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 mm² (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

<table>
<thead>
<tr>
<th>Formulae</th>
<th>√MSE</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>logₐ(MPA ED)=2.1844 + 0.0061*Height</td>
<td>0.1216</td>
<td>0.758</td>
</tr>
<tr>
<td>logₐ(RPA ED)=1.4572 + 0.0084<em>Height + 0.2921</em>Male – 0.0019<em>Height</em>Male</td>
<td>0.1283</td>
<td>0.803</td>
</tr>
<tr>
<td>logₐ(LPA ED)=1.6936 + 0.0071*Height</td>
<td>0.1195</td>
<td>0.812</td>
</tr>
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</table>
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.
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.

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<tr>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
</tr>
<tr>
<td>1</td>
<td>Enter Gender (1=Male, 0=Female)*</td>
<td>Enter Height (cm)</td>
<td>Enter observed diameter (mm)</td>
<td>Calculated predicted diameter (mm)</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>100.00</td>
<td>Pulmonary Artery</td>
<td>15.0</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>10.00</td>
<td>Right Pulmonary Artery</td>
<td>10.0</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>10.00</td>
<td>Left Pulmonary Artery</td>
<td>10.0</td>
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**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 ≤ -2 OR ≥ 2

**Green dot:** -2 < 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.
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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