Behind the Image - Cerebral Reflections

David Larraguibel

Figure. 1. Cerebral Reflections, winner of the BioCommunications BioImages 2022 Premiere Award in the Biomedical - Human & Animal category.© 2023 Government of Ontario. Reprinting or reproduction of this material is not authorized.

What is your title and field of expertise?

I am a forensic photography technologist and my field of expertise is forensic postmortem photography (FPM), defined as the photographic documentation of human remains and related effects during a medico-legal postmortem examination. These examinations are performed on individuals deemed to have died a sudden and unexpected death, and require an in-depth investigation by a qualified forensic team to resolve medical or legal concerns. These include, but are not limited to, determining the cause and manner of death, confirming the identity of the deceased, and identifying any relevant pathophysiology leading to the death of the individual and which may have implications for next of kin, or the general public. As a forensic photography technologist, I contribute to the investigation by providing visual documentation of findings identified during the physical examination of the decedent, any associated evidence and personal effects, image processing, and management of all case images, including those submitted by other agencies.

The objective of FPM photography is to provide:

A. A record of visual evidence which cannot be collected using any other standardized forensic practice, and which will be lost or destroyed during the course of a postmortem examination or once the body is released to the family for burial or cremation.
B. A supporting visual document of a forensic finding which can be collected by another standardized forensic practice.

The purpose of these photographs is to form a permanent visual record suitable for both the medical peer review process and the legal system during criminal or civil proceedings.

The subject field encompasses anatomy, pathophysiology and trauma, forensic anthropology, methods of human identification, and criminology. An FPM photographer is required to develop advanced knowledge of both traditional and forensic photographic techniques, as well as best practices related to accurate scientific documentation and chain of custody. Though the position of FPM within the field of photography has not been formally defined, I would place it at the intersection of bio-medical, scientific, and crime scene photography.

How is FPM photography used in the course of a medico-legal postmortem examination?

The examination can be broken down into five parts:

1. Scene, History, Circumstance
2. External Examination
3. Internal Examination
4. Ancillary Testing
5. Medical Opinion

FPM photography is primarily employed in parts 2 and 3, as those take place within the laboratory under the authority of the Coroner or Medical Examiner's office. The external examination begins with the photographic documentation of case identification assets and any other identifying information which has been applied to the exterior of the body pouch, such as a police seal. Once the body pouch has been opened, the initial set of photographs will include an overall photo of the decedent to establish their initial disposition, identifying features, clothing, medical interventions, personal effects, weapons, or evidence, as well as any obvious signs of trauma or other forensically relevant findings. Any ID tag placed on the decedent by a death investigator at the scene (such as a coroner's tag) must also be photographed for identification reconciliation at the facility, to ensure decedent information and state of identification is accurate.

Once the clothing and medical interventions have been removed and the decedent cleaned, additional anterior and posterior body photographs are taken to further document their disposition, any trauma, or relevant findings. If the decedent is unidentified or tentatively identified, infrared photography may also be used at this point to locate and document identifying features such as tattoos and other organized markings. After the body photographs are complete, anterior, and lateral photographs of the face are taken as well. In a suicide, suspicious, pediatric, or unidentified remains investigation, the standard set of external photographs can be greatly expanded to encompass anatomical areas and subjects of forensic interest such as: hands, neck, eyes, mouth, genitalia, any trauma, additional identifying features, and the collection of trace evidence. Often, subjects may be photographed for positive as well as negative findings for exclusionary purposes. In circumstances where there is suspected physical transfer of trace evidence or concealed trauma, a Forensic Light Source (FLS) examination may also be conducted using stokes shift fluorescence and reflected visible, non-visible wavelengths ranging from ultraviolet (350nm) to infrared (840nm), and cross-polarized photography.

Once external documentation is complete and blood, urine and vitreous samples have been taken, the body is opened using a Y-incision to examine the thoracic and peritoneal organs, as well as the airway, esophagus, and associated neck structures. Depending on the case history, this may also include examining the brain by reflecting the scalp and removing the top of the skull. If any findings are immediately noted or relevant upon opening, photographs may be taken in-situ before removal. Once each organ or structure is removed, additional photographs may be requested before and after dissection on the grossing table. The internal exam sometimes requires only a minimal set of photographs if the case is visually unremarkable, such as in a toxicology death. However, in some cases such as a traumatic, suspicious, or pediatric death, documentation is often more extensive and can include photographs of any relevant anatomy and/or trauma. For example, in a case involving multiple gunshot wounds to the torso including a fatal injury to the heart, an expanded set of images may include, but not be limited to: Infrared and visible light photos of the clothing and entrance wounds to determine range and angle of entry, a layered dissection of thoracic tissues to determine trajectory through the body when there are multiple gunshot wounds, close-up photographs of the cardiac injury due to perforation by projectile, any exit wounds to correlate with the trajectory, and any recovered projectiles or fragments.

Tell us something about the subject of this image. What technical issues did you have, or have to work out, to create the photo Cerebral Reflections?

This particular case had a preliminary diagnosis of a ruptured berry aneurysm, which can happen when a cerebral artery with localized aneurysmal dilatation eventually ruptures, resulting in a fatal bleed. Visually, this presents as a localized accumulation of subarachnoid blood, (**Figure 1**) with the identification of a specific rupture site only possible after close examination of the affected vessels; in order to visualize these vessels and the rupture site the arachnoid membrane and its underlying (subarachnoid) blood must first be carefully cleared away.

Photographically, this process is completed with a sequence of photos once the brain has been removed from the cranial vault:

A. An overall view of the four general aspects of the brain to document its overall disposition and the distribution of the blood: dorsal, left lateral, right lateral, and ventral surfaces;

B. A close-up of the suspected source of the bleed with the subarachnoid blood collection intact;

C. A close-up of the suspected source after the membrane has been resected and the blood has been gently washed away;

D. A macro photograph of the rupture site at the closest possible focusing distance for submillimeter detail of the defect. If these vessels are removed for closer examination, there may be additional photographs taken.

This particular image was a photo of opportunity, and is not part of the routine photographs taken during the course of an examination. When the organs are removed from the body, they are first weighed before being examined and dissected on the grossing table. When this brain was placed in the stainless-steel weighing pan, I noticed there was an interesting visual interaction between the brain and the reflective surfaces of the pan itself. I took this photo using the cross-polarized lighting equipment already mounted on the camera. Due to the specific properties of this form of lighting, the primary specular reflections of light from the brain were eliminated while the secondary reflections from the pan were still present and further enhanced the interaction between subject and substrate.

Can you describe the photographic environment, and some of the challenges or technical issues you face in capturing your photographs?

The work is primarily conducted in a controlled laboratory environment, where most of the variables that commonly affect photography are limited and predictable. The working area itself is a very large open-concept examination area broken up into a total of 8 smaller bays by half height walls to allow for communication between pathology teams. In addition, there are a few isolation and special use suites with their own unique environmental variables. The spaces are mostly illuminated by a combination of large, frosted, south-facing windows across the entire laboratory environment, and daylight balanced fluorescent bulbs in the ceilings of each bay and transit area. (**Figure 2**) The surfaces in this environment are stainless-steel examination tables and counters, white walls, and grey floors. Water is used extensively to ensure surfaces and subjects are clean of bodily fluids for both safety and enhanced visualization. The neutral color palette minimizes color casts, but there is enough sunlight penetrating the windows and illuminating the highly reflective surfaces that the environment itself becomes a lighting variable requiring some management. These combination of factors have necessitated the development of reflection mitigating techniques, and a dependance on battery-powered camera flashes as the primary light sources.

Figure 2. View of two open south facing bays. The autopsy facilities consist of eight open bays, two isolation bays, anthropology laboratory, teaching theatre, and a tissue recovery suite.

The technical teams in the autopsy laboratory are comprised of Forensic Pathologists, Forensic Anthropologists, Physician Assistants, Forensic Pathologist's Assistants, Forensic Services Technologists, Morgue Technologists, and Forensic Photography Technologists. The laboratory itself is a challenging work environment; there are a large number of staff in constant communication, the volume of the autopsy equipment used is loud and reverberant, and the physical distance between operational areas is large. Our team of 6 photographers are frequently called for, as they are required to document multiple concurrent cases in this space, while also processing case photography in real-time.

Which technologies or techniques have enabled you to do something you were not able to do before?

There are a few different imaging technologies and photographic techniques currently in use which allow a photographer to efficiently document a modern postmortem examination at the scale required by a large death investigation service. Chief among them are enhancing the visualization of photographic evidence, and managing large amounts of imaging data.

In FPM (Forensic Postmortem) photography, there are visual artifacts which may interfere with a standard camera system's ability to visualize relevant forensic subjects. Reflective artifacts on skin are commonly caused by inherent oils and sweat, condensation, blood and other bodily fluids, while injuries are often obscured by dark skin, or hidden by burns and inorganic matter limiting visualization due to competing tone and color. Additionally, the documentation of tattoos, scars, and body markings in thermally damaged or darkly pigmented skin can pose difficulties in cases requiring identification of remains. (**Figure 3**)

To manage these artifacts, specific photographic methods are used that leverage a few distinct qualities of anatomy and light physics.

Figure 3. Left image: Tattoo photographed under incoherent light, obscured by thermal damage to skin. Right image: Tattoo photographed under polarized light allows for enhanced visualization of tattoos in thermally damaged skin.

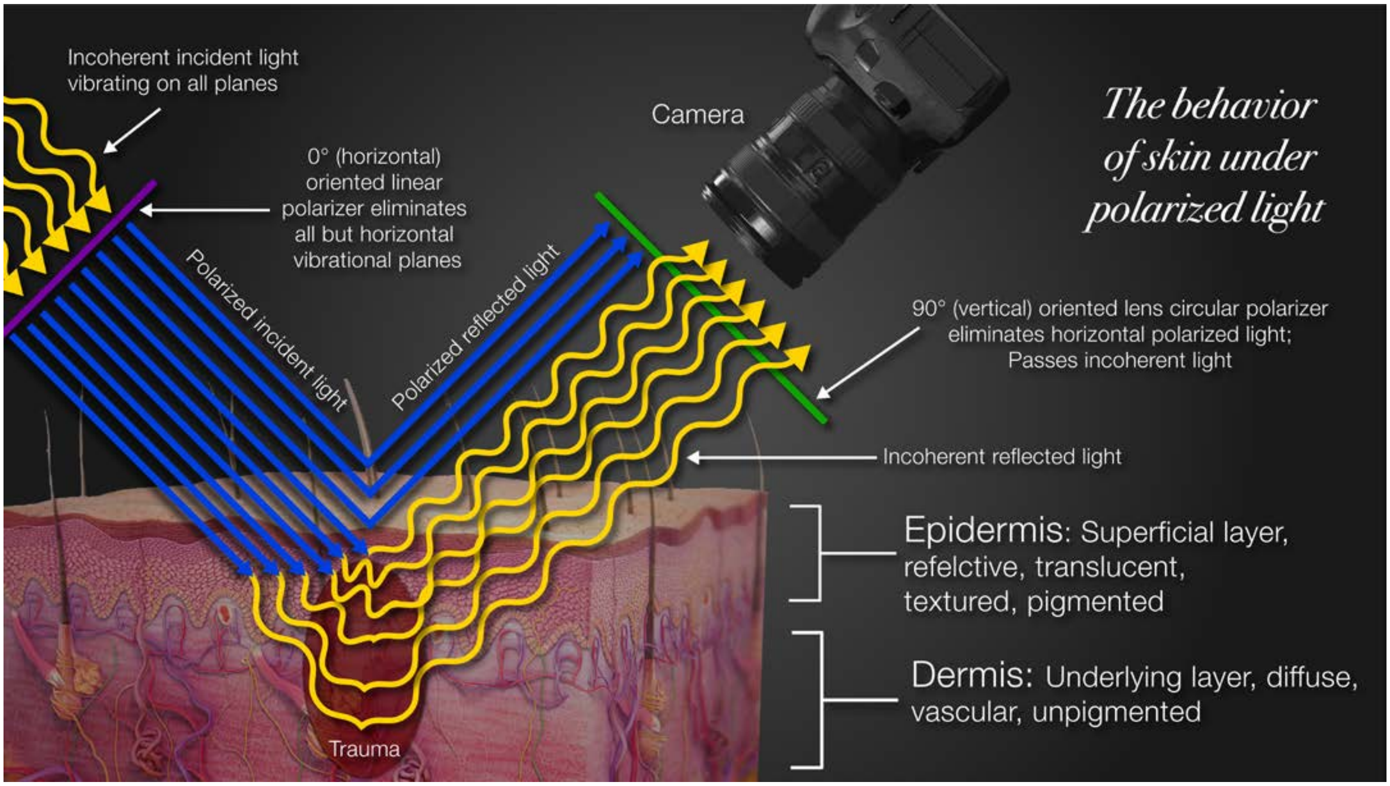

Figure 4. Artist's illustration of the behavior of skin under polarized light. Superficial reflections are minimized and underlying findings appear illuminated by a backscatter effect, a by-product of using cross-polarized light on a multi-layer subject. Diagram by David Larraguibel, Human Skin illustration by Scientificillustrations.com. Released under Creative Commons "BY-SA (Attribution-ShareAlike 4.0 International)"

Cross-polarized light photography

Normal light (incoherent light in discussions of polarization) can create many visual artifacts such as specular reflections from shiny surfaces like organs and tissues, often causing a loss of detail, contrast, and color saturation. To mitigate this extremely prevalent artifact, a crosspolarization technique is employed. This lens/lighting system is comprised of two pieces of equipment:

A. Canon MR-14EX II Macro Ring flash coupled with a high temperature linear polarizing gel oriented at 0° on both light emitters, thereby limiting the vibration planes of the emitted light to only a horizontal wave;

B. Canon 50mm f/2.5 Compact Macro lens or Canon EF 100mm f/2.8L Macro IS USM lens with a circular polarizing filter oriented at 90° relative to the polarization plane of the flash gels, which limits the vibration planes of the incoming light to a vertical wave.

When a flash photo is taken of a reflective surface such as skin or tissues, a portion of the flash's polarized 0° light strikes the surface and reflects back towards the lens while retaining its plane of polarization due to principles of light physics. (**Figure 4**) When the 0° reflected light hits the lens' polarizing filter oriented at 90°, it is blocked from entering the lens. However; due to the properties of skin and other multi-layer subjects, another portion of light is able to bypass the reflective surface of the skin tissue and becomes depolarized (incoherent) by the underlying structures of the dermis, adipose tissue, or the organs and muscles themselves. When the newly depolarized incoherent light exits these tissues and reflects back towards the lens, the polarizing lens filter is effectively bypassed as the returning light no longer has a specific plane of polarization. The resulting effect is the tissues appear to be internally lit by a back scatter effect, with significantly increased structural detail, contrast, and color saturation.

It is important to note the two reasons this technique works so well. First, all ambient incoherent light is excluded due to exposure settings on the camera so that only the controlled light coming from the flash is used for the photograph. Second, the anatomical structures and tissues are comprised of multiple varyingly translucent layers, which allow for both light reflection and penetration. In a single-layer material such as polished metals, the reflective surface is opaque and would only reflect polarized light. With no underlying layers to depolarize the light, there is no incoherent light reflected back. (**Figure 5**)

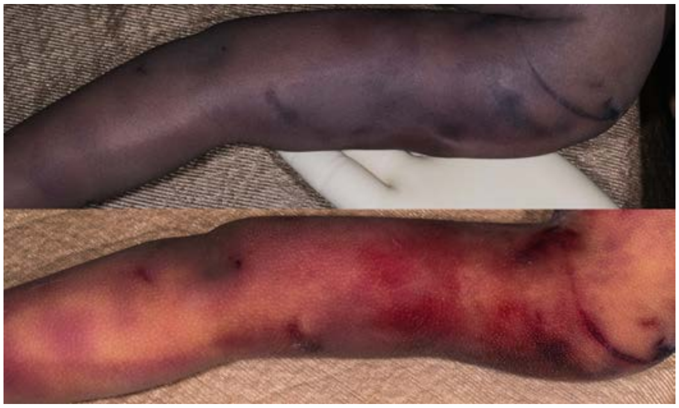

Figure 5. Upper image: Trauma photographed under incoherent light, obscured by dark pigmentation and reflective condition of the skin. Lower image: Trauma photographed under polarized light allows for enhanced visualization of trauma in darkly pigmented and reflective skin tissues. © 2023 Government of Ontario. Reprinting or reproduction of this material is not authorized.

Infrared Light Photography

Competing color and tone can obscure trauma, identifying features such as tattoos, and some evidence such as firearm discharge residue. These scenarios may appear in individuals with a darker complexion, bodies that have experienced moderate to severe decomposition or thermal trauma, and on dark or visually complex clothing. Infrared light can allow the photographer to visualize anatomical subjects and evidence related to death investigation which would otherwise be limited by visible light. This is made possible by identifying the differences in light absorption of each subject in both visible and infrared wavelengths and examining the relationship between each, such as: melanin (skin pigmentation); blood and related healing by-products; decomposition related pigmentation; black and dark tattoo ink; dark textiles; and firearm discharge residue.

Melanin is the pigment responsible for the coloration of skin and is highly absorbent of visible wavelengths of light. Higher concentrations of melanin in the epidermis results in the appearance of darker skin. Decomposing skin is also highly absorbent of visible light, but it does not have a predictable color, pattern, or distribution and appears as a dark multi-colored stain. Most black and dark tattoo inks are highly absorbent of visible light and, if applied properly, are deposited in the dermal layer of the skin, below the melanin producing epidermis.

Figure 6. Organs photographed using cross-polarized light, from left to right: Lateral view of right lung, kidney coronal section, heart with petechial hemorrhages. © 2023 Government of Ontario. Reprinting or reproduction of this material is not authorized.

Heme is the primary pigment of hemoglobin in blood and contains iron, which is responsible for its reddish color in white light. Blood, especially in higher liquid concentrations, absorbs white light and appears as a dark red substance.

Blood can often obscure relevant forensic subjects at autopsy and historically required washing or removing the blood to visualize the subject. Firearm discharge residue (FDR) can appear as a dark colored powder-like substance or small, solid, dark particles. (**Figure 7**) When FDR is deposited on dark textiles, the findings can be obscured and overlooked. The end result is that under visible light all the above subjects can appear similar in tone and color, making it very difficult to visualize relevant findings.

In an effort to combat these difficulties in visualization, infrared photography is used to examine these subjects. When viewed under infrared light, both melanin and decomposition related pigmentation becomes reflective, meaning they appear lighter and more uniform in appearance. Illuminated by infrared light, the red coloration of liquid blood can also become reflective and in lower concentrations is rendered mostly transparent, allowing for non-destructive visualization of subjects without the need to wash away the blood first. However, when liquid blood accumulates in larger quantities or dries out, the higher concentration of iron rich heme absorbs a greater amount of infrared light and appears darker and more opaque.

Figure 7. Left image: Gunshot trauma and firearm discharge residue photographed under white light, obscured by liquid blood. Right image: Gunshot trauma photographed under infrared light at 840nm before removal of blood, providing enhanced visualization due to the translucent characteristics of blood in infrared wavelengths. Unburnt powder is highlighted inside the circle. © 2023 Government of Ontario. Reprinting or reproduction of this material is not authorized.

Black, blue, green and other darker colored tattoo inks generally have a stable absorption response across both visible and infrared wavelengths, meaning they continue to absorb light. Additionally, if the ink is professionally applied, it will be deposited deeper in the skin making it resistant to disruption due to decomposition related sloughing of the skin. The visual effect results in the skin appearing light while the tattoo stays dark, thereby making it possible to visualize the tattoo against dark, burned, or decomposed skin. (**Figure 8**).

Dyed textiles and firearm discharge residue also have specific properties which can be leveraged by infrared light, allowing for enhanced visualization of forensic subjects. Many textiles which are naturally light in appearance, such as cotton, are colored or patterned using dyes which absorb white light quite easily and appear as a darker coloration. Under infrared light many of these same commercial dyes become reflective and appear variably light colored or seemingly transparent. If the textile is stained with blood, the blood will absorb more infrared than the dyes, both as a fluid and even more when dry, and appear as a dark stain. (**Figure 9**)

Figure 8. Left image: Ship tattoo photographed under visible light, obscured by decomposition related changes to the skin. Right image: Ship tattoo photographed using infrared illumination. The use of infrared light allows for enhanced visualization of tattoos in skin with darker pigmentation or affected by postmortem changes and thermal damage. © 2023 Government of Ontario. Reprinting or reproduction of this material is not authorized.

Much like the visualization of tattoos and darkly pigmented or decomposed tissues, there is a separation of subject from substrate and a blood pattern can become visible on dark textiles. Gunshot residue has a similar property as dried blood and tattoo ink, in that it has a stable response by absorbing both white and infrared light, appearing as a dark substance. This is leveraged when photographing clothing recovered from shooting victims, as it allows the photographer to localize the defect in the clothing, potentially allowing an expert to determine range and establish entrance vs. exit defects.

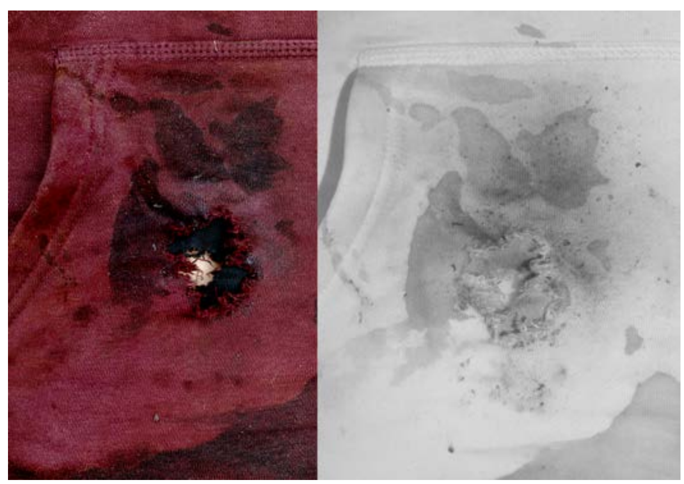

Figure 9. Left image: Gunshot defect and firearm discharge residue in burgundy hooded sweatshirt, photographed under white light; Findings obscured by liquid blood and red coloration of textile dyes. Right image: Gunshot defect and firearm discharge residue photographed under infrared light at 840nm, with findings visible due to the spectral characteristics of dyes, blood, and firearm discharge residue. © 2023 Government of Ontario. Reprinting or reproduction of this material is not authorized.

Wireless photography and remote processing

In addition to strict photographic technologies and techniques, there are two additional integrated technologies that have been built into the workflow to enable shooting a much higher caseload than would be feasible using traditional methods. Without going into great depth, a secure wireless communication system enables images to be sent from the camera to the photography server without manual intervention, and a remote administration system allows the processing of images on co-located office workstations in real time while still shooting in the laboratory areas. These two technologies have been a paradigm shift in multi-camera photography and allow for documenting and processing more cases over a larger physical area by fewer photographers. Due to scalability and portability of these technologies, there is potential application for a similar system in the large scale photographic documentation of multiple fatality or mass disaster scenarios, in remote locations and under portable power.

Tell us about your photography background. Were you formally trained? What first sparked your interest in forensic photography?

I attended OCAD University in Toronto, graduating with a Bachelor of Fine Arts with a specialization in Integrated Media. This program examined the intersection of art, science and technology, and focused on non-classical art forms such as video and audio production, computer generated artwork and programming for time based media. I paid particular attention to photography and technical image creation as this was an area I was passionate about, and during my studies I focused on human anatomy and movement as a study, and urban low-light imagery when I travelled. After completing my B.F.A., I worked as a freelance commercial photographer's assistant on large scale ad campaigns where I built my technical photography skills, eventually moving into video and content production for internet start-ups and media companies. This helped develop my knowledge of workflow and technical system design.

I eventually exited the creative industries and I began looking for a way to use my skill set in the public sector. Recognizing that I had always had an interest in anatomy, and that since graduation I had also developed an interest in criminology, I started looking at forensics as an option. When this position was initially posted, it was in a newly formed government organization created during the overhaul of the provincial death investigation system in Ontario, and the role had yet to be developed. I was fortunate enough to be the first hire, and was able to build this particular role from the ground up.

In Canada there is no dedicated bio-medical or forensic photography degree program, which made it difficult to find local resources for training. The provincial and federal police services have photography courses for their own officers, however there was nothing dedicated to the documentation of the human body in the course of a medico-legal investigation. I was an artist among scientists, and without a formal background in this subject matter or peers to guide me, it was a steep learning curve and much of it was done in a vacuum of practical information.

Figure 10. From left to right: 1. Canon EL-5 flash 2. Canon 5D Mark IV DSLR camera body & Canon ST-E3-RT Speedlite transmitter & Canon 24-70mm f/2.8L II USM lens 3. Canon R6 Mark II mirrorless camera body & Canon 50mm f/2.5 compact macro lens with B+W circular polarizer & Canon Macro Ring Light MR-14EX II with a high temperature linear polarization gel 4. Canon R6 Mark II camera body & Canon ST-E3-RT Speedlite transmitter & Canon 24-70mm f/2.8L II USM 5 lens. Canon 600EX II Flash 6. Canon Powershot G16 with 720nm Infrared Conversion 7. 840nm Handheld Infrared Illuminator

Tell us what camera and lighting gear is used in your work environment, and what settings are commonly used.

Routine photography is performed using either a Canon 5D Mark IV DSLR camera or Canon R6 Mark II mirrorless camera with a Canon EF 24-70mm f/2.8L II USM lens. (**Figure 10**) The cameras are all set to manual exposure with a setting of (1/200th @ f/8, 500ISO), which is standardized across all bodies for the purpose of consistency; settings are modified via aperture only in situations where additional depth of field is needed. The Canon 600EX II RT flash or Canon EL-5 flash is used handheld and is triggered by a Canon ST-E3-RT Speedlite transmitter. The flash is most often positioned for bounce illumination at a power output of +2 stops, but at times can also be positioned for oblique, direct, and sometimes trans-illumination. When lighting and exposure adjustments are required, the power output of the flash is adjusted rather than the exposure settings on the camera.

Macro photography is performed using the same camera bodies, mounted with a Canon EF 50mm Compact Macro f/2.5 lens and a B+W circular polarizing filter. The flash is substituted for a Canon MR14-EX II Macro Ring light, with a high-temperature linear polarizing gel permanently covering each light emitter. This configuration is specifically used for all high-value subjects as it minimizes the reflections caused by the wet tissues, and greatly enhances the detail, contrast, and saturation of the subjects.

Infrared photography is performed using a Canon Powershot G16 modified for infrared light by the removal of the hot mirror, and replaced with a 720nm Infrared filter. An 840nm handheld light source is used for additional illumination. The infrared camera and light combination is used in a visual survey capacity to identify relevant findings, at which point an infrared photograph will be taken. If nothing is found during the survey, a photograph does not need to be taken. All images are shot in RAW+JPEG in the sRGB color profile, and cameras are preset with a custom white balance centered at 5600K. Images are processed through Adobe Lightroom Classic with minimal adjustments performed, such as white-point correction, shadows and highlights, and rotation/crop. All adjustments are recorded in the image .xmp metadata as a sidecar file, which means any processing can be replicated when the files RAW and .xmp are transmitted to a requesting agency and processed using the same software.

What advice would you give photographers who are just starting out in this field?

- Know your equipment. The forensic pathologists, stakeholders, justice system, and victim's families are depending on you to accurately and efficiently document the examination.
- This is a very unique field with a limited amount of training opportunities and peers to learn from. Be prepared for self-directed learning and research, and to be considered an expert before you feel you are ready.
- Have a hunger for the subject matter as this field has a depth that feels almost unknowable; Never be satisfied that you know enough.
- Recognize that you will see tragedy and have daily exposure to trauma; You won’t know how or when it will affect you. Put in the effort to prepare for those times when the work becomes emotionally challenging, and try not to lose sight of the things in your own life that bring you peace.
- We normalize what we see, but what we see is not normal. Managing that perspective can be difficult.

What is something you would want other photographers to know about this particular type of photography?

There is a grace and wonder in the physiology of the human body, including the strange influences the world has on it as one’s life is ending. It is a great privilege and responsibility to be present as a photographer at the moment something meaningful reveals itself during the last examination. We are not only tasked with recording what can be seen, but must also be prepared to locate and document the findings no one but us can see, in order to bring justice and closure to the victims and families of the deceased.

Acknowledgements

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Author

David Larraguibel is a Forensic Photography Technologist with over a decade of experience in death investigation and forensic sciences, documenting in excess of 14,000 postmortem examinations. As the senior photographer with the Ontario Forensic Pathology Service, David developed a modernized photographic methodology and advanced digital imaging infrastructure tailored for high-volume death investigations in Ontario. This included specialized imaging modalities for documenting clandestine trauma and unique identifying features critical to suspicious cases and unidentified remains.

David also served with the Ontario Provincial Police as a Forensic Identification Support Technician, where he developed the photographic workflow for a multispectral crime scene body examination protocol. He frequently provided training on field-expedient photographic imaging equipment and techniques to Forensic Identification Specialists, Field Intelligence Units, and Scenes of Crime Officers. Prior to this, David was a Forensic Firearms Technologist at The Centre of Forensic Sciences in Ontario, where he established a customized photographic infrared imaging protocol for distance determination.

David has provided comprehensive training in postmortem and clinical injury photography to various agencies, including forensic pathologists, SANE/DVT investigators, law enforcement, and military personnel. Holding a Bachelor of Fine Arts in Integrated Media from OCADU, David has been recognized for his expertise and vision in the field of art and forensics, recently earning him the BioCommunication BioImages 2022 exhibition Premiere Award.

David is regarded as an expert in Forensic Postmortem Photography and multi-spectral imaging. He frequently contributes to forensic science conferences and events, most recently acting as the keynote speaker at the 2023 Forensic Photography Symposium in Toronto, and workshop instructor at the 107th IAI Annual Educational Conference in National Harbor, Maryland. He is currently focusing his efforts on civilian and law enforcement training, and conducting research and development in forensic imaging.

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