IMPORTANCE  Timely and efficient access to hospital care is essential for the health and well-being of children. As insurance networks, accountable care organizations, and alternative payment methods evolve, these new systems of care must continue to serve the needs of children.

OBJECTIVE  To test the hypothesis that the availability of definitive pediatric hospital care is significantly more limited than adult care and is decreasing disproportionately.

DESIGN  This study used case mix data during fiscal years 2004 through 2014 to measure transfer frequency and identify the site of care completion for all patients seen in acute care hospitals throughout Massachusetts. Patterns of care among children were then compared with patterns of care among adults. Participants were all patients seen in an emergency department or admitted to a hospital from 2004 through 2014, including more than 34 million encounters.

MAIN OUTCOMES AND MEASURES  Hospital Capability Index and Regionalization Index for all acute care hospitals and all conditions within the Clinical Classifications Software of the Healthcare Cost and Utilization Project.

RESULTS  Over the study period, the Commonwealth of Massachusetts hospital system was composed of 66 acute care hospitals. After excluding newborns and mental health conditions, there were 34,511,312 encounters, with 25,226,014 emergency department visits and 9,285,298 observation or full admissions. From 2004 through 2014, care for adults and children concentrated among hospitals but much more so for pediatric care. The number of children requiring care in more than one hospital increased 36.2% (from 7,190 to 9,793). The median (interquartile range [IQR]) Hospital Capability Index, reflecting the likelihood of a hospital completing a patient’s care without transfer, decreased 10.8% (from 0.74 [IQR, 0.65-0.81] to 0.66 [IQR, 0.53-0.76]) for adult care and 65.0% (0.20 [IQR, 0.05-0.34] to 0.07 [IQR, 0.01-0.23]) for pediatric care. Almost all of the shift was from nonacademic to academic hospitals. The median Regionalization Index, reflecting the degree to which care for specific conditions is regionalized, was very high for pediatric conditions and further increased from 0.79 (IQR, 0.67-0.91) to 0.87 (IQR, 0.80-0.91). Over the same decade, the mean Regionalization Index for adult conditions was low and increased modestly from 0.25 (IQR, 0.14-0.39) to 0.32 (IQR, 0.19-0.46). Among pediatric conditions, more than 75% were highly regionalized in 2014 compared with fewer than 50% in 2004.

CONCLUSIONS AND RELEVANCE  Pediatric hospital care has become increasingly concentrated, and many children with common conditions are now less frequently treated in the community. This finding has significant implications for systemwide capacity management and should be specifically accounted for in public health activities, disaster planning, and determinations of network adequacy.
Pediatric hospital care requires specialized resources and expertise. In addition, many adult studies and some pediatric studies have demonstrated positive correlations between volume and outcome. For these reasons, regionalization has been promoted as an appropriate mechanism for improving pediatric care.

Over the past decade, evidence of pediatric care regionalization has begun to appear. While pediatric cardiac surgery has long been concentrated among a few high-volume centers, other surgical specialties, including general surgery, otorhinolaryngology, and orthopedics, are now reporting similar trends. At the same time, emergency department (ED) physicians within academic centers are seeing large numbers of children referred with routine medical conditions, and pediatric inpatient transfers to academic centers are increasingly commonplace.

Trends in regionalization can result from a variety of forces. Public health initiatives may intentionally regionalize the care of some conditions, while market forces may regionalize or deregionalize the care of others. Similarly, interhospital transfer may sometimes serve as an efficient mechanism for directing patients to the care they need and at other times may reflect an inefficient system that fails to optimize patient outcomes. Therefore, the net consequence of regionalization can be variable, with clinical benefits accruing to only a subset of conditions and cost savings realized only under certain circumstances. As a result, research is necessary to understand how care networks and regionalization actually operate within specific geographic areas.

Because pediatric hospital care constitutes a smaller market and requires more specialized resources than adult care, we hypothesized that the qualitative signs of increasing regionalization reflect a disproportionate reduction in the availability of pediatric care. If so, this finding should be specifically accounted for in public health activities, disaster planning, and determinations of network adequacy. To explore this issue, we developed quantitative metrics for assessing care regionalization and applied them to a decade of pediatric and adult hospital experience in Massachusetts.

**Key Points**

**Question** Is pediatric hospital care becoming more limited than adult care?

**Findings** This study of case mix data during fiscal years 2004 through 2014, found definitive hospital care (from among 34,511,312 encounters) for both adults and children concentrated among Massachusetts hospitals but much more so for children. Hospital transfers of children increased 36.2% (from 7190 to 9793) and the likelihood of a hospital completing all of a child’s care without transfer (as measured by the median Hospital Capability Index) decreased 65.0% (from 0.20 to 0.07).

**Meaning** Pediatric hospital care is becoming increasingly concentrated, which should be accounted for in public health activities, disaster planning, and determinations of network adequacy.

**Methods**

**Data Source**

We used the Acute Hospital Case Mix data set from the Massachusetts Center for Health and Information and Analysis (CHIA). Like the Healthcare Cost and Utilization Project (HCUP) data, the CHIA data sets include all inpatient, outpatient observation, and ED visits within a given fiscal year and contain both demographic and clinical elements. Our proposed use of these data was reviewed and approved by the CHIA Data Release Committee, and a waiver of informed consent was obtained from the Boston Children’s Hospital Committee on Clinical Investigation.

**Hospital and Patient Selection**

We defined the Massachusetts acute care hospital system as that composed of all hospitals maintaining an active ED and admitting patients for general medical or surgical conditions. As described in detail elsewhere and summarized below, we used transfer frequency and completion of care as a measure of hospital capability and regionalization. We analyzed all inpatient and observation admissions, as well as all ED visits, within every acute care hospital in Massachusetts during fiscal years 2004 through 2014. For clarity in reporting, we mapped the principal diagnosis into one of 285 Clinical Classifications Software (CCS) codes provided by the HCUP. We categorized visits as transfers when the patient disposition field indicated transfer to a different acute care hospital and as admissions when visits resulted in either inpatient or observation admissions to the same hospital. Focusing on inpatient care and transfers for medical and surgical illness, we removed (1) ED visits discharged directly home from the first ED visit, (2) mental health conditions (CCS codes 65-75), and (3) well newborns (International Classification of Diseases, Ninth Revision, Clinical Modification codes V30-V39). For consistency with previous work, we also excluded rare conditions seen fewer than 20 times per year statewide. Patients were classified as pediatric (<15 years) or adult (≥15 years) according to pediatric service requirements within Massachusetts hospital regulations. For reporting, data were aggregated by hospital cohorts as defined by the CHIA and included in the eAppendix in the Supplement.

**Hospital Capability Index and Regionalization Index**

We have previously shown that hospital capability and regionalization of care can be captured and quantified by the Hospital Capability Index (HCI) and the Regionalization Index (RI), which focus on patients who require admission or care in more than one hospital. Hospitals that routinely admit patients directly or through their ED and later discharge them to home are considered “capable,” while those that routinely transfer patients for additional care elsewhere are not. Among ED to ED transfers, hospital 1 is assumed to lack some care capability that is supplied by hospital 2, and patients discharged home from hospital 2’s ED are excluded from further analysis. Therefore, all visits to hospital 2 are treated equally, and the second encounter is considered routine. Details of these calculations are included in the eAppendix in the Supplement.
For health services research, the HCI and RI may be stratified by condition or other variables of interest, including age. The RI can be calculated for a single condition or collection of conditions and reflects the mean probability that individuals with specified conditions will require transfer to a different hospital for completion of their care. Highly regionalized conditions carry RIs close to 1 (commonly transferred because care is completed in few hospitals), while nonregionalized conditions return RIs closer to zero (transfer is uncommon, and care is completed in most hospitals). The RIs allow quantitative comparison of the degree to which care for a given condition or range of conditions is effectively regionalized and accurately reflects the influence of public health initiatives focused on conditions like stroke, myocardial infarction, and trauma care.18

The HCI represents the mean probability of completing care across all CCS codes, thus providing information on the range of conditions that a hospital or hospital group handles routinely. For each condition, a hospital with a capability of 1 will never transfer patients and a hospital with a capability of zero will always do so. Because capability must be demonstrated, values of zero are assigned to conditions that are never encountered. The HCI averages condition-specific capabilities, thus approaching unity when a hospital completes the care of all patients across a wide range of conditions (eg, tertiary referral centers). The HCI is lower among specialty hospitals caring for a few conditions and among resource-limited hospitals that frequently transfer patients for higher levels of care. By definition, the HCI is a measure of how a hospital functions within a system and its demonstrated ability to definitively complete care. It is not a measure of existing resources or potential capability under different circumstances.

Statistical Analysis
All analyses used Python 3.5, an open-source programming language, and the iPython/Jupyter environment.23 We calculated the HCIs and RIs for all hospitals, hospital cohorts, and conditions, reporting descriptive statistics for each. Comparisons between the HCI and RI values across years used the Wilcoxon signed rank test. The Spearman rank correlation was used to assess the relative ranks for the comparison between multiple aggregated years and single years. Statistical significance was taken as a 2-sided P < .05.

Results
Over the study period, the Commonwealth of Massachusetts hospital system was composed of 66 acute care hospitals. After excluding newborns and mental health conditions, there were 34 511 312 encounters, with 25 226 014 ED visits and 9 285 298 observation or full admissions. From 2004 through 2014, the annual number of adult ED visits increased 8.2% (from 1760 443 to 1 905 721), the number of admissions increased 5.1% (from 761 765 to 800 394), and the number of transfers increased 28.1% (from 91 422 to 117 141). At the same time, the annual number of pediatric ED visits decreased 2.7% (from 379 056 to 368 697), the number of admissions decreased 15.0% (from 48 857 to 41 509), and the number of pediatric transfers increased 36.2% (from 7 190 to 9 793). Of the latter, ED to ED transfers increased 52.7% (from 5 600 to 8 555), while hospital to hospital transfers decreased 22.1% (from 1 590 to 1 238). The HCI and RI calculations were based on a final data set containing 580 859 pediatric and 9 381 431 adult encounters that resulted in admission or required care in more than one hospital.

Capability of Hospitals and Cohorts
From 2004 through 2014, the mean capability of Massachusetts hospitals declined more for children than for adults. The median (interquartile range [IQR]) HCI for adult care decreased 10.8% (from 0.74 [IQR, 0.65-0.81] to 0.66 [IQR, 0.53-0.76]) (P < .01), while the median capability for pediatric care decreased 65.0% (from 0.20 [IQR, 0.05-0.34] to 0.07 [IQR,
Concentration of Pediatric Care

With declining capability among nonacademic hospitals, both pediatric care and adult care were increasingly regionalized from 2004 through 2014. Reflecting this finding, the mean RI for all pediatric conditions increased from 0.79 (IQR, 0.67-0.91) in 2004 to 0.87 (IQR, 0.80-0.91) in 2014. Over the same period, the mean adult RI increased from 0.25 (IQR, 0.14-0.39) to 0.32 (IQR, 0.19-0.46) (P < .01 for both). When considering specific CCS codes, more than three-quarters of all pediatric conditions were highly regionalized in 2014, returning indexes above 0.80, compared with fewer than half in 2004.

The Table lists changes in regionalization among the 16 pediatric conditions most commonly transferred in 2014. In this list, it is notable that some of the most common pediatric conditions saw the greatest redistribution of care, including asthma, pneumonia, other upper respiratory tract infections, appendicitis and other appendiceal conditions, and fracture of upper limb. Some common conditions, such as fracture of lower limb. Some common conditions, such as fracture of appendicitis and other appendiceal conditions, and fracture of upper respiratory tract infections, pneumonia, other upper respiratory tract infections, Appendicitis and other appendiceal conditions, and fracture of upper limb, abdominal pain, and epilepsy or convulsions, were even more regionalized than intentionally regionalized adult conditions, such as stroke (RI, 0.39), trauma (RI, 0.53), and cardiac surgery (RI, 0.52). Neonatal respiratory distress syndrome, acute cerebrovascular disease, poisoning, and complications of diabetes were among those less frequent conditions transferred at the highest rates (eTable in the Supplement). Overall, 129 of 157 (82.2%) CCS codes for which children were seen between 2004 and 2014 were either concentrated among fewer hospitals or transferred more frequently.

The Commonwealth of Massachusetts Hospital System for Children vs Adults

Of the 66 acute care hospitals in Massachusetts, 55 (83.3%) admitted 10 or more children in 2004, while only 49 (74.2%) did so in 2014. Over the decade, the mean number of pediatric admissions per hospital fell from 1992 to 1766 (11.3%). Among nonacademic centers, 1 of 3 pediatric admissions (65 531 of 196 304) were under short-stay or observation status compared with fewer than 1 in 5 for adults (1 098 612 of 5 795 468). Overall, the fraction of pediatric patients admitted to academic centers (59.4%) was twice that of adults (29.6%).

0.01-0.23) (P < .01). Figure 1 shows that pediatric capability in most hospitals has always been far below adult capability and that pediatric capability comparable to the adult capability found in most general hospitals is limited to only a few outliers.

Figure 2 shows that the HCI changes within the Commonwealth of Massachusetts hospital system occurred primarily in nonacademic hospitals. While there was little change for adult or pediatric conditions among academic hospitals, there was a modest HCI decrease in adult care and a large decrease in pediatric care among other cohorts. Over the decade, teaching hospitals saw a 36.3% decline (from 0.22 to 0.14) in their mean pediatric capability, community hospitals saw a 40.9% decline (from 0.22 to 0.13), and community-disproportionate share hospitals saw a 44.4% decline (from 0.18 to 0.10) (P < .01 for all). For direct comparison of pediatric and adult capabilities, Figure 3 shows a profile of one representative community hospital (all conditions in eFigure 1 in the Supplement).
**Table. Most Frequently Transferred Pediatric Conditions in 2014**

<table>
<thead>
<tr>
<th>CCS Code</th>
<th>No. of Transfers in 2004</th>
<th>% of All Visits in 2004</th>
<th>RI in 2004</th>
<th>No. of Transfers in 2014</th>
<th>% of All Visits in 2014</th>
<th>RI in 2014</th>
<th>Difference in RI, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fracture of upper limb</td>
<td>460</td>
<td>2.7</td>
<td>0.65</td>
<td>652</td>
<td>5.1</td>
<td>0.86</td>
<td>32</td>
</tr>
<tr>
<td>Abdominal pain</td>
<td>230</td>
<td>3.1</td>
<td>0.58</td>
<td>599</td>
<td>5.0</td>
<td>0.73</td>
<td>26</td>
</tr>
<tr>
<td>Other injuries and conditions due to external causes</td>
<td>339</td>
<td>1.8</td>
<td>0.76</td>
<td>514</td>
<td>2.4</td>
<td>0.82</td>
<td>8</td>
</tr>
<tr>
<td>Epilepsy or convulsions</td>
<td>382</td>
<td>7.4</td>
<td>0.67</td>
<td>475</td>
<td>8.6</td>
<td>0.81</td>
<td>21</td>
</tr>
<tr>
<td>Asthma</td>
<td>239</td>
<td>1.7</td>
<td>0.34</td>
<td>446</td>
<td>3.3</td>
<td>0.56</td>
<td>65</td>
</tr>
<tr>
<td>Other lower respiratory tract disease</td>
<td>201</td>
<td>3.1</td>
<td>0.65</td>
<td>319</td>
<td>3.4</td>
<td>0.72</td>
<td>11</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>303</td>
<td>3.6</td>
<td>0.38</td>
<td>318</td>
<td>5.7</td>
<td>0.56</td>
<td>47</td>
</tr>
<tr>
<td>Fever of unknown origin</td>
<td>209</td>
<td>1.0</td>
<td>0.57</td>
<td>318</td>
<td>1.3</td>
<td>0.71</td>
<td>25</td>
</tr>
<tr>
<td>Open wounds of head, neck, and trunk</td>
<td>206</td>
<td>0.7</td>
<td>0.79</td>
<td>299</td>
<td>1.4</td>
<td>0.89</td>
<td>13</td>
</tr>
<tr>
<td>Other perinatal conditions</td>
<td>282</td>
<td>8.9</td>
<td>0.42</td>
<td>296</td>
<td>6.9</td>
<td>0.54</td>
<td>29</td>
</tr>
<tr>
<td>Other upper respiratory tract infections</td>
<td>114</td>
<td>0.3</td>
<td>0.40</td>
<td>255</td>
<td>0.7</td>
<td>0.58</td>
<td>45</td>
</tr>
<tr>
<td>Poisoning by other medications and drugs</td>
<td>144</td>
<td>9.8</td>
<td>0.67</td>
<td>217</td>
<td>13.5</td>
<td>0.84</td>
<td>25</td>
</tr>
<tr>
<td>Nausea and vomiting</td>
<td>108</td>
<td>1.6</td>
<td>0.67</td>
<td>205</td>
<td>1.5</td>
<td>0.17</td>
<td>10</td>
</tr>
<tr>
<td>Superficial injury or contusion</td>
<td>169</td>
<td>0.5</td>
<td>0.74</td>
<td>204</td>
<td>0.8</td>
<td>0.89</td>
<td>20</td>
</tr>
<tr>
<td>Appendicitis and other appendiceal conditions</td>
<td>64</td>
<td>4.2</td>
<td>0.30</td>
<td>196</td>
<td>14.5</td>
<td>0.58</td>
<td>93</td>
</tr>
<tr>
<td>Fracture of lower limb</td>
<td>173</td>
<td>3.6</td>
<td>0.55</td>
<td>193</td>
<td>5.1</td>
<td>0.82</td>
<td>49</td>
</tr>
</tbody>
</table>

Abbreviations: CCS, Clinical Classifications Software; RI, Regionalization Index.

**Figure 4** shows selected conditions that were common to both adults and children in 2014 (all conditions in eFigure 2 in the Supplement). From this perspective, a picture emerges of 2 separate systems. Most Massachusetts hospitals completed most of the care for their adult patients (61 of 66 completing care of >50% of patients for 80% of all conditions), while only approximately 20% did so for children.

**Discussion**

To our knowledge, this study is the first attempt to quantitatively describe an entire state’s existing network of pediatric hospital care. We find that hospital care for children in Massachusetts concentrated significantly over the past decade, even for common conditions, and that this result was mainly due to decreased care in nonacademic institutions. The emerging picture is one of increasing reliance on a handful of centers and necessity for including these centers in any viable networks of care. These findings carry significance for families selecting care plans, regulators determining network adequacy, and officials charged with disaster preparedness.

The information presented herein is consistent with frontline reports that a high fraction of interfacility transfers to pediatric referral centers are for conditions that were not referred in the past. For example, Li et al. studied information from 42 US tertiary care centers within the Pediatric Health Information System database and observed that 24.7% of children were transferred for minor conditions and discharged directly home, while another 17.0% were released in under 24 hours. As reasons for referral, they cited the same conditions identified herein, including abdominal pain, gastroenteritis, asthma, seizures, and orthopedic issues. In a separate, single-center experience, Gattu and colleagues saw a similar pattern and associated it with the absence of pediatric-trained physicians within referring hospitals. In surgical care, Salazar et al. used the national Kids’ Inpatient Database to show that pediatric general surgical cases are concentrating within tertiary centers, mainly owing to movement of low-risk, high-volume procedures. Similar trends have also been identified in other specialties, including pediatric orthopedics and otorhinolaryngology. These reports are consistent with our observation that pediatric community hospital care is disappearing.

Despite the trends reported elsewhere, our findings are surprising and potentially concerning. In Massachusetts, we identify a decline in already scarce pediatric inpatient care and no sign of leveling off. This trend antedated Massachusetts’ 2006 health care reform legislation and continued thereafter, despite full insurance for children. The overall result is that, statewide, many common pediatric conditions have become as effectively regionalized as some intentionally regionalized high-risk adult conditions.

In part, the concentration of pediatric care results from choices by hospitals to maintain or close their pediatric units. Indeed, we observed that a handful of hospitals stopped admitting children altogether. However, more of the care concentration we observed reflects patient self-selection and individual decisions to transfer children, even when inpatient pediatric units were available. The HCI and RI metrics capture demonstrated patterns of care and thus reflect the net influence of all care decisions. Structural, economic, workforce, medicolegal liability, knowledge, or other factors may all be posited as drivers for these decisions, and true hospital capabilities may be underestimated by our metrics if these factors are readily reversible. Clearly, however, hospitals in the past decade have varied much more widely in their patterns of care for children than for adults, and interfacility transfer has increasingly compensated for this occurrence.

The net influence of care concentration remains to be determined. An optimistic interpretation is that children are now...
and ambulance diversion may follow. In disaster plans into specialized referral centers, queues, overcrowding, and ambulance diversion may follow. Therefore, the concentration of care can carry unintended consequences. If excessivelow-acuity illness is shifted to pediatric care are included. Finally, total medical expenses may increase if care concentration disrupts market forces or redirects routine conditions to higher-cost centers.

Limitations and Generalizability
Our analysis has several limitations. First, identifiers were unavailable for many children during 2004 to 2008, so we were unable to match transfers using our previously described algorithm. This carries a small potential risk of overestimation when conditions are transferred outside the acute care hospital system. While uncommon among children, overestimation related to this issue can occur when adults are transferred to nursing homes and intermediate-care facilities. However, from data between 2012 and 2014, we estimate that potential differences in the mean aggregate indexes reported herein would vary less than 0.04 for adults and less than 0.01 for children. Therefore, even with this potential variability, all trends and conclusions would remain unchanged. Second, we excluded mental health conditions because the site of definitive care usually lies in mental health facilities outside of the acute care hospital system. Nonetheless, we acknowledge that mental health care regionalization is also critical to questions of network adequacy. Similarly, we excluded well newborns but acknowledge that maternal-neonatal care constitutes a separately regionalized system. Third, we did not include geography, although this variable must always be accounted for in network structures providing efficient and timely access to care. For example, it may be efficient to close services in one facility if they are readily available in a neighbor yet may be hazardous to do so if there are no neighbors or those neighbors are overcrowded. Regulatory bodies have sometimes focused on travel distances in determinations of network adequacy, but data herein suggest that the path to definitive care is more variable. Therefore, geographic analysis constitutes the “anatomy” of a health care system, while work like this study addresses the “physiology.”

The generalizability of these findings deserves special consideration. Massachusetts differs from other American states in its high insurance rates, historical health care legislation, and dominance of academic medical centers. While these or other factors might uniquely contribute to regionalization, 3 lines of evidence suggest that this occurrence is not an isolated phenomenon. First, as outlined above, corroborating reports from other states, across specialties, and using national data sets suggest similar experiences elsewhere. Second, the HCUP ED data show that transfers of children aged 1 to 17 years almost doubled nationwide from 2006 to 2014 (from 161,985 to 300,835 [ie, from 0.7% to 1.3% of all visits]), even as the total number of admissions decreased more than 20% (from 879,241 to 689,048 [ie, from 3.9% to 3.0% of all visits]). Third, our preliminary analysis of 2 larger US states shows similar trends over the same period. Taken together, these observations suggest that the concentration of pediatric hospital care is not limited to Massachusetts.

Conclusions
In summary, pediatric hospital care and adult hospital care are increasingly functioning as 2 separate systems. Care for...
children has concentrated such that many hospitals no longer manage the range of conditions that they once did. As a result, care for many common pediatric conditions is as regionalized as high-risk adult conditions, and access to definitive treatment is much more limited. This finding should be accounted for in many areas, including public health activities, disaster planning, and determinations of network adequacy.

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Acquisition, analysis, or interpretation of data: Both authors.
Drafting of the manuscript: Both authors.
Critical revision of the manuscript for important intellectual content: Both authors.
Statistical analysis: Franc.
Study supervision: McManus.

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