Int J Legal Med (1999) 112 : 101–106

ORIGINAL ARTICLE

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Macromorphology and histology of intramuscular hemorrhages in cases of drowning

Received: 31 July 1998 / Received in revised form: 31 August 1998

Abstract In a prospective autopsy series of 39 cases of fatal drowning, the detailed dissection of the skeletal muscles of the neck, anterior / posterior trunk and the upper extremities in layers revealed intramuscular hemorrhages of different size and shape in 20 cases (51.3 %). Light microscopy examination showed a premortal (vital/agonal) type of muscular alteration in 7 (50 %) out of 14 macroscopical hemorrhage-positive cases. These hemorrhages and histological muscle alterations are attributed to agonal convulsions, hypercontraction and overexertion of the affected muscle groups. As long as no cutaneous or subcutaneous hematomas above the hemorrhages can be found, these autopsy findings (with special reference to histology) can serve as an additional criterion concerning the differentiation of drowning and another cause of death.

Key words Drowning · Intramuscular hemorrhages · Skeletal muscles · Vital reactions · Postmortem changes · Muscle fiber alteration

Introduction

The diagnosis of fatal drowning is normally achieved by postmortem examination, but the autopsy findings are not always conclusive. Therefore, the differentiation between death by drowning and another cause of death in water requires comprehensive knowledge of the circumstances of death and recovery of the body. A detailed postmortem examination with supportive evidence of histology and different laboratory tests is essential [1, 3, 7–9, 12]. Besides intra-vital reactions, mainly affecting the cardiorespiratory system, the occurrence of intramuscular hemorrhages in cervical, pectoral and respiratory as well as auxiliary respiratory muscles has been described previously in the earlier forensic literature as an indirect sequelae of drowning [2, 10, 14, 16, 17, 22].

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The focus of our attention on intramuscular hemorrhages in cases of drowning derived from particularly suspicious autopsy cases of fatal drowning with the finding of conspicuous hemorrhages in the respiratory muscles of neck and upper chest wall [21]. In contrast to reports on such hemorrhages in various groups of skeletal muscles in cases of fatal drowning, no comprehensive micromorphological investigations on the subject have been carried out so far.

The aim of the present study was to investigate the frequency of intramuscular hemorrhages in a prospective autopsy series of drowning fatalities with special reference to micromorphological aspects concerning the vital origin of these hemorrhages. The diagnostic value and possible etiological factors were evaluated.

Material and methods

In a one-year period, a total of 39 cases (9 females, 30 males) of fatal drowning were studied by postmortem examination with regard to the frequency of intramuscular hemorrhages in the respiratory and auxiliary respiratory, cervical and pectoral muscles and their topographical arrangement. The age of the subjects ranged between 18 months and 82 years. The routine forensic autopsy procedures included histological examination of internal organs (i.e. Sudan III staining for histological identification of fat embolism), blood alcohol estimation and toxicological analysis. In every case, a detailed dissection of the skeletal muscles of the neck, anterior and posterior upper part of the body and the upper extremities was carried out in layers.

Phenomenological aspects of the circumstances and scene of death were taken from official reports or reconstructed from the autopsy findings with special reference to the following aspects: resuscitation attempts, traumatization of the body on recovery and during transportation, water temperature, type of water (i.e. sea, river, lake, swimming pool, bath-tub).

The macroscopic appearance of the hemorrhages concerning localization (right, left, bilateral), intensity (slight, medium, strong), size, shape (linear/striated, expansive), presence of intramuscular ruptures and blood extravasation was documented.

Out of 14 macroscopical hemorrhage-positive cases 95 muscle specimens of intramuscular hemorrhages were collected. The samples were taken parallel to the muscle fibers to avoid bruising and stretching of the muscles. At least five specimens were obtained from each intramuscular hemorrhage, fixed in buffered formalin

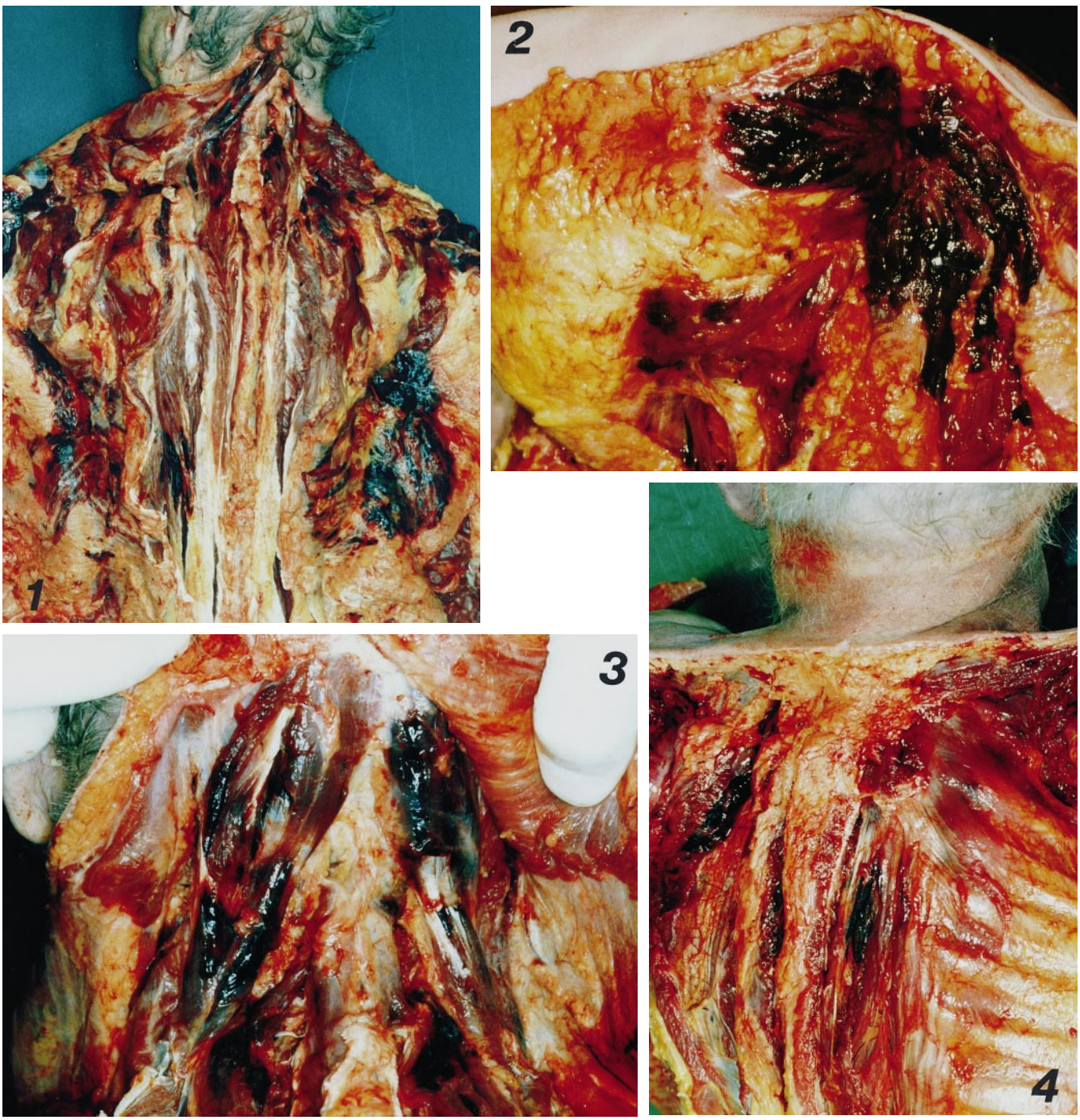

Fig. 1 Posterior trunk of a 84-year-old woman with multiple bilateral intramuscular hemorrhages

Fig. 2 Extensive bleeding cavity within the deltoid muscle. Note the skin and subcutaneous tissue unaffected

Fig. 3 Bilateral hemorrhages of neck muscles

Fig. 4 Uni- and bilateral intramuscular hemorrhages of the autochthonous back musculature and beneath the scapula

and embedded in paraffin for light microscopy examination. Sections (3–5 μm) were stained with hematoxylin-eosin (HE), phosphotungstic acid hematoxylin (PTAH), fibrin staining according to Weigert, Luxol-fast-blue (LFB) and Masson-Goldner (MG).

The histomorphological changes in muscle fibers were classified as premortal (vital/agonal), indifferent (pre- or postmortal) and areactive (postmortal) using the morphological criteria established by Sigrist [18] and Fechner [4]:

Premortal (vital/agonal) type of muscle alteration

Granular or discoid fiber disintegration, loss of striation, invaginated contraction caps, funnel-shaped edges adjacent to damaged and ruptured fibers and concave intra-sarcolemmal ruptures with empty sarcolemma.

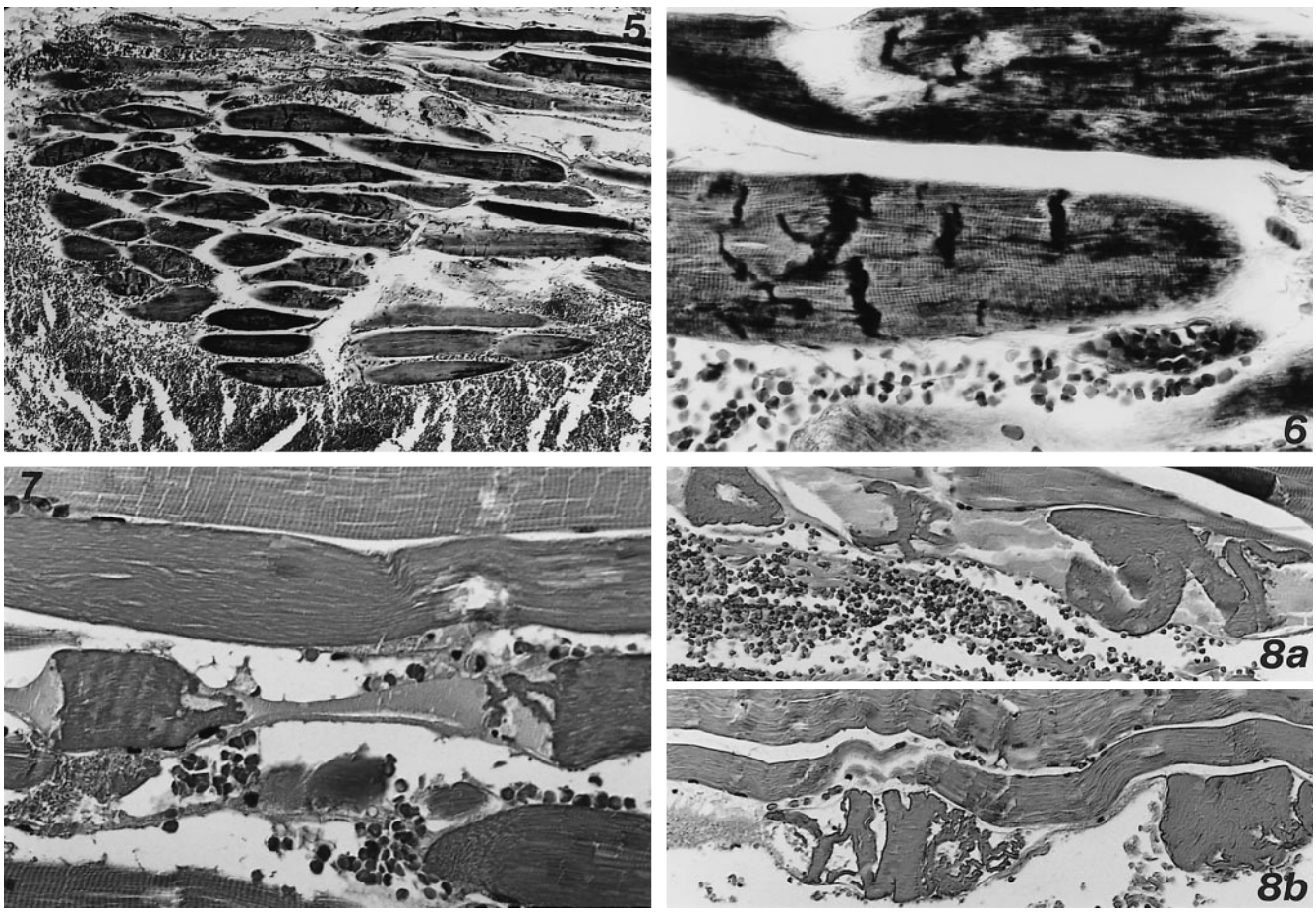

Fig. 5 Multiple hypercontraction bands in the centre of an hemorrhage (M. erector spinae), PTAH × 160

Fig. 6 Hypercontraction zones within an intact fiber, adjacent focal hemorrhage (M. erector spinae), PTAH × 400

Fig. 7 Broad hypercontraction areas with interponated emptied sarcolemma. Invaginated contraction caps. Granular and discoid disintegration of the contractile apparatus. Longitudinal striation of the neighbouring fiber (M. erector spinae), HE × 400

Fig. 8 a, b Focal loss of striation. **a** Irregular hypercontraction bands with interposed "empty" sarcolemma in a fiber with adjacent hemorrhage, HE × 250. **b** Discoid and granular muscle fiber disintegration. Longitudinal striation of the fibers (M. deltoideus), HE × 250

Indifferent type (possibly premortal as well as postmortal) of muscle alteration

Homogenization of the fibers, loss of cross-striation, appearance of longitudinal striation and the finding of distraction and contraction bands.

Areactive (postmortal) type of muscle alteration

Convex intra-sarcolemmal ruptures with or without empty sarcolemma.

Additional micromorphological criteria for vitality were the shape of hemorrhages, fibrin deposits, platelet aggregation and the type of leukocytic reaction.

The hemorrhage was classified as vital, if muscle fibers were separated and displaced by blood corpuscles (forming spiderweb-like configurations) and the intensity of the hemorrhage diminished towards its periphery.

Results

Frequency and localization of hemorrhages

Detailed dissection revealed intramuscular hemorrhages in 20 (51.3 %) out of 39 cases in various groups of skeletal muscles and 93 foci of hemorrhages (within the 20 hemorrhage-positive cases) were noted. The majority of hemorrhages was found in respiratory and auxiliary respiratory muscles (34.4 %) and in the musculature of the neck and back (30.1 %). Intramuscular hemorrhages were found also in the musculature of the shoulder girdle and upper arm (21.5 %) and in the cervical and laryngeal muscles (14 %).

Gender, age and phenomenological aspects

Of the 20 cases with hemorrhages, 15 were male and 5 female. The age of the deceased ranged between 18 months and 70 years. In 11 cases the body was found floating on the surface of the water, in 2 cases the deceased was washed ashore and one body was recovered from an automobile at the bottom of the harbour. Three fatalities hap-

pened in a bath-tub and the circumstances were uncertain in three cases. Resuscitation attempts had been carried out in 3 cases. The official reports (e.g. police records) were incomplete concerning premortal entry into the water, collision with obstacles (e. g. boats) in the water and traumatization during recovery of the body. Information about the status of the deceased as swimmer or non-swimmer was not available.

There was no correlation between age, sex or any of the investigated phenomenological aspects with reference to the frequency, intensity or localization of the intramuscular hemorrhages.

Macroscopic appearance of hemorrhages

Of the 93 foci of hemorrhages ascertained, unilateral hemorrhages were found in approximately 50 %. The intensity of the intramuscular hemorrhages was graded as slight in about 45 %, as medium in about 25 % and strong in approximately 30 %. Some of the hemorrhages showed extensively expanded bleeding cavities (up to 3 cm in diameter). Without exception, the skin and subcutaneous fatty tissue above the hemorrhages and the bleeding cavities were undamaged and showed no hematomas. The linear-shaped type of hemorrhage (70 %) predominated over the expansive-shaped type.

Histological findings

Light microscopy examination revealed a premortal (vital/agonal) type of muscular alteration in 7 (50 %) out of the 14 macroscopical hemorrhage-positive cases that were histologically investigated. The remaining six cases had to be excluded from the histological evaluation due to progressive autolysis or putrefaction. In order of frequency, the following premortal (vital/agonal) histomorphological changes were found: invaginated contraction caps, funnel-shaped edges adjacent to damaged and ruptured fibers, granular fiber disintegration, concave intrasarcolemmal ruptures with empty sarcolemma and discoid fiber disintegration. Out of the intramuscular hemorrhages that were classified as premortal (vital/agonal) by the type of histological muscle alteration, approximately 40 % showed spiderweb-like configurations with separated and displaced muscle fibers. Occasionally a distinct fibrin network was found amongst the separated muscle fibers in the interior of the hemorrhages. There were only very few intravascular platelet and fibrin aggregations. There was no leukocytic reaction adjacent to the hemorrhages and the fiber alterations.

Table 1 contains further information about the cases with histological fiber alterations of vital origin.

In five cases (36 %) histomorphological changes were present that were classified as indifferent type of muscular alteration, with the following order of frequency: loss of cross-striation, finding of distraction and contraction bands, appearance of longitudinal striation and homogenization of the fibers.

Table 1 Age, gender, blood alcocol concentration (BAC), distribution and intensity of muscle hemorrhages in 7 drowning cases with histologically classified vital fiber alterations

Age (years)	Gender	BAC (‰)	Muscles		Intensity
22	male	1.91	M. pectoralis major M. biceps brachii	right bilat.	no hemorrhage
61	male	1.64	M. erector spinae M. pectoralis major	bilat. right	strong
47	male	0.0	M. deltoideus	left	slight
2[a]	female	0.0	M. deltoideus M. deltoideus	right left	strong
2[a]	male	0.0	M. latissimus dorsi M. sternocleidomast. M. erector spinae	left bilat. left	medium
54	male	2.6	M. erector spinae M. deltoideus	left left	strong
20[a]	male	3.5	M. erector spinae M. infraspinateus	right right	strong

[a] Cases with preceded resuscitation attempts

Convex intra-sarcolemmal ruptures with or without empty sarcolemma and preserved cross-striation that were classified as the areactive (postmortal) type of muscle alteration were found in 5 (36 %) out of these 14 cases. – The different types of muscle alterations were sporadically combined.

Histologically the hemorrhages were found in the immediate vicinity of the premortal (vital/agonal) or the areactive (postmortal) type of muscle alteration, just as premortal and areactive muscle alterations occurred without adjacent hemorrhages.

The three cases with preceding resuscitation attempts showed premortal (vital/agonal) as well as indifferent alterations of muscle fibers.

Discussion

In the first description of intramuscular hemorrhages in cases of fatal drowning, Paltauf [10] related hemorrhages in the Mm. pectorales major and Mm. sternocleidomastoidei to the asphyxation struggle of the drowning victim and preceding resuscitation attempts. This finding of intramuscular hemorrhages in drowning has only been described occasionally, particularly in the earlier forensic literature. Reuter reported an overall frequency of 11.5 % [15] or 13.2 % [17] without giving details of whether a dissection of the skeletal muscles of the posterior of the body was performed regularly. He explained this finding by convulsive dyspnoea with subsequent ruptures especially of the respiratory and auxiliary respiratory musculature. Reh [14] considered the finding of intramuscular hemorrhages as highly suspicious of fatal drowning in bodies recovered from water when external blunt force could be excluded. Recently, intramuscular hemorrhages in the

musculature of the neck in cases of fatal strangulation have been described and were assumed to be asphyxia-associated by the authors [11].

The focus of our attention on these intramuscular hemorrhages originated from the finding of conspicuous hemorrhages in skeletal muscles in several cases of drowning. The attempt to evaluate the frequency of intramuscular hemorrhages in a retrospective analysis failed due to the irregularity of a detailed dissection of the skeletal muscles; histological muscle specimens were not available.

In the current prospective autopsy series, intramuscular hemorrhages could be demonstrated in 20 (51.3 %) out of 39 cases of fatal drowning. Macroscopically the hemorrhages showed no homogeneous pattern of distribution or preference of localization. In contrast to Paltauf [10], who reported the hemorrhages to be manifested uniformly and bilaterally in corresponding regions, we found unilateral hemorrhages in nearly the same frequency as bilateral hemorrhages.

Besides the investigation of the macroscopic appearance and topographical distribution of these hemorrhages, the aim of the present study was to classify histomorphological changes of muscle fibers [4, 18] and thereby draw conclusions concerning a potential vital origin: it is a well known fact that the macroscopical differentiation between postmortal and vital hemorrhages is uncertain [4, 6, 13, 18, 19]. Histological examination revealed premortal (vital/agonal) muscle fiber alterations in 7 (50 %) out of 14 hemorrhage-positive cases.

The influence of blunt external force as a causative agent for the observed hemorrhages was ruled out – as far as possible – by macromorphological and micromorphological aspects, especially taking into consideration that the dissection revealed no cutaneous or subcutaneous lesions above the affected muscles. Histologically there was no evidence for pulmonary fat embolism.

Besides the three cases with preceding resuscitation attempts showing vital as well as non-specific alterations of muscle fibers, there was no correlation between age, gender or any of the investigated phenomenological aspects with regard to frequency, intensity and localization of intramuscular hemorrhages. As a special point of interest it has to be mentioned that among the six bath-tub cases in our study, three showed muscle hemorrhages. No correlation between muscle hemorrhage and blood alcohol concentration was found (see Table 1). Of course, the small number of cases comprised in the study group requires careful interpretation.

The occurrence of indifferent and areactive, possibly artificially induced hemorrhages is a well-known fact of muscle pathology which might be attributed to postmortem traumatization and breaking of the cadaveric rigidity during recovery or transport of the corpse [23]. The potential postmortal origin of this areactive type of muscle alteration has been confirmed histologically in experimental investigations [4, 5, 13, 20].

According to the results of our study and with respect to the pathophysiology of drowning, the hemorrhages can be attributed to agonal convulsions during the asphyxation period or hypercontraction and overexertion of the muscles involved in swimming, self-rescue attempts and respiration.

Our findings and the observations of other authors indicate that a careful and detailed dissection of the skeletal muscles of neck, anterior and posterior trunk and upper extremities should be a standardized procedure of the postmortem examination in bodies recovered from water. It has to be emphasized that even though the occurrence of intramuscular hemorrhages is not pathognomonic for fatal drowning, the forensic pathologist should bear their potential existence in mind.

It is concluded that the autopsy finding of intramuscular hemorrhages with supportive evidence of muscle histology, as long as no hematomas of skin and subcutaneous fatty tissue above the hemorrhages can be found and premortal and postmortal traumatization can be ruled out, can serve as an additional criterion, allowing further differentiation between fatal drowning and other causes of death.

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