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Puget Sound Region

October 17, 2016

Mr. Ric Gillespie
TIGHAR
2366 Hickory Hill Road
Oxford, PA, 19363

RE: FORENSIC ESTIMATION OF AMELIA EARHART'S RADIUS TO HUMERUS LENGTH RATIO

Dear Mr. Gillespie,

I understand that there is an independent research track that needs Amelia Earhart's radius to humerus length ratio. This report describes the process used to forensically estimate this ratio from historical imagery.

Approach. Locate a photograph of Earhart in which at least one arm is largely visible, and is substantially in the same plane that is orthogonal to the camera. Correct any distortions in the photographs. Correct any measurement confounders.

Methodology. A photograph was located showing at least one arm of Earhart that is largely visible. Earhart is standing such that her arm is both substantially in the same plane, and orthogonal to the camera (Figure 1). The left arm will be used because position of the elbow is better imaged which will aid with the control of estimation error.

Figure 1. Photograph of Earhart with her left arm largely visible.
(Photograph Earhart-Arm.jpg)

The ratio of the radius to the humerus is a dimensionless calculation. To perform the calculation, the lengths of the radius and humerus must be estimated. To do so, the starting and ending points of each bone must be estimated. Because there is tissue over the skeleton in living people as seen in Figure 1, the location of each bone end must be estimated. Because the radius and humerus terminate in a shared location at the elbow, a total of three landmarks are required: The humeral head, the distal radius, and the shared location of the humerus and radius in the elbow. Cartilage is located where the humerus and radius meet in the elbow. Estimation of this landmark is ratio neutral, so there is no need to create separate landmarks for the humerus and radius at the elbow.

Confounders. The location of the humeral head is masked by both tissue and clothing. The elbow is better imaged in the left arm than the right arm. The presence of tissue, and its characteristic plasticity, means that the location of landmarks can be estimated, but not conclusively determined. The radius rotates around the ulna. There can be differences in the measurement of the radius based upon the rotation of the wrist and its projection onto the image plane.

Distal Radius. Figure 2 is a radiograph of a normal wrist which shows the relationship of the soft tissues to the skeleton. The distal end of the radius can be estimated by measuring from where the radius and hand meet, causing maximum inward deflection of the soft tissue.

Figure 2. Radiograph of a normal wrist.
(Case courtesy of Dr. Craig Hacking, Radiopaedia.org, rID: 37931)

Elbow. Figure 3 is radiograph of a normal elbow. The manner in which the humerus and radius meet in the joint is visible in the radiograph. The maximum deformation of the tissue corresponds with the tissue creasing located in the inner elbow. The shared landmark will be estimated by the location of the center position of the tissue crease.

Figure 3. Radiograph of a normal elbow.
(Case courtesy of Dr. Craig Hacking, Radiopaedia.org, rID: 37494)

Shoulder. Figure 4 is a radiograph of a normal shoulder. Both the humerus, other bones, and tissue are visible in this radiograph. The location of the humeral head can be estimated by projecting a horizontal line from the tissue 45 degree tangent line.

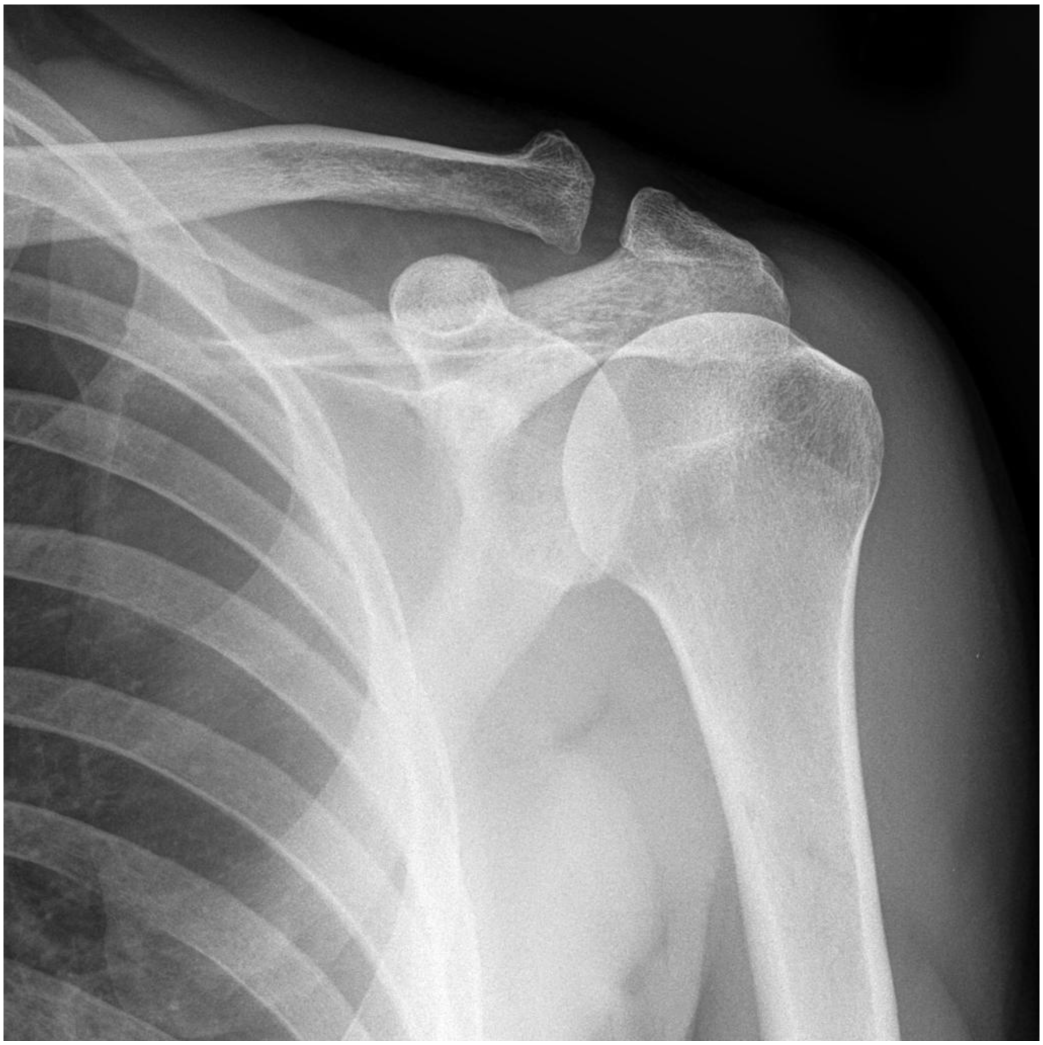

Figure 4. Radiograph of a normal shoulder.
(Case courtesy of A. Prof. Frank Gaillard, Radiopaedia.org, rID: 7505)

Correction. Figure 1 is rotated 3.7 degrees clockwise, and is corrected by a 3.7 degree counterclockwise rotation.

Landmark Locations. The landmarks are shown visually in Figure 5 and numerically in Table 1. The humeral head is located by finding the 45 degree tangent line of the cloth and tissue, and then projecting horizontally inward. The elbow is located at the center of the tissue crease in the inner elbow. The distal radius is located at the maximum inward deflection of tissue where the hand and wrist meet.

Landmark	**x location** (pixels)	**y location** (pixels)
A: Distal Radius	672	1064
B: Elbow	662	797
C: Humeral Head	640	446

Table 1. Landmark locations of Figure 5.

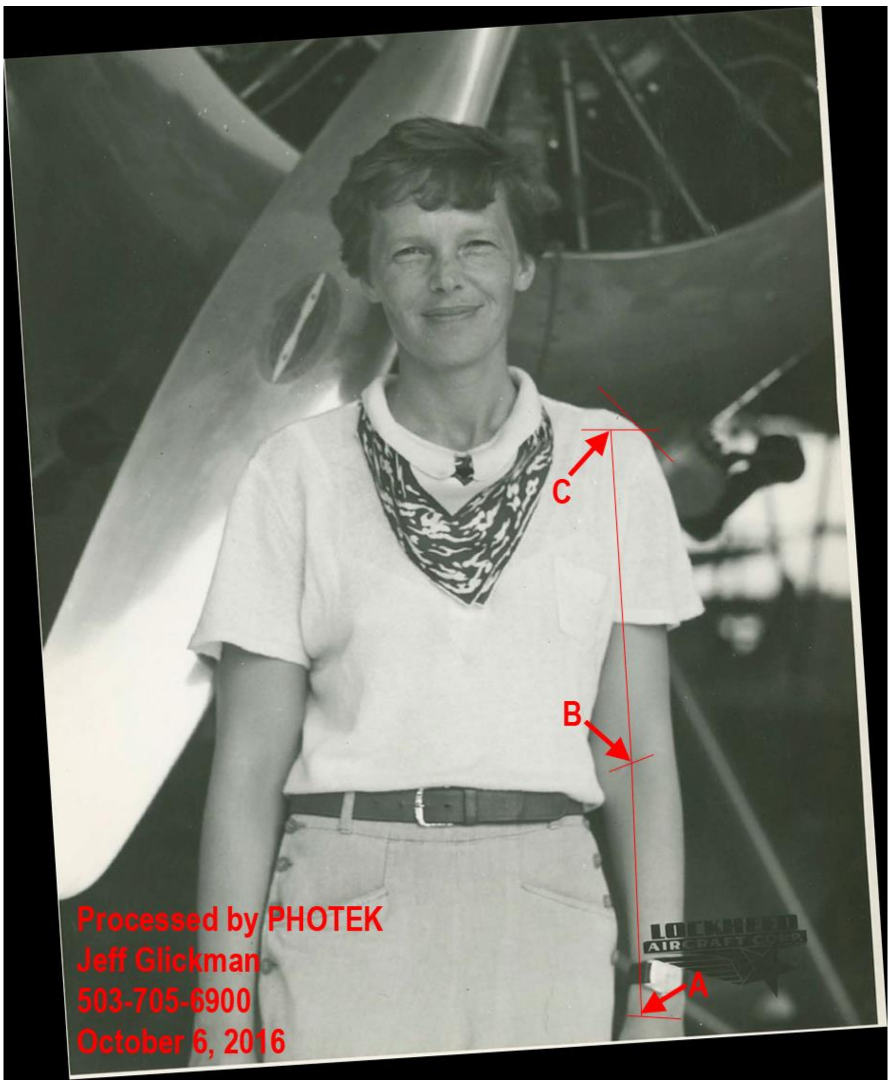

Figure 5. Annotated image of Amelia Earhart showing landmarks.

Humerus and Radius Lengths. The humerus and radius length can be calculated from the data in Table 1 by applying the Pythagorean theorem. The radius is 267.2 pixels and the humerus is 351.7 pixels.

Radius to Humerus Ratio. The radius to humerus ratio is 267.2 / 351.7 = 0.76.

Error Analysis. Traditional error analysis cannot be done when landmark positions are estimated.

Conclusion. Given the evidence and my experience in the field of photogrammetry and photointerpretation, I estimate that the radius-to-humerus ratio of Amelia Earhart in Figure 5 is 0.76. My estimate is based upon the facts that I have received and I reserve the right to revise my report should new information become available.

Sincerely,

Jeff B. Glickman, BSCS, BCFE, FACFE, DABFE
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