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Characterization of haemorrhages at the origin of the sternocleidomastoid muscles in hanging

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Abstract Haemorrhages at the periostal-clavicular origin of the sternocleidomastoid muscles were found in 52 out of 54 cases of death by hanging. This cervical haemorrhage is most frequently found in death by hanging, but only seldomly seen in other causes of death and can therefore be regarded as being typical for death by hanging. The frequency of this finding on the side of the highest point of the ligature mark is significantly higher, thereby supporting the hypothesis of extension as the causative mechanism. External cardiac massage and assisted breathing have no influence on the occurrence of haemorrhages. Histology shows the haemorrhages to be mainly directly epiperiostal, however, many cases displayed concurrent sub- and intraperiostal extravasations. Artificial post mortem production of these findings is discussed in the light of the literature.

Key words Hanging · Periostal-clavicular sternocleidomastoid haemorrhages · Resuscitation · Histology

Introduction

Clavicular haemorrhages of the sternocleidomastoid muscles are part of the indirectly induced findings in death by hanging. The findings are usually classified as haermorrhages at the point of origin, often falsely called insertion point haemorrhages, without their exact localisation being described. A small number of authors [5, 8, 16] found that, based on macroscopical findings, the haemorrhages could be found in the region of the clavicular periost. Systematic histological examinations pertaining to the site of the haemorrhages have not been carried out to date. As the mechanical stress at the clavicular origin due to neck extension seems to be the main factor in the development of haemorrhages [8, 16], it appears plausible that the intensity of the findings is associated with the localisation of the highest point of the ligature mark. Furthermore, the questions arise as to whether haemorrhages can be observed in other causes of death [17] or whether these findings can be caused by resuscitation attempts. These aspects were the reason for us carrying out this prospective study.

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Materials and methods

A total of 54 cases (11 females, 43 males) of suicidal hanging were examined, including 3 cases where death was delayed by 1, 1.5 and 6 days respectively after hanging. Age was between 12 and 82 years ($\bar{x}$ = 43 years). Resuscitation attempts had been employed in the cases of delayed death as well as in 8 cases where death was immediate. The position in which the deceased had hung was extracted from police records or reconstructed from post mortem findings. So-called typical hanging was only observed in 5 cases. Body mass was also recorded.

The control group consisted of 294 post mortem examinations (96 females, 198 males) in which a variety of causes of death, excluding hanging, had been found. The ages of the deceased were between 2 weeks and 93 years ($\bar{x}$ = 50 years). Resuscitation attempts had taken place in 138 of these cases, the remaining 156 had not been subjected to resuscitational measures. Apart from cardiac massage and assisted breathing, resuscitational measures also included the administration of central venous catheters in 26 cases, most of these being vena subclavia catheters. The time elapsed between death and autopsy in control and study groups was at most 4 days, but bodies with relevant signs of putrefaction were not included in this study.

After exsanguination of the neck region [16], the anterior cervical muscles were dissected in layers. The sternocleidomastoid muscles were detached directly from the claviculae in the usual manner. The tendons were displayed, the clavicular periost was split and the intensity of the haemorrhages recorded.

Haemorrhages from 51 sternocleidomastoid regions of origin (taken from 32 of the total of 52 positive cases) were also examined histologically. In order to prevent artefactual haemorrhages, the periost was not split in these areas of the specimens. Clavicula cross sections with attached soft tissues were taken, decalcified and stained by means of eosin-hematoxilin as well as by the Goldner method.

Results

Frequency of findings in hanging

Periostal-clavicular haemorrhages were found in 52 cases of hanging. Two cases were negative: a body found hanging in a lying position and a case of delayed death 1.5 days after hanging. The remaining 2 cases (one carrying a central venous catheter) of delayed death displayed signs of haemorrhaging. The site of findings in positive cases is shown in Table 1. Bilateral symmetrical haemorrhages were found in 4 cases of typical hanging.

Table 1 Localisation of periostal-clavicular haemorrhages in the region of origin of the sternocleidomastoid muscles in 52 cases of hanging

Localisation	*n*
At both clavicles	
symmetrical	15
asymmetrical	19
At one clavicle	18
Total	52

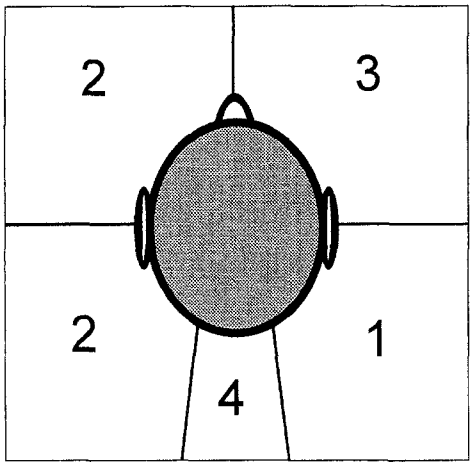


Fig. 1 Localisation of the highest point of the ligature mark in 12 cases of hanging with bilaterally symmetrical periostal-clavicular haemorrhages

Distribution of haemorrhages and highest point of ligature mark

In cases with bilateral symmetrical haemorrhages, no relationship was found between the highest point of the ligature and symmetry of the haemorrhages (Fig. 1).

Haemorrhages were stronger on the left side in comparison to the right in 12 cases, in which case the highest point of the ligature mark was also found on the left side (Fig. 2a). No relationship between the highest point of the ligature mark was found in cases examined by us in which haemorrhaging was stronger on the right hand side (Fig. 2b).

Figures 3a and 3b show that haemorrhaging on only one side of the clavicle is often accompanied by the highest point of the ligature mark being on the same side.

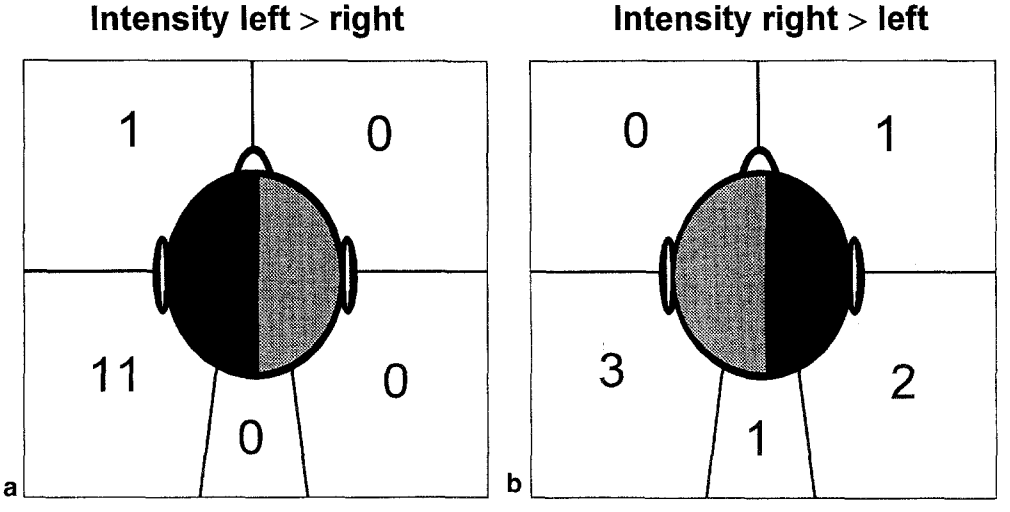
Frequency of haemorrhage and other causes of death

The 156 cases of the control group which had not been resuscitated are shown in Fig. 4, grouped according to the cause of death. Nine cases (5.7%) displayed low degree periostal-clavicular haemorrhages (4 cases of cranial trauma, 2 of suffocation, 2 of burning, and one in which the cause of death could not be determined). However, the haemorrhaging was nearly equal in intensity to that found in hanging in only 3 (1.9%) of these cases: a gunshot wound to the head, a case of burning to death and a case of entanglement of the neck in a machine with ensuing suffocation.

Frequency of haemorrhage and resuscitation

The distribution of findings is depicted in Fig. 5. As expected, central venous catheters can cause haemorrhages in the clavicular region of the sternocleidomastoid muscle. However, these extravasations were never in or under the periost, but always in the adjoining soft tissue. Of the 112 cases in which resuscitation had taken place in the form of

Fig. 2a b Localisation of the highest point of the ligature mark in 19 cases of hanging with bilaterally asymmetrical periostal-clavicular haemorrhaging



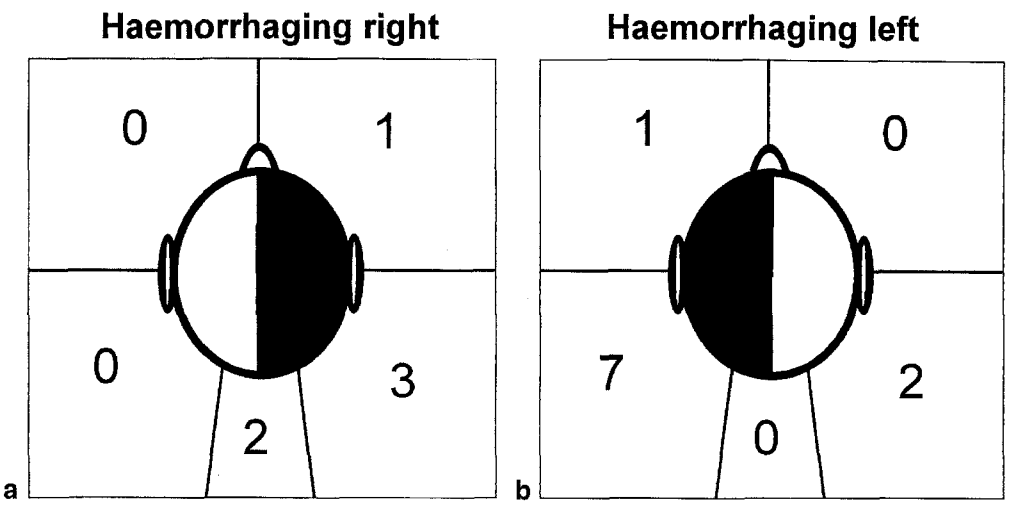


Fig. 3 a b Localisation of the highest point of the ligature mark in 16 cases of hanging with unilateral periostal-clavicular haemorrhaging

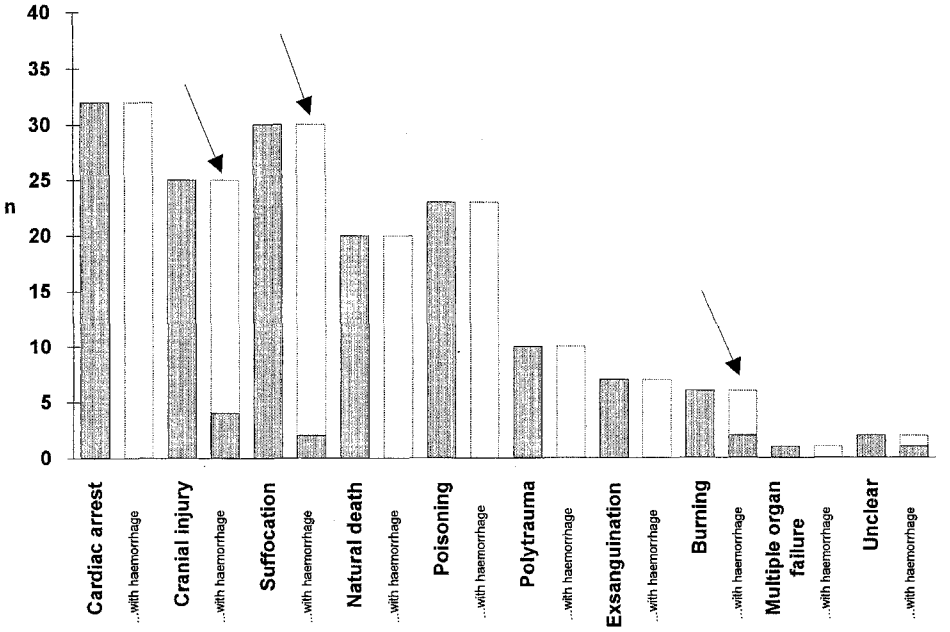
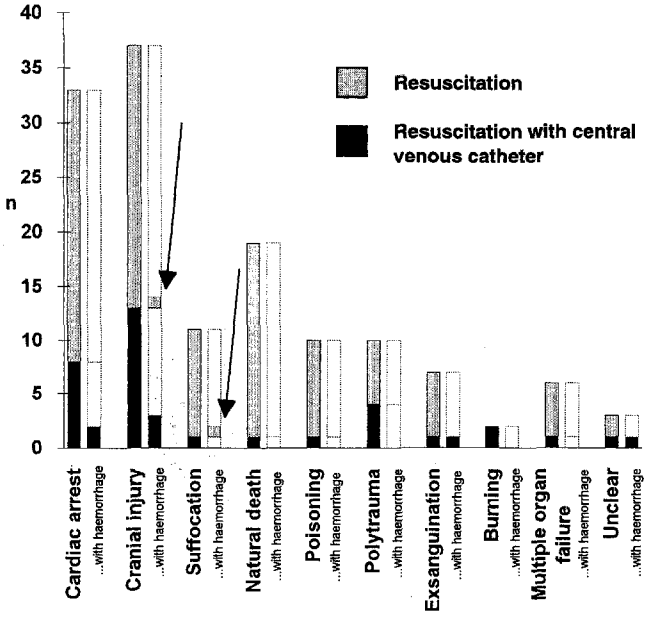


Fig. 4 Frequency of periostal-clavicular haemorrhages in 156 cases other than hanging without attempted resuscitation. Arrows indicate 3 cases which displayed haemorrhaging nearly equal to that found in cases of hanging. Suffocation: 12 × blockage of the upper airways, 5 × drowning, 4 × garotting, 3 × other mechanisms of cervical compression, 3 × plastic bag suffocation, 1 × asthma, 1 × choking on a foreign body, 1 × thoracic compression



◀ **Fig. 5** Frequency of periostal-clavicular haemorrhages in 138 cases other than hanging with resuscitation attempts or, in addition, administration of a central venous catheter. Arrows indicate 2 cases in which haemorrhaging occurred in the absence of a central venous catheter. Suffocation: 5 × thoracic compression, 2 × choking on a foreign body, 2 × drowning, 1 × garrotting, 1 × asthma

cardiac massage and assisted breathing without the administration of central venous catheters, only 2 (1.7%) displayed haemorrhages in the periostal region of the clavicular point of origin (cranial trauma and suffocation).

Degree of haemorrhage and body mass

A correlation between body mass and intensity of haemorrhage was not found. There was also no relationship to the hanging position, which has an influence on the degree of traction effected by the body mass. Nonetheless, 1 of 2 cases of hanging in a lying position displayed no haemorrhages.

Table 2 Histologically determined localisation of 51 haemorrhages at the clavicular origin of the sternocleidomastoid muscle in 32 cases of hanging. Combination of 2–12 observations

Localisation	*n*
Immediately epiperiostal	49
Intraperiostal	19
Subperiostal	26
Intramuscular	20
In the fat layer	17

Histological findings

Sources of haemorrhage were most often found in the immediate epiperiostal connective tissue, i.e. in the tendonous section of the muscle (Table 2). Isolated extravasations in this region were discovered in 10 clavicles, 17 clavicles were found to have intra- and/or subperiostal haemorrhages (Fig. 6) without involvement of the muscle tissue, and in another 17 cases the intra- and subperiostal haemorrhage was combined with muscle haemorrhages. An isolated intraperiostal haemorrhage was observed in only 1 case. Apart from this, the presence of intra- and subperiostal haemorrhages was always concurrent with haemorrhaging into the epiperiostal connective tissue and/or other neighbouring soft tissue. Bony avulsion with haemorrhage into a microscopically visible fracture crevice was present in 8 clavicles.

Discussion

Haemorrhages at the periostal-clavicular origin of the sternocleidomastoid muscle were observed in 52 of 54 cases of hanging (96%). It is remarkable that 2 of the delayed deaths were positive (one of these with a central venous catheter in situ). The high quota of haemorrhages found post mortem is apparently a result of the dissection technique, since the abovementioned haemorrhages may be present in the periostal region and not in the muscle itself. Walcher [16] pointed out that scrupulous dissection was necessary in order to demonstrate these haemorrhages and found them in 66% of cases of hanging examined. Other authors [2, 7, 10] observed haemorrhages in the clavicular region of the sternocleidomastoid muscle in 30–54% of autopsies of hanged persons, although it should be noted that this data was collected in retrospective studies. Haemorrhages after hanging were discovered in 76% [8] and 79% [6] of cases respectively in prospective studies. It can be said in conjunction with the available data that these haemorrhages are the most common finding in the cervical region in cases of fatal hanging. Nonetheless, a number of papers on the subject of death by hanging [3, 9, 15] as well as on the subject of the causative mechanism of haemorrhages in the cervical muscles [1] ignored this well-established finding [12, 16]. Studies concerned with cases of delayed death after hanging [11] also did not take these haemorrhages into consideration. It has been pointed out earlier that "unilateral" haemorrhages would appear mainly in cases of "asymmetrical hanging" [16]. By analysis of the available data in cases of bilateral asymmetrical as well as unilateral haemorrhaging (Table 1), it can be shown that these findings occur significantly more often or intensively on the side of the highest point of the ligature mark ($p < 0.001$, χ^2-Test). This supports the hypothesis of extension as the causative mechanism [8, 16], since it must be assumed that the soft tissues of the neck are subjected to a higher degree of extensional stress on the side of the highest point of the ligature position than on the opposite side. Cases with the highest point of the ligature located in the facial region (Fig. 1) frequently displayed bilateral and symmetrical signs of haemorrhaging accordingly. This is due to the dorsoflexion of the head in this position, leading to a relevant extension of both sternocleidomastoid muscles.

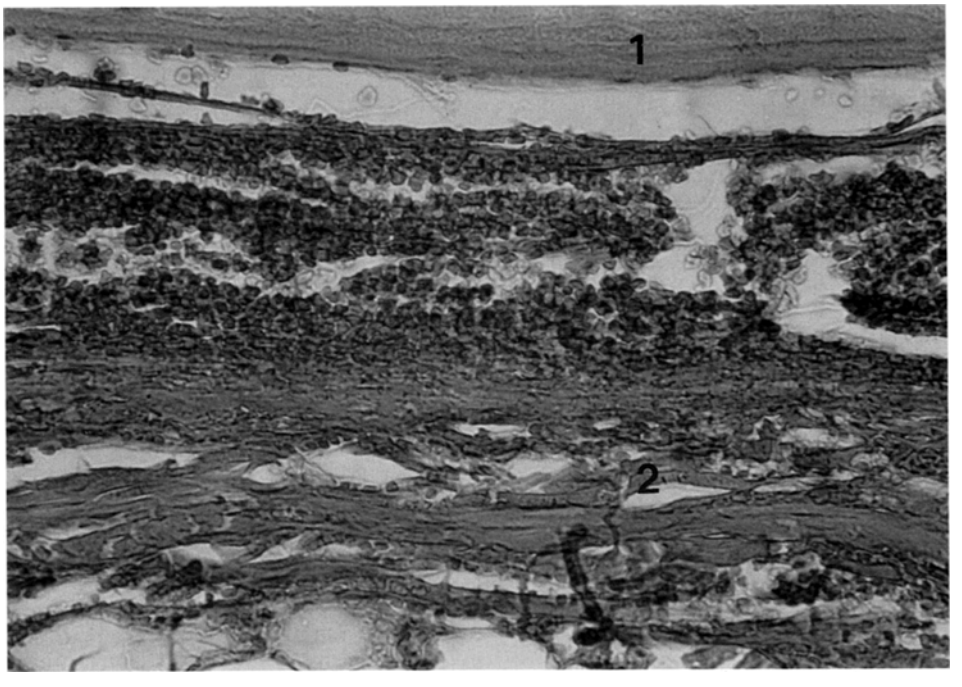


Fig. 6 Subperiostal haemorrhaging without infcusion of other soft tissues (hematoxilin-eosin, 400 ×). 1 = bone, 2 = periost

The macroscopic impression that haemorrhages may be limited to the periostal region of the clavicle without affliction of muscle tissue is supported by the histological findings. Haemorrhaging into the immediately epiperiostal as well as the intra- and subperiostal regions are much more frequently seen than haemorrhages into the muscle tissue. Bony avulsion might be an artefact and should be regarded with reservation. Nevertheless, haemorrhaging in the region of bone traumatisation is probably caused by hanging.

Findings of lesser intensity (rarely seen in cases of death by hanging) were observed in only 3 out of 156 cases (cause of death other than hanging) in which no resuscitational measures had taken place. The case in which entanglement of the neck region took place shows that haemorrhages may occur in situations in which intensive extension of the soft tissues of the neck is incurred by mechanisms other than hanging. Walcher [17] reported 2 such cases in which the head had been squashed by a train. It should also be taken into consideration that the haemorrhages may be caused by the auxiliary breathing apparatus function of the sternocleidomastoid as seen by us in a case of death by burning. Reuter [14] noted that haemorrhages into the sternocleidomastoid muscle could be seen in cases where death was directly preceded by severe dyspnoea, as in pneumonia or drowning. It should be emphasised that only 2 out of 30 cases of suffocation [Fig. 4] without resuscitation showed such findings. The auxiliary respiratory function of the sternocleidomastoid muscles is only responsible for the haemorrhages to a lesser degree in these cases. On the whole, periostal-clavicular haemorrhaging can be regarded as being typical for death by hanging in the light of their occurrence in less than 2% of cases of death other than by hanging. However, Prokop [13] indicated that haemorrhages may also be seen in cases where manual strangulation has taken place. This point of view, which raises the question of causative mechanisms, cannot be disregarded, as our study does not include cases of manual strangulation and 4 cases of garrotting (without resuscitation) were negative.

One earlier report [14] indicated that there is a possibility of haemorrhaging occurring in the anterior neck muscles after assisted breathing. It appears plausible that, in view of modern resuscitational techniques, not only intramuscular extravasations, but also haemorrhages might be produced at the clavicular points of origin of the sternocleidomastoid muscles. Findings of our study show that extrathoracic cardiac massage and pharyngeal intubation have no relevant influence on the formation of haemorrhages in the periostal-clavicular region. It cannot be differentiated in the 2 positive cases without central venous catheters (cranial trauma with rupture of the spinal cord, suffocation) whether the findings are due to resuscitation or whether they existed prior to resuscitation.

Limited data are available on the subject of artificial production of findings by means of post mortem hanging of the body. Walcher [16] managed to produce haemorrhages in 5 cadavers in this way, however, details of the experimental procedure are not supplied. Kerde and Heuschkel [5] observed haemorrhages produced post mortem in 4 out of 10 cases, with greater force (free fall into a ligature apparatus from a height greater than 1 m) being employed in at least 2 of these. It seems possible in the light of these experiments that the post mortem simulation of these findings is more difficult than that of all other cervical injuries known to be produced post mortem. From this aspect consideration should be given to the haemorrhages when evaluating cases of hanging.

It should be noted that haemorrhages were also observed at the sternal points of origin of the sternocleidomastoid in post mortem experimental hanging [5]. Isolated rupture of the sternal point of origin of the muscle after execution by hanging has been reported [4]. However, cases demonstrating these findings are extremely rare and no sternal haemorrhaging was observed in our study.

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