



Death by Frostbite: From Theory to Reality: A Case Report

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Abstract: Background: When the body temperature falls below 35 °C, a condition known as hypothermia occurs. This renders it impossible to regulate the body temperature and produce heat. In these cases, death is due to a cessation of vital functions and is triggered by a body temperature below 25 °C. A multidisciplinary approach is typically required when hypothermia is suspected to combine circumstantial evidence, external examination, autopsy, microscopic and biochemical findings, and other data useful to assess the diagnosis of fatal hypothermia. Post-mortem diagnosis of death by hypothermia frequently presents a medico-legal dilemma. **Methods and Results:** The authors present a case of hypothermia in which site inspection, autopsy, and histological examination simultaneously revealed the forensic and anatomopathological characteristic findings of hypothermia with some peculiar evidence: paradoxical undressing, thanatochronological phenomena, frost erythema, polyvisceral congestion and Wischnewski spots, and subnuclear vacuolization of renal tubular epithelial cells.

Keywords: frostbite death; paradoxical undressing; frost erythema; Wischnewski spot; renal tubular vacuolization



Citation: Duma, S.; Mele, F.; Calvano, M.; Leonardelli, M.; Macorano, E.; De Gabriele, G.; Cristalli, A.; Marzullo, A.; Introna, F. Death by Frostbite: From Theory to Reality: A Case Report. *Forensic Sci.* **2024**, *4*, 555–565. <https://doi.org/10.3390/forensicsci4040037>

Academic Editor: Matteo Nioi

Received: 31 July 2024

Revised: 21 September 2024

Accepted: 3 October 2024

Published: 11 October 2024



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1. Introduction

Hypothermia is a systemic condition in which the core body temperature is below 35 °C and the body loses its thermoregulatory capabilities and is not able to generate heat [1].

A body temperature below 25 °C is responsible for death caused by an arrest of the vital functions.

In addition to low temperature, other factors play a relevant role in causing this syndrome: environmental conditions (ventilation, atmospheric pressure, altitude, duration of exposure); age of the subject (children and elderly are more susceptible to extreme climate conditions); comorbidities (e.g., anemia, alcoholism, heart disease) [2].

The initial phase is reactive and is characterized by shivering: the human body is able to maintain thermal balance by increasing the production of heat, but beyond this limit the progressive cooling of the body is unstoppable and thermal decompensation occurs. The subsequent phase is that of exhaustion, dominated by decay of nervous functions and progressive failure of body defense, up to cardiorespiratory arrest.

Subjects dead from hypothermia are often missing people and come to the attention of the medical examiner in order to examine any possible hypothesis of crime, evaluating the presence of injuries produced by others, and to define the cause and time of death. Medico-legal findings in case of hypothermia are generally non-specific (polyvisceral vascular congestion; peripheral lesions from freezing). Often, only circumstantial information leads

to the diagnosis [3]. Furthermore, the application of various techniques, even considering new forensic approaches [4,5], could be reliable tools in the resolution of a criminal case.

The authors present a case of hypothermia in which rare diagnostic forensic and anatomopathological findings were found [6]. This represents a case study: the multiple finds identified, coexisting in the same subject, represent a rare event described in the literature, especially at our latitudes (south of Italy). So, the aim is to focus the attention on this peculiar evidence.

2. Case Report

In December 2021, an elderly 85-year-old man was reported missing. He had left home for a short walk and did not come back after a few hours. His relatives reported that the man was suffering from Alzheimer's disease, hypertensive heart disease, and epileptic syndrome.

The search of family members and the police was in vain; after 7 days, the lifeless body of the elderly missing man was found in a near-abandoned country field.

Forensic examinations were required in order to clarify time, cause, and modalities of death.

2.1. Site Inspection

The body was found completely dressed in the upper part of the body, but his trousers were lowered on his legs up to the thighs. Shoes were not worn and placed nearby the body (1 mt) (Figure 1).



Figure 1. Crime scene.

The evaluation of the thanatochronological parameters allowed to detect pale reddish hypostasis under acupressure (Figure 2) in the posterior areas of the trunk and lower limbs, generalized rigor mortis, and a rectal temperature lower than the environment (body temp 8.7 °C and environmental temp 11.5 °C). The average temperature that day and the previous two days was 12 degrees, minimum 8, maximum 16, with an average humidity of 90.



Figure 2. Hypostasis.

2.2. Cadaveric Inspection

External examination showed numerous abrasions on both forearms and thighs (Figure 3), some of which were roughly parallel, as well as purplish areas of discoloration on both elbows, knees, and gray-brownish discoloration on both hands (Figure 4) and feet (Figure 5) with no macroscopic evidence of hematomas.



Figure 3. Abrasions.



Figure 4. Discoloration of hands.



Figure 5. Discoloration of feet.

2.3. Autopsy Findings

No macroscopic alterations of heart, lungs, and brain were detected. At the opening of the stomach, the presence of widespread reddish hemorrhagic spots, mostly localized in the antral region, was evidenced (Figure 6). The liver had a poorly recognizable architecture.



Figure 6. Stomach with widespread reddish hemorrhagic spots.

2.4. Toxicological Findings

Toxicological analysis was performed to detect the presence of alcohol and/or drug abuse substances; none of the substances investigated (alcohol, methadone, cannabinoids, barbiturates, benzodiazepines, opiates, amphetamines, cocaine and metabolites, tricyclic antidepressants) were found in the analyzed biological samples (blood and urine).

2.5. Histopathological Findings

Microscopic observation of tissue sections stained with hematoxylin and eosin showed marked pulmonary congestion (Figure 7), micro- and macrovesicular hepatic steatosis (Figure 8), as well as vacuolization of the basal cells of renal tubules (Figure 9). Gastric wall showed edema and vascular congestion involving mucosa and submucosal layers and focal erosions of the mucosal surface consisting of necrotic foci delimited by a dense lympho-histiocytic infiltrate (Figure 10). At the level of the skin discoloration (Figure 11), small hemorrhagic extravasations in the dermis were detected.

The cause of death deriving from our medico-legal examination was hypothermia in subjects with hypertensive heart disease, Alzheimer's disease, and epileptic syndrome.

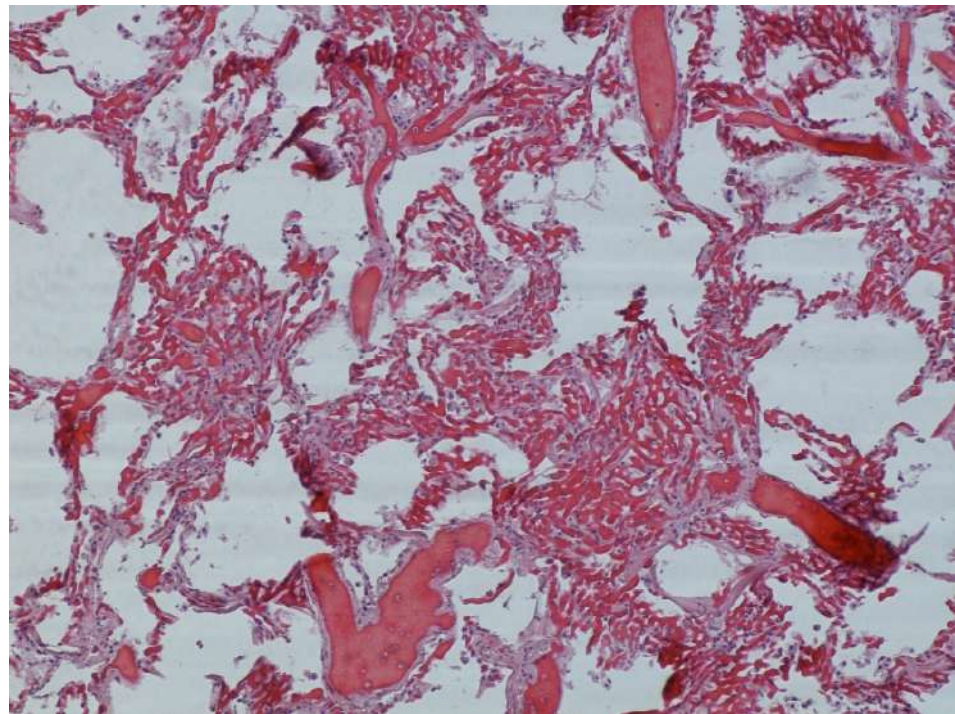


Figure 7. Pulmonary congestion.

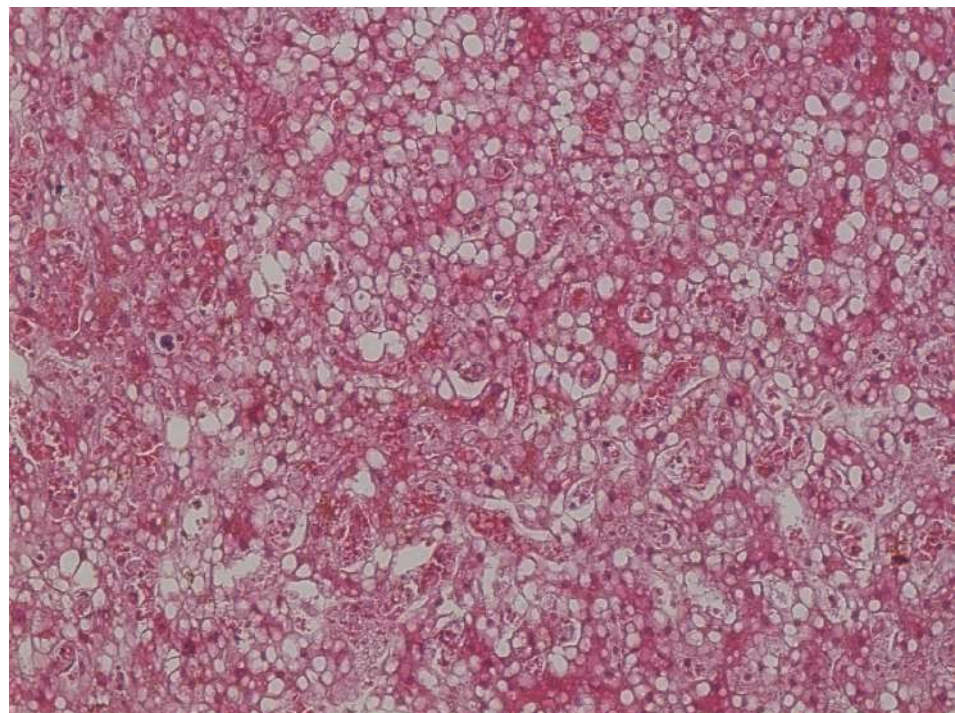


Figure 8. Micro- and macrovesicular hepatic steatosis.

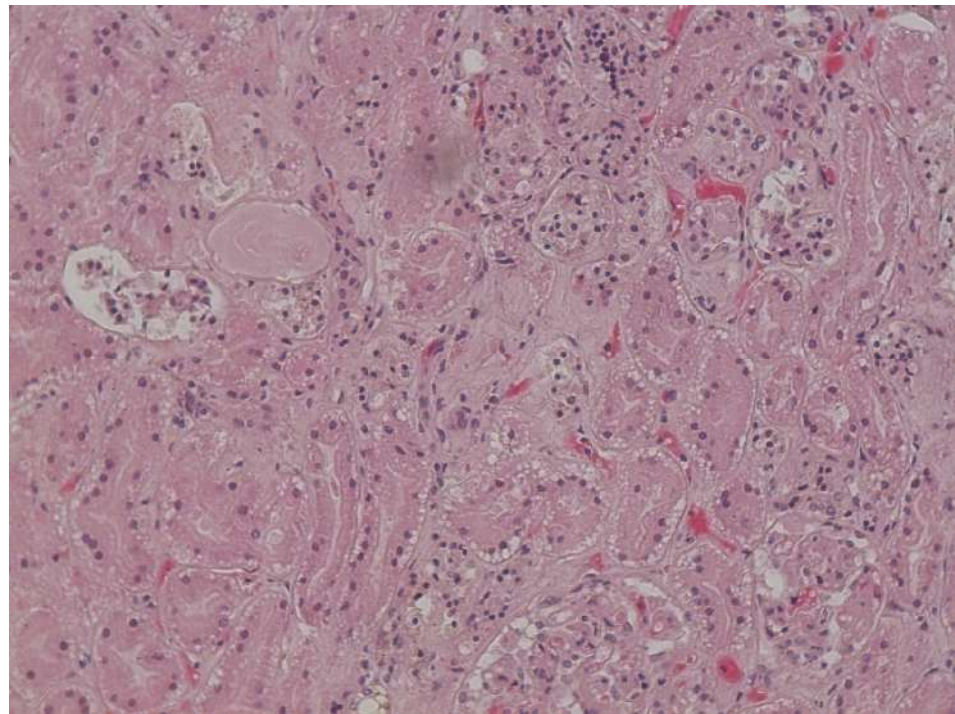


Figure 9. Vacuolization of the basal cells of renal tubules.

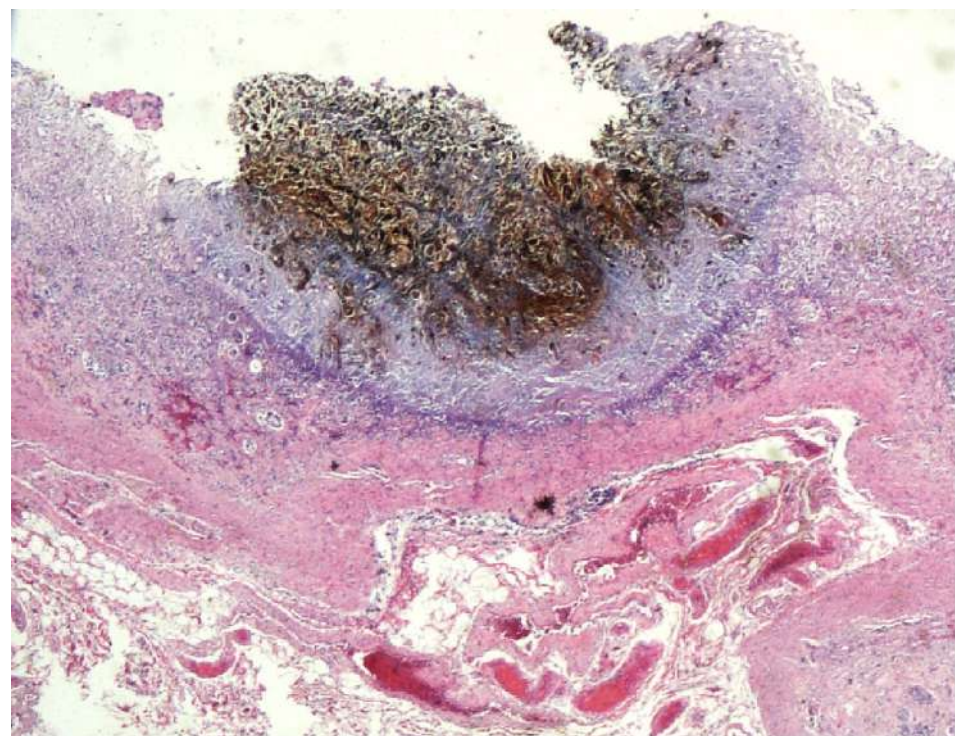


Figure 10. Gastric wall with focal erosions of the mucosal surface.

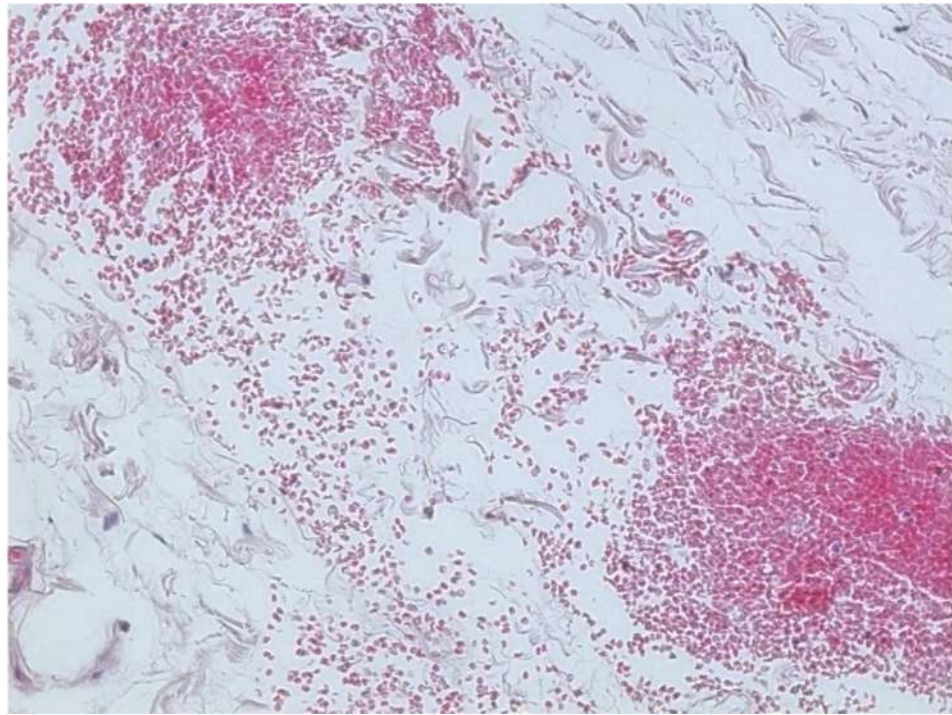


Figure 11. Skin with small hemorrhagic extravasations in the dermis.

3. Discussion

Post-mortem diagnosis of death by hypothermia is often a medico-legal dilemma; in most cases, in fact, a multidisciplinary approach is necessary to combine circumstantial findings, external examination, and cadaveric section evidence (mostly non-specific), as well as microscopic and biochemical findings, in order to assess the diagnosis of fatal hypothermia [7]. Furthermore, although hypothermia can happen even in mild temperature conditions, some risk factors should be considered such as old age, time of exposure, male subjects, and low population density [8].

There are no pathognomonic signs of fatal hypothermia at autopsy. In any case, some nonspecific features should be investigated, including time of exposure, medication intake, thermic lesions, and phenomena such as ‘paradoxical undressing’ and ‘hide-and-die syndrome’.

3.1. Paradoxical Undressing

Paradoxical undressing has been described in cases of lethal hypothermia [9,10].

In most cases, the subjects were found with clothing partially worn, and with the lower part of the body undressed, confirming that usually undressing begins from the lower regions [11].

This phenomenon affects up to 50% of hypothermia victims, and its pathogenesis has not yet been fully defined, but can be explained by two different theories: according to the first, this phenomenon would be due to a paralysis of the vasomotor centers that would alter the perception of body temperature; another possible explanation is that cold would be responsible for a vasorum nerve paralysis, which would cause a vasodilation, so that a certain amount of blood from the center of the body is diverted to the periphery [10].

This causes the hypothermic victim to suddenly feel hot (‘hot flash’) and begin to undress, in contrast to the body temperature that actually continues to drop.

In the course of judicial inspection and external examination it was found that the clothing worn by the victim was widely damp. It was also noted that, although the shirts and jacket were found to be properly worn, the victim had his pants down on his hips and his shoes removed and placed in proximity to the body. So, this finding could be correlated with the so-called phenomenon of ‘paradoxical undressing (denudation paradox)’.

3.2. *Tanatochronological Phenomena*

Post-mortal phenomena in case of fatal hypothermia present intense early and total rigidity, diffuse reddish hypostasis, and extreme low body temperature [12].

In our case, during the first cadaveric inspection, the body temperature was lower than the ambient temperature, the hypostases were reddish and localized in the posterior areas of the body, rigidity was diffuse to the main articular districts.

3.3. *Frost Erythema*

The phenomenon ‘frost erythema’ is a reddish-brown discoloration of exposed skin areas, particularly involving the extensor surfaces of large joints [7] as result of dermal hyperemia and edema without red blood cell extravasation and supports a diagnosis of fatal hypothermia. The peripheral areas may also be affected by frozen lesions due to ischemia of the tissues resulting from spasm of the arterial vessels, to which is added the direct action on the vital processes of the cells which are slowed down or inhibited. Frozen lesions show variability from the first degree or erythema that is the transient vasoconstrictive reaction followed by passive hyperemia from vasal paralysis (pale red skin and edema), to the second degree (skin with blisters, serum-hemorrhagic vesicles), and third degree or necrosis (dry or wet gangrene) [2].

In this case, two categories of lesions were found on the victim during the external inspection: excoriated lesions and frost erythema. The excoriated lesions (linear, scratching type) were mainly located to the lower limbs. Due to the irregular morphology, the areas involved, and the presence of some physical elements found during the site inspection (abundant presence of brambles and brushwood), this type of lesions was correlated to the brambles encountered during the victim’s protracted walk and wondering.

The thermic lesions from cold (frosts) consisted in multiple and diffused areas of cutaneous reddish discoloration, localized on the face (right auricle, left malar region), upper limbs (dorsal surface of the forearm and hand bilaterally), and lower limbs (anterior surface of the knee and leg bilaterally, dorsal surface of the foot bilaterally, plantar surface of the left foot). These lesions were related to the low temperature conditions at which the victim was exposed, due to the occurrence of reactive vasomotor phenomena of transient vasoconstriction and passive hyperemia from vasal paralysis. Histological analysis showed small hemorrhagic extravasations, attributing these lesions to a second degree.

Moreover, the macroscopic and histological analysis highlighted the characteristics most frequently attributable to cold-related death. In particular, polyvisceral congestion, fatty degeneration of liver and renal tubule epithelium [12], hemorrhages of the gastric mucosa, and subnuclear vacuolization of renal tubular epithelial cells (Armani–Ebstein phenomenon) were found [13].

3.4. *Polyvisceral Congestion and Wischnewski Spots*

In death from hypothermia the blood is fluid, the viscera are congested, and sometimes superficial erosions or small ulcerations of the gastric mucosa, known as Wischnewski spots and due to vascular thrombosis, are observed [14].

‘Wischnewski spots’ are diffuse brownish hemorrhagic spots that are variable in size and quantity. The incidence of Wischnewski spots of the gastric mucosa in fatal hypothermia vary between 40% and 91% [15].

They are usually 1–2 mm wide, visible on gastric mucosa and, less frequently, on lower gastrointestinal tracts, and they are inconstant but pathognomonic findings of fatal hypothermia [16].

The pathogenetic mechanism underlying the Wischnewski phenomenon should be related to the erythrocyte’s autolysis and the subsequent hemoglobin release in the gastric mucosa. So, Wischnewski spots do not represent erosions or ulcerations, although in some studies even erosions are reported and the histological analysis allow to highlight the major aspects of the autolytic phenomenon. No inflammatory infiltrates or fibrin exudates are shown. Histological and immunohistochemical analyses are the major techniques to

support the cause of death [17]. In the present case, although it was not possible to undergo immunohistochemical analysis, the histological findings confirm the presence of an erosion at the level of the macroscopic Wischnewski spots. This finding also suggests that other studies with large samples are needed to settle the issue of the real origin of these spots also because even the relevant literature is not one-sided on this theme: some studies concluded for erosion, others for the absence of it [17,18].

3.5. Subnuclear Vacuolization of Renal Tubular Epithelial Cells

The Armanni–Ebstein phenomenon consists in a lipidic vacuolization in the renal epithelium attributed to different pathological condition. Although the primary hypothesis was the attribution of these findings to diabetes [19], they may also be explained by hypoxia and altered fatty acid oxidative metabolism. This hypothesis was proposed by Preuss [20] because of the evidence of lipid vacuoles in 87% of the hypothermia cases. It appears to be a useful marker to confirm post-mortem diagnosis of fatal hypothermia, as well as the Wischnewski spots, but not to exclude it [21,22]. In our case, the diagnosis of hypothermia instead of diabetes was confirmed by the general practitioner of the deceased: he only suffered from hypertension, Alzheimer’s disease, and epilepsy.

In the case reported here, both macroscopic and histological analysis was in accordance with the previously reported literature.

4. Conclusions

This case describes most of the features and circumstances surrounding hypothermia-related deaths.

Diagnosis of cold-related death is based on unspecific data and can only be made thanks to exhaustive, complete, and integrated medicolegal investigations, including site inspection, external examination of the corpse, macroscopic observation, and specific analysis such as histology, immunohistochemistry, and toxicology, which are mandatory. Such a multidisciplinary approach would allow to reach more accurate diagnoses of hypothermia.

Author Contributions: Conceptualization, F.I.; methodology, M.L.; formal analysis, A.C.; investigation, M.C. and E.M.; resources, G.D.G.; writing—original draft preparation, S.D. and A.M.; writing—review and editing, F.M.; supervision, F.I. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: No new data were created.

Conflicts of Interest: The authors declare no conflicts of interest.

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