Scientific Documentation of the Human Body Using Highly Standardized Rotational Photography

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Over the last several decades, medical imaging technologies have proven so anatomically insightful that they have all but taken over management in many clinical situations. MRI, CT, and PET scanning technologies employ stringently controlled rotational data-harvest protocols. By contrast, standardization of visible-light imaging of human anatomy has lagged dramatically. This article is the first to present a rigidly standardized rotational protocol to photographically record human anatomy and permit subsequent analysis with less than 2% image variance.

Keywords
3-Dimensional photography, anatomy, body contouring, body shape, circumferential imaging, clinical photography, digital imaging, growth and development, plastic surgery, rotational imaging, standardized photography

Introduction

Images of scientific and medical subjects were captured within a year of the invention of photography. Later, photographs of Civil War casualties became iconic, bringing medical images to public attention and sparking their use for medical documentation and education. Medical photography subsequently grew as a defined specialty, and professional standards were developed. In the 1930s, hospitals began creating departments for medical photography to allow clinicians in many medical and dental specialties to document patient anatomy or disease processes. By 1966, photography was being used as a critical day-to-day component of clinical care in several specialties, including Plastic Surgery (Spear and Hagan 2008). Since then, many authors have stressed the importance of incorporating strict standardization of clinical imagery (Gherardini et al. 1997, Williams and Nieuwenhuis 1992, Peres et al. 1996) but we believe that the incomplete standardization proposed in previously published protocols (with resultant inability to extract meaningful data from the imagery) has prevented widespread adoption of the published methods.

Starting in the late 1980's, an explosion of highly standardized computer-generated imaging technologies (CT, MRI, and PET-Scans) not only allowed visualization of interior body spaces but made clinical photographs of the body surface seem simple and "old-fashioned". By the time digital cameras eclipsed the resolution of film in the late 1990s, few medical practitioners continued to use clinical photographs as sources of meaningful data. Rather, the ease of automated 'point and shoot' technology enticed Plastic Surgeons and others to produce unlimited and inexpensive "medical snapshots". Although most clinicians were satisfied with the resulting images to document their activities for the medical record and publication, the potential to obtain scientific data from these non-standardized visual anecdotes was lost (Teplica 2009).

In recent years, readily available and sophisticated computer software provided a precise and consistent tool for the possibility of detailed analysis of the anatomic information contained in medical images, but this could only occur if the images were *adequately standardized*. Unfortunately, to date, surgical imagery rarely is sufficiently standardized to permit this type of anatomic analysis. Of equal importance, circumferential images are only infrequently obtained despite a growing awareness that the body must be perceived 3-dimensionally and in the context of all adjacent anatomic regions (Teplica and Bundy 1996, Rohrich et al. 2006, Dabb et al. 2004).

The literature is virtually silent regarding reproducibility as it pertains to the various methods for standardizing clinical photography. The purpose of this paper is to outline an easily mastered, reproducible, and highly standardized, rotational photographic method to image the torso for meaningful anatomic comparison and analysis. New insights into anatomic mirroring of faces and body form in monozygotic twins (Teplica and Peekna 2005, Teplica 2010) and a published description of disease-influenced anatomic changes (Teplica 2013) make it more urgent that techniques be adopted to better document human surface anatomy in a quantifiable manner. Ideally the method would capture anatomic form and the bodily variations that occur over time, with gender, and as a result of hormonal changes, trauma, pharmaceutical exposure, and disease. Standardized digital strategies that are currently being used in radiology (MRI, CT, and PET scanning) yield insights far beyond what could ever be imagined by the historical pioneers of standardized human photography, including Eadweard Muybridge, W. H. Sheldon, and Alphonse Bertillon. Unfortunately, standardization for clinical and investigational *photography* (visible-light imaging) has lagged all the other modalities. With a growing emphasis on research that quantifies the effects of medical, surgical, and pharmaceutical interventions, highly standardized digital protocols must be refined for photographic imaging so that real data can be obtained to quantify treatment outcomes, track progression of anatomic change (from all causes), and facilitate anatomic discovery.

Photographic Set-Up

Strict consistency is as critical in clinical photographs as it is in all other forms of medical and scientific imaging. It is interesting to note that all other sophisticated forms of body imaging occur in dedicated spaces with equipment that is built to analyze anatomy from strictly standardized distances, using strictly standardized protocols. Ideally, a body-imaging studio would be installed with dedicated equipment that is structurally locked into position to ensure identical capture of anatomy. Few if any medical centers or offices have recognized the need for a dedicated and standardized space to photographically image the *surface* of the body. Nor do many (if any) facilities demand strict standardization of camera, lens, shutter speed, aperture, lighting, distances, rotational positions, or any other variables that would make the comparison and analyses anatomic data possible – either between different individuals or to document changes in a single individual who changes over time. In other words, to produce valid scientific images, photographers and medical personnel should strive to capture clinical or investigational photographs in which the ONLY variable is the *anatomy itself*.

Details for the elements that can be successfully controlled/standardized are provided in **Table 1**. This information can be used to guide creation of a dedicated space or (much less accurately and much less desirably) to set up equipment in a multi-use space for each imaging session.

A backdrop large enough to eliminate all extraneous objects from the final image is needed. A minimum background size of 1.33 meters wide and 2.0 meters high consistently allows full-torso imaging of subjects without capturing room details. In addition, these dimensions permit circumferential imaging with clearance of limbs during each full rotation. The color of the background should allow for visual anatomic separation, not reflect colored light that distorts natural skin tones, and not interfere with image analysis. A flat black backdrop not only meets all the above goals, but also embraces the well-established standards of the biomedical imaging community (Williams and Nieuwenhuis 1992), while permitting digital image analysis (Gherardini et al. 1997). Black is the most easily standardized and it shows no distracting shadows. These critical criteria are not met by any other color choice.

Table 1. Elements Requiring Standardization in Clinical Photography.

1.	**Photographic Environment Remains Constant** • Backdrop – flat black • Ambient lighting - Minimize • Points of focus on walls for subjects to orient their gaze (at 45° increments) • Quality of light (color temperature, minimal diffusion, intensity)
2.	**Equipment is Dedicated only for this Purpose Only** • Two studio strobe lights placed at 45° angles from the midline and 45° above the horizontal plane (passing through the umbilicus and the optical center of the lens) to enhance volumetric rendition • Ring flash or similar system to minimize shadows and best-ensure capture of all surface detail, even in subtle shadows cast by the overhead lighting • Tripod locked in position with points marked on floor ensuring consistency
3.	**Camera and Settings are the Same Every Time** • Camera body • Lens/Focal length (Macro, 60-95mm to approximate optics of the human eye) • Focus is determined and FIXED (NOT in autofocus mode) • Shutter speed fixed • Aperture fixed • Depth of focus fixed • Sharpness • Perspective • Resolution of camera – megapixels • White/color balance determined the same way each time • Camera's light meter • Contrast and saturation settings held constant
4.	**Preparing and Positioning Subjects** • Remove all jewelry, makeup, clothing, identifying objects • Explain tattoos will not be covered, but visibly masked if ever published
5.	**Digital Harvesting and Uploading** • Image labeling, storage, and retrieval always the same • Raw Image Capture with nondegradative compression • Image sensor plate clean • Viewfinder method always the same • Image processing by camera disabled • Use consistent image import methods

A rotating turntable (**Figure 1**) with ball-bearing wheels that move freely around a central axis -- regardless of subject weight – is an essential element of the set-up. A pointer on the base of the rotating platform allows alignment with white reference marks placed at 45° increments on the platform base. Circumferential photographs are routinely captured at these specified increments, which correspond perfectly to positions commonly referred to (but never conceptually acknowledged numerically) as: "frontal" (0°), "right oblique" (45°), "right lateral" (90)°, "right posterior oblique" (135°), "back view" (180°), "left posterior oblique" (225°), "left lateral" (270°), and "left oblique" (315°). We advocate use of the degrees designators to stress the scientific nature of imaging and to encourage accuracy of the rotational increments. If more detail is needed than what can be obtained with 45-degree rotations, for example if 3D modeling is desired, then smaller incremental rotations can be easily obtained.

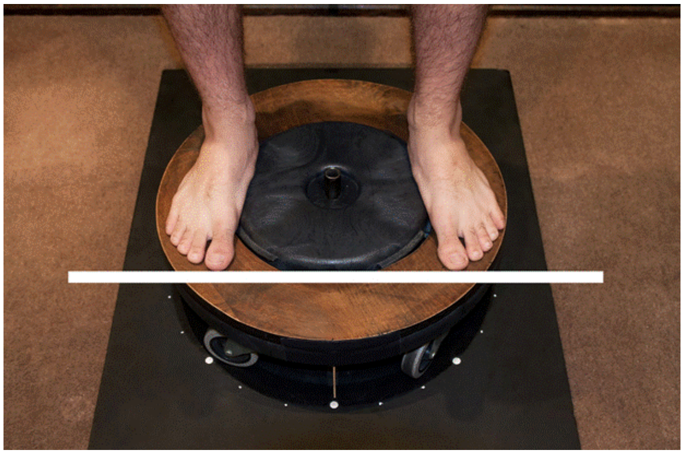

Figure 1. Basic construction of the turntable, showing white markers at 15° increments, with larger dots at 45°. The subject's toes should create an imaginary line parallel to the front edge of the turntable. Ideally, this will result in the anterior surface of the body being coplanar with the sensor plate of the camera. If the subject has pelvic or spinal malalignment, the feet can be adjusted to improve anterior positioning. Alternatively, the subject can be asked to rotate one hip forward to align planes, though this option is hard for the subject to maintain throughout the full imaging sequence.

The turntable should be centered in front of the backdrop. The distances between 1.) the rotational axis and the sensor plane in the camera, 2.) the rotational axis and the backdrop, and 3.) the subject and light sources must remain constant in order to ensure lighting consistency. A non-zooming (fixed focal length) macro lens is chosen with goals to produce the least anatomic distortion and most consistent focus. For any given digital SLR camera, a lens should be chosen that captures anatomy in a way that approximates the optics of the human eye, thereby minimizing errors of perception in the clinical setting. We have chosen the Nikkor 65mm Macro Lens and have not been able to discern any difference between our images and perceived reality. When the rotational axis of the platform is placed a minimum of 60 cm in front of the backdrop, subjects can rotate freely through all clinically relevant body and limb positions without having arms hit the background during rotation. A fixed distance of 4 meters from the rotational axis to the camera's sensor plate ensures that anatomy is digitally captured at a fixed reproduction ratio. The tripod-mounted camera then is leveled and adjusted in a left-right direction to ensure that the barrel of the lens and the platform's rotational axis create a line that is perpendicular to both the anatomic plane and the backdrop. Focus is obtained by having the subject press a metric ruler firmly against the skin of the upper abdomen, allowing the autofocus mechanism in the camera to find and fix on this standardized location. Autofocus is then turned off, so the lens is fixed, preventing errors of reproduction ratio in the final imagery.

In order for the lighting to appear natural, the shadows should fall downward (Vetter 1992). Overhead studio lighting should be fixed at 45° lateral to the rotational axis and 45° above the imaginary plane that passes through the optical center of the lens and the subject's umbilicus. Point sources of light in the strobes (without diffusion or reflective umbrellas) create shadows that best mimic natural sunlight. Supplemental lighting is necessary to fill the shadows inevitably created by the overhead lighting, so that anatomic detail is captured. Unfortunately, top-mounted flash creates harsh shadows that further block anatomic detail. Side-mounted (unilateral) flash creates unwanted asymmetry and data-blocking deep shadows on the side of the body opposite the flash. We have found that ring flash that surrounds the lens circumferentially is the best choice, providing subtle symmetrical fill-light for shadows and the slight 'flattening' of the appearance of the anatomy does not overpower volume perception created by the overhead lights if the power ratio of the overhead to ring-light is 2:1 or less. In our experience, the combination of overhead point sources of light combined with the Nikon SB-29s ring flash at full power consistently gives superb volume rendition and adequate anatomic shadow details. Before the imaging session begins, the photographer should confirm that the camera and flash batteries are fully charged. Stopping an imaging session to change batteries can throw the camera out of register and destroy critical focus, while low battery power can lead to inconsistent exposures if the photographer fails to realize that a "ready-light" has not illuminated. In our experience, devastating errors of exposure can be eliminated if fresh or newly charged batteries are used each time. This also ensures that recharging time is minimized to allow the rotations to happen as quickly and safely as possible.

Subject/Patient Imaging

Upon arrival, consent for imaging is obtained, then the subject is provided with a loose-fitting robe and is asked to remove all clothing and jewelry in complete privacy. Once the subject has changed, the photographic procedure is explained, and questions any questions are answered. It is important to explain that, because each position has its own set of advantages and disadvantages (**Table 2**), the photographer must capture three full image sequences to ensure visibility of all undistorted surface anatomy—one with arms down in the neutral anterior position, one with arms down in the neutral posterior configuration, and one rotation with arms elevated. During the dialog and studio preparation, elastic and other clothing marks should dissipate. Ask the individual being imaged to step onto the rotating platform and position both feet so an imaginary line connecting the great toes is parallel to the front edge of the base. (**Figure 1**) Ensure the subject's center of gravity is directly over the central axis of the turntable, usually by balancing the weight between both feet. Basic studio setup is shown in **Figure 2.**

Figure 2. The standardized setup can be integrated into an existing office or clinical space, here with only the tripod needing to be disassembled to permit normal traffic flow within the room. The relative positions of the backdrop, turn-table, imaging subject, the assistants, overhead lights, tripod, camera, lens-mounted ring flash, and photographer can all be seen. Importantly, patients or imaging subjects should always be given the option of a chaperone to enhance comfort and safety. In the depicted research project, a female subject underwent standardized torso photography once a week throughout her entire pregnancy to document volumetric expansion and anatomic changes in focal fat pad anatomy. A female member of the research group served to rotate the platform and the subject selected a male member of the team as her dedicated chaperone. With concerns about getting light-headed during imaging, this gentleman's size and strength gave the woman reassurance, as he was assigned specifically to watch for signs of a vaso-vagal response (pallor, sweating, glazed eyes, or decreased alertness) that could indicate that she was about to faint. Although he never needed to intervene, he was poised to respond quickly to protect the woman and her developing baby. As shown, a fan can also decrease the likelihood of a vasovagal fainting response. This documentary photograph was taken by Joe Ciarrocchi in 2014.

With robe on, ask the subject to assume a comfortable upright posture, but not rigid or forced, and with the shoulders relaxed. Using a tape measure to ensure accuracy, determine the distance of the umbilicus from the floor, and adjust the tripod up or down so the optical center of the lens is at the exact level of the center of the umbilicus. Finally, check the positioning in the view finder. This standardization format should capture all relevant anatomy for the great majority of subjects – extending from the chin to mid-calves in all but the very tallest of subjects. Only in the rare extremely tall individual will it be necessary to obtain several supplemental views (AFTER the standardized sequences are complete) to capture the distal-most portions of the lower extremities. With one end of a meter-long ruler resting on the rotating platform, focus is obtained by having the subject press the other end of the ruler against the anterior inferior rib cage. The center-weighted auto focus or the photographer's eye (in manual focus mode) can use the 1 mm divisions on the ruler to obtain focus. If autofocus was used, focus is then locked (or turned to Manual Mode) once focus is obtained and is not adjusted again throughout the imaging session.

Allow approximately 45 minutes for each photographic session. Immediately prior to taking the first image, the robe is removed. The use of modesty garments is not recommended as they interfere with anatomic visualization in full-torso imaging and circumferential tracking. As an example, in the field of plastic surgery, circumferential body contouring is quickly becoming the standard of care, usually with attention to the buttocks, hips, inner thighs, and the pubic mound. Covering anatomic sites that will undergo surgical treatment or be tracked for changes over time cannot have coverage (Gherardini et al. 1997, Teplica and Bundy 1996). Imaging subjects should be told that their images do not include faces.

Table 2. Advantages and Disadvantages of the Three Imaging Positions.

3 Arm Positions	Advantages	Disadvantages
Neutral Anterior With arms down and in the back	Provides accurate view of the subject's shoulders, chest, abdomen, and lateral portions of the flanks.	Blocks accurate view of subject's lower back, buttocks, and the lateral contours of flanks and latissimus dorsi.
Neutral Posterior With arms down and in the front	Provides accurate views of the subject's posterior deltoids, trapezius, lower back, and buttocks.	Blocks accurate view of the subject's lower abdomen, groin, and the lateral contours of the latissimus dorsi.
Arms Up With arms in salute position and arms in the plane of the chest	Provides accurate view of arms and legs. Allows 3-Dimensional visualization of the torso without visual obstruction caused by the arms.	Distorts the perception of the subject's anatomy, with chest flattened from pectoral stretch and flanks smaller than normal, stretched out of neutral.

All images in every sequence should only be taken after the subject gently exhales to ensure consistency and because the process of inhalation/exhalation alters the nipple-areolar position significantly. (**Figure 3**) In addition, the act of exhalation allows surgeons to consistently document native anatomy without muscular contraction, as it tends to cause relaxation of other muscle groups. Moreover, photographing at exhalation memorializes the least flattering views of a surgical patient's anatomy, both before and after surgery. This practice contrasts with the unfortunately common and *anatomically deceptive* technique when pre-operative views are obtained at expiration and post-operative views are captured at inspiration, thereby falsely enhancing perceived surgical changes. Once set-up is complete and test images have been obtained to ensure appropriate positioning, lighting, focus, and exposures, the subject is asked to remove the robe, and final adjustments are made to confirm that hand and body positions are correct. Take the first photograph at the "neutral anterior" position (other hand positions are described below). Proof the camera image to ensure that posture is truly vertical and that the body does not torque to the left or right. Pelvic and shoulder girdles twisted unwittingly and imperceptibly, but the entire anterior planar surface of the body must be perpendicular to the long axis of the lens to enhance the standardization process. Hips or chest may have to be rotated to have the anterior surface planar and without twist. Coach the subject through positional adjustments and ask that they hold the position throughout the rotational sequence.

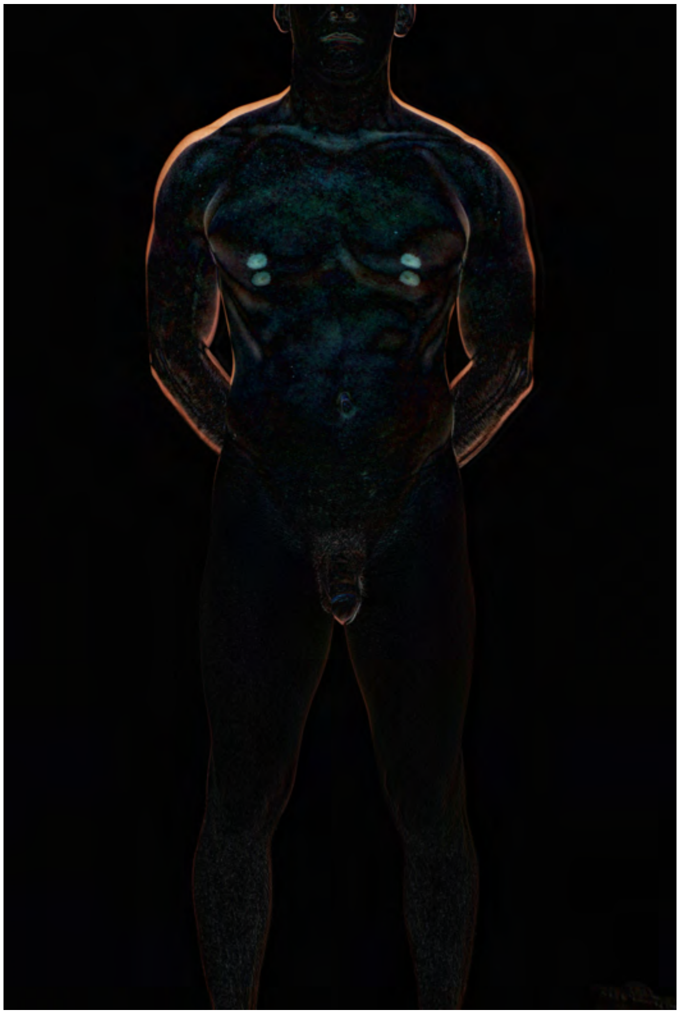

Figure 3. Digital subtraction shows the significant positional change that occurs in the chest and shoulders between inspiration and expiration. Complete disappearance of the abdomen and lower extremities indicates that there is no significant anatomic variance in the lower half of the body with respiration. However, the dramatic change in nipple position and shoulder height reinforces the need to capture all clinical photographs at average expiration –not forced or maximal– if one is imaging the upper half of the body.

Figure 4. Arm and hand positions for the "neutral anterior position" for unobstructed capture of the front half of the body. The subject stands erect with relaxed shoulders, a straight back, and with weight evenly distributed between the feet. Hands hang freely in the midline atop the buttocks, with the left hand loosely cupped inside the right.

Figure 5. Arm and hand positions for the "neutral posterior position" for unobstructed capture of the back half of the body. The individual being imaged stands erect with relaxed shoulders, a straight back, and with weight balanced between the two feet. Hands are placed atop each other over the groin, with the left hand cupped inside the right, although not holding or cupping the genitalia.

Ask the subject to close both eyes before rotating the platform counterclockwise to the 45° (right anterior oblique) view. Then, ask the subject to open the eyes and to gently inhale and exhale before the second image is taken. Closing the eyes during rotation helps maintain consistent anatomic position; inadvertent twisting often happens if eyes are open, as subjects tend to fix their gaze while being rotated. The head, neck, and chest tend to turn less than the lower half of the body, creating an anatomic twist that destroys standardization and renders post-surgical comparisons unreliable. The photographic session should proceed efficiently until all 45° incremental images are captured. Repeat the remainder of the complete imaging process as outlined stepwise in **Table 3**.

For the first rotation of torso imaging, the subject's hands overlap in the midline resting on the buttocks with thumbs in their palms and the left hand loosely cupped inside the right. This is the "neutral anterior" position. (**Figure 4**) For the second rotation, the subject cups the hands loosely over the groin, with thumbs in palms and the left hand inside of right, to establish the "neutral posterior" position. (**Figure 5**) The third standard position is "arms-up" (**Figure 6**) with a salute-like configuration with palms facing the floor, middle fingertips pressing against the skull just above the ears, and with the elbows in the plane of the chest. Three complete rotations – one for each hand position – document the entire skin surface of the torso circumferentially, permitting immediate and future anatomic evaluation, digital addition and subtraction of images for clinical or investigational purposes, or to document anatomic changes (when different imaging sequences are compared over time).

Figure 6. Arm and hand positions for the "arms up position" for unobstructed capture of the circumferential torso, albeit with stretch-distortion caused by arm elevation. (Left) Frontal view at 0°. Similar to saluting, the subject places his middle finger against his skull just above the helix of the ear. Palms are flat, facing the floor with thumbs against the index fingers and with elbows within the plane of the chest. (Right) Side view at 270°. This position places the long axis of the upper arm at 90° to the sagittal plane of the body and parallel to the floor.

To optimize comfort and propriety, never touch the nude subject, even if a third party is present, and do not look directly at the subject—restrict your viewing through the camera lens or onto the image screen. Before terminating the session, ask the subject to maintain the standardized position without moving while you cycle through all digital images to ensure proper image capture. Occasionally, an image must be retaken because of flash synch errors, air born dust flares, or if the subject unwittingly shifted position or if they were inhaling instead of exhaling. Errors can quickly be recaptured by rotating the subject to the correct station. Once the imaging results are satisfactory, hand the robe to the subject, then stabilize the platform, and extend a hand to help them step off the turntable, then ask the subject to redress as you leave the room. **Table 3** provides a detailed stepwise description of the process.

Imaging Results

Figure 7 shows a sequence of the most clinically most useful images (selected from the 3 rotations with 9 images each) that allow circumferential visualization of full body form. We recommend capturing a full image sequence with each of the three hand positions to thoroughly document body surface and shape, facilitating future anatomic analysis for the vast majority of scientific and clinical situations. Importantly, these same images also lend themselves to detailed quantitative comparison of anatomic change with time and for pre- and post-operative states in plastic surgical patients.

Figure 7. A composite image sequence of selected standardized views of the torso at 45° increments that allow complete visualization of the body form and the skin surface. Although all three hand positions were captured at each 45° station for the full rotation, this composite shows only those views that are deemed most clinically useful, chosen from each clinical station. Selection of appropriate hand positions will depend upon the anatomy being evaluated for any given subject. Alternatively, a composite could be created using all 12 views from each of the 3 rotational sequences.

Figure 8. Comparison of images captured by three different photographers at the 45° rotational increments as outlined in Table 2. The image-makers had vastly different levels of photographic skill and familiarity with the protocol. The degree of similarity is far beyond what is normally achieved in the best of hands without using a strict standardization protocol. The most obvious error of imaging was the failure of the medical student to place the hands in the correct position for visualization of the posterior anatomy. Most notably, the images captured by the photographically untrained office assistant (without knowledge of the protocol or goals) is nearly identical to the sequence obtained by the senior author (DT) with a 25-year experience refining the technique. Of interest, the medical model exhibits a significant degree of left hemicorporal microsomia with a shorter left torso, a smaller left buttock, a left leg shorter than the right, and with a resultant downward tilt to the pelvis and scoliosis of the spine, none of which were appreciated until the image sequences were assembled.

Table 3. Studio Protocol for Producing Full Torso, Highly Standardized Images

Check List for Studio and Equipment Set-Up

☐ 1. Ask the subject to remove all clothing and jewelry and put on a robe. It can take 15 minutes for unwanted elastic cinch lines to dissipate from the skin.

☐ 2. Confirm that the camera and flash batteries are either new or fully charged.

☐ 3. Position the turntable on the floor in the center of a large dense black backdrop measuring at least 1.33 meters in width and 2.0 meters in height. Use a tape measure to confirm that the axis of rotation of the platform is centered in the left/right direction.

☐ 4. Move the central post of the turntable (the rotational axis) to a position at least 70 cm in front of the back wall to prevent the subject's saluting arms from hitting the backdrop.

☐ 5. Lock the camera with a 65 mm lens (or a similar focal length that captures images with optics similar to the native human eye) onto the tripod. Use a long tape measure to place the optical center of the lens exactly 4 horizontal meters from the rotational axis of the platform.

☐ 6. Adjust the tripod's position in a left/right direction to ensure that the barrel of the lens and central post of the turntable create a line that is perpendicular to the backdrop. It is helpful to place marks on the floor or ink dots on carpet to ensure that the platform and tripod are always in the same fixed positions.

☐ 7. Place the camera in manual mode, activate the flash, and set the predetermined and constant aperture and shutter speed settings. With the Nikon SB-29s Flash at full power, *f* 10 and 1/100 of a second exposure, an excellent exposure is obtained at the 4-meter distance.

☐ 8. Begin creating the image sequences, following EVERY step in the tabular "Protocol for Photographer's Dialog and Actions". It helps to check off boxes at the completion of each step.

Check List Protocol for Photographer's Dialog and Actions for All Three Rotational Sequences with Differing Hand Positions: • *"Dialog with Subject" (in quotes and italics)* • Actions (in plain text)	**Image Numbers**	**Rotational Station**
☐ 1. *"Please step onto the turntable."* ☐ 2. Stabilize turntable with one foot and assist the robed subject onto the platform with one hand. ☐ 3. *"With your big toes, create an imaginary line that is parallel to the front edge of the turntable."* ☐ 4. *"Please stand upright with your shoulders relaxed. Distribute your weight evenly between your feet."* ☐ 5. Check alignment of great toes, have subject move feet to align and to ensure that the center of gravity is over the central rotational axis. ☐ 6. Use a tape measure to determine the distance from the floor of the deepest point of the subject's umbilicus and adjust the vertical stem of the tripod, so the optical center of the lens is at the same distance to the floor. ☐ 7. Adjust the tripod's tilt handle until the leveling device bubble confirms the tripod stage is co-planar with the floor. This should place the upper border of the image at or above the level of the chin. The inferior-most point of capture will vary depending on subject height, generally cropping at mid-calf. ☐ 8. To obtain focus, ask the subject to balance weight equally between both feet and place a meter ruler with 1 mm marks flatly and firmly against the black robe on anterior inferior chest next to the midline. Temporarily place the camera into autofocus mode and take an image. In our experience, center-weighted focus consistently recognizes linear black marks on a light-colored ruler placed over the black robe. Alternatively, manual focus mode can be used with the same ruler. Check the image for crisp focus. Take the lens out of AF mode, if necessary, and retrieve the ruler. ☐ 9. A chair is placed off screen near the platform in case the subject gets light-headed. With your back turned, ask "Please remove the robe and toss it onto the chair." ☐ 10. *"Please place your hands behind your back, allow them to hang freely on your buttocks, and cup your left hand inside the right."* (Fig. 5) ☐ 11. Looking at the nude subject only through the viewfinder, check posture, weight distribution, and hand placement. Ask them to adjust, as necessary. ☐ 12. "*Please gently inhale then exhale."* Capture image #1.	1	0°
☐ 13. *"Please close your eyes."* ☐ 14. Rotate the turntable to the 45° station. ☐ 15. *"Please open your eyes and look at the dot."* ☐ 16. *"Please gently inhale, then exhale."* ☐ 17. Capture image #2.	2	45°

☐ 18. *"Please close your eyes."* ☐ 19. Rotate platform to the 90° station. ☐ 20. *"Please open your eyes and look at the dot."* ☐ 21. *"Please inhale and exhale and hold."* ☐ 22. Recheck position for true lateral (only one leg and one side of the chest visible). Adjust subject if necessary. ☐ 23. *"Please inhale and exhale and hold."* ☐ 24. Capture image #3.	3	90°
☐ 25. *"Please close your eyes."* ☐ 26. Rotate platform to the 135° station. ☐ 27. *"Please open your eyes and look at the dot."* ☐ 28. *"Please inhale and exhale and hold."* ☐ 29. Capture image #4.	4	135°
☐ 30. *"Please close your eyes."* ☐ 31. Rotate platform to the 180° station. ☐ 32. *"Please open your eyes and look at the dot."* ☐ 33. *"Please inhale and exhale and hold."* ☐ 34. Recheck position for symmetrical posterior view with balanced weight distribution. ☐ 35. *"Please inhale and exhale and hold."* ☐ 36. Capture image #5.	5	180°
☐ 37. *"Please close your eyes."* ☐ 38. Rotate platform to the 225° station. ☐ 39. *"Please open your eyes and look at the dot."* ☐ 40. *"Please inhale and exhale and hold."* ☐ 41. Capture image #6.	6	225°
☐ 42. *"Please close your eyes."* ☐ 43. Rotate platform to the 270° station. ☐ 44. *"Please open your eyes and look at the dot."* ☐ 45. *"Please inhale and exhale and hold."* ☐ 46. Recheck position for true lateral (only one leg and one side of the chest visible). Adjust subject if necessary. ☐ 47. *"Please inhale and exhale and hold."* ☐ 48. Capture image #7.	7	270°

☐ 49. *"Please close your eyes."* ☐ 50. Rotate platform to the 315° station. ☐ 51. *"Please open your eyes and look at the dot."* ☐ 52. *"Please inhale and exhale and hold."* ☐ 53. Capture image #8.	8	315°
☐ 54. *"Please close your eyes."* ☐ 55. Rotate platform to the 360/0° station. ☐ 56. *"Please open your eyes and look at the dot."* ☐ 57. *"Please inhale and exhale and hold."* ☐ 58. Recheck position for symmetrical anterior view with balanced weight distribution. ☐ 59. *"Please inhale and exhale and hold."* ☐ 60. Capture image #9. ☐ 61. *"Please hold your position while I check the images."* Review the sequence for focus, cropping, exposure, and correct posture. Recapture any image of concern.	9	360°
☐ 62. *"Now we are going to begin the second rotation with your arms in front. Please move your left hand with its thumb in the palm to a position over the groin and place your right hand with its thumb on the palm over the left. Make sure your weight is still evenly balanced between your two feet."* (Fig. 6) ☐ 63. *"We are now going to repeat the entire sequence with this new hand position."*. ☐ 64. Repeat steps numbered 12 to 61 above.	10 -18	0° - 360°
☐ 65. *"Now we are going to begin the third rotation with your arms in a modified "salute" position. Please raise your arms and salute the tops of your ears, pressing both middle fingers against your scalp, just above your ears. Please make your palms flat and have them face the floor, with your thumbs against your index fingers, and elbows within the plane of your chest. Make sure your weight is still evenly balanced between your two feet."* (Fig. 7) ☐ 66. Check for symmetry and balanced weight and make sure the elbows are within the plane of the chest. ☐ 67. *"We are now going to repeat the entire sequence with this new hand position."*. ☐ 68. Repeat steps numbered 12 to 61 above. ☐ 69. Check that all images in all three sequences are perfect, if necessary, recapture any image of concern. ☐ 70. *"Thank you for your patience and cooperation. Please place this robe on."* ☐ 71. Hand the robe to the subject without looking at them. Assist if necessary. Finally, stabilize the turntable with one foot and assist the subject as they dismount the turntable. ☐ 72. Exit the room with the camera while the subject dresses.	19 -27	0° - 360°

The technique is incredibly consistent and reproducible as seen in the composite illustration. (**Figure 8**) A direct comparison of unaltered photographs obtaining using the imaging technique by three individuals with vastly different levels of photographic experience and training is presented. As shown, remarkably similar outcomes (less than 1.7% error in all measured axes) can be achieved, whether the photographs were captured by a completely untrained office staff member, an individual with minimal photographic experience, or by a professional with both photographic and surgical training.

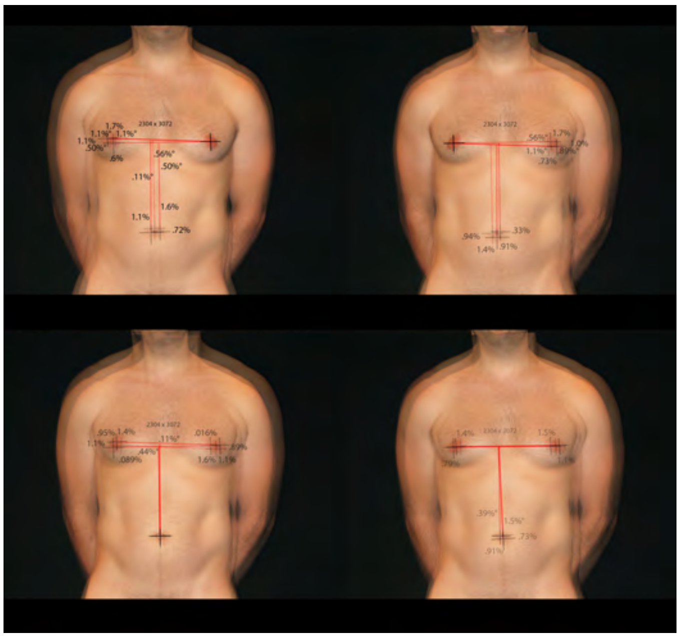

Figure 9. Analysis of variance in image capture by the three photographers in Figure 8 who had different levels of photographic experience and familiarity with the imaging protocol. The percent variances shown in each image correspond to the alignment of the following points: top left: left nipple; top right: right nipple; bottom left: umbilicus; and bottom right: the alignment of the points where the inter-nipple line and a vertical line from the umbilicus meet. All image variances are less than 1.7%, well within limits for valid scientific analysis, while image variance in CT and MRI can be as high as 10%.

Figure 9 shows image variance (error) analyses when four separate anatomic points of reference were held constant (left and right nipples, mid-point of the chest, and the umbilicus). Image overlay allowed quantification of rotational error and positional differences. The average vertical error among all four anatomic points of reference was 0.69%. Average horizontal error amounted to 1.2%. Overall, the average positional error (horizontal and vertical) was 1.0%. Average angular (rotational) error was calculated to be 1.2 degrees (0.65%). If desired, variance in anatomic size can also be calculated using this method, although it is not shown in this sequence.

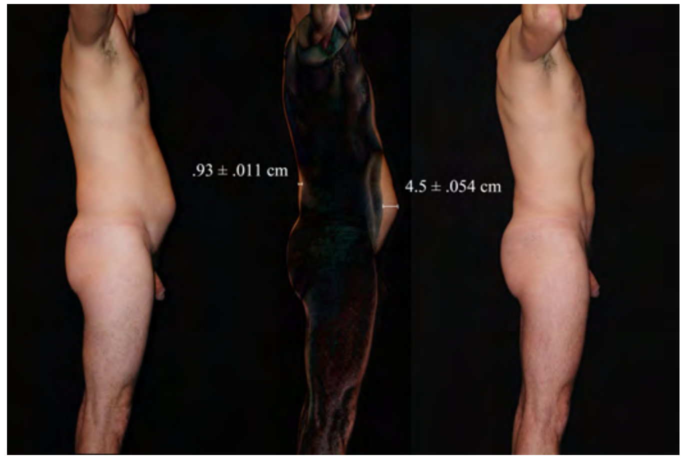

Figure 10. (Left) Preoperative view. (Right) Postoperative view. (Middle) Digital subtraction analysis of highly standardized "Before and After" photographs, illustrating how actual surgical change can be quantified with high confidence.

Comments and Considerations

This paper presents the first description of a stepwise, highly standardized protocol for photographically capturing human anatomy over a full 360° rotation in a reproducible way. The protocol functions well in the world of medicine and surgery for a variety of patient-care applications where quantification of changes would be useful: (1) evaluating a single patient over time to document surgical changes from the pre- to the post-operative stages (**Figure 10**); (2) documenting disease progression; (3) assessing changes in developmental anomalies over time; (4) making valid, quantitative circumferential comparisons between surgical patients; (5) tracking anatomic aging; (6) documenting and analyzing changes in body form caused by hormonal change; and many more clinical situations.

Absent strict standardization, anatomic imagery is only anecdotal, but highly standardized rotational photography provides an enormous cache of reproducible data for the complex analysis of anatomy and anatomic change. Following the stepwise set-up presented and using the protocols outlined, a wide range of image-makers can quickly start producing superb imagery with little anatomic variance. If all variables are held constant -- except for the actual anatomic changes – the photographer can utilize existing software (such as Adobe Photoshop) for the detailed analysis of 3-dimensional form and the quantification of change with small amounts of error that are calculable and acceptable. Surgical outcomes, the effects of pharmaceuticals, disease progression, human growth and development, and the process of aging would all be informed by real anatomic data. To optimize results and reproducibility, we recommend that the protocol, as outlined in **Table 3**, be followed at every photographic session.

On rare occasions, an imaging subject may experience a vaso-vagal episode during the photographic process, especially if knees are "locked" in a parade-like stance. We recommend that the subject be informed in advance to immediately let the staff know if they are feeling light-headed or nauseated and that the imaging session be terminated immediately and that the session only be re-launched once the subject is hydrated and stable.

Direct transfer of the images to a tethered computer monitor allows the subject to see that face and identity are not being captured and permits the photographer to immediately inspect and correct any visible lapses in standardization. Also, we highly recommend that a GretagMacbeth color card (or similar) be incorporated into the first image taken of any subject to allow for tracking of color consistency or for color correction, if necessary. In an effort to better standardize the issue of inspiration/expiration and timing the shutter to happen only after expiration, we are considering having the subjects audibly exhale at each station, so the image can be captured only after that sound has been heard. Those exhalations must only be small and modest to prevent the subject from blowing off too much carbon dioxide and becoming dizzy from hypocapnia. Finally, with concern for the safety of the imaging subjects, we offer and provide an assistant/chaperone to stand off to the side (out of the field of capture) as indicated. It is rare for young subjects to need assistance, but elderly, pregnant, or disabled individuals routinely reassured and helped by an assistant who provides support.

Conclusions

It is possible to achieve highly standardized photographs of human torso anatomy with very little variance between imaging sessions using a standardized protocol and rotational imaging strategies as presented. The method described affords many new and exciting possibilities for anatomic discovery, data analysis, and the potential to quantify anatomic change over time, whether from aging, hormonal influence, disease progression, or surgical intervention. The method may also provide a more efficient and cost-effective way to promote visible light imaging in healthcare delivery systems, like that in the United States, where insurers are reluctant to reimburse for the service.

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Disclosure

None of the authors has any financial disclosures or any other conflicts of interest regarding materials, products, or methods described in this paper.

Photographic Consent

Paid medical models were used to develop and test the mechanical and digital imaging systems described in this paper and provided consent for the reproduction of their information and imagery. The one surgical patient depicted in Figure 10 gave written consent for the use of his de-identified information for research, education, and publication purposes.

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