Fig. 2 Fused PET/CT images. *Left* fused attenuation corrected CT and regular PET images. *Right* fused amplitude gated phase matched PET/CT images

compared to the sharp amplitude-gated phase matched PET/CT image where the functionally active image pixels closely surround the outline of the line detector.

Conclusion

We have presented an approach for low radiation motion-free PET/CT guided biopsy. Our preliminary results with a moving Anzai phantom show the qualitative improvement of our approach over the standard PET/CT image protocols. After further testing, we plan to begin a clinical trial using this technique. IRB approval for this clinical trial has already been obtained.

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A quantitative method for mosaic gas trapping based on residual mass

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Keywords Air trapping · Biomarker · Computed tomography · Registration

Purpose

Air trapping is a pathophysiologic condition indicating the retention of excess gas in all or part of the lung at any stage of expiration. Expiratory CT has been used to reveal air trapping in patients with airway diseases such as pulmonary emphysema, chronic bronchitis, asthma, and small-airway disease. Air trapping can be classified as extensive and mosaic. Extensive gas trapping is characterized by well-defined low attenuation areas in expiratory scans. Mosaic air trapping is characterized by the appearance of inhomogeneous air emptying on expiratory compared to normal inspiratory chest CT scans. A number of quantitative chest CT methods have been proposed to assess extensive gas trapping [1, 2], however those methods fail to detect the diffuse nature of mosaic gas trapping. We have developed an approach to tackle this problem and we have validated the technique in a population of World Trade Center workers with abnormal lung emptying reported by a radiologist [3].

Methods

The new quantitative approach is based on measuring the residual mass between the inspiratory scan and the expiratory scan registered into the inspiratory scan reference frame. When heterogeneous emptying of the lung occurs, the residual mass between the expiratory and inspiratory scans that cannot be accounted by the change in volume that take place can be used a metric for the amount of mosaic air trapping that may have occurred. The residual mass image is computed by subtracting the densities of the registered expiratory scan from the inspiratory scan and multiplying by the determinant of the Jacobian of the deformation between expiration and inspiration. The determinant of the Jacobian measures the change in volume that occurs due to the deformation of the lung. The registration between expiratory and inspiratory scans is performed using a diffeomorphic elastic registration implemented in ANTs [4]. The registration has three steps: linear translation, affine registration and diffeomorphic elastic registration following the approached proposed in [5]. The residual image is then defined as

$$\text{Residual Mass} = (I_{insp}(\mathbf{x}) - (T \circ I_{exp}(\mathbf{x}))|\mathbf{J_T})|\mathbf{J_T}|$$

where I_{insp} and I_{exp} are the inspiratory and expiratory scans respectively, T is the concatenated transformation and $\mathbf{J_T}$ is the Jacobian of the transformation.

The residual mass percentage (RMperc) is defined as the percentage of the lung whose residual mass is above a given threshold. For this study, we define RMperc100 as the percentage of the lung whose residual mass is above 100 mg.

Our approach was validated using a cohort of 24 former WTC workers. A radiologist visually assessed these subjects and the extent of abnormal air trapping was reported using a 0–4 scale for each lung region. A total scored was computed by summing the regional scores.

We reviewed a previously reported set of paired view chest CT scans on 29 former WTC workers [3]. Our method was compared against three other methods to assess extensive air trapping: (1) percentage of the lung whose expiratory attenuation was less than −856 HU (AT856) [2], and (2) the recently proposed functional small airway disease (fSAD) [1]. Our comparison was done at a global level (All) and for the upper, middle and lower lung regions.

Results

Figure 1 shows the residual mass map computed by the proposed method corresponding to one case with mosaic gas trapping. The correlation between the expert visual score for air trapping and each metric for each lung region is shown in Table 1. RMperc100 achieves the best positive correlation. It is worth noting that both AT856 and fSAD have a negative correlation with the visual score suggesting that these previously proposed quantities may not be suitable for mosaic gas trapping.

Figure 2 shows the mean metric value for each visual score level. RMpec100 mean value increases with increase level of severity. However, AT856 and fSAD show an inverse trend. All the methods report a mean value greater than 10 % for a baseline visual score of 0 suggesting that the methods are more sensitive to sublet changes than the visual assessment performed by the radiologist.

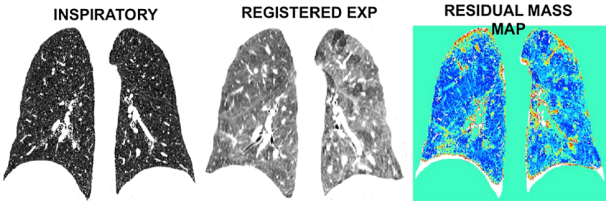

Fig. 1 Residual map image corresponding to a case with mosaic air trapping. More *blue* indicates a greater residual mass disparity suggesting air trapping

Table 1 Correlation between the expert visual score for air trapping and each metric for each lung region

Metric	All	Upper	Middle	Lower
RMperc100	0.744	0.723	0.851	0.579
AT856	−0.587	−0.44	−0.641	−0.49
fSAD	−0.579	−0.412	−0.638	−0.562

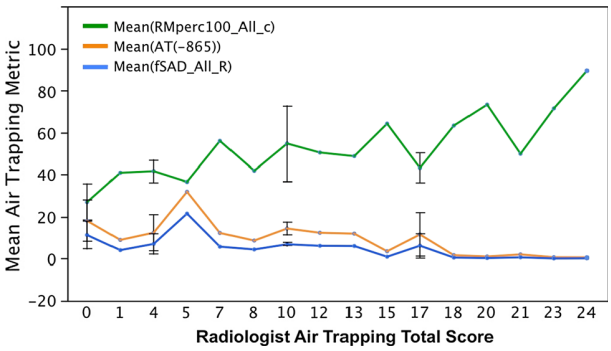

Fig. 2 Mean air trapping metric for each radiologist visual score level

Conclusion

We have introduced a method to objectively assess mosaic gas trapping based on the mass discrepancy between inspiratory and expiratory CT scans that cannot be explained just by volume change. The results of approach show that our method is highly correlated (greater than 0.7) with visual scoring done by a radiologist. In contrast, current proposed methods to quantify extensive air trapping show a negative correlation suggesting that they may not be adequate to capture mosaic air trapping. More work is needed to elucidate the pathophysiological meaning of the residual mass approach. Additional work is needed to quantify the range of normality for residual mass.

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Preliminary study on color micro optical-CT: evaluation of experimental system using biological samples

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Keywords Biomedical · Optical CT · Microscope · Color

Purpose

Optical computed tomography (CT) obtains a tomographic image using visible ray and near infrared ray unlike X-ray CT. Therefore, there are many advantages against X-ray CT. For example, there is no risk of radiation exposure. Furthermore, it is possible to design compact and inexpensive equipment. Optical-CT can be classified into two categories: one uses the reflection information and one uses transmission information [1]. In this study, we focused on the optical-CT employing the transmission information using visible ray. It provides a tomographic image using reconstruction algorithm similar to that of X-ray CT. This technique is intended for mainly inorganic such as the gel dosimeters used in radiotherapy [2], and objects that visible light is easily to transmit such as cells and tumors [3]. In particular, optical-CT for micro-object such as cells and tumors is called micro optical-CT. Since it is possible to obtain three-dimensional image easily, as well as undistorted, compared with tomographic image by the conventional sectioning method. However, existing micro optical-CTs output monochrome images; useful color information that we use at the time of observation has not been obtained. Therefore, the main purpose of this study was to develop a color micro optical-CT system to obtain the colored tomographic images. Furthermore, we also evaluated proposed system using color phantom and biological samples.

Methods

Our experimental system (Fig. 1) consists of digital single-lens reflex camera (Canon EOS 60D) and a trinocular microscope (Carton, DSZT-44FT). Observable sample size is in the range of 1.7–7.0 mm at the viewpoint of the depth of field. Magnification of the microscope can be changed between ×10 and ×44, and total pixel resolution of camera connected to the microscope can be changed between 0.7 and 3.1 μm by changing magnification. The sample was fixed in a test tube by the cellulose solution. The test tube was connected to a step motor; it was rotated automatically by motor driver. In order to obtain color slice image, the projection images were obtained from various projection angles by rotating the test tube. And then, the projection images were decomposed R, G, B components, and performed image reconstruction for each component using filtered back projection method. Finally, color tomogram is obtained by combining three-color component images. Here, these processing, were automated by computer program that was developed by Microsoft Visual C++ 2010.

Results

In the experiment, color phantom and color biological sample excellent in light transmission characteristics were scanned by our experimental system. Using phantom, the reproducibility of color and

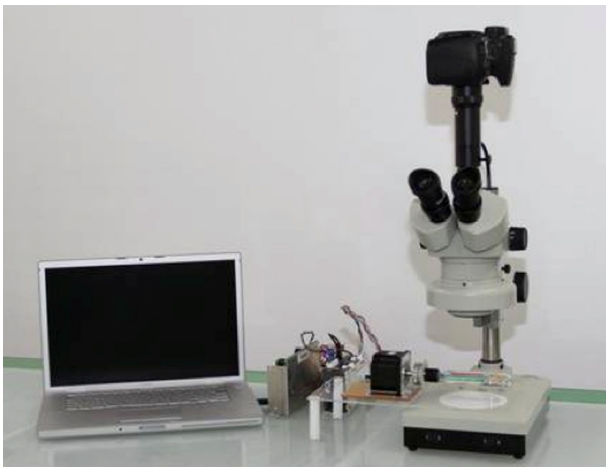

Fig. 1 Color micro optical-CT