MEASURING LUNG VESSEL TREE GROWTH DURING DEVELOPMENT IN PEDIATRIC PATIENTS

Aren Saini, Shruti Siva Kumar, Walter O'Dell

Departments of Radiation Oncology and Biomedical Engineering, University of Florida, Gainesville, FL

I. INTRODUCTION

- More than one in ten babies are born prematurely, leaving them highly vulnerable to infections and other complications.[1]
- One of the more serious complications is the lack of lung development and functionality. Often times, these children are put on respirators to increase the probability of survival.[2]
- The use of a respirator is highly problematic. There is little to no data that specifically pinpoints when it is safe to take a child off a respirator; thus, if a child is removed too soon or too late, it can result in serious complications.

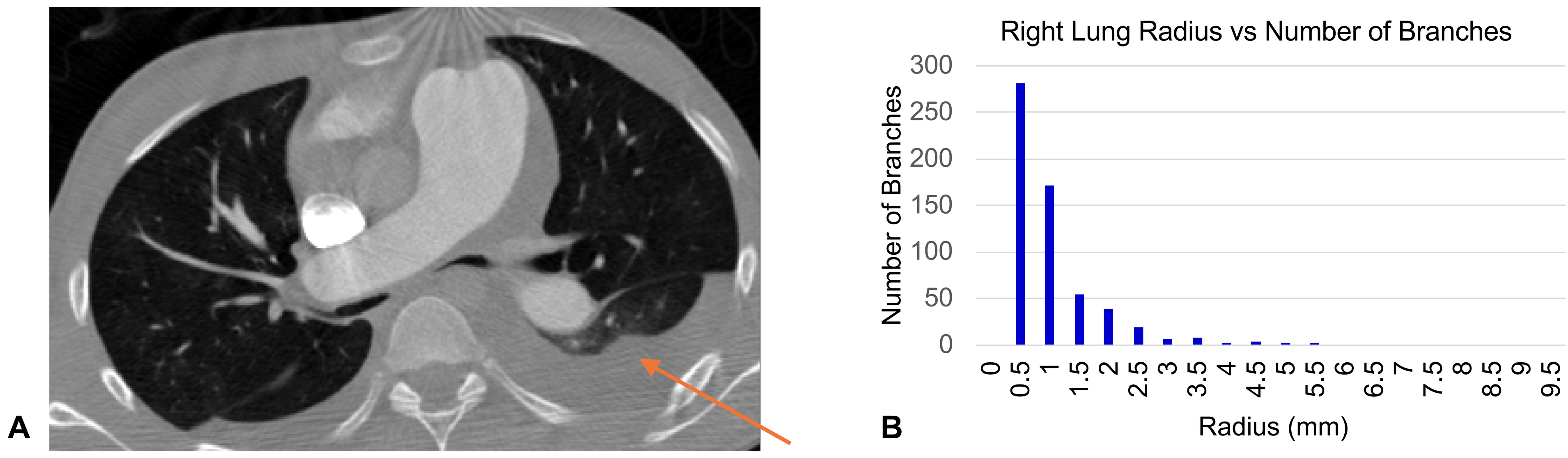

Figure 1: Representative pediatric lung appearance and metrics. Often times, one or more of the patient's hemi-lungs is affected by edema and/or plural effusion as is most pronounced in this patient's left hemi-lung (arrow). The number of branches per radii size was computed for this patient's right hemi-lung.

Hypothesis: By documenting the normal, healthy growth of lung vasculature tree structure as a child ages, we will be able to better determine whether a prematurely born patient's lungs are adequately developed to safely remove him/her off a respirator.

OBJECTIVE: To quantify the pulmonary vasculature branch structure and branch radii increase during development in pediatric patients.

II. METHODOLOGY: IMAGING AND SKELETONIZATION

CHEST CT IMAGE ACQUISITION and LUNG VOLUME SEGMENTATION[3]

- Lung CT scans at 1 week to 22 years of age were retrospectively gathered across 9 patients seen at the UF Health Shands Pediatric Pulmonary Care Center from 2005-2012 within an IRB-approved protocol.
- In-house software built upon the NIH ImageJ platform was used to segment the hemi-lungs using active contours/snakes (Fig 2A).
- This was performed for each 2D CT slice and the results combined to create a 3D lung volume data set (Fig 2B)

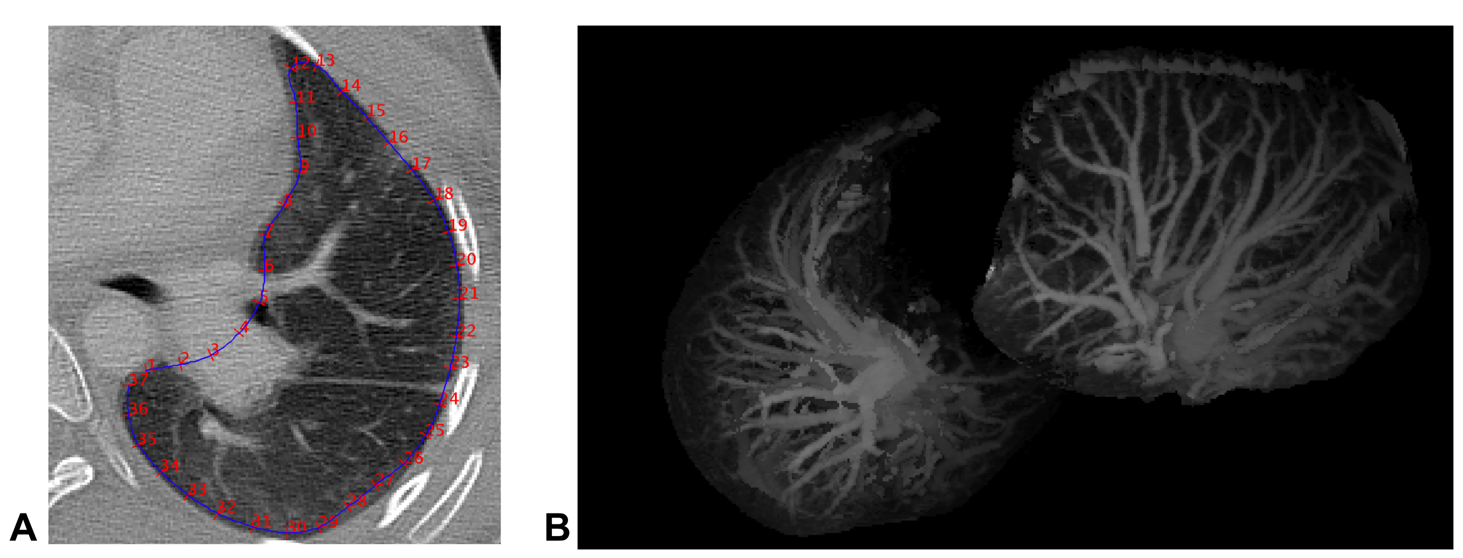

Figure 2: 3D CT datasets and lung volume segmentation. The image in [A] shows a pediatric patient's representative chest CT scan with a snake (blue contour with red node points) used to segment the left hemi-lung volume. [B] displays the 3D maximum-intensity projection (MIP) after stacking all segmented slices (each acquired with a 1.25 mm slice thickness) across both hemi-lungs.

LUNG VESSEL TREE SEGMENTATION[3]

- A region-growing method starting from a manually-selected seed point in the trachea was used to extract and remove the airways.
- The pulmonary vessel trees were extracted using region-growing starting from a manually-selected seed point in a main vessel.
- Skeletonization of the tree structure was applied to facilitate traversing and labeling each branch in the tree structure.
- The radius and length of each branch were then computed automatically from the branch centerline and the image 3D distance map.

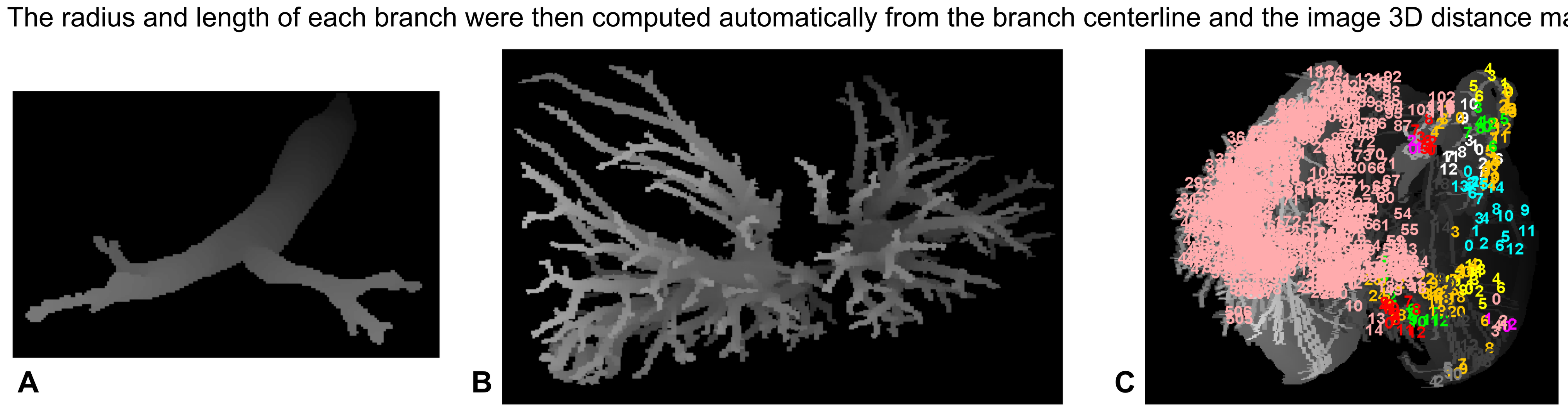

Figure 3. Airway and vessel tree segmentation, and branch labeling. The image in [A] shows the airway tree that was extracted and subsequently removed to improve the vessel tree segmentation. [B] shows the resulting segmented vessel tree in the same patient. Centerline extraction of that tree enables tree traversal and the identification of individual branches within each tree structure. [C] shows the number-labeled branches where each tree structure uses a different color.

ACKNOWLEDGEMENTS

Funding for this work is provided by the UF University Scholars Program and donations to the UF Foundation.

III. RESULTS AND DISCUSSION

- Data about the number of branches per radii size in each patient data set was automatically computed.
- The number of branches versus age of the patient was tabulated.

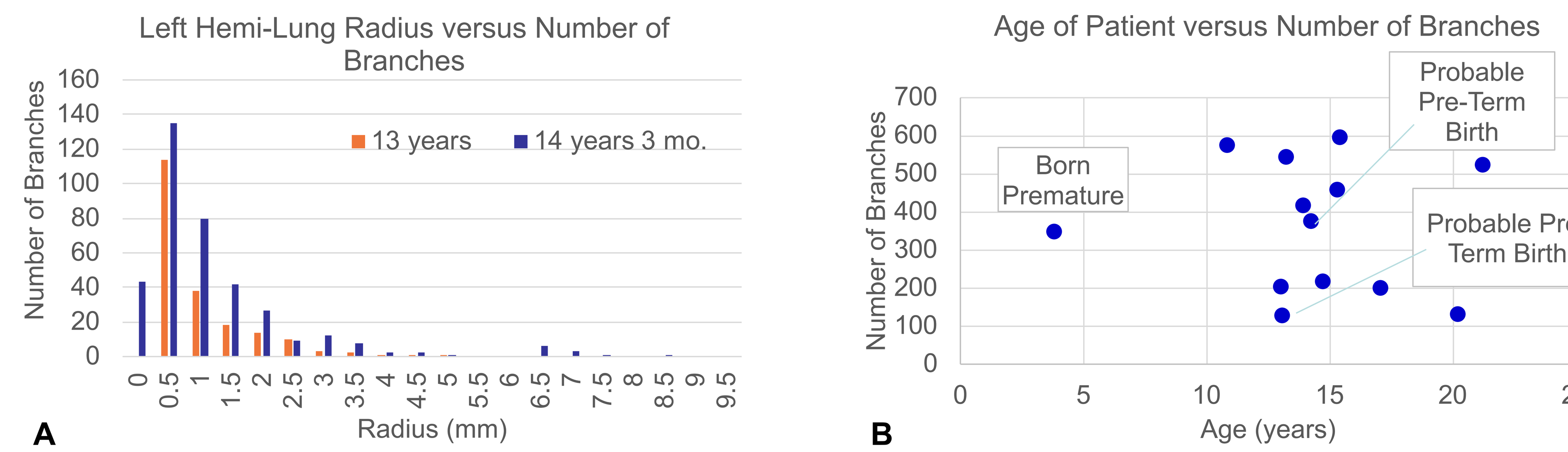

Figure 4: Number of branches for pediatric patients during development. [A] shows a branch radius histogram for a representative patient at 13 (orange markers) and 14 (blue) years of age where slice thickness was 3 mm for both scans. [B] shows total number of branches versus patient age (range 3 – 22 years) compiled over 9 patients, with 4 providing 2 scans.

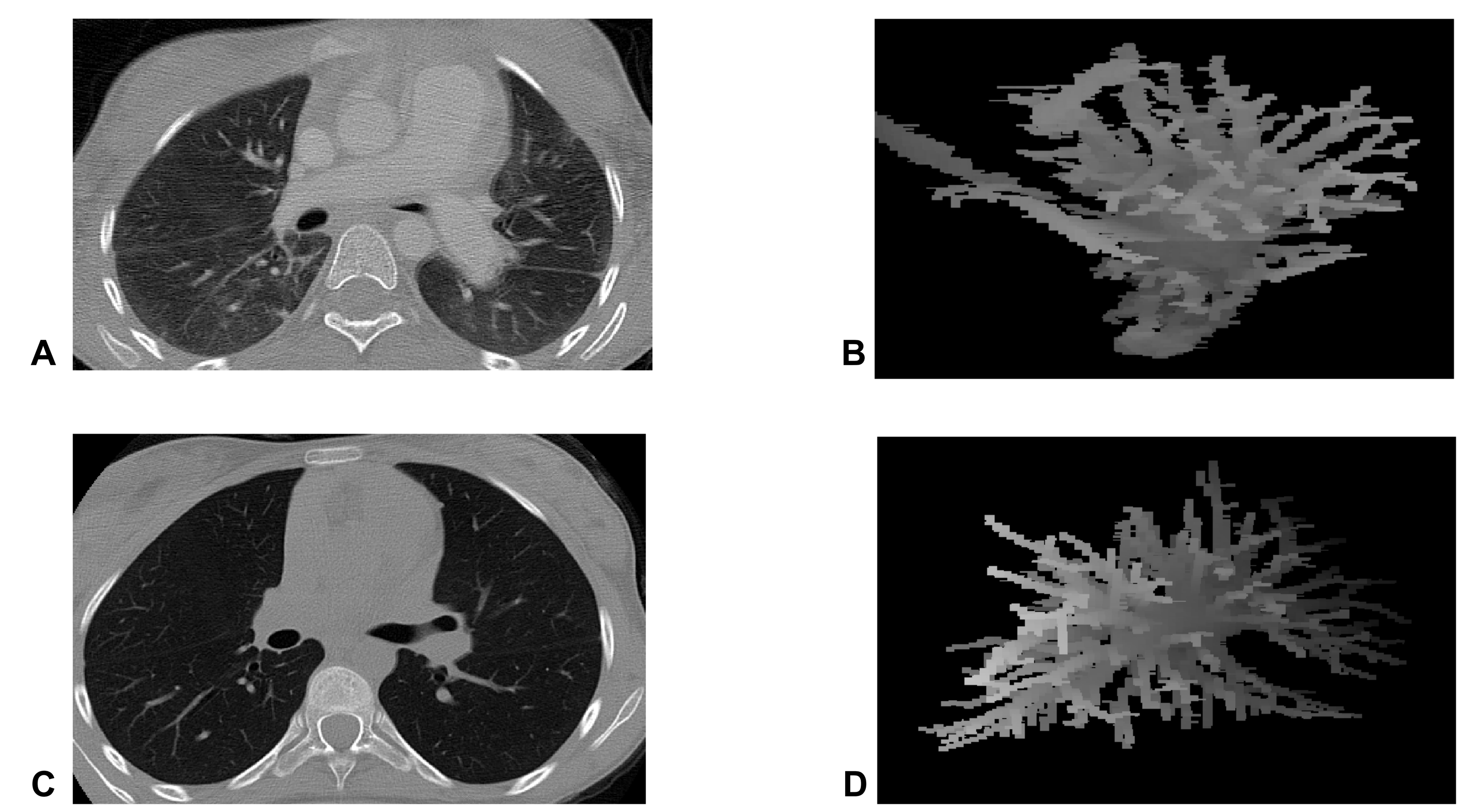

Figure 5: Visual inspection of vessel tree extraction results. Images [A] & [C] each show a single slice of a chest CT scan for a patient acquired at 13 and at 14 years of age, respectively. [B] and [D] show the extracted vessel trees for the same time points. The number of branches slightly increased over time (data plotted in Fig. 4A), however, the resolution of these lung scan were lower than ideal (3 mm slice thickness) which reduces our ability to account for vessels < 3 mm in diameter. .

The general trend is that the number of branches increases as a child ages (Figure 4B). The CT dataset for a patient that had a baseline scan at age 13 years showed a higher number of branches at 14 years, particularly in the 0-0.5 mm size range (Figs. 4A & 5).

IV. CONCLUSIONS AND FUTURE DIRECTIONS

- We have demonstrated a set of software tools for objectively quantifying the number and size distribution of pulmonary vessels from repeat chest CT scans acquired over time in pediatric patients.
- Our data shows a trend for an increase in the number of branches over time but with much variability.

Challenges to Achieving Consistent Vessel Tree Extraction

- Pediatric patients are typically CT scanned only when they have health issues with their lungs, such as infection or edema.
- When scanning very young patients, the scans often suffer from fewer slices and increased motion artifact.
- When scanning the same patient over time, the image pixel size and slice thickness can vary.

Plans for Future Work

- Increase the number of patients, increase the number of time-points per patient, and separating results based on patients' baseline issues (e.g, PAH, premature gestation, and infections).
- Corrections for variable slice thickness are being developed.
- Ongoing work is being done to develop a way to match individual lung vessels and vessel trees over multiple scans to document the changes occurring on a vessel-by-vessel basis.

IV. REFERENCES

1. Preterm birth. (2018, February 19). Retrieved September 18, 2018, from http://www.who.int/news-room/fact-sheets/detail/preterm-birth
2. Latzin, P., Roth, S., et al. (2009). Lung Volume, Breathing Pattern and Ventilation Inhomogeneity in Preterm and Term Infants. *PLoS One,4*(2). doi:10.1371/journal.pone.0004635
3. O'Dell, W.G, Govindarajan, S.T., Salgia, A., Hegde, S., Prabhakaran, S., Finol, E.A., White, R.J., *Traversing and labeling interconnected vascular tree structures from 3D medical images.* In S. Ourselin & M. A. Styner (Eds.), Proceedings of SPIE Medical Imaging 2014; (p. 90343C). doi:10.1117/12.2044140