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The Macroscopic Detection of Metallization in the Latent Current Mark

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Summary. Immediate revelation of latent current mark (LCM) was investigated by means of macroscopic detection of metallization (M). LCM were produced on corpses using electrodes of metals most frequently involved in electrocution (iron, copper, zinc, aluminium, chrome, nickel, and brass). Also, current marks of accidental electrocutions (10 cases) were examined.

Single metals can be identified by spraying specific reagents on the suspected skin.

The following multiple systems can be used to simultaneously produce the above mentioned metals:

A. Sequence: 10% ammonium sulphid—H_2O—0.2% solochrome cyanine in 1% HCl.
B. Sequence: 0.5% 2.nitroso.1.naphtol in acetone—H_2O—0.2% solochrome cyanine in 1% HCl.

Instead of appearing on the skin, metallization can sometimes be found on clothes or shoes.

Macroscopic search for LCM metallization is a very simple method and it is recommended in both certain and suspected electrocution, as well as in cases of sudden, unexpected death, particularly during work.

Key words: Current mark, detection of metallization – Metallization, detection in latent current marks

Zusammenfassung. Die unmittelbare Darstellung der verborgenen elektrischen Strommarke ist mit Hilfe der makroskopischen Demonstration der Metallization untersucht worden.

Die verborgenen elektrischen Strommarken sind an Leichen erzeugt worden, indem man Elektroden angebracht hat, die aus den am häufigsten bei der Elektrokution benutzten Metallen gemacht sind: Eisen, Kupfer, Zink, Aluminium, Chrom, Nickel, Messing. Außerdem sind 10 Fälle von Unfallelektrokution untersucht worden.

Jedes Metall kann durch Aufsprayen der spezifischen Reagenzien an der betreffenden Stelle identifiziert werden.

Um die erwähnten Metalle gleichzeitig darzustellen, kann man folgende kombinierte Methoden benutzen:

A. 10% Ammonium Sulfid —H_2O— 0,2% Solochromocyanin in 0,1% HCl oder

B. 2.Nitroso.1.Naphtol 0,5% in Aceton — H_2O — 0,2% Solochromocyanin in 0,1% HCl.

Außer auf der Haut können die Metalle manchmal auch auf Kleidung und Schuhen aufgezeigt werden.

Die makroskopische Untersuchung der Metallisation in verborgenen elektrischen Strommarken ist eine sehr einfache Methode, und wir können sie bei der bewiesenen und vermuteten Elektrokution empfehlen, sowie im Falle eines plötzlichen Todes, besonders wenn ein Arbeitsunfall vorliegt.

Schlüsselwörter: Strommarke, Metallisation – Metallisation, Darstellung bei unsichtbaren Strommarken

The characteristic current mark (CM) is usually able to demonstrate electrocution. The diagnosis, however, is difficult when electrical traces are not evident (Sellier 1975; Somogyi and Tedeschi 1977). Under these circumstances, we tried to immediately identify the "latent" current mark (LCM) by means of macroscopic detection of the metallization (M).

Electrical metallization, first shown by Schrader (1932), can be qualitatively and quantitatively analyzed by the spectrographic method (Sellier 1966), and qualitatively by the stereomicroscope (Bosch 1965), by the acroreaction test (Adjutantis and Skalos 1962) and by histochemical techniques (Schäffner 1965; Böhm 1966a, 1968a, b, c; Pioch 1966a, b, 1967; Buris et al. 1967; Lo Menzo and Sciabica 1975). Electrical M can be precisely defined by means of the scanning electron microscope and the microprobe analyzer (Böhm 1970, 1971a, b; Schneider and Hantsche 1973; Böhm and Milz 1975; Schneider 1978), and by means of the transmission electron microscope (Böhm 1978).

The differentiation between thermal and electrical M, easy by electron microscope, can also be performed by macrochemical observations. With this method the former results in a negative imprint on the skin of the metallic surface, the latter in strong metal accumulations in the form of targets around the characteristic current penetration sites. Böhm (1967a) obtained this picture experimentally (conditions: alternating current, 220 V, exposure periods 1 s) in latent current marks, using specific reagents for electrode metals (rubeanic acid for copper, nickel and brass; Perls reagent for iron; eriochromocyanine for aluminium; potassium ferrocyanide and diethylaniline for zinc).

On the basis of these data, we experimentally researched the simplest methods for the macroscopic detection of metallization, and therefore of the latent current mark.

Materials and Methods

Both electrical and thermal applications were carried out on the corpse skin. Electrical traces were produced by means of a modified device, already used in preceding research (Andreuzzi et
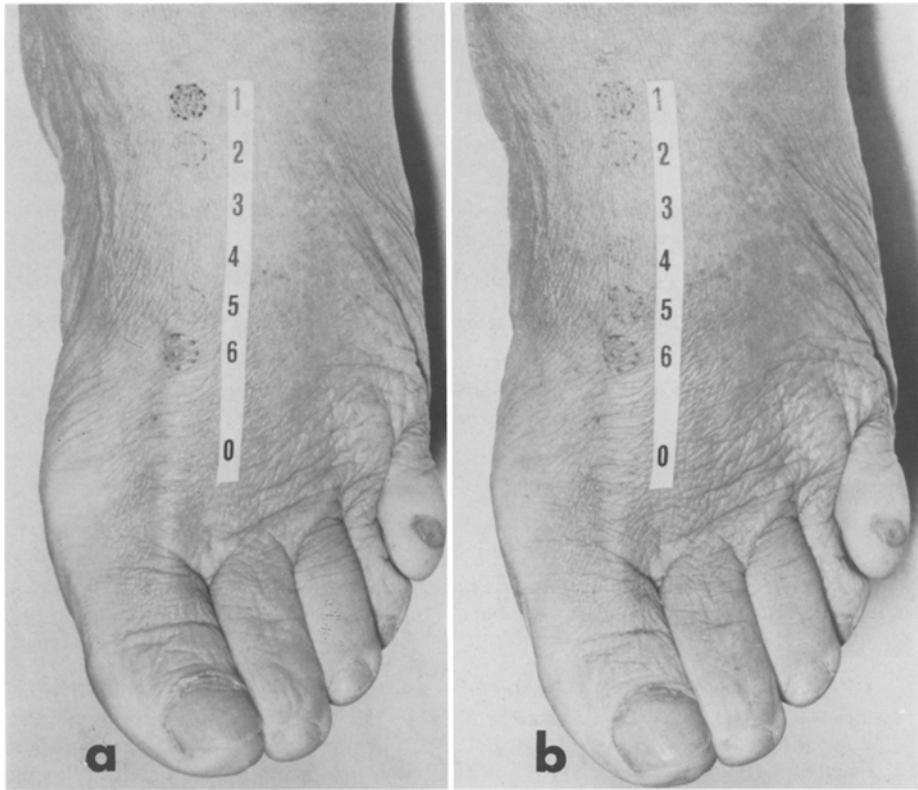
Fig. 1. a Detection of metallization in latent current marks by means of sequence ammonium sulfid; **b** solochrome cyanine. *1* = iron; *2* = copper; *3* = zinc; *4* = aluminium; *5* = chrome; *6* = nickel; *0* = brass

al. 1972; Danesino 1978), which permitted the following variations in the experimental conditions: current flow time ($T > 0.05$ s) and potential (25—300 V). Frequency was constant at 50 Hz.

The electrodes were constructed of the pure metals or of alloys most frequently involved in electrocution (iron, copper, zinc, aluminium, chrome, nickel, and brass). They were cylinder-shaped, with a circular cross-section of 6 mm, with the exception of brass electrodes (14 mm).

The electrodes were applied in pairs to the skin of hand (palm-back) or of the foot (sole-top), at 220 V.

The exposure periods were empirically established for each metal and were equivalent to the longest time possible with a latent current mark: usually 0.2 s on the dry skin, and 0.4 s on the wet skin. We also tested the time threshold for each metal. The electrodes were held to the skin manually, with as constant a pressure as possible: the contact pressure appreciably influences the CM evidence.

The experiments were carried out in several ways. Sometimes many LCM were produced in a single region, either by the same or by different metals. Some electrical applications were carried out interposing wet cloth between the electrodes and the skin.

We also studied ten cases of accidental electrocution.

Thermal lesions were obtained by contact with hot objects of the same metals and alloys.

Macrochemical reactions were carried out usually "in situ", sometimes on skin specimens. Skin specimens underwent also histological and histochemical examinations.

We attempted to show the eventual metallization of the latent current mark macroscopically by means of a specific reagent used in analytical chemistry and/or in histochemistry. The reactives were sprinkled by a simple hand pump or by a glass sprayer with a gas propellent. Before spraying reagents, it is useful to moisten the skin with the solvent.

The experiments were carried out in a planned sequence. First we attempted to document the single metals by means of specific reagents in the following way (for the single methods see Pearse 1972).

Iron: a) Perls reagent (equal parts of 2% potassium ferrocyanid and 2% HCl). b) Turnbull reagent (equal parts of 20% potassium ferricyanid and 1% HCl).

Copper: 0.1% rubeanic acid in 70% ethanol.

Zinc: Stock solution (A): 0.01% dithizone in absolute acetone; working solution: sol. A : H_2O = 1.5 : 1.

Aluminium: a) Aluminon method: b) 0.2 morin in 85% ethanol, UV observation; c) 0.2 solochrome cyanine in 1% HCl; running hot tap water.

Chrome: saturated sol. diphenilcarbazide in ethanol (s. Treadwell 1955).

Nickel: rubeanic acid (see above).

Brass: rubeanic acid and/or dithizone (see above).

In the second phase we looked for a multiple revelation system and found that saturated, aqueous, or alcoholic solution of sulphid acid (H_2S) offered considerable advantages. 10% ammonium sulphid—$(NH_4)_2S$—was better yet. 0.2% solochrome cyanine in 1% HCl (aluminium reactive) was also tested.

Furthermore, we looked for M revelation by means of the recent "trace metal detection technique" (TMDT): 0.5% 2.nitroso.1.naphtol in acetone (Glass and Grais 1979).

While the above mentioned systems do not reveal all the named metals, we looked for a way to combine systems. The sequence $(NH_4)_2S$-H_2O-dithizone-H_2O-solochrome cyanine, or the simplified sequence $(NH_4)_2S$-H_2O-solochrome cyanine was used successfully.

Afterwards, 2.nitroso.1.naphtol-solochrome cyanine solution (for aluminium) was used.

The above mentioned reactions were also investigated on experimental thermal lesions, on electrical current applications with cloth interposed between the electrodes and the skin, on skin traces of defibrillator and on accidental electrocution. Thus, electrical M was researched both on the skin and on clothes, on the latter especially if negative on the former.

Also, the persistence of the metallization was tested after washing the skin with water and/or 50% ethanol jet.

After macroscopic detection of LCM, skin specimens were often removed to perform histological-histochemical examinations. Ethanol or H_2S-ethanol-fixed paraffin sections as well as cryostat fresh sections were examined. The method included: "blank" sections, H & E, Garvin sequence (Danesino 1978), and M investigation by means of specific histochemical reactions (Pearse 1972): Perls and Turnbull methods for iron, rubeanic acid for copper, nickel, and brass, dithizone for zink, solochrome cyanine for aluminium, diphenilcarbazide for chrome.

Similar methods were also applied to thermal lesions.

Results

The results of the various steps of the experimental sequence will be outlined briefly.

The macroscopic detection of the single metals was used successfully. However, it requires some explanatory comments.

Table 1

	H₂S	(NH₄)₂S	2.nitroso.1.naphtol	Solochrome cyanine
Iron	+ (brownish)	+ (black)	+ (deep green-bluish)	+ (bluish)
Copper	+ (black)	+ (brownish)	+ (amaranth)	+ (red-orange)
Zinc	− (—)	− (—)	+ (orange)	+ (orange)
Aluminium	− (—)	− (—)	− (—)	+ (red-violet metallic)
Chrome	+ (brown)	+ − (brownish)	+ (black-violet)	+ (violet)
Nickel	− (—)	+ (pitch-black)	+ − (red-violet)	+ − − (orange)
Brass	+ − − (pale)	+ − (brownish)	+ (red-brownish)	− (—)

Iron: Perls reaction (blue) is strong and rapid in LCM. Turnbull reaction is weak, but it is reinforced by pretreatment with H₂S or (NH₄)₂S (see below).

Copper: Rubeanic acid reaction (black) strong and rapid.

Zinc: Dithizone reaction (reddish-purple) weak, slow, and transient: the reaction's product is soluble in the reagent. The former becomes insoluble by pretreatment with H₂S or (NH₄)₂S. Furthermore, in our experience, the reaction is reinforced by using 1% acetic acid solution instead of H₂O in working solution.

Aluminium: Aluminon reaction is practically always negative. Morin reaction is strong and rapid (bright greenish-white fluorescence); disadvantage are the necessity of using ultraviolet light and the need for a dark room. Solochrome cyanine reaction (pinkish-red metallic) is slow, but strong after a prolonged rinse with running hot water.

Chrome: The diphenilcarbazide reaction (red-violet) is rapidly positive.

Nickel: The rubeanic acid reaction (brown-violet) is strong and rapid.

Brass: Brass reacts with rubeanic acid (violet) and with dithizone (reddish-purple).

In Table 1, we show the results of metal multiple revelation by means of following methods.

The 2.nitroso.1.naphtol reaction's products are moderately soluble in the reagent.

In the sequences 2.nitroso.1.naphtol-H₂O-solochrome cyanine and (NH₄)₂S-H₂O-solochrome cyanine we obtained, for the single metals, the results reported in Table 2.

The reactive picture of the solochrome cyanine is practically unmodified after following treatments by H₂S, (NH₄)₂ or 2.nitroso.1.naphtol.

Table 2

	2.nitroso.1.naphtol-H_2O-solochrome cyanine	(NH$_4$)$_2$S-H_2O-solochrome cyanine
Iron	+ (unmodified)	+ (unmodified)
Copper	+ (unmodified)	+ (unmodified)
Zinc	+ − (pale)	+ − (pink-orange)
Aluminium	+ (red-violet metallic)	+ (red-violet metallic)
Chrome	+ (unmodified)	+ (violet or pink-orange)
Nickel	+ (unmodified)	+ (unmodified)
Brass	+ (unmodified)	+ − (pink pale)

In the termal injuries (loss of epidermis), single metals reactions are very slight and slow, superficial and uniform in the derm.

We applied the above mentioned reactions also in cases of electrocutions, obtaining comparable results (in nine of 10 cases: metallization by iron).

With the experimental interposition of wet cloth between electrodes and skin, M is detectable on the former rather than on CM. We also found that in accidental electrocution M is sometimes present on the clothes rather in the skin (one case, metallization by aluminium).

The CM metallization, contrary to soiling metallization, is very persistent: the respective reactions are positive even after washing with water and/or 50% ethanol jet.

By means of *2.nitroso.1.naphtol, H_2O and solochrome cyanine sequence* or of *(NH$_4$)$_2$S, H_2O and solochrome cyanine sequence,* we were able to macroscopically detect the main electrodes metallization.

We examined ethanol- or H$_2$S.ethanol-fixed paraffin sections and/or cryostat, fresh sections by light microscope. In "blank" sections, the macroscopically colored reaction is sometimes still detectable (Perls reaction, etc.). Despite previous macroscopic treatments we were usually able to obtain metal detection using the previously mentioned histochemical methods.

The threshold-time of the metallization is about the same with both the main revelation systems (0.05—0.1 s), but it depends on the kind of metal: the lowest value resulted for iron.

Discussion

Electrical current application on the skin by means of metallic electrodes always causes a local metallization which is characteristic for each single metal (Böhm 1970). As has long been known (Böhm 1967a), and as our research verifies, metallization is detectable even in the case of latent current marks. Deriving from electrolytical, non-thermal processes, M is massive in the case of wet skin (Böhm and Milz 1975), i.e., in cases in which no current mark is evident. Indeed, CM evidence depends directly on temperature and on electrical resistence. There-

fore, the M investigation seems to be a suitable method for latent current mark detection.

In the experimental conditions of Lo Menzo and Sciabica (1975), metallization failed in "exit" CM: in this one circumstance, the positiveness of reaction shows the "entrance" CM. On the contrary, M is present in the case of earth contact by interposition of metallic objects (Kunnen et al. 1970).

In the case of accidental electrocution which we observed and in experimental researches, M failed if cloth was interposed between skin and electrodes, but was detectable on the clothes. This suggests the advisability of always searching for M on the clothes in suspected cases with negative CM or/and M on the skin. Also scanning microscope examination and electronmicro-probe analysis of clothes is useful in such a circumstance (Schneider and Hantsche 1973). In one case of accidental electrocution, without "exit" CM, we found metallization on the shoes.

The M detection of patent or latent current marks can profit by specific reagents only if the kind of metal is known or, at least, suspected. In general, combined methods may be used. Personally, we successfully tested a revelation system based upon the development of insoluble or slightly soluble metal sulphides by reaction between metals and H_2S or—better—$(NH_4)_2S$. The successive treatment with solochrome cyanine is able to identify aluminium as well as zinc. The latter can be revealed by dithizon reaction as well. Also the sequence 2.nitroso.1.naphtol-solochrome cyanine is suitable for the detection of the metals usually involved in electrocution (iron, copper, zinc, aluminium, chrome, nickel, and brass).

To differentiate between LCM and soiling metallization, it is useful to wash previously investigated skin with water and/or 50% ethanol jet: as electrical metallization is more resistant than the metallic smear. However, we consider the macroscopic evidence of metallization, even if characteristically "target" shaped (Böhm 1967a), only as a likely sign of probability, particularly in comparison of thermhal M. The certain diagnosis will be performed by means of successive investigations, to which—besides scanning electron microscope, microprobe analyzer, and transmission electron microscope—also belong histological and histochemical examinations. Histochemical inhibition of ribonucleic acid can demonstrate a latent current mark (Danesino 1978).

Because of the preventive macrochemical revelation, the genetric histochemical metal detection (Pioch 1966b; Böhm 1968a), such as can be obtained by the Timm original or modified method (Timm 1958a,b; Voigt 1959; Danscher and Zimmer 1978) seems useless. On paraffin and/or cryostat, fresh sections (Schäffner 1965), we performed specific histochemical metal research as indicated above. Furthermore, for copper the semiquantitative screening procedure could be applied by the 5-p-dimethylaminobenzilidene rhodanine method and by atomic absorption spectroscopy (Irons et al. 1977). In our opinion, paraffin embedding requires ethanol fixation; Pioch (1967) recommends H_2S-ethanol, to prevent the metal dissolution. Indeed, during electrical current application, anodic metal oxidation occurs, and oxidation products are widely soluble in a formalin fixative (Böhm and Milz 1975).

According to our preliminary experience, metal specific histochemical behavior is not appreciably influenced by previous macrochemical reactions. The subject, however, requires further careful investigations; the 2.nitroso.1.naphtol reaction's products are moderately soluble in the reagent.

Besides LCM detection, the proposed macroscopic revelation systems can suggest the kind of metal by means of colored reactions. Therefore, in our opinion, one of M revelation methods should be used systematically both in cases of certain and, more importantly, of suspect electrocution; as well as in cases of sudden, unexpected death, especially during work. Furthermore, the method is extremely simple and thus useful for common practice.

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