A National Survey of Pediatric Critical Care Resources in the United States

Folafoluwa O. Odetola, MD*‡; Sarah J. Clark, MPH‡; Gary L. Freed, MD, MPH‡; Susan L. Bratton, MD, MPH*; and Matthew M. Davis, MD, MAPP‡§

ABSTRACT. Objective. To characterize resources available for the care of critically ill and injured children in the United States.

Study Design. In January through May 2004, we conducted a cross-sectional survey of medical directors of intensive care facilities for children.

Results. Pediatric critical care medical directors from 257 of 337 eligible hospitals responded to the survey (response rate: 76%). The median number of beds was 12 (interquartile range: 8–17 beds), with a median of 58 admissions per PICU bed (interquartile range: 44–70 admissions per PICU bed) in 2003. The median numbers of admissions per PICU bed were not statistically different among PICUs of different sizes. Fewer than 6% of hospitals shared PICU space with space for critically ill adults. The smallest units (1–6 beds) had higher physician and nurse staffing ratios per PICU bed. Advanced therapeutic technology, particularly renal replacement and inhaled nitric oxide therapy, was significantly more likely to be available in larger PICUs (≥7 beds).

Conclusions. PICUs with the fewest beds had higher physician and nurse staffing ratios per PICU bed and lower resource capacity for high-intensity renal and respiratory therapy. The impact of PICU resource availability on referral patterns and outcomes of pediatric critical illnesses warrants additional study.

ABBREVIATIONS. IQR, interquartile range; AHA, American Hospital Association.

Pediatric intensive care facilities support the medical needs of children at risk of imminent death resulting from acute illness or injury, but not all intensive care settings provide equivalent care. Care of more severely ill and injured children in a tertiary medical center PICU has been associated with lower odds of death, compared with care in a nontertiary pediatric critical care setting. This contrast raises questions about the staffing and technologic capacities of pediatric critical care resources and how they are distributed across the United States.

A recently published analysis of pediatric critical care resources through 2001 found that the number of PICU beds in the United States has increased since 1995, beyond what would be expected on the basis of population growth. A concurrent study of data based on the annual American Hospital Association (AHA) survey illustrated that PICU facilities were available in only 9% of US counties, predominantly in urban areas. Uneven distribution of PICU resources despite an apparent increase in the overall supply over time raises questions about access to timely appropriate care for critically ill and injured children.

To facilitate characterization of US PICUs, 2 levels of PICU care have been defined. Critically ill children who require services not available or infrequently used in level II PICUs are referred to level I PICUs, with higher levels of subspecialist and technologic support. Delineation of the available resources for the care of critically ill and injured children is a first step in evaluating the adequacy and efficiency of PICU care. This study was conducted to describe the availability and characteristics of facilities for critically ill and injured children across the United States in 2004.

METHODS

Sample

The initial sampling frame included all hospitals that reported having PICU facilities on the AHA 2001 annual survey, the most recent, publicly available data at the initiation of the study in 2003. Additional hospitals listed through the National Association of Children’s Hospitals and Related Institutions, the Virtual Pediatric Intensive Care Unit, or the Shriners Hospitals for Children were contacted via telephone to ascertain the availability of facilities for critically ill and injured children. Through this process, 337 hospitals were identified as having facilities for the care of critically ill and injured children; these units included PICUs, burn ICUs, and ICUs for orthopedic and spinal injuries (Fig 1). We excluded NICUs. Of note, certain hospitals listed in the AHA annual survey as having PICU facilities did not in fact have such facilities when they were contacted by the authors, and this is one of the reasons why the study sample differed from that in a recent study by Randolph et al.

Survey Design

The study was approved by the institutional review board of the University of Michigan Medical School. A 1-page survey was
designed to collect information on unit characteristics, including the unit size, patient volume, nurse staffing, and capacity to implement certain therapeutic modalities. Specific data on physician characteristics included the presence and number of pediatric intensivists, hours of daily in-house pediatric intensivist coverage, and presence of 24-hour coverage by pediatric intensivists.

Survey Administration
The medical director for each PICU was identified through Internet information or through hospital telephone operators. Surveys, accompanied by a personalized cover letter, were sent via surface mail to PICU medical directors. A second mailing was sent to nonrespondents 8 weeks later. At study conclusion, all nonresponding hospitals were contacted via telephone in an attempt to verify the presence of a unit for the care of critically ill children other than preterm neonates and to ascertain the number of beds therein. Survey administration occurred from January through May 2004.

Data Analyses
All analyses were conducted with Stata 7 for Windows (Stata Corp, College Station, TX). Univariate and bivariate analyses were performed to describe the responses obtained regarding the distribution of pediatric critical care facilities, physician and nursing supply, and technologic capacity. Pearson’s $\chi^2$ test was used for bivariate comparison of proportions, and the Kruskal-Wallis test was used for comparison of nonparametric continuous data among PICU categories. A 2-tailed a level of .05 was used as the threshold for statistical significance.

RESULTS
Characteristics of PICU Facilities
Of 337 eligible hospitals, 257 hospitals responded to the survey (response rate: 76%). Nonrespondents did not differ significantly from respondents in terms of distribution according to census region or PICU size.

All respondents reported a unit within the hospital for the care of critically ill or injured children. The median number of beds per PICU was 12 (interquartile range [IQR]: 8–17 beds). There were more admissions in PICUs with larger numbers of beds; however, the number of admissions per PICU bed was not statistically different among PICUs of different bed size categories (Table 1). Twenty-five PICUs reported having a separate cardiac care area; these areas were located primarily among PICUs with ≥12 beds.
was a decrease in pediatric intensivist/bed ratios were adjusted for the number of PICU beds, there was a decrease in pediatric intensivist/bed ratios with increasing numbers of PICU beds. However, when results were adjusted for the number of PICU beds, there was a decrease in pediatric intensivist/bed ratios and nurse/bed ratios as the number of beds increased (P < .01) (Table 1). Pediatric intensivists provided coverage in these PICUs for a median of 12 hours (IQR: 12–15 hours) during the day. They also provided 24-hour coverage in 68% of the units overall; this proportion increased with the number of PICU beds (Table 1). Fourteen PICUs (5.5%) had no pediatric intensivists on staff. The nurse/patient ratios were similar among all of the units.

Available Therapeutic Modalities

Nearly 100% of PICUs reported a capacity for mechanical ventilation and invasive monitoring of arterial blood pressure, intracranial pressure, and central venous pressure. Less than 80% of all PICUs had facilities for renal replacement or nitric oxide therapy (Table 2), with the availability of advanced therapies increasing with the size of the PICU (P < .01) (Table 3).

Coresident PICUs

Fourteen hospitals (5.5%) had facilities for critically ill adult and pediatric patients within the same area. These PICUs had a median number of 4.5 pediatric beds (IQR: 2–10 beds). Eleven of the units had at least 1 pediatric intensivist, with 24-hour coverage by a pediatric intensivist occurring in 8 of the units. All had the capacity to provide mechanical ventilation and vascular pressure and intracranial pressure monitoring for their pediatric patients. Hemodialysis, hemofiltration, and nitric oxide therapy could be performed in fewer settings (71%, 57%, and 79% of the PICUs, respectively).

**DISCUSSION**

Our study follows reports detailing the growth of pediatric critical care resources in the United States with time and, in a rapidly evolving field, is the most recent national attempt to describe in detail the various settings in which care for critically ill and injured children is coordinated currently. Furthermore, this is the first report of "coresidence," in which care of critically ill and injured adults and children is conducted within the same setting. We also report a significant difference in the availability of advanced technology as a function of the number of PICU beds, with the larger PICUs (≥7 beds) having such technology available more often. The smallest units (1–6 beds) had the lowest availability of advanced therapeutic modalities but had higher ratios of nurses and physicians to beds.

Pediatric intensivists represented part of the health care delivery team in 94% of the PICUs in our survey. This is similar to findings reported recently and is a significant increase over the results of the first national survey of PICU resources conducted in 1989, which reported this practice for 73% of the PICUs surveyed. Studies in both the adult and pediatric literature have indicated that staffing ICUs with intensivists may improve outcomes and decrease resource use by reducing inappropriate admissions, preventing complications of care, and ensuring prompt discharge. We observed that smaller units (1–6 beds) had higher pediatric intensivist/bed ratios than did larger units. In a study of outcomes according to PICU status, Pollack et al reported similar differences in resource availability, with nontertiary units providing more labor-intensive care and tertiary PICUs demonstrating greater availability of technology. Children in the higher strata of critical illness had a greater likelihood of death in the nontertiary settings, despite higher provider/patient ratios.

To improve the quality of care provided in the

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**TABLE 1.** Organizational Characteristics of Pediatric Critical Care Services

<table>
<thead>
<tr>
<th>Aggregate (n = 257)</th>
<th>PICU Size (No. of Beds)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Admissions in year 2003*</td>
<td>662 (372–1050)</td>
<td>300 (150–372)</td>
</tr>
<tr>
<td>Admissions per bed*</td>
<td>58.6 (45.0–70.0)</td>
<td>57.3 (37.8–70.0)</td>
</tr>
<tr>
<td>No. of pediatric intensivists*</td>
<td>4 (2–5)</td>
<td>2 (2–3)</td>
</tr>
<tr>
<td>Pediatric intensivist/bed*</td>
<td>0.30 (0.24–0.38)</td>
<td>0.40 (0.33–0.50)</td>
</tr>
<tr>
<td>No. with 24-h intensivist coverage (%)</td>
<td>176/257 (68)</td>
<td>32/60 (53)</td>
</tr>
<tr>
<td>Nurse/patient ratio</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>PICU nurse/bed ratio*</td>
<td>2.9 (2.2–3.8)</td>
<td>3.3 (2.2–4.7)</td>
</tr>
<tr>
<td>No. with separate cardiac ICU</td>
<td>25</td>
<td>1</td>
</tr>
</tbody>
</table>

Pearson’s χ² and Kruskal-Wallis tests were used for comparisons of categorical and continuous data, respectively. NS indicates not significant.

* Values reported as median and IQR.

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**TABLE 2.** Availability of Therapeutic Modalities in PICU Settings

<table>
<thead>
<tr>
<th>Modality</th>
<th>No. of PICUs</th>
<th>Proportion of PICUs, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical ventilation</td>
<td>257</td>
<td>100.0</td>
</tr>
<tr>
<td>Invasive arterial BP monitoring</td>
<td>256</td>
<td>99.6</td>
</tr>
<tr>
<td>Central venous pressure monitoring</td>
<td>255</td>
<td>99.2</td>
</tr>
<tr>
<td>ICP monitoring</td>
<td>241</td>
<td>93.8</td>
</tr>
<tr>
<td>Inhaled nitric oxide therapy</td>
<td>199</td>
<td>77.4</td>
</tr>
<tr>
<td>Hemodialysis</td>
<td>195</td>
<td>75.9</td>
</tr>
<tr>
<td>Hemofiltration</td>
<td>187</td>
<td>72.8</td>
</tr>
</tbody>
</table>

BP indicates blood pressure; ICP, intracranial pressure.
intensive care setting, timely access to care by an intensivist has been advocated by the Society for Critical Care Medicine and the Leapfrog Group. The latter organization has advocated that, in hospitals with either adult ICUs or PICUs, intensivists manage or comanage the care of critically ill patients, be present during daytime hours, and be easily accessible at other times. In our study, pediatric intensivists provided coverage in the ICU for an average of 12 daily hours.

The optimal duration of daily coverage by intensivists in the PICU is not known, and a clear association between the duration of coverage and patient outcomes in the PICU has not yet been described. However, 24-hour coverage of PICUs by intensivists has been associated with improved outcomes. We report 24-hour coverage of the PICU in more than two thirds of the responding hospitals in our study, a substantial increase from the 1989 survey, which documented such practice in ~50% of the units surveyed. Additional research is warranted to elucidate the impact of physician staffing models, particularly the duration of daily coverage, on patient outcomes in pediatric critical care.

We observed a nurse/patient ratio of 1:2 in 204 (81%) of the PICUs surveyed. This is consistent with guidelines suggested by the American College of Critical Care Medicine Task Force on Models of Critical Care Delivery. Although excessive nursing workloads have been associated with burnout, job dissatisfaction, and poor patient outcomes in the ICU, the optimal nurse/patient ratio in intensive care remains unclear. The intensive care environment often requires the use of invasive devices for monitoring and life support. For adults, the availability and amount of technologic support in an ICU have been associated with reductions in hospital mortality rates. We found greater availability of specific advanced technology and therapeutic modalities in PICUs with greater numbers of beds. This distribution merits additional study, focusing on its influence on referral patterns and outcomes for critically ill and injured patients who require these modes of therapy.

Nearly 6% of our responding PICUs reported coresidence of critically ill pediatric patients with critically ill adult patients. Coresident PICUs are often staffed by pediatric intensivists and provide core critical care services but lack other advanced therapeutic modalities that may influence patient outcomes. Coresidence may influence the quality and intensity of care for children, as indicated in a prior study that showed shorter severity-adjusted lengths of stay and fewer days of mechanical ventilation for adolescent trauma victims admitted to a PICU, compared with an adult surgical ICU. Although the number of coresident PICUs is small now, the phenomenon of coresidence warrants additional investigation, because constrained fiscal or staffing resources may force some smaller facilities that have separate PICU beds currently to consider coresidence in the future.

This study has certain limitations. Data reported by the PICU medical directors were self-reported and therefore not subject to verification. This could affect the results in either direction but might be more likely to lead to overestimation of resource availability. We achieved an excellent response rate of 76%, collecting information from all states with pediatric critical care facilities, which strengthens the external validity of our findings. Nevertheless, there could be selection bias resulting from the lack of responses from all eligible PICU sites. To mitigate this shortcoming, we determined the number of beds reserved for critically ill children at each hospital without a survey response, which allowed us to ascertain the count and distribution of facilities across the entire United States.

An additional limitation of our survey was that we were not able to distinguish between PICUs in community settings and those in academic medical centers. Although this distinction is important for understanding the availability of ICU care in communities and connections to academic centers that may offer more access to advanced technology, we think that more salient distinctions pertain to pediatric intensivist staffing and the availability of renal replacement and advanced respiratory therapies, which we report above.

### CONCLUSIONS

As the number of PICU beds in the United States continues to grow, it is essential to understand how the availability of PICU resources may affect the care of critically ill and injured children. In 2004, the availability of PICU resources varied principally according to the number of PICU beds. The smallest PICUs (1–6 beds) had higher physician and nurse staffing ratios per PICU bed than did larger PICU settings. In contrast, larger PICUs had significantly

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**TABLE 3. Availability of Therapeutic Modalities According to PICU Bed Size**

<table>
<thead>
<tr>
<th>Modality</th>
<th>PICU Size (No. of Beds)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1–6 (n = 60)</td>
<td></td>
</tr>
<tr>
<td>ICP monitoring, no. (%)</td>
<td>48 (80)</td>
<td></td>
</tr>
<tr>
<td>Hemodialysis, no. (%)</td>
<td>24 (40)</td>
<td></td>
</tr>
<tr>
<td>Hemofiltration, no. (%)</td>
<td>20 (33)</td>
<td></td>
</tr>
<tr>
<td>Nitric oxide therapy, no. (%)</td>
<td>33 (55)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7–12 (n = 90)</td>
<td></td>
</tr>
<tr>
<td>ICP monitoring, no. (%)</td>
<td>86 (96)</td>
<td>.32</td>
</tr>
<tr>
<td>Hemodialysis, no. (%)</td>
<td>69 (77)</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Hemofiltration, no. (%)</td>
<td>65 (72)</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Nitric oxide therapy, no. (%)</td>
<td>62 (69)</td>
<td>&lt;.01</td>
</tr>
<tr>
<td></td>
<td>13–18 (n = 55)</td>
<td></td>
</tr>
<tr>
<td>ICP monitoring, no. (%)</td>
<td>55 (100)</td>
<td>.32</td>
</tr>
<tr>
<td>Hemodialysis, no. (%)</td>
<td>52 (95)</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Hemofiltration, no. (%)</td>
<td>51 (93)</td>
<td>.01</td>
</tr>
<tr>
<td>Nitric oxide therapy, no. (%)</td>
<td>53 (96)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>≥19 (n = 52)</td>
<td></td>
</tr>
<tr>
<td>ICP monitoring, no. (%)</td>
<td>52 (100)</td>
<td></td>
</tr>
<tr>
<td>Hemodialysis, no. (%)</td>
<td>50 (96)</td>
<td></td>
</tr>
<tr>
<td>Hemofiltration, no. (%)</td>
<td>51 (98)</td>
<td></td>
</tr>
<tr>
<td>Nitric oxide therapy, no. (%)</td>
<td>50 (98)</td>
<td></td>
</tr>
</tbody>
</table>

Kruskal-Wallis tests were used for comparisons of data among PICU categories. More than 95% of all PICUs, regardless of bed number, had facilities for mechanical ventilation, invasive arterial blood pressure monitoring, and central venous pressure monitoring, which are not shown. ICP indicates intracranial pressure.
greater capacity to provide advanced therapies, such as renal replacement and inhaled nitric oxide therapy. Future studies should address the relationships of the availability of pediatric critical care facilities to referral patterns and to outcomes of life-threatening pediatric illnesses.

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