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Cooling The Hot Spots Where Child Hospitalization Rates Are High: A Neighborhood Approach To Population Health

ABSTRACT Improving population health requires a focus on neighborhoods with high rates of illness. We aimed to reduce hospital days for children from two high-morbidity, high-poverty neighborhoods in Cincinnati, Ohio, to narrow the gap between their neighborhoods and healthier ones. We also sought to use this population health improvement initiative to develop and refine a theory for how to narrow equity gaps across broader geographic areas. We relied upon quality improvement methods and a learning health system approach. Interventions included the optimization of chronic disease management; transitions in care; mitigation of social risk; and use of actionable, real-time data. The inpatient bed-day rate for the two target neighborhoods decreased by 18 percent from baseline (July 2012–June 2015) to the improvement phase (July 2015–June 2018). Hospitalizations decreased by 20 percent. There was no similar decrease in demographically comparable neighborhoods. We see the neighborhood as a relevant frame for achieving equity and building a multisector culture of health.

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Inequities "entail a failure to avoid or overcome inequalities that infringe on fairness and human rights norms."[1] Equity gaps are ever present in pediatrics, with neighborhood-to-neighborhood variation in child morbidity paralleling differences in underlying rates of poverty.[2–6] Such gaps have persisted for generations, driven at least in part by upstream social, environmental, and economic challenges (for example, racial discrimination, substandard housing, limited access to health-promoting resources, and socioeconomic deprivation).[7–10] These challenges affect one's ability to access preventive services, adhere to care recommendations, and trust that the health care system has one's interests at heart.[11–13] They also trigger morbidity directly via adverse exposures (such as in-home cockroaches and asthma exacerbations) or indirectly via "toxic" stress responses (for example, repetitive stress that alters immunologic functioning).[14,15]

With an evolution toward value-based payments, health care systems are focusing more attention on population health outcomes for lower-income patients. Whether driven by mission or margin, health care systems increasingly see themselves as accountable to more than just the people who walk through their doors.[16–20] They recognize that achieving equitable outcomes requires different—often multilevel—approaches, but little has been published about how to do this for, and with, populations.

Population health is defined as "the health outcomes of a group of individuals, including the distribution of outcomes within that group."[21(p381)] Cincinnati Children's Hospital Medical Center recently committed "to help[ing] ensure Cincinnati's 66,000 children are the healthiest in the nation through strong community partnerships," as part of its strategic plan for 2020.[22(p610)]

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Discrete goals were outlined in early 2015, one of which was to reduce the rate at which children from high-morbidity, high-poverty neighborhoods spend days in the hospital—narrowing the gap between their neighborhoods and healthier ones. Meeting this goal required being accountable for an entire population and focusing on the root causes of place-based inequities.[23] The work has employed the Model for Improvement[24] and a learning health system[25] approach to spur cross-sector collaboration and a move toward scale.[12,13,22]

Study Data And Methods

CONTEXT Hamilton County, Ohio, is the setting for this population health quality improvement work. The county includes roughly 190,000 children, of whom about 66,000 live in Cincinnati proper. Cincinnati Children's Hospital Medical Center manages approximately 95 percent of all pediatric hospitalizations for in-county children, which facilitates the quantification of truly population-level pediatric outcomes.
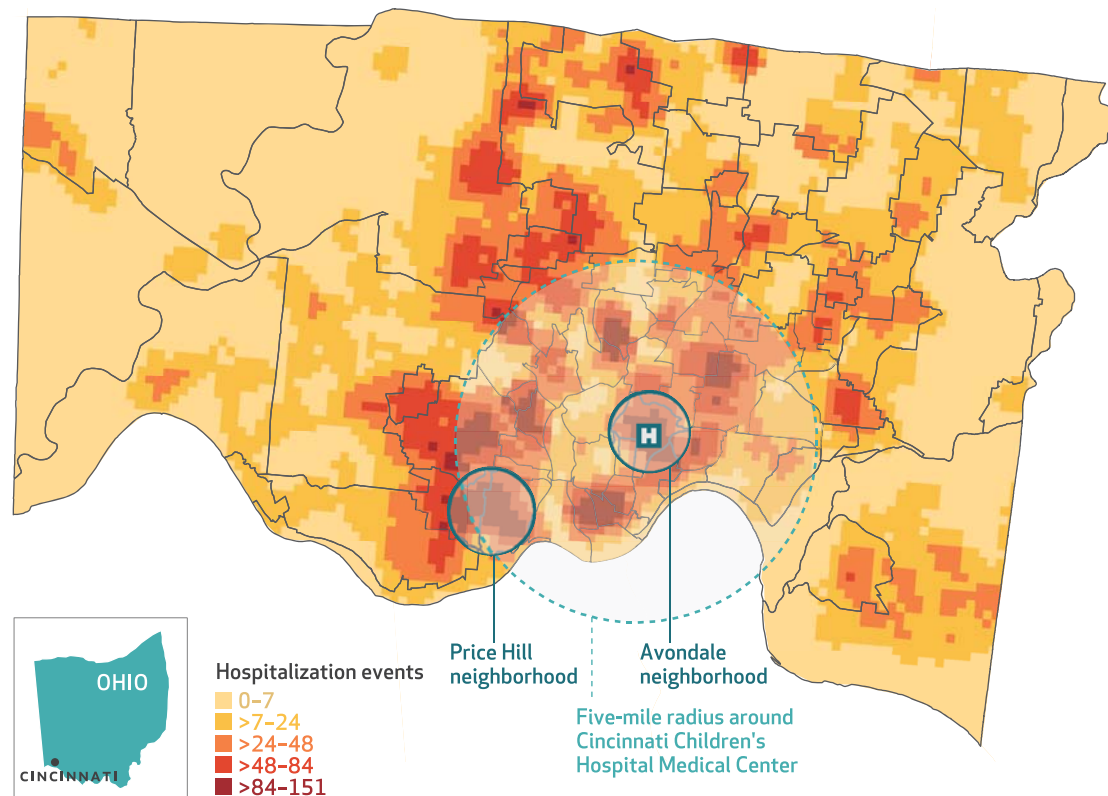
In the period July 2012–June 2015 there were multiple hospitalization hot spots, including the Avondale and Price Hill neighborhoods (exhibit 1). With the support of the medical center's leadership, we chose to focus initial quality improvement efforts on these two neighborhoods, given existing relationships with community-based partners and knowledge of the extent of medical and social need. There are about 3,200 children living in Avondale, and the median household income is $18,120.[26] Avondale children experience housing instability and food insecurity at rates significantly higher than those of more affluent neighborhoods in Hamilton County, and they are also less likely to receive prescribed medications and complete preventive services.[5,6,27,28] Price Hill's roughly 5,500 children have similar medical and social characteristics, and the median household income in Price Hill is $27,633.[26] We selected other "hot" in-county neighborhoods as controls, which collectively included about 7,500 children with similar sociodemographic profiles. "Intervention" and "control" neighborhoods were comparable with

Hot spots of hospitalizations for children ages 0–18 years in Hamilton County, Ohio, July 2012–June 2015

OHIO

CINCINNATI

Hospitalization events
- 0–7
- >7–24
- >24–48
- >48–84
- >84–151

Price Hill neighborhood

Avondale neighborhood

Five-mile radius around Cincinnati Children's Hospital Medical Center

SOURCE Authors' analysis of data from Cincinnati Children's Hospital Medical Center and the Cincinnati Area Geographic Information System. **NOTES** "Heat" refers to the numbers of hospitalization events per half-mile square per year in July 2012–June 2015, before the onset of the formal improvement activities described in the text. The solid lines in the map indicate neighborhood boundaries.

respect to multiple census indicators, including percentages of the population defined as nonwhite (approximately 65 percent), living in poverty (roughly 40 percent), and residing in rented housing units (about 70 percent). Neighborhoods did not change appreciably over the study period.[26]

We pursued our quality improvement efforts with the All Children Thrive Learning Network (ACT). Such networks connect teams across sectors to navigate complex, multidimensional problems.[25] ACT was developed to encourage the discovery and implementation of co-created solutions for child health equity. The network is organized around multidisciplinary improvement teams that include parents and community partners. Innovation is supported by data analytics and quality improvement capability building. ACT's initial focus has targeted disparities in the number of days children spend hospitalized, infant mortality, readiness to learn in school, and reading proficiency by the third grade. In the article we discuss efforts to address the first of these four outcomes.[22,29]

DEVELOPMENT OF IMPROVEMENT THEORY We defined our improvement aim in spring 2015: to reduce the inpatient bed-day rate for children from Avondale and Price Hill by at least 10 percent by June 30, 2020. Improvement efforts began in July 2015, with the assembly of a multidisciplinary team that included inpatient and outpatient medical providers, social workers, community partners (for example, legal aid), and parents of neighborhood children. The team developed a list of key drivers (exhibit 2). This list, representative of our change theory, has gone through multiple iterations as we learn from testing, new research, and fresh perspectives.[24] The depicted key drivers are those factors deemed necessary for to achieve specified aims, supportive of our local work but potentially generalizable elsewhere. Testable focus areas are also displayed.

KEY DRIVERS In creating and adapting a list of drivers, we, with our extended improvement team, placed the child (and family) at the center of our efforts, as both receivers of care and partners in intervention design. With respect to care delivery, the team highlighted the importance of families' receiving the right care at the right place and time, understanding that what is "right" may vary and involve different definitions of care. Next, we emphasized the importance of trusted relationships between families

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EXHIBIT 2

Key drivers needed to achieve the specific population health improvement aim

GLOBAL AIM

To help ensure that Cincinnati's children are the healthiest in the nation

SPECIFIC AIM

To reduce the inpatient bed-day rate for children from Avondale and Price Hill by at least 10% by June 30, 2020

KEY DRIVERS

Families are partners in co-creating improvement strategies
Families receive the right care in the right place at the right time
Families trust that they are receiving the right care for them
Clinical decision making is standardized but can be adapted to patient and family needs
Families are well equipped to self-manage acute and chronic disease symptoms
Proactive supports assist families in removing barriers to health
The health care system is accountable to the population and able and willing to address disparities in care settings
Families and the community are activated in support of achieving health equity

FOCUS AREAS

Chronic conditions
    Proactive care (focus on control)
    Integrated services/personnel
Transitions of care
    Multidisciplinary huddles
    Care gap closure during hospitalization
    Connections back to home and school
Mitigation of social risk
    Balanced approach to medical and social needs
    Partnerships with community agencies and schools around key barriers (for example, housing and hygiene)
Actionable, real-time data
    Health care system: transparent data on disparities across conditions or clinical divisions
    Community: parents or other family members and partnered agencies see data, recognize patterns

SOURCE Authors' analysis.

and health care providers (and systems). When families enter the system, evidence-based approaches are important foundations for clinical decision making. Still, we have been pushed to recognize that such approaches must be capable of changing to meet a family's needs, to ensure that families have what they need to effectively self-manage acute symptoms and chronic conditions. Without this adaptability, standardized protocols could actually widen the gaps we aim to narrow.[30,31] Thus, complementary social, environmental, and economic supports are critical adjuvants to care.[9,10] The last two drivers in the list are illustrative of the "culture of health" vision that "everyone in our diverse society" can lead healthier lives,[32(p3)] a vision that includes an activated health care system accountable to a population and an activated community that supports a move toward health equity.[33]

FOCUS AREAS Our improvement team focused efforts within four areas, shown in exhibit 2 and detailed in online appendix exhibit 1.[34] We started by investigating how chronic conditions added to inequities. For instance, despite evidence of recent improvements in outcomes,[35] asthma remained the most common chronic bed-day contributor. We therefore saw asthma as a vehicle through which we could further narrow gaps and also learn how to translate efforts to other conditions. In August 2015 our extended improvement team initiated proactive outreach to children with asthma to ensure that they had a ready supply of medications in advance of the fall exacerbation season. Our team subsequently advanced partnerships with pharmacies capable of delivering medications to homes, schools, or both. The team also facilitated the integration of services and personnel, ensuring that care coordinators, nurses, social workers, community health workers, and community-based partners were more closely aligned. We have since spread these efforts to other chronic conditions (such as diabetes), pairing a data-driven approach with front-line knowledge of family and community needs.

The second focus area has been transitions of care, such as when a patient leaves the hospital for home. By late 2015 key team members were receiving automated daily alerts from the electronic health record system for children from Avondale or Price Hill ZIP codes who had been hospitalized in the preceding twenty-four hours. This group designed a multidisciplinary huddle to discuss the identified patients, modeling discussions after "safety huddles" that are used in health care systems to aid in effective, efficient information sharing.[36] Huddles initially focused on learning and on identifying common patterns and missed opportunities for hospitalization

prevention. They have evolved to focus more on closing care gaps during hospitalizations (for example, overdue immunizations) and meeting care needs that follow children home (such as medication questions, follow-up appointments, and going back to school). Current huddle participants include physicians, nurses, social workers, community engagement consultants, and teachers from school services at Cincinnati Children's Hospital Medical Center who help with schoolwork completion in the hospital and support connections to teachers in a child's regular school. Although parents have not yet been included in huddles for patient privacy reasons, members of our improvement team have presented anonymized cases and cross-cutting themes in community settings. These adapted "morbidity and mortality" conferences have been used to discuss suboptimal processes or outcomes[37] and to identify opportunities for improvement in how families navigate their way into, through, and out of the hospital.

Huddles and morbidity and mortality discussions have frequently highlighted the need for more balanced approaches to medical and social needs.[7,10,38] In the health care system, the improvement team now engages with social workers, community health workers, and community partners to mitigate social risks at the household level and identify potentially actionable patterns at the population level.[39,40] In the community, parents come together through ACT-driven groups to focus on issues such as housing rights, hand hygiene, and preventive care access.[22] Such groups also shine a light on needs that may be best met by bringing new partners into the mix.[25]

Integration has been accelerated by the use of actionable, real-time data. In the health care setting, electronic health record data are used to transparently illustrate inequities across conditions and clinical subspecialty divisions.[4] In the community, data overlays and patient stories identify patterns and partners more quickly.[38,39] For example, we showed neighborhood-based asthma data at a community meeting. Partnered housing attorneys quickly noticed an asthma "hot spot" in a building complex in which they were already aware of multiple housing complaints. These data overlays accelerated their efforts, and they were able to more efficiently match needs (for example, housing issues among children with asthma) with tangible supports (such as legal advocacy). Indeed, data help tell the equity story more effectively, bringing more individuals and sectors into alignment.

MEASURES Our primary outcome was the neighborhood inpatient bed-day rate. We saw hospital days as a valuable population health measure, one that was representative of the com-

plex interplay between medical and social factors. We also saw inpatient bed-days as inherently disruptive to families and communities.[4,41] To calculate this inpatient bed-day rate, we divided the number of days neighborhood children spent hospitalized by the number of children living in the neighborhood. This measure is normalized by 1,000 children and is tracked using monthly data points.

For this measure, we opted a priori to exclude hospitalizations for cancer, organ transplantation, and complex congenital cardiac disease, given the months that such patients may spend hospitalized. We also excluded psychiatric hospitalizations, given that these events more often occur at locations other than Cincinnati Children's Hospital Medical Center. Using baseline data (for the period July 2012–June 2015), we found that a fourteen-day length-of-stay was three standard deviations above the mean. Consequently, we excluded these prolonged events to avoid skewing our theory development toward atypical patient presentations. That said, as a secondary outcome, we measured hospitalization rates, evaluated with and without the aforementioned conditions and inclusive of events regardless of length-of-stay. We also tracked emergency department visit rates as a balancing measure.

ANALYSES AND ETHICAL CONSIDERATIONS July 2012–June 2015 was the baseline phase and July 2015–June 2018 the improvement phase. We assessed outcome rates in time series using statistical process control methods, tracking X-bar and range charts for both intervention and control neighborhoods. X-bar charts evaluate continuous quantitative data elements and provide an average over time. Companion range charts examine sample variability, which supports the determination of control limits surrounding X-bar averages. Together, these charts allowed us to differentiate, using established rules, between variations with special and those with common causes. Special cause indicates changes resulting from specific circumstances (for example, certain interventions). Common cause is stable point-to-point variation inherent in the system.[24]

This work was determined to be non–human subjects research by the Cincinnati Children's Hospital Medical Center Institutional Review Board.

LIMITATIONS This work was not without limitations. First, these efforts might not be generalizable to other regions. That said, we feel that the stated methods and theory would be of great relevance to other pediatric population health improvement projects.

Second, it was difficult to determine which of the multilevel interventions made the most difference. We also could not rule out the possibility that improvements in intervention neighborhoods were due to background trends. However, our comparison to control neighborhoods makes this highly unlikely.

Third, we made a priori exclusion decisions. Our secondary outcomes, inclusive of excluded conditions and prolonged lengths-of-stay, support our conclusions. However, even these outcomes excluded psychiatric hospitalizations. Clearly, this is an area in need of further study, which we plan to undertake in the coming years.

Fourth, neighborhood composition changes over time—children age out, others are born, and people move in and out. Available census data suggest that the sociodemographic characteristics of our intervention and control neighborhoods did not change substantively during the study period.

Fifth, given the multilevel, multifactorial nature of the interventions studied, including many that repurposed or restructured existing work, we were not able to measure the cost of our efforts. Future studies that evaluate costs and benefits from multiple perspectives (those of the health care system, families, and society) are warranted.

Finally, children could have been hospitalized at sites other than Cincinnati Children's Hospital Medical Center. That said, the medical center has near-complete local market saturation.

Study Results

As noted above, there were multiple hospitalization hot spots during the baseline period, July 2012–June 2015 (exhibit 1). Across the entirety of the study period, between July 2012 and June 2018, there were a total of 38,583 hospitalizations for in-county children, of which 37,337 (97 percent) lasted less than fourteen days. Hospitalizations meeting diagnostic and length-of-stay inclusion criteria contributed 76,759 inpatient bed-days. The county's inpatient bed-day rate was 5.6 days per 1,000 children per month.

The baseline rate for Avondale and Price Hill was 8.4 days per 1,000 children per month. This equated to neighborhood children collectively spending about 75 days each month and 900 days each year on inpatient units in Cincinnati Children's Hospital Medical Center before improvement efforts began. Those improvement efforts, and focus areas, that proceeded during the intervention phase were mapped to the key drivers described above and listed in exhibit 2.

Exhibit 3, an X-bar chart, depicts special-cause variation beginning in the summer of 2015, when improvement efforts began. At that time, the average monthly inpatient bed-day rate de-

EXHIBIT 3

Inpatient bed-day rate per 1,000 children per month in the Avondale and Price Hill neighborhoods of Hamilton County, Ohio, July 2012–June 2018
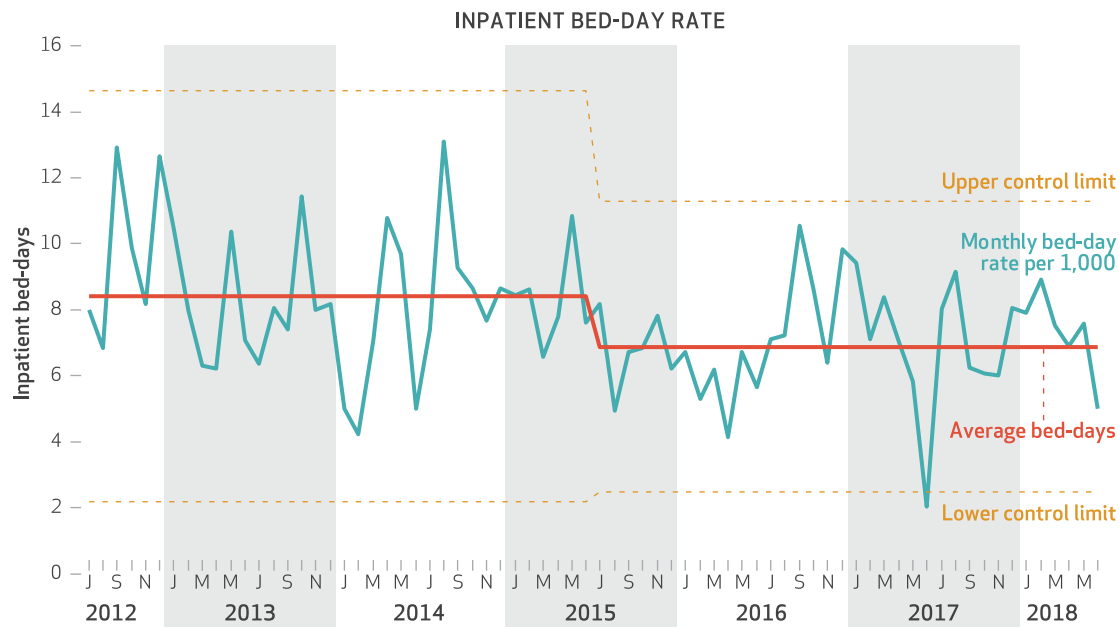
SOURCE Authors' analysis. NOTES Hospitalizations that would otherwise have met our inclusion criteria (see the text) but were longer than fourteen days were excluded. The average bed-day rate is per 1,000 children. The upper and lower control limits were calculated using a companion range chart that is not shown. The data were calculated using a statistical process control chart, or X-bar chart (see the text).

creased to 6.9 per 1,000 children, or 18 percent fewer in-hospital days than at baseline. There was no similar decrease in the rate for control neighborhoods (appendix exhibit 2).[34] There the rate remained at 7.6 inpatient bed-days per 1,000 children per month throughout the study period.

The rate reduction in Avondale and Price Hill was likely driven by fewer hospitalizations instead of shorter lengths-of-stay. In a similar pattern to the inpatient bed-day chart, the hospitalization rate dropped 20 percent—from 4.1 events per 1,000 children per month to 3.3 events—again beginning during the summer of 2015 (exhibit 4). There was no similar drop in control neighborhoods (data not shown). Hospitalization rate patterns for intervention and control neighborhoods were similar when we included hospitalizations for cancer, transplantation, and complex cardiac disease.

Emergency department visit rates increased slightly during the study period. However, this pattern was present in both intervention and control neighborhoods (data not shown). This suggests a relationship to background trends as opposed to a direct consequence of improvement efforts, which have not yet focused on emergency care.

Finally, we assessed the degree to which the efforts narrowed equity gaps relative to the rest of the county. For the baseline period, Avondale had the fourth-highest and Price Hill the eleventh-highest inpatient bed-day rates out of eighty county neighborhoods. In that period Avondale and Price Hill children spent 2,720 days in the hospital, compared to 2,145 in the improvement period (July 2015–June 2018). The number of hospitalizations decreased from 1,344 to 1,041. Indicative of a move toward equity, Avondale improved to the ninth-highest and Price Hill to the fifteenth-highest inpatient bed-day rates.

Discussion

We committed to improving outcomes and narrowing gaps for a defined population. As part of this effort, we and our extended improvement team reduced the rate at which children from two medically and socially at-risk neighborhoods spent days in the hospital by roughly 20 percent, leading to children spending hundreds of additional days at home and in school. With no similar change in comparable local neighborhoods, we believe that the improvements were associated with this team's efforts.

EXHIBIT 4

Hospitalization rate per 1,000 children per month in the Avondale and Price Hill neighborhoods of Hamilton County, Ohio, July 2012–June 2018
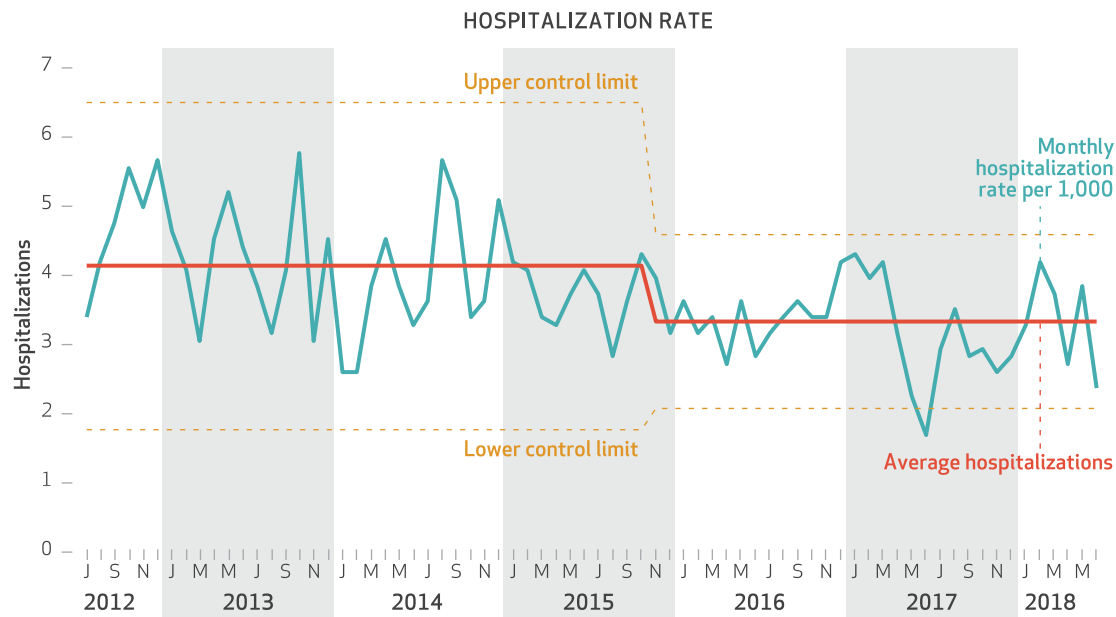
SOURCE Authors' analysis. NOTES The average hospitalization rate is per 1,000 children. The upper and lower control limits were calculated as explained in the notes to exhibit 3. All hospitalizations that met our inclusion criteria (see the text) were included, regardless of length-of-stay. The data were calculated using a statistical process control chart, or X-bar chart (see the text).

We started by viewing child health equity through a neighborhood lens. Although similar hot-spotting efforts frequently and rightfully have focused on "super-utilizing" adults,[42] we opted to focus instead on super-utilizing neighborhoods, knowing that there are fewer child than adult super-utilizers.[43] We also saw novelty in the commitment to working with an entire population and not one subdivided to be convenient to the health care system.[33]

This neighborhood focus has been strengthened by accessible electronic health record data. Countywide and neighborhood-specific analyses are now made possible by knowing (and geocoding) patient addresses. Other regions with single dominant health care systems, or with data pooled across systems, can similarly characterize the distribution of key outcomes. We see power in this use of electronic health record data to both specify population health outcomes and link them to contextual factors such as neighborhood housing quality.[38,44] These linkages led to actionable insights across the health care–community continuum. Organizations and individuals within ACT brought to light opportunities for collaboration by looking at data together.[22,25]

Throughout this quality improvement project, we grappled with the reality that local payment models do not fully incentivize value over ser-

vice. Thus, efforts were largely mission driven and funded through repurposed resource deployment, philanthropy, and grants. Reach and impact, and perhaps areas of focus, might have looked different had the medical center been operating in a pay-for-value model.[45] For example, Partners for Kids is an accountable care organization with an extensive reach in central Ohio. Its reach incentivizes innovation outside the traditional health care purview. Kelly Kelleher and coauthors recently described the organization's direct housing investments in a Columbus neighborhood, illustrating how the organization saw housing as a critical vehicle through which health (and value) could be realized.[16]

We have tended to address such determinants by supporting activated partners. A central tenet of ACT is building capabilities among partners.[22] We believe that our collaborative efforts, and the capacity of our community-based partners, would be supported by an amended view of fee-for-service. For instance, "referrals" to housing experts could influence health outcomes just as much as referrals to clinical experts.[40,46] Perhaps this more expansive view of which referrals (or interventions) are of relevance to health outcomes should influence which referrals (or interventions) are reimbursed. Such

reimbursements—for example, for legal advocacy for housing needs—could also support sustainable cross-sector innovation that is less reliant on time-limited grant funding, which could allow health care systems (and their partners) to rapidly accrue evidence about what works. We see policy implications in support of this more balanced medical-social approach, such as that recently envisioned by Secretary of Health and Human Services Alex Azar—who saw value in "aligning federal health investments with our investments in non-healthcare needs."[47]

We have sought balance in our approach to medical and social determinants of health. Indeed, as our team has worked to optimize the management of chronic conditions such as asthma, providers across the medical center have also routinely screened for and acted upon patients' social needs.[46] With this in mind, our team has also considered the degree to which the health care system has a responsibility that extends to our neighbors, not just our patients. Thus, we now screen entire neighborhoods for patterns of addressable risk (for example, adverse housing exposures).[38,44] This is informed and bolstered by trusted cross-sector relationships and efferent intervention arms that are capable of translating data into action.[22]

ACT pushes toward action using four main strategies. First, network members focus on equity-oriented outcomes via a strong measurement framework and analytic core. Second, strategic multisector partnerships are pursued, fostering collaboration inside and outside of health care. Third, the network builds capability by teaching quality improvement methods; accrued skills are then deployed to integrate initially siloed sectors. Finally, everyone involved keeps children and families at the center of the work. The multidisciplinary collective codesigns solutions, supports sustained involvement, and cultivates relationships to ensure that health becomes and remains a shared value.[12,13,22]

Conclusion

We have pushed our health care system and community to be accountable to populations and neighborhoods that are disproportionately affected by medical and social challenges. We have made early progress toward keeping children out of the hospital. We now seek to take what we have learned and push toward scale and spread. ∎

NOTES

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