# Ideal measurements of pediatric pulmonary artery and branch pulmonary arteries in the era of personalized medicine

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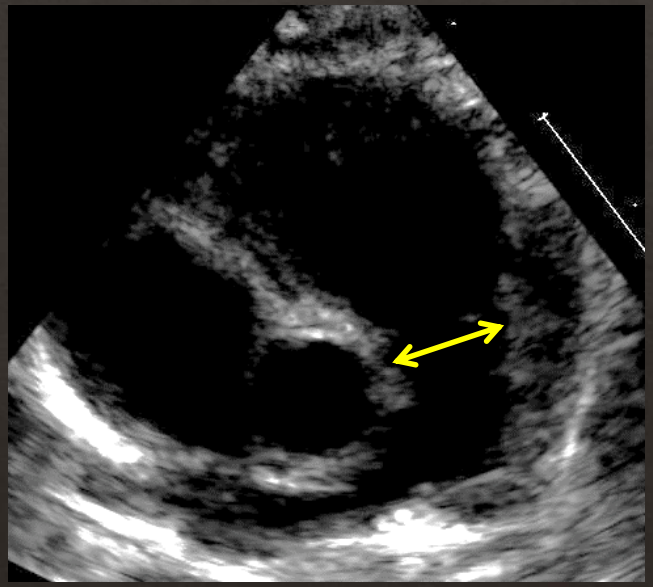
Disclosures: None

Ethics Review: IRB approved

# Background

- Standards for determining size of pulmonary artery are based on echo
  - Single diameter measurement
  - Assumes that all arteries are round
- No standards based on cross-sectional imaging/cross-sectional area



# Purpose

- To establish normative diameter standards for the pulmonary artery and branch pulmonary arteries in children.

- To ascertain the roundness of the pulmonary artery and branch pulmonary arteries.

# Inclusion and Exclusion Criteria

## Inclusion criteria

- Chest computed tomography exam with intravenous contrast performed at Arkansas Children's Hospital
- Exams performed between 2/3/2016 and 11/13/2016
- Patient age between birth and 18 years of age

## Exclusion criteria

- Height and weight <1 percentile
- Severe pulmonary disease specifically pulmonary hypertension, severe asthma, severe infection, extensive metastatic disease, interstitial lung disease, large pleural effusions
- Cardiac disease
- Source images unavailable (0.5 mm)

# Patients (n=155)

## Included Patients (n=108)

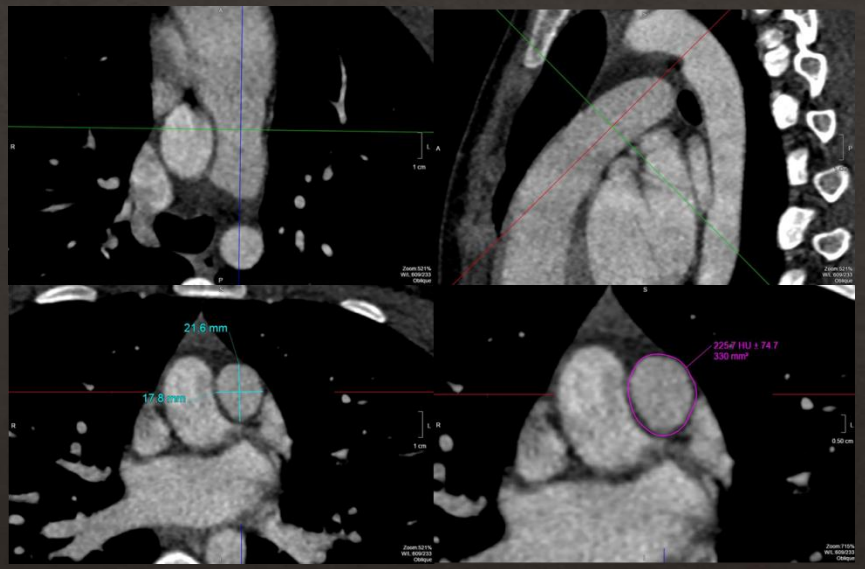
- Gender
  - 64 male, 44 female
- Age
  - Range: 3 months to 18 years
  - Mean: 11 years, Standard Deviation: 5.9 years

## Excluded Patients (n=47)

- Severe lung or pleural disease (n=27)
- Congenital heart disease (n=9)
- Height/weight information not available (n=4)
- Height or weight <1 percentile (n=7)

# Methods: Measurements

- Two independent readers (Pediatric Imaging Cardiologist and Cardiac Pediatric Radiologist)
- Pulmonary artery and branch pulmonary artery size measured:
  - Double oblique measurements using 1 mm slice thickness
  - Effective diameter: average of the two perpendicular diameters
  - Cross-sectional area measured using freehand automated ROIs by planimetry
  - Ideal diameter calculated using cross-sectional area, based on $A = \pi r^2$
- Height & weight were measured and body surface area was calculated using the Haycock method



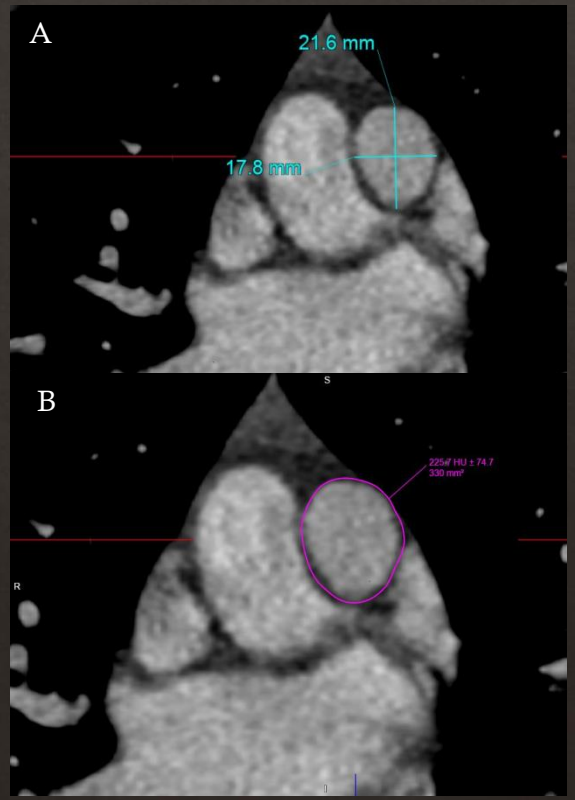

Planes for double oblique measurements of pulmonary artery and illustration of measurement of cross-sectional area using freehand ROI

# Methods: Statistics

- Ordinary least squares regression methods to investigate models with various functional forms that related effective diameters at each level to
  - Patient height
  - Body surface area
  - Age

# Methods: Statistics

- Roundness of the pulmonary artery defined by Aspect Ratio (AR)
  - (AR) = Short D/Long D
    - For example 17.8/21.6 mm = 0.82 (Figure A)
  - Ideal perfect roundness score = 1
- Ideal diameter (ID) calculated using cross-sectional area, based on $A = \pi r^2$
  - For example cross sectional area using ROI is 330 $mm^2$ (Figure B)
  - ID = 20.5 mm

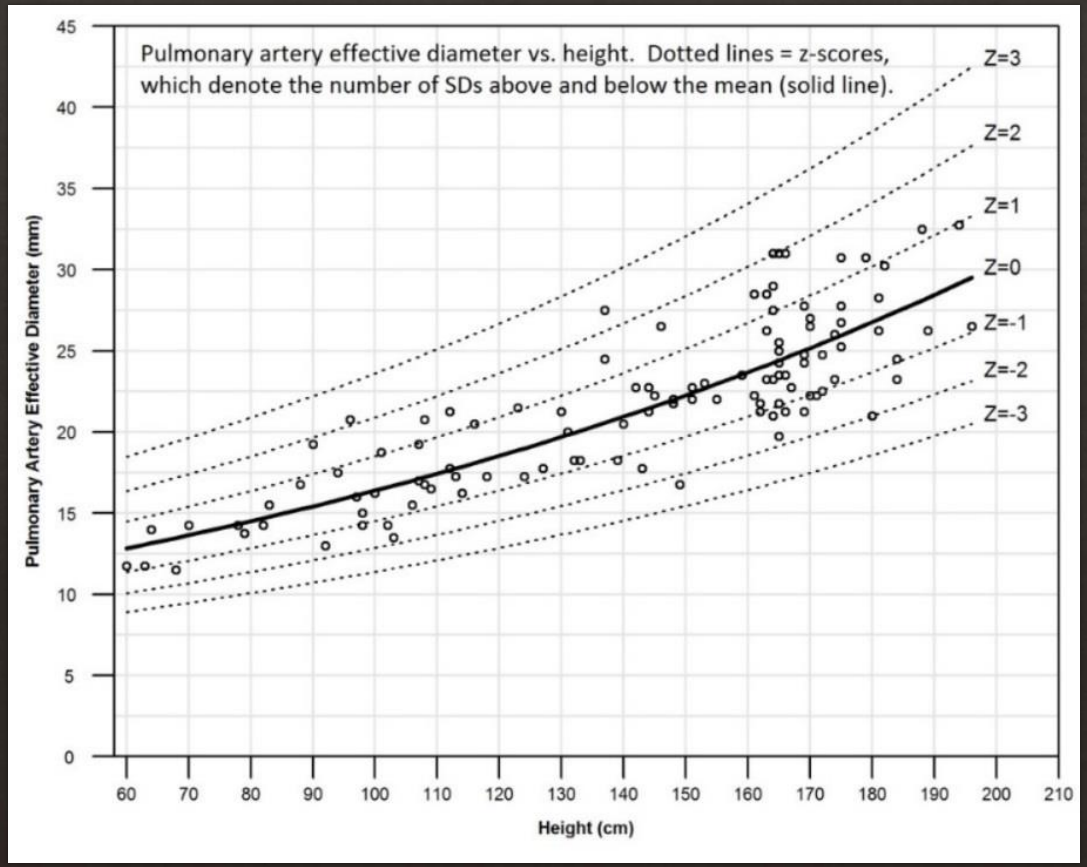


# Results

- Inter-rater reliability
  - Intraclass correlation was excellent (> 0.91 )
- Formulae to calculate the predicted effective diameter for main pulmonary artery(MPA) and right and left branch pulmonary arteries (RPA & LPA) on natural log scale

| Formulae | √MSE | $R^2$ |
|---|---|---|
| $\log_e$(MPA ED)=2.1844 + 0.0061*Height | 0.1216 | 0.758 |
| $\log_e$(RPA ED)=1.4572 + 0.0084*Height + 0.2921*Male – 0.0019*Height*Male | 0.1283 | 0.803 |
| $\log_e$(LPA ED)=1.6936 + 0.0071*Height | 0.1195 | 0.812 |

# Results: Pulmonary Artery Effective Diameter vs. Height




The graph demonstrates that for a given height and main pulmonary artery measurement, Z-score can be determined. Similar graphs are available for branch pulmonary arteries.

# Excel program to determine Z-Score

| | A | B | C | D | J | K |
|---|---|---|---|---|---|---|
| 1 | Enter Gender (1=Male, 0=Female)* | Enter Height (cm) | | Enter observed diameter (mm) | Calculated predicted diameter (mm) | Z-Scores |
| 2 | 0 | 100.00 | Pulmonary Artery | 15.0 | 16.4 | -0.73 |
| 3 | | | Right Pulmonary Artery | 10.0 | 10.0 | 0.01 |
| 4 | | | Left Pulmonary Artery | 10.0 | 11.0 | -0.82 |

**Interpretation:** The z-score indicates how many standard deviations (SDs) above (positive value) or below (negative value) the observed diameter is relative to what would be predicted for a pediatric population without any known cardiac or pulmonary disease. Based on the theoretical normal distribution, 68.3% of the population would fall within the predicted diameter +/- 1 SD, 95.4% within +/- 2 SD, and 99.7% within +/- 3 SD.

**Red dot:** Z-score $\leq -2$ OR $\geq 2$
**Green dot:** $-2 < \text{Z-score} < 2$

**Instructions: Enter Gender, Height, and observed diameter only in YELLOW highlighted fields.**
***Gender is only used in the calculation of the predicted diameter for the right pulmonary artery, as gender was not a statistically significant term for use in the model for either the pulmonary artery or the left pulmonary artery.**

The figure demonstrates the excel program, which calculates the Z-score when the measured diameters and demographics are entered in their respective fields. Normal and abnormal Z-scores are indicated by green and red dots respectively. It is used at our institution in everyday practice.

# Aspect ratio (Roundness)

- The mean AR ranged from 0.88-0.91.
- The Aspect ratios were measured as < 0.9:
  - Main pulmonary artery (MPA) – 38%
  - Right pulmonary artery (RPA) – 55%
  - Left pulmonary artery (LPA) – 37%
- Long Diameter and Short Diameter measurements were significantly different from Ideal diameter measurements for PA & Branch PA (all P- values < 0.0001)
- The Ideal Diameters, extrapolated from the cross sectional ROI were not statistically different from Effective Diameter. P-Value: MPA – 0.28; RPA – 0.51; LPA – 0.52

# Conclusion

- Z-scores derived from double oblique measurements should be the new gold standard for pulmonary artery and branch pulmonary artery normative values
- Pulmonary arteries are not very round (AR<0.9) in 37-55% of normal subjects, in whom a single measurement will not reflect the cross-sectional area

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