Computer-Aided Forensics: Metal Object Detection

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Problem

Modern X-RAY Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) scanners are capable of providing high-resolution cross-sectional images of the interior of human bodies. Forensic investigators have started using these diagnostic radiology devices to acquire image data from cadavers.

The emerging field of Computer-Aided Forensics (CAF) uses image analysis techniques to locate and analyze foreign objects within virtual autopsies. The virtual autopsy, has the potential to provide a low cost, non-invasive alternative or supplement to conventional autopsies.

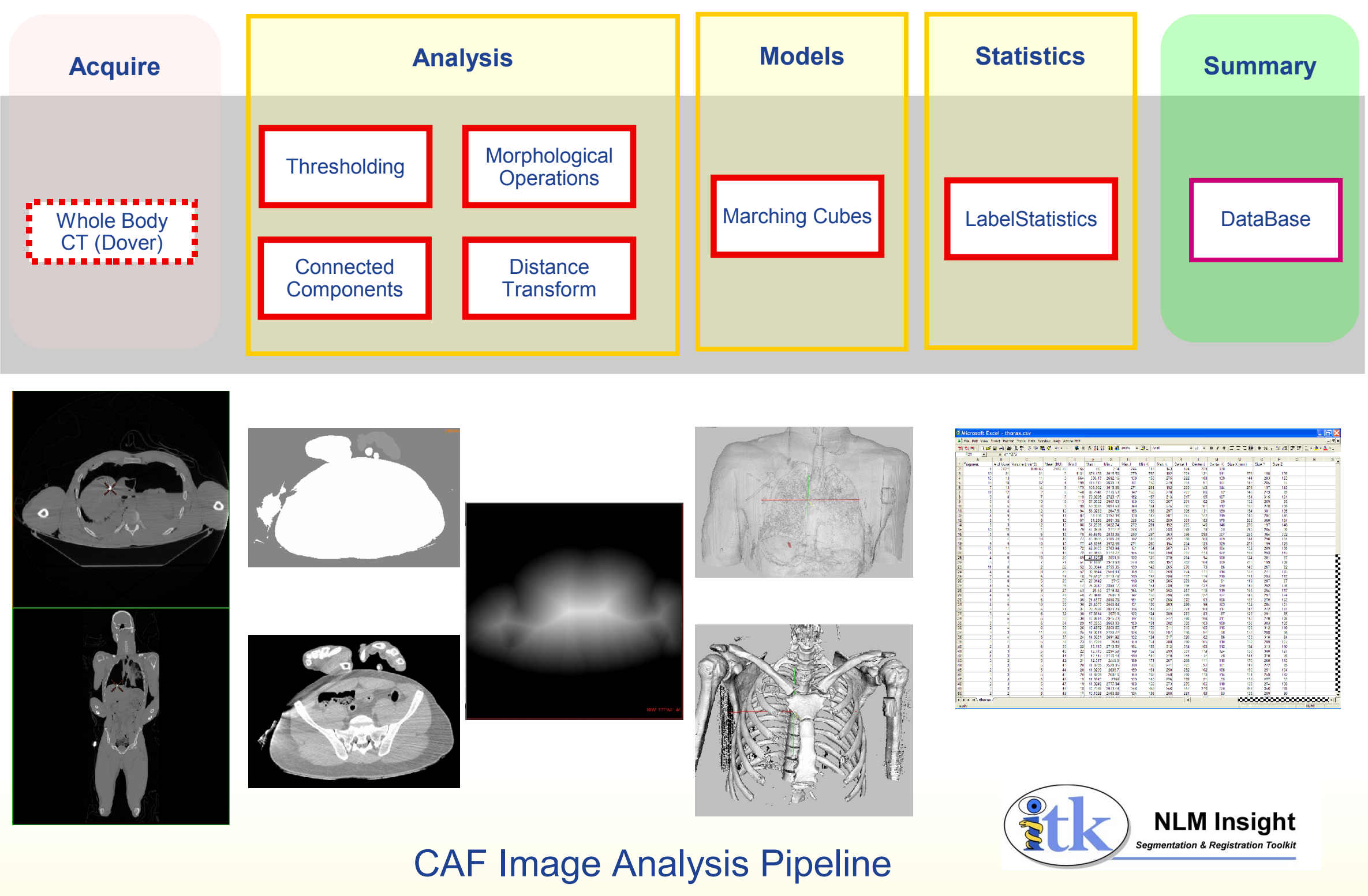
Method

The virtual autopsy begins with a whole body CT study (GE Lightspeed 16, GE Healthcare Technologies). The exams are constructed with .625 mm pixels and slices spaced 1.25 mm. The data is transferred to a radiology workstation (GE Advantage Windows) for review by radiologists. For CAF processing, we transfer the studies to Linux and Windows workstations using DICOM protocols.

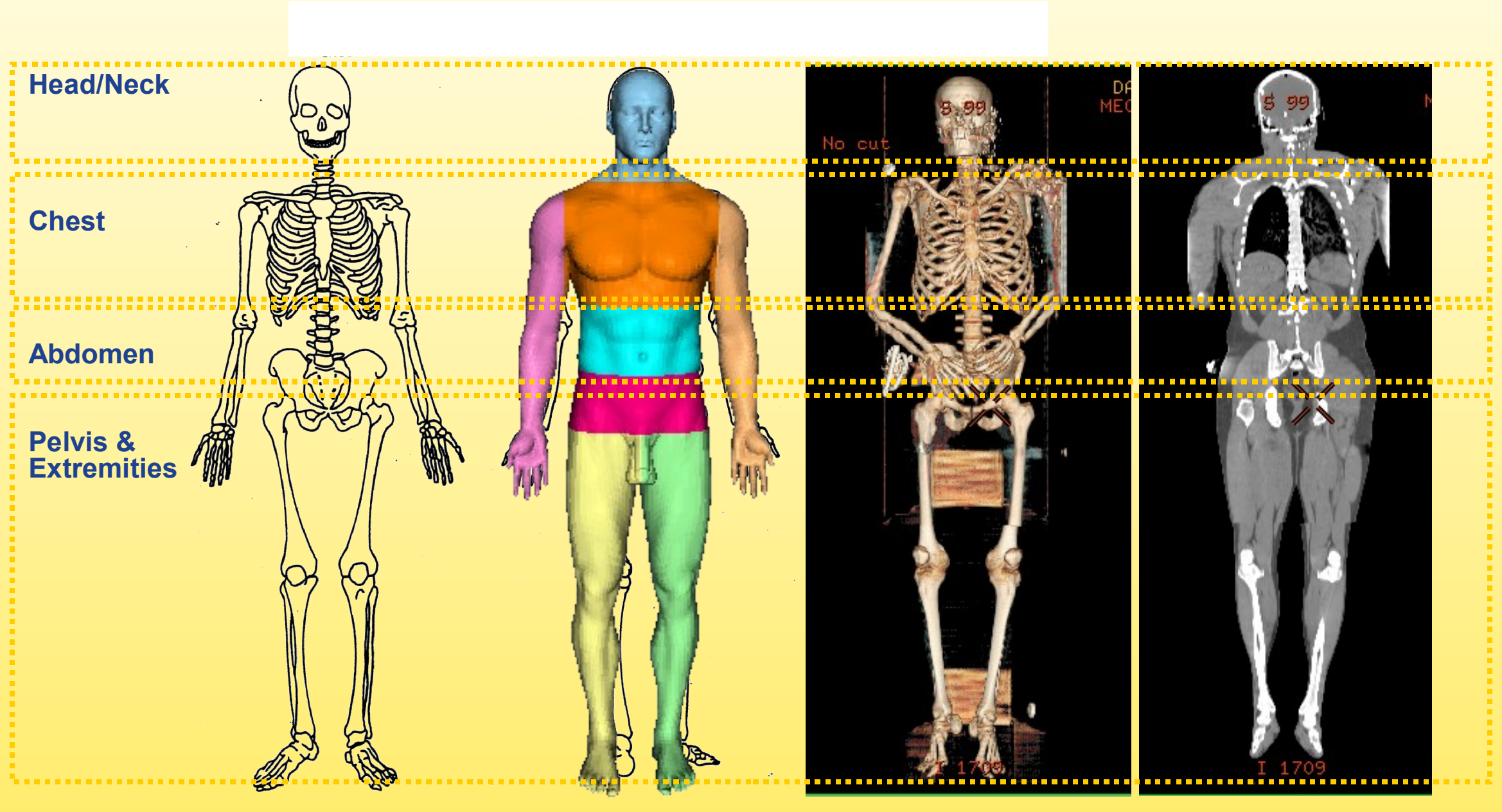
This CAF application analyzes metal fragment location, size and distribution. The first step of this CT-CAF process locates the body within the images. We generate a body mask using thresholding, masking, and connected component labeling. Next, morphological operators followed by another connected component algorithm segment the remaining objects. The statistics of these objects are then classified to decide if they represent parts of the body or foreign objects contained in the field of view.

We apply the body mask to the original gray-scale CT data and identify all voxels that exceed 1900 Hounsfield units. This value is sufficiently above any densities that exist naturally in the human body to distinguish the metal from the body. Statistics are computed for each group including location, size, mass and orientation.

We adapt a posable model (Stickman) to each individual using deformable registration. Each metal object is associated with these regions.

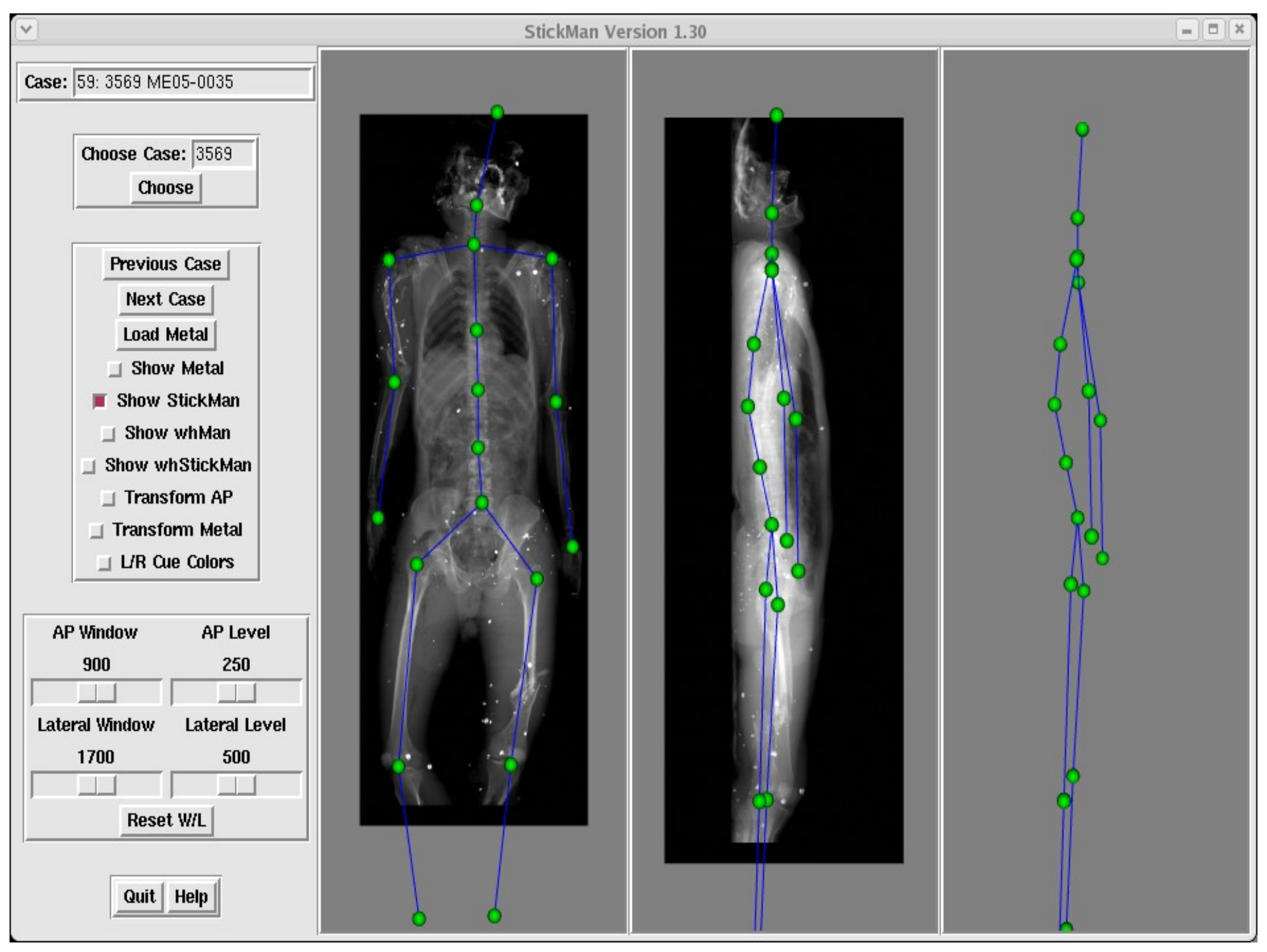

Acquire
Whole Body CT (Dover)
Analysis
Thresholding
Morphological Operations
Connected Components
Distance Transform
Models
Marching Cubes
Statistics
LabelStatistics
Summary
DataBase

CAF Image Analysis Pipeline

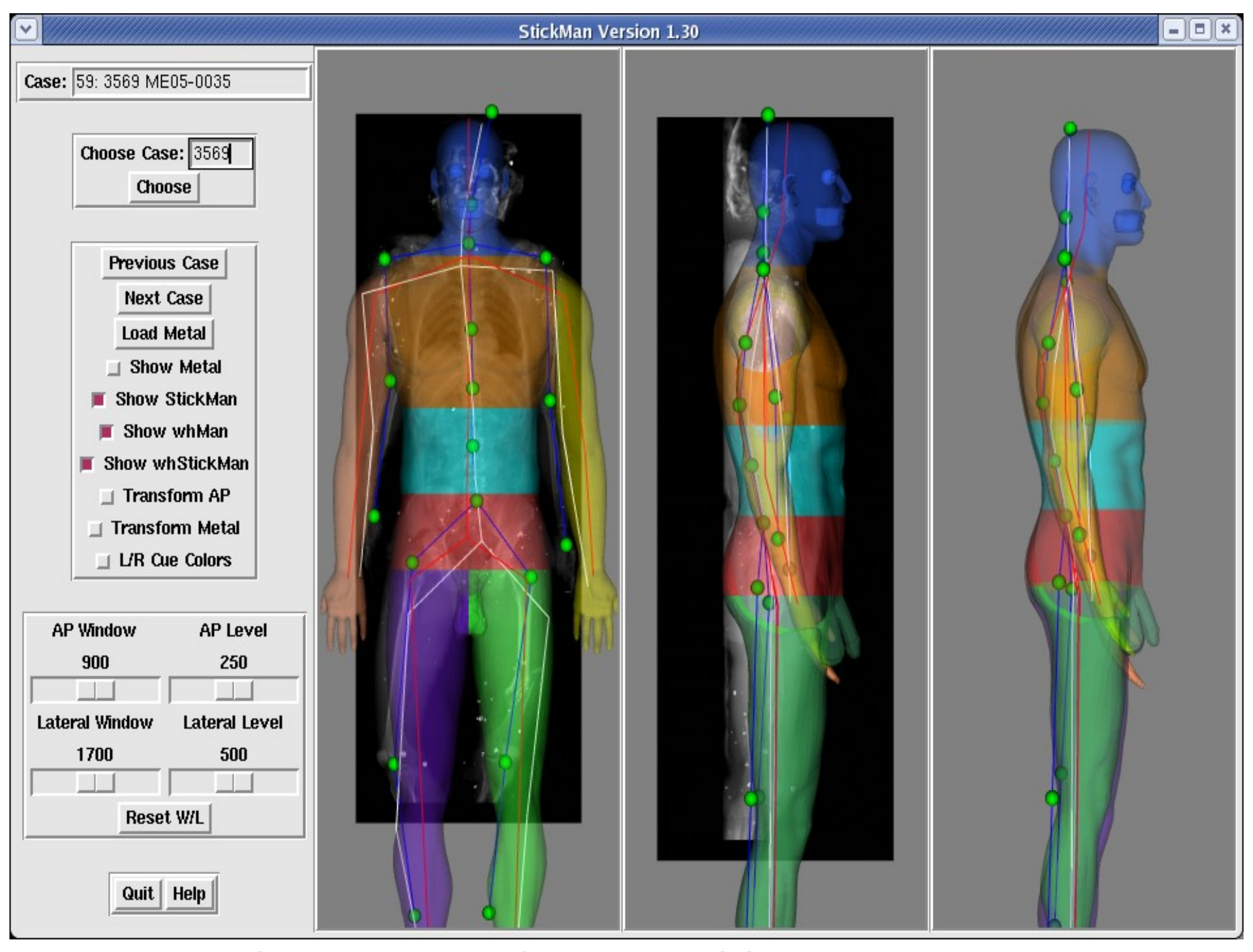


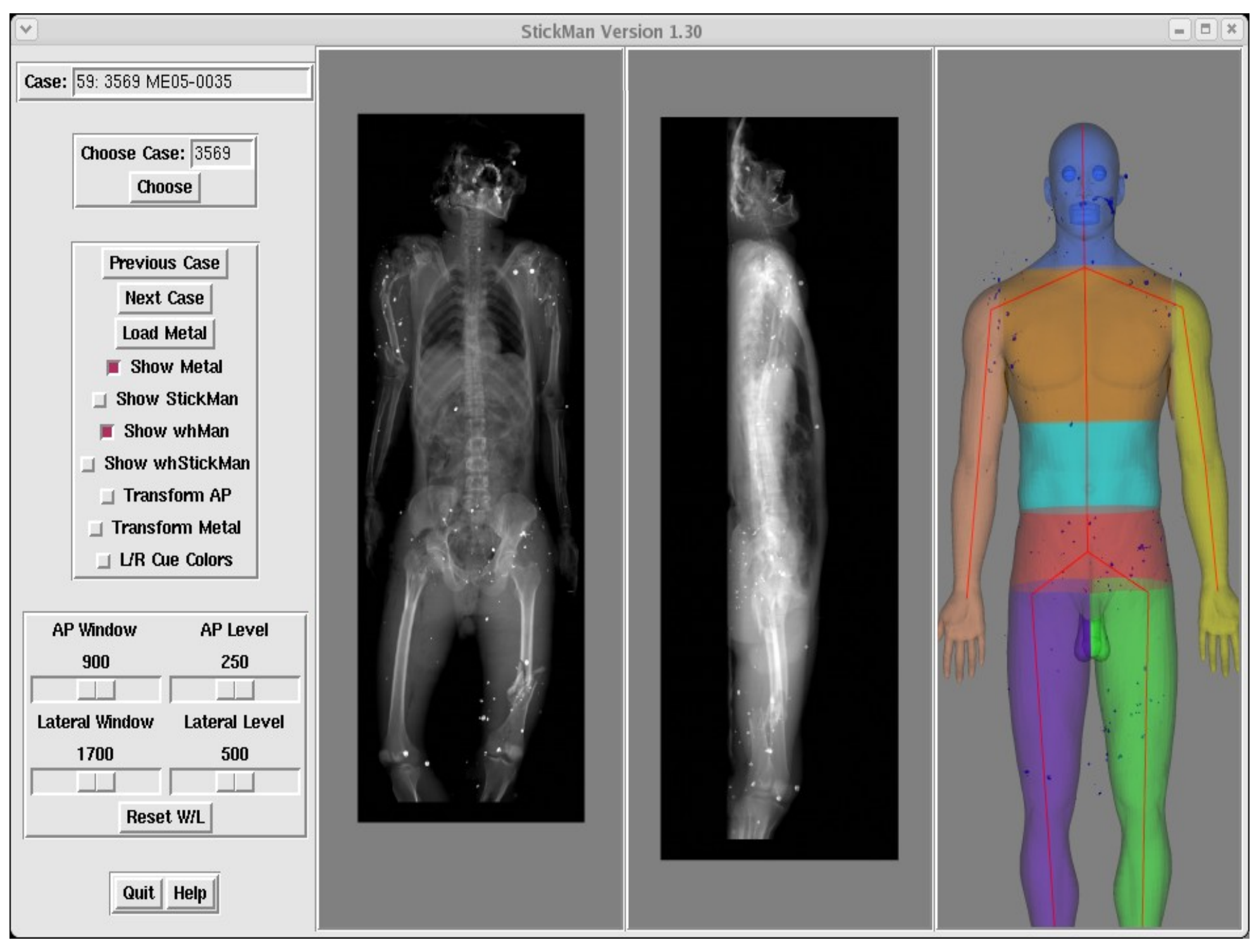
Injury Severity Score (ISS) Definition of Body Regions

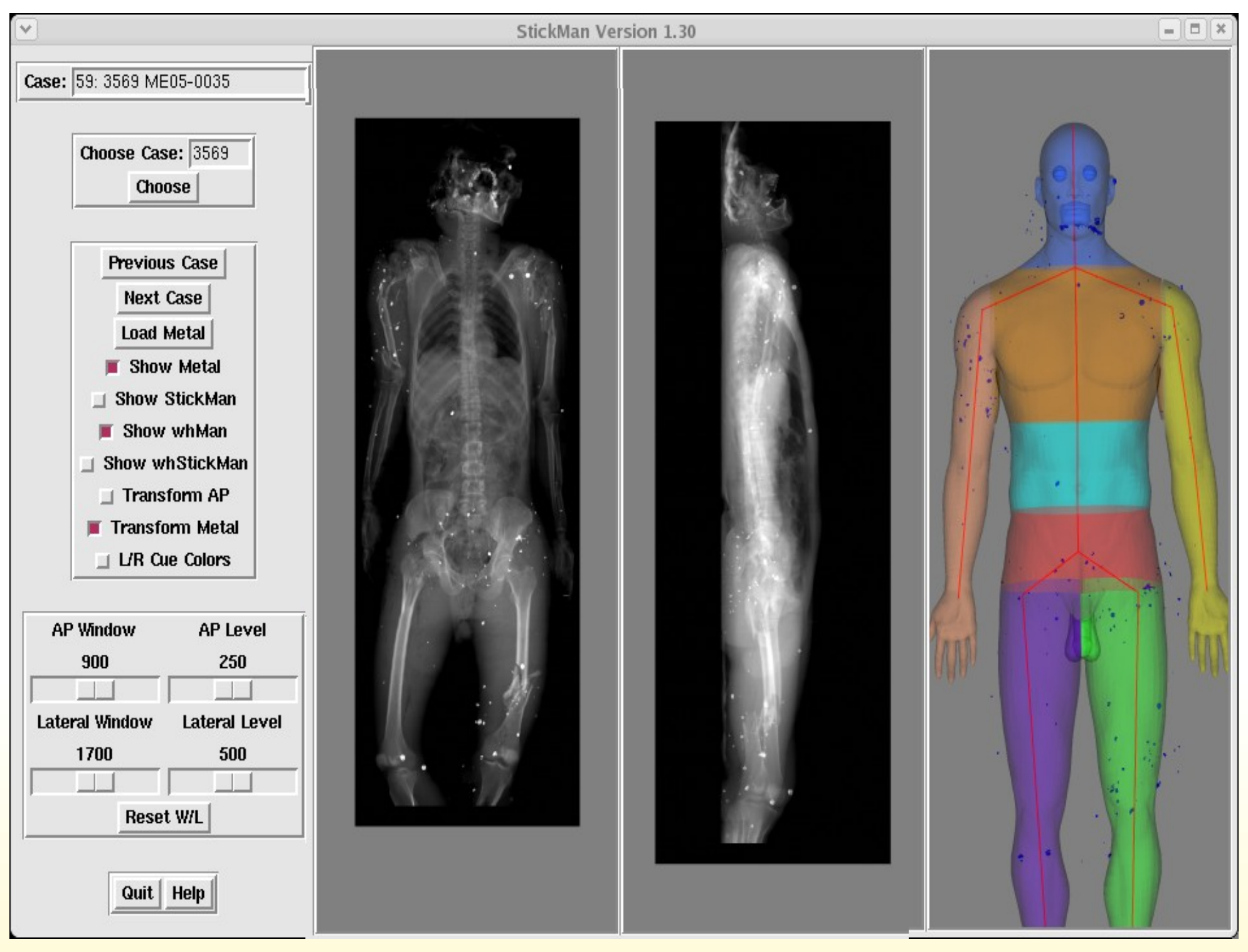
Stickman was developed to aid subject to ISS reference registration. A canonical stickman serves as the reference. A subject stickman is interactively posed to match the scan data. Deformable registration is used to warp the subject to the reference frame.The segmented metal can be viewed in the Stickman interface is see the fragments in the reference context.

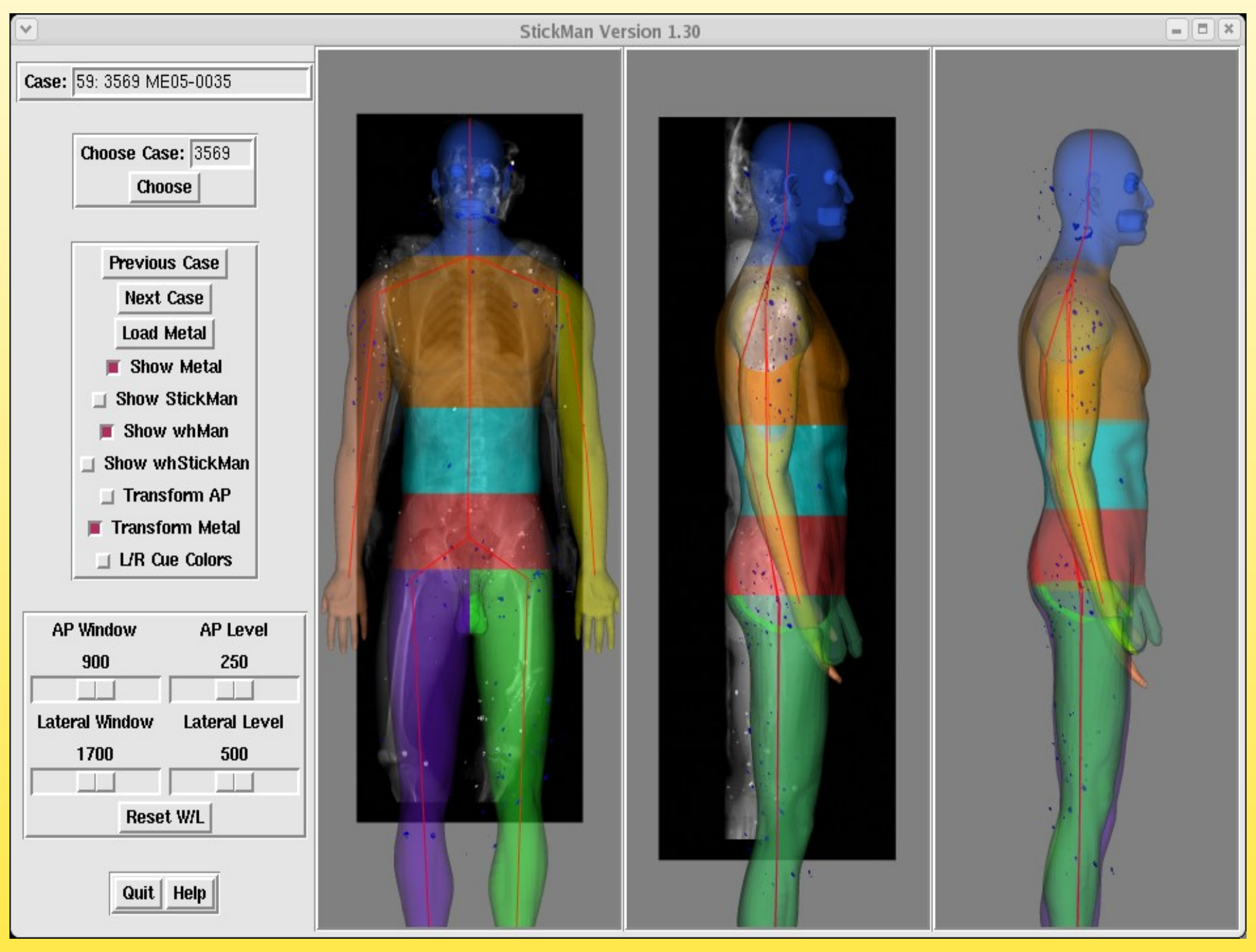


Stickman posed to match the individual


Stickman transformed to ISS coordinates.


Metal before transformation.

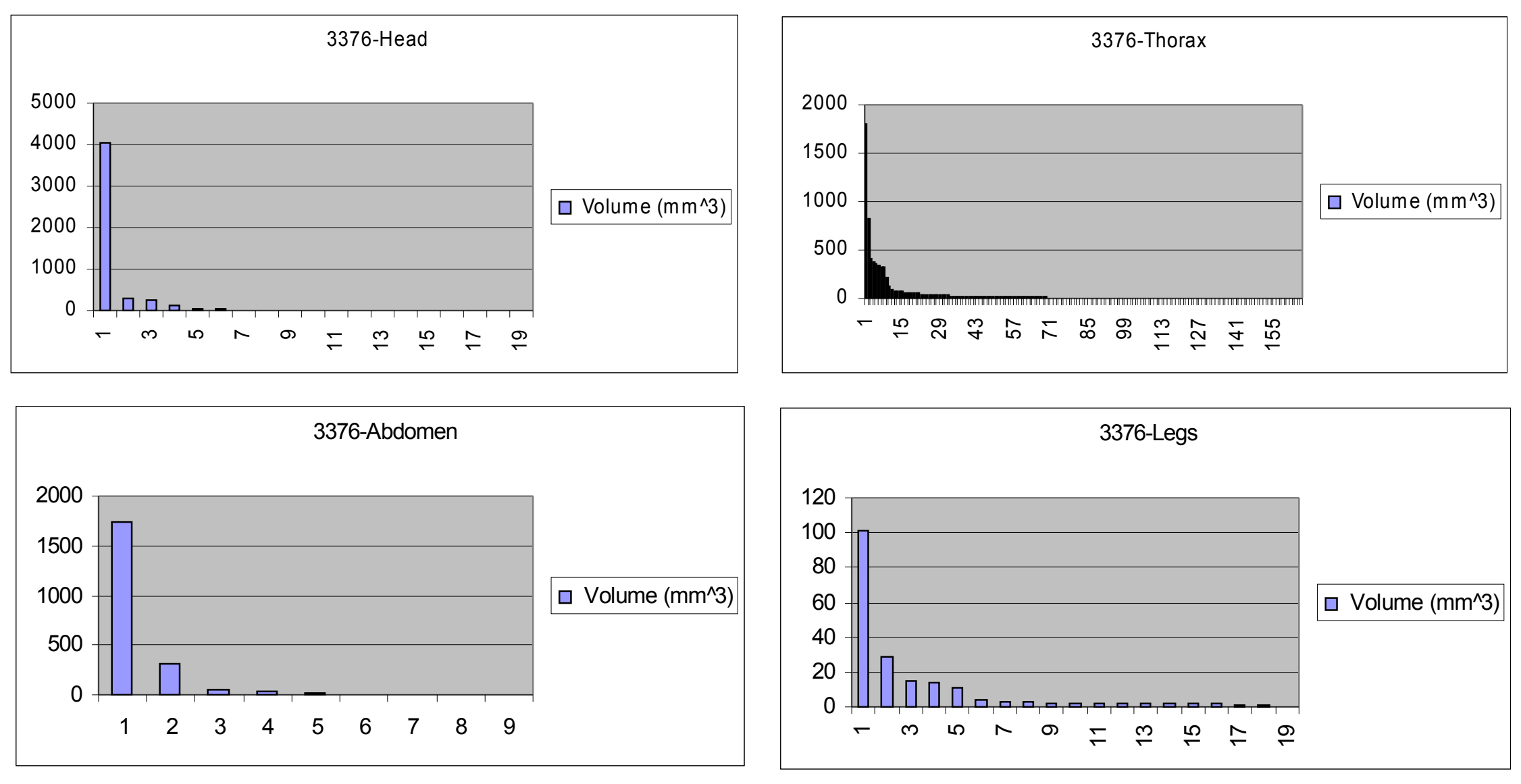

Metal transformed to ISS coordinates.


Lateral view.

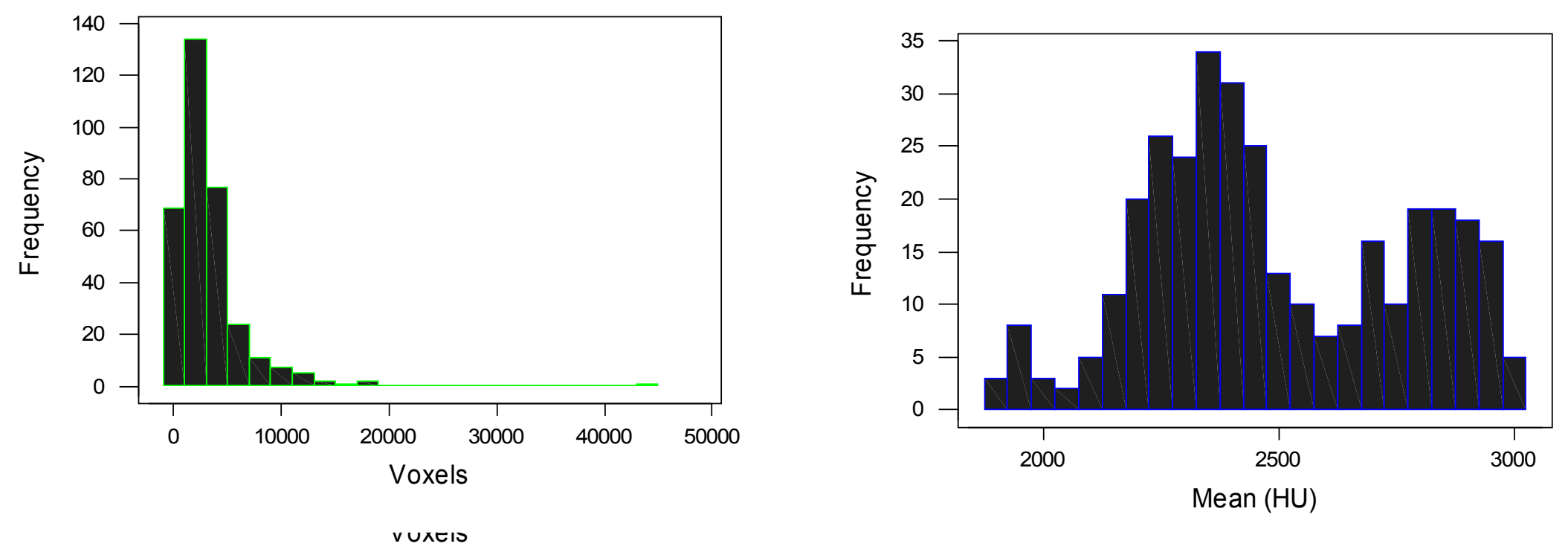
Results

We have run the metal fragment extraction on hundreds of virtual autopsies containing anywhere from zero fragments to more than 2000 metal fragments.

A number of statistics are computed for each group including location, size, mass and orientation. We have created an atlas of the human body, dividing the body into head, neck, thorax, abdomen and upper/lower extremities. We adapt the atlas to each individual using deformable registration. Each metal object is associated with the atlas regions. The quantitative results are exported in a form suitable for database insertion.



Fragment size histograms by region.

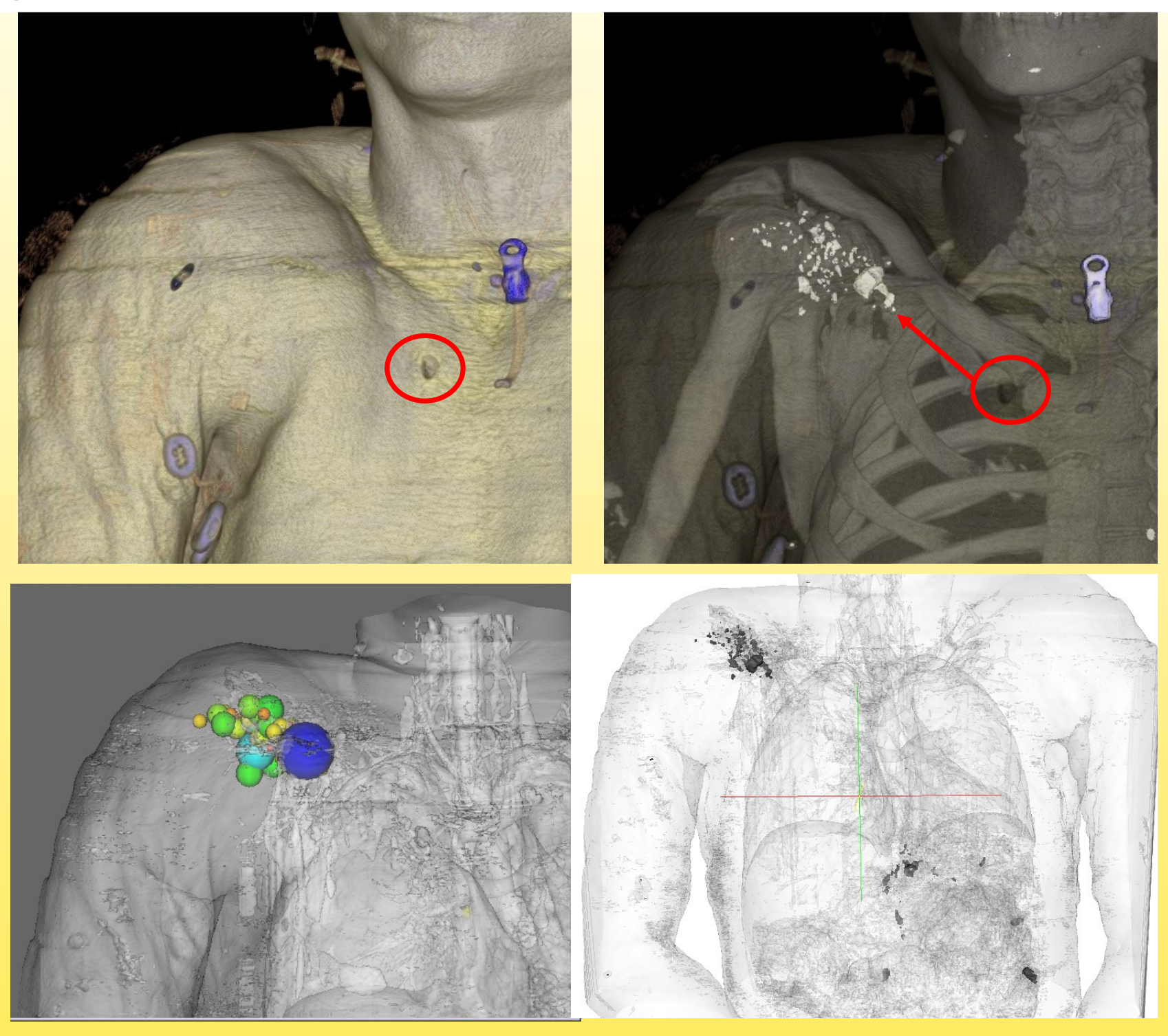


Population statistics for fragments in the head.

For each subject, we create a digitally reconstructed radiograph, DRR in both lateral and AP views. The DRRs are used later in the process both as a quality control check to ensure proper mask generation and as a visualization aid in displaying the extracted metal.


Visual index of the Digitally Reconstructed Radiographs, (DRR).

Results for a single case are shown below. In this case, the individual had a gunshot wound to the right shoulder as well as abdominal wounding. This example had 78 metal objects. The size of the metal objects varied from 1 mm to 14 mm. A distinct clustering of fragments is seen in the shoulder where the projectile hit the bone and fragmented into many pieces.


3D Visualization of metal distribution: Upper two are volume renderings; lower two are surface renderings.

This work was supported by a grant from DARPA, executed by the U.S. Army Medical Research and Materiel Command/TATRC Assistance Agreement, Contract # W81XWH-05-2-0059.