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ORIGINAL ARTICLE

The diagnostic value of synovial membrane hemorrhage and bloody discoloration of synovial fluid ("inner knee sign") in autopsy cases of fatal hypothermia

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Abstract We describe and discuss autopsy findings of synovial membrane hemorrhage and bloody discoloration of synovial fluid ("inner knee sign") within a study population comprising 36 cases of fatal hypothermia and 300 control cases. Synovial membrane hemorrhage and bloody discoloration of synovial fluid of the knees were seen in 27 cases of fatal hypothermia (75%). Though we are not dealing here with an obligatory autopsy finding in fatal hypothermia, the detection of the inner knee sign might be used as another corroborative sign of vital hypothermia after considering all differential diagnostic aspects. However, the absence of this finding does not exclude death due to hypothermia.

Keywords Synovial membrane hemorrhage · Synovial fluid hemorrhage · Inner knee sign · Vital signs · Hypothermia · Autopsy

Introduction

Autopsy findings in death due to hypothermia are variable and unspecific [1]. The most frequent diagnostic and informative morphological findings in hypothermia are Wischnewsky spots of the gastric mucosa, cold erythema and lipid accumulation in epithelial cells of renal proximal tubules [1–5]. However, in some cases, especially after a rapid drop of body core temperature, typical macroscopic autopsy findings are missing. Accordingly, forensic pathologists have been searching for additional macroscopic and histological findings related to fatal hypothermia for decades [6], e.g., for hemorrhage in core muscles [7], a difference in the color of blood from the right and left ventricle [8], hemorrhagic pancreatitis [9], depletion of thyroid colloid [10], depletion of the cells of the adrenal cortex [11] and hemorrhage and vacuolization of the pituitary gland [12, 13].

Besides the basic diagnostic signs of hypothermia, in the German medico-legal literature, hemorrhages in the synovial membrane and synovial fluid of the knee joint, determined as the "inner knee sign", are mentioned [3–5, 14]. This phenomenon has been so far described as an empirical observation without scientific basis for its diagnostic reliability and value [14].

The main aim of this study was to scrutinize the inner knee sign as a potential diagnostic autopsy finding in autopsy cases of fatal hypothermia.

Materials and methods

The project was designed as a prospective case control autopsy study. The analysis was performed in four winter seasons (2007–2010). During this time period, 43 cases of fatal hypothermia in total and 300 control cases were examined prospectively. All subjects included in the study sample of hypothermia victims died at the scene without a survival period and without any attempts of cardiopulmonary

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resuscitation preceding death. The time that had passed from death to autopsy ranged between 6 and 36 h. We excluded all such cases in which a postmortem interval of 36 h was exceeded before autopsy to avoid the possibility of misinterpretation due to possible autolytic and/or putrefactive tissue changes of the knee joints.

The diagnosis of hypothermia was based on the case history, circumstances and findings at the death scene, body temperature measurement as well as autopsy and histological findings. In all cases, a toxicology screening including determination of blood and urine alcohol levels was performed.

In all cases of hypothermia and in the controls, a direct visualization of the inner structures of both knee joints was performed using a surgical approach (Fig. 1). The character of synovial fluid (blood mixture) and synovial membrane (hyperemia, presence of hemorrhages) was evaluated and documented with a standardized protocol. Also, samples of synovial fluid and the synovial membrane for histological examination were collected from both knee joints.

To exclude the risk of a false-positive finding, the following exclusion criteria were applied: trauma of knee joint, hemocoagulation disorder or anticoagulant therapy in the previous medical history, postmortem interval of <36 h, concurrence of severe injuries and hypothermia (e.g., complicated suicide, avalanche accident).

The control group comprised of a total of 300 cases of sudden and violent death (e.g., cerebral hemorrhage, pulmonary embolism, myocardial infarction, dissection of aorta, pneumonia, hanging, drowning, shot injury). The control group of non-hypothermia cases was according to the inclusion criteria used in hypothermia cases (the subjects died at the scene without a survival period and without undergoing any cardiopulmonary resuscitation, the time which passed from death to autopsy was <36 h, no trauma of knee joint, and no signs of putrefaction). Control cases covered all four seasons.

Fig. 1 The inner structures of both knee joints were visualized with a surgical approach. The synovial fluid is tinged with blood

Statistics

Statistical analysis was carried out using the chi-square test for contingency tables and Fisher's exact test. A p-value less than 0.05 was considered significant and less than 0.001 was considered highly significant. Calculations were performed using NCSS software for Windows.

Results

A total of 43 cases with fatal hypothermia were prospectively investigated during the study period, seven of which were excluded according to the above mentioned exclusion criteria. Out of the remaining 36 cases, the age range was 29–88 years (average 67.8 years) with a male/female ratio of 4:5. Blood alcohol levels (BALs) were measured in all cases; BAL was positive in five cases (range of BAL between 0.35‰ and 3.45‰). Toxicologically relevant findings were detected in two cases only: one case with combined nonlethal methadone and zolpidem intoxication and the other with a nonlethal overdose of diazepam.

In 36 evaluated cases of hypothermia, cold erythema was detected in 29 cases (80%) and Wischnewsky spots were present in 30 cases (83%). Histologically, 34 cases (94%) showed lipid accumulation in epithelial cells of renal proximal tubules (Table 1).

Bloody discoloration of synovial fluid and synovial membrane hemorrhages of the knee joint were present in 27 cases (75%) (Fig. 2). In 22 cases of the hypothermia group, these findings were bilateral and unilateral in the remaining five cases.

Synovial membranes of the knee joints histologically showed congestion and strong dilation of vessels that were engorged with erythrocytes (Fig. 3). Grossly visible bloody discoloration of synovial fluid could be attributed to hemorrhage into synovial fluid (Fig. 4). In all hypothermia cases where bloody discoloration of synovial fluid was present, fresh hemorrhages of different size that lacked any inflammatory cell reaction were seen microscopically beneath synovial cells. No synovial membrane and synovial fluid hemorrhages were present in any of the 300 controls. All relevant findings are summarized in Table 1.

Statistical results

Statistical evaluation (chi-square test, Fisher's exact test) of the study group did not show significant associations between lipid accumulation in epithelial cells of renal proximal tubules, Wischnewsky spots and the occurrence of synovial

Table 1 Study group

Nr.	Age	Sex	Place of discovery	W	EA	P	H	C	SF	SM
1	36	F	Outdoor	0	1	1	1	B	B	B
2	72	F	Indoor	1	1	0	0	0	0	0
3	29	M	Indoor	0	1	0	0	B	L	B
4	80	F	Indoor	1	1	0	0	B	B	B
5	86	F	Indoor	1	1	1	1	R	0	0
6	73	F	Indoor	0	1	1	0	B	0	0
7	73	F	Indoor	1	1	1	1	B	B	B
8	61	F	Outdoor	1	1	1	0	B	B	B
9	73	M	Outdoor	1	1	0	0	B	L	B
10	55	F	Indoor	1	1	1	1	B	B	B
11	86	F	Indoor	1	1	0	0	B	B	B
12	30	M	Indoor	1	1	1	0	B	B	B
13	82	F	Indoor	1	1	0	0	0	0	0
14	81	M	Indoor	0	1	1	1	B	R	B
15	64	M	Indoor	0	1	0	0	B	B	B
16	80	M	Indoor	1	1	0	0	B	B	B
17	77	M	Outdoor	1	1	1	0	B	B	B
18	88	M	Indoor	1	0	0	0	0	0	0
19	49	F	Indoor	1	1	1	1	B	B	B
20	85	F	Indoor	1	1	1	1	B	B	B
21	68	M	Outdoor	1	1	0	1	0	0	0
22	81	F	Outdoor	1	1	0	0	B	R	B
23	36	M	Indoor	1	1	1	0	0	0	0
24	78	M	Outdoor	1	1	0	0	B	B	B
25	77	F	Indoor	1	1	1	0	B	B	B
26	69	F	Indoor	1	1	0	0	B	B	B
27	66	M	Outdoor	1	1	0	0	B	B	B
28	87	F	Outdoor	1	0	0	1	B	B	B
29	84	F	Indoor	1	1	1	0	0	B	B
30	63	M	Indoor	1	1	1	1	B	B	B
31	86	M	Indoor	1	1	0	1	B	L	B
32	48	M	Outdoor	1	1	1	0	B	0	0
33	61	F	Outdoor	0	1	1	0	B	B	B
34	59	M	Indoor	1	1	0	0	B	B	B
35	52	F	Outdoor	1	1	1	1	0	0	0
36	66	F	Indoor	1	1	0	0	B	B	B
37	53	F	Indoor	1	0	1	0	0	0	0

W Wischnewsky spots, *EA* lipid accumulation in epithelial cells of renal proximal tubules, *P* fresh hemorrhages in psoas major muscles, *H* fresh hemorrhages in pancreas, *1* positive, *0* negative, *C* cold erythema, *SF* bloody discoloration of synovial fluid, *SM* hemorrhages in synovial membrane, *B* bilateral, *R* right side, *L* left side, *0* negative

hemorrhages of the knee joints. However, the same statistical methods confirmed, within the study group, a significant association between the occurrence of synovial membrane hemorrhage and bloody discoloration of synovial fluid and cold erythema ($p=0.004$).

Fig. 2 Bloody discoloration of synovial fluid of the knees in a case of fatal hypothermia

Discussion

The autopsy diagnosis of fatal hypothermia has always been difficult for forensic pathologists as morphological findings are relatively unspecific [1]. Considerable effort has been exerted to find more specific and sensitive autopsy signs or laboratory evidence pointing out to fatal hypothermia [1–6, 15, 16]. Synovial membrane hemorrhages and bloody discoloration of synovial fluid of the knee joints is an under-recognized and neglected observation in hypothermia that is only rarely considered in the medicolegal literature. This subject is occasionally mentioned in German textbooks of forensic pathology or by German authors in general [2–5, 14]. In relevant forensic texts, this autopsy sign is usually introduced with a question mark symbol or a (+/−) sign. These symbols represent yet unspecified and unknown diagnostic significance of this phenomenon in hypothermia. Unlike the German literature, Anglo-American representative textbooks and monographs on Forensic Medicine do not mention this sign at all [17–20].

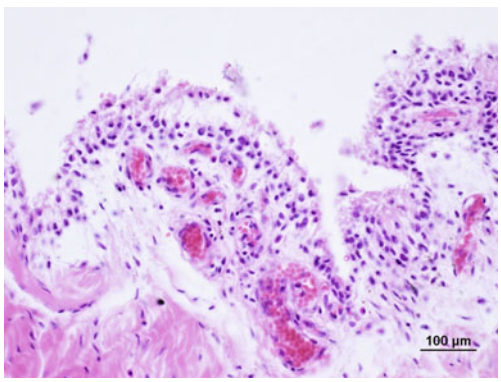

Fig. 3 Histological findings: synovial membrane of the knees—congestion and strong dilation of vessels that were engorged with erythrocytes. Hematoxylin–eosin staining, ×20

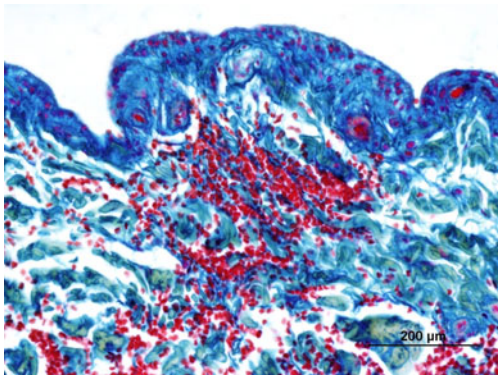

Fig. 4 Histological findings: synovial membrane of the knees—strong fresh hemorrhage. Azan blue staining, ×20

In 2007, Eberhardt Lignitz published a scientific paper "New Autopsy Signs in Violent Death" that drew attention to "new" (so far underrecognized) autopsy signs in forensic pathology: orbita sign, Simon sign, inner knee sign and findings associated with kicking to death [14]. Lignitz pointed out in this publication the possible and so far undetermined diagnostic significance of synovial membrane hemorrhages in fatal hypothermia [14]. With his publication, the author expressed an international appeal for a closer study of this phenomenon; previous investigations of the inner knee signs in fatal hypothermia were merely empirical and unsystematic. In the forensic literature, not one case-control study on the analysis of synovial hemorrhage in fatal hypothermia has been published so far. However, a new valid finding would be a real enrichment for the autopsy diagnosis of fatal hypothermia.

In 1996, Weinke [21] described 19 cases with hyperemia and hemorrhages of the synovia and bloody discoloration of synovial fluid of the knee joints mostly concerning both sides. In a previous investigation of 28 hypothermia cases over a of 6-year period (1977–1982) in the same geographical region, these findings had not been observed or, at least, were not mentioned [14, 22].

Finally in 2009, Mengel [23] presented a doctoral thesis which should prove synovial membrane hemorrhages as vital hypothermia sign. His study comprised 20 cases of hypothermia (1993–1998) and 20 control cases. The rather small number of cases was neither observed consecutively and consistently over a minimal period of time of two cold periods and one warmth period nor was the control material assigned to the corresponding periods of time. Synovial hemorrhages were observed in the given period in 18 cases of hypothermia (90%) and in no control.

Similarly to cold erythema, the pathogenesis of synovial hemorrhage is not entirely clear [2–5, 24]. The occurrence of hemorrhages in the synovial membrane is most probably related to the vascular supply of this membrane [14]. The blood supply of the synovial membrane is a vascular system independent of the fibrous membrane of articular capsule with capillaries that penetrate into the inner cell layers of the synovial intima. Since this blood supply regulation is influenced by the environmental temperature, it seems quite reasonable that cold environment leads to stasis and extravasation of erythrocytes within the synovial membrane.

The results of the present study imply an obvious relation between synovial hemorrhage and cold erythema. Between these two phenomena, a statistically significant dependence (p=0.004; Fisher's exact test) could be demonstrated. Our observations also show that synovial membrane hemorrhages in hypothermia do not only occur in the knee joints, but also in other locations (e.g., large limb joints). We observed synovial membrane hemorrhages and bloody discoloration of synovial fluid in hypothermia in the hip, shoulder and elbow joints. Regarding its possible occurrence, the term "inner knee sign" appears to be inaccurate and misleading. The original and explicit term "synovial membrane hemorrhages and bloody discoloration of synovial fluid" seems more appropriate. The evaluation of synovial hemorrhage in other large limb joints, however, requires further intensive research in larger autopsy series.

Our findings strongly indicate that synovial membrane hemorrhages and bloody discoloration of synovial fluid of the knee joints can be used as a helpful marker for diagnosis of death due to hypothermia in questioned cases. These findings seem to have similar diagnostic value as cold erythema. For the interpretation of synovial membrane hemorrhages and bloody discoloration of synovial fluid, it is important to rule out older trauma and post mortem influences.

From this perspective, pathological changes of the synovial membrane in hypothermia have entered the range of other autopsy signs which have been studied more closely recently or have been newly described [25–27]. These morphological changes are important not only from an academic point of view, but above all for the possibility of their immediate use in routine practice of forensic pathology.

Conclusion of practical interest

The findings of synovial membrane hemorrhages and bloody discoloration of synovial fluid of the knee joints are another vital sign of hypothermia after considering all differential diagnostic aspects in respective cases. These findings have a limited diagnostic value in cases with simultaneous trauma to the knees preceding death and the absence of synovial membrane hemorrhage, however, does not exclude the possibility of death due to hypothermia.

References

1. Türk EE (2010) Hypothermia. Forensic Sci Med Pathol 6:106–115
2. Madea B, Preuß J, Lignitz E (2004) Unterkühlung: Umstände, Morphologische Befunde und ihre Pathogenese. Rechtsmedizin 14:41–59
3. Madea B, Preuß J, Henn V, Lignitz E (2004) Morphological findings in fatal hypothermia and their pathogenesis. In: Oehmichen M (ed) Hypothermia—clinical, pathomorphological and forensic features. Schmidt-Römhild, Lübeck, pp 181–204
4. Lignitz E (2007) Kälte. In: Madea B (ed) Praxis Rechtsmedizin. Springer, Berlin, pp 185–190
5. Madea B, Tsokos M, Preuß J (2008) Death due to hypothermia—morphological findings, their pathogenesis and diagnostic value. In: Tsokos M (ed) Forensic pathology reviews, vol 5. Humana Press, Totowa, pp 3–21
6. Dettmeyer R (2011) Forensic histopathology. Springer, Berlin, pp 165–171
7. Dirnhofer R, Sigrist T (1979) Muskelblutungen in Körperkern – ein Zeichen vitaler Reaktion bei Tod durch Unterkühlung? Beitr Gerichtl Med 37:159–166
8. Richter M (1905) Gerichtsärtzliche Diagnostik und Technik. Hirzel, Leipzig
9. Preuß J, Dettmeyer R, Lignitz E, Madea B (2007) Pancreatic changes in cases of death due to hypothermia. Forensic Sci Int 166:194–198
10. Simon A, Müller E (1971) Einige Aspekte zur Physiologie und Morphologie des Kältetodes unter besonderer Berücksichtigung der sogenannten Kälteschilddrüse. Kriminal Forens Wiss 6:131–138
11. Büchner F (1943) Die Pathologie der Unterkühlung. Klin Wschr 22:89–92
12. Ishikawa T, Miyaishi S, Tachibana T, Ishizu H, Zhu BL, Maeda H (2004) Fatal hypothermia related vacuolization of hormone-producing cells in the anterior pituitary. Legal Med (Tokyo) 6:157–163
13. Doberentz E, Preuß-Wössner J, Kuchelmeister K, Madea B (2011) Histological examination of the pituitary glands in cases of fatal hypothermia. Forensic Sci Int 207:46–49
14. Lignitz E, Henn V (2007) New autopsy signs in violent death. Forensic Sci Int 165:172–177
15. Yoshida C, Ishikawa T, Michiue T, Quan L, Maeda H (2011) Postmortem biochemistry and immunohistochemistry of chromogranin A as a stress marker with special regard to fatal hypothermia and hyperthermia. Int J Legal Med 125:11–20
16. Palmiere C, Mangin P (2011) Postmortem chemistry update part I. Int J Legal Med. doi:10.1007/s00414-011-0625-y
17. DiMaio VJ, DiMaio D (2001) Forensic pathology. CRC Press, Boca Raton, pp 428–432
18. Saukko P, Knight B (2004) Knight's forensic pathology, 3rd edn. Arnold, London, pp 414–420
19. Dolinak D, Matshes EW, Lew EO (2005) Forensic pathology. Principles and practice. Elsevier Academic Press, London, pp 248–250
20. Perper JA Microscopic forensic pathology. In: Spitz WU (ed) Spitz and Fisher's medicolegal investigation of death. Charles C Thomas, Springfield, p 1117
21. Weinke H (1996) Ein neues Zeichen beim Unterkühlungstod. 5. Frühjahrstagung der Deutschen Gesellschaft für Rechtsmedizin – Region Nord. Rostock, 10./11.05.1996
22. Grobe N, Philipp K, Weinke H, Gibb B (1982) Befunde beim Tod durch Unterkühlung. 9. Regionaltagung Nord der Gesellschaft für Gerichtliche Medizin der DDR. Bad Saarow
23. Mengel A (2009) Kältebedingte innere Kniegelenkbefunde beim Unterkühlungstod unter Berücksichtigung anderer kälteassoziierter pathomorphologischer Befunde. MD thesis. Greifswald
24. Türk EE, Sperhake JP, Madea B, Preuß J, Tsokos M (2006) Immunohistochemical detection of hemoglobin in frost erythema. Forensic Sci Int 10:131–134
25. Nikolić S, Zivković V, Juković F, Babić D, Stanojkovski G (2009) Simon's bleedings: a possible mechanism of appearance and forensic importance—a prospective autopsy study. Int J Legal Med 123:293–297
26. Schulz F, Schäfer H, Püschel K, Tsokos M, Brinkmann B, Buschmann CT (2011) Bowel wall hemorrhage after death by hanging. Int J Legal Med 125:403–410
27. Schulz F, Buschmann C, Braun C, Püschel K, Brinkmann B, Tsokos M (2011) Haemorrhages into the back and auxiliary breathing muscles after death by hanging. Int J Legal Med 125:863–871