Measuring Lung Volumes: How, Why and When

Amy R. Mehollin-Ray, MD FAAP
Division Chief, Fetal Radiology
Texas Children’s Hospital
Disclosures

• None
Objectives

- How to do it
- Why do it
- When to do it
  - In what scenarios?
  - At what gestational age?
How to measure fetal lung volumes

- Manual tracing
- **Automated segmentation**
- Combination (semi-automated)
Manual tracing method

- Contiguous slices
- Trace with freehand ROI
- Add areas (cm$^2$)
- Multiply by slice thickness (cm)
- Volume in cm$^3$ (mL)
Semi-automated method

Dr. Mariana Meyers and Dr. Beth Kline-Fath
Normal ranges

- TFLV

Expected FLV = 0.0033 x GA^{2.86}
Normal ranges

- TFLV

Normal ranges

- TFLV
Why measure fetal lung volumes

• Pulmonary hypoplasia
  • Mortality
  • Morbidity
    • ECMO
    • Chronic lung disease
Causes of pulmonary hypoplasia

- Congenital diaphragmatic hernia
- Congenital lung malformation
- Omphalocele
- Skeletal dysplasia
- Oligohydramnios
  - PROM
  - Renal dysfunction
- Cervical teratoma
Congenital diaphragmatic hernia

O/E TFLV < 25%

Congenital diaphragmatic hernia

O/E TFLV < 35% + LH > 20%

- Mortality
- Need for ECMO

O/E TFLV < 35%

- Chronic lung disease

Congenital diaphragmatic hernia

O/E TFLV < 25%  
Mortality

O/E TFLV < 35% + LH > 20%  
Mortality
Need for ECMO

O/E TFLV < 35%  
Chronic lung disease
Congenital lung malformation

## Omphalocele

**Table 1. Comparison of clinical outcome in GO children based on O/E TLV**

<table>
<thead>
<tr>
<th></th>
<th>O/E TLV ≤50% of expected (n = 11, 65%)</th>
<th>O/E TLV &gt;50% of expected (n = 6, 35%)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>GA at evaluation, weeks</td>
<td>24.1 ± 2.7 (23; 21–29)</td>
<td>26.3 ± 4.6 (24.5; 22–33)</td>
<td>0.31</td>
</tr>
<tr>
<td>Right lung volume, ml</td>
<td>7.7 ± 2.7 (6.5; 3.9–13.1)</td>
<td>16.3 ± 8.9 (11.3; 8.9–30.3)</td>
<td>0.007</td>
</tr>
<tr>
<td>Left lung volume, ml</td>
<td>6.2 ± 2.3 (5.8; 3.1–11.1)</td>
<td>12.7 ± 6.8 (9.6; 6.4–21.4)</td>
<td>0.01</td>
</tr>
<tr>
<td>TLV, ml</td>
<td>16.8 ± 10.2 (12; 7–44)</td>
<td>28.7 ± 15.4 (20.6; 15.3–50.4)</td>
<td>0.005</td>
</tr>
<tr>
<td>Male gender, n (%)</td>
<td>5 (45)</td>
<td>5 (83)</td>
<td>0.15</td>
</tr>
<tr>
<td>GA at delivery, weeks</td>
<td>36.4 ± 1.8 (37; 33–39)</td>
<td>37.6 ± 0.8 (38; 37–38)</td>
<td>0.07</td>
</tr>
<tr>
<td>Body weight, g</td>
<td>2,982.1 ± 300.1 (3,000; 2,600–3,500)</td>
<td>3,005 ± 355.1 (3,043; 2,395–3,400)</td>
<td>0.53</td>
</tr>
<tr>
<td>Median Apgar score at 1/5 min (range)</td>
<td>6 (2–8)/8 (5–9)</td>
<td>8 (6–9)/9 (8–9)</td>
<td>0.03</td>
</tr>
<tr>
<td>Intubation within the 1st hour after delivery, n (%)</td>
<td>8 (73)</td>
<td>4 (67)</td>
<td>0.29</td>
</tr>
<tr>
<td>Length of ventilatory support, days</td>
<td>37.7 ± 21.9 (37; 7–75)</td>
<td>6.5 ± 6.1 (5.5; 1–14)</td>
<td>0.005</td>
</tr>
<tr>
<td>Age at first closure, days</td>
<td>4.7 ± 3.3 (3; 2–10)</td>
<td>1.8 ± 0.4 (2; 1–2)</td>
<td>0.01</td>
</tr>
<tr>
<td>Age at final closure, days</td>
<td>14.9 ± 6.6 (15; 5–22)</td>
<td>10.0 ± 1.9 (10; 8–13)</td>
<td>0.22</td>
</tr>
<tr>
<td>Median number of reducing surgeries (range)</td>
<td>4 (2–7)</td>
<td>4 (3–6)</td>
<td>1.0</td>
</tr>
<tr>
<td>Age at first oral feed, days</td>
<td>25.9 ± 13.1 (23; 8–45)</td>
<td>12.2 ± 6.5 (15; 2–19)</td>
<td>0.02</td>
</tr>
<tr>
<td>Age at full oral feed, days</td>
<td>32.2 ± 15.1 (32; 9–54)</td>
<td>16.5 ± 6.8 (17; 5–23)</td>
<td>0.03</td>
</tr>
<tr>
<td>Age at discharge, days</td>
<td>67.1 ± 47.5 (48; 18–184)</td>
<td>29.0 ± 11.8 (31; 8–43)</td>
<td>0.01</td>
</tr>
</tbody>
</table>

**O/E TFLV < 50%**

Skeletal dysplasia

- FL/AC < 0.16
- TC < 5\textsuperscript{th} centile
- TC/AC < 0.6
- O/E TFLV < 48%
Oligohydramnios – PPROM


O/E TFLV < 60%
Oligohydramnios – Renal causes

Cervical teratoma

When to measure fetal lung volume

• Impact on fetal care
  • Fetal intervention (FETO for CDH)
  • Prognosis (CDH, omphalocele)
• Planning for delivery
  • Need for neonatal management (CDH, CLM)
When to measure fetal lung volume

- ≥ 21 weeks (Rypens data)
- Pulmonary morbidity – ≥ late 2\textsuperscript{nd} trimester
When to measure fetal lung volume

<table>
<thead>
<tr>
<th>GA (Weeks)</th>
<th>N</th>
<th>Mean (mL)</th>
<th>SD</th>
<th>Median</th>
<th>Rypens FLV (mL)</th>
<th>P-value</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>13</td>
<td>11.1</td>
<td>2.2</td>
<td>10.9</td>
<td>12.8</td>
<td>0.0165</td>
<td>-3.029 to -0.371</td>
</tr>
<tr>
<td>19</td>
<td>27</td>
<td>12.4</td>
<td>2.5</td>
<td>12.5</td>
<td>15</td>
<td>0.0001</td>
<td>-3.589 to -1.611</td>
</tr>
<tr>
<td>20</td>
<td>32</td>
<td>15.5</td>
<td>3.9</td>
<td>15.4</td>
<td>17.4</td>
<td>0.0097</td>
<td>-3.306 to -0.494</td>
</tr>
<tr>
<td>21</td>
<td>43</td>
<td>17.4</td>
<td>5.0</td>
<td>17.0</td>
<td>20</td>
<td>0.0005</td>
<td>-3.992 to -1.208</td>
</tr>
<tr>
<td>22</td>
<td>52</td>
<td>20.4</td>
<td>4.9</td>
<td>20.0</td>
<td>22.8</td>
<td>0.0009</td>
<td>-3.764 to -1.036</td>
</tr>
<tr>
<td>23</td>
<td>56</td>
<td>24.1</td>
<td>6.1</td>
<td>24.3</td>
<td>25.9</td>
<td>0.0314</td>
<td>-3.434 to -0.166</td>
</tr>
<tr>
<td>24</td>
<td>45</td>
<td>27.8</td>
<td>7.6</td>
<td>26.7</td>
<td>29.2</td>
<td>0.2231</td>
<td>-3.683 to 0.883</td>
</tr>
<tr>
<td>25</td>
<td>47</td>
<td>31.6</td>
<td>7.2</td>
<td>31.0</td>
<td>32.9</td>
<td>0.2221</td>
<td>-3.414 to 0.814</td>
</tr>
<tr>
<td>26</td>
<td>31</td>
<td>34.8</td>
<td>6.7</td>
<td>36.5</td>
<td>36.8</td>
<td>0.1069</td>
<td>-4.458 to 0.458</td>
</tr>
<tr>
<td>27</td>
<td>33</td>
<td>40.3</td>
<td>10.2</td>
<td>40.6</td>
<td>40.9</td>
<td>0.7376</td>
<td>-4.217 to 3.017</td>
</tr>
<tr>
<td>28</td>
<td>40</td>
<td>48.8</td>
<td>15.8</td>
<td>46.5</td>
<td>45.4</td>
<td>0.1813</td>
<td>-1.653 to 8.453</td>
</tr>
</tbody>
</table>

Garcia J et al. IPR 2016.
Summary

- **CDH:**
  - O/E TFLV < 25% \(\rightarrow\) Mortality
  - O/E TFLV < 35% + %LH > 20% \(\rightarrow\) Mortality and ECMO
  - O/E TFLV < 35% \(\rightarrow\) Pulmonary morbidity

- **CLM:** O/E TFLV < 75% \(\rightarrow\) Neonatal symptoms

- **Omphalocele:** O/E TFLV < 50% \(\rightarrow\) Pulmonary morbidity
Summary

• Skeletal dysplasia: O/E TFLV < 48% → Mortality
• PPROM: O/E TFLV < 60% → Mortality
• Renal disorders: N/A
• Cervical teratoma: TFLV > 1 SD below median → Mortality
Bottom line

- All pulmonary hypoplasias are not equal
  - CDH ≠ CLM ≠ PPROM …

- Must use
  - Right method
  - Right cut-off
  - Right time
  - Right disorder
Thank you!