3D Image Analytical Detection of Intussusceptive Pillars in Murine Lung

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Introduction

A variety of diseases can lead to loss of lung tissue. Currently, this can be treated only symptomatically. In mice, a complete compensatory lung growth within 21 days after resection of the left lung can be observed. Understanding and transferring this concept of compensatory lung growth to humans would greatly improve therapeutic options.

Lung growth is always accompanied by a process called angiogenesis forming new capillary blood vessels from pre-existing ones. Among the processes, the formation of tissue pillars within the capillary vessels (intussusceptive pillars) is observed. Therefore, pillars can be understood as an indicator for active angiogenesis and microvascular remodeling. Thus, their detection is very valuable when aiming at characterization of compensatory lung growth.

Materials and Methods

The mice's temporal regeneration process was to be investigated. For this purpose, first the left lung of all mice was resected. Second, the vascular system was casted with resin and the tissue was corroded. After this procedure, a plastic replica of the vascular system remains. In a third step, we imaged the vascular system by micro computed tomography using synchrotron radiation (SRμCT) with a resolution of 370 nm. Finally, we analyzed the resulting 3D images in order to detect and quantify pillars.

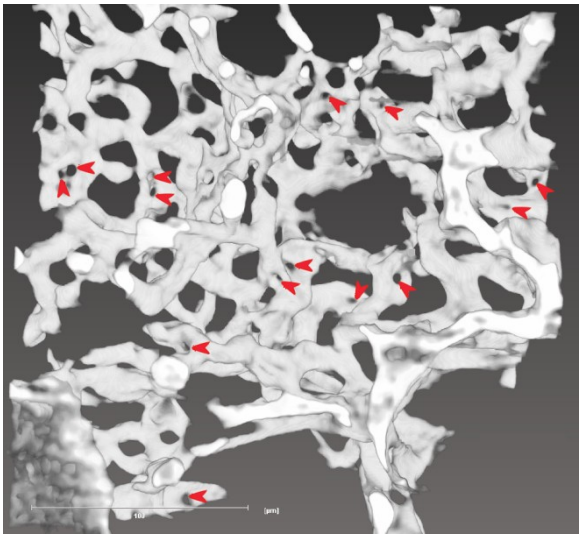


Figure 1. SEM image of alveolar capillary plexus with intussusceptive pillars (arrows) [3].

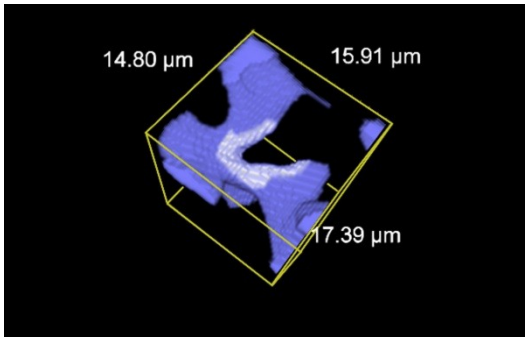
Results and Discussion

In a vascular corrosion cast, pillars appear as small holes that pierce the vessels.

So far, pillars were detected visually only based on 2D images as shown in Figure 1. We developed the first algorithm to automatically detect and quantify pillars. Automatic detection is essential in lung research, as manual pillar detection is not feasible due to the complexity and size of the 3D structure (see Figure 2).

Figure 2. Volume renderings of X-ray SRμCT images showing corrosion casts of blood vessels. The images were taken at beamline TOMCAT at Paul-Scherrer-Institut (Villigen, Switzerland)[5]. Visualization using MAVI software package [2]. Physical size: $(0.8\ \mathrm{mm})^3$, nominal resolution: 370 nm

The algorithm mainly consists of basic morphological operations to identify potential pillars. Using the Euler number [4] we are able to recognize pillars out of the set of potential pillars.



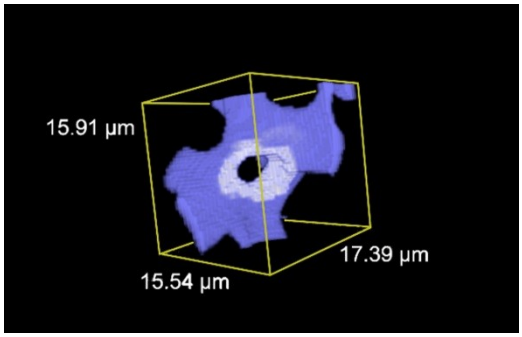


Figure 3. Volume renderings of examples of potential pillars. Using the Euler number, the algorithm correctly detects the right on as pillar and rejects the left one.

We validated our algorithm on two test sets, where we marked all pillars manually. This showed that our algorithm is able to detect more than 94% of the pillars.

Conclusion

A careful examination of the process of lung growth in mice may help to also force lung growth in human lungs. This is of great interest, especially regarding the treatment of lung-destructive diseases like cancer.

The number of pillars is an indicator for active lung growth and therefore crucial to investigate the growing process. Using our algorithm, several thousands of pillars can be detected automatically and subsequently analyzed e.g. regarding their spatial arrangement, size and shape.

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