

## Medical & Clinical Case Reports Journal

<https://urfpublishers.com/journal/case-reports>

Vol: 2 & Iss: 4

Research Article

# Beyond Imagination: Evidence of Rigor Mortis and Cadaveric Spasm on the Shroud of Turin

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**Citation:** Pappas TA. Beyond Imagination: Evidence of Rigor Mortis and Cadaveric Spasm on the Shroud of Turin. *Medi Clin Case Rep J* 2024;2(4):603-616. DOI: doi.org/10.51219/MCCRJ/Theodora-A-Pappas/158

**Received:** 19 November, 2024; **Accepted:** 16 December, 2024; **Published:** 19 December, 2024

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### ABSTRACT

This paper will examine how inconspicuous details in the body images on the Shroud of Turin indicate that a crucified man is depicted who is in a state of cadaveric spasm and rigor mortis. Moreover, the precise positioning of the body indicates that death, cadaveric spasm, and rigor mortis all occurred while the man was still nailed upright to a cross with his arms stretched outward and at an upward angle. Additionally, since the Shroud is said to be the burial cloth of Jesus of Nazareth, evidence is presented that proves that, in general, rigor mortis and cadaveric spasm are capable of being sustained for 39 hours (the approximate maximum amount of time that Jesus was dead according to the Gospels) or longer.

**Keywords:** Shroud of Turin; Jesus of Nazareth; Cadaveric spasm; Rigor mortis; Post-mortem changes; Crucifixion

### Introduction

While the body images on the Shroud have historically been hailed by many as not being made by human hands, there are some who claim that the body images and bloodstains on it are the work of a clever medieval forger. So, the question arises: aside from the extensive chemical and physics-based tests which have been performed on samples taken from the Shroud and/or the Shroud, itself—which provide compelling evidence that the Shroud is not a painting or other type of artwork—<sup>1,2</sup> is there another reliable way to falsify the claim that the Shroud's body images are the result of a forger's efforts?

Yes, there is.

Look for details that are so subtle and complex that it is unreasonable to think that even the cleverest medieval forger could have ever imagined them. The very inconspicuous details which constitute evidence of rigor mortis and cadaveric spasm in the body images on the Shroud are exactly this type of evidence.

Since there are many who think that the image formation mechanism for the body images on the Shroud is due to energy from the Resurrection of Jesus, and since the body images on the Shroud point to a man in a state of rigor mortis and cadaveric spasm, if the Man of the Shroud is Jesus, then it would be important to know whether or not scientific evidence supports rigor mortis and cadaveric spasm being visibly sustainable in a corpse up to 39 hours<sup>1</sup> post-mortem (which is approximately the maximum amount of time for Jesus' Resurrection to occur according to multiple details from the Gospels.) As such, the duration of rigor mortis and cadaveric spasm will be closely examined in this paper.

### Curated Highlights About The Shroud of Turin

Within the hallowed walls of the Cathedral of St. John the Baptist in Turin, Italy, there is a linen<sup>ii</sup> cloth that a very substantial body of credible evidence<sup>iii</sup> from science, forensics, medicine and history points to its being the authentic burial cloth

that actually once wrapped the dead body of the historical Jesus of Nazareth. Many refer to this cloth as the “Shroud of Christ” or the “Holy Shroud,” but it is more commonly referred to as the “Shroud of Turin” or, more simply, the “Shroud,” as it will be referred to hereinafter.

On this 4.36 m x 1.10 m (14'3" x 3'7") burial cloth are life-sized, full-length,<sup>iv</sup> anatomically correct frontal and dorsal body images of a naked, well-formed, well-nourished and muscular adult male human. As even a simple visual inspection of the two body images reveals, neither is flat nor positioned in precisely the same way. However, when these two images are overlayed, they exhibit a remarkable anatomical correspondence and compatibility. The location and forensic details of bloodstains<sup>v</sup> on this cloth are indicative that this cloth once wrapped an actual crucifixion victim who received a pre-crucifixion scourging.

The body images and bloodstains on the Shroud contain numerous features which, individually, are often rather unexpected, strange and puzzling. Cumulatively, this linen cloth contains answers that are discoverable alongside mysteries that are endlessly explorable.

The following is a non-exhaustive listing of just some of the many curious features that the images on the Shroud have: (1) aged bloodstains that remain reddish in color instead of turning brownish in color,<sup>vi</sup> (2) an absence of capillary flow<sup>vii,viii</sup> or cementation<sup>1,ix</sup> with the fibers in the pure<sup>x</sup> body image areas of the cloth, (3) the actual photographic negative of the Shroud (e.g. Secondo Pia’s photographic plate) reveals an image that appears more detailed and more like the natural face of a man to the naked eye compared to what is seen with the naked eye when viewing the image on the cloth, itself (or a traditional positive photograph of the cloth, itself),<sup>xi,xii,xiii</sup> (4) the body image on the cloth is extremely superficial<sup>1</sup> and is contained within the top 1-3 fibers of thread in the cloth<sup>22,23</sup> with a thread being composed of approximately 100-200<sup>22</sup> linen fibers,<sup>xiv</sup> (5) the straw-yellow color of the body image is strikingly uniform<sup>14,21</sup> in color (as confirmed by a densitometric study of photographic images of the Shroud) with less than 2%<sup>14</sup> variation in the absorbance of the individual colored body image fibers,<sup>xv</sup> (6) the image contains no brushstrokes<sup>21</sup>, has no sense of directionality,<sup>xvi,xvii</sup> and is neither a finger-painting<sup>21</sup> nor a powder-rubbing<sup>21</sup>, (7) the body image on the Shroud is encoded with three-dimensional information<sup>24,25</sup> (regarding actual depth or remoteness<sup>xviii</sup>) which (unlike an albedo image such as a photograph) is capable of producing a three-dimensional effect of an overall undistorted anatomical human form on the screen of a VP-8 Image Analyzer,<sup>xix,xx</sup> (8) evidence that the very superficial body image in the facial image on frontal body image exhibits “double superficiality” in that it can be (quite strangely) detected (albeit to a lesser extent) on the opposite side of the cloth<sup>22</sup>, (9) no “snow-fencing”<sup>xxi</sup> of pigment (as exists with powder-rubbings/finger-paintings), (10) no fluorescence of the body image under ultraviolet light (as would be the case if the body image were a scorch mark<sup>1,26,27</sup>), (11) the body image is not visually perceptible with any real sense of clarity unless one observes it from a distance of at least about 1 meter<sup>28</sup> (3.28 feet), yet it fades from visibility at a distance of approximately 30 feet (9.14 meters)<sup>16</sup>, (12) no outlines forming the body images<sup>14, xxii</sup> (13) chemical tests evidence that the Shroud was *first*<sup>xxiii</sup> stained with blood (through a contact process) *before* the body image was formed through a process that does not require contact<sup>1,xxiv,xxv,xxvi</sup> (14) dumbbell-shaped markings (which

appear like wounds from a scourge with leaden balls attached to it) are scattered over both body images and exhibit finely detailed scratch marks which are visible under ultraviolet light but which are *invisible* in visible light<sup>1</sup>, and (15) pale white fluorescences in the margins of these dumbbell-shaped marks are visible under ultraviolet light but *invisible* in visible light, and these white fluorescences are similar to the white fluorescences around the margins of the much heavier bloodstains which evidence points to their being serum halos<sup>xxvii</sup> derived from transfers of blood clots<sup>16</sup>.

## Historical Details For Context To Forensic Findings

**A. Crucifixion in Ancient Rome :** The historical evidence for when the Romans began to use crucifixion<sup>xxviii</sup> as a method of execution appears to be during the time of the Second Punic War (218-201 BC)<sup>32</sup>. This extreme form of capital punishment was considered to be the “most pitiable of deaths,”<sup>33</sup> because it was “cruel and terrifying”<sup>34</sup> due to the agony of death being slow and drawn out<sup>32,35</sup>. The Romans used this extreme form of capital punishment extensively<sup>32</sup>, and the class of people who were typically the recipients of it were slaves, Christians, and non-Roman citizens,<sup>xxix</sup> however, sometimes freedmen, freed women, and Roman citizens and/or Roman soldiers (usually for treason) could be subjected to the extreme penalty of crucifixion, as well<sup>32</sup>. In the 4th century, Constantine the Great—the first Christian emperor of Rome—abolished the practice of crucifixion within the Roman Empire.

**B. Pre-crucifixion scourgings:** Pre-crucifixion beatings in general were commonly performed in ancient Rome<sup>35-37</sup>. Among the various weapons that could be (and often were) used for pre-crucifixion beatings was the dreaded scourge<sup>5,6,8,33,38,39</sup>.<sup>xxx</sup> The 3rd century historian Eusebius recorded the following description of the degree of damage that can be done to a body receiving a scourging:

For they say that the bystanders were struck with amazement when they saw them lacerated with scourges even to the innermost veins and arteries, so that the hidden inward parts of the body, both their bowels and their members, were exposed to view<sup>40</sup>.

Additionally, the Roman-Jewish historian Josephus wrote that a man was “scourged until bones were laid bare<sup>33</sup>.<sup>33</sup>” However, pre-crucifixion scourgings (as opposed to a scourging being meted out as a stand-alone punishment)<sup>xxxii</sup> required the scourger to attempt to navigate a delicate balance between (1) inflicting enough pain to weaken the condemned so that he cannot engage in much, if any, resistance when being affixed to the cross, and (2) the avoidance of beating the condemned so severely that one of the main goals of crucifixion—protracted<sup>32,35</sup> torture before the relief of death—is undermined.

**C. Scourges with Lead-tipped Balls:** The pagan historian Zosimus (AD 460-AD 520) chronicled important events within the Roman Empire from the reign of Augustus (beginning in 27 BC) to the reign of Diocletian (ending in AD 305) in his work “New History.” In one such important event, Zosimus referred to a man’s being ordered to be “beaten on the neck with leaden balls until he expired<sup>41</sup>.<sup>41</sup>” Such leaden balls were likely attached to a scourge much in the same manner that the Romans had been attaching astragalus bones to the tips of scourges since 300 BC. Moreover, within the Theodosian Code,<sup>xxxii</sup> there are references to the beating and torturing of people with lead balls (plumbatarum)<sup>42</sup>.

When Christians were still being persecuted prior to Constantine's issuance of the Edict of Milan in AD 313, the poet Aurelius Prudentius wrote a poem, circa AD 392, about Roman and Spanish Christian martyrs, and in the tenth poem, he wrote: "Let his back be beaten with many strokes and his shoulders swell up with the blows of the leaden lash<sup>43</sup>."

**D. Nails Used in Crucifixions:** The Romans were notorious for using nails to affix the condemned to the cross<sup>32,33, xxxiii, xxxiv</sup>, and, sometimes, they were known to even amuse themselves by crucifying the condemned in unconventional ways<sup>45</sup>. In having both observed suspension experiments and personally undergone one, Dr. Bucklin of the STURP team learned the vast importance of the feet of the condemned being secured to the cross in that suspension from just the wrists leads to death within a very short time<sup>46</sup>. Since the whole point of crucifixion is for it to be a long, drawn-out punishment, there would need to be some sort of support for the feet—most likely nailing—so that the torture does not end too quickly. Evidence of the feet being nailed during crucifixion to provide support to the body is seen with the excavated heel bone of a 1st century man named Yehohanan which was found in an ossuary in an area known as Giv'at ha-Mivtar which is northeast of Jerusalem. The heel bone contained an 11.5 cm (4.5") nail with traces of wood at both ends<sup>47,48</sup>.

**E. Crurifragium:** In general, within the Roman Empire, Jews were given relatively broad liberties to govern themselves with their own laws and customs, as acknowledged by the first century Jewish historian and military leader Josephus<sup>33,49,50</sup>. A very pertinent Jewish law that is relevant to crucifixions is Deuteronomy 21:22-23 which required that those who have been condemned for a capital offense and are crucified must not remain suspended overnight and must be buried the same day so as to not desecrate the land<sup>51</sup>. But, because crucifixion was designed to be a long, drawn-out punishment, crucifixion victims could often survive on the cross beyond one day. As such, in order to accommodate this Jewish law, Romans had a "custom"<sup>xxxv</sup> of employing the practice of crurifragium (striking a blow to the legs of a crucified person so as to break and/or shatter them) so as to hasten death.<sup>xxxvi</sup>

While Quintilian wrote that the executioners would not forbid burial to crucifixion victims if they had been pierced or struck<sup>32,53, xxxvii</sup> this does not appear to be a firm rule as there were times when a body might not be permitted to be released for burial, such as in some (or perhaps even all) cases of high treason<sup>32</sup>. Nonetheless, crucifixion victims were commonly left to rot<sup>32</sup> on crosses and then unceremoniously dumped into a burial pit<sup>32</sup> with other crucifixion victims.

#### **F. Jesus of Nazareth: Supernatural powers, Crowned, Scourged, Nailed, Crucified, No Crurifragium, Lanced and Buried in a Shroud:**

**Supernatural powers:** First century Jewish historian Flavius Josephus wrote the following about Jesus in his monumental 1st century work, "Antiquities of the Jews."

There was, in those times, Jesus, a wise man, if really it is right to call him a man. He was the doer of miraculous<sup>xxxviii</sup> works and the teacher of men who gladly hear things that are true. He joined to him many of the Jews and many of the Gentiles. He was the Christ. When Pilate, upon an accusation of the most important men of our race, decreed him to be led

to the cross, those who had loved him from the beginning did not desert him. He appeared to them on the third day, alive again, according to what the divinely inspired prophets had predicted that both these and innumerable other wonders about him would occur. But even until today, both the name and descendants of the Christians, who were called from him, have persevered<sup>49</sup>.

Matthew 12:22-24 reports how the Pharisees believed that Jesus had supernatural powers but demonically derived:

Then they brought to him a demon-possessed man who was blind and mute. Jesus healed him so that he could speak and see. All the crowds were amazed and said, Could this one be the Son of David? But when the Pharisees heard this they said, 'He does not cast out demons except by the power of Beelzebul, the ruler of demons!'

Additionally, in the Babylonian Talmud, Jesus is said by the Jews to have practiced sorcery and enticed Israel to apostasy<sup>54</sup>.

**Crowned:** John 19:2-3 reports how the soldiers mocked Jesus as the "King of the Jews" by putting a crown of thorns on His head and putting Him in a purple robe to signify royalty as they then mocked him, over and over again, saying, as they repeatedly struck Him in the face: "Hail, King of the Jews!"

**Scourged:** John 19:1 reports that Pilate took Jesus and had Him scourged. Additional reports of this are in Mark 15:15 and Matthew 27:26. Jesus' pre-crucifixion scourging was, quite likely, far more severe than the two criminals that were crucified with Him, since Jesus died after only about 6 hours on the cross, whereas the other two were still alive and required crurifragium to hasten their death per John 19:31-34.

**Nailed:** John 20:25 reports that Thomas the Apostle tells Jesus' other disciples that "[u]nless I see in His hands the imprint of the nails and put my finger into the place of the nails and put my hand into His side, I will not believe." Jesus then told Thomas per John 20:27-28, "Place your finger here and see My hands; and take your hand and put it into My side; and do not continue in disbelief, but be a believer. Thomas answered and said to Him, "My Lord and my God!"

**Crucified:** In the 1st century, Josephus, a Jew, wrote about how the Jews brought accusations against Jesus to Pilate, and that Pilate had Jesus crucified<sup>49</sup>. Additionally, Tacitus, one of the most renowned Roman historians, wrote in "The Annals" (circa AD 116) that Jesus suffered the "extreme penalty" at the hands of Pontius Pilate during the reign of Tiberius (AD 14 - AD 37)<sup>55</sup>.

**No crurifragium, lanced:** Joseph of Arimathea, a member of the Sanhedrin<sup>xxxix</sup> and a secret disciple of Jesus, asked for, and received, permission from Pontius Pilate to claim the body of Jesus for burial<sup>5-8</sup>. However, in order for Jesus' body to be put into private custody for a burial (so as to avoid the typically unceremonious public disposal that crucified bodies received), the condemned's body needed to first be struck (crurifragium)<sup>32</sup> or pierced<sup>53</sup>.

John 19:31-34 reports the following:

Now it was the day of Preparation and the next day was to be a special Sabbath. Because the Jewish leaders did not want the bodies left on the crosses during the Sabbath, they asked Pilate to have the legs broken and the bodies taken down. The soldiers therefore came and broke the legs of the first

man who had been crucified with Jesus and then those of the other. But when they came to Jesus and found that he was already dead, they did not break his legs. Instead, one of the soldiers pierced Jesus' side with a spear, bringing a sudden flow of blood and water<sup>8</sup>.

**Buried in a shroud:** Mark 15:46, Matthew 27:59-61, and Luke 23:53-56 report that Jesus was buried in a linen cloth ("sindon") which is a "shroud," since a "shroud" can be a cloth used to wrap a corpse for burial.

In John 19:40, a different word is used for what Jesus was buried in: "othoniois." Some translations define this word as "linen strips" which can cause confusion—as if Jesus might have been wrapped in linen strips like a mummy. However, the New English Translation "NET" Bible (which is widely acclaimed as having probably the most exhaustive translator notes of any version of the Bible and is a favorite among scholars) has a very important translator note (number 117)<sup>56</sup> concerning the word "othoniois" in John 19:40 which is as follows:

The Fourth Gospel uses ὥθονίοις (othoniois) to describe the wrappings and this has caused a good deal of debate, since it appears to contradict the synoptic accounts which mention a στινδών (sindōn), a large single piece of linen cloth. If one understands ὥθονίοις to refer to smaller strips of cloth, like bandages, there would be a difference, but diminutive forms have often lost their diminutive force in Koine Greek (BDF §111.3), so there may not be any difference. Also, Luke uses both terms to refer to the wrappings, which suggests they are interchangeable in some contexts at least (Luke 23:53; 24:12.)

## Two Types of Death

There are two types of death that a body undergoes: "clinical death" and "cellular death." With clinical death, the brain, heart and lungs irreversibly cease to function.<sup>51</sup> As such, the oxygen supply—the primary and preferred energy source for all cells—comes to an end. However, at this point in time, the cells in the body are not dead, and, in fact, many cells will remain alive after death anywhere from several hours to even several days. Once all of the cells in a cadaver have died, then molecular death has occurred.

## Post-Mortem Changes To Muscles

Rigor mortis and cadaveric spasms are best understood within the overall context of the several types of post-mortem muscular changes that develop in a corpse which are set forth, below:

**Primary muscular flaccidity:** Initially, there is an automatic and total relaxation of the muscles that occurs immediately after death which is known as "primary muscular flaccidity"<sup>57</sup>." With primary muscular flaccidity, its duration typically ranges from 1-3 hours post-mortem<sup>57</sup>, and during this time, the muscles remain soft and the joints are capable of being flexed<sup>58</sup>. During this period of primary muscular flaccidity, the state of relaxation in the corpse's muscles is due to the presence of energy known as adenosine triphosphate ("ATP") which continues to be generated in the corpse for a finite length of time via anaerobic glycolysis. Once the corpse becomes unable to resynthesizes ATP, the level of ATP in the body will progressively diminish until it is depleted.

**Rigor mortis:** As all of the muscles, both voluntary and involuntary, progressively lose their ability to remain relaxed by way of receiving energy from ATP, they, correspondingly, contract in a systematic way so as to progressively induce stiffening throughout the body by way of the process known as "rigor mortis"<sup>59,60</sup>.

**Pattern of rigor mortis:** Rigor mortis' pattern of onset, known as the "March of Rigor," proceeds to the following body parts, from first-to-last, in the following order: the involuntary heart muscles, the eyelid muscles, the muscles of the lower jaw, the neck, the upper limbs, the muscles in the trunk, the lower limbs, and, lastly, the muscles in the fingers and toes<sup>57,61,62</sup>. Rigor mortis progressively fades away from the body in the same order that it appears; as such, the muscles which first develop rigor mortis will typically be the first to lose it<sup>61</sup>.

**Timeline for rigor mortis:** As the post-mortem period of primary muscular flaccidity comes to an end, the classic "Rule of 12" holds that rigor mortis progresses with the following timeline: 12 hours to progressively set in, 12 hours of remaining constant at its peak, and 12 hours to progressively subside. Therefore, according to the Rule of 12, from around 24-27 hours post-mortem (which includes an estimated 1-3 hours for the typical period of primary muscular flaccidity), the effects of rigor mortis would start waning and be gone by around 37-39 hours post-mortem.

With the window for Jesus' third-day Resurrection ranging from around 28-39 hours post-mortem, *supra*, does this mean that a later resurrection time would preclude any evidence on the Shroud of rigor mortis? Let's see.

The classic Rule of 12's timeline—which can still be found being repeated in more modern texts<sup>63</sup>—is, however, in significant conflict with other reports for timelines regarding how long rigor mortis can be sustained. For example, it is reported that under typical circumstances, rigor mortis *begins* to fade away after approximately 36 hours of being in effect<sup>57</sup>—as opposed to being gone by 36 hours per the Rule of 12.

Additional sources have the *onset* of rigor mortis spanning from 2-6 hours post-mortem<sup>64</sup>, the persistence of rigor mortis spanning from 24-84 hours, and the gradual relaxation of the muscles occurring after the 24-84-hour time period<sup>64-67</sup>.

Yet, other sources state that rigor mortis will not typically *begin* to disappear until the even more expanded time period of around 36-48 hours<sup>57,61</sup> post-mortem, and that there still might even be some rigidity that persists in the lower limbs for up to 3-5 days (72-120 hours)<sup>57,61</sup>.

Lastly, a meta-analysis was performed by H.J. Mallach regarding the timing of rigor mortis' development in corpses by calculating the mean and standard deviation of data concerning rigor mortis from 108 publications spanning from 1811-1960<sup>68</sup>. He found that the mean for total rigidity was 8 hours (with a standard deviation of 1 hour with the lower limit at 6 hours and the upper limit at 10 hours post-mortem)<sup>69</sup>. Regarding the persistence of rigor mortis, Mallach found the mean to be 57 hours (with a standard deviation of 14 hours with a lower limit at 29 hours and an upper limit being at 85 hours post-mortem)<sup>69</sup>. Regarding the resolution of rigor mortis, he found the mean to be 76 hours (with a standard deviation of 32 hours with a lower limit at 12 hours and an upper limit at 140 hours [5.8 days] post-mortem)<sup>69</sup>. See, also,<sup>70,71</sup>.

**Factors affecting onset and duration:** The timing for the onset and duration of rigor mortis can vary from one cadaver to the next due to differing internal and/or external factors<sup>61</sup> such as the ones set forth below:

**Early onset:** Death between the ages of 18-50<sup>61</sup>; fatigued muscles<sup>61</sup> at or near the time of death (which can potentially induce almost immediate rigor mortis)<sup>10</sup>; a violent death<sup>10,61</sup>; dying in an open environment<sup>57</sup>; muscle convulsions shortly before death<sup>57,61</sup>; death in a warm and humid environment<sup>61</sup>; and high metabolic status (caused by things such as fever, exercise, or heat) which can also potentially result in the atypical development of rigor mortis<sup>61,66</sup>.

**Delayed onset:** Sudden death to a healthy body<sup>61</sup>; a cold<sup>xli</sup> ambient temperature<sup>61</sup>; death by hanging<sup>61</sup>; severe hemorrhage immediately prior to death<sup>61</sup>; and death from asphyxia<sup>61</sup>.

**Shorter duration:** Intense muscle spasms/convulsions just prior to death; death occurring in a warm and humid environment; and a violent death<sup>61</sup>.

**Longer duration:** Death between the ages of 18-50; a healthy and muscular body just prior to death<sup>61</sup>; less clothing on a body; and a cold ambient temperature<sup>61</sup>.

Additional influences on the onset, degree and duration of rigor mortis are as follows: the degree to which the body was nourished (and hydrated) just prior to death<sup>61,73</sup>, the degree of acidity in the muscle tissue just prior to death<sup>74</sup>, and whether or not the corpse was moved prior to the onset of rigor mortis<sup>74</sup>.

When assessing rigor mortis' time of onset and/or duration, there might be factors that compete with each other. It cannot be assumed that each factor carries the same weight when attempting to assess which factor/s might be determinative<sup>61</sup>.<sup>xliii</sup> For example, if there are two factors which are in the category of triggering the early onset of rigor mortis, but there are three factors that are in the category for causing a delay in the onset of rigor mortis, it should not be assumed that rigor mortis was delayed. Why? Because some factors (either alone or in conjunction with other particular factors) might have a greater propensity than other factors for either inducing or delaying the onset and/or duration of rigor mortis. Moreover, one or more weaker factors that are present to a higher degree might dominate over a stronger factor that is present to a lesser degree. For these and other reasons, rigor mortis is considered to be the least reliable of the post-mortem changes for estimating a cadaver's time of death.

**Reversibility of rigor mortis:** In the early stages of rigor mortis—typically 6-8 hours post-mortem<sup>75</sup>—stiffness can be reversible due to there still being muscle fibers which have yet to contract; however, while breaking this rigidity in muscle fibers during this period of time can be accomplished by, for example, bending a joint, doing so will then induce rigidity in not yet stiffened muscle fibers located either above or below the area where rigor was broken<sup>75</sup>. Once maximum rigidity is reached, the corpse will become practically rock-hard, and the rigidity will be fixed<sup>10</sup> until it progressively diminishes and then disappears. During this decline in rigidity, the muscles undergo a new and different form of post-mortem relaxation known as “secondary muscular flaccidity”<sup>57</sup>.

**Secondary muscular flaccidity:** Secondary muscular flaccidity causes the stiff muscles of rigor mortis to progressively relax; however, it is completely unconnected to ATP which had initially

enabled the muscles to remain relaxed during the period of primary muscular flaccidity and which is now already completely depleted from the corpse. Instead, the relaxation of the muscles during secondary muscular flaccidity is due to the action of proteolytic enzymes, as well as the body's overall process of cellular breakdown<sup>60,64,65</sup>, which corresponds to the changes occurring to the cadaver due to the process of putrefaction<sup>59</sup>.

### Is the repositioning of a corpse detectable?

Prior to rigor mortis, there is, as aforementioned, the period of primary muscular flaccidity. During this typically 1-3 hour time period when the corpse's muscles are relaxed, the body can easily be repositioned. However, there still might be a way to detect if a corpse has been repositioned at this point in time through the tell-tale signs of livor mortis (a.k.a. “hypostasis.”)<sup>xliv</sup> Although the timing for livor mortis can vary rather substantially from corpse-to-corpse, its signs can begin to develop as discolored spots on the skin as early as 30 minutes to 1 hour post-mortem<sup>63</sup>, and, over time, these skin discolorations become larger and turn into purplish-blue patches<sup>59</sup>. However, prior to livor mortis' reaching its maximum effect, it is said to be in an “unfixed” state, because the blood has not yet coagulated; as such, this means that the aforementioned discoloration can shift during this earlier post-mortem time period if the body is moved<sup>76</sup>. But, once maximum lividity is reached, it becomes “fixed” so that if the corpse is moved and/or repositioned, the discoloration in the skin will not shift, but, instead, it will remain where it is.

Livor mortis can become fixed as early as 4 hours<sup>64</sup> post-mortem to as late as 15 hours<sup>61</sup> post-mortem. Moreover, once livor mortis is fixed, it will not disappear, but, instead, it will then just blend into the rest of the body's discoloration from the decomposition process. If a corpse is found where it is positioned in a way that the discoloration of the skin from livor mortis is not positioned at the lowest points of the body, this indicates that the body has been moved/repositioned post-mortem.

If a corpse is found in rigor mortis, its position is an indication of either how it was positioned at the time of the onset of rigor mortis (which might, or might not, be different from the position of the body at the time of death, because the body might have been repositioned during the period of primary muscular flaccidity), or the body might have been repositioned by external forces during rigor mortis. A tell-tale sign that a corpse has been repositioned is if it is still in substantial rigor mortis, but the body is positioned in a way that defies gravity<sup>xlv</sup> without some means of support<sup>73,78</sup>.

If a body is repositioned by “breaking” rigor mortis through the forcible bending of a limb at a joint<sup>10</sup> while the body is still in a state of rigor, rigidity will quickly become re-established in the new position, albeit to a lesser degree<sup>64,79</sup>.

If a corpse is repositioned after rigor mortis has passed, this means that the corpse is now in the state of secondary muscular flaccidity where the muscles will be relaxed again. The corpse can, once again, be moved without the stiffness of rigor mortis. However, repositioning/movement of the corpse might still be detectable if the skin discoloration from livor mortis is found in a location that is inconsistent with gravity, and if there is a detectable contrast between the discoloration due to livor mortis and the particular state of decomposition that the corpse is found in.

**Cadaveric Spasm:** Cadaveric spasm—often thought of as “instantaneous rigor mortis”<sup>80</sup> is a controversial post-mortem condition that is said to be extremely rare<sup>81</sup>, and it is said to typically involve a group of muscles that (1) are heavily used right before death, (2) are immediately stiffened at the moment of death<sup>82,83</sup> or immediately after death<sup>80</sup>, (3) remain stiff with the onset of rigor mortis<sup>84</sup>, and (4) remain stiff until rigor mortis is resolved<sup>85</sup>.

Although the stiffness brought on by a cadaveric spasm can appear the same as rigor mortis, it is distinguishable from rigor mortis in that it presents with stronger muscular stiffening than rigor mortis, and it is more difficult to “break” the stiffness from a cadaveric spasm than from rigor mortis<sup>86,87</sup>. Moreover, while it is possible for a cadaveric spasm to affect the entire body (“cataleptic rigor mortis”)<sup>82</sup>, it more typically involves a particular part of the body that would have been under stress at the time of death<sup>80</sup>. Additionally, the immediacy of a cadaveric spasm at the time of death means that it can preserve muscles in a stiffened, gravity-defying state that bypasses the gravity-inducing influence of primary muscular flaccidity on the position a body takes prior to its typically going into rigor mortis<sup>82,83</sup>.

Retired chief medical examiner Dr. Marcella F. Fierro has only seen three instances of cadaveric spasms in her over 30 years of practice. In all three of these cases, asphyxia was an important factor in the cause of death<sup>81</sup>.

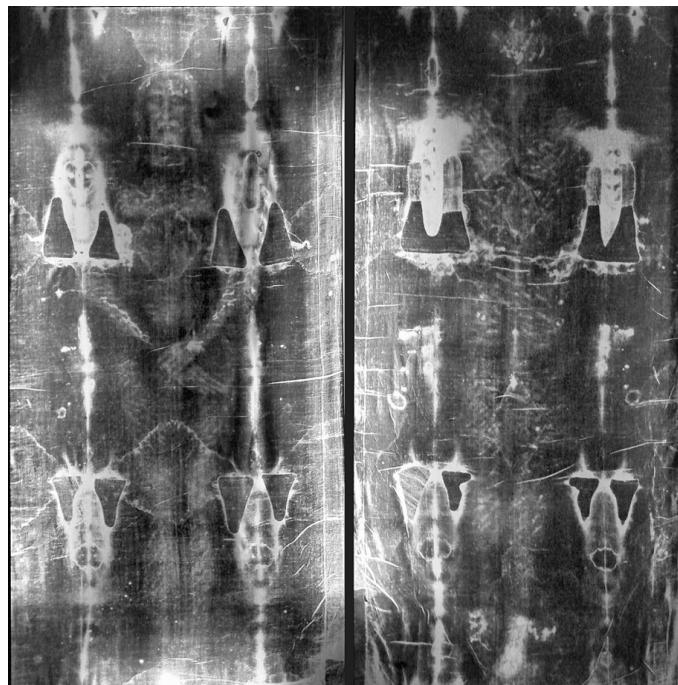
An example of a case evidencing a cadaveric spasm was with a murder victim who was found with his mouth unusually positioned the upper central teeth were visible and biting down on the lower lip<sup>83</sup>. Typically, cadavers are found with an *open* mouth due to (1) the jaw’s dropping during primary muscular flaccidity, (2) rigor mortis’ then preserving that open-mouthed position, and then (3) the mouth continues to remain open during both the period of secondary muscular flaccidity<sup>83</sup> and the corresponding decomposition of the corpse.

Another example of a case evidencing a cadaveric spasm was when a man was chasing his wife with a straight razor, and she shot him in self-defense. The husband collapsed to his knees, and he died instantly while still clutching the weapon (in defiance of gravity) that he had been holding during his attack<sup>70</sup>.

It is said that while *rigor mortis* provides information about the *amount of time* since death, a *cadaveric spasm* provides a comment on the *manner of death*<sup>80</sup>. Perhaps most importantly, a cadaveric spasm captures the body’s final action prior to death that was preceded by severe, highly stressful physical or emotional activity<sup>81,82</sup>.

### Forensic Findings Regarding Rigor Mortis, Cadaveric Spasm And Crucifixion

The findings of two renowned American forensic pathologists are presented below as they pertain to evidence of rigor mortis, cadaveric spasm, and crucifixion which they detected during their close study of the details contained within life-sized photographs of the full-sized, frontal and dorsal body images on the Shroud. Their advanced training, along with decades of experience in examining forensic and anatomical details in order to determine both the cause and manner of a cadaver’s death, gave them the precise skills that are needed to understand what the body image reveals.



**Figure 1:** Frontal and dorsal photonegative images of the Shroud of Turin taken in 1931 by professional photographer Giuseppe Enrie. As he was photographing the Shroud, Enrie was flanked by a French scientist, a priest and Secondo Pia as witnesses. This was because Pia—the first to ever photograph the Shroud in 1898—had been dogged by accusations that he had manipulated the photonegative images due to the shocking detail that emerged in the frontal facial image. As such, Enrie proactively published details regarding the lighting, lenses, filters, exposure times and camera settings that he used while taking these photographs. <https://shroud.com/pdfs/ssi18part4.pdf> With Enrie’s photonegative images matching Pia’s, Pia was exonerated.

Dr. Frederick Zugibe,<sup>xlii</sup> M.D., M.S. and PhD in Human Anatomy (1928-2013), was the chief medical examiner of Rockland County, New York from 1969-2003. During his tenure, he performed approximately 10,000 autopsies.

Dr. Robert Bucklin, M.D., J.D. (1916-2001), worked for over 50 years as a forensic pathologist, and he performed over 25,000 autopsies. During part of this time, and among just many of his accomplishments, Dr. Bucklin was the chief of the forensics division<sup>xlvii</sup> under Chief Medical Examiner-Coroner Dr. Thomas Noguchi in Los Angeles County, California during a time when this county was widely considered to be the “murder capital” of the United States.<sup>xlviii</sup> This gave Dr. Bucklin and his forensics division a vast amount of experience in performing autopsies where the detailed evidence for a corpse’s cause and manner of death would often be of pivotal importance in many murder trials. Dr. Bucklin was, also, a member of the STURP team, however, approximately 20 years prior to joining the STURP team, he had already closely scrutinized the images on the Shroud and published his medical and forensic findings regarding them<sup>46</sup>.

While studying full-sized photographs of a body image cannot be said to be the equivalent to performing an actual, full autopsy on a corpse—where the forensic pathologist can touch, manipulate and cut into the body—nevertheless, to the well trained and highly-experienced eyes of Dr. Zugibe and Dr. Bucklin, many pertinent details about cause and manner of death were still noticeable from such photographs which untrained, inexperienced eyes would never notice—much less imagine.

## A. Dr. Zugibe<sup>10</sup>

**Neck, Head and Shoulders:** With the frontal body image, there is an apparent absence of neck space, whereas, with the dorsal image, there appears to be an *elongation* of the neck. This can be explained by the head being bent forward in rigor mortis.<sup>xlix</sup>

Zugibe explains that the head on the Shroud is positioned as it is, because the violence of Jesus' death triggered a cadaveric spasm which kept the neck muscles solidly contracted post-mortem (as opposed to becoming flaccid at the moment of death due to primary muscular flaccidity), and that the positioning of the head was maintained until rigor mortis was fully developed.

The shoulders<sup>l</sup> appear to be in a raised<sup>li</sup> position, and the head appears caught in between the raised shoulders and, as aforementioned, bent forward. Moreover, the right shoulder appears somewhat lower than the left.

Zugibe performed suspension experiments with volunteers who weighed in the range of 174-204 pounds since the body image on the Shroud appears to be that of a man weighing approximately 175 pounds<sup>89</sup>. From these suspension experiments, Zugibe discovered that, when the volunteers were put in the upright position of crucifixion, their arms would fall into formation at an angle in the range of 65°-68°, and their head would get caught between their shoulders and be capable of only a limited amount of movement from side-to-side and from front-to-back.<sup>li</sup> Zugibe's suspension experiments, therefore, confirmed his explanation for the appearance of the neck and shoulders in the Shroud's two body images.

### Arms: But, what about the arms?

The Shroud contains no depiction whatsoever of outstretched arms—much less arms outstretched to a 65°-68° angle. Instead, as Zugibe points out, the hands in the body image are crossed just below the umbilicus at the hip level with the left hand over the right hand. Quite obviously, this is not the position of a person who went into rigor mortis while still crucified to a cross. Yet, to the well-trained and experienced eye, the matter is not closed. Zugibe's expertise in examining bloodstains and determining their origin enabled him to uncover the full story behind the bloodstains on the arms so as to explain the incongruence. With regard to the bloodstains on the arms, he made the following observations:

It is obvious that the blood flows on the arms occurred right after removal of the nails (which had sealed the wounds during suspension) from the hand area, causing the blood that contained fibrinolysins to flow down the back of the arms from the nail exit wound while the arms were suspended above the head still in rigor at the same angle in which they had been nailed to the crosspiece. The [blood] flow patterns are consistent with the position of the crucarius<sup>hi</sup> [sic] on the cross<sup>10</sup>.

Zugibe further explained that while the image of the arms on the Shroud exhibits the stiffness of rigor mortis, their position was altered for the purpose of entombment.<sup>liv</sup> Specifically, for them to be in the position that they are in on the Shroud, rigor mortis had to be broken<sup>lv</sup> at the shoulder joint and, also, slightly at the elbows. He referred to the Shroud Man's body conforming to the position of crucifixion during entombment with the exception of the arms—where the rigor had been broken *and maintained* (as in there was still rigor mortis in the arms after they were repositioned.)

As aforementioned, rigor mortis can be broken through the forced bending of a limb at a joint. Moreover, if rigor mortis is still in a reversible, unfixed state, rigidity can be reestablished in the new position —albeit to a lesser degree of stiffness than prior to the repositioning<sup>64,79</sup>. If, however, rigor mortis is fully developed and, therefore, fixed, it is doubtful that even with the exertion of great force that the body will be capable of being repositioned by way of stretching or flexing a joint<sup>75,78</sup>; moreover, if it were repositioned, there would be no stiffness in that area where rigor was broken<sup>78</sup>.

Since the Shroud is thought by many, including the author, to be the actual burial cloth of Jesus of Nazareth, it is relevant to note that Jesus' death was reported to be at 3:00 pm<sup>6,7</sup>. His burial took place within, at most, a couple of hours afterwards (as it was Preparation Day with sundown quickly approaching to mark the Sabbath<sup>7</sup>). As such, in Jesus' particular case, there is a strong likelihood that (1) rigor mortis was not yet fixed, that (2) the arms were still repositionable into the very stylized and very dignified burial position that is on the Shroud's body image, and that (3) after the arms were repositioned, enough stiffness returned to the arms to give them the stiff appearance that Zugibe observed.

Zugibe further noted that the repositioning of the arms by breaking rigor in the shoulder joints and elbows would not have disturbed the raised position of the shoulders with the head caught in between them.

Additionally, concerning the *amount*<sup>lvii</sup> of blood that is seen on the arms on the frontal body image, Zugibe mentions that while it might seem like a lot, that it really is not. He explains that the reason why is because there was not a beating heart when the nails were removed, and because the arms were in a suspended position. He further noted that, even prior to death, that the nail wounds would not have caused bleeding down the arm, because (1) the large nails would have sealed the wounds, (2) the arms were in an elevated position, and (3) the blood pressure would have been very low.<sup>lvii</sup>

**Chest:** Zugibe noted that the chest appears raised in a way that is consistent with a cadaver's experiencing rigor mortis while still suspended from a cross.

**Legs and Feet:** Zugibe observed the right calf is denser than the left calf, and there is only a partial imprint of the left heel which suggests that there is "either a very slight bend at the left knee with the foot flexed slightly forward, or a turning inward of the left foot over the right[.]". Moreover, with the foot area showing an image of the right sole and heel, this is further evidence that the knees in the body image are bent. Zugibe's suspension experiments confirmed what his predecessor Dr. Pierre Barbet<sup>lviii</sup> maintained: that when a crucifixion victim is nailed to a cross with the soles of the feet nailed flat to the vertical beam of the cross, this will cause the knees to bend forward to an angle of about 120° +/- 2°.

Zugibe also pointed out that the calves exhibit a natural roundness in their appearance which is in contrast, and in conflict, with the expected flattened appearance that a cadaver should exhibit if reclining flat with *unbent* knees. As such, this is further evidence of bent knees being kept bent by the effect of rigor mortis as opposed to the flattening that occurs with primary or secondary muscular flaccidity.

Regarding the bent position of the legs, Zugibe thought that the legs, also, experienced a cadaveric spasm so as to maintain this bent position until rigor mortis occurred (thereby avoiding the flattening of primary muscular flaccidity.) However, while the author thinks that it is quite possible that the legs experienced cadaveric spasm, she does not see this as definitive. Why? Because the position of the soles of the feet being pressed flatly against the vertical beam of the cross (*stipes*) should mechanically hold the knees in place in a bent position regardless as to whether the muscles became flaccid, or not, through primary muscular flaccidity at the moment of death.

The left foot is slightly shorter than the right, and the image of the tip of the right foot has an unusual position which could be considered evidence that one nail was used to secure both feet to the cross.

This positioning of the leg and foot is evidence that a man's body was in rigor mortis at the time that he was placed in the Shroud. Corroborating this is the asymmetry of the legs in the body image, because if rigor mortis had not been in effect at the time of image formation, the legs in the body image would be symmetrical due to primary muscular flaccidity.

**Buttocks:** Zugibe noted that the right side of the buttocks is lower than the left side which causes the buttocks to appear asymmetrical. This asymmetry with the buttocks corresponds with Zugibe's observation of asymmetry with the position of the legs.

#### B. Dr. Bucklin<sup>89</sup>

**Overall Appearance:** Bucklin reported that the body image has an overall appearance of stiffness.

**Legs and Feet:** With regard to the lower extremities, Bucklin noted that "specific alterations in the appearance of the lower extremities from the posterior aspect" are evidence of rigor mortis. The following are further details with regard to this:

The imprint of the right calf is much more distinct than that of the left indicating that at the time of death the left leg was rotated in such a way that the sole of the left foot rested on the ventral surface of the right foot with resultant slight flexion [bending] of the left knee. That position was maintained after rigor mortis had developed . . . [T]here is a reasonably clear outline of the right foot made by the sole of that foot having been covered with blood and leaving an imprint which reflects the heel as well as the toes. The left foot imprint is less clear and it is also noticeable the left calf imprint is unclear. This supports the opinion that the left leg had been rotated and crossed over the right instep in such a way that an incomplete foot print was formed.

Moreover, the following is evidence that the Man of the Shroud was crucified, and that his feet were overlapped so that one nail could be used to affix them both to a cross:

In the center of the right foot imprint, a definite punctate defect can be noted. This puncture is consistent with an object having penetrated the structures of the feet and from the position of the feet the conclusion would be reasonable that the same object penetrated both feet after the left foot had been placed over the right.

**Arms:** Regarding evidence that the body was in the position of crucifixion, Bucklin noticed that the flow of the bloodstains on

the wrist and the two arms on the frontal image of the Shroud could not have happened while the arms and wrist were in the position that they are depicted in on the Shroud, because they would have flowed counter to the laws of gravity. In having reconstructed the position that the arms would have needed to have been in so as to create blood flows on the wrist and arms like with what is seen on the Shroud, Dr. Bucklin discovered that the arms would have needed to have been outstretched upward in a 65° degree angle with the horizontal.

**Position of the Body at Death:** Regarding the position that the Man of the Shroud was in when he died, Bucklin reported:

The position of the puncture<sup>lix</sup> defects in the wrist, coupled with the blood flow towards the elbows and also associated with the punctures of the feet, permit the pathologist to conclude that the victim was in an upright position with his arms extended when the blood flow took place. A crucifixion type posture would be the most plausible explanation for these findings.

**Chest:** The nature of the bloodstain from the chest area is indicative of a dead body which corroborates the separate findings of rigor mortis. Specifically, with the bloodstain from the chest, Bucklin stated the following:

There is distinct evidence of a gravitational effect on this stain with the blood flowing downward and *without spatter or other evidence of the projectile activity which would be expected from blood issuing from a functional arterial source*. This wound has all of the characteristics of a postmortem type flow of blood from a body cavity or from an organ such as the heart. [Emphasis added.]

Bucklin also found additional evidence of death in the upper plane of the bloodstain from the chest where he detects "an ovoid skin defect which is characteristic of a penetrating track produced by a sharp puncturing instrument."

Regarding the chest, Bucklin further noted that the appearance of "an increase in the anteroposterior diameter of the chest due to bilateral expansion."

It is the author's note that this increase in the anteroposterior diameter of the chest due to bilateral expansion that Bucklin described is *precisely what occurs when one breathes in or inhales*. More specifically, the following occurs when a breath is drawn in:

During inspiration, the anteroposterior diameter of the thorax is increased when the ribs are raised. Because ribs slope downward, any elevation during inspiration results in an upward movement of the sternum at the manubriosternal joint and an increase in the anteroposterior diameter of the thorax<sup>90</sup>.

Although Bucklin does not make this comment, the author observes that Bucklin's report concerning the appearance of the chest in the body image is evidence of a cadaveric spasm in the chest that indicates to us that, at the moment of death, the Man of the Shroud was inhaling taking in the "Breath of Life." This indication on the Shroud's body image has important Christian theological implications in that this particular cadaveric spasm could be said to foreshadow Jesus' resurrection where Life was exhaled from Death.

While inhaling requires the use of muscles, exhaling is often a passive process unless, for example, someone is exercising. But,

with the primary muscular flaccidity that occurs immediately after death, the chest muscles would relax which would cause the passive process of exhalation<sup>91</sup>. However, a cadaveric spasm at the moment of last inhalation at the time of death would fix the muscles that were used to effectuate the bilateral expansion (until the onset of secondary muscular flaccidity or, as in Jesus' case as Christians believe, Jesus' resurrection.)

### Piczek Experimentally Confirms Bent Knees

The internationally acclaimed artist Dame Isabel Piczek noticed that the knees in the frontal and dorsal depictions of the body images on the Shroud are bent. She then sought to objectively prove her subjective observation through an elegantly simple experiment: Piczek had a live artist's model lay in the supine position with his body positioned in the same way as the body is positioned in the frontal body image on the Shroud. Then, she directed the model to take two different poses while in this supine position so as to determine if the frontal body image on the Shroud can appear as it does if a real man's knees are unbent.

The first pose had the model reclining with his back and legs completely flat, while the second pose had him reclining flat on his back *but with his knees bent*. In observing these two positions, Piczek was able to confirm that the knees in the frontal body image would have had to have been bent if the body image on the Shroud had somehow been imprinted from an actual body. Why? Because the manner in which the arms and hands are positioned on the Shroud cover the man's genitals, and when the model was lying flat in the supine position with unbent knees, his genitals were exposed due to the arms not being long enough in this position to cover his genitals. *However*, Piczek noticed that when the model was in this same position *but with his knees bent*, his arms were long enough so that his crossed hands could cover his genitals—just like what is seen with the frontal body image on the Shroud<sup>92</sup>.

### Conclusion

The forensic findings of two preeminent forensic medical examiners indicate that both the bloodstains on the Shroud and its frontal and dorsal body images are indicative of a crucifixion victim that died, went into a cadaveric spasm, and then rigor mortis while (1) still nailed to a cross (2) in the upright position with (3) arms in an upwardly outstretched position, and (4) where one nail attached both feet to the cross. They noticed further details in the frontal image that point to the arms having been repositioned into a very stylized burial position after the body had been deposited from the cross while still in a state of cadaveric spasm and rigor mortis.

Additionally, an internationally acclaimed artist performed an experiment with a live model which demonstrated that the knees on the body images are bent (which is a piece of evidence that supports the claim that both body images depict a man in a state of rigor mortis.) This corroborated the separate findings by the two medical examiners that the knees in the body images are bent.

Regarding whether or not rigor mortis and cadaveric spasm could have been sustained to around the maximum time period (39 hours) that the Gospels indicate that Jesus was resurrected, the answer has been conclusively shown to be "yes." The classic "Rule of 12" has been shown to be an unreliable measure for the onset and duration of rigor mortis. Instead, the pertinent factors

relevant to rigor mortis' onset and duration in a corpse should be examined on a case-by-case basis.

With many deaths, but in particular with Jesus' death, there are numerous competing factors that can impact the onset and duration of rigor mortis. Since it is highly unlikely that there is a 1:1 correspondence in the weight of each of these particular factors, and since there are most likely unknown factors that could have impacted the timing of onset and the duration of rigor mortis in Jesus' body, one cannot merely tally up the number of factors for early versus delayed onset and duration of rigor mortis, and then see which side has the greatest number of factors, and then expect to have arrived at a reliable determination.

Instead, having an awareness of the type and quantity of these factors is useful insofar as telling us what the reasonable possibilities are and giving us an educated guess as to probabilities, but it does not extend beyond that. However, what is important is that from what we know about Jesus, His death, and the events which preceded it earlier that day, is that there were factors which could have triggered a cadaveric spasm which was followed by the early onset of rigor mortis which persisted in Jesus' body 39 hours post-mortem. As such, there is no conflict between evidence of rigor mortis and cadaveric spasm being indicated on the frontal and dorsal body images on the Shroud, and that Jesus' body created those body images.

While extraneous to the issue of rigor mortis and cadaveric spasm, but relevant to the issue of the identity of the Man of the Shroud, the bloodstains on the head are consistent with a crown of thorns<sup>10,89</sup>. Since History knows of only one person—a crucifixion victim—who had a crown of thorns placed on his head, and since both secular and non-secular sources tell us that this crowned crucifixion victim was Jesus of Nazareth, this is compelling evidence as to whose dead, crucified and bloodstained body the Shroud once wrapped.

What is most compelling about the details pointing to rigor mortis and cadaveric spasm on the frontal and dorsal body images on the Shroud is how inconspicuous they are to undoubtedly all except those with both a very trained eye and a very trained mind with regard to the various changes that a body undergoes in relationship to its surroundings during the post-mortem process. With regard to whether a forger put in these details to make the body images on the Shroud convincing to the public, one must not just ask such a question, but one must *critically think through it*.

The eyes cannot see what the mind does not know. As such, a medieval forger cannot create that which he cannot conceive. The details with regard to the head, neck, shoulders, arms, legs, bent knees, calves and feet are so subtle that it would strain credulity to think that any forger (much less a medieval one) could have even imagined such details. Moreover, there is the question of WHY would a forger include details so subtle that they would be meaningless to the public? How does the public become convinced of something that they are not even aware of?

Adding to the complexity of things, even if we imagine the unimaginable—that a forger imagined these details—there is the additional problem that no known person has ever managed to produce a body image that exhibits *all* of the special features that the Shroud's body images possess.<sup>1x</sup> Nonetheless, with the findings of these experts whose results are discussed in this paper, our minds are now aware of these details, along with their

explanations, and we can use our own eyes to easily confirm many of them for ourselves.

Most importantly, these very subtle details point to the Shroud as the authentic burial cloth which once wrapped Jesus' corpse. The still unknown and unreproducible way in which these body images were formed are, perhaps, not surprising since the evidence points to their having been made by a Man whose continued reputation for nearly 2,000 years is still closely intertwined with His involvement with supernatural acts.

## Dedication

This paper is dedicated to the memory of my beloved Uncle Ted—Aristotle Theodore Pappas (September 15, 1928–October 30, 2022.) He was my wing-maker, my greatest teacher, and my biggest champion. Those of us who had the great pleasure of knowing him knew him to be a very good, kind, and generous man. His “mantra” regarding the achievement of a goal was always: “Dedication, determination, and persistence.” He drilled that into my brain on a regular basis for at least the first three decades of my life. Having internalized that important life lesson from him has been invaluable to me regarding my research activities regarding the Shroud.

You continue to be loved and missed by me beyond what any words can adequately express. Rest in peace, Unc.

## Acknowledgements

Endless thanks to Giulio Fanti for his ongoing kindness, generosity and helpfulness to me in all of the areas of Shroud research that I have explored, and for his very useful advice on several issues in this paper. Thanks, also, to Peter Schumacher and Janis Winchester for their helpful comments concerning the VP-8 Image Analyzer, to Randy Hale, Russell Peterson and Chris Coleman for their technical advice on some computer issues, and to Dr. Gilbert Lavoie and Gerardo Ballabio for their helpful comments regarding the issue of negative images.

Special thanks to Editor Michael Kowalski of the British Society for the Turin Shroud Newsletter who published my first paper on the subject of rigor mortis and cadaveric spasm in the Summer 2024 issue of said newsletter and for his useful editorial help with that paper<sup>94</sup>.

Lastly, deep thanks to Barrie Schwortz (September 12, 1946–June 21, 2024.) As a scientific photographer, STURP team member and founder of shroud.com, Barrie was an endless source of first-hand information about the Shroud. He was always so kind and generous in answering the many questions that I (and so many other people) had for him. He always made time for us, and he was always happy to do so. When discussing Shroud matters with him on the telephone, the biggest treat was always in listening to him recount many of his fascinating experiences related to his involvement with investigating the Shroud. He is missed very much by me and so many others, but he leaves us with his legacy in the form of shroud.com, and the wonderful memories that we have of him. Rest in peace, dear friend.

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- i. To maximize the likelihood that one correctly interprets a reference to time, context is of vital importance. If someone tells someone to "wait a minute," this is not properly interpreted to mean for them to wait 60 seconds. Moreover, sometimes people refer to a "day" without meaning a 24-hour period of time or just the daylight hours—which are sometimes referred to as being from "dawn-to-dusk." Cultural peculiarities are, also, quite relevant. For example, in 1st century Palestine, an hour of time was not measured strictly as 60 minutes. Sometimes, it was more, and sometimes it was less—depending upon the season [3],[4]. Moreover, one day was not strictly measured as the passage of 24 hours. Instead, while a day was typically measured from sundown-to-sundown, a portion of a day could, also, be referred to as "a day." According to the Gospels, Jesus was resurrected on the third day—which can, as aforementioned, be very different from three 24-hour days. The breakdown of what constitute the "three days" is as follows: The "first day" of Jesus' death was a preparation day before the Sabbath, the "second day" of Jesus' death was the Sabbath/Saturday, and the "third day" of Jesus' death was considered to be the "start of the week" per Matthew 28:1, Mark 16:1-2, Luke 24:1, and John 20:1 [5-8]. As such, the "first day" was a partial one on Friday (from the time of Jesus' death at 3:00 p.m., until sundown.) The "second day" of Jesus' death (the Sabbath) was a full day starting at (or immediately after) sundown on Friday and lasting until sundown on Saturday. The "third day" of Jesus' death (Sunday) was a partial day that began at (or immediately after) the sundown that closed out the Sabbath (which would be around 7:00 p.m., on what we now typically consider to be Saturday.) The women went to Jesus' grave on, or around, the break of dawn on Sunday (which would be around 5:40 a.m., during April in Jerusalem), and the tomb was already empty. Therefore, Jesus' resurrection could have occurred as early as soon after the close of the Sabbath or as late as dawn on Sunday. This would give a range of around 28-39 hours post-mortem for when the Resurrection occurred on the "third day."
- ii. Cotton contamination has been detected within the Shroud's handspun [1] linen fibers, and it is thought that this is a result of contamination from the handloom [1] that was used to manufacture this cloth.
- iii. Commencing on October 1978, 33 American researchers that were part of the Shroud of Turin Research Project ("STURP") gained unprecedented access—120 continuous hours—to perform a hands-on, scientific investigation of the Shroud with various state-of-the-art equipment that they brought with them from the United States to Turin, Italy. The primary purpose of this investigation was to determine whether or not the Shroud was a painting and to determine how it was made. The late professional scientific photographer Barrie Schwortz was a STURP team member who founded shroud.com which is the largest repository of information about the Shroud [9].
- iv. The height of the man in the body image on the Shroud is 72" as measured directly from the Shroud (not from a photograph) during a private exposition in 1946 by anatomist Dr. Luigi Gedda [10]. See, also, [11].
- v. With the exception of just a few of the genuine bloodstains [2] that went onto the cloth as a liquid [12], the bloodstains on the Shroud are transfers of blood clot exudates [13].
- vi. When blood is exposed to air, the oxygen in the air oxidizes the blood and turns its red color into a brownish color [14].
- vii. Capillary flow involves the flowing of liquid through narrow spaces (such as thin tubes or the voids in a porous substance) without the aid of any external forces such as gravity. An example is if one puts the tip of a linen napkin in a bowl of ink. The ink will slowly absorb into the porous fibers that comprise the threads in the cloth of the napkin until either the ink is fully drawn into the napkin, or the napkin reaches its saturation point.
- viii. If an image were created on a linen cloth with a liquid (such as paint, stain or dye), the liquid would detectably flow along the threads of the cloth via capillary action. However, the Shroud exhibits no evidence of such capillary flow where the body image is [14]. There is, however, detectable evidence of capillary flow where the bloodstains are (which is expected.) However, the degree of capillarity in the bloodstains is not as much as if the blood went on as a liquid; instead, there is a reduced capillary flow due to evidence that almost all of the bloodstains on the Shroud are blood clots that were somehow transferred from a body to the cloth [14].
- ix. While the pure body image areas remain on top of the crowns of the threads, and there is nothing "cementing" the body image to the threads, the bloodstains penetrate the cloth and are "cemented" to its fibers [14].
- x. "Pure" body image areas are straw-yellow in color and specifically exclude the reddish bloodstains as well as the clear-to-light yellow serum halos that can be found at the perimeter of most of the bloodstains on the Shroud [14].
- xi. Traditional (but not digital) photography produces an albedo image. Light from a scene is focused onto photosensitive paper or film that undergoes a chemical reaction in proportion to the quantity of light that has been focused onto it. This image that is created is actually a negative image of the actual scene in that the light areas in the scene and its subjects will be dark, and the dark areas will be light. The photographic process evolved over time so that photographic prints could be made by shining light through the negative image onto a piece of photosensitive paper to reverse the negative image and produce a positive one [15]. Experimental results from analyzing albedo images (in the form of normal photographs) with the VP-8 Image Analyzer exclude the body image from the Shroud as being an albedo image. Why? Because when albedo images are analyzed by the VP-8 Image Analyzer, they are incapable of yielding an undistorted anatomical form of a human (e.g., a nose will appear in an unnatural position), whereas photographs of the Shroud's body images can achieve such a natural, undistorted anatomical form when examined via the VP-8 Image Analyzer [14],[16].
- xii. A positive image is a representation of a subject that matches its luminance and tones. A negative image inverts the lights and darks of a positive image. Ideally, and in principle, a negative image contains the exact same information as its positive counterpart, and it would seem like this should always yield two images that appear precisely the same but in reverse. However, in reality, this is not always true. For example, in photography, film negatives possess a broader range of tones than what is typically seen in positive printed images, and this broader range of tones results in an image that exhibits less contrast to the human eye. In order to make printed positive images easier to see with the human eye, the level of contrast in the image is typically enhanced via the printing process. Additionally, humans typically exhibit a very well-known impairment in their capacity to recognize faces (as opposed to other classes of objects) in photographic negatives [17-19]. The aforementioned low contrast in photographic negatives—as well as the broader range of tones that they exhibit—could be a possible explanation for this. However, the reversal of shadows from dark to light can also make the interpretation of the three-dimensional shapes of a face more challenging for the human eye to interpret [17]. Moreover, data from behavioral studies on face representation under varying lighting conditions found that "[t]he absolute magnitude of contrast across different regions of a face changes greatly under different imaging/lighting conditions, but the local polarity relationships between the eye regions and their neighborhood are maintained in all but the most unnatural lighting setups (such as lighting a face from below). Contrast negation of face images leads to the destruction of otherwise highly consistent polarity relations [18]." As such, because two-dimensional ordinal relationships around the eyes are major determinants in facial recognition, when these ordinal relationships around the eyes are destroyed via a negative image of the face, this appears to account for the results from both behavioral studies and neuron-imaging data that demonstrate impairment in recognizing faces when in negative images [18]. As such, an actual negative image of a human face should appear less detailed to the human eye and less like an actual face that we would see in its positive state. This makes the greater perceived detail

of the Shroud's photographic negative quite strange and outside of the natural order of things. How could a potential forger have even imagined adding details in the image on the Shroud which, in their photonegative state, would yield a more natural-looking face to the human eye through a very particular area of the human brain—the lateral occipitotemporal gyrus (aka “fusiform gyrus”—which is linked with neural pathways that pertain to the recognition of faces [18]? It strains credulity to think that a forger could have planned this out, or that this detail could have happened purely by chance. It is a detail that is *beyond imagination*.

xiii. In a darkroom in 1898, Secondo Pia—a lawyer and amateur photographer with many years of experience in taking and developing photographs—was developing the photographs that had just taken of the Shroud. Yet, what Pia saw on that glass plate was so stunning to him that he almost dropped it. Why was Pia so surprised? Because, as Dr. Gilbert Lavoie has aptly described, “the image on the photographic negative was not the negative image that he [Pia] expected. Rather, it was the positive image of a man.” [20]; See, also [1,21]. And this, of course, means that the image on the Shroud's cloth, when viewed with the naked eye, reads as a *negative* image of a man.

xiv. Giulio Fanti has noted in a private correspondence with the author, dated November 3, 2024, that there is often confusion in the description of the fibers and microfibers. He specified that each thread is composed of about 100-200 fibers, and each linen fiber is composed of hundreds of microfibers.

xv. In areas of the body image that appear darker, this is not due to a variation of the degree of the yellowing of the fibrils, but the presence of more yellowed fibrils per unit area [1].

xvi. “Directionality” refers to an observable direction from which light is coming from to either illuminate something or to cast shadows upon it.

xvii. Image analysis of numerous Shroud photographs was performed by STURP team members Don Lynn and Jean Lorre who were both from the Viking team of NASA's Jet Propulsion Laboratory (“JPL.”) Lynn was the supervisor for the Space Processing Group at JPL [16]. Heller's report references Lynn's finding that the directionless body images could not have been painted by human hand [16].

xviii. STURP team member Dr. Alan Adler explained that the VP-8 Image Analyzer “treats the intensity of the image at each pixel point as if it were a projection from a surface. The algorithm employs an inverse distance function analyzer such that darker pixels are translated into points closer to the receiving surface and pixels of lighter intensity are translated into points farther away. The shape of this distance projection surface is then displayed on a video screen [14].” He further explained that with the VP-8's analysis of the photograph of the Shroud's body image “an excellent correlation of the image intensity to the 3-dimensional shape of a human body is revealed, i.e., true 3-D information is encoded into the Shroud's body images [14].” And, this characteristic of the body image does not arise from a reflectance of an albedo image (e.g. a photograph) of its “source [1].” Additionally, further data from the VP-8 analysis indicates that the distances encoded in the Shroud's body image are consistent with a cloth that was draped over a body and not from the surface of a body to a cloth that is tightly stretched over it [14].

xix. Among its more common uses, the VP-8 Image Analyzer had been used since 1972 in the Landsat program to instantaneously process images from satellites for the remote acquisition of spectral information about Earth from space. These Landsat satellite missions have been developed and managed through NASA and the Department of the Interior's U.S. Geological Survey Program.

xx. The following artistic techniques have been tested with the VP-8 Image Analyzer in an effort to see if they could produce a three-dimensional image without unnatural distortion to the human form when examined by the VP-8 Image Analyzer: traditional photographs of a person, statue or landscape [16], albedo images as well as phosphorescent emission images from a bust of a bearded man, paintings and drawings (including drawings of the facial image on the Shroud), chemical contact images, thermal imaging, diffusion images, electrostatic imaging, bas reliefs, dry powder contact images, scorching contact with an engraving and various hybrid mechanisms [14,25]. All of these techniques, however, failed the VP-8 test.

xxi. If, in an attempt to avoid brushstrokes, a person uses powdered pigment to create an image on linen, this creates the effect of “snow-fencing” (especially if something like a finger is used to draw/paint the image) which is where the pigment accumulates on the sides of the linen fibers that makes the cloth [16]. There is no evidence of snow-fencing with the Shroud's body images [14].

xxii. Infrared thermographs of the Shroud show no evidence of any outlines or underlying paint structures [14],[29].

xxiii. The evidence points to the bloodstains staining the Shroud before the body image appeared on the Shroud, because when the blood is removed from body image areas, the cloth is uncolored in the same way that the background cloth is [14]. The “blood first, image second hypothesis” seems to indicate that the blood's initial presence on the cloth shielded the cloth from becoming colored by whatever later formed the body image [14].

xxiv. There are some areas of the body image where there would not have been contact between a body and a cloth covering it [14].

xxv. For additional evidence that the bloodstains came to be on the Shroud in a different type of process than the body image go to [30]. Moreover, the author recently made a novel finding regarding an apparent scourge mark that is placed outside of the frontal body image [31].

xxvi. From a private correspondence on November 7, 2024, between Giulio Fanti and the author concerning the body image formation process, Fanti provided some important nuance to the popular claim that the body image was formed through a non-contact process: “While most of the HS [Holy Shroud] body image was formed in the areas where the fabric was in contact with the human body, in some fairly limited areas such as the area between the nose and cheeks and part of the belly area the body image was formed even though the fabric was certainly not in contact with the human body. Since the process of body image formation does not show differences (apart from the intensity) between the areas in contact and not in contact, it is usually said that this process of image formation has the characteristic of being a process that does not require contact.”

xxvii. Under ultraviolet light, the apparent scourge marks (1) appear darker than the pure body image, and (2) they appear far more sharply defined than they do in visible light—which is a well-known spectral characteristic of porphyrin compounds contained in blood [1]. Additionally, fibers from the above-mentioned areas that fluoresced white under ultraviolet light tested positive for protein via both fluorescamine and enzymatic testing and tested positive for albumin via testing with Bromcreosol green [16].

xxviii. “Crucifixion” is execution by way of suspension and is to be distinguished from “impalement” or “hanging” [32].

xxix. Jews were typically considered to be non-citizen residents; however, under certain circumstances, they could attain full Roman citizenship—just as the Roman-Jewish historian Flavius Josephus did.

xxx. There is evidence that there was, at minimum, at least some codification of the use of scourges in crucifixions during the reign of Augustus—such as the mandate that scourgers were to be used in the crucifixion of slaves at private expense in, at least, Campania [32].

xxxi. In contrast to how Roman citizens were not typically subjected to the long, torturous and humiliating penalty of crucifixion, Roman citizens did not have such a general exemption by way of their citizenship from scourging as a singular punishment for such crimes as treason as well as certain forms of murder [32].

xxxii. The Theodosian Code was published in AD 438 and contained the laws of the Roman Empire spanning from AD 312-AD 437. While this timespan begins after the crucifixion of Jesus of Nazareth, there is no reason to think that the plumbatarum was not in use by the Romans prior to this time period, since the Romans had been attaching astragalus bones to scourges since around 300 BC.

xxxiii. In ancient Roman times, it was the “rule” that people were crucified by having their hands and feet nailed to the cross, and binding the person's hands and/or feet to the cross was the exception to the rule [37] (typically when nails were unavailable.)

xxxiv. Archeological evidence of a nailed foot from an apparent

crucifixion [44].

xxxv. Lactantius (AD 240-320) mentions that Jesus 'executioners did not think it necessary to break His bones, as was their prevailing custom [52]. The evidence seems unclear to the author as to how consistently the Romans used curvifragum and under what conditions. Was it only in Palestine and with Jewish crucifixion victims, and only when the Jews were not in rebellion against the Roman government? Or, perhaps, curvifragum was also used to expedite death when many people needed to be crucified in a short amount of time with a limited supply of crosses?

xxxvi. Dr. Frederick Zugibe instructs that a single closed femoral (thigh bone) fracture can lead to 2 liters of blood being lost and up to 4 liters of blood being lost if both thigh bones are fractured. He states that breaking the legs would cause severe hypovolemia, and that death would come from severe traumatic hemorrhagic shock or, in rarer cases, from a fatty embolism (where fat globules enter the bloodstream) [10].

xxxvii. The key word in Quintilian's "Declamations" [53] for what has to be done for a body to be released for burial is "percussos" which can mean "beat," "strike," or "pierce." As such, curvifragum or being lanced in a place like the chest—to ensure that death has come to the condemned—would be required before a body could be released for burial.

xxxviii. The original Latin used for the translated word "miraculous" is "mirabilium" which, in Latin, means "of miracles." However, there are translations on the internet which arbitrarily seek to eliminate the supernatural description that Josephus used, and they substitute words like "surprising" for miraculous—which, rather obviously, changes the meaning and importance of the word used in the text. It should, in fact, not be at all surprising that Josephus would use such a word as "miraculous" in connection with Jesus as the Jews who had observed or heard about Jesus' miraculous works did not accuse Him of fakery. Quite the contrary. The Jews understood Jesus to have supernatural powers—they were just, however, of the opinion that Jesus' powers were not derived from God but from Satan/Beelzebub/Beelzebul [5],[54].

xxxix. Within the Roman Empire, the Sanhedrin was an official Jewish governing body that presided over judicial, religious and political matters for the Jewish people living in Palestine.

- xl. For all 50 states within the United States, "death" is defined by the Uniform Determination of Death Act as an irreversible cessation of the circulatory and respiratory functions and/or an irreversible cessation of all functions of the entire brain, including the brain stem.
- xli. While the norm is for bodies to immediately start cooling after death, corpses have been known to exhibit post-mortem fevers. In a retrospective study of 744 violent deaths, it was found that the incidence rate of post-mortem fever was at 10% [72].
- xlii. An ambient temperature below 5°C/ 41°F will indefinitely impede the development of rigor mortis in a corpse [61].
- xliii. Drowning deaths are an example of how the early onset of rigor mortis does not necessarily compel the early cessation of rigor mortis. This is because while the muscular fatigue from trying to not drown is a factor for the early onset of rigor mortis, if the corpse is in cold water, the cold temperature of the water could prolong the effect of rigor mortis on the body.
- xlv. One of the important signs of death is the irreversible cessation of a heartbeat in a body. When this happens, the veins and arteries no longer receive blood flow, and the red blood cells (which are heavier than other components in blood) settle in accordance with gravity to the lowest portions of the body in what is known as "livor mortis" or "post-mortem lividity."
- xlv. Putrefactive gases can cause bloating in a corpse as early as three days post-mortem [63], and this bloating can result in certain body parts becoming distended in such a way that they defy gravity; however, this is not actual rigor mortis [77]. Moreover, since there is no indication of post-mortem bloating on the body images on the Shroud, any appearance of stiffness or a gravity-defying position

cannot reasonably be attributed to bloating from putrefactive gases.

- xlii. The first of the 7 times that Dr. Zugibe saw the Shroud in-person was on October 7, 1978. Presumably, the number is this high, because he stood in line more than once during the time period that the Shroud was on ostension in a given year, although he specified that he once was given the special privilege of seeing the Shroud outside of its protective case in a private showing [10].
- xlvii. When working as the chief of the forensics division in Los Angeles County, Dr. Bucklin had 17 pathologists working under his charge [88].
- xlviii. For full details of Bucklin's professional experience performing over 25,000 autopsies see [88].
- xlix. While acknowledging that rigor mortis in a corpse can be quite variable, Zugibe's calculation for the timing of the typical onset and duration of rigor mortis is as follows: approximately 3 hours post-mortem for the onset, 18-36 hours for rigor mortis to fully set in, about 12 hours for rigor to be sustained in full force, and 12 or more hours for rigor to gradually leave the body [10].
- l. The shoulders are made up of three bones: (1) collarbone/clavicle, (2) scapula/shoulder blade (where all of the shoulder muscles interact), and (3) the humerus/upper arm bone (which connects the upper arms to the torso.)
- li. The main bones used to raise one's shoulders are the scapula/shoulder blade and clavicle/collarbone.
- lii. Zugibe further notes that this is in sharp contrast to the many artistic depictions of Jesus on the Cross where Jesus' head is in various positions (as depicted by the imagination of artists but not factually accurate) such as "hanging way over to the left or right, arched forward with and without the shoulders bent forward, etc." [10].
- liii. The Latin word for a person executed via crucifixion is "cruciaris."
- liv. The author notes that the post-mortem repositioning of the arms was, also, likely prompted by the desire to fully contain the corpse within the confines of the burial cloth (without, for example, having the arms being outstretched and sticking out of the relatively narrow burial cloth) and to possibly place the corpse on a built-in bench in a niche as exist within cave tombs in Jerusalem.
- lv. The term "breaking" rigor mortis is not about breaking bones; instead, it involves the forcible bending of a limb at a joint [10] so as to unstiffen the muscle fibers that are responsible for the post-mortem rigidity.
- lii. Zugibe mentions that a major part of his work as a medical examiner is to estimate the quantity of blood on various items during investigations for homicides, suicides, etc. [10].
- lvii. Zugibe notes that with someone crucified to a cross, for a significant amount of time prior to death there would be a decrease in the flow of blood from wounds due to marked hypotension induced by shock [10].
- lviii. Dr. Pierre Barbet (1884-1961) was a French battlefield surgeon during World War I and the chief surgeon at St. Joseph's Hospital in Paris. He was a prominent Shroud researcher and a pioneer in the area of performing Shroud-related experiments (with cadavers) to learn more about important details regarding crucifixion, and he applied that knowledge to details that he was observing about the bloodstains and body images on the Shroud.
- lix. See [32] regarding nails used for crucifixions in the 1st century. Also, corroborating the evidence that points to the Man of the Shroud as a crucifixion victim are the patterned injuries all over the frontal and dorsal area of the body image which are consistent with a commonly administered pre-crucifixion scourging [5],[6],[8],[33],[36],[39].
- lx. British filmmaker David Rolfe made a public \$1,000,000 challenge to the British Museum and/or any American that can replicate the Shroud using only tools and techniques that were known and available during the 14th century or earlier [93]. This challenge has remained unmet by anyone.