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Review

Forensic aspects and blood chemistry of the Turin Shroud Man

Niels Svensson* and Thibault Heimburger

[1]Kalvemosevej 4, 4930 Maribo, Denmark.
[2]15 rue des Ursulines, 93200 Saint-Denis, France.

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On the Turin Shroud (TS) is depicted a faint double image of a naked man who has suffered a violent death. The image seems to be that of a real human body. Additionally, red stains of different size, form and density are spread all over the body image and in a few instances outside the body. Forensic examination by help of different analyzing tools reveals these stains as human blood. The distribution and flow of the blood, the position of the body are compatible with the fact that the Turin Shroud Man (TSM) has been crucified. This paper analyses the already known essential forensic findings supplied by new findings and experiments by the authors. Compared to the rather minute gospel description of the Passion of the Christ, then, from a forensic point of view, no findings speak against the hypothesis that the TS once has enveloped the body of the historical Jesus.

Key words: Blood chemistry, crucifixion, forensic studies, Turin Shroud.

INTRODUCTION

The interest of the forensic examiners for the Turin Shroud Man (TSM) image began with Paul Vignon and Yves Delage at the very beginning of the 20th century, after the remarkable discovery of the "negative" characteristics of the Turin Shroud (TS) image allowed by the first photography of the TS by Secondo Pia in 1898. Starting from the negative plates, everybody could now see with a high accuracy the shape and many details of the TS image, instead of a vague, faint, human form.

Since this time, dozens of medical examiners have studied the image of the TSM. Almost all of them were doctors and most of them were specialized in forensic medicine, anatomy or surgery (Antonacci, 2000). Although the interpretations of some observations are different among the examiners, there is a general agreement to conclude beyond any doubt that the TSM image is that of a real human body that died after having suffered from Roman crucifixion. A complete, traditional forensic description of the TS can be found elsewhere in Shroud literature (Barbet, 1993; Bucklin, 1970, 1997; Edwards et al.,1986; Zugibe, 2005). The TSM imprint is made of two different kinds of features:

i) The image itself, which has most of the properties of a negative "photography" and, as such, is best seen on the negative plates. The image has no well defined contours, is monochromatic (yellow) without any kind of cementation or capillarity at fiber level, is very superficial at thread and fiber level, has a very particular spatial distribution (for example, some bundles of colored fibers are adjacent to uncolored fibers on the same thread) and results from some kind of oxidation-dehydration of a very thin layer at the surface of the colored fibers (Fanti et al., 2010; Pellicori and Evans, 1981; Schwalbe and Rogers, 1982).
ii) The "blood" stains, which are obviously contact imprints in "positive". The properties of the "blood" stains are the exact opposite of those of the image. These two kinds of features are clearly different (color, chemistry, microphotography, and spectroscopy) but spatially related: the "blood stains" and rivulets borders do not flow out of the image (with some exceptions explained by the enveloping of the body).

Therefore, we must conclude that we are dealing with two different but related kinds of features: probably two

*Corresponding author. E-mail: nsvensson@dadlnet.dk. Tel: +45 54715005. Fax: +45 54715393.

Figure 1. The double image of the Turin Shroud Man in the autopsy room. © Niels Svensson.

different events at two different times. However, this difficult question (called “double registry”) is out of the scope of this paper. The present paper aims:

i) To look at the TSM image, in its different parts from a forensic point of view, as in an autopsy room.
ii) To summarize the scientific facts regarding the “blood” stains, including chemistry.
iii) To discuss some problems or questions regarding some controversial interpretations, including some new experiments.

THE TURIN SHROUD MAN EXAMINED IN THE AUTOPSY ROOM

Before entering into a forensic description of the TSM (Figure 1) a few clarifying notes are needed. If a shroud is removed from a body that has left an imprint, an observer will naturally stand in front of a mirrored or reversed image, that is, the right hand on the image represents in fact the anatomical left hand. This means, to be exact that the blood flow from the hand wrist is related to the anatomical left hand of the TSM. Likewise the large blood flow on the forehead is mirrored and changes its original form from “3” to “ε” (epsilon). Therefore, to give a natural, anatomical description of the body, it is necessary to “mirror back” the image. In addition, the TSM imprint appears like a photographic negative. To get the man in positive, it is required to look at a negative image, which reveals the anatomical details (Figures 3 and 5). However, blood studies are best done on the TS in positive (Figures 2 and 4).

The following forensic examination is inspired by the procedure in an autopsy room and focus on selected and new findings.

General: On the Shroud is left a faint, double image of a naked man in supine position. One half of the Shroud shows the man from the front (Figure 3), the other half from behind (Figure 5). No outlines and no lateral parts of the body are visible. The length of the frontal image is difficult to measure precisely. An author (Bucklin, 1997) found that the man was about 180 centimeters high with an estimated weight of 80 kg. However, more recent studies (Fanti et al., 2010) found that the frontal image is 195 cm long while the dorsal image is 202 cm long. Both measures were in fact found “compatible with the wrapping of a man 175±2 cm tall that had a position similar to that of a crucified man.” The body is slim and muscular with more body parts fixed in a stiff position. The age is about 30 to 40 years. Numerous different pale, carmine red (Wilson, 2010) blood stains on the TS are related to the body image, referring to specific injuries

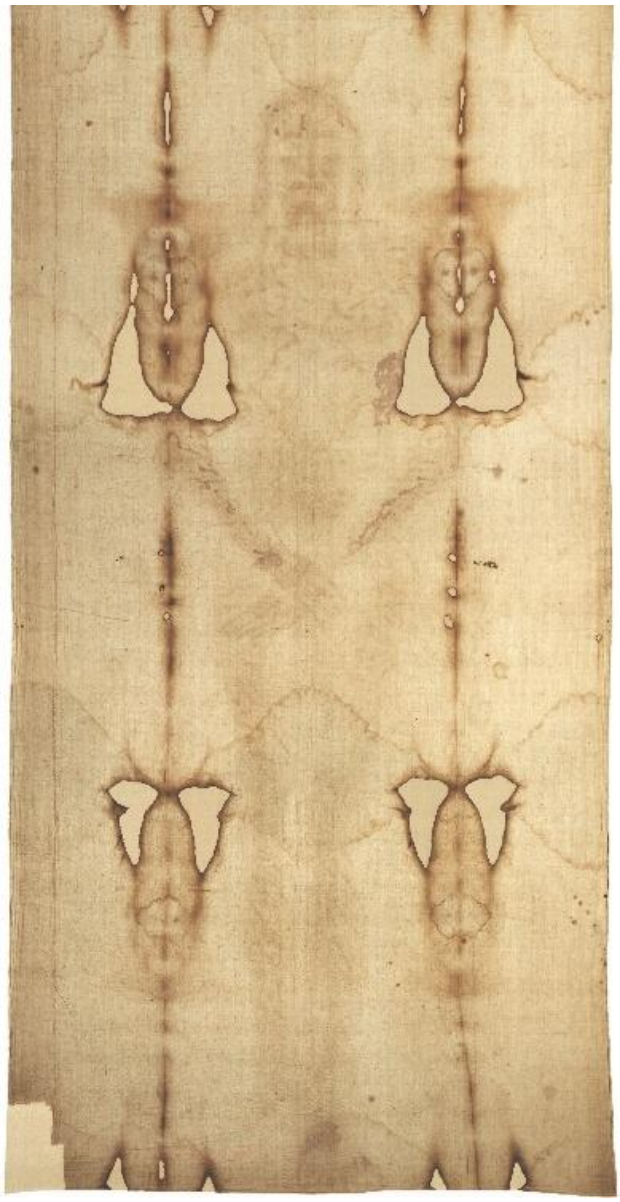

Figure 2. Positive, frontal image. © ODPF, Torino.

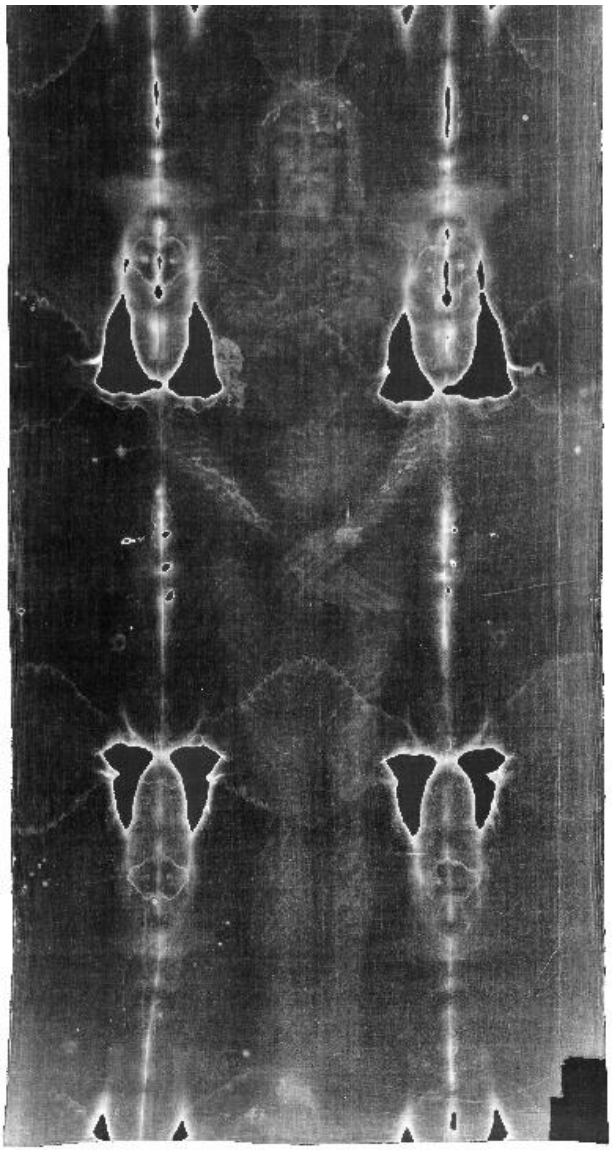

Figure 3. Negative, grey scale, reversed frontal image. © ODPF, Torino.

due to a violent death.

Head: The hair is shoulder long; the TSM wears a short, forked beard; the face is long and narrow with eyes and mouth closed (Figure 6). A well defined moustache covers the upper lip. The eyebrows are prominent and the nose long and narrow.

The pathologic findings count several blood stains as meandering rivulets running downwards by gravity in the hair, the forehead and the back of the head. The blood rivulets seem to have their origin from puncture wounds arranged in a specific pattern all over the scalp forming a semicircle on the back of the head.

A characteristic meandering, broadening, letter “3” rivulet on the forehead starts at the hair border, runs down and stops at the prominent left eyebrow.

The right cheek is swollen and involves the orbit. The swelling seems divided in a major upper and minor lower. The distal, cartilaginous third part of the nose is slightly displaced to the right due to a cartilage injury starting at an irregular line crossing the nose bridge.

Chest: The frontal view of the chest reveals well developed chest muscles with the chest fixed in an inspiratory phase (Figure 3).

At the right side a hand size, blood stain consisting of meandering rivulets is seen flowing in distal direction and apparently continuing around the small of the back (Figures 3 and 5). This flow emanates from a proximal, clear demarcated, oblique oval shaped wound (Figure 15). Judged from the shape and amount of blood/fluid

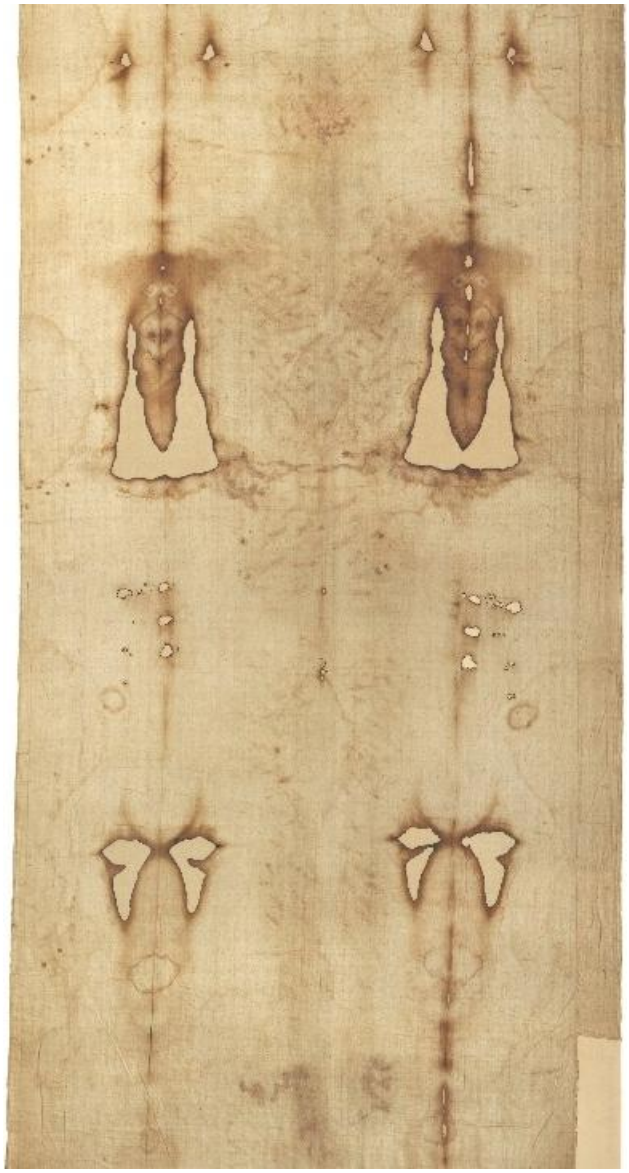

Figure 4. Positive, dorsal image. © ODPF, Torino.

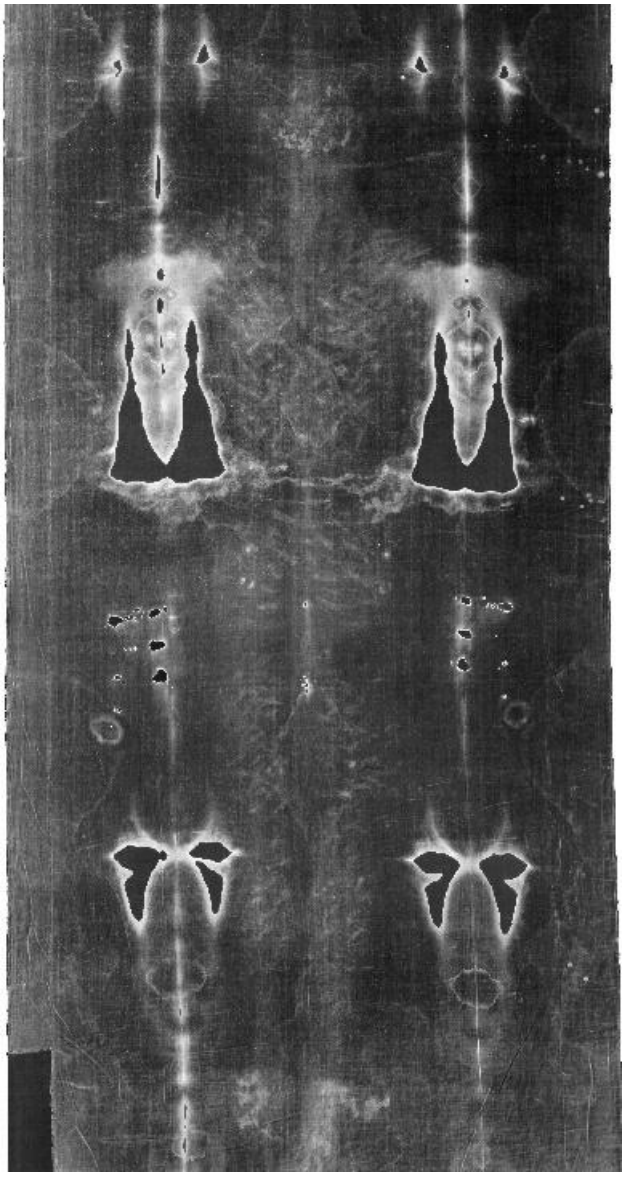

Figure 5. Negative, grey scale, reversed dorsal image. © ODPF, Torino.

this wound seems caused by a sharp object, able to penetrate deep into the chest cavities emptying these cavities from blood and fluid.

Spread over the frontal part and especially the entire dorsal part of the chest are blood stains of different form and size, some dumbbell other streak shaped (Faccini, 2010). No rivulets of blood emanate from this kind of injuries (Figure 7).

Abdomen: A significant part of the abdomen is distended (Figure 3).

Arms and hands: The right shoulder seems lower than the left. The possible cause might be a shoulder dislocation, although difficult to diagnose, as the lateral parts of the shoulders are missing caused by the burn holes.

The hands cover the genital area and are crossed in such a way that the left hand slightly grasps and covers the dorsal part of the right hand and part of the right wrist (Figure 8). The proximal interphalangeal joints of finger II - V of the left hand are slightly flexed, due to their natural position, while all four fingers of the right hand are stretched due to their placement on the left thigh. No thumbs are seen.

Two large blood flows emanates from a single puncture wound in the left wrist. Apart from a brake they seem to wriggle along the forearm to the elbow. The flow changes all the way in two to three distinct directions. The same phenomenon is seen on the right arm, but here no wrist wound is visible, apparently because the left hand covers the right wrist. One blood rivulet continues out of image at the right elbow (Figure 3). The specific directions of blood

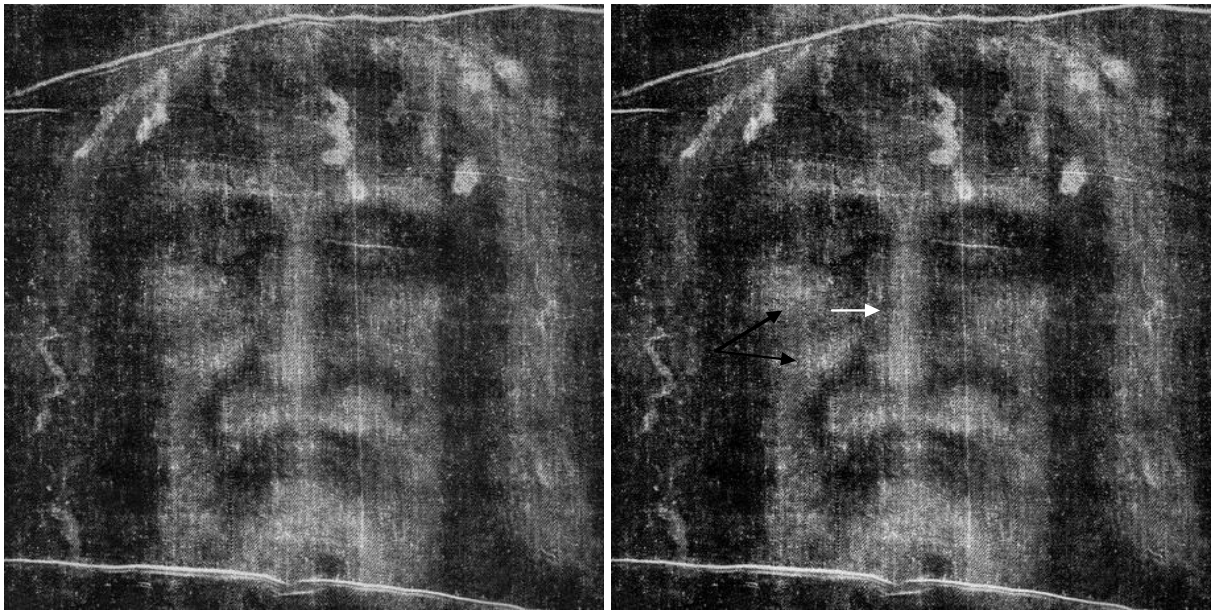

Figure 6. Left: The injured face; note the puncture wounds. Right: injuries of the cheek (black arrows) and nose (white arrow), which is slightly displaced. © ODPF, Torino.

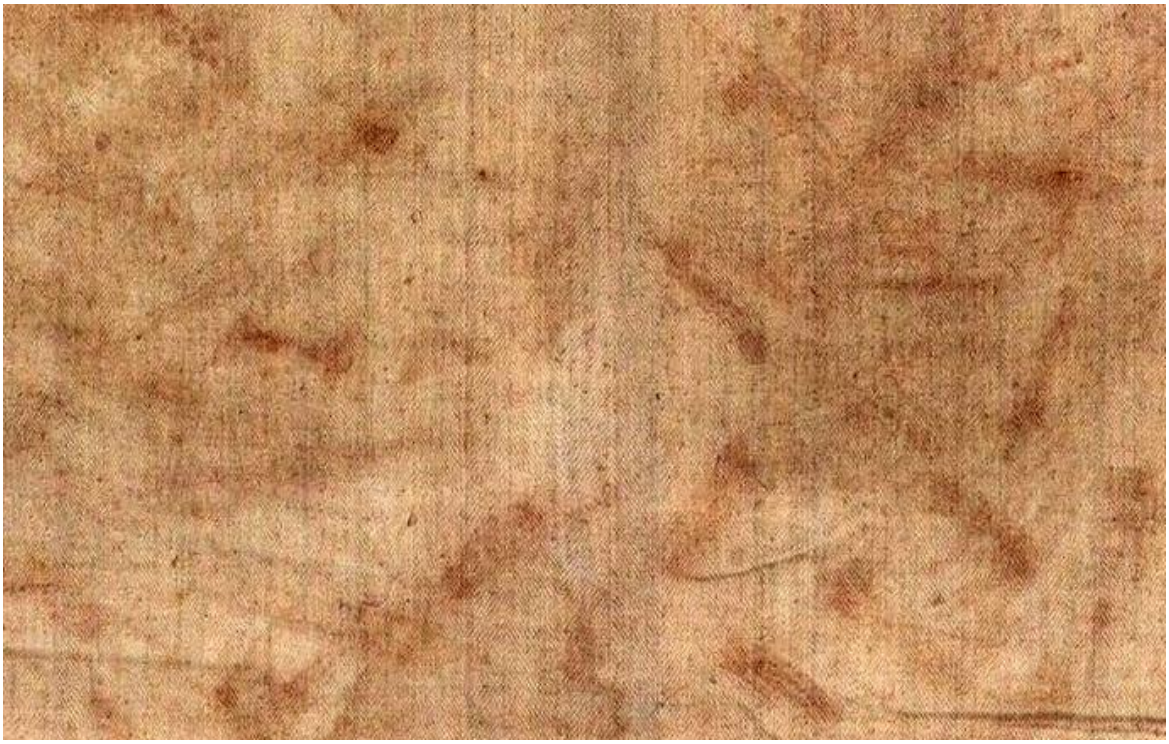

Figure 7. Detail of the upper part of the back showing the different kinds of injuries: dumbbell-like imprints and scratches made of 3 or 4 parallel lines. No blood flow is associated with these injuries. The right upper part on the positive photo is more reddish than the left part. This observation has been widely interpreted as the result of excoriations made by a heavy object**. © ODPF Torino/Photo** (Durante, 2000).

flows from wrist and forearms, following gravity, make sense, if the arms have been stretched upward at an angle of about 65° and from this position having slightly changed the positions in the frontal plane (Zugibe, 2005).

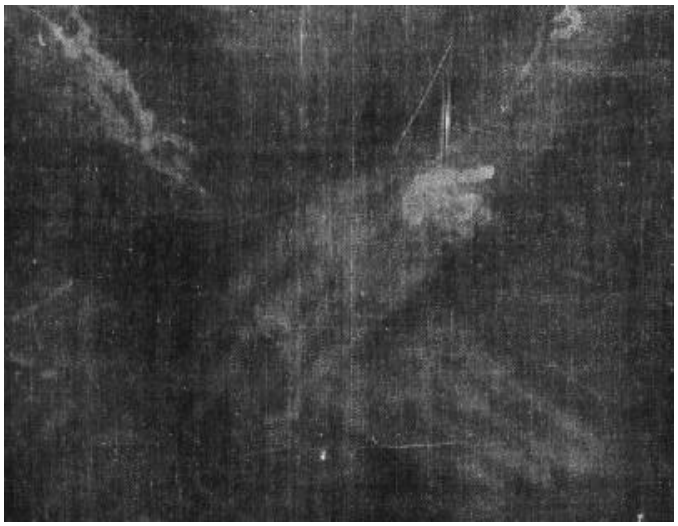

Figure 8. The crossed hands with a huge puncture wound in the left wrist and blood rivulets running along the forearms. © ODPF, Torino.

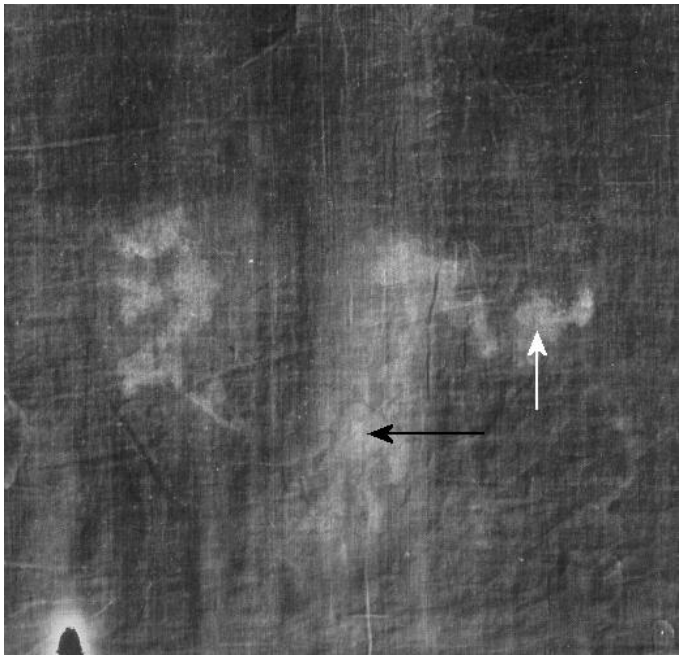

Figure 9. The entire right foot sole is covered with blood. A puncture wound is seen (black arrow). The blood from the heel area flows out of image to the right (white arrow). Only part of the bloody left foot sole is visible. © ODPF, Torino.

Legs and feet: From a frontal view the legs are seen to ankle level (Figure 3). From a dorsal view the right leg and the entire foot sole are visible. Most of the left leg is visible, but only the upper two thirds of the left foot sole is seen with the distal part converged, hidden and placed upon or close to the right (Figure 9).

No signs of broken legs (shins) are visible, neither from a frontal nor a dorsal view. The right knee seems to have a swelling above the knee cap as can be seen in the discussion.

Large blood stains and rivulets in different directions seem to emanate from a puncture wound in the middle of the right foot. Blood runs out of image from the lateral part of the heel (Figures 5 and 9).

From a frontal view both legs are slightly flexed and fixed, the left more than the right. This fact is supported by the positions of the feet.

Lots of dumbbell and streak shaped blood imprints are seen at buttocks, thighs and shins.

BLOOD CHEMISTRY

Macroscopically, the “blood” marks are very different from the body image. They appear as a dried liquid or semi-liquid phase that has gone naturally from the “image side” to the back side through the entire sheet by capillarity and through the interstices of the weave: direct observation of the back side proves that. A careful observation shows that the borders of the blood marks are denser than the center as expected for a blood clot.

At thread level, microphotographies (Figure 10) demonstrate clearly the differences between the body-only image and the blood areas. Blood appears as dark red dense spots more or less randomly distributed on the reddish brown fibers. Direct observation shows that the red spots are made of brittle agglomerates often abraded and the spatial distribution of the color is completely different from that of the body-only image.

From a forensic point of view, the blood marks are macroscopically consistent with blood, except for the color which is too red for centuries-old blood. Blood is a mixture of plasma (the liquid phase containing many biological molecules, in majority of albumin and other proteins) and cells, mainly erythrocytes (or red blood cells, RBC). RBC has no nucleus and can be seen as tiny bags full of hemoglobin. Hemoglobin is made of four proteins with a chemical structure named “heme” in their center. Heme pertains to the large family of the porphyrins found in many biological materials (for example vegetables). In blood, an atom of iron (Fe) is at the center of the heme. On the Turin Shroud, spectroscopy has shown that only iron, calcium and strontium are detectable above trace level and found more or less uniformly on the entire cloth (Schwalbe and Rogers, 1982). The amount of iron is slightly higher in the blood areas and consistent with the expected level of iron in blood (Schwalbe and Rogers, 1982).

Forensic tests for blood

Usually, the mean tools used in forensic medicine to know if a suspect stain is real blood are based on classical methods involving the catalytic peroxidative

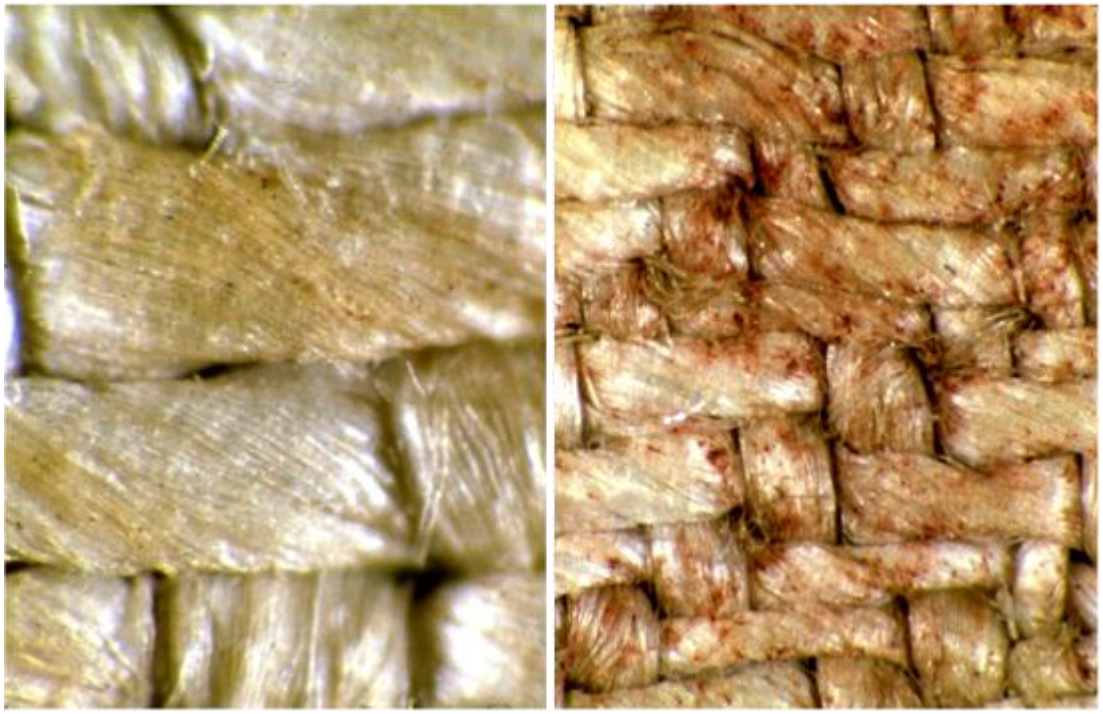

Figure 10. Left: body image color (nose area, contrast enhanced). Right: blood area (scourge marks of back, contrast enhanced).

action of the heme group (benzidine, phenolphthalein, Takayama and Teichman tests). The results of these tests performed in 1973 by an Italian scientific group (Frache and Rizzatti, 1976) and later by Walter McCrone (McCrone and Skirius, 1980, 1981) were negative. Contrary to the latter, the Italian group stated that no definitive statement could be made because “the pigmented incrustations did not pass in the solvents…” and concluded (Frache and Rizzatti, 1976) “...the negative results of the tests do not allow an absolute judgment, which could exclude the possibility for the examined material to be blood.”

A comprehensive survey of the literature (Heimburger, 2008) shows that 1) there are very few articles (often controversial) about the recognition of old blood in archaeological context and 2) some laboratory experiments seem to demonstrate that the classical tests are not reliable for blood samples after some years.

Microscopy

With high resolution microscopy, the blood areas are made of: 1) in blood areas: red coated fibers, 2) in the margin of blood areas: golden yellow coated fibers (serum), 3) agglomerates of amorphous material (some micrometers, color: orange to red in the blood areas, brown in the blood-scorch margins), 4) red particles, about 1 µm large, mainly found in the waterstain margins and blood scorch areas.

According to Heller and Adler (1981), the material described above (1, 2 and 3) in blood areas, after removing it from the tape (which changes the optical properties), is not birefringent, demonstrating that it is not a pigment as claimed by Walter McCrone (McCrone and Skirius, 1980, 1981). Therefore this material is not made of pigment. Most of the birefringent particles (iron oxide) were found in the waterstain margins and blood scorch areas.

Microchemistry and microspectroscopy

Heller and Adler (1981), in addition to high resolution polarized microscopy, did use microchemistry and microspectroscopy to characterize the different kinds of particles and fibers found on 22 of the tapes removed from the surface of the Shroud (including 3 samples coming from the patches and backing “Holland cloth” stitched in 1534 by the nuns after the 1532 fire) in 1978 by the STURP. They performed 8 tests for the detection of proteins, 23 tests for the detection of metallic species, 22 tests for the detection of organic structures and functional groups and 7 solvents for dye extraction tests. They also performed many experiments on different kinds of control samples.

In Table 5 of their paper (Heller and Adler, 1981) are summarized the 12 tests “…confirming the presence of

whole blood on the Shroud."

From a forensic point of view, we must notice that this article has been published in a peer-reviewed journal (Canadian Society of Forensic Sciences Journal) dedicated to Forensic Science. The most important results (Heller and Adler, 1981) are:

i) "Indicative reflection" and "microspectrophotometric transmission spectra": the Soret band (400-450 nm), highly specific of porphyrins (Heller and Adler, 1981).
ii) "Chemical generation of characteristic porphyrins fluorescence". Other kinds of porphyrins, like chlorophyll does fluoresce, but its fluorescence does not have to be generated (Adler, 1986).
iii) "Positive hemochromagen and cyanmethemoglobin tests".
iv) "Positive detection of bile pigments".
v) "Positive demonstration of protein". The tests (particularly the highly sensitive and specific fluorescamine test) show that proteins are only found in blood areas and not on the image fibers.
vi) "Positive indication of albumin specifically."
vii) "Protease tests, leaving no residues". This is very important: "Within a half hour this solution completely "dissolved" the non-birefringent red particulate coated fibrils coating, leaving no particulate residues… This protease treatment also removes the golden yellow fibrils, corroborating their identification as "serum" coated fibrils. Interestingly, fibrils freed of their coating using this technique closely resemble the non-image fibrils when viewed under phase-contrast… Proteases have absolutely no effect on the yellow (body) image or the pale yellow non-image fibrils of the Shroud." This test shows that 1) the blood and serum coated fibrils and particles does contain proteins as expected for blood, 2) the image itself does not contain proteins, in particular no collagen used as binder for a painting contrary to McCrone claims (McCrone and Skirius, 1980, 1981) and 3) there is no image color under the blood stains.
viii) "Microscopic appearance as compared with appropriate controls".

Recent unpublished data from the vacuumed "dust" (by Riggi Di Numana) coming from specific areas of the TS have been furnished to the authors. Some of the reddish particles have the characteristics of blood (SEM and Raman spectroscopy). These preliminary studies seem to confirm the presence of hemoglobin and iron as well as the biological (not mineral) origin of these particles. A very low level of potassium is confirmed. Unexpected relatively high levels of Na and Cl were found in these particles which are interpreted as possibly coming from sweat (personal communication 2011 with Prof. Giulio Fanti).

Immunology

Heller and Adler (1981) performed some immunochemical tests for whole human serum and for globulin as well as control tests with serum from other species to avoid false results coming from cross-serology. They concluded that the blood derived material is "definitively" from primate blood. Pierluigi Baima Bollone also confirmed the presence of human globulins in the blood (Bollone, 1990). In summary,
i) The "blood" is real blood: it does contain all the molecular components of blood (iron, amount of iron consistent with real blood, iron specifically attached to heme, porphyrins, human serum including proteins, albumin, and finally high levels of bilirubin) as demonstrated by microscopy, microspectroscopy, microchemistry and immunology.
ii) The blood also contains very unusual high amounts of bilirubin. This fact was not expected before the experiments but can be understood if a quick and large hemolysis occurred as should be the case for Roman scourging.
iii) However, two facts seem to be contradictory with the hypothesis of real blood: the very low amount of potassium and the red color. To explain that, Adler wrote that the blood on the Shroud is not whole blood but exudates (Adler, 1986) that left an imprint during the clotting process on the corpse. In blood, almost all the potassium is inside the red cells which remained on the body during the clotting process. Adler (1986) wrote: "But a torture, scourging and crucifixion leading to shock - that would produce a tremendous hemolysis. In less than 30 s, the hemolyzed hemoglobin will run through the liver, building up very high bilirubin content in the blood. If that blood then clots, the exudates forms, and all the intact cells with hemoglobin stay behind, only the hemolyzed hemoglobin goes out along with the serum albumin which binds the bilirubin…. The blood has no cells, is very low in potassium and has the right color and composition for the blood of a man who was severely flogged and crucified". This hypothesis implies that the imprint occurred within a particular (short) stage of the clotting process on the corpse. Afterwards the exudates could form a clot on the sheet itself. This hypothesis has to be tested and compared with the hypothesis of the spontaneous (under some conditions) fibrinolysis of dried clots on the corpse. Regarding the second point (the blood is too red), Adler's hypothesis suggests that the mixture of brown hemolyzed methemoglobin with orange bilirubin explains the unusual red color of the blood.

However, a recent experiment (Svensson, 2010) demonstrates that, after four months, no detectable difference in color could be found between normal blood and blood with very high levels of bilirubin. This interesting experiment, however, can not be used as a definitive proof that Adler was wrong since 1) the blood used in this work is whole blood and not exudates of blood (hemolyzed methemoglobin in Adler's hypothesis) and 2) in Adler's hypothesis, bilirubin is mainly non-conjugated (or free) bilirubin, while the bilirubin in this

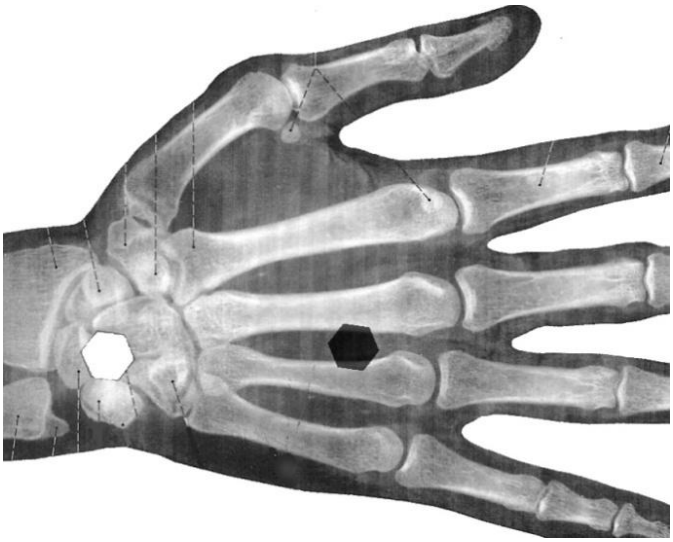

Figure 11. X-ray photo of a left hand, palmar aspect. The white hexagon marks the entrance of a nail between the wrist bones. The black hexagon marks the favorite painters' entrance. © Niels Svensson.

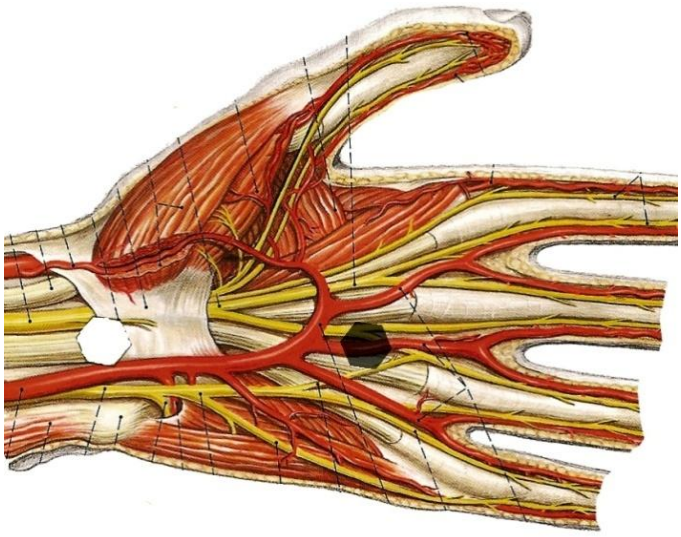

Figure 12. As in Figure 11 with appended soft parts. The white hexagon (nail) stimulates the motor part of the median nerve causing the thumbs' contracting into the palm (not shown on this illustration). © Niels Svensson.

experiment is mostly composed of conjugated bilirubin.

Another possibility to explain the anomalous red color of the blood is suggested by Rogers and Arnoldi (2002): *Saponaria officinalis* (soap weed) was likely used to wash the Shroud as was the case for most of the textile in the past. Diane Soran tested in 1977 the hemolytic effect on red blood cells by a *Saponaria officinalis* washed cloth. The blood was still red after 26 years in 2003.

It has also been shown that UV irradiation of blood might explain the redness of the blood stains (Goldoni, 2000), a fact that has been independently confirmed: 3 years after UV irradiation, blood on linen remains red, while the non irradiated blood has the brownish expected color (Personal communication 2011 with Prof. Giulio Fanti with photos). However, this kind of experiments, using UV irradiation, implies some hypothesis about the image formation process which is out of the scope of this paper. Therefore, the unusual redness of the blood stains has no explanation reached by consensus.

DISCUSSION

As the TS is considered by many to be the actual burial cloth of the crucified Jesus Christ, the first task of the forensic studies is to verify that the image characteristics are consistent with those of a real body and the second task to compare some facts with the story of the Passion according to the Gospels. In any case, forensic studies alone cannot provide a definitive conclusion regarding the authenticity of the TS as the actual burial cloth of the historical Jesus.

Rigor and livor mortis (death stiffness and discoloration of dependent parts of the body) are specific signs of death, one of which must be observed to declare a person dead and deliver to an undertaker. Rigor is determined by handling the deceased, livor by inspection. None of these methods can be applied on the TSM as we deal with an image. Yet, the position of the body and body parts indicates rigor mortis (Figures 3 and 5). The chest is stiffened in inspiration, the thumbs in the palms, the knees and ankles in flexion. If the person has died on a cross fastened by nails in wrists and feet, it would be expected that the extremities and chest "freeze" in this position as observed on the TS. If the motor part of the median nerve in the hand wrists is mechanically stimulated by an adjacent nail (Figures 11 and 12), the net effect of this nerve irritant acting on the different thenar muscles causes the thumb to contract into the hand, that is, the thumb would be hidden in the palm of the hand in rigor mortis, when seen in a frontal view. This phenomenon seems to be the cause of the "missing thumbs" (The "missing thumb problem" has divided physicians in different camps. One camp favors the mechanical stimulation of the median nerve during crucifixion (Dr. Barbet and Dr. Bucklin). Another camp (Dr. Zugibe) claims that the nail seems to be too far from the median nerve to have any stimulating influence - forgetting that the body weight during crucifixion brings the nail close to the nerve. Furthermore, Dr. Zugibe claims that the position of the thumbs in the palm is normal. This is not true when by simple inspection it is observed from the dorsal side of the hand that at least one half is visible on most people). If the median nerve instead was cut at this place the thumb would place itself lateral to the index finger because of paralyzed thenar

muscles, a medical condition, if chronic, called “ape hand”.

A main issue of dispute refers to the question: was the TSM dead or alive (coma)? It has been asserted that the heart must still pump, since a corpse cannot bleed. But this statement is refuted by the fact that the body shows the aforesaid signs of rigor. The large blood rivulets, except the chest wound, could have been formed while the TSM was alive and after death redissolved by external fibrinolytic (“melting”) activity (E-mail answer (2011) from Prof. K. Linnet, Department of Forensic Medicine, Copenhagen) (Brillante, 1983) or alternatively by smudging in a humid environment (Lavoie et al., 1983) and then transposed to the cloth. One of the main questions is related to the scourge marks: how is it possible to explain the lack of blood flows and even their highly detailed imprint on the Shroud many hours after the scourging of the TSM, according to the Gospels? This question remains open but might be explained by a quick washing of the pre-mortem injuries of the TSM. Another sign that indicates clinical death seems to be the chest stab wound causing large amounts of blood and liquid pouring out. As an additional sign of death the abdomen seems distended referring to postmortem intestinal meteorism (gas development). Taking all these observations into account and even more (Faccini et al., 2009), it can certainly be concluded that the TSM was dead, when he was enveloped in the Shroud.

The face seems to be too narrow (Figure 6). This observation seems correct, but is actually due to banding of the Shroud texture. More faint but still present on the left side of the face it is possible in a facsimile image to follow the protruding eyebrow and cheek continuing lateral from the very sharp band border of a long line in the texture.

It has been claimed that the sharp demarcated blood rivulets in the hair, most prominent in the right side, in reality originates from the parietal and temporal region of the head (Lavoie et al., 1983). An experiment making cutouts on a cloth have been made corresponding to these stains and then placed over a bearded man’s face. Finally the cutouts were filled with paint. After removing the cloth, the rivulets once present in the TSM’s hair were now placed in the temporal and cheek area on the volunteer. This experiment suggests that the production of blood marks and the formation of the image were two different events.

The meandering, broadening letter “3” rivulet on the forehead is caused by wrinkles and by tilting the head to both sides just as the characteristic forked rivulet running in two directions at the right temple region (Svensson, 2010).

The displacement of the distal, cartilaginous part of the nose and the swelling of the right cheek are probably due to direct blows (Svensson, 2010).

Some researchers have observed (roots of) teeth, particularly at the upper part of the mouth (Accetta et al., 2000). This observation has been opposed by the fact of banding in this area. Likewise banding effect might be in play, when stated that the metacarpal bones of the left hand are visible.

Most probably the swelling above the right knee cap is due to internal knee injuries having caused bleeding into the knee capsule, hemarthrosis (Figure 13). If such a swelling comes up shortly after a bump of the knee cap against a hard surface, an x-ray photo often reveals a knee cap fracture. Therefore the TSM has most likely got a knee cap fracture probably by knocking his right knee against a hard surface (Svensson, 2010).

It appears that the feet have been nailed by a single nail forced through the dorsal part of both feet and the exit at the plantar parts (Figure 14). The left foot has been forced medially and placed upon the right one. Large blood vessels are located in this area and may have caused considerable bleeding. Since the whole right foot sole is visible, this fact may indicate a dislocation of the ankle joint.

The dumbbell and streak shaped type of wounds are spread all over the body - except face, forearms, hands and feet. The instruments used are presumably a Roman flagrum whip (*Flagrum plumbatum*) with two or more leather straps ending in dumb bell formed, heavy lead objects (Rich, 1874) and Roman whips like *bucadae* or *virgae*, that is, consisting of strips of leather and birch. The wounds are, beside their recognizable shape, characterized by forming no blood rivulets. The impact of the heavy lead objects concerns structures under the skin such as hematoma (bruise) in connective and muscle tissue, rib fracture and lung injury. The considerable power of the lead object left on a rib is dependent on the speed and angle of the object relative to the rib and may as a consequence cause rib fracture (Svensson, 2010). The sharp ends of a fractured rib are able to damage intercostal veins and arteries during respiration followed by bleeding into a damaged lung sac, a common condition in emergency practice known as hemothorax (Svensson, 2010; Zugibe, 2005). Most physicians agree that the blood from the large wound in the right side of the chest is that of a postmortem type (Figure 15). The whole blood of the hemothorax separates postmortem into two layers by gravity (sedimentation) (Figure 17). A huge amount of blood of high viscosity and serum of low viscosity - the latter best recognized in ultraviolet light as a surrounding ring of the blood stain (Figure 16) - poured out of the wound, while the deceased was in upright position. The Gospel term “blood and water” flow after the lance thrust (Figure 18) and documented by an eyewitness (John 20: 34) corresponds to blood and serum and is expected to emanate in this succession.

Some Shroud researchers claim that the postmortem blood from the side wound does not derive from the lung sac cavity, but from the heart sac as a result of a ruptured heart, after an acute myocardial infarction (AMI). A heart rupture event is rare after only a few hours of AMI, and if

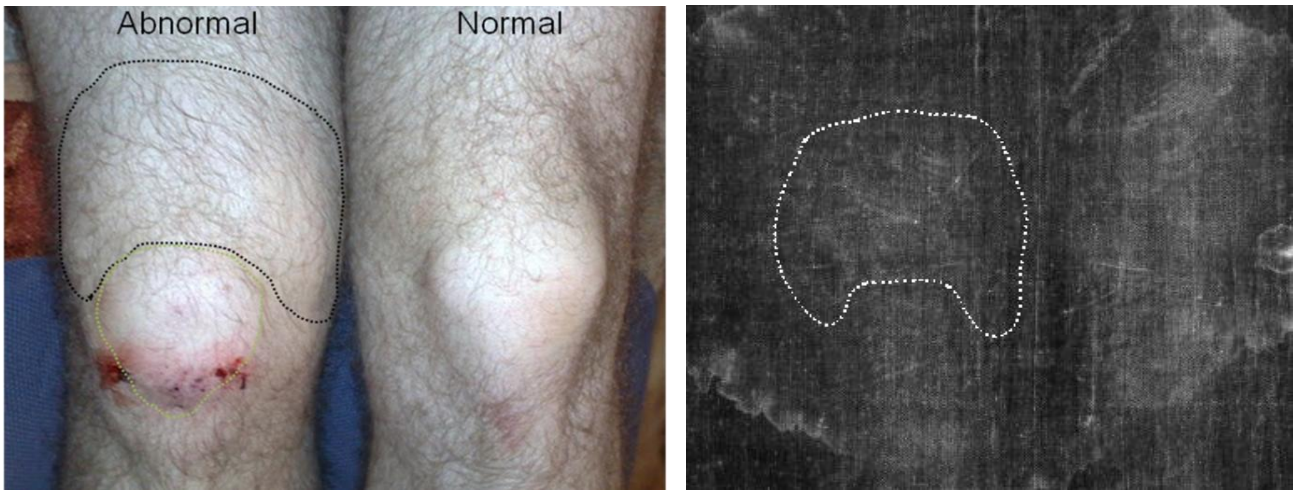

Figure 13. Left: Fresh right knee cap fracture causing hemarthrosis (black dotted line). Right: The possible hemarthrosis indicated on the right knee of the TSM (white dotted line). © Niels Svensson and ODPF, Torino.

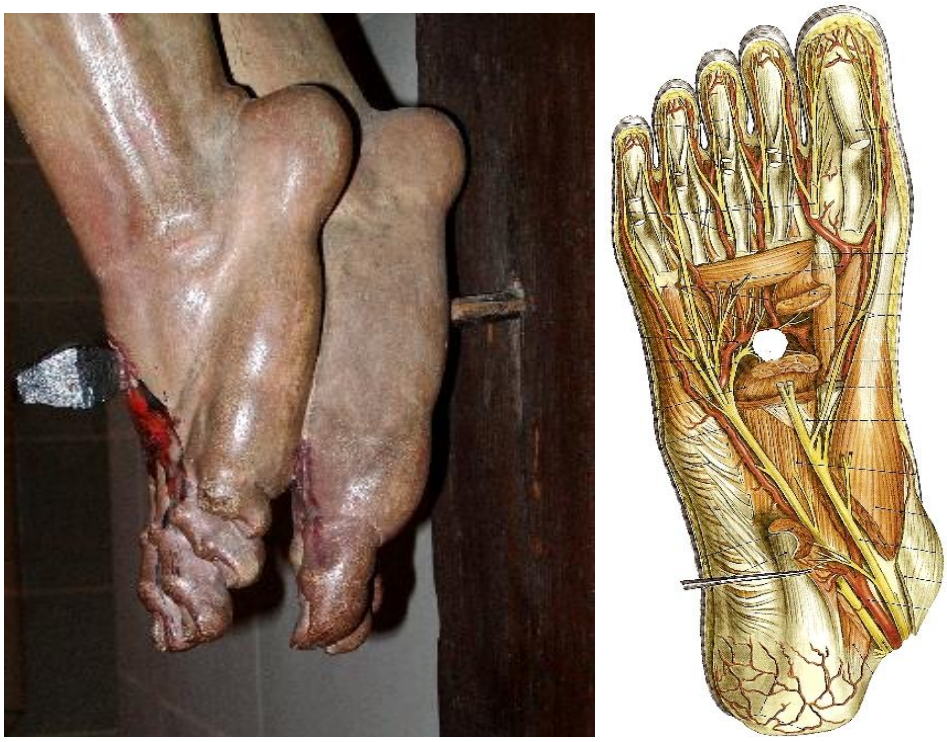

Figure 14. Left: Artistic reproduction of one nail through both feet. Right: The possible exit (white spot) of the nail in the right foot. Note the close relationship to the artery (red). © Niels Svensson.

it happens, the heart usually suffers from other diseases (The clinical diagnosis *stress induced takotsubo cardiomyopathy* followed by left ventricular rupture has been proposed as a possible TSM cause of death. The condition cannot be excluded, but is rare and most frequent in elderly women. The few reported cases of rupture related to this phenomenon occurred 1 to 3 days after symptom début). On the other hand it is not unlikely that the sharp object has penetrated right to the distended heart chambers (Barbet, 1993). From here the postmortem blood, already separated, might have poured out through the stab wound channel and possibly mixed with blood from the lung sac cavity.

A final and intriguing problem has to be discussed.

Figure 15. Close-up of the side wound. Note the oblique oval shaped puncture insert (red) at the top, resembling the transverse section of a Roman lance, and the blood rivulets running downwards in different directions**.** © ODPF, Torino.

Figure 16. Same area as figure 8 in ultraviolet light. The bright serum ring surrounding the blood stain is clear. © INSTAR.

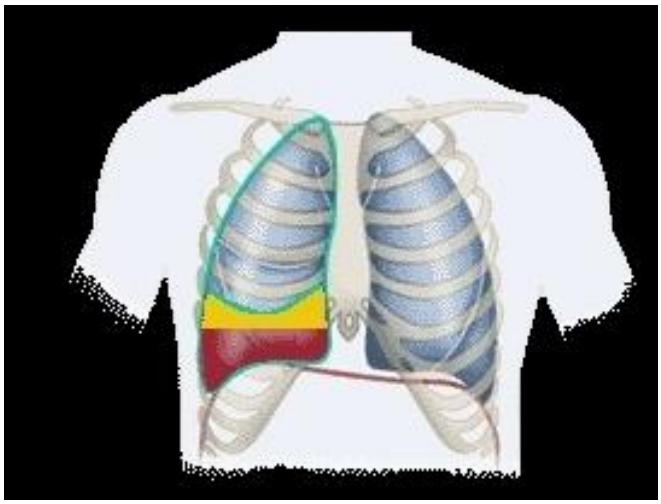

Figure 17. The postmortem separation of blood in two layers in the lung sac. © Niels Svensson.

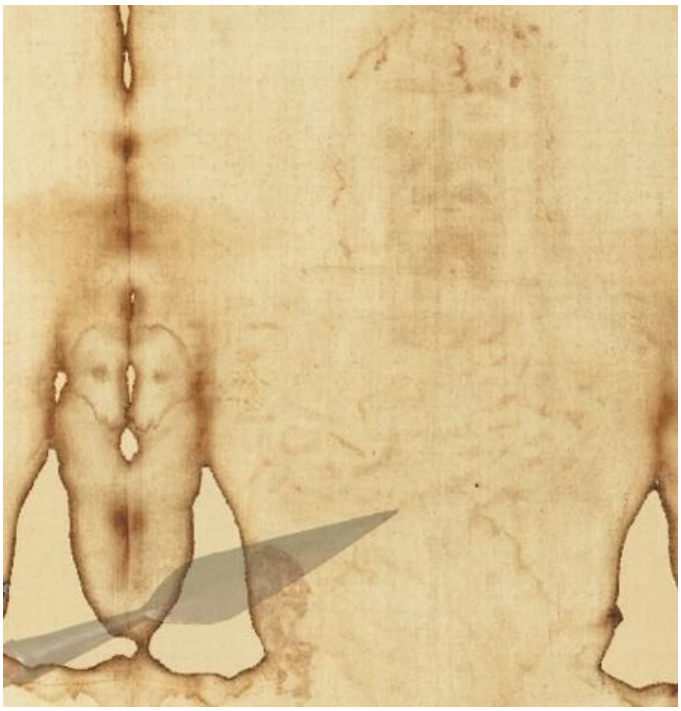

Figure 18. The supposed weapon causing the side wound (image is mirrored). © Niels Svensson and ODPF, Torino.

Was the TSM washed or not before enveloped in the Shroud? The washing idea has come to light following the very logic presumption that the dumbbell and streak shaped wounds have dried and smeared long before enveloping the corpse thus preventing blood transfer to the Shroud, even if anticipated that the Shroud had been moist or the corpse wet from sweat. It has been clearly shown that corpses ooze blood from wounds after wash-

ing, particularly if the deceased died a violent death (Zugibe, 1989). Yet, another transfer mechanism, which does not involve washing, has been proposed, namely the aforementioned blood clots' ability to redissolve after clotting by so-called external fibrinolytic activity that, so to say, melts a clot enabling it to make a blood imprint. So conclusively, it cannot be definitive determined whether the TSM was washed or not.

CONCLUSION

In spite of different forensic interpretation of observables, the majority of physicians agrees that no observation speaks against the Turin Shroud Man having suffered the same punishment as Jesus Christ revealed in the Gospel account of the Passion, that is, the cheek and nose injuries account for the blows, the dumbbell and streak shaped wounds for the scourging, the scalp wounds for the crown of thorns, swollen knee for a crossway fall, the wounds in hands and feet for the crucifixion nails, the intact shins for the non-broken legs, the chest wound for the lance thrust as well as the rigor mortis for Christ's death on the cross.

Finally, the most likely causes of death are compromised circulation due to intense pain, compromised preload caused by the hanging position, hypovolemic shock due to dehydration and blood loss (Lavoie et al., 1983), accentuated by trauma-induced coagulopathy (Bergeron, 2011) (Trauma induced coagulopathy is a common complication of traumatic shock. This complication often occurs when several factors are present: shock, tissue injury, hypothermia, systemic inflammation and acidemia. Most, if not all these conditions, are expected in the case of the historical Jesus) and asphyxia (suffocation) (Barbet, 1993) due to exhaustion.

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