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Research Article

Blood Transfer to the Shroud of Turin: The Washing Hypothesis Revisited

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Abstract

The Shroud of Turin is an important archaeological artifact that has been suggested to represent either the burial cloth of the historical Jesus of Nazareth or a clever hoax created during the medieval era. Previous studies have established that authentic blood components are present within the wound areas and shown that numerous serum borders exist, indicative of clotted blood being transferred to the cloth. Controversy exists regarding whether the body would have been washed prior to envelopment in the burial shroud. It has been suggested that Jewish burial customs would have prohibited washing of the body under these circumstances; in this case, resultant blood transfer would likely have occurred either when the blood was relatively fresh and in a liquid or gelatinous state, or after having dried and being remoistened via a high humidity, cave tomb environment. Alternatively, it has been proposed that the body was washed, followed by post-mortem emission from wounds, which were then transferred onto the cloth. Indeed, post-mortem blood has been found to rarely coagulate under these conditions, making such transfer possible even hours after death. The current study demonstrates that inhibition of coagulation precludes the formation of serum borders in bloodstains, an observation which is incompatible with what is observed on the Shroud. These data indicate that it is unlikely that the primary blood transfer mechanism involved washing of the body and subsequent post-mortem emission from wounds.

Keywords

Turin Shroud, Blood, Washing, Serum Halos

1. Introduction

The Shroud of Turin is a long linen cloth bearing the faint image of a bearded man with wounds corresponding to scourging and crucifixion. Chemical and immunological studies have shown that the wound areas contain genuine blood components, and current evidence suggests that the blood was transferred from a body and not simply added to the textile [1-5]. In the initial examination of the cloth, it was thought that the image might have been formed through contact with a hot statue, an idea that was quickly ruled out using ultraviolet light for detection of specific burn emission signatures [6]. Serendipitously, such studies led to the observation that many wound areas contained fluorescent borders (Figure 1), consistent with the transfer of clotted blood to the cloth [4-6].

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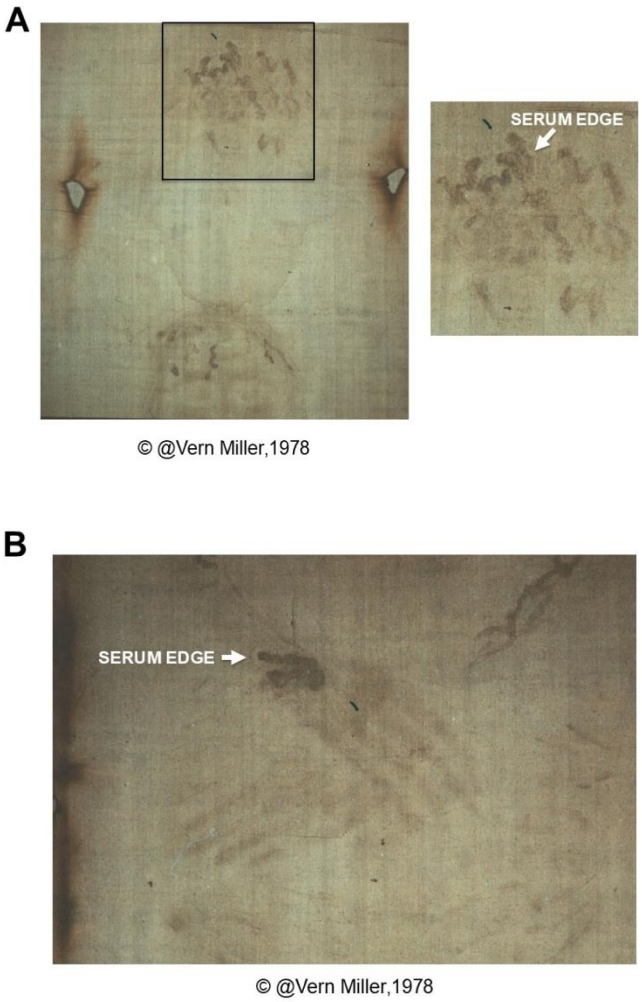

Figure 1. *(A) Image of the Shroud taken with ultraviolet photography showing a partial view of the top of the ventral face region (bottom) and the dorsal area corresponding to the back of the head (top). An enlargement of the area indicated by the rectangle is shown to the right and fluorescent serum edges of bloodstains are indicated (white arrow). (B) Image of the Shroud taken with ultraviolet photography showing a view of the wrist wound. The fluorescent serum edges of bloodstains are indicated (white arrow).*

In Jewish tradition, washing of the body is prohibited under conditions of a violent death as such blood must remain with the corpse and may not be removed [7]. Zugibe, a forensic pathologist with many years of experience, contended that certain exceptions may be made, an idea that he witnessed first-hand many times. He also noted that when wounds of cadavers were washed, the blood would subsequently ooze out, and most importantly that "after postmortem blood flows from a wound, it rarely coagulates but may dry" [8]. This observation is supported by previous studies by Virchow showing that unlike normal blood which is spontaneously coagulable, capillary blood of the cadaver is always fluid and incoagulable; and the blood in the veins of the limbs is more often fluid than not and is only exceptionally coagulable [9]. Haba reported that "it is well known that the blood in sudden death, asphyxia or shock shows the fluidity but no coagulability" [10]. Taken together, these observations led Zugibe to propose that the vast majority of bloodstains on the Shroud represented post-mortem blood that had oozed from wounds due to washing of the body [8]. This idea is significantly divergent from alternative suggestions that the body was not washed, and that clotting blood was transferred while either relatively fresh; or that clotted bloodstains were imprinted after drying via humidity transfer mechanisms [7, 11]. Intriguingly, the observations that Zugibe and others have made regarding the general failure of post-mortem blood to effectively coagulate seems at odds with what has been observed on the Shroud.

Recent studies have established that ultraviolet light is an effective alternative light source in the detection and characterization of serum stains [5, 12]. In the current report, ultraviolet photography was used to demonstrate that the failure of blood to coagulate is associated with the lack of formation of serum halos/edges in bloodstains. As fluorescent borders are characteristic of several major blood marks on the Shroud, these results suggest that the washing hypothesis is likely incorrect.

2. Materials and Methods

Blood collection and treatment

Human blood was obtained from healthy volunteers by the finger stick method using a Health Lancing device (CVS pharmacy, USA) fitted with a micro lancet (CVS Pharmacy, USA). For anti-coagulant experiments, blood was transferred to Meterbox vacutainer collection tubes coated with K_3EDTA on the interior of the tube wall. For certain experiments, the pH of blood was adjusted using 0.1 M HCl via calculations based on the Henderson-Hasselbach method, which was verified using universal indicator solution. Blood was dropped onto untreated glass slides (Amscope, Irvine, CA) or mouse skin using a 1-10 or 10-100 microliter (ml) Eppendorf® micro pipettor (Hamburg, Germany). Newborn mice approximately 1-2 weeks of age were obtained from Rodent Pro LLC (Inglefield, IN) and used in skin drying and transfer experiments.

Ultraviolet light source and photography

A LED UV flashlight, 365 nm, LED-UV301-365 nm (Shenzhen Lightfe Light Limited, Shenzhen, China), positioned at a ~ 45 ° angle from the subject was used as the UV source. All photographs were taken using a Sony 6500 digital camera fitted to a Unitron ZST stereomicroscope.

3. Results

Recent studies have documented the initial and final stages of serum movement in drying blood on various non-absorbent surfaces, including glass or skin [13, 14]. As the blood begins to coagulate, an initial "plasma blister" is formed, followed by clot retraction and movement of serum to the edges, forming a serum "halo", which may be visualized using ultraviolet light

[5, 13, 14]. As demonstrated in Figure 2, serum halos were readily observed in normal blood dried on either glass or skin but failed to form in blood treated with anti-coagulant (Figure 2).

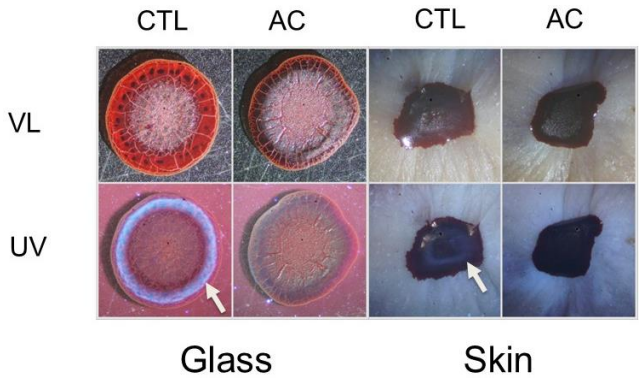

Figure 2. *Control (CTL) and anti-coagulant (AC) treated blood were placed on glass or skin, allowed to dry, and observed under visible light (VL) or ultraviolet light (UV). The position of the serum halo is indicated by the white arrow.*

In addition to impaired coagulation, reduction in pH values has also been reported in cadaveric blood *in vivo* [15]. To approximate these conditions, the blood pH was adjusted to match the range reported for hours after death, and blood allowed to dry on skin as before. As shown in Figure 3, the formation of serum halos was precluded under conditions of reduced pH and impaired coagulation, conditions which are characteristic of post-mortem blood *in vivo* (Figure 3). In contrast, serum halos were effectively observed in reduced pH samples without anti-coagulant treatment (Figure 3).

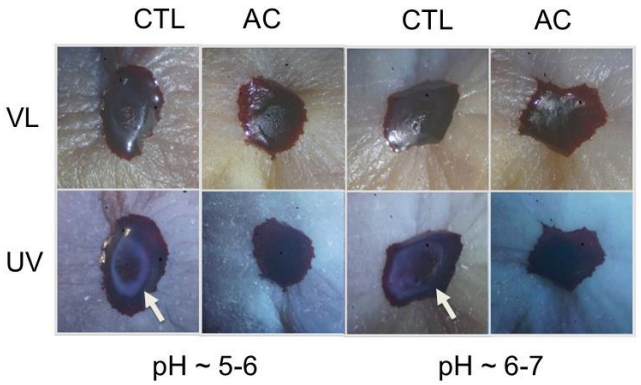

Figure 3. *The pH of (CTL) and anti-coagulant (AC) treated blood (AC) was adjusted to the indicated range, placed on skin, allowed to dry, and observed under visible light (VL) or ultraviolet light (UV). See Materials and Methods section for specific details. The position of the serum halo is indicated by the white arrow.*

Finally, previous studies have shown that transfer of blood to material during the coagulation/drying phases results in the formation of imprints in which the serum halos/edges are present as (ultraviolet) fluorescent borders [5]. The transfer method used in these experiments is shown in Figure 4. Consistent with the previous results shown in Figures 2 and 3,

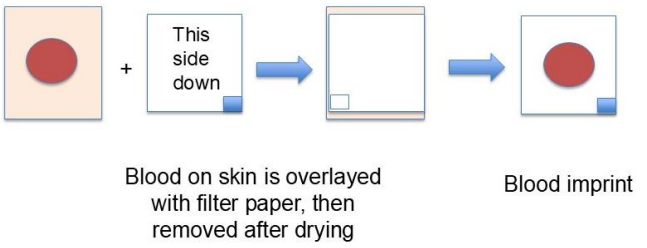

Figure 4. *Schematic showing the method of blood imprinting. Blood is added onto skin and then after 20-25 minutes is overlayed with filter paper, which is removed after drying. Samples are then examined under visible and ultraviolet light to monitor the formation and transfer of serum edges.*

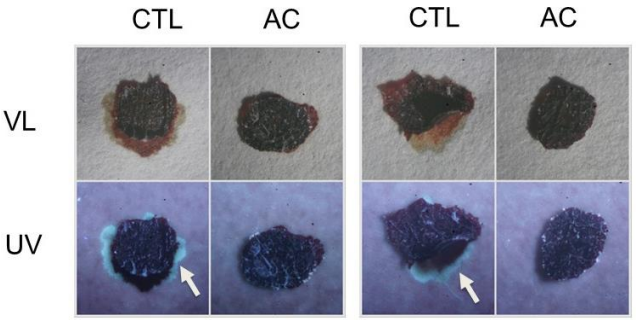

Figure 5. *Blood from control (CTL) and anti-coagulant (AC) treated samples were added onto skin and then overlayed with filter paper after 20-25 minutes. After drying, the filter paper was removed and examined under visible light (VL) or ultraviolet light (UV). The position of the fluorescent serum borders is indicated by the arrow. The small fluorescent specks observed in both groups results from minor skin transfer from the immature mice cadavers used in these studies.*

serum edges/halos were readily apparent in control transfer groups but were absent in samples in which coagulation was impaired (Figure 5). Taken together, these results effectively demonstrate that formation of serum halos is precluded under conditions that have been described for post-mortem blood issued from (washed) wounds.

4. Discussion

This current study has examined the washing hypothesis for the transfer of bloodstains onto the Shroud of Turin. According to this idea, the body was washed, followed by the oozing of post-mortem blood from wounds that was absorbed onto the cloth. As noted first-hand by Zugibe, blood issued from wounds under these conditions dries but rarely coagulates, observations which are supported by previous studies in-

volving post-mortem blood [8-10]. As one of the key features of many bloodstains on the Shroud is the presence of serum borders/halos indicative of clotted blood having transferred to the cloth, the suggestion of washing seems to be incompatible with these observations [2, 6]. Indeed, the current report has verified that decreased coagulation precludes the formation of serum halos. Additionally, this study shows that in blood with similar characteristics as post-mortem effusions (non-coagulability, low pH), serum borders were absent. Thus, it is unlikely that the sequence of body washing, oozing of post-mortem blood, and transfer to the cloth is correct.

In the absence of washing of the body, blood transfer to the Shroud could have occurred via adsorption of semi-liquid, gelatinous clots on the body while the blood was relatively fresh, or alternatively by transfer of dried blood that was remoistened within in a cave tomb environment [7, 11, 16]. Transfer of dried blood from the body to the cloth via radiation pressure has also been proposed, although no current scientific data exists to explain how transfer mechanisms that mimic liquid-based absorption might proceed [17]. Clearly, in any proposed scenario, multiple unknown variables that could have affected blood transfer from the body might exist, including sweat, dirt, extent of bleeding, etc. Importantly, previous studies have provided evidence that blood transfer to the Shroud involved movement of clotting/clotted blood to the cloth and was most likely not the result of simple addition [5]. Alternative mechanisms involving added blood have been presented that mimic the formation of fluorescent serum halos/edges, specifically the use of additives or mild heating [5, 12]; however, if such means were responsible, it would be expected that every single wound mark on the Shroud would be surrounded by a fluorescent border. Although Adler, a primary investigator in the original characterization of the chemical properties of the Shroud bloodstains, would state that this was the case after examining an initial series of photos [4], this is clearly an exaggeration. Indeed, while the first-hand observations of the entire Shroud by Miller and Pellicori describe fluorescent borders for many of the wounds, this is by no means absolute [2, 6], an idea which can be confirmed by viewing the entire series of ultraviolet photographs which is freely accessible at shroudphotos.com [18]. Thus, the logical conclusion is that fluorescent serum edges resulted from the transfer of clotting/clotted blood. In extension of this idea, the data in this report indicate that serum borders would be absent if the body had been washed prior to wrapping it in the cloth.

5. Conclusion

In summary, the current study has evaluated the washing hypothesis for transfer of blood onto the Shroud of Turin. These data provide evidence that formation of serum edges/halos is prohibited under conditions that are characteristic of post-mortem blood excretion from washed wounds, findings which suggest that the washing hypothesis is not consistent with what is observed on the Shroud.

Abbreviations

CTL	Control
AC	Anti-coagulant
VL	Visible Light
UV	Ultraviolet Light

Author Contributions

Kelly Kearse is the sole author. The author read and approved the final manuscript.

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Conflicts of Interest

The author declares no conflicts of interest.

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