Supplemental Methods

Pulmonary Contusion Measurement. A computerized, semiautonomous method for quantifying injured lung volumes has been previously described and published by our institution.\textsuperscript{1,2} These methods were initially developed using positron emission tomography (PET) and CT scans to quantify pulmonary pathology in rats subjected to a direct lung impact. The pathological contused lung volumes coupled with experimental impact data were used to validate an injury prediction model of rat lungs by means of imaging-based finite elements, also known as segmentation.

In the current study, a methodology similar to but unique from the initial approach for segmenting the rat CT data was used. In this newer approach, we created a computer-based model to isolate and differentiate normal from pathologic lung tissue on chest CT scan. This is a semi-automated, attenuation-defined approach designed specifically to segment CT scans in subjects sustaining blunt chest trauma.

Lung segmentations were performed in Mimics, Version 12.3 (Materialise, Ann Arbor, MI) using attenuation thresholds as well as dilatation and erosion operations; there was minimal manual editing. An attenuation threshold is a cutoff, defined in Hounsfield units (HU), which separates normal-appearing lung parenchyma from non-normal parenchyma. Dilatation and erosion operations are software tools which allow more precision in separating normal from non-normal-appearing lung, right at their apposition. Parameters defining the attenuation thresholds as well as the dilatation and erosion operations varied slightly from those used by Daly and associates.\textsuperscript{3} The attenuation thresholds used in the current study are in line with HU thresholds reported in the literature for nonaerated, poorly aerated, and normally aerated lung tissue.\textsuperscript{4}
In the segmentation process, the total chest cavity was first isolated, and then volumes of low-attenuation, lung-attenuation, and high-attenuation tissues are defined. Detailed steps of the segmentation of the total chest cavity are as follows: 1) A voxel within normal lung tissue is chosen and voxels within 200 HU of this chosen voxel are selected. 2) Dilatation and subsequent erosion by 10 voxels is performed to enclose small cavities. 3) Manual editing is used to ensure the entire chest cavity is selected. 4) The low-attenuation volume representing air is isolated by selecting voxels of -1024 HU within the total chest cavity. 5) The high-attenuation volume representing PC is isolated as follows: 5a) An attenuation threshold is applied to select voxels within the total chest cavity between -562 to 3071 HU; 5b) Erosion and subsequent dilatation by 1 voxel is performed to remove small edges; 5c) Dilatation and subsequent erosion by 1 voxel is performed to enclose small cavities; 5d) Manual editing is used to ensure all PC is selected. 6) The lung-attenuation volume corresponding to normal lung tissue (-1023 to -563 HU) is isolated by subtracting the low-attenuation and high-attenuation volumes from the total chest cavity mask. 7) The percentage of high-attenuation tissue can then be calculated for each patient relative to the lung-attenuation volume. This percentage of high attenuation tissue corresponds to the area of PC (Figure 1). Figure 1, A1-D1, is an automatic 3D rendering of the lung, with left pulmonary contusion, using software for CT image viewing. Figure 1, A2-D2, is the same patient’s lungs depicting our model’s segmentation results; defining the high-opacity tissue in blue (also known as high-attenuation tissue) allowed for calculation of percent contusion.

For the current study, lung tissue was classified based on opacity/attenuation alone, and therefore high-attenuation findings such as atelectasis and aspiration were not separated from PC. Concomitantly, pneumothorax was isolated as the low-attenuation volume in the CT scan.
analysis; pneumothorax volume was subtracted from the total lung volume so that the percentage of PC was taken relative to the normal lung tissue.

References:


FIGURE 1