was established that the older the person was, the possibility of Simon's bleedings to occur would be less (Spearman's correlation coefficient= -0.225 , $p<0.001$; Wald coefficient= 29.798 ,

$p<0.001$). In the cases of hanging, there is statistically significant difference in average age between the groups with and without Simon's bleedings ($t=2.875$, $p=0.017$). The older the person was, the lower the likelihood of Simon's bleedings to occur: if the person was more than 60 years old, there was 70% probability of not having Simon's bleedings, and if older than 70, this probability would rise to 88% (Wald coefficient= 7.609 , $p=0.021$). In older persons who died due to hanging, throat skeleton fractures accompanied by local hemorrhage could be considered as a vital sign. In younger persons, where throat skeleton fractures are less frequent, Simon's bleedings could be the vital sign of premortem hanging. Simon's bleedings, in cases of asphyxiation, most likely occur due to agonal convulsions and forced movements in lumbosacral part of spinal column. Additional factor for the appearance of Simon's bleedings in hanging is traction of body and especially this part of spinal column due to gravity.

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Introduction

Hanging is a form of ligature strangulation in which the force applied to the neck derives from the gravitational drag of the weight of the body [1]. A furrow is the ligature mark on the skin in cases of hanging, usually localized above the larynx. Initially, the furrow is a pale or slightly yellow parchment-like area, which, with suspension time, becomes brownish [2]. The furrow is more detectable as the suspension time becomes longer and as the ligature material becomes harder. The furrow is a postmortem phenomenon.

Internal neck injuries, caused by direct compression or indirect stretching mechanisms by ligature in hanging, could be considered as vital signs in these cases: fracture of the throat skeleton, or soft tissue hemorrhage. Various reports of the frequency of solid neck structure fractures can be found in the literature, and these results range from 9.5% to 76.7% [3–9]. The rate of fractures increased with the age of the deceased [4, 9] and the length of suspension time [10, 11]. The incidence of these injuries is higher in prospective than in retrospective studies [11, 12]. Therefore, in some cases of hanging, there are no fractures of the throat skeleton or even neck soft tissue injuries, and the question arose if these hangings were postmortem. Some authors suggested some new vital signs in cases of hanging such as high postmortem levels of thyroglobulin [13], histological finding of aggregates of pulmonary surfactant released in cases of mechanical asphyxia due to strong forced breathing [14], pneumomediastinum and neck soft tissue emphysema [15], and levels of stress hormones such as adrenaline and noradrenaline and their quotient, which are different compared to levels in sudden death or to the deaths with long agony [16]. Some authors suggest magnetic resonance imaging examination of the neck in addition to classical examination [17].

One of the aims of this study was to determine the frequency of Simon's bleedings (Simon's sign or symptom) in the lumbar region of the spinal column in cases of hanging, as well as in other cases of suffocation and strangulation, and also in asphyxial deaths caused by physical injuries (electrocution) and intoxication (carbon monoxide poisoning). This study also aimed to determine the frequency of Simon's bleedings in cases where the cause of death was not asphyxia, to determine if the age of deceased correlated with the occurrence of Simon's bleedings, to propose a possible mechanism of appearance of this phenomenon, based on results of the research, and to determine if Simon's bleedings in the lumbar region of the spinal column could be considered as a vital sign of hanging.

Materials and methods

A prospective autopsy study was performed. In selected cases, the preparation of soft tissue and organs was performed to make the lumbar region of spinal column completely visible. In each case, gross examination of this region showed if Simon's bleedings were present or not, without grading the intensity of bleeding (more or less intensive) and also without specifying the precise level of the lumbar region of the spinal column where the bleeding occurred. The sample consisted of persons who died immediately or died shortly after the event or occurrence of symptoms (e.g., during transport to a hospital). The

survey included only suicidal hangings; hanging in a sitting or lying position was excluded. The time from death to autopsy was in the range from 12 to 48 h. The sample was analyzed with respect to the occurrence of Simon's bleedings, cause of death, and age. The obtained data were statistically analyzed using Pearson's χ^2 -test, Student's *t*-test (with Mann–Whitney sum ranks test when necessary) for estimating differences, binary logistic regression, and Spearman's correlation coefficient for estimating relationships. A *p* value less than 0.05 was considered significant and less than 0.01 as highly significant.

Results

A total of 647 cases were included in the study, 454 men and 193 women (gender ratio, 3:1). Table 1 shows the sample distribution in relation to Simon's bleeding, age, and cause of death.

A total of 147 cases of hanging were included in the study. We also studied and observed the group of asphyxiation deaths other than hanging—total of 39—which consisted of 28 cases of strangulation and suffocation (nine cases of choking on food, 13 immersions, one case of smothering, and five cases of thoracoabdominal compression), seven cases of physical (electrocution), and four cases of chemical asphyxiation (carbon monoxide poisoning). The group of cases where the cause of death was due to blunt trauma (154 cases) included 42 pedestrians, 46 car passengers, 16 motorcycle and bicycle riders, 37 suicidal and accidental falls from heights, eight falls from one's own height, and five cases of blunt trauma caused by fight. The group where the manner of death was natural (214 cases) included 146 cases of sudden cardiac deaths, 20 cases of pneumonia, 18 cases of complications of acute or chronic peptic ulcer, 13 cases of malignoma, 12 cases of pulmonary thromboembolism, three cases of cerebrovascular insult, two cases of acute renal insufficiency, and one case of sepsis. Deaths due to firearms injuries (44 cases), stab wounds (seven cases), and deaths caused by thermal burns (four cases) made a separate group. Average ages of persons with or without Simon's bleedings, with respect to cause of death, are shown in Table 2.

Discussion

Indirect lesions due to hanging, which could be regarded as vital signs, include hemorrhages at the origin of the sternocleidomastoid muscles, hemorrhages in the auxiliary inspiratory muscles, as well as stripe-like hemorrhages on the ventral surface of the intervertebral disks of the lumbar part of the spinal column [18].

Table 1 Sample distribution with respect to Simon's bleedings, age, and cause of death

Cause of death	Simon's bleedings	Age (years)								Total	
		<20	21–30	31–40	41–50	51–60	61–70	71–80	>80		
Hanging	Yes	2	10	14	19	26	10	8	4	93	148
	No	0	8	3	10	7	7	14	6	55	
Strangulations and suffocations	Yes	1	2	2	2	2	5	2	0	16	28
	No	1	1	0	0	5	3	2	0	12	
Electrocution	Yes	1	3	1	0	1	1	0	0	7	7
	No	0	0	0	0	0	0	0	0	0	
Carbon monoxide poisoning	Yes	0	0	1	0	0	0	0	0	1	4
	No	0	0	0	1	1	1	0	0	3	
Blunt trauma	Yes	3	12	4	7	3	4	0	0	33	154
	No	8	22	9	16	20	21	18	7	121	
Natural death	Yes	0	1	5	2	11	6	4	4	33	214
	No	1	2	11	25	39	32	41	30	181	
Hypothermia	Yes	0	0	0	1	1	1	1	1	5	14
	No	0	0	0	1	1	2	1	4	9	
Drug abusers	Yes	1	4	5	1	0	0	0	0	11	33
	No	0	8	3	1	0	0	0	0	12	
Other ^a	Yes	0	3	2	2	2	1	0	0	10	55
	No	4	6	4	9	6	3	6	7	45	
Total	Yes	8	35	34	34	46	28	15	9	209	647
	No	14	47	30	63	79	69	82	54	438	

^a Other includes firearms injuries (44 cases), stab wounds (seven cases), and deaths caused by thermal burns (four cases)

In 1968, Simon first described streaky hemorrhages of the ventral surface of the spinal disk (in 53 out of 63 cases) and, later, the hemorrhages at the dorsal surface (in 36 out of 39 cases) in the cases of hanging. Brinkmann recapitulated results of German authors and quoted Prokop who had found this type of bleeding in cases of immersion [19]. Most of the authors quoted by Brinkmann and also by Lignitz and Henn had confirmed the findings of Simon: Geserick et al. in 1976 (in 29.2% of retrospectively evaluated 840 cases), Kleiber et al. in 1982 (in 47% of 222 cases) as well as Saternus in 1979 (56% in 32 cases), and Kerde have not found these bleedings in postmortem hanging and therefore considered them not to be a postmortem phenomenon [19–21]. All of these findings date 20 to 40 years ago, and there are no recent studies on this subject.

In our sample, Simon's bleedings were present in 62.8% cases of hanging.

Furthermore, in cases of other mechanical asphyxiation, Simon's bleedings were present in considerable number: in 57.1% of cases in asphyxia due to physical injuries; in all seven cases of electrocution, and in one out of four cases of chemical asphyxiation—carbon monoxide poisoning. Therefore, considering asphyxial deaths other than hanging in our sample, Simon's bleedings occur in 61.5% of cases (24 out of 39). Comparing the frequency of Simon's bleedings in cases of hanging to other mechanical asphyxia—suffocation and strangulation—as well as all the other asphyxiation deaths, we established no statistically significant difference between them ($\chi^2=0.324$, $p>0.05$ and $\chi^2=0.022$, $p>0.05$, respectively). Therefore, concerning all other types of asphyxia, Simon's bleedings are not specific for hanging.

Table 2 Sample distribution with respect to Simon's bleedings, average age, and cause of death

Cause of death	Average age (years)		
	Group total	Simon's bleedings present	Simon's bleedings absent
Hanging	53.7±17.9	50.5±16.4	59.0±19.0
Other asphyxiations ^a	50.4±18.6	46.8±19.3	56.9±16.2
Blunt trauma	48.5±20.3	37.5±15.7	51.5±20.4
Natural death	62.8±16.0	59.1±15.8	63.5±16.0

^a Other asphyxiations include 28 cases of strangulation and suffocation, seven cases of physical, and four cases of chemical asphyxiation

In cases of natural death, Simon's bleedings are exceptions rather than the rule and statistically much less frequent than in cases of hanging ($\chi^2=92.311$, $p=0.000$). Most of them were present in cases of sudden cardiac deaths.

Simon's bleedings were statistically less frequent in cases where blunt trauma was the cause of death, compared to hanging ($\chi^2=82.154$, $p=0.000$). Other authors also found them in the cases of blunt trauma [19]. In that observed group, in our sample, Simon's bleedings were most frequent in motorcycle and bicycle drivers (seven out of 16), as well as in car drivers (12 out of 46), falls from heights (seven out of 37), and pedestrians (six out of 42).

Analysis of our results so far showed that the underlying mechanism of Simon's bleedings in cases of hanging compared to other asphyxial deaths is presumably similar but not identical. Saternus et al. [20] pointed out the traction force as the causative factor for Simon's bleedings: bleeding originates due to caudo-rostral hyperextension of the spinal column, as gravity affects the body during hanging. Nevertheless, occurrence of Simon's bleedings in other types of asphyxia suggests that the possible mechanism could also be movement of the spinal column due to agonal convulsions of the subject (e.g., they are present in all seven cases of electrocution). In our series, Simon's bleedings appeared in five out of nine cases of hypothermia. The phenomenon of intense shivering is typical in cases of fatal hypothermia, and this corresponds with the appearance of bleeding in muscles of the iliopsoas and of the back of the trunk [21, 22]. Intense shivering and forceful movements in the lumbosacral part of the spine could also be the mechanism for the appearance of Simon's bleedings in cases of hypothermia. The lumbar part of the spinal column is mostly movable in the junction of the fifth lumbar vertebra and sacrum—extension movements in lumbar intervertebral joints are less intensive. Guan et al. [23] found these structural and mechanical responses under relatively low load magnitudes (up to 4 Nm), close to physiologic load state. Anterior longitudinal ligament at the level of lumbosacral joint is softer than its superior counterparts in the lumbar spine [24]. These are the reasons why we considered complete hangings as well as incomplete hanging in standing and kneeling position—the load was practically sufficient to produce eventual bleeding in lumbosacral complex. Agonal convulsions in suicidal hangings begin shortly after the onset of hanging [25, 26], followed by decortication rigidity with extension of trunk and lower limbs [25]. This could be an initial mechanism for the development of Simon's bleedings, with only few convulsions sufficient to produce it, considering the biomechanics of lumbosacral joint, followed by the effect of gravity and caudo-rostral hyperextension of the body.

Considering the death due to blunt trauma, the basic underlying mechanism of Simon's bleedings could only be the direct or indirect effect of blunt force in the lumbosacral part of spinal column. In our analyzed sample, Simon's bleedings were usually, but not always, apparent in pedestrians hit from behind as well as car occupants in motor vehicles: it seems that the underlying mechanism of Simon's bleedings in these cases is forced extension or flexion movement in the lumbar part of spinal column. Nevertheless, Simon's bleedings are diagnosed in cases of postural asphyxia exactly where forced extension of this part of spinal column existed [27].

Considering the entire sample (total of 647 cases), it is established that the older the person was, the lower the possibility of Simon's bleedings to occur (Spearman's correlation coefficient= -0.225 , $p<0.001$; Wald coefficient= 29.798 , $p<0.001$).

In cases of hanging, there was a statistically significant difference in the average age between the groups with and without Simon's bleedings ($t=2.875$, $p=0.017$). Analyzing this part of sample, it was established that there was low probability of persons older than 55 years having this type of bleeding: if the person was more than 60 years old, there was 70% probability of not having Simon's bleedings, and if older than 70, this probability would rise to 88% (Wald coefficient= 7.609 , $p=0.021$). This is completely opposite to the observation of Saternus et al. [20] that Simon's bleedings are not dependent on the age of deceased or any existing degenerative changes of the spine. We believe that the absence of Simon's bleedings in the elderly, in cases of hanging, is the consequence of degenerative changes in lumbosacral part of the spinal column, which makes it less mobile.

Even in cases where the cause of death was blunt trauma, the probability of a person having Simon's bleedings decreased with age (Spearman's correlation coefficient= -0.280 , $p=0.008$; Wald coefficient= 11.305 , $p=0.010$). However, analyzing the cases of asphyxial death other than hanging, correlation is not statistically significant but only getting close to statistical significance (Wald coefficient= 2.209 , $p=0.071$). There is no statistically significant difference in the average age of persons who died from hanging and those who died from other types of asphyxia ($t=1.030$, $p=0.285$). However, persons who died due to blunt trauma were statistically significantly younger than those who died due to hanging, either comparing whole groups ($t=3.950$, $p=0.008$, $z=3.177$, $p=0.011$) or just those with Simon's bleedings ($t=2.360$, $p=0.019$; $z=2.140$, $p=0.027$).

The rate of throat skeleton fractures in cases of hanging increased with age of the deceased [4, 9]. This could be explained by a greater rigidity of the entire throat complex, with ossification of laryngeal cartilages completing around 30–40 years of age [28, 29]. Hence, in older persons who

died due to hanging, fractures of superior horns of thyroid cartilage and greater horns of the hyoid bone, accompanied by local hemorrhage, could be considered as vital signs of hanging and could be proof of premortem strangulation. On the other hand, specifically in younger persons, where throat skeleton fractures are undoubtedly less frequent, finding of Simon's bleedings in lumbar part of the spinal column could be the vital sign of premortem hanging as well as the proof of premortem hanging.

Simon's bleedings are not specific to hanging. They are also found in other types of asphyxia. Simon's bleedings in cases of asphyxia most likely occur due to agonal convulsions and forced movements in the lumbosacral part of the spinal column. An additional factor for the appearance of these bleedings in hanging is also traction of the body and especially this part of spinal column due to gravity. Simon's bleedings are statistically more frequent in younger persons who died due to hanging. Finding of these bleedings in the lumbar part of the spinal column in younger persons is the vital sign of hanging. The mechanism for the appearance of Simon's bleedings in persons who died due to blunt trauma is forced extension or flexion in lumbosacral part of spinal column, under either direct or indirect effect of mechanical force. Simon's bleedings in cases of natural death are extremely rare.

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