# Using Quality Improvement to Improve Value and Reduce Waste

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**KEYWORDS**

• Value • Quality • Waste • Outcomes • Infant • Neonate

**KEY POINTS**

- Neonatologists should care about the value of care they provide.
- Improving the value of care should ideally focus on improving outcomes and reducing cost.
- There are several high-priority areas for improvement in value-based neonatal care that could be readily addressed by local quality improvement initiatives.

## WHAT IS VALUE?

Value in health care has been best described by Michael Porter as "health outcomes achieved per dollar spent."[1] Value is often described as the output of an equation with health outcomes achieved in the numerator, and total costs of care in the denominator (Value = outcomes/cost). The emphasis on improving value in health care was emphasized in the Institute for Healthcare Improvement's "Triple Aim." This framework for optimizing health system performance focuses on the following: (1) improving the individual experience of care, (2) improving the health of populations, and (3) reducing the per capita costs of care for populations.[2] At its core, value is patient-centered and outcomes-focused. Importantly, it is not about the "amount" of health care provided but the actual outcomes achieved, and the cost needed to achieve those outcomes. Improving value is not simply cost reduction. Without concurrently measuring outcomes achieved, cost-reduction is "dangerous and self-defeating, leading to false savings and potentially limiting effective care."[1]

In neonatal medicine, Dukhovny and colleagues[3] argue that 3 key components of clinical practice should be combined to achieve value: (1) evidence-based medicine, (2) evidence-based economics, and (3) quality improvement (QI). One simple way to

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apply the concepts of evidence-based medicine and evidence-based economics is to consider the value of individual interventions across 2 axes on a "cost-effectiveness plane": outcomes and costs (Fig. 1). Evidence-based medicine helps to identify interventions that are most likely to improve outcomes (falling to the right of the y-axis). Evidence-based economics identifies which of those interventions are the "best bet for the money" (high value vs low value), often defined by some specific "cost-effectiveness" threshold.[4] Those interventions that have been shown to have worse (or no better outcomes) regardless of cost are considered nonvalue added care, or "waste." We can then use QI to ensure interventions that are cost-effective and most likely to improve outcomes (high-value care) reliably reach our patients, whereas lower value (and wasteful) interventions are minimized or eliminated. The provided visual aid is a simplification, and it is important to highlight that a single intervention may be in the high-value care category for a specific population or indication, whereas falling in the waste category in a different clinical scenario and/or indication (a theoretic example of overuse or misuse of an intervention).

One example would be the use of pasteurized donor human milk, which would be of relatively high value for use in very low-birth weight infants for the prevention of necrotizing enterocolitis (NEC) but of relatively lower value for in-hospital use in well newborns. In addition, although all interventions have an associated cost, some may lead to net cost savings overall, which could result in interventions plotting below the x-axis (with net benefits in terms of both outcomes and costs). For example, pasteurized donor human milk use could lead to a net cost-savings in units with high-NEC rates but might not be cost saving in populations with high mother's milk use.[5,6] The combination of evidence-based medicine, evidence-based economics and QI should consider the intervention along with the specific population and indication for use when determining the value of care being provided.

Although a significant focus in neonatal medicine has been on health outcomes, the numerator of the value equation, there has been less focus on costs, the denominator.

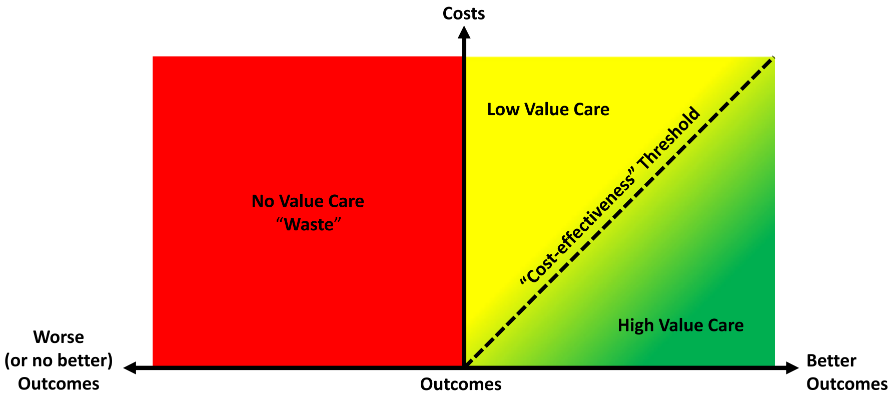


**Fig. 1.** The "cost-effectiveness plane"—defining high value care using outcomes and costs. A visual representation of value-based care. High-value care includes interventions that benefit patients (improve outcomes) and have costs less than a predetermined "cost-effectiveness" threshold. Low-value care includes interventions that benefit patients but have increased costs that place them above the threshold. Wasteful care does not benefit patients, regardless of costs. (*Adapted from* A Pandya, MPH, PhD. High and Low Value Care. Available at: https://vimeo.com/270682342. Accessed Oct 28 2022. Also refer: Pandya A. Adding Cost-effectiveness to Define Low-Value Care. JAMA. 2018;319(19):1977–1978. https://doi.org/10.1001/jama.2018.2856.

Both are important if we want to achieve the Triple Aim in neonatal medicine. A national survey of neonatologists found generally poor knowledge about the costs of commonly used tests, diagnostic studies, and hospitalization costs.[7] Understanding the structure of costs, because they relate to neonatal care, is an important first step when thinking about how to consider incorporating cost into efforts to improve the quality and value of neonatal care.

In this review, we summarize the successes of QI in improving the value of neonatal care. First, we make the case for why value is important for the neonatologist to consider. Next, we discuss how traditional QI focused on processes and outcomes has great potential to improve value but requires explicit cost accounting to demonstrate it. Then, we review important cost measures that can be incorporated into QI. Finally, we apply the concept of waste to examples of overuse of the neonatal intensive care unit, as well as categories of tests and treatments, while proposing additional QI opportunities to improve the value of neonatal care and reduce waste.

## WHY SHOULD THE NEONATOLOGIST CARE ABOUT VALUE?

There are several reasons why neonatologists should care about value. Health-care spending in the United States continues to grow rapidly, and annual expenditures attributed to waste are estimated to account for more than US$900 billion dollars.[8,9] Lifetime excess costs related to prematurity are estimated to be more than US$25 billion dollars, a large contribution on health-care costs for a relatively small subset of the population.[10] Neonatal care also has long-term implications, being responsible for 4 of the top 25 leading causes of disability-adjusted life years (preterm birth, neonatal encephalopathy, neonatal sepsis, congenital anomalies).[11] Beyond the impact to society, the direct financial impact on families of infants requiring neonatal care, while understudied, is significant.[12] The American College of Physician's Manual of Ethics also argues that physicians have an ethical imperative to use health-care resources responsibly.[13] A focus on value can benefit our patients, by reducing spending while achieving better health, as well as providing greater efficiencies and patient satisfaction, and can benefit the health-care system and society as a whole by reducing long-term chronic morbidities.[14]

With the changing landscape of reimbursement, improving value through QI not only makes sense for our patients but also makes financial sense. Associated reductions of hospital costs from improvement efforts make a strong business case for investment in QI.[15] Health-care reimbursement is increasingly shifting toward methods that reward value instead of volume of care. Diagnostic-related groups-based and bundled payments, which set reimbursement rates based on a patient's condition rather than the amount of services delivered, incentivize efforts to reduce wasteful care.[16,17] Although these payment models do not specifically focus on value (outcomes and costs), value-based models have been expanding in adult medicine, and will likely also become more prevalent in pediatrics.[18,19]

## INCORPORATING VALUE AND COST INTO TRADITIONAL QUALITY IMPROVEMENT

Although QI efforts are often focused on process or outcome measures, and not specifically cost, reduction in common neonatal morbidities have a great potential to reduce cost and improve value. Johnson and colleagues used a single institution sample of very-low birth weight infants infants to estimate the additional hospital costs related to bronchopulmonary dysplasia (BPD), NEC, brain injury and late-onset sepsis (LOS), after controlling for infant characteristics.[20] They estimated that those 4 morbidities added US$31,565, US$15,440, US$12,048, and US$10,055, respectively, to the inpatient costs related to the initial hospital stay. These are likely low estimates, as other studies have suggested higher costs, and they also do not include lifetime costs after discharge with long-term effects of these morbidities.[21–23] Common neonatal conditions such as hypoglycemia may also potentially have significant lifetime costs associated with them.[24] Given the costs (both immediate and across the child's lifetime) associated with these common morbidities, successful QI initiatives that reduce these outcomes can be presumed to also reduce cost.

Adverse events are also common targets for traditional QI in neonatology. These include reducing central-line associated bloodstream infections (CLABSIs) and unplanned extubation (UPE). Studies have estimated that the attributable cost and added length of stay related to these events in pediatric patients may surpass US$50,000, with 19 additional hospital days associated per CLABSI and 6.5 days for UPE.[25–27] A systematic review of economic evaluations related to QI interventions focused on reducing CLABSIs found substantial cost savings-related quality programs focused on reducing CLABSI events, with an estimated incremental net savings of US$1.85 million per hospital during 3 years.[28]

## COST MEASURES IN QUALITY IMPROVEMENT

Although the potential for cost savings by reducing neonatal morbidities is clear, QI projects aiming to demonstrate value improvement need to include robust cost measures. At present, incorporating robust cost measures in traditional QI is relatively novel and underutilized. A systematic review of QI collaboratives found that few reported cost estimates or economic evaluations.[29] One of the earliest examples is from the work of Jeannette Rogowski and VON, where they showed significant sustainable cost savings because of collaborative QI efforts across neonatal intensive care units (NICUs).[30] Although treatment costs in control hospitals that did not participate in the QI collaboratives increased, they saw a decrease in treatment costs among infants with infection and chronic lung disease (the 2 areas of focus). After considering costs related to the QI collaboratives, the average savings per hospital in patient care costs were more than US$2 million in the year following interventions.

For those interested in incorporating robust cost measures in their QI efforts, hospital-billing data can be used to estimate total costs from the hospital perspective, using department-specific cost to charge ratios.[31] Thompson and colleagues provide an excellent review of cost structures because they relate to costing NICU care.[32] Cost measures should include fixed costs (eg, NICU bed-space) and variable costs (interventions eg, radiographs, laboratory tests, surfactant) involved in patient care. In a simplified way, separate departmental billing (room and board charges, laboratory charges, pharmacy charges, and so forth) can be combined with department-specific ratios of cost to charges to estimate the costs incurred within each department.

One approach that might be more practical for clinical teams without access to cost data would be to use published data on the costs of individual tests and treatments to estimate utilization. Cost data may not be hospital-specific but could estimate utilization and track changes over time. For example, a recent publication using cost estimates from cost-to-charge ratios averaged across US children's hospitals could allow estimation of per-day costs (eg, US$264 for parenteral nutrition, US$1593 for gas therapy such as nitric oxide, US$81 for blood chemistry) and allow calculation of potential cost reductions to decreases in per-day utilization.[33] Although this approach is imperfect, it might be a start for improvement teams that desire a general cost estimate for projects focused on the reduction of utilization without more intensive accounting efforts.

There are several alternative approaches that could also be considered to aid in cost measures for QI efforts. Ho and colleagues summarized simple examples of cost metrics that QI projects can measure in neonatology.[34] A modified version of their table is reproduced here (**Table 1**). Zupancic and colleagues developed a daily cost prediction model for NICU care and found that 8 tests and treatments predicted daily variable costs.[35] These resources were surfactant, chest radiographs, red blood cell transfusion, cranial ultrasound, abdominal radiograph, parenteral nutrition infusions, platelet transfusions, and echocardiograms. Individual projects can also utilize cost measures from the published literature that fit their needs, to combine with other types of cost data collection. For example, a QI effort focused on reducing CLABSI may be able to include published estimates of the incremental costs associated with CLABSI events in their assessment of changes in cost overtime. However, caution should be taken with this approach because it is important to measure both positive and negative cost measures (eg, cost-associated interventions introduced through QI such as added nursing time/staffing to adhere to central-line maintenance protocols) to fully estimate the influence on hospital costs.

Length of stay has also been used as a surrogate for cost measures. For example, Kaempf and colleagues examined value improvement in a subset of NICUs participating in a Vermont Oxford Network (VON) quality collaborative. They created a novel "value metric" where benefit (the numerator) was defined by risk-adjusted inverse rates of morbidities and cost (the denominator) was measured as mean total hospital length of stay in survivors. They found that value improved over time for NICUs involved in collaborative QI compared with other NICUs in VON, although the magnitude of value improvement was diminished by an increase in length of stay (cost) during the study period.[36] This highlights the importance of tracking not only benefit/outcomes but also cost to ensure a net gain in value.

Although methods of estimating costs based on a hospital or payer perspectives are most commonly used in neonatal QI, a societal approach to cost measures is

**Table 1**
**Cost categories for potential inclusion in quality improvement projects**

| Cost Categories | Examples |
|---|---|
| Aggregate measures | Length of stay<br>Ventilator days |
| Testing and treatment costs | Number of imaging studies (eg, radiographs, ultrasounds, echocardiograms)<br>Number of laboratory studies<br>Parenteral nutrition utilization (eg, parenteral nutrition days)<br>Antibiotic days |
| Supply costs | Oxygen probes<br>Near-infrared spectroscopy monitors<br>Endotracheal tubes |
| Personnel costs | Nursing hours and ratios<br>Physician hours and ratios<br>Other support services (eg, respiratory therapy, nutrition, therapists) |
| Family costs | Lost productivity<br>Travel costs (transportation, accommodation, meals)<br>Equipment costs (eg, breast pump rentals) |

*Adapted from* Ho T, Zupancic JAF, Pursley DWM, Dukhovny D. Improving Value in Neonatal Intensive Care. Clin Perinatol. 2017;44(3):617-625.

preferred. Expenses incurred by families that are related to interventions should be accounted.[37] These costs are understudied but are likely substantial and influence families.[12] In addition, potential cost savings from a reduction in morbidity must be weighed against changes in resource use (eg, new interventions introduced, or changes to staffing ratios) and labor costs associated with QI efforts themselves.[38]

## OVERUSE/MISUSE OF NEONATAL INTENSIVE CARE

NICU care is costly and the use of the NICU itself can be considered a resource. Fixed room and bed costs are high, even before the addition of variable costs that inevitably occur following an intensive care admission. A recent study in children's hospitals estimated that more than 70% of total hospital costs were related to these fixed costs, with an average daily cost of US$2339.[10,33] There is a wide variability in NICU utilization, with some evidence that there is a growing use of NICUs for infants who may potentially not require intensive care (eg, infants who are not premature, do not have serious congenital anomalies and are not critically ill).[39,40] In a study of the VON database in 2018, there was wide variation in "short stay" (<3 days) NICU admissions for infants greater than 34 weeks (0%–100%), and only a small proportion of infants greater than 34 weeks were considered "high-acuity" admissions.[41] Evidence suggests that the use of the NICU for term infants of relatively low acuity has been increasing overtime.[42,43]

Safely reducing utilization by decreasing admissions of lower risk infants to the NICU can improve value. This idea was initially introduced by Pursley and Zupancic and has since been featured by VON in their "Using the NICU Wisely" campaign.[40,41] Enhancing resources available in newborn nurseries can safely reduce unnecessary NICU admissions with many other added benefits due to a reduction in maternal–infant separation. Interventions designed to allow for low-risk infants to be cared for in a well-newborn setting have included standardized, risk-based approaches to sepsis evaluations in asymptomatic infants, noninvasive approaches to the treatment of neonatal hypoglycemia, and changes to nonpharmacologic management for opioid-withdrawal syndrome. Many of these interventions also have the added benefit of reducing unnecessary testing and treatment, further reducing waste and improving value. Based on published evidence-based economics, the interventions below all have the potential to both improve patient outcomes while also producing net cost savings (falling below the x-axis on the cost-effectiveness plane in **Fig. 1**). We summarize the available evidence related to these interventions and their effectiveness at reducing potentially unnecessary NICU admissions below.

### *Well-Appearing Infants at Risk for Sepsis*

Management of well-appearing term newborns with risk factors for sepsis has evolved during the recent decade, with national guidelines endorsing approaches including sepsis risk calculators and clinical surveillance that can be more easily performed in a well-newborn setting.[44] A cost–benefit analysis using a decision-tree model examined the impact of implementing a sepsis-risk calculator and demonstrated an incremental net benefit of US$3998 per infant in their base case analysis, in addition to a 67% reduction in antibiotic use.[45] Additionally, there was a net per-patient benefit of US$1930 in direct medical costs alone. Similar data from the implementation of the Kaiser calculator in affiliated NICUs showed a reduction in sepsis evaluations from 15% to 5% of newborns and an accompanying 50% reduction in antibiotic exposure.[46] Achten and colleagues demonstrated a significant reduction in hospital costs among term newborns, primarily driven by a decrease in length of stay, as well as decreases in antibiotic utilization. They found a relative 9% reduction in combined costs associated with early onset sepsis-related care per term newborn in their Dutch NICU.[47] In addition to demonstrating decreases in the overuse of sepsis laboratory evaluations and antibiotic treatment, several single-center studies have also shown significant reductions in NICU admissions, and reduced length of stay contributing to the value improvement seen with implementation of validated sepsis-risk calculators.[47–49]

### *Neonatal Hypoglycemia*

Oral glucose gel has been studied as both a treatment of neonatal hypoglycemia and as prophylaxis in newborns at risk. When used to treat hypoglycemia, oral glucose gel can reduce NICU admissions and maternal–infant separation by allowing care to continue in a well-newborn setting. The Sugar Babies Trial,[50] a double-blind randomized trial in New Zealand that randomized infants who were hypoglycemic to receive 200 mg/kg 40% dextrose gel or placebo, observed a significant reduction in treatment failure (14% vs 24%, $P = .04$), as well as a reduction in NICU admissions for hypoglycemia (14% vs 25%, $P = .03$) and less formula feeding at 2 weeks of age (4% vs 13%, $P = .03$). Several studies reporting the experience of single centers implementing oral glucose gel for the treatment of hypoglycemia have shown reductions in NICU admissions, in addition to reductions in length of stay, costs, and improvements in exclusive breastfeeding.[51–53] A decision-tree analysis modeling costs related to oral glucose gel, based on data from The Sugar Babies Trial, found cost savings of US$1300 per infant, with cost savings persisting across a range of sensitivity analyses.[54] Although most of the published literature supports a positive cost–benefit assessment of oral glucose gel to treat hypoglycemia, the hPOD Trial of prophylactic glucose gel administration demonstrated reduced rates of hypoglycemia without a reduction in NICU admissions or maternal–infant separation.[55] Based on the available evidence, patient selection is important for QI efforts focused on glucose gel, if the goal is to reduce unnecessary NICU admissions.

### *Infants with Neonatal Abstinence Syndrome*

The incidence of neonatal abstinence syndrome (NAS) or neonatal opioid withdrawal syndrome continues to increase in the United States. These infants are at increased risk of NICU admission, medication exposure, and prolonged lengths of stay, with significant associated economic burdens.[56,57] Efforts to improve care for this population, and specifically reduce NICU admission and decrease mother–infant separation, provide significant opportunities to improve the value of care. In 2017, Yale New Haven Children's Hospital published their QI initiative to improve care for infants with NAS, using an approach now referred to as "eat, sleep, console" (ESC). They significantly reduced NICU admissions (100% to 20%), length of hospital stay (22–6 days), and hospital costs (US$45,000–US$10,000 per patient), with no adverse events or increase in readmissions for NAS (**Fig. 2**).[58] In the last 5 years, many institutions have adopted ESC approaches and significantly reduced NICU admissions, length of stay and medication exposure for infants with NAS.[59–62] The Colorado Hospitals Substance Exposed Newborn Quality Improvement Collaborative employed ESC across 19 birthing hospitals in Colorado, and significantly reduced average LOS (14.8–5.9 days) and pharmacologic therapy (61%–23%). Admissions to Level III NICUs also decreased from a baseline mean of 16% to 12% (Unpublished data, courtesy of authors).[63] Even in a population of infants already admitted to a Level IV NICU with maternal–infant separation, the ESC method has reduced length of stay and medication exposure.[64]

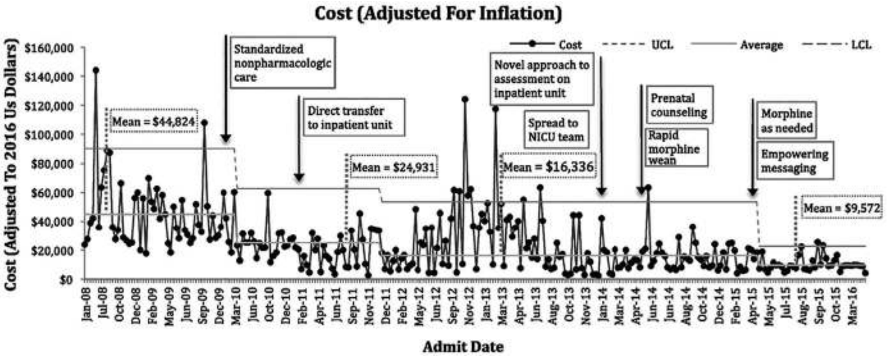


**Fig. 2.** Example of cost-based outcome measure: direct hospital costs per infant prenatally exposed to methadone. Figure shows hospital costs per-patient prenatally exposed to methadone in an initiative to improve care for infants with NAS using the ESC method. During the study period, average hospital costs decreased from US$44,824 to US$10,289, along with significant reductions in the use of pharmacologic therapy and the average length of stay. (Reproduced with permission from Pediatrics, 139(6):e20163360. © 2017 by AAP.)

## OVERUSE OF POTENTIALLY UNNECESSARY TESTS AND TREATMENTS

Overuse and overtreatment is estimated to account for more than US$185 billion in wasteful spending per year and has been identified as the "next quality frontier" by Donald Berwick, former Administrator for the Centers for Medicare and Medicaid Services.[9,65] The challenge is distinguishing between appropriate use of tests and treatments, and inappropriate overuse. This is where efforts to improve value must combine QI methodologies with evidence-based medicine and evidence-based economics to identify the right tests and treatments in the right patients at the right time.[3] Some tests and treatments may be wasteful (or harmful) in specific populations, falling to the left of the y-axis on the cost-effectiveness plane (see **Fig. 1**), whereas others may provide only marginal benefits with added costs that make their "value for money" questionable.

There have been some efforts to set priorities for targeting high-yield areas of overuse in neonatology (**Table 2**). The "Choosing Wisely" campaign, an initiative that seeks to advance a national dialog on avoiding unnecessary tests and treatments, published their top 5 list in newborn care in 2015 using a national survey and modified Delphi approach to prioritizing topics.[66] Although this list offers an initial starting point based on expert consensus and an evidence-based review of the literature, one limitation is that it did not consider the prevalence of overuse among different test and treatment options commonly used in neonatology. Similarly, King and colleagues used billing data from freestanding children's hospitals to describe the cost of tests and treatments among preterm infants, and created a prioritization list by combining data on cost, hospital variation, and prevalence.[33,67] This data can also serve as a starting point for hospitals to identify and focus on areas for improvement that are large drivers of cost, based on high utilization and/or high costs for the specific test or treatment. Both of these approaches (Choosing Wisely and the King Prioritization Framework) offer reasonable starting points to identify high-yield areas of overuse. Here, we also propose and review a third "categorical" approach, that focuses on high-yield areas of overuse across key resource-type categories in neonatal care; laboratory use, imaging use, medication use, and feeding and nutrition.

**Table 2**
**Potential targets to prioritize value-based efforts to reduce overuse and waste in the neonatal intensive care unit**

| Prioritization Tool | List |
|---|---|
| Choosing Wisely[66] | Avoid routine use of antireflux medications in preterm infants<br>Avoid routine continuation of antibiotics beyond 48 h<br>Avoid routine use of predischarge pneumograms for apnea in preterm infants<br>Avoid routine use of daily chest radiographs<br>Avoid routine screening term-equivalent MRI in preterm infants |
| Prioritization Framework[67] | Optimizing feeding advancement, use of TPN and reducing central line days<br>Safely reducing commonly ordered routine laboratories (hematology, chemistry, blood gases)<br>Safely reducing frequently ordered imaging studies (chest and abdominal radiographs, cranial ultrasounds) |
| Categorical Approach | Safely reducing laboratory utilization<br>Safely reducing imaging utilization<br>Safely reducing medication utilization<br>Optimal use of parenteral nutrition and feeding advancement |

*Abbreviations:* MRI, magnetic resonance imaging; TPN, total parenteral nutrition.

### *Reducing Laboratory Utilization*

This area of focus is currently understudied in the NICU. In 2021 Yale New Haven Children's Hospital published their initiative to decrease laboratory utilization in the NICU (**Fig. 3**). In their baseline data, they found that 3 laboratory tests, glucose measurements, blood gases, and bilirubin levels, constituted more than two-thirds of all laboratory testing.[68] These findings are similar to a national study of inpatient billing within children's hospital NICU's.[69] During 2 years, interventions primarily targeting these 3 tests led to a 27% decrease in laboratory tests per 1000 patient days (51,000 tests), as well as a significant decrease in blood drawn and cost savings of more than US$250,000.[68] They also developed an online dashboard that allowed providers to review their own laboratory ordering practices and compare this to their peers. This is an effective way to make the system visible, and encourage discussion around utilization. More examples of successful QI projects focused on reducing laboratory utilization can be found in the Pediatric Hospital Medicine and Pediatric Cardiac ICU literature.[70–72]

In 2008, Intermountain Healthcare's Dixie Regional Medical Center in Utah launched a unique initiative called the POKE Program, which categorized all interventions on infants (painful and nonpainful) as "pokes" and sought to reduce unnecessary "pokes." They have reported improved care and outcomes from this program, including a reduction in more than 11,000 "pokes," a 28% reduction in operational costs, significant reductions in central-line associated blood stream infections, and a 21% reduction in length of stay.[73] This program has expanded to other NICUs across the country, although peer-reviewed publications are not yet available. These 2 QI efforts suggest that targeted reduction in laboratory utilization may provide both benefits in clinical outcomes, and reduced costs (Falling below the x-axis on the cost-effectiveness plane).

### *Reducing Unnecessary Imaging*

Among the "Choosing Wisely" Top 5 list, 3 are types of diagnostic imaging (chest radiographs, brain MRI, and pneumograms). Wide variation in the use of radiographs,

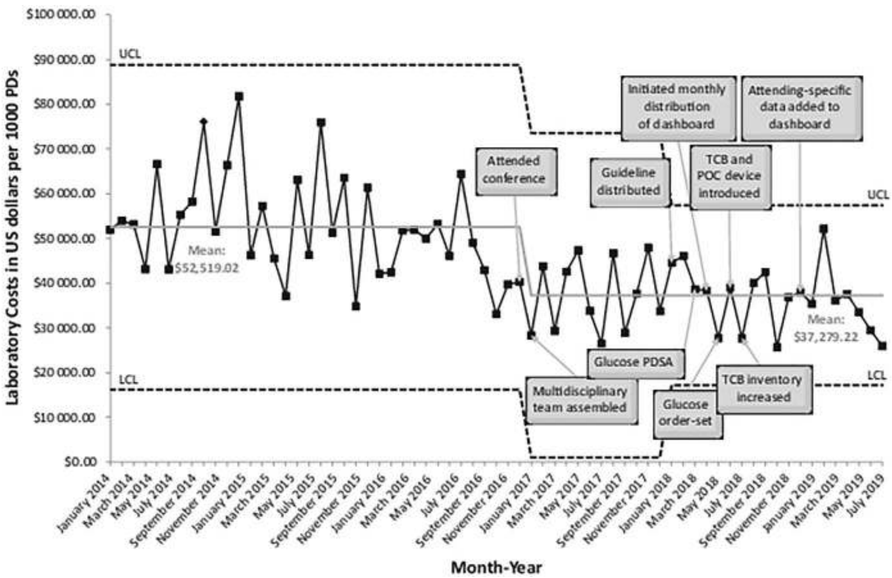


**Fig. 3.** Example of cost based outcome measure: monthly laboratory costs. Figure depicts monthly laboratory costs per 1000 NICU patient days during an initiative to reduce laboratory testing in the NICU. During a 30-month period, this initiative led to a savings of US$258,000, as well as a significant reduction in blood draws (approximately 8 L of blood). LCL, lower control limit; POC, point of care; PDSA, plan-do-study-act; TCB, transcutaneous bilirubin; UCL, upper control limit. (Reproduced with permission from Pediatrics. 148(1):e2020000570. © 2021 by AAP.)

brain MRI, and head ultrasounds have been described by Goodman and colleagues, across a variety of populations and payer types and largely unexplained by differences in illness severity.[74] In a Texas Medicaid population, they observed a greater than 7-fold variation in brain MRI, almost 3-fold variation in head ultrasounds, 4-fold variation abdominal radiographs, and 2-fold variation in chest radiographs, all after adjustment for illness severity.[75] When combining cost, prevalence, and hospital variation, King and colleagues's prioritization framework included both chest radiographs and head ultrasounds in their Top 10 list of overused tests and treatments.[67] Despite the wide variation in the use of brain MRI and high cost per test, it was not featured in the prioritization framework due to its relatively low overall prevalence and subsequently low total cost. This highlights costly procedures that are not commonly used may not be the most effective targets for value-based improvements. At the individual hospital level, NICUs with high brain MRI utilization rates could still consider this an excellent target for value-based improvement.

Single centers have reported on QI efforts aimed at reducing unnecessary radiographs. Motz and colleagues at Seattle Children's Hospital were able to reduce radiographs for peripherally inserted central catheter and endotracheal tube placement by more than 20% by instituting guidelines focused on optimal patient position, radiograph frequency, and endotracheal tube depth.[76] A QI initiative at Nationwide Children's aimed to primarily reduce UPE, also included a restrictive radiography policy in their interventions. They were able to decrease their UPE rate from 1.75 to 0.68 per 100 ventilator days while also cutting chest radiograph use in half.[77,78] Nathan and colleagues demonstrated an approximately 20% reduction in abdominal radiographs performed as part of a QI collaborative aimed at reducing the incidence of NEC.[79] These efforts highlight how QI initiatives aimed at more traditional quality outcomes can include resource utilization metrics to better demonstrate how their initiative changes resource use, and potentially improves value through a reduction in unnecessary imaging. Additional opportunities to potentially reduce the overuse of imaging studies could include reducing repetitive head ultrasounds to screen or follow intraventricular hemorrhage, periventricular leukomalacia, or posthemorrhagic hydrocephalus, and echocardiography to evaluate the patent ductus arteriosus or for pulmonary hypertension screening.

### *Reducing Unnecessary Treatments*

Preterm neonates are exposed to a wide variety of medications and treatments, most of which are used off-label with limited safety or efficacy data.[80,81] For example, in infants with severe BPD admitted to US Children's Hospitals, Bamat and colleagues found a median of 30 medication exposures per patient, with significant variation in exposures across centers.[82] Although the lack of evidence should not completely preclude the use of certain medications in our population, routine use of medications without data to support its safety and efficacy is a questionable practice. Prioritizing potentially unnecessary treatments for targeted reduction should be based on the tenants of evidence-based medicine, by including the best available evidence with provider and patient values.[3] Particular attention should be made toward evidence for potential harm, particularly when high or moderate certainty of evidence for efficacy is lacking. Additional considerations could include evidence-based economics, when cost-effectiveness studies are available. By combining the best available evidence and economic data (when available), questionable interventions that are likely wasteful (fall to the left on the cost-effectiveness plane in **Fig. 1**) can be identified for targeted reduction.

The use of antireflux medications, one of the Top 5 in the "Choosing Wisely" list, is an example where QI initiatives have successfully reduced potentially unnecessary and harmful medication use. Wide variation in the diagnosis and treatment of gastroesophageal reflux among preterm infant have been reported, with up to 13-fold variation in diagnosis across children's hospitals, high rates of medication use, and significantly increased costs associated with diagnosis and treatment.[83,84] Following the "Choosing Wisely" initiative, multiple institutions have used relatively simple interventions, such as evidence-based guidelines and education, standardized documentation, and electronic medical record support, to successfully reduce the nonindicated use of antireflux medications in the NICU.[85–88] Although more recent population-level studies in the United States have not provided an overall estimate of the impact of QI efforts in reducing antireflux medication use, a recent national cohort study in England and Wales suggests continued frequent diagnosis and treatment of reflux in preterm infants, implying more efforts are needed.[89]

Although not included in the "Choosing Wisely" Top 5 list, inhaled nitric oxide (iNO) is a costly treatment with clear indications among term infants with hypoxic respiratory failure but has not been shown to improve outcomes among preterm infants.[90,91] Due to the lack of supporting data, there have been calls for reducing overutilization of iNO among preterm infants.[92] Wide variation in the use of iNO among preterm infants has been demonstrated in US centers, and a recent nationwide study in England that found increasing use.[93,94] As such, it is an ideal target for QI focused on maintaining use for the appropriate indications while limiting overuse. Although more evidence is needed to best identify appropriate indications among preterm infants, several "iNO stewardship" programs have successfully reduced utilization with no adverse effects.[95–97] Similar stewardship programs have also taken place in other critical care subspecialties, resulting in decreases in iNO utilization and expenditures.[98,99]

### *Optimizing Enteral Feeding and Reducing Unnecessary Parenteral Nutrition Use*

The use of parenteral nutrition, intravenous fluids, and central venous access is associated with significant costs among preterm infants. King and colleagues found that parenteral nutrition accounted for the greatest proportion of total costs related to clinician-driven tests and treatments in preterm infants, and parenteral nutrition and intravenous-line related billing (eg, intravenous fluids, heparin-containing fluid infusions) featured prominently in their prioritization framework.[33,67] In addition, the harms and increased costs related to central line days and CLABSIs are well documented.[100,101] Therefore, optimizing enteral feeding regimens with subsequent reductions in central line days and parenteral nutrition use represents a significant opportunity to improve the value of care for neonates by reducing potentially unnecessary central line days involving parenteral nutrition. Additionally, increasing human milk feeding is a key target for value improvement. This has been reviewed in detail by Johnson and colleagues, and therefore, we refer readers to this detailed review.[102]

Similar to QI efforts previously highlighted, centers have used standardized protocols to decrease parenteral nutrition use in very-low birth weight infants. This has been achieved by earlier enteral feeding initiation and faster feeding advancement to shorten the time to full feeds, reduce central line days, decrease the use of parenteral nutrition, and reduce the length of stay while also improving growth outcomes.[103–105] For example, Chu and colleagues utilized a standardized feeding regimen among very preterm infants to shorten the time to full feeds (from 12.8 days to 7.7 days), reduce central line days by 35%, and reduce total parenteral nutrition (TPN)-related costs by approximately US$2500 per patient.[105] Beyond initial feeding advancement strategies, standardization of feeding advancement following medical and surgical NEC is another opportunity for improving value.[106,107] Patel and colleagues standardized feeding advancement after nonsurgical NEC and demonstrated a reduction in days to reach full feeds (24–15.7), central line days (16–11), and parenteral nutrition use.[107]

## SUMMARY

Value-based care focuses on achieving the best health outcomes for patients for the lowest cost. QI plays an integral role in translating evidence-based medicine and evidence-based economics into clinical practice. Improving value through QI requires accounting for the costs of neonatal care to demonstrate cost savings from improvements in outcomes, as well as expenditures related to interventions. Opportunities to improve value through QI include interventions that focus on reducing unnecessary NICU admissions among term and late-preterm infants, as well as reducing potentially unnecessary care.

## CLINICS CARE POINTS

- Incorporating cost metrics into QI can help provide a “business case” for quality improvement by demonstrating improvement in outcomes, while reducing costs.
- Reducing potential overuse of neonatal intensive care provides ample opportunities for value-based QI, with examples that include improvements in care for well-appearing infants at risk for sepsis, neonatal hypoglycemia and neonatal abstinence syndrome.

## DECLARATION OF INTERESTS

R.M. Patel serves as a consultant for Noveome, Inc, receives honorarium from Mednax and serves on the data-safety monitoring committee for Infant Bacterial Therapeutics/Premier research.

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