

# Rooming-In to Treat Neonatal Abstinence Syndrome: Improved Family-Centered Care at Lower Cost

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**BACKGROUND AND OBJECTIVE:** The incidence and associated costs of neonatal abstinence syndrome (NAS) have recently risen sharply; newborns with NAS occupy 4% of NICU beds. We implemented a coordinated program for NAS including standardized protocols for scoring, medications and weaning, and a calm rooming-in environment, to improve family-centered care and to decrease both length of stay (LOS) and hospital costs.

**METHODS:** In early 2013, a multidisciplinary quality improvement team began consecutive plan-do-study-act (PDSA) cycles. We trained nurses in modified Finnegan scoring, ensured scoring only after on-demand feeds during skin-to-skin care, and standardized physician score interpretation. We provided prenatal family education, increased family involvement in symptom monitoring and nonpharmacologic treatment, and treated otherwise healthy infants on the inpatient pediatric unit instead of in the NICU. We measured outcomes using statistical process control methods.

**RESULTS:** At baseline, 46% of inborn infants at-risk for NAS were treated with morphine; by 2015, this decreased to 27%. Adjunctive use of phenobarbital decreased from 13% to 2% in the same period. Average LOS for morphine-treated newborns decreased from 16.9 to 12.3 days, average hospital costs per treated infant decreased from \$19 737 to \$8755, and costs per at-risk infant dropped from \$11 000 to \$5300. Cumulative morphine dose decreased from 13.7 to 6.6 mg per treated newborn. There were no adverse events, and 30-day readmission rates remained stable.

**CONCLUSIONS:** A coordinated, standardized NAS program safely reduced pharmacologic therapy, LOS, and hospital costs. Rooming-in with family and decreased use of NICU beds were central to achieved outcomes.

Between 2000 and 2009, opioid use during pregnancy tripled in the United States, and rates of neonatal abstinence syndrome (NAS) doubled between 2009 and 2012 to 0.58% of live births.<sup>1–3</sup> Newborns with NAS occupy 4% of US NICU beds.<sup>4</sup> NAS incidence varies regionally and is highly prevalent in northern New England, with a 2012 rate of 1.9% of neonates at our tertiary center.<sup>5</sup> By 2014, 6% of newborns at our

institution had confirmed exposure to opioids in utero.

Newborns with moderate to severe NAS are typically treated with oral opioids, and then weaned over days to weeks.<sup>2</sup> Pharmacologically treated NAS is prolonged and costly, with lengths of stay (LOS) of 2 to 12 weeks and estimated charges of \$90 000 per admission.<sup>3,6–8</sup> An overwhelming majority of infants

## abstract

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Dr Holmes conceptualized and designed the improvement initiative and the plan of study; led the project team meetings in phase 1; drafted the initial abstract, introduction, and discussion sections of the manuscript; and reviewed and revised the manuscript; Ms Atwood reviewed and abstracted patient charts, carried out the initial data analysis, drafted the initial results section of the manuscript, drafted the initial tables and figures, and reviewed and revised the manuscript; Dr Whalen participated in the project team meetings as newborn nursery medical director, led the community prenatal education sessions, and reviewed and revised the manuscript; Ms Beliveau led the project team meetings in phase 2, drafted the initial methods section of the manuscript, and reviewed and revised the manuscript; Ms Jarvis reviewed and abstracted patient charts, carried out the preliminary data analysis, and reviewed and revised the manuscript; Dr Matulis assisted with data analysis, constructed analyses of means and control charts, and reviewed and revised the manuscript; Dr Ralston participated in the project team meetings as pediatric hospital medicine section chief, assisted in data analysis, and reviewed and revised the manuscript; and all authors approved the final manuscript as submitted.

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with NAS are publically insured, and Medicaid incurs a substantial cost burden.<sup>1,3</sup> Interventions known to decrease resource utilization include rooming-in; low-stimuli environments; gentle handling, swaddling, holding, on-demand feeding, breastfeeding (for mothers maintained on methadone or buprenorphine); and standardized weaning protocols.<sup>2,8-14</sup> Newborns with NAS are typically cared for in NICUs, where daily cost of care is high, and many of the preceding interventions are difficult to institute.<sup>15,16</sup>

At project outset at our hospital, there was not a coordinated, standardized system that determined when, where, and how newborns with NAS would be cared for, and expectations for family participation in care were variable. The aim of this project was to improve the care of opioid-exposed newborns by involving families, standardizing assessment and treatment, and transitioning to rooming-in for the full hospital stay. Specifically, we sought to decrease the proportion of opioid-exposed infants treated with medications and to decrease LOS and costs.

## METHODS

### Ethical Concerns

The Dartmouth Committee for the Protection of Human Subjects determined the project exempt from review as quality improvement. There was involvement and oversight from the Children's Hospital at Dartmouth-Hitchcock (CHaD) Section of Neonatology, Director of Nursing, and the Chief Officer of Quality and Safety.

### Setting

CHaD is a Children's Hospital Association member, 63-bed/16-basinette children's hospital within a 396-bed rural academic tertiary care center. CHaD provides inpatient,

critical care, and pediatric specialty services to most of New Hampshire and a portion of Vermont, with ~1400 inborn infants, 450 neonatal critical care admissions, and 2500 pediatric inpatient admissions annually.

Before 2013, opioid-exposed newborns roomed-in on a mother-infant unit, with a minimum observation period of 96 hours after exposure to long-acting opioids. Newborns needing increased observation or pharmacologic intervention with oral morphine transferred to the NICU; morphine was supplemented with phenobarbital or clonidine in severe cases. After stabilization, patients sometimes transferred to inpatient pediatrics, where families could resume rooming-in and provide newborn care. This system was based on provider and staff competencies and preferences, not on family wishes, and often resulted in multiple transitions for families and multiple handovers between teams across different units. The open-bay NICU layout was not ideal for opioid-exposed infants or families. A sentinel case that drove improvement was an infant who transferred units 7 times during 1 hospitalization.

### Planning the Intervention

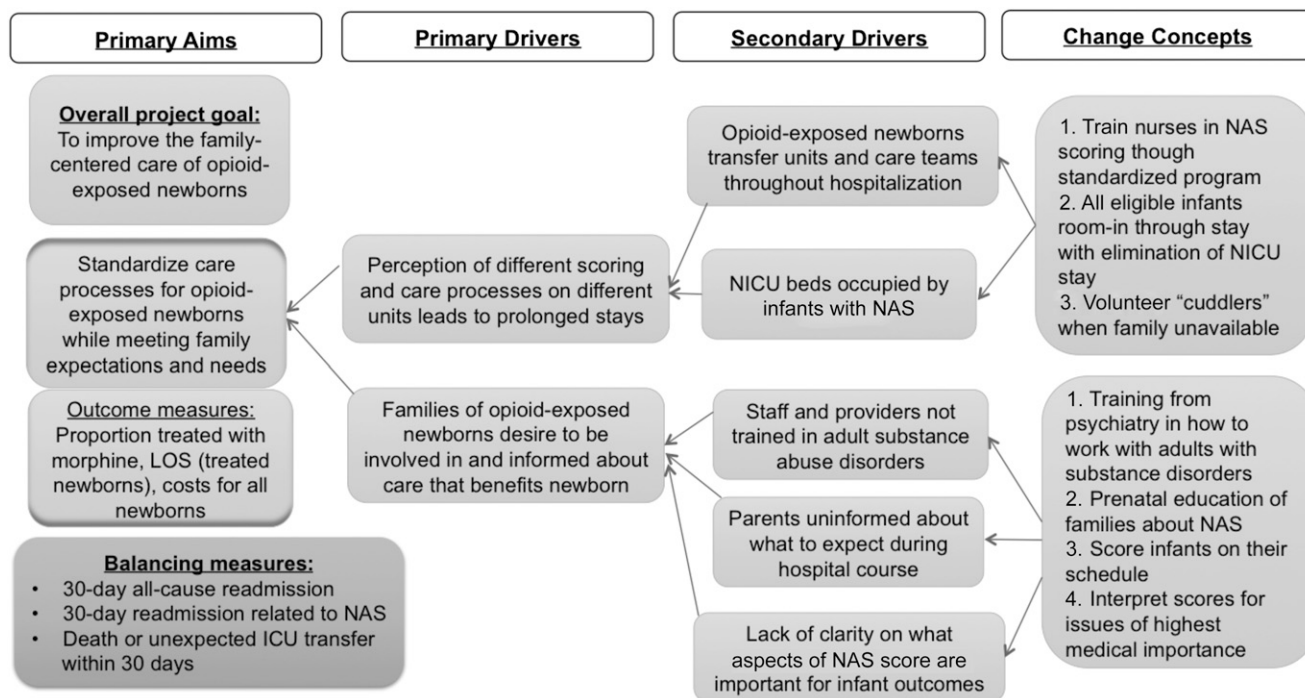
In early 2013, because NAS incidence was rising, we formed a multidisciplinary team of subject-matter experts and front-line clinicians, including physicians, nurse practitioners, nurses, medical and undergraduate students, social workers, laboratory personnel, a parent representative, and a hospital administrator. The team divided into several small workgroups to plan and implement early PDSA cycles; in late 2013, key project components transitioned to an operations team for implementation of care model changes. Motivators for change are summarized in Fig 1.

### Phase 1: Small-Scale Clinical Processes

PDSA cycle 1 focused on standardization of modified Finnegan scoring on all 3 units (mother-infant, NICU, pediatrics), within the Vermont Oxford Network NAS improvement collaborative.<sup>17</sup> A training tool used videos of infants with NAS, and the project team conducted spot checks of interrater reliability between 2 independent, blinded raters.<sup>18</sup> In the second PDSA cycle, we conducted qualitative interviews with families of newborns hospitalized with NAS, which yielded information that shaped further PDSA cycles (Table 1).<sup>19</sup>

Families informed us that some infants were being awakened from sleep for scoring, given points for crying when hungry, and removed from family members' arms to be assessed. PDSA cycle 3 changed the timing of NAS scoring to every 2 to 4 hours just after each feeding, during skin-to-skin holding, while the infant and family were already awake ("infant-centered scoring"). Because families desired more education about NAS and direct involvement in care,<sup>19</sup> PDSA cycle 4 involved prenatal preparation sessions at 2 local perinatal substance abuse treatment centers and updated education materials on NAS for obstetric clinic appointments. In PDSA cycle 5, we incorporated parent symptom recording into care processes.

The physicians led PDSA cycle 6, wherein they changed modified Finnegan score interpretation. Like many other centers, we had initiated or increased morphine treatment of 3 consecutive scores of  $\geq 8$  or 2 consecutive scores of  $\geq 12$ . Outcomes of this approach have never been rigorously evaluated, and clinical practices vary widely.<sup>20-22</sup> Although we continued to use scores as guides, we no longer strictly initiated, increased, or weaned morphine based on scores alone. We placed more emphasis on overall infant



**FIGURE 1**  
Key driver diagram for NAS QI project aims and change concepts

**TABLE 1** Summary and timeline of interventions

Timeline	Initiative Description [PDSA #]	Start Date	End Date
Winter 2013	Joined VON iNICQ Collaborative on NAS Care	Jan 2013	Dec 2015
	Identified initial priorities and aims for improvement	Feb 2013	Apr 2013
Summer 2013	NAS Scoring Inter-rater reliability: Staff Training <sup>1</sup>	Apr 2013	Oct 2013
	NAS Scoring - Inter-rater reliability: Audits <sup>1</sup>	Sept 2013	Jan 2014
	Qualitative interviewing and analysis <sup>2</sup>	Aug 2013	Jan 2014
	Change from scheduled assessment and scoring every 2 or 4 h to assessment and scoring while infant awake after feed and held by caregiver "baby-centered scoring" <sup>3</sup>	Oct 2013	ongoing
	Outreach with prenatal education for families in local treatment program <sup>4</sup>	Sept 2013	ongoing
	Use of parent symptom diary to assist with symptom capture and scoring <sup>5</sup>	Oct 2013	ongoing
Fall 2013	Finalized recommendations for Pilot Care Model changes	Nov 2013	Dec 2013
	Change in physician score interpretation (Table 2) <sup>6</sup>	Oct 2013	ongoing
	Staff and provider training: Working with families with addiction/trauma-informed care	Nov 2013	Dec 2013
Winter 2014	Rooming-in pilot with families from local buprenorphine program <sup>7</sup>	Dec 2013	Jan 2014
	Rooming-in pilot outcomes analysis <sup>7</sup>	Feb 2014	Mar 2014
Spring 2014	Development of NAS volunteer "cuddler" program <sup>8</sup>	Apr 2014	Jul 2014
	Full implementation of NAS volunteer "cuddler" program <sup>8</sup>	Jul 2014	ongoing
	Staff and Provider training: NAS scenarios (assessment/scoring/treatment)	May 2014	Jun 2014
Summer and Fall 2014	Implementation: all internal transfers of NAS to Pediatrics <sup>9</sup>	Jul 2014	ongoing
	NAS morphine treatment dosing change to every 3 h from every 4 h <sup>10</sup>	Aug 2014	ongoing
	Safe Sleep emphasis for families with NAS	Aug 2014	ongoing
	Transfers in of external referrals for NAS observation or treatment to inpatient pediatrics instead of to NICU <sup>11</sup>	Nov 2014	ongoing

condition and prioritized concern for feeding difficulty, poor weight gain, inability to sleep, and inconsolability above items with fewer detrimental effects (ie, tremors, increased tone, sneezing, yawning) (Table 2). The physician group delayed initiating

pharmacotherapy in the first 24 to 36 hours when exposure to long-acting opioids together with tobacco or selective serotonin reuptake inhibitors exacerbated early withdrawal symptoms; these exposures co-occur frequently.<sup>23</sup>

### Phase 2: Hospital Operations Processes

By fall 2013, small-scale changes were progressing but not yielding significant results, and the team advocated for full rooming-in with all observation and treatment on the

**TABLE 2** Physician interpretation of modified Finnegan scores

More Emphasis on These Symptoms	Less Emphasis on These Symptoms
Excessive crying	Tremors, disturbed
Poor sleep	Tremors, undisturbed
Poor wt gain	Exaggerated Moro reflex
Excessive wt loss	Increased tone
Poor feeding	Yawning
Emesis	Sneezing
Diarrhea	Excoriations
Tachypnea	
Fever	

mother-infant and pediatric units for patients without other conditions requiring critical care. Administrative changes were needed for this phase. We began with a pilot group of 10 opioid-dependent women treated in the Dartmouth-Hitchcock perinatal addiction treatment program. Prenatal education prepared families for the hospital stay and included instruction on ideal environmental measures, expected LOS, and the expectation of a consistent family caregiver. Contemporaneously, we conducted staff education on how to best work and communicate with families struggling through addiction and recovery.

Analysis of the pilot yielded additional recommendations: expansion for all infants, and implementation of a volunteer program to support families. Both were accomplished by early July 2014. The volunteers cared for patients when parents were unavailable. In the final PDSA cycles, we admitted newborns transferred from other hospitals to our pediatric unit and changed morphine dosing from every 4 to every 3 hours to be more aligned with both morphine half-life and newborn sleep and feeding cycles.

### Planning the Study of the Intervention

We included all birth hospitalizations between March 2012 and February 2015 with reported or laboratory confirmed maternal opioid use. A research nurse (J.D.J.) tracked and reported data quarterly, and another

team member (E.C.A.) manually reviewed charts to verify abstracted data.

### Description of Measures

Outcomes of interest included concordance of paired scores by independent observers, average daily score, percentage treated with oral morphine, percentage treated with an adjunctive medication, cumulative morphine dose, LOS, and costs for all opioid-exposed infants and for those treated pharmacologically. For balancing measures we examined adverse events (death or unplanned ICU transfer), 30-day readmissions, and discharge in parental care, and we contacted primary care providers of 2014 newborns with higher NAS scores who were discharged without pharmacologic treatment to examine any unintended consequences.

### Methods of Evaluation and Analysis of Results

We excluded infants who were either not “otherwise well newborns” because of gestational age <35 weeks or another reason for NICU admission or who completed treatment at another facility. The 3 years of the intervention were divided as baseline year (March 1, 2012–February 28, 2013), intervention year 1 (March 1, 2013–February 28, 2014), and intervention year 2 (March 1, 2014–February 28, 2015) because the first clinical changes began in March 2013.

We used  $\kappa$  correlations for interrater reliability measures. We calculated mean daily, modified Finnegan scores for each newborn, with day 1

beginning at the first 7:00 AM of life. To test for change in scoring across years, we used a mixed effects linear regression model, including year, day of life, and treatment as fixed effects. Random effects were used to account for variation within infant, and first-order autoregressive variance covariance structure to account for time. We tested for changes in infant median, maximum, or first score across years using analysis of variance.

We compared static categorical variables by Fisher exact test and static continuous variables by independent *t* test. We used analysis of means for categorical variables over time, and statistical process control (XmR) charts for continuous variables over time. We recalculated XmR means and control limits when interventions led to all subsequent data points being on 1 side of the center line (24). We calculated hospital costs by multiplying hospital charges by annualized cost-to-charge ratios.

### RESULTS

From March 2012 to February 2015, 207 newborns were observed and/or treated for NAS. Of these, 163 (79%) met inclusion criteria, including 54 in the preintervention year, 61 in intervention year 1 and 48 in year 2. Sixty-nine newborns (42%) received pharmacologic treatment including 28 (17%) infants born at outside hospitals and transferred for NAS therapy. The average birth weight was 2979 g (range 1775–4200 g), and average estimated gestational age was 39 weeks (range 35–42 weeks). Half of mothers (75) were in opioid maintenance programs, with a quarter of these (16) on maintenance methadone and three-quarters (59) on buprenorphine.

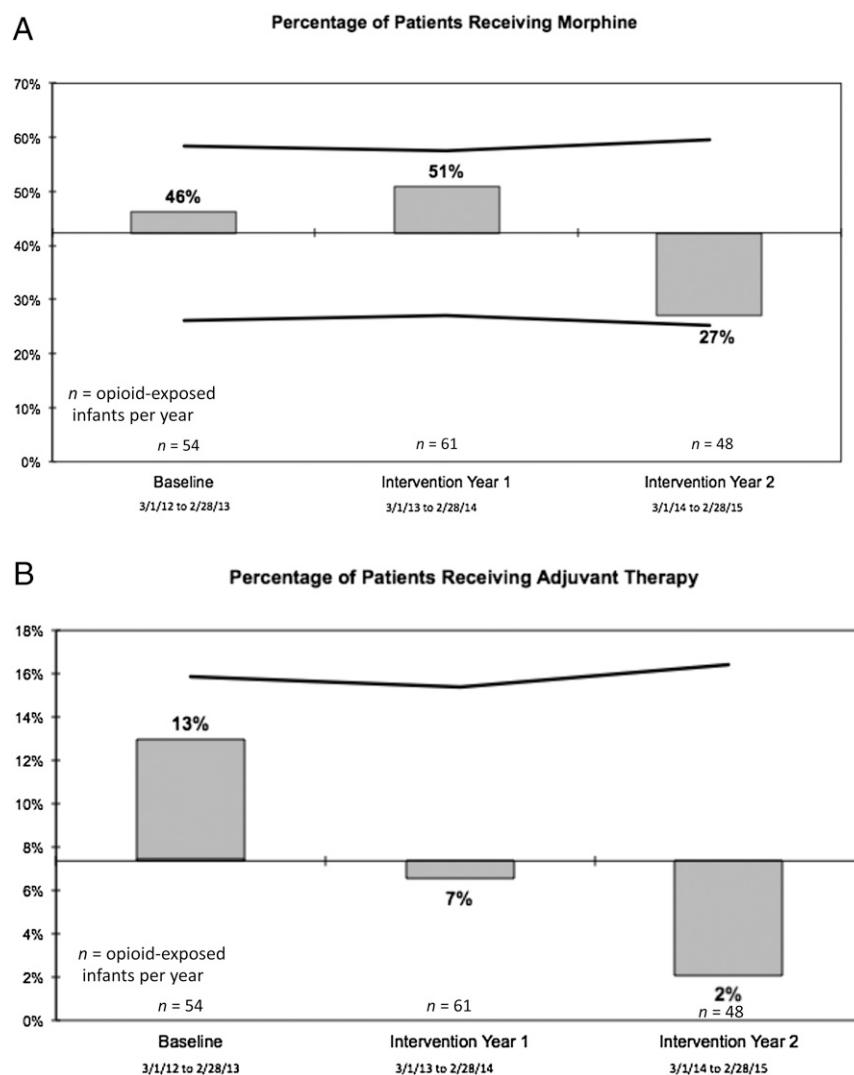
From September to December 2013, each unit conducted 10 paired, blinded, modified Finnegan scores. Concordance within 1 point was



>90% for all units in all months. Mean daily score did not change over time. Adjusting for day of life and treatment, score coefficients relative to baseline were not significant for year 1 (0.23,  $P = .35$ ) or year 2 (0.12,  $P = .66$ ). There was no significant difference in median score, maximum score, or first score by year ( $P = .53, 0.29, 0.48$ , respectively). The proportion of newborns requiring treatment with morphine declined over time from 46% to 27%, as did the percent of newborns requiring adjunctive treatment with phenobarbital or clonidine (Fig 2).

The cumulative morphine exposure per treated infant decreased from 13.7 mg during the preintervention year to 6.6 mg by project completion (Fig 3A). The average length of stay for pharmacologically treated NAS decreased from 16.9 to 12.3 days (Fig 3B). LOS for newborns not requiring pharmacologic treatment remained stable (4.2–4.4 days,  $P = .33$ ). Mean hospital costs for newborns requiring pharmacologic treatment declined from \$19 737 to \$8755 (Fig 3C), and costs for all opioid-exposed newborns also decreased, from \$11 000 during the study's baseline year to \$5300 during the second intervention year ( $P < .01$ ).

There were no adverse events. Thirty-day all-cause readmission remained stable. Two newborns were readmitted during the baseline year, with 3 and 4 newborns readmitted during the first and second years of intervention (4%, 5%, and 7% respectively,  $P = .46$ ). No newborns were readmitted for NAS treatment; however, 1 newborn in the baseline year and 1 in the second intervention year were admitted for failure to thrive, possibly due to NAS. One infant readmitted during the first intervention year suffered a skull fracture after a fall. All other readmissions were for infection concern or hyperbilirubinemia, issues likely unrelated to NAS. The number of newborns discharged in



**FIGURE 2**

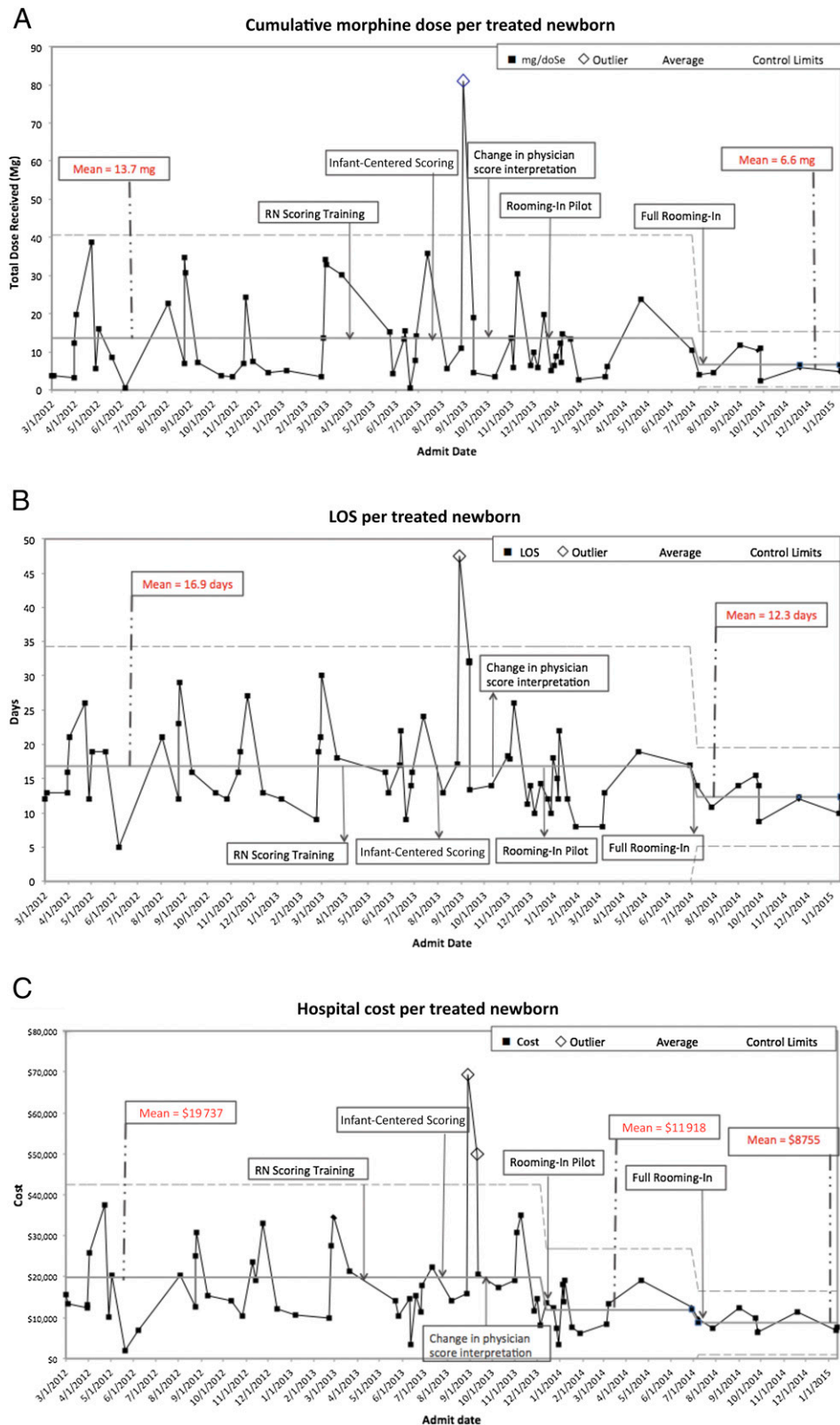
Analysis of means of (A) percentage of opioid-exposed newborns treated pharmacologically with morphine; (B) percentage of morphine treated newborns also treated pharmacologically with a second (adjunctive) agent—phenobarbital or clonidine. Bars that cross the black lines (control limits) represent statistically significant results to 3  $\sigma$ .

parental custody remained stable: 93% in the baseline year and 90% in the second intervention year ( $P = .73$ ). Primary care providers of 10 high-risk newborns in the intervention phase (higher NAS scores but no pharmacologic treatment or treatment with LOS under 12 days) reported no growth or feeding concerns at 1 to 4 months.

## DISCUSSION

We describe a successful quality improvement (QI) effort to

standardize scoring, rooming-in, and environmental and pharmacological management of NAS. We decreased the proportion of opioid-exposed newborns treated pharmacologically, use of adjunctive agents, LOS for treated infants, and costs for all opioid-exposed infants, including the subset treated for NAS. While achieving these outcomes, we engaged families in the improvement process, we increased family preparation and involvement, and we trained our clinical teams to better serve those struggling with addiction.



**FIGURE 3**

Statistical process control (XmR) charts where each dot represents an infant that was treated pharmacologically. Chart (A) is the cumulative morphine dose for each treated infant, (B) is the LOS for treated each infant, and (C) is the cost per each treated infant. Mean costs, and the associated control limits shift downward per standard rules for special cause variation in January 2014, coinciding with both the rooming-in pilot and the change in physician score interpretation, and shift downward again in July 2014, with full rooming-in. Morphine dose and LOS decidedly shift downward per standard rules for

The decreased LOS and costs began contemporaneously with the rooming-in pilot and change in physician score interpretation then dropped further and sustained after full rooming-in. The control limits became narrower, demonstrating decreased variability (Fig 3B). Development and sustenance of the volunteer program was critical for successful rooming-in. Team training on working with families struggling with addiction, including content on trauma-informed care, and case-based training in small groups (academic detailing) were important for success. Process changes are likely sustainable because a small, stable pediatric hospitalist team attends in both newborn nursery and inpatient pediatrics, and our neonatologists prefer that care of opioid-exposed infants occur in a noncritical care setting. The infant volunteer program is permanent, maintained via nursing leadership, and oversubscribed with new volunteers.

Our study had numerous strengths, including data integrity verified by chart review. We conducted ongoing measurement through 11 PDSA cycles. We included infants inborn at a tertiary care center and those transferred from regional hospitals. We benefitted from a highly engaged multidisciplinary team over 3 years and strong support from neonatology and hospital leadership. Despite the elimination of a NICU stay, we had no adverse events. Our geographic location as the only tertiary care center in an 80-mile radius permitted reliance on readmission data as a sound balancing measure, and we verified no increase in outpatient morbidity by tracking patients through primary care review. Systemic cost-of-care analysis is another strength. Although other

studies have described cost data, no previous NAS QI project has demonstrated cost improvements (our changes more than halved hospital costs).

We based many of our interventions on data gleaned from family interviews.<sup>19</sup> Our approach to physician score interpretation was innovative and focused on increased attention to NAS symptoms most detrimental to infants and most concerning for parents while limiting the weight of items less likely to effect outcomes (Table 2). We began the change in score interpretation in the fall of intervention year 1, after nurse score training transiently led to a higher proportion of infants being treated (Figs 2 and 3B). The physician group identified NAS symptoms in the first 36 hours as likely due to tobacco and/or antidepressants and avoided initiating a potentially long course of opioid treatment until NAS was the clear diagnosis. There is a higher likelihood of pharmacologic therapy for NAS in infants exposed to tobacco and antidepressants.<sup>23</sup>

Most previous NAS QI reports have not aimed to reduce the proportion of pharmacologically treated infants. We achieved a 41% relative reduction in the proportion of opioid-exposed infants treated with medications. Other studies that measured proportion of at-risk newborns treated pharmacologically had similar results with rooming-in; 55% and 75% relative risk reductions compared with standard NICU care.<sup>9,11</sup>

Our study corroborates the findings of previous studies demonstrating reduction in NAS LOS with rooming-in.<sup>9-11</sup> Most studies of NAS LOS are in drug comparison trials in which LOS is used to demonstrate superiority of one agent over

another. However, this body of literature demonstrates tremendous variability; infants treated with morphine may be treated as long as 37 days or as short as 12 days.<sup>9,23-25</sup> This variation supports the theory that the environment of care is likely more important than the medication used for treatment. Two recent multicenter Ohio collaborative reports and a single-center study in NICUs showed a decreased LOS to between 18 and 23 days with use of a standardized weaning protocol.<sup>8,26,27</sup> Recent US national data show average LOS for a pharmacologically treated infant is 23 days.<sup>3</sup>

Limitations include that the project occurred in a children's hospital within a hospital. Generalizability might be limited to children's hospitals where labor and delivery services are colocated. In addition, the same 6 pediatricians serve as attending physicians in both newborn nursery and inpatient pediatrics. Group consensus and rapid change were relatively easy to achieve and might be more difficult in larger groups or when separate services attend in the 2 settings. Our service area is predominantly rural and ethnically homogeneous. More mothers in our region are maintained on buprenorphine as opposed to methadone; rates of newborn treatment of NAS are similar between these groups, but length of treatment can be shorter when mothers take prescribed buprenorphine.<sup>28</sup> NICUs with individual rooms for rooming-in could achieve similarly reduced LOS, but comparable cost reductions would be unlikely. New Hampshire and Vermont do not impose mandatory foster care placement for opioid-exposed newborns, and illicit drug use during pregnancy is not criminalized in our region, explaining our high rates of

### FIGURE 3 Continued

special cause variation after full rooming-in; all measures demonstrate decreased variability over time with project progression. XmR means and control limits were recalculated at points where all subsequent measures are below the previously calculated mean.

newborns discharged with parents. Social acceptability of a rooming-in program might meet with opposition where legal or child protection systems are more punitive.<sup>29,30</sup>

There are some financial downsides to this intervention, including reduction in hospital revenue in fee-for-service environments. NICUs frequently drive children's hospital revenue, so reducing admission and LOS could financially penalize some health systems, although this may change under new payment models.<sup>31</sup> The cost savings herein were realized by 3 reductions: percent treated with morphine, reduced LOS, and reduced NICU utilization. This project was viable in New Hampshire as Medicaid reimbursements provide less revenue than actual cost of care. Notably, otherwise well newborns with NAS do not require critical care; they thrive with comforting environmental measures. In terms of providing high-value care to populations, this is a preferable approach to quality improvement and cost reduction. Cost savings from this project benefit the region's population and accrue to Medicaid

and taxpayers who might otherwise be funding unnecessary care.

## CONCLUSIONS

We reduced the rate of pharmacotherapy for NAS to 27% and LOS for treated infants to 12 days. We reduced system costs by more than half by caring for infants with prenatal opioid exposure and NAS in a rooming-in model, safely eliminating the use of critical care beds for this condition.

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## ABBREVIATIONS

CHaD: Children's Hospital at Dartmouth-Hitchcock  
LOS: length of stay  
NAS: neonatal abstinence syndrome  
PDSA: plan-do-study-act  
QI: quality improvement

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