# VALIDATION OF SIZING OF PULMONARY VESSELS FROM 3D MEDICAL IMAGES

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## I. INTRODUCTION

- Detailed characterization of vascular anatomy is important for the diagnosis and management of a variety of pulmonary vascular diseases including bronchopulmonary dysplasia in premature infants[1], adult chronic pulmonary hypertension, and the effects of radiation toxicity to lung vasculature in cancer patients.[2-5]
- Clinical estimates of vessel radii from 3D X-ray computed tomography (CT) datasets are unreliable because they are highly dependent on the selected intensity threshold, background image noise, and human subjectivity.
- We developed Gatortail (U.S. patent #9,471,989)[6] to objectively estimate vessel size by mathematically modeling the CT-appearance of each vessel and determining the vessel trajectory and 3D surface to match the patient's CT image.

**OBJECTIVE** Validate the ability of the Gatortail method to accurately compute vessel diameter using a realistic physical phantom of a human subject's right lower-lung vascular tree.

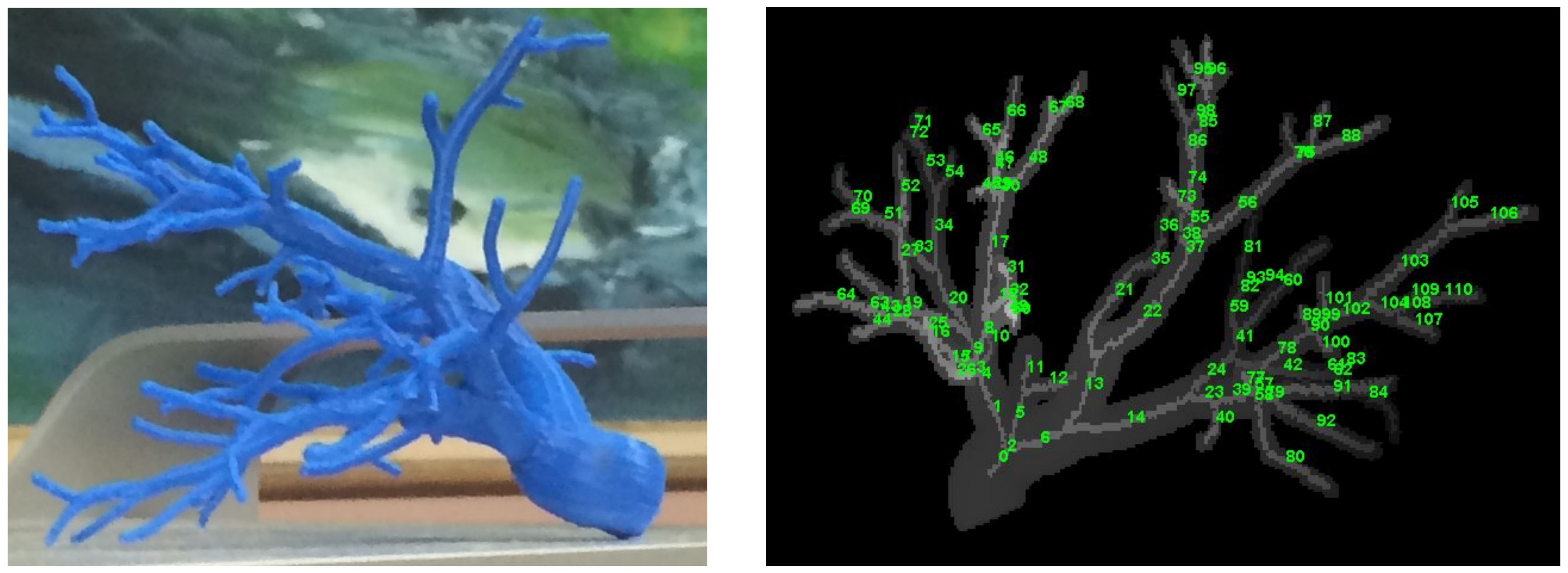
## II. METHODOLOGY

**PHANTOM CREATION**

- We segmented and modeled the 3D arterial vasculature from the CT scans of the patient's lower-right lung using software developed in our lab, where each branch is modeled as a tube-like structure along a curvilinear trajectory in 3D space.
- We created 3D physical model of the patient's lung vascular tree in ABS plastic via 3D printing.
- We scanned the physical phantom in a conventional clinical CT scanner with kVp 120, tube current 163, exposure 150, and voxel dimensions 0.8457x0.8457x1.0 mm.

**PHYSICAL MEASUREMENTS**

- We manually labelled each branch of the physical phantom with a unique number.
- We measured each of 74 branches in the physical phantom using digital calipers, 3 times each by investigators blinded to the results from the vessel optimization algorithm.
- We recorded our measurements and computed an average radii of each branch based on the 3 measurements.



A B

**Figure 1: Physical vascular tree phantom**. [A] is a photograph of the 3D vascular tree physical model as 3D printed in ABS plastic based on the initial extraction and modeling of the lower right hemi-lung of a human volunteer from a chest CT scan. [B] is an augmented maximum-intensity projection of the CT scan of the physical model from the Gatortail software package. The segmented vessel-pixels are show in transparent gray. The lighter gray pixels represent the extracted centerlines of each branch, labeled in green.

**COMPUTATION THROUGH GATORTAIL METHOD**

- We processed the CT dataset of the physical model with our in-house software to generate Gatortail-based values for branch radii, with the software-based set of branch numbers.

**MATCHING BRANCHES**

- We matched each branch on the physical model with the labeled branches of the image-based reconstruction.

**STATISTICAL ANALYSIS**

- We compared the average radii measurements computed by Gatortail with the physical average radii measurements taken from each branch of the physical phantom.
- We performed statistical comparison of the physical measurements and the computed measurements with the branch vessel size to determine to compute the $R^2$ value of the fit and p-value of the correlation.

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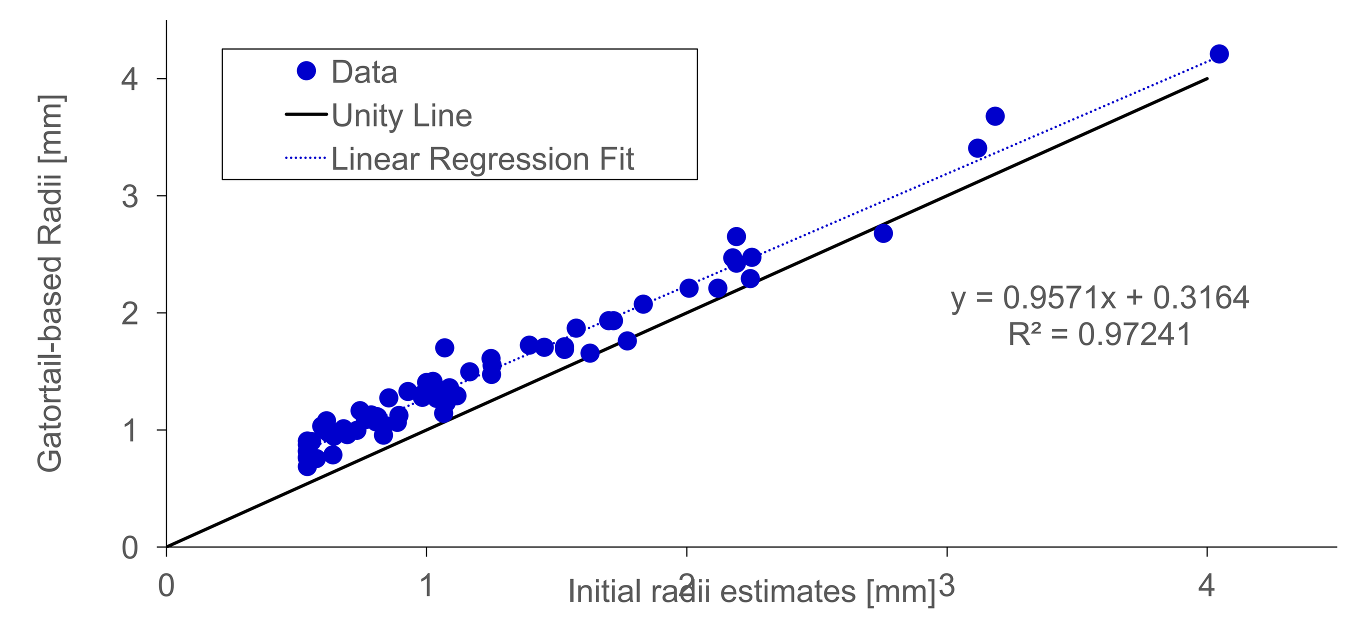
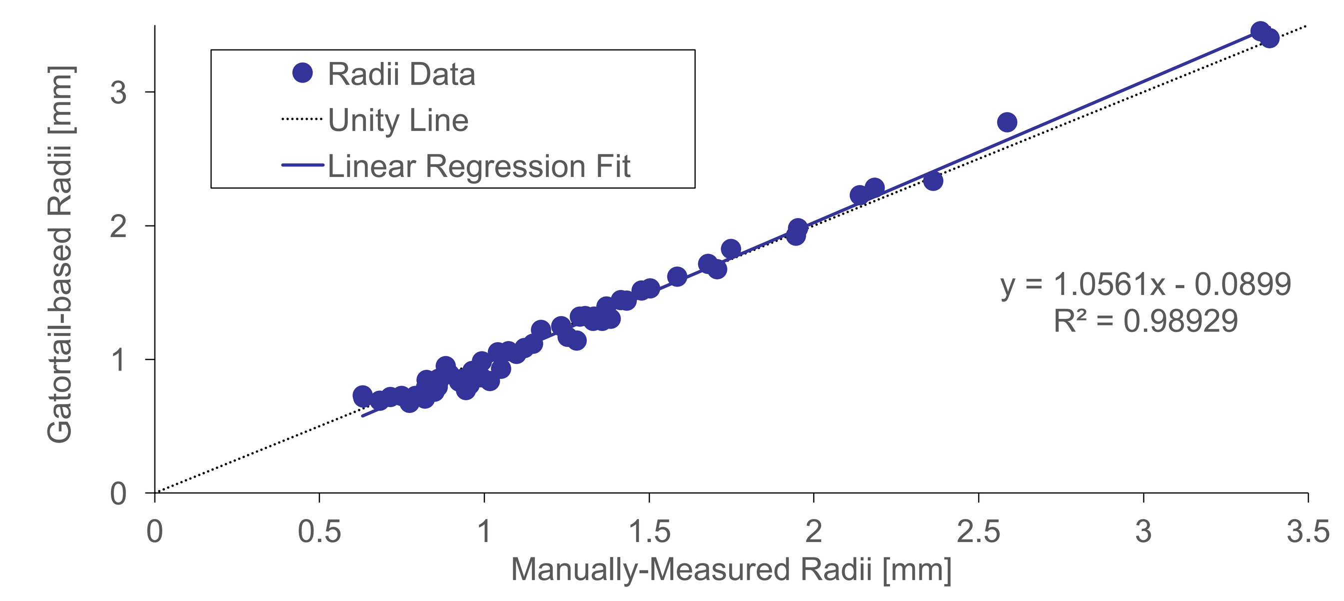
## III. RESULTS

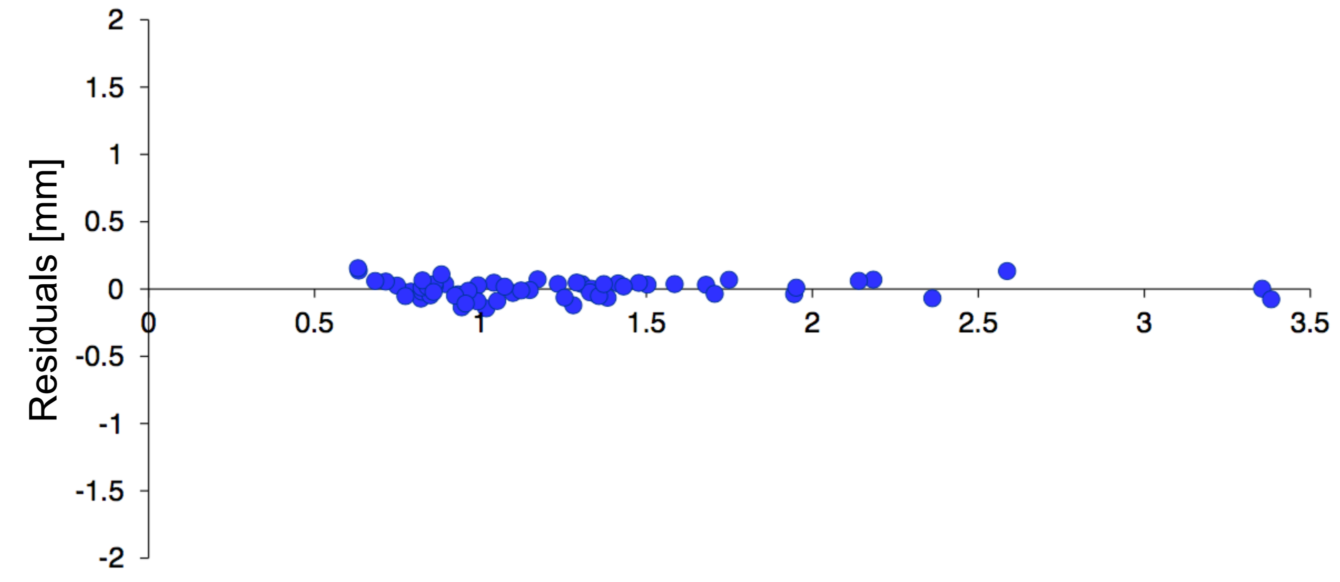
**1. GATORTAIL INCREASES VESSEL RADII ESTIMATES RELATIVE TO INITIAL THRESHOLD-BASED ESTIMATES**




**2. COMPARISON OF PHYSICAL RADII MEASURMENTS AND COMPUTED RADII MEASURMENTS**




**COMPARISON OF THE DIFFERENCE BETWEEN PHYSICAL RADII MEASURMENT AND COMPUTED RADII MEASURMENTS BASED ON THE VESSEL SIZE OF EACH BRANCH**




| Regression Statistics | |
|---|---|
| Multiple R | 0.995 |
| R Square | 0.989 |
| Standard Error | 0.064 |

| Standard Error | t Stat | P-value |
|---|---|---|
| 0.0140 | 13.03 | 1.54E-19 |

## V. CONCLUSIONS

- The Gatortail method tended to increased the diameter estimates over the initial threshold-based estimates.
- The Gatortail method achieves accurate vessel size estimations compared with manual measurement as gold standard.
- The accuracy was consistent across all size ranges.
- It is hoped that the this work will facilitate the use of Gatortail for quantifying vascular changes in the management and treatment of a variety of pulmonary vascular disease.

## VI. REFERENCES

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