Helmut Maxeiner,[1] *M.D.*

''Hidden'' Laryngeal Injuries in Homicidal Strangulation: How to Detect and Interpret These Findings

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ABSTRACT: These studies were designed to demonstrate that the usual method of laryngeal dissection carries a significant risk of overlooking important laryngeal injuries. Formalin-fixed hyoid-larynx complexes were prepared in a prospective forensic study involving 191 cases of homicidal strangulation, 1984 to 1997. The basic steps of the applied method included: complete resection of the thyroid cartilage, a horizontal incision through the cricoid cartilage before opening the larynx dorsally, inspection of the laryngeal joints, and incisions of the laryngeal muscles.

Using this procedure allowed us to detect the following injuries, which otherwise would have been destroyed or overlooked: (*a*) 17 incomplete fractures restricted to the dorsal surfaces of the thyroid laminae and 10 incomplete or non-dislocated fractures of the cricoid cartilage. In 7 cases, such a ''hidden'' fracture was the only laryngeal injury resulting from neck compression. (*b*) Extensive laryngeal muscle hemorrhages, especially of the vocal folds, were found in almost half of all cases, more rarely in strangulation by ligature and more frequently in manual strangulation. Gross hemorrhages were the decisive local laryngeal finding in 19 cases. (*c*) Laryngeal joint injuries (bleedings) were found in 18% to 52% of the different strangulation types. (*d*) Hemorrhages of the laryngeal mucosa were common findings that occur in about 60% of all cases; only in rare cases do such bleedings have a special diagnostic value.

The quantity and significance of findings obtainable from complete preparation clearly document Camps's demand made in 1976 to dispense with the usual laryngeal dissection technique (dorsal scissor incision through the cricoid cartilage), at least in (questionable) strangulation cases.

KEYWORDS: forensic science, forensic pathology, strangulation, laryngeal injuries, autopsy, neck dissection technique

When performing a forensic autopsy, the careful examination of cervical structures plays a particularly important role. Neck muscle hemorrhages as well as hyoid-larynx complex injuries occur in very different types of death; however, the most common cause is strangulation (1–9). These internal cervical findings play a decisive role in the diagnostics of such deaths. Recent examples have again demonstrated the difficulty in interpreting homicide by strangulation with meager findings and unclear or initially unsuspicious circumstances (10). Any experienced forensic pathologist will recall some unresolved cases of this type.

A general description of the neck dissection technique has been extensively discussed in all relevant textbooks (1–6,8,9). However, there are very few reports on a suitable procedure for postmortem examination of the larynx, as if the proper method would become self-evident from the anatomy in the course of the autopsy. As shown in most textbook illustrations, a dorsomedial cut with scissors through the larynx and breaking open the anterior parts of the thyroid (th.c.) and cricoid cartilage (cr.c.) would be the usual procedure in the majority of forensic autopsies after exposing the cornua of the hyoid bone (h.b.) and th.c.

Camps has already deemed this technique to be unsuitable (1). From my own experience, it should also be noted that such a procedure infringes upon the basic approach required—record the findings and only then continue to dissect the structure. The aim of this extensive prospective study was to demonstrate the possible diagnostic benefit of a modified technique.

Materials

For more than 12 years, the author has used a simple laryngeal examination technique described elsewhere (11,12). In an initial series of 1000 unselected, consecutive forensic autopsies (1984 to 1985), all relevant laryngeal findings were examined using formalin-fixed specimens. In routine cases, preparation was then done with unfixed specimens during autopsy (another 1000 autopsies 1986 to 1996). This material provides a comprehensive basis of laryngeal findings from cases other than homicidal strangulation. This study is limited to those cases dealing with homicidal strangulation. Since 1984, the formalin-fixed laryngo-hyoid complexes of all homicides involving strangulation were examined by the author according to this method. The laryngeal findings of these 191 cases investigated in both institutes of Legal Medicine of former West Berlin will be presented here. The external and internal findings of autopsies not performed by the author were taken from autopsy protocols. The circumstances of the cases were taken from police or court records. Case data were coded using 80 variables. We included not only the cases with strangulation as the cause of death but also homicides in which strangulation occurred (almost always with petechial hemorrhages in the conjunctivae/eyelids) but where death was probably or definitely due to other injuries.

Cases were classified as manual strangulation (m.str., type 1) or strangulation by ligature (l.str., type 2), only if the anatomical findings were clear and not essentially different from the perpetrator's statement. On the other hand, ''combined strangulation'' (c.str., type 3) includes cases with a confirmed combination of types 1 and 2 as well as those in which m.str. or l.str. definitely occurred but an additional attack by the other method was at least probable. Type 4 consists of cases in which a clear classification was (previously) not possible; type 5 comprises all other cases, as

[1] Professor of forensic medicine, Institute of Forensic Medicine, University Medical Center Benjamin Franklin, Free University of Berlin, Berlin, Germany.

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TABLE 1—*Types of neck compression and causes of death (191 homicides).*

Type of Neck Compression	Cause of Death: Only Strangulation	Concurrent Cause	Other Cause
Type 1, m.str. (58):	30	15	13
Type 2, l.str. (56):	44	8	4
Type 3, c.str. (44):	37	6	1
Type 4, unclear (16):	8	4	4
Type 5, all other (17):	6	4	7
1–5 total (191):	125	37	29

NOTE: m.str = manual strangulation; l.str. = strangulation by ligature; c.str. = manual strangulation combined with strangulation by ligature.

for example, neck compression with objects. Table 1 shows the incidence of these strangulation types as well as their role in the cause of death. Table 2 lists the age and sex distribution as well as the percentage with laryngo-hyoid fractures (fxs.).

Method of Preparation and Examples of Typical Injuries

The recommended method differs only slightly from routine neck preparation, which is well known to any forensic pathologist (1,3,8). A detailed, illustrated description has already been presented elsewhere (11). The same technique can be applied during autopsy or after formalin-fixation of the removed laryngo-hyoid complex. During autopsy, the additional time required is negligible, but frequently leads to artificial hemorrhages in the small muscles. This hinders the interpretation of a later histological examination which is useful for proving the vitality of the laryngeal injury and provides valuable information about the chronology of the event (12,13). Therefore, preparation after fixation (fixation time: not less than 2 days) is advisable for all homicides by strangulation as well as suspicious cases to obtain better results and establish a more reliable basis for the expertise.

Figure 1*a* shows the typical posterior aspect of the neck structures after removal from the corpse. The esophagus and the hypopharyngeal wall are completely resected, and the posterior parts of the th.c. with the upper and lower horns as well as the greater hyoid horns are exposed. Careful removal of the perichondrium from these horns has recently been recommended by others to detect non-dislocated fxs. or those without perichondral tearing (14). The following steps will then disclose any ''hidden'' injuries: (*a*) Incisions into the cricothyroid joints from a caudal-dorsal direction between the cr.c. and the lower thyroid horn reveal any bleeding into the cavity or joint capsule. The lower thyroid horns can be checked as well as the stability of the anterior fusion of the thyroid laminae. (*b*) Incision of the posterior cricoarytenoid muscles following the dorsal surface of the cr.c. exposes the cricoarytenoid joints. (*c*) The soft tissue of the paraglottic space can be removed from the dorsal surface of the thyroid laminae beginning at the posterior borders of the cartilage. This is difficult in unfixed specimens, especially if the th.c. must be completely separated from the remaining larynx. If the condition of the thyroid laminae is suspicious (visible bleedings, striking mobility), it is preferable to continue the examination after formalin-fixation. Breaking open the thyroid cartilage (Fig. 1*b*) should never be done in this case. (*d*) The main difference from the usual preparation method is the horizontal incision through the cr.c. If the cartilage is not yet markedly calcified, the incision can be made with a stable sharp knife; otherwise a fine saw may be necessary. A ventral-to-dorsal incision

TABLE 2—*Age (decade), sex and laryngo-hyoid fractures in 191 victims of homicidal strangulation.*

	Decade								
	1	2	3	4	5	6	7	8	9
Types 1–5: all cases									
Females (131)	1	10	17	19	14	17	13	18	22
Males (60)	7	4	5	6	10	12	6	7	3
All victims (191)	8	14	22	25	24	29	19	25	25
1/h.fx. (138)	0	4	14	16	21	24	14	22	23
l.t.s.1 (2.6)*	. . .	0.8	1.8	1.6	3.4	2.5	2.0	3.4	4.9
l.t.s.2 (3.6)*	. . .	3.7	3.0	2.4	4.0	3.0	2.8	3.8	5.3
max.l.t.s. (13)†	. . .	5	8	6	10	8	6	11	13
Type 1: m.str.									
Females (50)	1	4	4	5	6	8	5	7	11
Males (7)	0	0	0	1	1	1	2	1	1
All victims (58)	1	4	4	6	7	9	7	8	12
1/h.fx. (47)	0	2	2	3	6	9	6	8	11
l.t.s.1 (2.9)*	. . .	1.5	1.5	0.7	3.0	2.8	2.7	3.8	4.6
l.t.s.2 (3.6)*	. . .	3.0	3.0	1.3	4.2	2.8	3.2	3.8	5.0
max.l.t.s. (13)†	. . .	4	5	2	9	8	6	10	13
Type 2: 1.str.									
Females (30)	0	4	3	6	3	4	5	3	2
Males (26)	5	1	2	2	3	8	4	0	1
All victim (56)	5	5	5	8	6	12	9	3	3
1/h.fx. (30)	0	1	3	5	5	8	5	1	2
l.t.s.1 (1.3)*	. . .	0.4	1.0	1.2	1.5	1.4	1.2	0.7	1.7
l.t.s.2 (2.4)*	. . .	2.0	1.7	2.0	1.8	3.7	2.2	2.0	2.5
max.l.t.s. (7)†	. . .	2	2	3	3	7	4	2	4

NOTE: 1/h.fx. = number of cases presenting laryngo-hyoid fractures in each age group; l.t.s.1 = mean value of laryngeal trauma score. of all cases; l.t.s.2 = mean value of l.t.s. of the cases presenting fractures; max.l.t.s. = observed maximum value of laryngeal trauma score; m.str. = manual strangulation; l.str. = strangulation by ligature.

* Mean value of all cases.

† Observed maximum.

is preferred to avoid artificial fxs. because the anterior arch of the cartilage is thinner and less stable than the posterior cricoid lamina. (*e*) After a division of the upper fragment of larynx along the midline, the laryngeal cavity is visible (Fig. 1*b*). Horizontal or frontal incisions of the vestibular and vocal folds complete the macroscopical laryngeal investigation.

Some stages of the preparation method are illustrated by formalin-fixed specimens with laryngeal injuries (each photograph represents a different case). Figures 2 and 3 show different types of th.c. and cr.c. fxs. Figure 2*a* demonstrates a displaced fx. of the anterior thyroid fusion, obviously visible even in routine neck dissection. On the other hand, a fissure restricted to the dorsal surface of the th.c., as shown in Fig. 2*b*, can only be detected if the th.c. is completely isolated. Displaced cricoid fxs. (Fig. 3*a*) are readily visible from the external inspection of the undissected larynx, whereas an effort must be made to detect incomplete fxs. as additional findings (Fig. 3*a*) or sometimes as the only injury (Fig. 3*b*). Injuries of the laryngeal soft tissues and joints are illustrated in

FIG. 1—*Laryngeal preparation method.* (a) *Posterior aspect of the neck structures (unfixed specimen). The cricothyroid joints are opened and the cricoid is horizontally incised. The stability of the thyroid cartilage is checked prior to the dorsomedial incision through the upper part of the cricoid lamina and breaking open the larynx* (b).

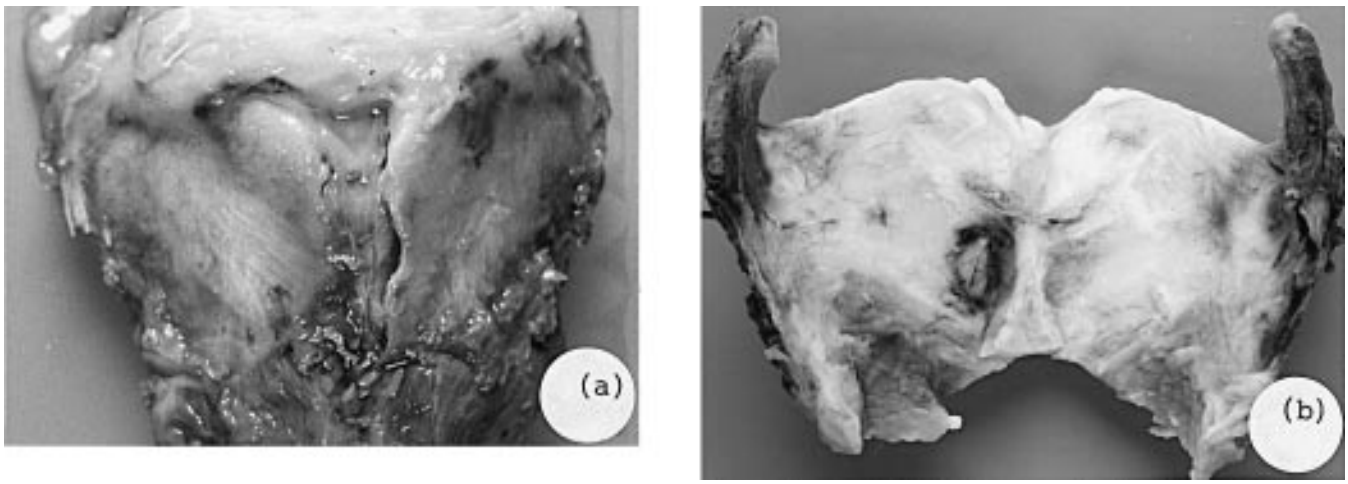

FIG. 2—*Fractures of the ventral fusion of the thyroid laminae.* (a) *A dislocation fracture near the midline is clearly visible and should hardly be overlooked even in a routine examination.* (b) *Th.c. detached from the laryngeal specimen. On the dorsal side of the paramedian left lamina, there was strong hemorrhaging of the perichondrium, which was not torn but only partially detached to demonstrate the fissure underneath. Incomplete fractures of the upper and lower horns are also only visible after removing the perichondrium (not performed here).*

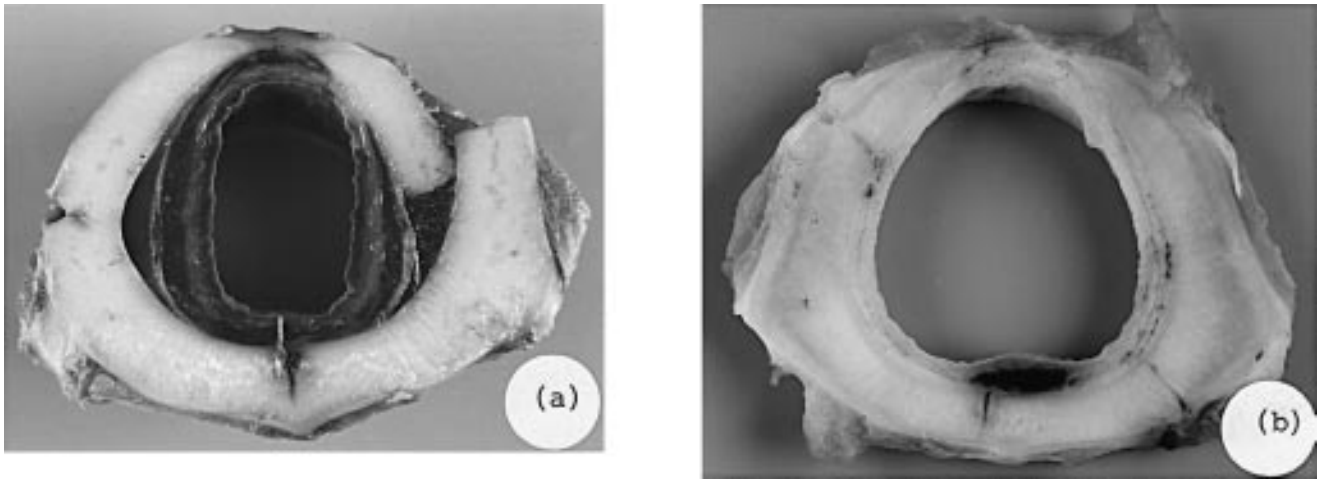

FIG. 3—*Fractures of the cricoid cartilage.* (a) *A dislocation fracture of the side of the cr.c. is obvious and can also be seen externally even on a nondissected specimen. However, the two other injuries are visible only after horizontal incision: a contralateral external and an internal mid-dorsal fissure. The injury pattern shows compression of the cr.c. in the sagittal direction from front to back. The internal soft tissue is massively hemorrhaged and partially torn from the cr.c.* (b) *On the lateral dorsal surface of the corpus of the cr.c., a nondislocated fracture is visible with posterior cricoarytenoid muscle hemorrhage* (lower right corner)*. There is also a dorsal paramedial fissure involving only the internal cartilage, with severe mucosal hemorrhage.*

FIG. 4—*Injury of a cricothyroid joint. The th.c. is removed and the posterior cricoarytenoid muscles are incised. The capsule of the right cricothyroid joint is severely hemorrhaged.*

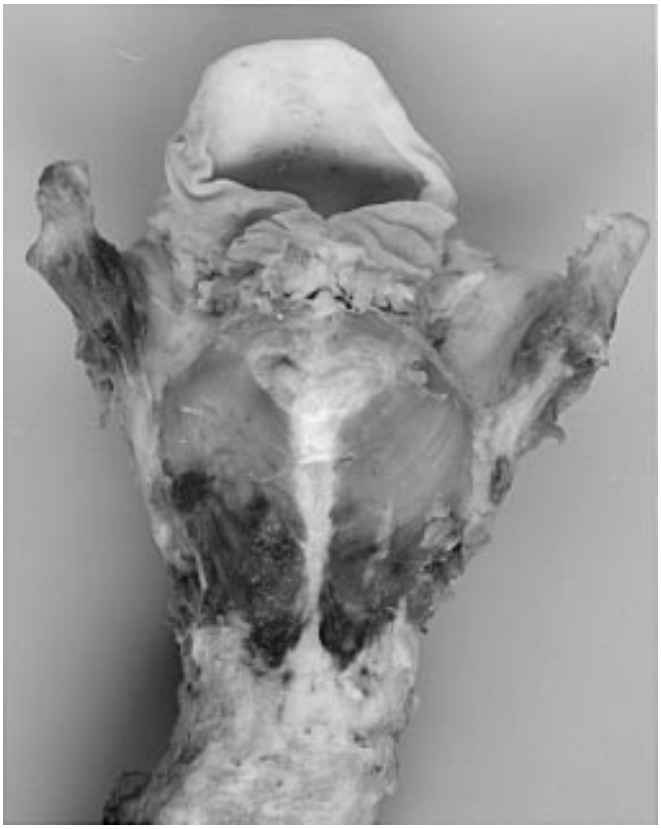

FIG. 5—*Extensive hemorrhage in the lower part of both posterior cricoarytenoid muscles resulting from compression of the larynx against the spine.*

Figs. 4–6. Figure 4*a* shows the posterolateral view of the larynx after resection of the th.c., and before the horizontal incision through the cr.c. Marked capsular bleeding of the right cricothyroid joint is visible. The left posterior cricoarytenoid muscle is incised parallel to the cricoid lamina and the right muscle removed. In Fig. 5 there are hemorrhages in the lower part of these muscles. Figure 6*a–c* illustrate bleeding into the vocal folds. Figure 6*a* presents a left anterolateral view of a larynx after removal of the th.c. In the lower part of the photograph, the anterior arch of the cr.c. and the incised cricothyroid muscles are visible as well as the epiglottis at the top. There is extensive bleeding of the left vocal fold up to the paraglottic soft tissue. Figure 6*b* shows a frontal

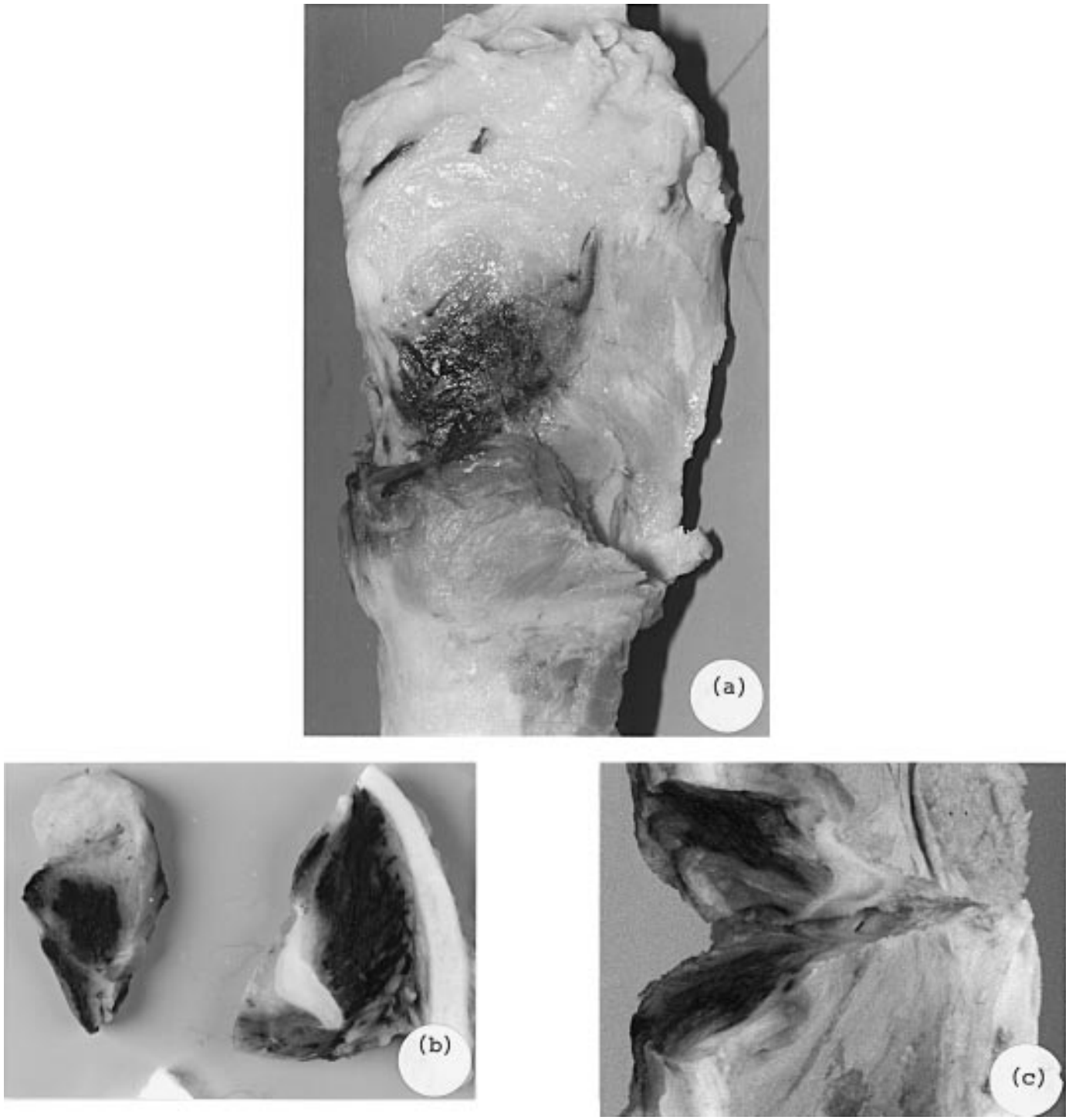

FIG. 6—*Large hemorrhages of the inner laryngeal structures caused by laryngeal compression.* (a) *Oblique frontal view of the laryngeal specimen after removal of the th.c.: an extensive hematoma of the left vocal fold is visible.* (b) *A frontal incision (*left*) through one side of the inner laryngeal soft tissue and a horizontal incision (*right*) through the other. Both vocal folds are entirely permeated by extensive hemorrhaging.* (c) *Horizontal incision through the right side of the larynx after removal of the th.c.. While only small extravasations are found on the vocal cord and laryngeal mucosa, the entire vocal fold is also permeated here by a hematoma. Its existence and spread usually cannot be determined by observing the laryngeal lumen and is visible only after incision.*

(left) and a horizontal (right) incision through the inner laryngeal tissue. In Fig. 6*c*, a massive hematoma of the right vocal fold can be seen after a horizontal incision in the frontodorsal direction.

Results

Fractures of the Hyoid Bone, Cricoid and Thyroid Cartilage

The findings are summarized in Tables 2–4. Table 2 lists the number and severity of fractures in relation to age, sex and the predominant strangulation types. While none of the 14 children and adolescents (<18 years) had skeletal injuries, there were 3 cr.c. fxs. and 1 h.b. fx. among the eight victims aged 18 to 20 years. For evaluating injury intensity, the individual injuries were summarized in a simple score (l.t.s. = laryngeal trauma score): Each broken horn of the h.b. or th.c. was assigned 1 point, incomplete th.j. or cr.c. fxs. 2 points, and dislocation fxs. of these cartilages 4 points. Thus, a maximum score of 14 points was possible. Combined involvement of the different cartilages is given in Table 3. The upper horns of the th.c. were the most frequently affected structures in both m.str. and l.str. (115 cases, with 60 bilateral), whereas fxs. of the lower horns of the th.c. were uncommon (15 cases). Fractures of both the h.b. and th.c. (54 cases) were the most frequent injury combination. Fxs. of the h.b. alone were rare (Table 3).

Because the aim of this paper is to point out those injuries overlooked by incomplete preparation, Table 4 lists the different types of th.c. and cr.c. fxs. Only 15 of 36 th.c. fxs. were complete (Fig. 2*a*), whereas a fissure without dislocation or a completely torn perichondrium (Fig. 2*b*) was found in 21 cases. Of the 31 cases with cr.c. fxs., 21 presented dislocation fxs. (Fig. 3*a*) and 10 showed no signs of a fracture before the cartilage was incised (Fig. 3*b*). Most of the victims with such ''hidden'' cr.c. or th.c. injuries, however, had suffered additional fractures making violent neck compression apparent. Step 2 in Table 5 shows how often detecting or overlooking these ''hidden'' injuries would have been decisive, since there were no other fractures (7 of the 191 cases).

TABLE 3—*Combinations of laryngo-hyoid fractures.*

	All Cases th.c. −	(191) th.c. +	m.str. th.c. −	(58) th.c. +	l.str. th.c. −	(56) th.c. +
h.b. −	60	71	14	21	28	17
(cr.c. − / +)	(56/4)	(56/15)	(12/2)	(18/3)	(27/1)	(17/0)
h.b. +	6	54	3	20	2	9
(cr.c. − / +)	(4/2)	(44/10)	(2/1)	(16/4)	(2/0)	(7/2)

NOTE: th.c. = thyroid cartilage; h.b. = hyoid bone; cr.c. = cricoid cartilage; − / + = fracture not present/present.

TABLE 4—*Fractures of the cricoid cartilage and the thyroid laminae.*

Strangulation Type	Fracture of Cricoid	Thyroid Laminae	Both Cartilages
1 m.str. (58)	10 (4/6)*	10 (0/6/4)†	2
2 l.str. (56)	3 (1/2)	4 (0/2/2)	0
3 c.str (44)	10 (3/7)	11 (3/4/4)	4
4–5 others (33)	8 (2/6)	11 (0/6/5)	6
1–5 all cases (191)	31 (10/21)	36 (3/18/15)	12

NOTE: m.str. = manual strangulation; l.str. = strangulation by ligature; c.str. = manual strangulation combined with strangulation by ligature.

* Fracture without/with dislocation.

† Incomplete fracture of the ventral/incomplete fracture of the dorsal surface/complete fracture.

TABLE 5—*Rate of laryngeal injuries in relation to the extent of laryngeal preparation in 191 cases of homicide.*

Strangulation Types	Number/Rate of Cases Presenting Laryngeal Injury		
	Step 1	Step 2	Step 3
1 m.str. (58)	44 = 76%	47 = 81%	55 = 95%
2 l.str. (56)	27 = 48%	30 = 54%	33 = 59%
3 c.str. (44)	35 = 80%	35 = 80%	39 = 87%
4–5 others (33)	25 = 76%	26 = 79%	30 = 91%
1–5 all cases (191)	131 = 69%	138 = 72%	157 = 82%

NOTE: m.str. = manual strangulation; l.str. = strangulation by ligature; c.str. = manual strangulation combined with strangulation by ligature; step 1 = conventional preparation; step 2 = ''hidden'' fractures detected; step 3 = including laryngeal soft tissue trauma.

TABLE 6—*Injuries of the laryngeal joints.*

Strangulation Type	Cricothyroid Joint	Cricoarytenoid Joint	Both Joints	Total
1 m.str. (58)	19	5	6	30 (52%)
2 l.str. (56)	6	3	1	10 (18%)
3 c.str. (44)	12	2	2	16 (36%)
4–5 others (33)	5	2	4	11 (33%)
1–5 all cases (191)	42	12	13	67 (35%)

NOTE: m.str. = manual strangulation; l.str. = strangulation by ligature; c.str. = manual strangulation combined with strangulation by ligature.

Injuries of the Laryngeal Joints

Capsular hemorrhages or bleeding into the laryngeal joints cavity can occur as a result of laryngeal compression. Such findings were found in 67 cases, considerably more often in the cricothyroid (Fig. 4) than in the cricoarytenoid joint (Table 6). Similar to the fracture rate, there is also a pronounced difference between m.str. and l.str. as an expression of the varying strain on the laryngeal structure. Understandably, there is a clear relationship to fracture intensity: in the injury grades (1.t.s.) 1 to 3, articular lesions were found in 33% of the cases, in grades 4 and 5 in 50% of the cases and in higher l.t.s. in 75% to 80%. However, articular injuries could also be detected in 5 cases without fxs. (4 m.str., 1 l.str.), but no isolated increase in the injury rate (see Table 5) resulted from detecting laryngeal joints injuries because gross laryngeal muscle bleedings were also present. Remarkably, complete tearing of the cricothyroid joint capsule rarely occurred even in severely fractured larynges, confirming their high stability.

Hemorrhages of the Laryngeal Muscles

In 15 of the 191 cases, analysis of soft tissue injuries was impaired because of severe putrefaction. In those cases without putrefaction, hemorrhages in the laryngeal muscles were observed in numerous locations, sizes and combinations. For an initial overview, a simple classification was done (Table 7); disseminated small extravasations were usually thought to result from congestion and occurred most frequently in l.str. On the other hand, there are those cases with extensive hemorrhages (with or without congestion), as shown in Fig. 5 and Fig. 6*a–c* for different locations. These are not only found

TABLE 7—*Occurrence of laryngeal muscle hemorrhages.*

Strangulation Type	All l.m.h.	Small l.m.h.*	All Gross l.m.h.	Gross Vocal Fold l.m.h.†
1 m.str. (58)	43 (74%)	6	37 [20/13]‡	11/20§
2 l.str. (56)	22 (41%)	12	10 [7/3]	1/ 9
3 c.str. (44)	34 (77%)	9	25 [9/13]	7/12
4–5 others (33)	25 (76%)	1	24 [11/8]	7/15
1–5 total (191)	125 (65%)	28	96 [47/37]	27/56

NOTE: l.m.h. = laryngel muscle hemorrhage; m.str. = manual strangulation; l.str. = strangulation by ligature; c.str. = manual strangulation combined with strangulation by ligature.

* These bleedings are attributed to laryngeal congestion.

† These bleedings were seen to be mechanically caused by laryngeal compression.

‡ Cases [without/with] severe skeletal injury.

§ Unilateral/bilateral hemorrhages.

in cases with major fractures and laryngeal instability but also in those with uninjured laryngeal skeletons, especially in young people with very elastic laryngeal cartilages. The most important locations of the hemorrhages are the dorsal larynx (Fig. 5) and the vocal folds (Fig. 6*b–c*). In 19 cases, such hemorrhages were the decisive laryngeal finding (step 3 in Table 5).

Hemorrhages of the Laryngeal Mucosa

Hemorrhages of the mucosa were also a frequent finding. They were found in 60% of all preparations irrespective of the strangulation type. The most common types were petechial hemorrhages alone (50 cases) or combined with ecchymoses (21 cases), i.e., findings attributed more to congestion than to mechanical violence. However, in 20 cases (only one in 1.str.), there were extensive extravasations such as those depicted or described by other authors (3,6). In some of these cases, the hemorrhages are sharply delineated and located in the subglottic area, symmetrically on both sides. This type of hemorrhage results from trauma due to arytenoid cartilage dislocation by external pressure on the larynx (15,16) and is, thus, indicative of a respiratory tract occlusion during laryngeal compression (for more details see Ref 17). These characteristic extravasations are always combined with large hemorrhages in the inner laryngeal muscles; they were not found in other causes of death except in cases with emergency intubation or in septic conditions. There was no additional increase in the rate of injured laryngeal specimens (Table 5) due to hemorrhages of the laryngeal mucosa.

Combination of Laryngeal Findings

The findings of the 176 preparations without putrefaction described above are summarized as follows. There were only 11 cases without any crime-related macroscopic finding on the hyoid-larynx complex. In 14 others there were only congestion-related hemorrhages; l.str. occurred in 18 of these 25 cases, while clear results of mechanical laryngeal injury were seen in 95% of cases with m.str.

Discussion

Systematic analyses of laryngeal injuries after homicidal strangulation are rare. The reports are primarily based on relatively small case numbers and few details are given. The relationship to age is often omitted. For the most part, the studies are retrospective, implying a very heterogeneous examination technique. For this reason, it is not surprising that there are clear differences in the reported injury rates (Table 8). These injury rates are almost exclusively limited to fractures of the hyoid bone or laryngeal cartilages. Although clinicians have demonstrated soft tissue damage by CT after attempted strangulation (15,16,19) and such findings have been described or exemplified in forensic medicine textbooks, they have apparently not yet been systematically analyzed. In view of the numerous factors influencing the complex of injuries [age and constitution of the victim, localization, intensity and type of strangulation, anatomical characteristics of each case (8,20)], even a much larger study series than presented here would be required

TABLE 8—*Incidences of laryngeal and hyoid fractures in homicidal strangulation reported in the literature.*

Author	Strangulation Type	Number of Cases	Number/Rate of All fx.	thyr	cric	Age*
Gonzales (18)	m.str.	24	12/50%	?†	5	−
Luke (23)	m.str.	7	5	?	0	+
	l.str.	6	2	0	0	
Green (24)	m.str.	34	21/61%	4	2	+
	l.str.	31	17/54%	0	4	
Haarhoff (25)	m.str.	26	12/46%	2	1	−
	l.str.	21	0			
	c.str.	14	5/36%			
Haensch (26)	l.str.	30	11/37%	0	0	+
Koops et al. (27)	l.str.	99	65/66%	?	?	−
Missliwetz (28)	m.str.	32	81%	14%	28%	−
	l.str.	23	48%	4%	0	
	c.str.	10	80%	20%	50%	
Vanezis (8)	m.str.	26	19/73%	1	1	+/−
	l.str.	14	33%	?	1?	
Di Maio (2)	m.str.	12	11/92%	?	3	−
Present report	m.str.	58	47/81%	12	12	+
	l.str.	56	30/54%	4	3	
	c.str.	44	35/80%	15	14	

NOTE: thyr. = fracture of the thyroid laminae; cric. = fracture of the cricoid cartilage; fx. = fracture(s); m.str. = manual strangulation; l.str. = strangulation by ligature; c.str. = manual strangulation combined with strangulation by ligature.

* The relationship between fractures and age of the victims is specified (+)/not specified (−).

† ? = The occurrence or number of such fractures is not mentioned.

for a conclusive analysis. However, to my knowledge, another prospective study of comparable size has not yet been performed.

One of the important results of this study is that a definite diagnostic deficit must be assumed for all examinations not performed in a manner comparable to the preparation method presented here. This not only involves incompleteness due to overlooking secondary findings, but in about 10% to 20% of the homicidal cases there are also ''hidden'' findings that can, or even must, be regarded as decisive evidence for relevant neck compression (see Table 5). It requires no further explanation that this is not acceptable in forensic practice.

The ''hidden'' findings include nondislocated cricoid fissures not involving the whole width of the cartilage and those of the anterior fusion of the thyroid laminae. However, hemorrhages of the intrinsic laryngeal muscles, especially of the vocal folds, are equally important. This type of hemorrhage is often found together with severe laryngeal fractures in older victims. In young persons with elastic cartilages, however, it is frequently the only and thus diagnostically decisive morphological result of laryngeal compression. Such findings not only appear in individual cases but were observed in more than half of all deaths with intensive, direct frontal pressure to the neck (Table 7); the rate is markedly lower after strangulation by ligature.

Bilateral hemorrhages in the vocal folds (Fig. 6*b–c*) result from severe deformation of the inner laryngeal space during neck compression, which may cause the vocal folds to be pressed together (6). Muscular damage in the vocal folds may also be due to pressure-induced dislocation of the arytenoid cartilages (15,16). The mechanical pathogenesis of these muscle findings is confirmed by muscle cell ruptures found in the histological examination. In our opinion, these types of findings are highly valuable evidence of traumatic violence to the larynx, even if the skeletal structure is not, or only slightly, injured. Extensive hemorrhages of this type point to a temporary closure of the airways and are, therefore, important for understanding the pathophysiology of the death. Histological examination of such laryngeal muscle hemorrhages may also indicate the vitality of these injuries (12,13).

The generally lower intensity of mechanical damage caused by 1.str. than by m.str. has been known for many years (Table 8) and was confirmed in this investigation. Irrespective of age or sex, the rate and severity of laryngo-hyoid fractures are clearly greater in manual than in ligature strangulation (see Tables 2–6). Our material also confirms the increase in the age-related rate of injury due to laryngeal calcification/ossification. However, there is no clear increase from about the 5th decade of life except in very old victims (Table 2).

Of course, neither laryngeal fractures nor mucosal bleedings nor laryngeal muscle hemorrhages are specific for strangulation and can result from many other situations (1–9,21), but the most frequent cause is strangulation. Moreover, most of the other possible causes can be excluded in a case under investigation. However, it is particularly noteworthy that under certain conditions resuscitation and especially emergency intubation can lead to severe internal laryngeal injury (22).

According to the results of this study, it seems justified to recommend the laryngeal examination described here, at least for cases with obvious or suspected strangulation—not only for the purpose of scientific analysis but especially in routine forensic practice.

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Additional information and reprint requests:
Helmut Maxeiner, M.D.
Institute of Forensic Medicine
University Medical Center Benjamin Franklin
Free University of Berlin
Hittorfstr. 18