Is Bigger Better?
Does PICU Volume Impact Volume

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DISCLOSURE

The content of this presentation does not relate to any product of a commercial entity; therefore, I have no relationships to report.
Objectives

Present overview of patient care outcomes as related to patient volumes

Present current literature for volume effect on patient care outcomes in regards to pediatric trauma, cardiac surgery, burns, and ECMO

Briefly discuss regionalization of pediatric critical care in the United States
Volume Affects Outcome

- Three decades of published research have shown improved outcomes with high volume centers and/or providers versus low volume centers.
  - Demonstrated over a wide range of medical and surgical issues
    - High risk or high complexity
  - Some studies have not confirmed this association
    - Lack precise definitions, risk adjustment models, and properly defined outcomes
Volume Affects Outcome

  – 11,000 U.S. deaths could have been avoided from 2010 to 2012 if patients had used the highest volume fifth of hospitals instead of the lowest volume for five procedures:
    • Hip replacements, knee replacements, cardiac bypass (basic and valve repair), heart failure, and COPD

• Dartmouth-Hitchcock, Johns Hopkins, and U of Michigan plan to implement voluntary minimal-volume standards for 10 surgeries in their systems
More Cases, Fewer Deaths: Knee Replacement

Mortality rate higher than expected
- Mortality rate lower than expected
- Results within this range could occur by chance (99.8% control limit)

Expected Mortality Rate

Better

Worse

<table>
<thead>
<tr>
<th>Volume</th>
<th>Very Low</th>
<th>Low</th>
<th>Moderately Low</th>
<th>Moderate</th>
<th>Moderately High</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Average Medicare cases per hospital)</td>
<td>(11)</td>
<td>(43)</td>
<td>(95)</td>
<td>(181)</td>
<td>(329)</td>
<td>(804)</td>
</tr>
</tbody>
</table>
Surgical Volume: Outcome Relationship Review
Chowdry, Br J Surg 2007
Adult ICU

• Volume-outcome relationships have been demonstrated in:
  – Mechanical ventilation (United States 2006)
  – Sepsis (Netherlands 2007)
  – Respiratory Failure/ECMO (UK 2007 (CESAR))
  – ICU Bed to Hospital Bed Ratio (Japan 2015)

• Other studies have not demonstrated this association
# Adult ICU Volume:Outcome

<table>
<thead>
<tr>
<th>Reference</th>
<th>Population</th>
<th>Volume level</th>
<th>Hospitals (n)</th>
<th>Patients (n)</th>
<th>Clinical risk adjustment?</th>
<th>Effect?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jones, 1995 [12]</td>
<td>All intensive care</td>
<td>ICU</td>
<td>26</td>
<td>8,796</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Durairaj, 2005 [14]</td>
<td>Select diagnoses</td>
<td>Hospital</td>
<td>29</td>
<td>43,635</td>
<td>Yes</td>
<td>Yes†</td>
</tr>
<tr>
<td>Kahn, 2006 [15]</td>
<td>Invasive mechanical ventilation</td>
<td>Hospital</td>
<td>37</td>
<td>20,241</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Glance, 2006 [16]</td>
<td>All intensive care</td>
<td>ICU</td>
<td>76</td>
<td>70,757</td>
<td>Yes</td>
<td>Yes‡</td>
</tr>
<tr>
<td>Needham, 2006 [17]</td>
<td>Invasive mechanical ventilation</td>
<td>Hospital</td>
<td>95</td>
<td>20,219</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Peelen, 2008 [18]</td>
<td>Severe sepsis</td>
<td>ICU</td>
<td>29</td>
<td>4,605</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Nguyen, 2007 [19]</td>
<td>Invasive mechanical ventilation</td>
<td>ICU</td>
<td>33</td>
<td>41,747</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Moran, 2008 [20]</td>
<td>All intensive care</td>
<td>Hospital</td>
<td>NR</td>
<td>223,129</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Lin, 2008 [21]</td>
<td>Pneumonia</td>
<td>Physician</td>
<td>NR</td>
<td>87,479</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Lecuyer [22]</td>
<td>Haematological malignancy</td>
<td>ICU</td>
<td>28</td>
<td>1,752</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Kahn, 2009 [23]</td>
<td>Invasive mechanical ventilation</td>
<td>Hospital</td>
<td>169</td>
<td>30,677</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Carr, 2009 [24]</td>
<td>Post-cardiac arrest</td>
<td>Hospital</td>
<td>39</td>
<td>4,674</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Pediatric Trauma

- Compared Oregon and Washington
  - Statewide trauma system implemented in Oregon (1987-1991)
- Despite increase in pediatric population, the incidence of hospitalization for all injured children declined
- Risk adjusted odds of death for seriously injured children was significantly lower in Oregon than in Washington in the later time period

Pracht, J Trauma 1997
Pediatric Trauma

- 27,313 patients < 19yrs, Florida 1995-2004
  - Compared outcomes in non trauma hospitals, trauma centers, and pediatric trauma centers
  - Treatment in trauma center vs non trauma center
    • 3.5% reduction in mortality for 0-19 (p < 0.0001)
    • 1.6% reduction for 0-15 (NS)
  - Treatment in pediatric trauma center vs trauma center (16,607 patients)
    • 4.8% reduction in mortality for 0-19 (p < 0.0001)
    • 4.5% reduction for 0-15 (p < 0.0001)

Pracht, J Pediatr Surg 2008
Pediatric Trauma

- 58,583 patients < 15 years of age admitted to New England hospitals 1996-2006
  - Compared states with and without statewide trauma systems
  - Presence of statewide trauma system decreased hospitalization rates over time
  - Both had increased admissions of severely injured to trauma centers and decreased mortality over time

Mooney, Pediatric Surg Int 2013
Pediatric Cardiac Surgery

- Numerous studies have demonstrated a relationship between outcome and volume
  - Increased effect with increased complexity
- Theoretical regionalization in California for congenital heart disease patients
  - 83 lives could be saved annually if patients from low volume/higher-mortality centers were cared for in high volume/lower-mortality institutions

Chang, Peds 2002
Pediatric Cardiac Surgery

- California patient data (1998-2003) found a statistically significant relationship with mortality (OR 0.86 per 100-patient increase in annual volume; 95% CI 0.81 to 0.92)
  - Removal of largest center (high performer) affected model
    Bazzani, Circ 2007

- Pediatric Cardiac Care Consortium (49 centers in North America-109,475 cases) from 1982-2007
  - Odds ratio for mortality decreased > 10-fold during timeframe
  - Surgical volume was associated inversely with odds of death
    - Consistent across age, risk categories (except lowest), and time
  - Significant variability persisted after adjustment for volume
  - Cautioned against using only volume as marker
    Vincour, Pediatr Cardiol 2013
Intussusception

- Compared non-operative reduction in three volume levels
  - Large-64%, Medium-36%, Small-24%
- Median length of stay and charges were significantly less in the large children’s hospitals

Bratton, Peds 2001
Pediatric Burns

- American Burn Association National Burn Registry
  - 33,115 patients < 18 years (2000-2009)
- Odds of mortality reduced by 40% for every 100 increase in median yearly pediatric burn admissions
  - High volume centers (>200 pediatric patients/year) had the lowest mortality when adjusting for age and injury characteristics
  - For a 75% total body surface area injury:
    - 30% estimated mortality with median yearly burn pediatric admissions of 75
    - 17% estimated mortality with median annual pediatric burn admissions of 300

Mooney, PCCM 2015
**Burns**

*Figure 4.* Estimated mortality for a 10-year-old child without inhalation injury with 25%, 50%, or 75% total body surface area (TBSA) for varying facility sizes.
ECMO

- Compared KID database hospitals with ECMO
  - Groups: < 15 cases/year vs. 15-30 cases/year vs. >30 cases/year
  - Cardiac and non-cardiac cases
    - Cardiac Cases mapped to RACHS
ECMO

• Compared PHIS hospitals with ECMO
  – Groups: < 20 cases/year vs. 21-49 cases/year vs. > 50 cases/year
  – 7 diagnostic categories:
    • congenital diaphragmatic hernia, neonatal or pediatric respiratory failure, neonatal or pediatric cardiac disease, and neonatal or pediatric cardiac arrest
  – Case mix adjusted
  – Limitations- administrative data lacks ECMO indications, ECPR, and physiologic data

Freeman, CCM 2014
For each additional 10 cases/year mortality decreased 5% (OR 0.95; 95% CI 0.92-0.98)

**TABLE 3. Center Volume and Mortality Risk Model**

<table>
<thead>
<tr>
<th>Factor</th>
<th>OR</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center volume</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>1</td>
<td>Reference group</td>
</tr>
<tr>
<td>Medium</td>
<td>0.86</td>
<td>0.75–0.98</td>
</tr>
<tr>
<td>High</td>
<td>0.75</td>
<td>0.63–0.89</td>
</tr>
</tbody>
</table>
ECMO

• Utah (Kirkland 2015) examining complications and adjunct therapies in pediatric patients who receive ECMO within the first week of life (neonates) and those older using PHIS data
  – Increased pulmonary hemorrhage, acute renal failure, seizures, and IVH in smaller neonatal centers
  – Increased acute renal failure and liver failure in smaller pediatric centers
    • Decreased incidence of pancreatitis in smaller centers
  – Increased use of dialysis and bronchoscopy in larger pediatric centers

• Oregon (Williams 2015) examining complications and adjunct therapies by center volume in pediatric cardiac patients who receive ECMO
  – Similar distribution of age and RACHS score by case volume
  – Increased cardiac arrest and need for ECMO on day of operation in smaller pediatric centers
  – Increased incidence of renal failure, liver failure, and IVH during ECMO in smaller pediatric centers
  – Increased use of cardiac catherization and CRRT in larger pediatric centers
    • Increased use of peritoneal dialysis in smaller pediatric centers
If Bigger is Better, Why?

- Increased familiarization with complex patients and/or procedures
- Increased cross training of staff
- Increased nursing staff ratios
- Increased access to specialists
- Increased availability of resources
- Improved coordination of care
What about ICU?

• Limited ICU bed capacity may contribute to:
  – delay of admissions to the ICU
  – premature discharges of patients
  – admission of only the sickest patients which may stress the ICU resources

• Less availability or use of adjunct therapies
Regionalization of Pediatric Care

• Studies have varied on effect
  – Most studies have looked at neonatal care, congenital heart disease, and pediatric trauma
  – Studies often lack precise definitions, risk adjustment models, and properly defined outcomes
Regionalization

FIGURE 2
Conceptual framework for the development of regional systems. Various factors contribute to the development of both the type of regionalized system described in Fig 1 and the overall degree of regionalization. SES indicates socioeconomic status.

Lorch, Regionalization of Pediatric Care. *Peds* 2010:126:1182
<table>
<thead>
<tr>
<th>Age</th>
<th>Basic</th>
<th>Advanced</th>
<th>Comprehensive</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASA classification</td>
<td>Older than 1 y</td>
<td>Any</td>
<td>Any</td>
</tr>
<tr>
<td></td>
<td>1–2</td>
<td>1–3*</td>
<td>1–5</td>
</tr>
<tr>
<td>Multidisciplinary management of comorbidities</td>
<td>None</td>
<td>Typically single surgical specialties; neonatology; pediatric anesthesia</td>
<td>Multiple medical and surgical specialties; pediatric anesthesia</td>
</tr>
<tr>
<td>Operations†</td>
<td>Common, low-risk procedures typically performed by a single specialty</td>
<td>Common anomalies and diseases typically treated by most pediatric surgical specialists and that do not require substantial multispecialty coordination</td>
<td>Major congenital anomalies and complex disease, including those that are uncommon or require substantial multidisciplinary coordination</td>
</tr>
<tr>
<td>Ambulatory‡</td>
<td>ASA 1–2</td>
<td>ASA 1–3</td>
<td>ASA 1–3</td>
</tr>
<tr>
<td>Age older than 1 y</td>
<td>Full-term and preterm infants can be cared for as ambulatory patients based on written guidelines established by the pediatric anesthesiologist in charge of perioperative care. Institutional guidelines generally require full-term infants younger than 4 weeks or preterm infants younger than 50 post-conceptual weeks to be monitored for at least 12 h postoperatively.</td>
<td>Full-term infants and preterm infants can be cared for as ambulatory patients based on written guidelines established by the pediatric anesthesiologist in charge of perioperative care. Institutional guidelines generally require full-term infants younger than 4 weeks or preterm infants younger than 50 post-conceptual weeks to be monitored for at least 12 h postoperatively.</td>
<td></td>
</tr>
<tr>
<td>Resource</td>
<td>Basic</td>
<td>Advanced</td>
<td>Comprehensive</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>-------</td>
<td>----------</td>
<td>---------------</td>
</tr>
<tr>
<td>General surgeon with pediatric expertise</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Pediatric surgeon available</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Pediatric surgeons 24/7</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Anesthesiologist with pediatric expertise</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Pediatric anesthesiologist available</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Pediatric anesthesiologists 24/7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiologist with pediatric expertise</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Pediatric radiologist</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Pediatric diagnostic and interventional radiology 24/7</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Level I or higher NICU</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Level III or higher NICU</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level IV NICU</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Ability to stabilize and transfer critically ill children</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>ICU capacity with pediatric critical care</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Pediatric ICU with pediatric intensivists</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Emergency physician with pediatric expertise 24/7</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Pediatric emergency physician 24/7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pediatric resuscitation in all areas</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>In house physician with PALS certification or equivalent and pediatric resuscitation</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Reciprocal relationship with higher level for transfer</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Required database participation</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Pediatric surgical nursing expertise</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Pediatric medical and surgical specialists available for consultation</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Pediatric medical and surgical specialists 24/7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pediatric ancillary staff 24/7</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Transfer team</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pediatric rapid response team 24/7</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
PCC Resources

- SCCM 2012 Statistical Brochure
  - 67,357 Adult ICU beds
  - 20,000 NICU beds
  - 4,004 PICU beds
Summary

• Growing body of evidence that patient outcomes and volumes are inversely related
  – Variety of medical and surgical issues including critically ill pediatric patients

• Regionalization efforts depend on location, patient population, and a variety of other factors including payment models

• Topic will continue to grow in light of internal and external factors
  – Is there such a thing as too big?
  – Will this affect access?
  – Is volume just a surrogate for something else
The End