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Comparison of tympanic membrane injuries between hanging and other non-asphyxiating deaths by otoscopic examination

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Background : *Hanging is the most frequent suicidal method. It can cause tympanic membrane (TM) injuries. Otoscopic examination is a non-invasive procedure to explore TM injuries that may be related to the pathological changes from hanging.*

Objective : *To evaluate the value of TM injuries as a diagnostic tool in hanging cases.*

Methods : *We prospectively examined 20 of hanging cases and 12 of non-asphyxiating deaths by otoscopic examination, photographed and blindly evaluated TM injuries by an otolaryngologist from grade 0 to grade 3 according to severity. P – value, confidence of interval, sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), area under the curve, and odd ratio (OR) were used to explore the correlation between TM injuries and hanging.*

Results : *There was higher number of TM injuries in the hanging cases than non-asphyxiating cases. (OR = 5.293 at 95% CI, 1.290 – 21.72413 with P - value = 0.0149 for right ear and OR = 3.579 at 95% CI, 1.354 – 12.645, P - value = 0.0091 for left ear. Diagnostic odds ratio = 8.748)*

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Conclusions : *The injuries found in ears tympanic membrane seemed to be the indicative findings in hanging. A larger sample size will be required to yield more accurate study results.*

Keywords : *Hanging, asphyxia, forensic otoscopy, tympanic membrane injury, autopsy.*

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เปศล โกศัลลกูฏ, กรวิก มีศิลปวิกกัย, เพิ่มทรัพย์ อิสีประดิฐ. การศึกษาเปรียบเทียบการบาดเจ็บของเยื่อแก้วหูในศพผูกคอเสียชีวิตกับศพที่ไม่ได้เสียชีวิตจากการขาดอากาศ ด้วยเครื่องส่องหู. จุฬาลงกรณ์เวชสาร 2561 ก.ค. – ส.ค.; 62(4): 687 – 96

เหตุผลของการทำวิจัย : *การผูกคอตาย เป็นวิธีฆ่าตัวตายที่พบบ่อยที่สุด ซึ่งเคยมีรายงานว่าทำให้เกิดการบาดเจ็บต่อแก้วหู และการส่องหูด้วยเครื่องส่องหูนั้นเป็นหัตถการที่ไม่ก่อให้เกิดการบาดเจ็บเพิ่มเติม อันอาจช่วยในการวินิจฉัยการบาดเจ็บในแก้วหูที่เกี่ยวข้องกับการผูกคอตาย*

วัตถุประสงค์ : *ประเมินคุณค่าของการบาดเจ็บในแก้วหู ต่อการวินิจฉัยศพผูกคอ*

วิธีทำการวิจัย : *เปรียบเทียบศพผูกคอเสียชีวิต จำนวน 20 ศพ และศพที่เสียชีวิตจากสาเหตุ อื่นที่ไม่เกี่ยวข้องกับการขาดอากาศ จำนวน 12 ศพ โดยทำการส่องหูทั้งสองข้าง บันทึกภาพ และแบ่งระดับความรุนแรงของการบาดเจ็บตั้งแต่ระดับปกติ จนถึงระดับรุนแรง โดยแพทย์ผู้เชี่ยวชาญทางโสต ศอ นาสิก โดยไม่ให้แพทย์ผู้แปลผลทราบการวินิจฉัยล่วงหน้า เพื่อเปรียบเทียบความแตกต่างด้วยการเก็บตัวอย่างไปข้างหน้า ใช้ค่าสถิติ P – value, confidence of interval, sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), area under the curve และ odd ratio (OR) เพื่อศึกษาความสัมพันธ์ดังกล่าว*

ผลการศึกษา : *การบาดเจ็บของเยื่อแก้วหูในศพผูกคอ พบจำนวนมากกว่าในศพที่เสียชีวิตด้วยหาเหตุอื่น อย่างมีนัยสำคัญทางสถิติ (OR = 5.293, 95% CI, 1.290 – 21.72413, P = 0.0149 ในหูขวา, OR = 3579, 95% CI, 1.354 – 12.645, P = 0.0091 ในหูซ้าย ค่า diagnostic OR = 8.748)*

สรุป : *การบาดเจ็บของเยื่อแก้วหูในศพผูกคอ อาจเป็นสิ่งตรวจพบใหม่ในศพที่ผูกคอเสียชีวิต แต่ควรมีการศึกษาเพิ่มเติมในขนาดประชากรที่มากขึ้น*

คำสำคัญ : *ผูกคอ, การขาดอากาศ, การส่องหูทางนิติเวช, การบาดเจ็บของเยื่อแก้วหู, การผ่าศพ.*

Death by hanging is the most common suicidal method found in Thailand [1] and globally.[2] The medico-legal autopsy plays an important role in identifying the cause of death. Only in few cases that the results of hanging were obscured in which rendered the difficulty in hanging death diagnosis.[3]

Classic signs of hanging, facial, and conjunctiva petechial hemorrhage, persistent fluidity of blood, right-sided heart dilatation, and cyanotic appearance were unreliable.[4] Some case studies had shown the possibly positive otoscopic findings in hanging.[5 - 8] This study aimed to evaluate the value of TM injuries as a diagnostic indicator for hanging.

The author selected otoscopy based on the reason that it was shown to be beneficial in other cases such as head injury, gunshot wound at the head, base of skull fracture, drowning, and explosive injury.[5] However, in hanging, the benefit of otoscope is unknown.

Otoscopy can be easily performed by general practitioners.[9] While in the rural area, suicidal cases were ignored because of the lack of forensic autopsy service. The findings from otoscope could be beneficial as a diagnostic tool for hanging cases.

Materials and Methods

Subjects

The study protocol has been approved by the Ethics Committee for Research Affairs, Faculty of Medicine, Chulalongkorn University (Institutional Review Board Number 676/59).

Deceased subjects, who died from hanging and other non-asphyxiating cause of death from January 2017 to September 2017, were sent to the Department of Forensic Medicine, Faculty of Medicine, King Chulalongkorn Memorial Hospital, Bangkok, Thailand for the medico-legal autopsy.

They were selected according to the following inclusion criteria:

1. The deceased was pronounced dead within 24 hours before the examination.
2. The age of the deceased was more than 18-year-old[10] with the informed consent from their next of kins.
3. Cause of death was compatible with hanging or other causes of death without asphyxia at autopsy.

Exclusion criteria were as follows:

1. Cardiopulmonary resuscitation was performed prior to autopsy. [11]
2. There were severe head and neck injury identified.
3. The otoscopic examination results were not applicable.

Methods

The recommended number of sample size is between 10 to 20. [12] The study subsequently examined 20 cases of hanging death and 12 cases of non-asphyxiating death. Twenty-five deceased were male (age range from 18 to 75 years, mean of age = 43.32 years) and 7 were female (age range from 18 to 60 years, mean of age = 39.71 years)

Each body was labeled from No. 1 to 32 to protect their confidentiality. Firstly, the simple otoscope was introduced to examine both ears and ear canals in which were cleaned by dry cotton bud (Figure 1). Secondly, a digital otoscope with capability to capture the pictures of the tympanic membranes was inserted into the proper angle (Figure 2). Finally, the files were captured as we saw the entire tympanic membranes.

Figure 1. Otoscope Mark II Classic.

Figure 2. Andonstar USB digital video otoscope for ENT Camera for files capturing.

As for the evaluation, we consulted with an otolaryngologist who was blinded to the results of the autopsy. Tympanic membrane injury was classified as follows: grade 0 = no pathological finding, grade 1 = TM congestion, grade 2 = TM with petechial hemorrhage, and grade 3 = hemotympanum (Figure 3)[5]

Grading was compared between the hanging group and the control group on the aspects of sensitivity, specificity, positive predictive value, negative predictive value, area under the curve, odd ratio and *P*-value through RStudio Statistics Program for Macintosh version 3.43. P – value < 0.05 was considered to be statistically significant.

Results

Table 1. Number of hanging cases and grading of TM injuries.

Hanging cases	Left ear	Right ear
Grade 0	1	3
Grade 1	6	4
Grade 2	4	8
Grade 3	3	2
Not applicable (Excluded)	6	3
Total	14 (20)	17 (20)

Table 2. Number of control (non-asphyxiating) cases and grading of TM injuries.

Control cases	Left ear	Right ear
Grade 0	5	5
Grade 1	2	4
Grade 2	2	0
Grade 3	0	0
Not applicable (Excluded)	3	3
Total	9 (12)	9 (12)

Table 3. Optimal cut point of grading between hanging and non-asphyxiating cases from R Studio Statistic Program for Calculation.

Grade Cut Point	OR	95% CI	*P* - value
1.25	7.071	1.073 - 46.617	0.0333

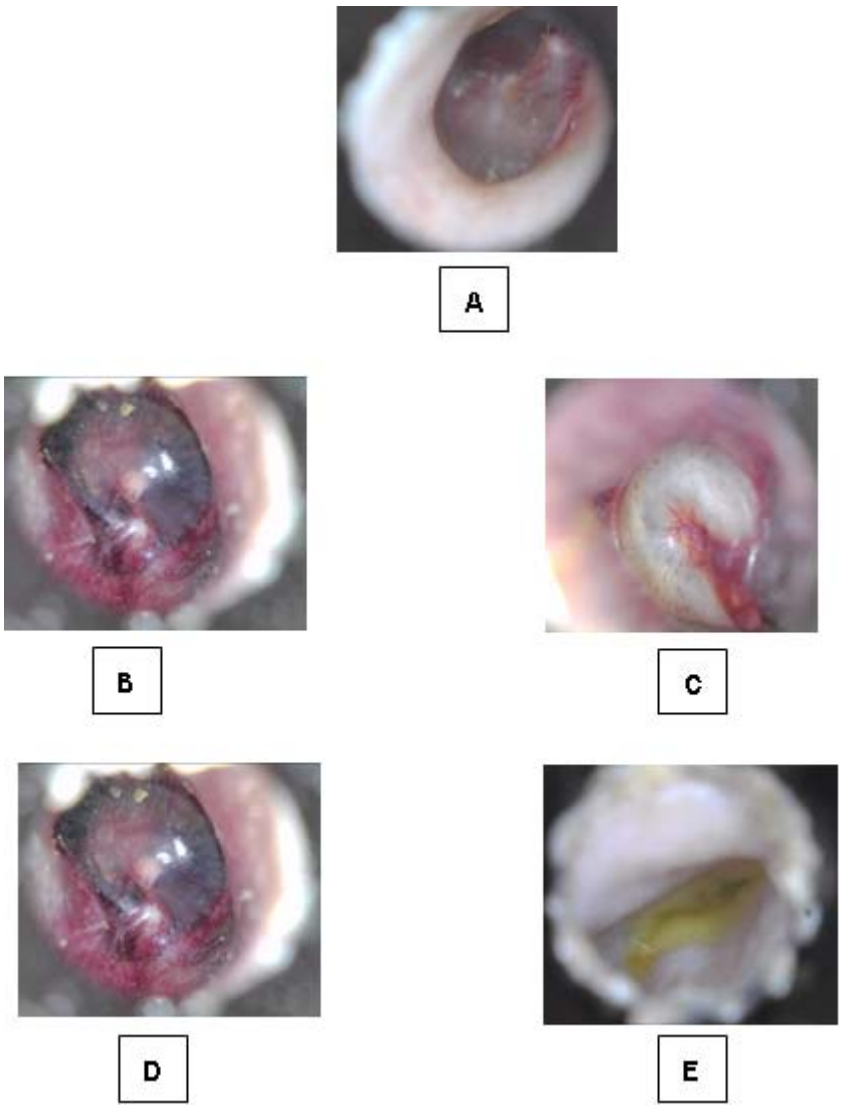

Figure 3. TM injuries classified as grade 0 to grade 3 and inapplicable grade in this study. (A) Grade 0 TM injury (Normal): There is no bleeding observed, (B) Grade 1 TM injury (Congestion): There is vascular engorgement in TM, (C) Grade 2 TM injury (Petechiae): There are bleeding spots in TM, (D) Grade 3 TM injury (Hemotympanum): Blood is found in tympanic cavity. (E) Inapplicable: There is cerumen impaction in ear canal.

According to total of information, the pathological findings of tympanic membranes in the hanging cases presented a higher significant severity compared to the control cases (right ear OR = 5.293 (95% CI = 1.289 – 21.724), *P* - value = 0.015 and left ear OR = 3.579 (95%CI = 1.002 – 12.771) *P* - value = 0.037 respectively). In hanging cases, TM injuries were predominantly observed in grade 1 to grade 3 (Table 1). On the other hand, TM injuries were mostly presented in grade 0 to grade 1 (Table 2) in non-asphyxiating cases. The optimal cut point to differentiate hanging from other non-asphyxiating death was 1.25 (Table 3). The sensitivity and specificity of the otoscope in hanging cases were 0.833 and 0.636 (Table 4). There were about 50% of cases that presented the same grade injury in both ears (Table 5). From ROC curve (Figure 4), the difference of hanging cases between grade 0 group and grade 1 to grade 3 group were significantly identified (Table 6).

Table 4. Statistic data from R Studio Statistic Program for Calculation at cut point equal to 1 due to nearest optimal cut point.

Statistics	Value
Sensitivity	0.833
Specificity	0.636
PPV	0.789
NPV	0.700
LR+	2.291
LR-	0.261
Diagnostic OR	8.748

Table 5. Number of hanging and non-asphyxiating cases with both TM injuries with similar grade.

Both ears	Hanging	Control
Grade 0	1	3
Grade 1	3	2
Grade 2	4	0
Grade 3	2	0
Total	10	5
Samples	20	12

Table 6. Number of hanging cases from grade 0 and grade 1 - 3 in left ear and right ear and significant difference between both groups of grading.

Ear	Grade 0	Grade 1 - 3	Total	Significance
Left ear	1 (7.1%)	13 (92.9%)	14	*P* - value = 0.001
Right ear	3 (17.6%)	14 (82.4%)	17	*P* - value = 0.008
Total	4 (12.90%)	27 (87.10%)	31	*P* - value = 0.004

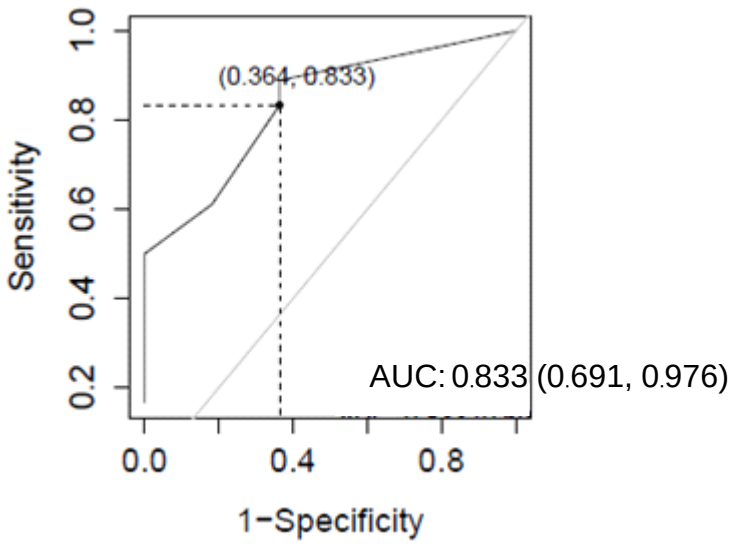

Figure 4. Receiver operator characteristics (ROC) curve at cut point = 1 area shown under the curve which equal to 0.833 with the relation between true positive and false positive rate.

Discussion

The results of this study showed that otoscopic examination of tympanic membranes in the hanging cases could be one of the indicative signs of hanging. The number of injury in hanging cases appeared to be higher than in the non-asphyxiating cases.

Cerumen impaction, variation of ear canal anatomy and abnormal position of head and neck could be the very important obstacles in TM evaluation.

The cardiopulmonary resuscitation process could interfere the interpretation as mentioned in some reports[10] due to the petechial hemorrhage appearance.

In this study, grading was referred to the research by Kuˊerova S, *et al*.[5] that graded on 250 autopsy cases. They divided them into 6 categories from grade 0 to grade 4 with the inapplicable grade. We applied their grading by selecting only from grade 0 to 3 and inapplicable grade. This was because we did not have the case of grade 4 severity (rupture TM) since there was no trauma case examining thus, it was rationally applied in this study.

In the hanging cases, the findings varied from grade 1 to grade 3. On the other hand, in the control cases, the findings varied in grade 0, grade 1 and very few in grade 2. The difference was significant when the cutting point was lesser than grade 1 as can be seen in Table 5.

In hanging group analysis as in table 8 which we selected cut point at <1 and ≥ 1 according to figure 1 curve, the findings of hanging cases between grade 0 and grade 1 to grade 3 were 1 case and 13 cases respectively in left ear and 3 cases in grade 0 and 14 cases in grade 1 to grade 3 respectively. The significant difference was identified in hanging group between grade 0 and grade 1 to grade 3 because hanging might cause some degree of TM injury.

In the non-asphyxiating cases, it was reported that some conditions such as congestive heart failure or stroke would make the facial congestion and more vasculature in the TM.[5]

TM findings in hanging in the previous article claimed that it might result from two mechanisms. One mechanism was the "engorgement theory."[8] The increasing pressure of the jugular veins caused by a neck ligature could cause the middle ear congestion and hemorrhage by impeding the return of venous blood flow. A second mechanism was an effort to breathe against the closed glottis that caused the higher middle ear pressure that led to the tympanic barotrauma. As pressure increased in the pharynx, the Eustachian tube opened. This pressure increased an osseous cavity in the middle ear which led to the tympanic tear.[8]

According to Table 4, the statistical data can plot ROC curve in Figure 1 in which the area under the curve showed the ratio between true and false positive rate if the cut point was in grade 1. The utility of otoscope was quite acceptable as its sensitivity and specificity were equal to 0.833 and 0.636 respectively, compared to the gold standard autopsy. If we found the positive tympanic membrane injury only from one ear from a hanging case, it might help confirm that hanging was the cause of death.

Conclusion

Tympanic membrane injury might be an indicative sign for hanging but this could be varied

by grading from grade 1 to grade 3. Meanwhile, in the non-asphyxiating cases it appeared with normal or minor TM injury. This otoscope for the forensic purpose might be useful if the signs of hanging are not visible. However, the most important factors to determine the cause of death in hanging were from the crime scene and full autopsy.[13-14] Further studies with larger sample size should be performed to confirm the findings.

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Conflicts of interest

The authors declared with no potential conflicts of interest in respect to the research, authorship, and/or publication of this study.

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