Artur Wójcik
Specialist at the Dactyloscopy Section of the Forensic Laboratory of Warsaw Police Headquarters
Ewa Rogoża
Senior Research and Technical Specialist at the Fingerprint Examination Department of the Central Forensic Laboratory of the Police
Katarzyna Drzewiecka
Research and Technical Specialist at the Fingerprint Examination Department of the Central Forensic Laboratory of the Police
Marcin Wudarczyk
Expert at the Dactyloscopy Section of the Forensic Laboratory of Warsaw Police Headquarters

Fingerprinting and improvement of the readability of the fingerprints of corpses

Summary

Fingerprinting of corpses is always problematic even for experienced forensic experts and technicians. This publication is a compendium of the knowledge about physical and chemical methods in dactyloscopy and improving the readability of the friction ridges of corpses. It mentions the possibility of a very broad use of not only dactyloscopic paints, but also fingerprinting powders, films, as well as silicone casts, latex matrices etc.

The publication also highlights the necessity of photographic documentation of fingerprints in every case and after every completed procedure, with the aim of improving the readability of the corpse's friction ridges.

Keywords identification of corpses, fingerprinting of corpses, elastification of epidermis

Introduction

Natural phenomena, such as earthquakes, tsunamis, hurricanes, volcanic eruptions, avalanches, as well as events resulting from human activity, including war, acts of terrorism, accidents and disasters in surface, air and water transport, and, in particular, criminal offenses, often involve fatalities. The identity of victims found at the crime scenes in many cases remains undetermined. Depending on the circumstances under which the corpse was discovered, various methods of identification are used. Every method is characterized by its own level of reliability. The order of methods of corpse identification, from the most reliable ones to those only suggesting the identity, was developed at the 5th Interpol Conference on the Identification of Victims of Mass Disasters and Natural Disasters held in Lyon in 1993. The order is as follows: "comparison of the DNA profile, comparison of fingerprints, examinations of teeth and other odontological data, radiological examinations, comparison of medical data (history of medical and surgical treatments), comparison of characteristic features: scars, tattoos, comparison of descriptions, identification of personal objects including clothing, jewelry, etc., identification based on the documents found with the corpse or remains, identification by witnesses, family members or friends" [1, p. 8].

The second place given to the dactyloscopic identification of the corpse based on fingerprints, just after DNA tests, is not accidental. The foundations of fingerprint identification are based on such properties of fingerprints as invariability, indestructibility (irremovability), individuality (uniqueness). As has been shown in previous studies, long fingerprint examination practice and statistical calculations indicate that the probability of occurrence of two identical fingerprint patterns is 1 in 64 billion. This estimation is confirmed by the data from the existing worldwide fingerprint registers in which no identical fingerprint patterns in two different persons have been reported to date.

Establishing the corpse identity by means of fingerprint identification is possible if the investigators are in possession of comparative material, i.e. a TP card, obtained during the life of the person. "Fingerprinting of a corpse is generally more difficult than that of a living person and often requires the use of special techniques. The scope of the difficulties depends on the condition of the corpse, which in turn depends on the time that has elapsed since the death and the conditions that the corpse has been subjected to. If the corpse was not exposed to particularly detrimental external factors, within several days after death, the skin and subcutaneous tissues remain flexible enough to use the standard fingerprinting technique using ink" [2, p. 69].

Postmortem changes in the corpse

If the corpse has been found after a longer period since the death, the body undergoes multiple processes which depend on the conditions that it has been subjected to, which in turn has a major impact on the possibility of obtaining readable prints. One of the postmortem changes is mummification, a conservation process that prevents decomposition. It is due to the natural environment in which the corpse remains after the death or due to human activities. Natural mummification occurs in dry air, in well-ventilated and hot environments. "Such conditions are encountered in desert climates or, at our geographical latitude, in dry and well-ventilated attics, dry tombs and cellars, as well as graves dug in sandy soil, usually located at a high level, where there is no access of groundwater, while rainwater quickly penetrates into underlying layers. Under such conditions, a very rapid loss of water occurs, which in turn both destroys putrefying bacteria and disables the body's own enzymes" [3, p. 36]. The corpse acquires a characteristic appearance: the body retains its shape, the skin becomes hard and gray brown colored, the body is light (with the mass up to three times lower than the original), brittle and susceptible to even slight mechanical injuries. The mummification process may be of various duration, but takes at least a few weeks.

Corpses subjected to high temperature become scorched or completely burned. Above 42°C, the destructive effect of heat on proteins is equal to or greater than their recovery capacity, whereby every increase by half a degree increases this destructive activity forty times, causing proteins to denature. The possible causes of burns are heat shock, exposure to flames, explosions, electric current or lightning. The hands of burn victims have a tendency to close into fists, which protects the fingerprints located on the inside of the hands. The high temperature produced in a fire causes the epidermis to separate. The separation of the epidermis from the dermis is also promoted by corpse refrigeration.

In Poland, most cases of the fingerprinting of corpses regard bodies found in the aquatic environment. In general, these are the victims of drowning, or corpses exposed to rain or lying on humid ground. Prolonged exposure to cold water causes the skin of the corpse to develop the so-called goosebumps, as a result of pronounced stiffening of the arrector pili muscles. In the case of longer exposure to water, diffusion smears, swelling, separation of the epidermis from the body surface, loosening of toenails from nail bed, shredding separation of the epidermis, as well as separation of nails and hairs may be observed. The morphological changes in the corpse may be affected by water temperature and depth, the variability of water temperature at different depths and the time the corpse remained in water, but there is no impact of the degree of water pollution. Water temperature depends on the depth and the season of the year. In the summer, the corpse may move up to the surface after only a week, while in the winter, after 4–6 weeks. The sudden temperature drop at a certain depth is defined as thermocline. The difference in the temperatures between the warm upper layer and the cold layer below the thermocline can be up to 10°C. The morphological changes in the corpses remaining in water at 4–6°C appear at different times and in a different order than those observed in water at the temperature of 10–11°C and higher. At 4°C, the putrefaction processes are slowed down to such an extent that the small amounts of the putrefaction gases produced are insufficient to "lift" the corpse to the water surface. Generally, it is presumed that corpses located below the thermocline never move up to the surface. As a rule, corpses decompose more slowly in water and secondary factors, such as thermocline, cause a significant slow-down of putrefaction. "For example, in water at 19°C, the epidermis becomes separated after only 3 days, while at 5°C, it takes one month for this process to be observable. In general, putrefaction processes in corpses remaining in water appear later than in the air in the same season of the year, and in cold water reservoirs (mountain lakes) or below the thermocline, corpses may not undergo putrefaction for years, do not move up to the surface, remain in depth and undergo adipocere formation (from the third month)" [4, p. 146].

Among the most important stages and morphological changes in corpses remaining in water, which have impact on the identification by means of dactyloscopic methods, are those cited below.

"At stage 1, as a result of the relatively short-term exposure to water, skin softening and maceration occurs. As a consequence, the superficial pattern of the epidermis becomes less distinct and, what is more, even partially ruptured. Stage 2, after longer exposure to water, is characterized by a high degree of skin softening and the epidermis can be separated from the dermis similarly to a glove that is slipped off a hand. Stage 3 is the final stage in which the epidermis is completely lost, but the friction ridges of the dermis remain" [5, p. 125].

Due to maceration and decomposition, the fingerprints or palmprints may be barely visible or invisible. The human body may also undergo putrefaction, i.e. a type of postmortem decomposition. It involves tissue break-down due to the decomposition of organic compounds, mainly containing nitrogen, catalyzed by enzymes produced by putrefying bacteria. Putrefying bacteria are saprophytes inhabiting the digestive tract, oral cavity, nasal cavity and skin. The onset of corpse putrefaction and its rate depend on many factors. Among them, the most important role is played by air temperature and humidity in which the corpse remains. "The optimum temperature for the growth of putrefying bacteria is approximately 30°C, therefore ambient temperature is crucial. The higher the temperature, the longer the time of cooling of the corpse and the longer the conditions promoting putrefaction persist, although an extremely high temperature (e.g. in tropical countries) can inhibit bacterial growth" [4, p. 55].

At the temperature around 0°C, the decomposing activity of putrefying bacteria is much lower and the corpse may undergo only minor changes even after several months. Corpse putrefaction is accelerated by external damage, but slowed down by a preceding heavy blood loss.

"A certain pattern known for a long time, called Casper's Law, claiming that a corpse in the open air decomposes two times faster than a corpse in cold water, while a corpse in water decomposes four times faster than a corpse that is buried in dry soil, mostly reflects the effect of ambient temperature, in addition to that of oxygen content" [4, p.55].

Another important factor affecting the onset of corpse putrefaction and the speed of the process is ambient humidity, i.e. the content of water vapor in the air. Poland, located in the warm temperate climate zone, is considered as a humid country. In the majority of the area of Poland, humidity remains at 80%. The correct humidity of the air in closed spaces is within 30–65%. The minimum humidity of the air in homes should not be lower than 30%. Humidity above 60% results in a specific odor, bacterial growth, metal corrosion and agglomeration of loose materials, as well as malfunction of electronic devices. When humidity exceeds 70%, molds and other fungi grow in hygroscopic materials, which often causes various diseases. Humidity of 80–90% considerably accelerates putrefying processes.

The process of corpse putrefaction may be significantly varied. Very often the corpse emits a characteristic odor, the skin is slick with a dark or waxy color and vermin is present. The corpse may also lack the epidermis on fingers and hands.

Fingerprinting of corpses

According to the current regulations, in the event of finding an unidentified body, the examiners are obliged to take the prints of fingers or palms [6]. The procedure is performed on site or in a forensic medicine institution, if allowed by the condition of the corpse. Fingerprint examinations are performed by forensic technicians, members of an investigation team. Fingerprinting of a corpse should not pose a problem for a technician within a few days after the death, even if the body has been exposed to unfavorable conditions. Once a photographic record of the fingerprints has been created, standard fingerprinting techniques are used, among which the primary method is applying dactyloscopic ink onto the fingers using a roller, a pad or a fingerprint spoon. Moreover, the techniques of finger sooting and silicone or latex casts can be used. Once the casts have been made, dactyloscopic ink can be applied onto them to obtain prints on TP cards.

The use of fingerprint ink not always leads to positive results and, therefore, other solutions are used as well. One of the attempts to replace the traditional ink-based method of postmortem fingerprinting was the so-called Schifferdecker's method in which ink was substituted by soot and paper was substituted by five-layer, five-color plastic film. Every color was reserved for a particular finger, which eliminated the possibility of confusion. Cleaned and dried fingertips were coated with soot using a dactyloscopic brush and once the excess of soot was removed, the prints of the friction ridges were transferred onto elastic dactyloscopic film. The drawback which prevented this method from widespread adoption was the need to produce or import a special type of film and to make photographs of the friction ridges transferred onto the film [7]. Although the use of Schifferdecker's method has been ceased, there have been many attempts to use dactyloscopic powders and films in the fingerprinting of corpses. "The use of dark dactyloscopic powders instead of printing ink proved beneficial. Good results are also achieved by using soot, ferromagnetic powders or anti-static powder. The image of the friction ridges was transferred onto a positive dactyloscopic film of the "filmoux" type. The background adherence of the film was a favorable factor as it helped to avoid accidental dislocation (very frequent in the finger–paper setting) when the film is pressed against different parts of the fingertip. This improves the image of the friction ridge pattern, preventing from virtually any smears" [8, p. 49].

A surprisingly simple method of the fingerprinting of corpses, which, at the same time, provides better results than the traditional method (ink–paper) and eliminates the need for special films and photographic documentation of the collected friction ridge prints, is a method developed by Ryszard Wagner, inspector at the District Office of Internal Affairs in Mielec and a forensic crime scene investigators. The effectiveness of the method was tested at the Institute of Forensic Science of the Voivodeship Office of Internal Affairs in Rzeszow. "(The method) is based on the use of adhesive tape. To this end, the surface of the fingertips should be cleaned and dried, and then printing ink should be applied with a rubber roller, producing a sufficiently thick layer. Subsequently, a piece of transparent adhesive tape is applied with the sticky side toward the fingertip, and delicately but fully pressed. After removing the tape from the finger, the tape is attached to the appropriate position on a dactyloscopic card and the procedure is repeated for all fingers" [9, p. 85]. The above described method is particularly useful in the dactyloscopy of stiff and bent fingers, but also in the case of macerated skin, allowing a direct production of fingerprints without injecting any aqueous glycerin solution. Thus, the prints of friction ridges produced on the dactyloscopic card are in reverse order compared to the prints taken using the traditional method. This disadvantage can be eliminated by sticking the pieces of tape with the prints onto a larger piece of tape and reversing the order while attaching the prints to the dactyloscopic card. This way, the correct order of the fingerprints is retained.

Sometimes, due to the long period between the death and the finding of the corpse, and due to adverse environmental conditions, the described methods appear ineffective and cannot provide readable friction ridges suitable for identification and search in the AFIS system. In such cases, further attempts using chemical methods, preceded by the amputation of the fingers or the whole hand, are necessary to improve the readability. "Among the unacceptable reasons for finger amputation are: lack of time for fingerprinting procedures, lack of technical means of fingerprinting, unavailability of a trained technician, difficult weather or room conditions (on the crime scene)" [10, p. 46].

Special attention must be paid to maintaining the appropriate length of the fingers amputated from the corpse. A very common mistake is cutting them above the phalangeal fold resulting in epidermal or dermal damage of the fingertip, which significantly limits or even prevents obtaining the full print of the friction ridges. In the absence of contraindications, the cut must be made in a way that the cutting line is below the phalangeal line and the entire fingertip remains intact. The amputated fingers or hands should also be properly protected from the formal and technical point of view (to eliminate any confusion in the order of the fingers). In practice, fingertips and hands are labeled and packed into individual paper envelopes or plastic containers with lids.

"It is also important to store the material properly in order to protect it against the adverse influence of environmental factors (temperature, humidity, insects). Freezing fingers and hands is indicated to minimize any progressive changes in the material (putrefaction) as much as possible" [11, p. 58].

Improvement of the readability of the friction ridges of corpses

The amputated fingers should be elastified to enable obtaining readable prints of the friction ridges. Before performing any activities, the fingers should be photographed "as-is" with a ruler in a 1:1 scale and an identification number. One of the most frequently used methods of elastification of both the skin and soft tissues is bathing the samples in a solution based on glacial acetic acid. The formula was developed by A. N. Razniewski based on many years of research. It was changed several times (in terms of the hydrogen peroxide content) and was eventually fixed at the following proportions:

Ethyl alcohol 96%	200 ml,
Glacial (anhydrous) acetic acid	100 ml,
30% hydrogen peroxide	5 ml,
distilled water	800 ml.

"As a result of the combined action of the formula components, the fingers are preserved and protected from any further progress of putrefaction (ethanol); coloration and superficial deposits due to putrefaction are removed, and the fingers become clear, with well-visible friction ridges, which allows photographic documentation (hydrogen peroxide); the elasticity of the fingers becomes similar to that of a "fresh" corpse (glacial acetic acid)" [10, p. 50]. The time of immersion in the solution depends on the condition of the skin and should be under control. The estimated duration of immersion should be between 3 weeks and approximately 1 month.

Among the benefits of the method are the relatively good availability of the formula components, no need for continuous monitoring of the process, as well as high effectiveness of the action on the epidermis and the dermis. Among the disadvantages are the relatively long time required for elastification and the need for precise compliance with the recipe for the solution.

Another method leading to the elastification of soft tissues with partially damaged epidermis and friction ridges is bathing the samples in ammonium hydroxide solutions of different concentrations. The immersion should be started at a concentration of 5–10% and the tissue regeneration process should then be monitored for 1–2 days. The concentration should be increased if no improvement is observed. After the separation of the epidermis or when no epidermis is present, once the desired elasticity is obtained, the procedure is similar to that for the lower concentration. "The advantages of the method are the very high effectiveness confirmed in most cases in Poland and other countries, easy preparation of the solution, no firm rules regarding volume and mass, good availability of the reagents and short elastification time. The disadvantages of the method are: the need for continuous monitoring of the process, difficulties in making a decision to suspend or continue the process which requires experience, invasiveness of the method, possibility of destruction of the biological material, negative effects on mucous membranes, eyes and respiratory tract (ammonia): the need for strict compliance with the EHS guidelines" [10, p. 56].

It is also possible to bathe the fingers amputated from the corpse in a sodium hydroxide solution. In this method, the epidermis is separated and it is possible to read the friction ridges from the dermis after an approximately 24-hour immersion in a 1–3% sodium hydroxide solution, followed by a similarly long bath in a detergent solution, such as washing-up liquid.

Another method is a bath in a 2% potassium hydroxide solution. "The time needed to achieve the desired effect may vary from 30 minutes to several days, depending on the condition of the corpse. The solution used may leave a thin layer on the skin, which should be removed by washing the fingers in water. If the skin becomes too elastic, the fingers should be placed in a 1–3% formaldehyde or alcohol solution for 10–20 minutes, which will harden them" [12, p. 147]. The method is characterized by high effectiveness, however, in view of the damaging effect of this solution on the investigated material, it is necessary to constantly monitor the process.

If the skin of the fingers is heavily folded and the friction ridges are preserved and undamaged, it is possible to employ the Bieri method (1971) used at the Institute of Forensic Medicine of the University of Zurich. "Negative casts of the friction ridges from a greater number of fingertips were made using the PRESIDENT™ mass (a two-component silicone molding mass of high viscosity). The obtained three-dimensional mold was covered with a mixture of talc and water-soluble white glue (dispersion adhesive) several times. Covering the mold four or five times with the mixture of 10 g of the dispersion adhesive and 4 g of talc allows obtaining a skin-like film. The materials used are characterized by a low price and simplicity of use. The durability and storage potential of the casts do not pose any problems. The described method is effective, useful, quick and simple, allowing the technician to obtain fingerprints in which deep folds of the skin are straightened with very small deviations of dimensions" [13, p. 102].

In the literature, examples of use of tannic acid, acetic acid, detergents and a solution of disodium or tetrasodium ethylenediaminetetraacetate can be found.

Karen Anne Rice described a case of a corpse exposed to a high temperature. The amputated hands of the corpse were placed in a cold storage for approximately 5–7 days, until a complete separation of the epidermis from the dermis occurred. Once the hands were removed from the containers and their friction ridges were cleaned of degraded fragments and photographed, the removal of the epidermis from the hands and the fingers was initiated. After removing, the epidermis was immersed in warm water and once again cleaned using soap and a toothbrush. By using a dactyloscopic roller with a thin layer of dactyloscopic ink, prints of the friction ridges of the fingers and hands from the inner part of the epidermis were taken [14].

If the skin is not brittle, in order to soften it, immersing it in ammonia water or sodium hydroxide solution is recommended. In such cases, the occurring processes should be closely monitored in order not to destroy the investigated material. If the epidermis of fingers is brittle, soaking of the material in pure water may be performed, as it brings the beneficial effect of natural elasticity and readability of the friction ridges, and allows making ink prints on a card, photographs or silicone replicas [15, 35–37].

If the corpse remained in water, the friction ridges may be hardly noticeable or not visible due to maceration and decomposition, which precludes taking photographs, classical dactyloscopic procedures or casts. In the light of the above, after the amputation of the hands or fingers, attempts should be made to make the friction ridges visible using laboratory methods.

If the folded epidermis remains connected with the dermis, it can be stretched and straightened, and the fingertips can be rounded by injecting glycerin (avoiding skin rupture by the excess of the fluid), and then taking ink prints or making silicone casts. The usefulness and effectiveness of the silicone cast method was confirmed already in the 1960s. "The value of this new method was verified by the author based on silicone masses produced by the chemical industry of East Germany. (...), using the presented method gives excellent results as the silicone mass tightly fills all folds and furrows, which allows obtaining clear fingerprints. It also enables gaining clarity of every detail, which often is of great importance in identification tests" [5, p. 128–129].

Skin maceration can be mitigated by filling the space between the skin and the muscles with paraffin. "The injected paraffin should be heated to a temperature allowing it to be sufficiently liquid. In order to facilitate the paraffin injections, the finger of the corpse should also be heated (preferably in hot water at 50–60°C for 10–15 minutes). After the injection of paraffin, the technician should wait until the finger cools down to the ambient temperature. It is indicated to insert the needle through the second segment of the finger toward the fingertip. The tip of the needle should be guided into at least three different areas of the fingertip (using the same puncture site) to fill the entire space until the folds of the macerated skin are straightened" [16, p. 353].

If the epidermis is separated from the dermis, the technician performing the procedures puts the epidermis over his/her own fingers protected with gloves and takes ink prints. The better preserved side, inner or outer, should be used. If the epidermis is not suitable for the prints, similarly as in the case of the fingers of putrefying corpses, the dermis is used. "If the epidermis is unnaturally smooth due to abnormal swelling of the fingertips and the friction ridges are barely visible, the natural appearance of the epidermis can usually be restored by boiling the fingers of the corpse in edible oil at 100°C. During the process, the fingers should be observed continuously until their normal shape is obtained. Once the fingers have been removed from the oil, they should be washed with chloroform or a similar reagent to remove fat" [12, p. 147].

D.M. Keating and J.J. Miller described a case of employing the vapor of cyanoacrylate adhesive to improve the readability of the friction ridges of one finger from a corpse found in water. The polymerization process was carried out in a chamber for 35 minutes and resulted in an improved clarity of the ridges. Once the ridges were photographed, 16 characteristic features were determined. Subsequently, an attempt to further improve the readability of the friction ridges was made by using ninhydrin. Ninhydrin was applied onto the finger with a cotton swab and then treated with steam from an iron for approximately 20–30 seconds. The reaction of ninhydrin with amino acids in furrows produced a purple color fully visualizing the friction ridges. The finger was then cooled for 1 minute and photographed, which allowed the determination of 70 characteristic features of the friction ridges [17].

Putrefying corpse covered with vermin must be cleaned with chloroform or ether, followed by an additional insecticide and finally by water with soap. After photographic documentation, it is necessary to make an attempt to use the retrieved epidermis or dermis, if the former is unsuitable, for making prints of the friction ridges using a rubber roller and printing ink or casts from silicone pastes. If, in the course of the analyses, only the dermis is available, the best results are obtained with silicone masses which tightly fill all types of furrows, even on an apparently smooth skin, and allow obtaining clear fingerprints with preserved details.

Both the fingerprinting and the improvement of the readability of the friction ridges of corpses are difficult tasks. The readability of the prints of friction ridges depends on the condition of the corpse's fingertips and on the selection of the appropriate skin elastification method and dactyloscopic techniques. Forensic science technicians and experts are responsible for the proper execution thereof. Once a dactyloscopic card has been created, it cannot be repeated due to the burying or cremation of the body.

Translation *Ronald Scott Henderson*