

Factors Affecting Neck Injuries in Hanging Deaths

ปัจจัยที่มีความสัมพันธ์กับการบาดเจ็บภายในลำคอในศพแขวนคอ

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Abstract

Objective: This study was conducted to investigate the circumstances of hanging death and evaluate the factors in association to the frequency of neck injuries.

Materials and Methods: A cross-sectional study of 118 cases of hanging deaths autopsied in Department of Forensic Medicine, Faculty of Medicine, Siriraj Hospital between March 2006 and October 2007 was carried out. The autopsy reports and the digital photographs of these cases were reviewed to collect information. The measurement of the association was performed by Fisher's Exact test ($p=0.05$).

Results: There were 93 males (78.8%) and 25 females (21.2%) in this study. The age ranged from 16 to 75 years. Strap muscle hemorrhages were noted in 23 cases (19.5%). The neck muscle hemorrhages were significantly related to the width of the ligature marks up to 0.5 cm ($p=0.02$). The thyroid cartilage was fractured in 8 cases (6.8%) and the hyoid bone was fractured in 5 cases (4.2%). The frequency of throat-skeleton fractures increased with the body weight ($p=0.005$). In addition, a higher rate of fracture (92.3%) was found with the ligature marks above thyroid prominence ($p=0.014$).

Conclusion: The injuries of the muscles were the most frequent injuries of all neck structures in hanging death. Its frequency was inversely proportional to the width of ligature mark. The thyroid cartilage and hyoid bone fractures were related to the increasing weight and the ligature traction above the larynx.

Keywords: Hanging, Neck injury, Muscle hemorrhage, Fracture

บทคัดย่อ

วัตถุประสงค์: เพื่อศึกษาและรวบรวมข้อมูลทั่วไปของศพแขวนคอ, ความถี่ของรูปแบบต่างๆของการแขวนคอและลักษณะต่างๆของรอยกดรัดบริเวณลำคอและวิเคราะห์หาความสัมพันธ์กับการบาดเจ็บของอวัยวะต่างๆภายในลำคอ

วิธีการ: ศึกษาแบบภาคตัดขวางในศพแขวนคอจำนวน 118 ศพ ที่มีการผ่าชันสูตรศพ ณ ภาควิชานิติเวชศาสตร์ คณะแพทยศาสตร์ศิริราชพยาบาล ตั้งแต่เดือนมีนาคม พ.ศ. 2549 ถึงเดือนตุลาคม พ.ศ. 2550 โดยใช้การตรวจดูจากรายงานการผ่าชันสูตรศพ, รูปถ่ายการชันสูตรพลิกศพ ณ ที่เกิดเหตุ และรูปถ่ายจากการผ่าชันสูตรศพ และนำข้อมูลต่างๆที่เก็บรวบรวมได้มาวิเคราะห์หาปัจจัยที่มีความสัมพันธ์กับการบาดเจ็บภายในลำคอ โดยการทดสอบหาความสัมพันธ์กับปัจจัยต่างๆด้วย Fisher's Exact test ที่ความเชื่อมั่นร้อยละ 95 ($p=0.05$)

ผลการศึกษา: ตัวอย่างการศึกษาเป็นผู้ชาย 93 คน (78.8%) และผู้หญิง 25 คน (21.2%) ช่วงอายุตั้งแต่ 16 ปีถึง 75 ปี พบเลือดออกในกล้ามเนื้อลำคอจำนวน 23 คน (19.5%) ซึ่งมีความสัมพันธ์กับรอยกดรัดที่กว้างไม่เกิน 0.5 ซม.อย่างมีนัยสำคัญทางสถิติ ($p=0.02$) พบการหักของกระดูกอ่อนกล่องเสียงจำนวน 8 ศพ (6.8%) และกระดูกโคนลิ้นจำนวน 5 ศพ (4.2%) การหักของกระดูกบริเวณลำคอพบได้มากขึ้นตามน้ำหนักของศพที่เพิ่มขึ้น ($p=0.005$) นอกจากนี้การหักของกระดูกยังพบมากในกลุ่มที่มีรอยกดรัดที่อยู่เหนือปุ่มกระดูกเดือย ($p=0.014$)

สรุป: อวัยวะในลำคอที่พบการบาดเจ็บได้มากที่สุดในศพแขวนคอก็คือกล้ามเนื้อลำคอ ความถี่ของการบาดเจ็บของกล้ามเนื้อลำคอที่เพิ่มขึ้นจะผกผันกับขนาดความกว้างของรอยกดรัดที่ลดลง ส่วนการหักของกระดูกอ่อนกล่องเสียงและกระดูกโคนลิ้นมีความสัมพันธ์กับน้ำหนักของศพที่เพิ่มขึ้นและระดับรอยกดรัดเหนือกล่องเสียง

Introduction

Hanging is a form of strangulation in which the force applied to the neck by a noose or other constricting band derived from the gravitational drag of the weight of the body.¹ Distribution and frequency of inner neck injuries caused by hanging may indicate the mechanism of injuries. Various studies in the forensic literature have reported the differences in the incidence of the neck injuries in cases of hanging. According to the literature records, the percentage of neck muscle injuries ranged from 20% to 34%.^{10, 13} The injuries of sternocleidomastoid muscles are the most frequent injuries of all other neck structures. Nikolic S. et al. reported that the frequency of the neck muscle injuries was not related to the location of the ligature knot or the type of hanging.¹⁰

In the forensic literature, various records of the frequency of neck structure fractures in hanging death could be found ranging from 9% to 68%.^{1, 2, 3, 4, 5, 8, 9, 10, 12, 14} Many studies reported that there might be quite a difference in the frequency of neck injuries with regard to the relevant characteristics of the victim, the ligature employed and the type of suspension. superior horn thyroid cartilage fractures are the most frequent injuries of solid neck structures.

In reviewing the Thai literature, an analysis of hanging autopsy had never been performed. This study is made to analyze and correlate certain demographic and the circumstantial data with the frequency of neck injuries in hanging deaths. In addition, the possible reasons for their occurrence are discussed.

Materials and methods

The subjects of our study were 118 autopsy cases of hanging deaths that were performed at the Department of Forensic Medicine, Faculty of Medicine Siriraj Hospital from March 2006 to October 2007. The autopsy reports and the digital photographs of the external and internal examination prepared by the doctors working in the department were reviewed. In a number of cases, the digital photographs of the scene were checked if available to collect information about the scene of crime. Sex, age, weight, type of hanging, type of ligature material, point of the ligature knot, width and location of the ligature mark, tongue protrusion, site of petechial hemorrhage, and pattern and site of internal neck injuries were noted. In addition, toxicological analysis data including blood alcohol level was recorded. The categorical data were reported as frequency and percentage. The quantitative data were reported as mean, median, and standard deviation. The measurement of association for the categorical variables were performed by Fisher's Exact test ($p= 0.05$).

Results

Demographic data

There were 118 cases included in this study: 93 males (78.8%) and 25 females (21.2%). The age ranged from 16 to 75 years. The mean age was 36.31 years (median 35 years, SD 12.75 years). The average age of males was 36.39 years (median 35 years, SD 12.74 years) and that of females was 36 years (median 33 years, SD 13.08 years). In this study, the incidence of hanging was more commonly found in the fourth decade for male and the third decade for female. The bodies' weight ranged from 37 to 85 kg. The mean weight was 57.06 kg (median 56 kg, SD 9.67 kg). The average

weight of males was 58.17 kg (median 56 kg, SD 9.34 kg) and of females was 52.92 kg (median 52 kg, SD 9.96 kg). All cases were suicidal hanging.

Type of suspension

24 cases (41.4%) were found completely suspended, and 34 cases (58.6%) were incomplete hanging. However, this determination could not be made in 60 deaths due to lacking of data from the scene. In incomplete hanging, the position was standing in 21 cases (36.2%), kneeling in 2 cases (3.4%), sitting in 9 cases (15.5%), and lying in 2 cases (3.4%).

Ligature and ligature mark

The ligature materials used included a rope in 43 cases (45.3%), a length of sheet or other cloth in 30 cases (31.6%), an electrical cord in 16 cases (16.8%), and other ligature materials in 6 cases (6.3%). There was no information of the ligature material in 23 cases.

The site of the ligature knot was at the back of the neck in 86 cases (72.9%), at the left side of the neck in 15 cases (12.7%), at the right side of the neck in 14 cases (11.9%), and at the front of the neck in 3 cases (2.5%).

The narrowest and widest ligature marks were 0.3 cm and 11 cm, respectively, with mean 1.979 cm (median 1.3 cm, SD 1.8 cm). It was also recorded as range, which was 0.5 cm or less in 13 cases (11%), ranged from 0.6 cm to 3.5 cm in 85 cases (72%), and was greater than 3.5 cm in 20 cases (17%). In 70 of 118 cases (59.3%), the ligature marks were located superior to the thyroid prominence.

External findings

Tongue protrusion was noted in 43 cases (36.4%). The tongue protrusion was found in 52.9% of incomplete hanging and 33.3% of complete hanging. According to the point of the ligature knot, this finding was discovered in 35 of 86 typical hanging deaths (40.7%) and 8 of 32 atypical hanging cases (25%). The tongue protrusion was noted in 22 cases (31.4%) whose ligature marks were above the larynx. The statistical analysis of the tongue protrusion according to weight, type of suspension, location of the ligature knot, location of the ligature mark, and width of the ligature mark showed no statistical significant difference.

Conjunctival petechial hemorrhages were identified in 50 cases (42.4%), while petechiae involving the skin surfaces of the face or periorbital tissues were identified in 27 cases (22.9%). The

conjunctival petechiae were presented in all cases of facial petechiae. The conjunctival petechiae were recorded from complete hangings in 7 cases (29.2%) and incomplete hangings in 16 cases (17.1%). Moreover, these petechiae were observed in 32 cases (37.2%) in the typical hangings and 18 cases (56.2%) in the atypical hangings. In both the complete and incomplete hangings, the facial petechiae were found in 3 cases (12.5%) and 10 cases (29.4%) respectively. They were also observed to be more common in cases with atypical hangings (11 cases, 34.4%) than in cases with typical hangings (16 cases, 18.6%). The statistical analysis of the conjunctival petechial hemorrhages according to weight, type of suspension, position of the ligature knot, and width of the ligature mark showed no statistically significant differences ($p=0.726, 0.188, 0.093, \text{ and } 1.000$ respectively).

Internal findings

There was no petechia involving epicardium and visceral pleurae in 64 cases (54.2%). The presence of only epicardial petechiae was found in 18 cases (15.3%) and only pleural petechiae were found in 9 cases (7.6%). The rest (22.9%) had both epicardial and pleural petechiae.

Soft tissues were injured in 25 cases (21.2%). Of these cases, the presence of hemorrhages involving the subcutaneous tissue, neck muscles, submandibular gland, and thyroid gland were found in 5 cases, 23 cases, 2 cases, and 2 cases, respectively. Strap muscle hemorrhages were noted in 5 of 24 cases (20.8%) found suspended completely and in 5 of 34 cases (14.7%) found incompletely suspended. According to the position of the ligature knot, the incidences of the muscle injuries in typical and atypical hangings were 20.9% and 15.6% respectively. Hemorrhage in the neck muscle was noted in 12 cases (17.1%) whose ligature marks were above the larynx. The statistical analysis of the neck muscle hemorrhages according to weight, type of suspension, location of the ligature knot, and location of the ligature mark showed no statistically significant difference. The distribution of neck muscle injuries in relation to the width of the ligature mark was presented in **Table 1**. Only one case with the ligature mark wider than 3.5 cm showed hemorrhage of neck muscle. The neck muscle hemorrhages were significantly related to the width of the ligature marks up to 0.5 cm ($p=0.02$). Intimal tear of the carotid arteries was not seen in this study.

Table 1. Frequency of strap muscle hemorrhages in relation to the width of the ligature mark

Width of ligature mark [cm]	Strap muscle hemorrhage			
	No		Yes	
	Frequency	Percentage	Frequency	Percentage
≤0.5	7	53.85%	6	46.15%
0.6-3.5	69	81.18%	16	18.82%
>3.5	19	95%	1	5%
Total	95	80.51%	23	19.49%

Fractures of the larynx or hyoid bone were presented in 13 cases (11%). The thyroid cartilage was fractured in 8 cases (6.8%) and the hyoid bone was fractured in 5 cases (4.2%). In all cases of thyroid cartilage fractures, the superior horn was the site of fracture, while fractures of greater horn of the hyoid bone were the most common. Fractures of the cervical vertebrae were not observed in this study. According to the age, only 2 of total 13 fractures occurred in cases under the age of 26 years. The youngest victim found to have fracture was 21 years of age. Fracture distribution, however, was disproportional with the age range. Frequency of bony structure fractures in relation to weight was presented in Table 2. The least body weight having a fracture was a 54-kilograms female and the heaviest body weight having a fracture was an 85-kilograms male.

Table 2. Frequency of bony structure fractures in relation to weight

Weight [kg]	Bony injuries			
	No		Yes	
	Frequency	Percentage	Frequency	Percentage
<40	2	100%	0	0%
40-59	74	94.87%	4	5.13%
60-79	26	81.25%	6	18.75%
>79	3	50%	3	50%
Total	105	88.98%	13	11.02%

The frequency of throat-skeleton fractures increased with the body weight ($p=0.005$). The throat skeletons injuries were found in 2 cases of complete hanging (8.3%) and 4 cases in the incomplete hanging (11.8%). The fractures of neck structures were found in 9 cases (10.5%) and 4 cases (12.5%) according to typical and atypical hangings, respectively.

The statistical analysis of the fracture according to type of suspension and position of the ligature knot showed no statistically significant difference. In 12 of 13 cases (92.3%) who had fracture of thyroid cartilages or hyoid bones, the ligature marks were above the larynx. This correlation was statistically significant ($p=0.014$). Only one case whose ligature mark was wider than 3.5 cm revealed a fracture. However, the association between the fracture and the width of the ligature mark was not statistically significant. In this study, the strap muscle hemorrhage was strongly associated with the fracture ($p=0.001$).

Toxicological analysis

Positive postmortem blood ethanol levels were noted in 53 cases (44.9%), ranged from 2 to 358.31 mg%. The mean blood ethanol level was 55.86 mg% (median 0 mg%, SD 88.04 mg%). Blood ethanol levels valuing equal to or greater than 100 mg% were found in 30 cases (25.5%).

Discussion

The frequency and distribution of injuries to the inner structure of neck caused by hanging might also indicate the mechanism of injuries. According to the literature records, the percentage of neck muscle injuries ranged from 20% to 34%.^{10, 13} Nikolic S. et al. reported that the frequency of the neck muscle injuries was not related to the location of the ligature knot or the type of hanging.¹⁰ In the sample we observed, the injuries of the muscles were most frequently found when compared with the injuries of all neck structures (74.2%). As same as the previous literature reports, the frequency of neck muscle injuries was not related to the type of suspension and the location of ligature knot. Nikolic S. et al. explained that the ligature pressure on the muscle is contra-lateral in relation to the knot, while the traction of muscle is ipsilateral in relation to the knot.¹⁰ The result of analysis showed that the frequency of the neck muscle injuries was related to the width of the ligature, which could be explained by the ligature pressure on the muscle.^{1, 10, 13} Pressure is the force over an area applied on an object in a direction perpendicular to the surface. According to the ligature mark, an area exerted by the compressive force is equal to the width of the ligature mark multiplied by the length of the

ligature mark. If the length of the ligature mark is assumed to be equal in all hanging deaths, the ligature pressure is inversely proportional to the width of the ligature mark as expressed by the following formula:

$$P = \frac{F}{A} = \frac{F}{W \times L}$$

If	P = Pressure (N/m ²)
	F = Tension force (N)
	A = Area (m ²)
	W = Width of the ligature mark (m)
	L = Length of the ligature mark (m)

According to the above equation, one of many factors, which are correlated to the pressure, is a tension force. Tension is a reaction force applied by a stretched string (rope or a similar object) on the objects which stretch it. If an object hangs from a rope due to gravity, the gravitational force on the object points downward while an equal tension force in the rope points upward. That means the tension force in the ligature is directly proportional to the weight of the body according to the Newton's second law: law of acceleration expressed as:

$$F = ma$$

In the other hand, this study showed that the neck muscle injuries was not related to the weight of victims. It could be explained that the weight altered proportionally less than the width of the ligature mark. For example, when the weight gets greater from 40 kg to 80 kg in the constant width, the width of the ligature mark only gets wider from 0.5 cm to 1 cm in the constant weight for an equal ligature pressure. Furthermore, the compression force from the weight can be potentiated by stretching force to injure neck muscles.

No injuries of the neck blood vessel were found in this study. Thus, it was impossible to obtain any definitive conclusion. However, one study has reported that there is a higher tendency of blood vessel injuries ipsilateral in relation to the location of the ligature knot.¹⁰ This report corresponds to the theory that injuries of blood vessels in hanging are caused by traction and not by direct pressure on a blood vessel. Different studies have reported that intimal tears in carotid arteries may be found if there has been a sudden drop in hanging and the carotid injuries are found most commonly at or near the bifurcation.^{2, 11} These findings could be explained by a complex multivariate process secondary to a combination of stresses: sudden and dramatic rise in arterial blood pressure because of the carotid artery compression; shearing due to traction force; pinching of the carotid artery between the ligature

material and cervical vertebrae; and most importance the water-hammer effect theory. The water-hammer effect, proposed by Lundewall, results when the flow of a noncompressible fluid is occluded dramatically, which leads to high- pressure waves being reflected back along the vessel wall. During the compression of neck by the ligature, it is suspected that the carotid artery may be occluded at the point above bifurcation as a result of the compression of the ligature and sudden flexion of neck. It was established that a sudden occlusion of the blood flow in the carotid artery would lead to a significant pressure pulse in the carotid artery. This would be expected to be significantly greater at the bifurcation on account of the branching reflecting and intensifying the pressure wave. This explains that why the injuries to the neck blood vessels in hanging are unusual event.

Various records of the frequency of solid neck structure fractures can be found variably in the forensic literature. Values ranging from 9 to 68% were described.^{1, 2, 3, 4, 5, 8, 9, 10, 12, 14} In the present study, the fracture was found in 13 cases (11%). The striking differences in the results of various studies may be explained by the methodical factor. A careful dissection of the neck structures discloses reliable results. Fracture of the superior horn of the thyroid cartilage is the most frequent in hanging. The presented results show no significant difference in the percentage of the neck structure fractures according to the type of suspension, the location of the ligature knot, and the width of the ligature mark but these fractures are significantly correlated with weight and location of the ligature mark. More fractures were found in case of hanging whose ligature marks were above the larynx and whose weights were greater. A possible mechanism of these fractures can be explained by the mechanism of the injuries to the inner neck structures in hanging death. The neck injuries in hanging are caused by two ways.¹⁰ First, the injuries occur directly at the location of the ligature's highest compression, which is at the side opposite to the point of suspension. The other way is the stretch of neck muscles which is most detectable in the area surrounding the point of the ligature knot. It is also assumed that the higher the ligature in relation to the larynx and the greater the body weight, the more intensive the neck traction. One of the possible mechanisms of the horn thyroid cartilage fractures in hanging appears to be indirectly caused by the stretching of lateral thyroid ligament and thyroid membrane, while a possible mechanism of hyoid bone fractures is assumed to be the pressure that the horns of these structures exert on to the spine because of a greater traction. Some authors

suggest that the frequency of solid structure injuries increases with the length of suspension time^{9, 14} and age of victims due to ossification of cartilage^{4, 10}.

Conclusion

The pathophysiologic mechanism of neck injuries can be defined based on the correlation between the circumstances of death and the pathologic finding identified. The injuries of the muscles were the most frequent injuries of all neck structures in hanging death. Its frequency was inversely proportional to the width of ligature mark. The thyroid cartilage and hyoid bone fractures were related to the increasing weight and the ligature traction above the larynx.

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