The value of MRI for assessing danger to life in nonfatal strangulation

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Abstract: The assessment of danger to life (DTL) is the central question for medicolegal reports in cases of nonfatal strangulation. Petechiae (petechial hemorrhages on conjunctivae, mucosal surfaces and facial skin), and subjective symptoms, such as loss of consciousness, serve as indicators for the forensic assessment of DTL. However, only distinct petechiae are considered an objective finding for life-threatening strangulation. Since the presence of only a few petechiae does not necessarily indicate an asphyxial process and since petechiae may vanish within 1-3 days after the incident, further objective indicators are desired. Radiologic imaging has been considered a potential supplement for the forensic assessment of DTL. Computed tomography (CT) is the most commonly used radiologic modality for detecting the extent of injuries from blunt trauma to the neck and CT angiography allows the diagnosis of vascular injuries, such as carotid dissection. However, the focus of clinical radiology is the diagnosis of injuries that require medical treatment; thus, the applied examination methods and imaging protocols are not necessarily appropriate for forensic assessment in cases of strangulation. Furthermore, exposing a victim to radiation using CT may not be justifiable if the victim does not present severe symptoms. Consequently, noninvasive magnetic resonance imaging (MRI) has been considered for medicolegal examinations in cases of nonfatal strangulation. The aim of this article is to discuss the role and potential value of MRI for the assessment of DTL in cases of nonfatal strangulation. For this purpose, the results, conclusions and recommendations of individual studies were compared and assessed.

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Introduction

Strangulation describes compression of the neck. More precisely, strangulation interferes with oxygen flow to the brain, either by compression of the carotid arteries or jugular veins (leading to cerebral hypoxia) or by compression of the airways (causing asphyxia), and it may cause reflexory stimulation of the carotid sinus with subsequent bradycardia and hypotension [1,2]. According to this description, the definition of strangulation differs from the definition of suffocation, which denotes an accidental or intentional obstruction of the airway at the nose or the mouth [2]. While hanging involves the body weight of the person concerned, the term “strangulation” usually refers to manual strangulation using hand(s), an arm (e.g., chokehold), or leg(s) to put pressure on the neck or to ligature strangulation using any kind of material tightened around the neck. Partial or interrupted strangulation may be applied deliberately in choking games, erotic asphyxia or combat sports [3–6].

Forensic investigations in cases of nonfatal strangulation are usually related to violent assaults, including domestic violence and sexual assault. Therefore, cases of manual and ligature strangulation are much more common in medicolegal routine work than cases of individuals surviving attempts at hanging. In the following discussion, the term “strangulation” is used as the collective term for manual and ligature strangulation. Concerning gender-specific differences in strangulation, females are mostly victims, while suspected offenders are most commonly males [2,7]. The essential questions in cases of nonfatal strangulation are the severity of the assault and the potential danger to life (DTL) [7]. This assessment is often challenging when solely based on the presence or absence of external findings and subjective symptoms reported by the victim. In addition to clinical external examinations, radiologic imaging may aid the assessment of the severity of the assault by revealing internal injuries. Such objective findings may serve as evidence in court.

In addition to endoscopic examination, computed tomography (CT) is the first-line radiologic modality for detecting the extent of injuries from blunt trauma to the neck in clinical radiology [8–10]. In addition to two-dimensional multiplanar reconstructions and three-dimensional volume renderings, CT data can be reconstructed for virtual endoscopy to assess the pharynx [8]. The additional application of contrast agents facilitates the diagnosis of vascular injuries. CT angiography is, therefore, a preferred examination in cases of strangulation [9]. Radiologic diagnosis of vascular injuries, particularly carotid artery dissection, or distinct fractures of the
laryngeal skeleton or hyoid bone are indicators of severe assault, which will be taken into account for the medicolegal report. However, these radiologic diagnoses are rare [9], and in view of this, the primary role of CT angiography in the emergency setting is to rule out clinically relevant pathologies. In rare cases, these CT findings may contribute to the assessment of DTL. Other more frequent findings in strangulation must be identified and associated with DTL. Since health-related aspects must be weighed against radiation exposure for CT scanning, this imaging modality is rarely applied for forensic purposes to assess radiologic criteria of strangulation. To circumvent the issue of radiation exposure, magnetic resonance imaging (MRI) can be performed, although a few contraindications must be considered for MRI examinations as well [11]. As MRI provides more information on soft tissue injuries than CT, MRI is considered a potential supplement to external examination in cases of nonfatal strangulation.

The aim of this article is to discuss the potential value of MRI for the assessment of DTL in cases of nonfatal strangulation. For this purpose, the results and conclusions of previous studies were compared and assessed.

**Classic criteria for life-threatening strangulation**

Assessing the severity of strangulation or the intensity of an assault is the main forensic task in cases of nonfatal strangulation. Plattner et al. [7] assigned external findings and subjective symptoms to four categories:

- 1 superficial skin lesions: hyperemia, abrasions and intracutaneous hemorrhage;
- 2 subjective symptoms indicative of pharyngeal and laryngeal hematomas or swelling: painful palpation, hoarseness and sore throat;
- 3 distinct petechiae: petechial hemorrhages on conjunctivae, mucosal surfaces and facial skin;
- 4 subjective symptoms indicative of cerebral hypoxia: for instance, loss of consciousness or loss of urine.

Based on these classic criteria, the authors proposed the classification of non-life-threatening (light and moderate) strangulation when only findings and symptoms of category 1 and 2 are detected and life-threatening strangulation when findings and symptoms of category 3 and 4 are additionally detected [7]. According to this classification, petechiae are the only objective finding of strangulation. The authors also pointed out that petechiae, as an indicator of the intensity of the assault, should be combined with findings of the other categories of symptoms [7]. A few petechiae do not necessarily indicate an asphyxial process [12]. Furthermore, petechiae may vanish within 1-3 days after the incident [7], and superficial skin lesions or soft tissue lesions can be few or not present at all, independent of the severity of the assault. Signs of cerebral hypoxia, in turn, are solely based on subjective symptoms and thus are not necessarily appropriate for an objective forensic assessment. Therefore, a forensic distinction between life-threatening and non-life-threatening strangulation is difficult when solely based on the clinical external examination. Plattner et al. [7] speculated that radiologic imaging may contribute to clinical external examination for the assessment of DTL in strangulation.

**Studies on MRI in strangulation victims**

Four studies [13–16] investigated the diagnostic value of neck MRI for the investigation of DTL in cases of nonfatal strangulation. Assuming that radiologic findings may be less pronounced after a certain period after the assault, radiologic examinations were performed soon after the external examinations. Yen et al. [13] evaluated 1.5 T (Tesla) MRI examinations of 14 cases of nonfatal strangulation, including manual strangulation (n = 10), chokeholds (n = 2), and ligature strangulation (n = 2), with a mean time of 44.7 hours between the assault and the MRI examination. The time between the assault and the MRI examination was less than 72 hours, but in one case, the interval was approximately 300 hours. This particular case (case 8 in the study of Yen et al. [13]) was not included in the assessments concerning life-threatening and non-life-threatening strangulation since the results of this case remained unclear. Christe et al. [14] evaluated 1.5 T MRI examinations of 56 cases of nonfatal strangulation, including manual strangulation (n = 37), chokeholds (n = 5), ligature strangulation (n = 6), and “mixed” strangulations (n = 8). The mean time between the assault and the MRI examination was 50 hours. In one case, the victim did not report the incident for more than 430 hours. Heimer et al. [15] evaluated 3 T MRI examinations of 114 cases of nonfatal strangulation, including manual strangulation (n = 95; two-handed: n = 48; one-handed: n = 47), chokeholds (n = 14) and ligature strangulation (n = 5). The mean time between the assault and the MRI examination was 48.3 hours. In nine cases, the time between the assault and the MRI examination exceeded 72 hours. Bruguier et al. [16] evaluated 3 T MRI examinations of 11 cases of nonfatal strangulation, including manual and ligature strangulation. The time between the assault and the MRI examination ranged between 24 and 120 hours (median 48 hours).

**Clinical forensic MRI protocols**

Table 1 provides an overview of the MRI protocols used in the four

| MRI protocols. | Yen et al. 1.5 T MRI | Christe et al. 1.5 T MRI | Heimer et al. 3 T MRI | Bruguier et al. 3 T MRI |
|----------------|----------------------|-------------------------|---------------------|-----------------------|
| **STANDARD WEIGHTINGS** |                      |                         |                     |                       |
| weighting       | T1                   | T1*                     | T1                  | T1                    |
| repetition time (TR) [ms] | 400                  | 687                     | 700                 | 620                   |
| echo time (TE) [ms] | 15/20                | 12                      | 10                  | 9.8                   |
| slice thickness [mm] | 2/4                  | 3                       | 4                   | 3                     |
| orientations    | tra/cor              | tra                     | tra                 | tra                   |
| weighting       | T2                   | T2*                     | T2                  | T2                    |
| repetition time (TR) [ms] | 4000                 | 3930                    | 9000                | 5000                  |
| echo time (TE) [ms] | 90/105               | 76                      | 80                  | 96                    |
| slice thickness [mm] | 2/4                  | 3                       | 4                   | 3                     |
| orientation     | tra/cor              | tra                     | tra                 | tra                   |
| **FAT SATURATION** |                      |                         |                     |                       |
| weighting       | T2                   | T2*                     | T2                  | T2                    |
| saturation method | STIR                | TIR                     | DIXON w.o.          | STIR                  |
| repetition time (TR) [ms] | 3000                 | 4000/5620               | 9000                | 6750/6460             |
| echo time (TE) [ms] | 14                   | 20/28                   | 80                  | 80                    |
| slice thickness [mm] | 2/4                  | 3                       | 4                   | 4                     |
| orientations    | tra/cor              | tra                     | tra                 | tra                   |
| weighting       | T1                   | T1**                    | T2                  | T2                    |
| saturation method | fat-sat              | DIXON w.o.              | fat-sat             |                       |
| repetition time (TR) [ms] | 693                  | 790                     | 6590                |                       |
| echo time (TE) [ms] | 12                   | 10                      | 90                  |                       |
| slice thickness [mm] | 4                    | 4                       | 4                   |                       |
| orientations    | tra/cor              | tra                     | tra                 |                       |
| **SPECIAL SEQUENCES** |                      |                         |                     |                       |
| weighting       | T2                   |                         |                     |                       |
| method          | true                 |                         |                     |                       |
| repetition time (TR) [ms] | 4.48                |                         |                     |                       |
| echo time (TE) [ms] | 2.24                 |                         |                     |                       |
| slice thickness [mm] | 3                    |                         |                     |                       |
| orientations    | tra                  |                         |                     |                       |

tra = transversal, cor = coronal, w.o. = water only, fat-sat = fat-saturated, ms = milliseconds, TR = repetition time, TE = echo time, TIRM = turbo inversion recovery magnitude, FISP = fast imaging with steady-state free precession

*DIXON in phase
**the T1 DIXON w.o. (water only) was replaced by the T2 DIXON w.o. after the first MRI examinations
***true fast imaging with steady-state precession is a coherent technique that uses a fully balanced gradient waveform
The terms “hemorrhage”, “edema” and “fluid accumulation” are used synonymously by some of the authors since the differentiation of blood from edema within the soft tissue can be very challenging or even infeasible on MRI, and the coappearance of both conditions is frequent in traumatized tissue [14]. The term “hemorrhage” is used as a collective term in the following discussion.

The total number of MRI examinations of cases investigated in all four studies combined was 195 (100 %). MRI findings in the superficial soft tissue were subcutaneous hemorrhages (28.7 %), platysma hemorrhages (14.9 %), and intracutaneous (superficial) hemorrhages (11.3 %). In the middle and deep soft tissue, MRI revealed lymph node hemorrhages (18.5 %), intramuscular hemorrhages (14.9 %), and perilyngeal fluid accumulations (13.3 %). Other findings, such as edema or hemorrhage of the salivary glands, were detected in ≤ 7 % of the cases, which were deemed rare findings.

**Associating the location of MRI findings with life-threatening strangulation**

An MRI examination can aid in assessing the actual extent of superficial soft tissue lesions. However, superficial soft tissue lesions are not considered signs of DTL. Christe et al. [14] defined three zones to assess radiologic findings in correlation with the clinical assessment of DTL: a superficial tissue zone (skin and subcutaneous fatty tissue), a middle tissue zone (muscles, cervical lymph nodes, vessels, and salivary glands), and a deep tissue zone (larynx and perilyngeal tissue). Cases with classic criteria of life-threatening strangulation demonstrated significantly more findings in the middle tissue zone than did cases without, while findings in the deep tissue zone did not significantly differ between the two groups. Therefore, the authors concluded that the middle tissue zone could be considered the “danger zone” in strangulation. In a follow-up study, Christe et al. [20] re-evaluated their cases to compare the classic criteria (objective score and subjective score) with MRI findings (radiologic score) for the assessment of DTL. The defined scores showed that the MRI findings contributed almost equally to the classic criteria in assessing the severity of strangulation. However, this observation was not shared by Heimer et al. [15]. Although Heimer et al. [15] also detected more MRI findings in cases with classic criteria of life-threatening strangulation, they could not confirm that any location of MRI findings was associated with the assessment of DTL based on classic criteria.

MRI findings were associated with classic criteria of life-threatening strangulation to investigate the potential relevance of individual MRI findings in strangulation. However, the benefit of an additional MRI in cases that already present classic criteria of life-threatening strangulation is low. MRI only provides additional value when it is able to reveal findings in cases to compare the classic criteria (objective score and subjective score) with MRI findings (radiologic score) for the assessment of DTL. The defined scores showed that the MRI findings contributed almost equally to the classic criteria in assessing the severity of strangulation. However, this observation was not shared by Heimer et al. [15]. Although Heimer et al. [15] also detected more MRI findings in cases with classic criteria of life-threatening strangulation, they could not confirm that any location of MRI findings was associated with the assessment of DTL based on classic criteria.

MRI findings in 195 cases of nonfatal strangulation

The MRI findings detected in the four studies [13–16] are summarized in Table 2.

| Table 2 | MRI findings |
|---------|--------------|
|         | Y. et al. NoC | C.et al. NoC | H. et al. NoC | B. et al. NoC | OVERALL NoC | %       |
|SUPERFICIAL TISSUE ZONE | 14 | 56 | 114 | 11 | 195 | 100 |
| - intracutaneous hemorrhage | - | 16 | 6 | - | 22 | 11.3 |
| - subcutaneous hemorrhage | 10 | 31 | 15 | - | 56 | 28.7 |
| - platysma hemorrhage/swelling | 5 | 16 | 5 | 3 | 29 | 14.9 |
|MIDDLE TISSUE ZONE | 10 | 12 | 13 | 1 | 36 | 18.5 |
| - lymph node hemorrhage | 10 | 16 | - | 3 | 29 | 14.9 |
| - intramuscular hemorrhage | 10 | 16 | - | 3 | 29 | 14.9 |
|DEEP TISSUE ZONE | 4 | 8 | 14 | - | 26 | 13.3 |
| - perilyngeal fluid accumulation | - | - | - | - | - | - |
|RARE FINDINGS | 4 | 8 | - | - | 12 | 6.2 |
| - edema/hemorrhage of the salivary glands | 2 | 7 | - | - | 9 | 4.6 |
| - parapharyngeal hemorrhage | 5 | - | 2 | 7 | 3.6 |
| - glottic/vocal cord edema | - | - | - | - | 2 | 1.0 |
| - thyroid hemorrhage | - | - | - | - | 1 | 0.5 |
| - blood serum level in the glottis space | - | - | - | - | 0.5 |
| - fluid accumulation in the vessel-nerve sheath | - | - | - | - | 1 | 0.5 |
| - laryngeal fracture | - | - | - | - | 1 | 0.5 |

NoC = number of cases. Y. = Yen; C. = Christe, H. = Heimer, B. = Bruguier

In Table 3, the number of hemorrhagic lymph nodes and intramuscular hemorrhages detected in the four MRI studies [13–16] are listed separately for cases with and without classic criteria for life-threatening strangulation.

Yen et al. [13] reported four cases with classic criteria for life-threatening strangulation. In addition to petechiae (and subjective signs of cerebral hypoxia), hemorrhagic lymph nodes were detected on MRI in all of these cases. Christe et al. [14] concluded that lymph node hemorrhage might be the internal correlate of petechiae, since both are caused by venous obstruction in concordance with severe strangulation. They detected hemorrhagic lymph nodes in 6/15 cases in the group of life-threatening strangulations. Heimer et al. [15], in turn, considered

The diagnostic value of hemorrhagic lymph nodes and intramuscular hemorrhage

In all of these studies, the scan protocol included a T1-weighted sequence, a T2-weighted sequence, and a fat-saturated T2-weighted sequence. Yen et al. [13] performed these sequences in transversal and coronal orientations, while in the other studies, only the fat-saturated T2-weighted sequence was performed in two orientations, and the T1-weighted and T2-weighted sequences were performed in a transversal orientation only. The slice thicknesses varied between 2 and 4 mm.

According to Yen et al. [13] and Christe et al. [14], intramuscular hemorrhages present diffuse areas that appear hyperintense (bright) on T2-weighted images or isointense (gray) in the first three days after the incident. On T1-weighted images, a hemorrhage can vary from iso- or hypointense (dark) in the first 2-3 days to hyperintense after 2-3 days [13,17]. Christe et al. [14] additionally applied a balanced steady-state gradient echo sequence (trueFISP) to identify potential carotid artery dissections by detection of a hypointense dissection membrane in the arterial lumen. However, carotid artery dissection was not detected in any of the 195 cases of all four studies [13–16]. Heimer et al. [15] performed an additional head MRI examination using diffusion-weighted imaging (DWI) in addition to standard T1- and T2-weighted images. However, the additional examination did not reveal relevant findings in over one hundred strangulation cases. Only one single case presented a localized lesion in the corpus callosum, which can be related to a variety of pathologic or traumatic causes and was not considered a strangulation-related finding [18,19].

The duration of the 1.5 T MRI examinations performed by Yen et al. [13] and Christe et al. [14] did not exceed one hour. Regarding the 3 T MRI examinations, neither Heimer et al. [15] nor Bruguier et al. [16] indicated the duration of the MRI examination. Heimer et al. [15] performed three additional sequences for a head MRI examination. The duration of the MRI examination may be important for patient compliance and for organizational reasons.

MRI findings in 195 cases of nonfatal strangulation

The MRI findings detected in the four studies [13–16] are summarized in Table 2.
hemorrhagic lymph nodes uncommon and not associated with severe strangulation. Notably, neither Christe et al. [14] nor Heimer et al. [15] differentiated between cases with petechiae and those without petechiae in their group of life-threatening strangulations. The cases were assigned to the group of life-threatening strangulations according to the assessment of the forensic examiner. It cannot be excluded that cases without distinct petechiae but subjective symptoms together with other distinct findings were assessed as life-threatening strangulation by the forensic examiner. The four strangulation victims with petechiae examined by Bruguier et al. [16] did not present with hemorrhagic lymph nodes. Regarding this finding, it appears that the presence of lymph node hemorrhage may not necessarily be correlated to the presence of petechiae. Bruguier et al. [16], Heimer et al. [15] and Christe et al. [14] also detected lymph node hemorrhage in approximately 15% of cases without classic criteria of life-threatening strangulation. Yen et al. [13] detected hemorrhagic lymph nodes in four cases without petechiae but subjective symptoms of cerebral hypoxia and assumed that lymph node hemorrhage might be an early sign of congestion and may even occur before externally visible petechiae, since a corresponding hemorrhage in the overlying soft tissues was not detected on MRI. Furthermore, petechiae can vanish within 1-3 days after the event [7], while lymph node hemorrhage appears to be visible for a longer period on MRI. Yen et al. [13] detected lymph node hemorrhage on MRI 300 hours after the incident in a case of strangulation with a belt. As mentioned previously, this case was not included in the tables since classic criteria were not reported and the assessment of DTL remained unclear. Yen et al. [13] concluded that lymph node hemorrhage on MRI might be a valuable sign for life-threatening strangulation, particularly in cases where objective classic criteria for life-threatening strangulation are missing. In this context, however, it should be noted that the differentiation between hemorrhagic lymph nodes (related to strangulation) and swollen lymph nodes (unrelated to strangulation) is challenging on MRI. Heimer et al. [15] also detected lymph node hemorrhage in three cases with unremarkable external examination of the neck and no subjective symptoms of cerebral hypoxia. In these cases, no other distinct soft tissue injuries allowing the classification of life-threatening strangulation were detected on MRI. Therefore, the diagnostic value of lymph node hemorrhage as a sign of life-threatening strangulation remains controversial and requires further scientific evaluation taking into account the extent of petechiae and the time between the incident and the examination.

Similar to lymph node hemorrhage, intramuscular hemorrhage was reported by Yen et al. [13] in all cases with classic criteria for life-threatening strangulation. In this group of cases, Christe et al. [14] detected intramuscular hemorrhage in 8/15 cases. In cases without classic criteria for life-threatening strangulation, Yen et al. [13] and Christe et al. [14] detected intramuscular hemorrhage in 3/4 and 8/41 cases, respectively. Bruguier et al. [16] detected intramuscular hemorrhage in one case with classic criteria for life-threatening strangulation assaults but also in two cases without. The studies by Yen et al. [13], Christe et al. [14] and Bruguier et al. [16] lack information on the extent of intramuscular hemorrhage, which is of particular interest since intramuscular hemorrhages were detected in cases with and without classic criteria. It is conceivable that only distinct intramuscular hemorrhage may serve as an additional indicator of the severity of the assault. In addition to a very small number of hemorrhagic lymph nodes, Heimer et al. [15] did not report any intramuscular hemorrhage in the middle or deep soft tissue either in the group with classic criteria for life-threatening strangulation or in the group without.

### The diagnostic value of perilaryngeal fluid accumulations

A specific finding in the deep tissue zone was considered relevant by Heimer et al. [15]. Cases with perilaryngeal fluid accumulation were significantly associated with difficulty swallowing; thus, MRI can provide an objective confirmation for this subjective symptom. Furthermore, cases with perilaryngeal fluid accumulation were significantly associated with the occurrence of chokeholds. MRI may be of particular value in such cases, since chokeholds often demonstrate only a few external findings [10]. Yen et al. [13] detected perilaryngeal fluid accumulations (indicated as edema or hemorrhage in the laryngeal region) in three cases and suspected this finding in one additional case. In these cases, the victims complained of pressure pain in the laryngeal region, and one of them had been put in a chokehold. Petechiae were not detected in these cases. Christe et al. [14] detected perilaryngeal fluid accumulations in eight cases. Whether the victim was put in a chokehold was not mentioned in one of these cases, but four of the cases were not classified as DTL. Bruguier et al. [11] did not detect perilaryngeal fluid accumulations on MRI in the eleven cases examined, but presumably, in none of these cases was the victim put in a chokehold, since the authors did not mention this type of strangulation at all.

### Learning from the dead to diagnose the living

Radiologists involved in postmortem examinations draw on their clinical experience to read postmortem imaging data [21], but the reverse approach, that is, drawing on experiences gained from postmortem imaging, can also be used when reading clinical imaging data in forensic radiology. To date, two postmortem studies have evaluated the use of postmortem MRI in (manual and ligature) strangulation [22,23]. Compared to clinical MRI, the signal intensities are altered on postmortem MRI, and thus the image contrast depends on the temperature of the body [24], which affects the radiologic assessment together with decomposition-related gas or fluid accumulation and sedimentation [25]. Notwithstanding these alterations, Yen et al. [22] detected hemorrhagic lymph nodes in 4/4 cases on postmortem MRI confirmed by autopsy. By contrast, Deininger-Czermak et al. [23] detected no lymph node hemorrhage on postmortem MRI or at autopsy in six examined cases. This is another discrepancy concerning the diagnostic value of lymph node hemorrhage for life-threatening strangulation. Yen et al. [22] also detected intramuscular hemorrhage confirmed by autopsy on postmortem MRI in 3/4 cases, while an intramuscular hemorrhage was missed on postmortem MRI in the fourth case. Deininger-Czermak et al. [23] detected intramuscular hemorrhage in 4/6 cases on postmortem MRI, which was confirmed by autopsy. A discrete hemorrhage was indicated in a fifth case on postmortem MRI but could not be confirmed by autopsy. In both studies, perilaryngeal fluid accumulation was not mentioned. Due to the small number of cases investigated by Yen et al. [22] and Deininger-Czermak et al. [23], their results do not provide essential information for the assessment of DTL in cases of nonfatal strangulation.

In a further study, Deininger-Czermak et al. [26] investigated the
use of postmortem MRI in 22 cases of hanging. The detection of intramuscular hemorrhage on postmortem MRI was only confirmed in six cases, while in nine other cases, the autopsy did not confirm intramuscular hemorrhage at the corresponding location in the deep soft tissue of the neck. Considering that the weight of the body puts permanent pressure on the ligature surrounding the neck while hanging, the observation of fluid accumulation in the muscle tissue may not necessarily facilitate the interpretation of hemorrhage but rather may aid the diagnosis of edema or decomposition-related fluid, which are not visible at autopsy. The findings on postmortem MRI in hanging are therefore not appropriate for comparison to MRI in cases of nonfatal strangulation. A much larger number of strangulation victims was examined with postmortem CT [27]. Investigations by Yen et al. [22] and Deininger-Czemak et al. [23,26] are in accordance with other studies of cases of fatal hanging in demonstrating that postmortem CT has high sensitivity for the detection of laryngeal and hyoid fractures [27]. Compared to clinical CT, postmortem CT is advantageous because radiation exposure can be neglected, thereby improving imaging quality [28,29].

Routine application of MRI in strangulation victims

Although the validity of lymph node hemorrhage as an explicit sign of life-threatening strangulation on MRI is still controversial, the detection of intramuscular hemorrhage on MRI may still aid the assessment of DTL according to the quantity and quality (extent/size of the finding). However, the application of MRI is cost-intensive and associated with logistic efforts, and therefore, the degree of expectation for positive MRI findings has to be considered. The application of MRI in cases of strangulation was highly recommended by Yen et al. [13] and Christe et al. [14]. By contrast, Heimer et al. [15] and Bruguier et al. [16] were more reserved concerning the value of MRI for the forensic assessment of strangulation. An MRI is usually not endorsed if distinct petechiae together with distinct superficial skin lesions are detected [15,16], since these objective findings already allow the classification of life-threatening strangulation and do not require additional MRI findings for confirmation. In cases with few or no superficial skin lesions and few or no subjective symptoms, additional value provided by MRI is also not expected [15]. Rather, the role of MRI is restricted to victims with few or no superficial skin lesions and only a few petechiae who nonetheless report subjective symptoms. In such cases, MRI can reveal additional objective findings, such as distinct intramuscular hemorrhages. In particular, chokeholds frequently cause relatively few superficial skin lesions [15], and an additional MRI may be considered, especially for this type of strangulation.

If an MRI is considered, the correct interpretation of potential findings according to their signal appearances are important factors for the forensic-radiologic assessment of the examination. Additionally, the selection and number of appropriate MRI sequences within an adequate examination period is important. Examined strangulation victims frequently become anxious because of the loud knocking noises during the MRI examination, the small bore diameter of the MRI scanner, and the positioning of the coil close to the throat. Furthermore, victims of severe strangulation may suffer from cervical pain. For these reasons, the likelihood of motion artifacts on the images increases with the duration of the MRI examination. Moreover, MRI examinations of strangulation victims have to be conducted in a timely manner, since a very long time interval between the event and the MRI examination may have a higher additional value in chokeholds than in other types of strangulations, since victims of chokeholds in particular present few superficial injuries. Moreover, the injury pattern and locations of the injuries should be assessed according to the type of strangulation (one-handed or two-handed strangulation, use of a ligature tool, and chokeholds). Further research is desired to define the role of forensic MRI in cases of nonfatal strangulation for the assessment of DTL.

Conclusion

The increasing number of MRI scanners in clinical radiology may facilitate opportunities for clinical doctors to provide support in more profound diagnosis of medicolegal cases involving pressure to the neck region. Further studies are warranted to evaluate the diagnostic value of MRI in strangulation under consideration of the extent of superficial injuries and the type of strangulation. An additional cost-intensive MRI examination may have a higher additional value in chokeholds than in other types of strangulations, since victims of chokeholds in particular present few superficial injuries. Moreover, the injury pattern and locations of the injuries should be assessed according to the type of strangulation (one-handed or two-handed strangulation, use of a ligature tool, and chokeholds). Further research is desired to define the role of forensic MRI in cases of nonfatal strangulation for the assessment of DTL.

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